TIME
TRAVEL

MEGATRENDS AND SCENARIOS FOR QUEENSLAND TRANSPORT OUT TO 2048

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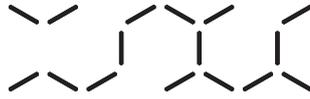Bratanova and Kelly Trinh

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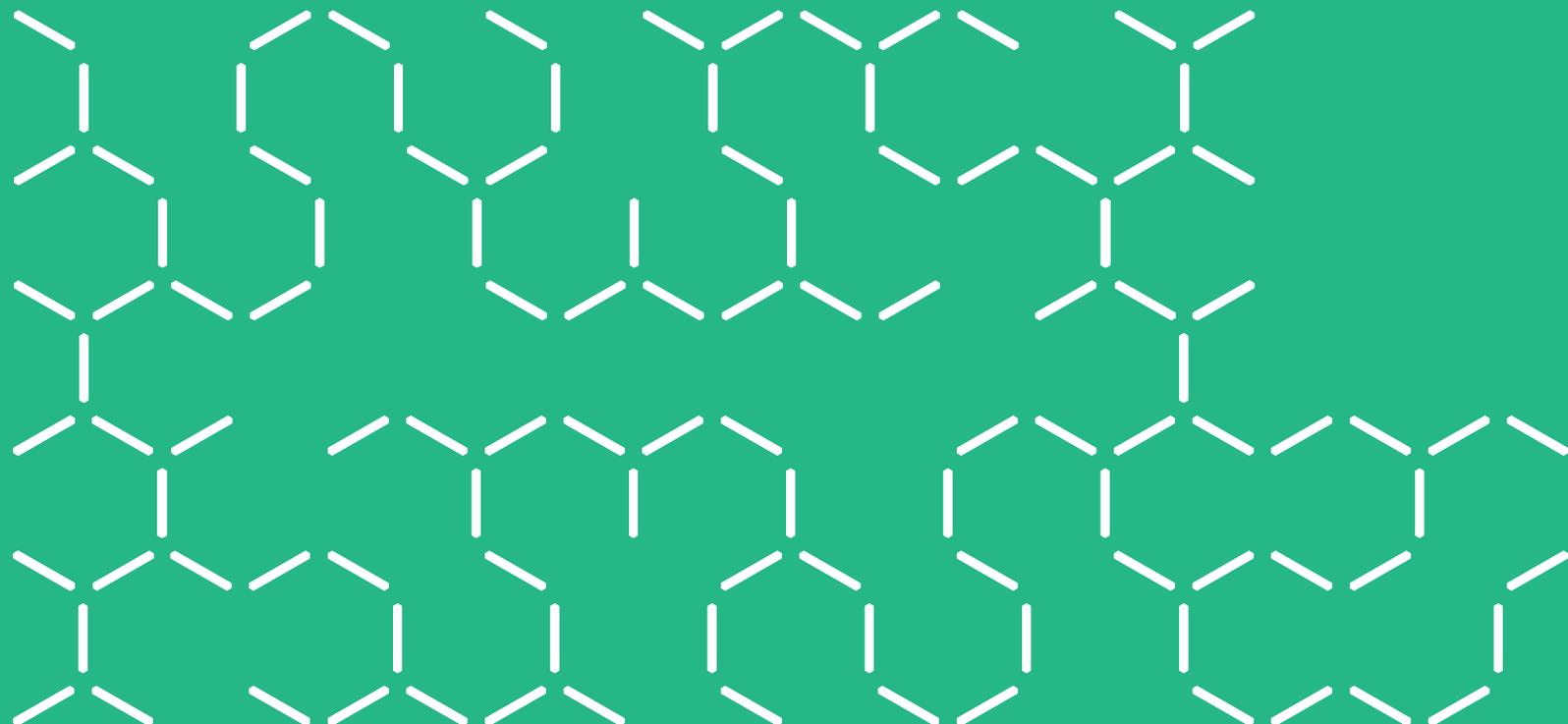
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FOREWORD

The future of transport is uncertain, with potentially massive changes on the horizon.

Some of these changes are widely discussed—automated and electric vehicles, drone deliveries, new ways of travelling such as through ride-sharing and car-sharing, growing and aging populations and changed work practices like work from home—to name just a few. The Department of Transport and Main Roads (TMR) is tasked with planning for the future of transport, and it is important that we take such changes into account as we develop our 30 year plan for the transport system—the Queensland Transport Strategy. Responding to the challenges of the future is critical if we are to achieve the department's vision of creating a single integrated transport network accessible to everyone.

I am pleased, therefore, to release this report—Time travel: Megatrends and scenarios for transport in Queensland out to 2048.

Transport and Main Roads has worked closely with CSIRO's Data61 to develop this report, which helps us to understand and plan for the challenges, risks and opportunities that the future may hold for transport in Queensland. The report identifies:

- emerging technological, social and business trends (such as the "sharing economy") that are likely to affect transport
- key uncertainties around how these trends could emerge and impact transport over time
- how Queensland communities, and those who use our transport system, could be affected by these changes in how people and goods move.

To help us understand how these upcoming changes might impact transport in Queensland, TMR and Data61 have developed four plausible scenarios that might play out, depending on:

- how quickly Queenslanders take up emerging technologies (like driverless and electric vehicles) and business models (such as ride-sharing and car-sharing)
- where and how they choose to live and work, which will determine length and number of trips Queenslanders need to make and whether (in urban centres) peak-hour weekday commutes continue to be the norm.

The four different worlds identified in this report show very different outcomes for transport fundamentals such as public transport usage, the cost of transport for households, and road safety. For instance, the number of road fatalities and injuries could be very different in a world where automated vehicles are widely adopted, or where people travel shorter distances, less often—compared to a world where automated vehicle technology is not taken up, or people continue to travel longer distances during peak hours.

In this report, these key transport fundamentals are modelled for each of the four scenarios, to show us what could be at stake and help us to prepare for the changes coming our way. This will assist TMR in ensuring that no group is unfairly disadvantaged by these changes and that the benefits are shared equitably across our communities, steering us towards the best future for transport in Queensland.

Neil Scales OBE

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EXECUTIVE
SUMMARY
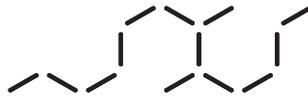
Queensland's transport system has evolved rapidly over the past decade and emerging trends suggest further changes are on the horizon. But what will it look like in 2048? There are a host of unknowns when it comes to forecasting the future of Queensland's transport system. Will people still need to own a car or will they rely on autonomous vehicles and other mobility services? How will the transport sector respond to future environmental, technological and economic challenges and opportunities? And how will changes in the transport system differ for urban, regional and rural areas?

This report explores possible future changes in Queensland's transport system out to 2048 and the impact of these changes on the operating environment of the Queensland Department of Transport and Main Roads (TMR). It aims to identify and understand the critical risks, challenges and opportunities for the transport system across the state over the next 30 years, and inform future strategy and policy decisions. It does so using strategic foresight to analyse, both qualitatively and quantitatively, the emerging trends impacting Queensland's transport system and how these trends could plausibly unfold in the future.

The megatrends

This report identified five overarching 'megatrends' for Queensland's transport system over the coming decades. Megatrends represent trajectories of change which occur at the intersection of numerous geopolitical, social, economic, environmental and technological trends with a tighter spatial, temporal and typological definition. The megatrends are:

- **On the move.** Demand for transport has grown, with people travelling more and increasingly likely to consume goods and services purchased online. On the Move explores the technological, demographic and consumer shifts that will continue to drive this growth in demand.
- **Digital dividends.** Emerging technologies look to become increasingly capable, affordable and widespread. Automated vehicles, connected infrastructure, drones and big data analytics all have the potential to make the transport system more efficient, cheaper and more responsive to demand.
- **Virtually there.** Advances in technology are enabling more processes to be automated or completed online, transforming the way we work, shop and access services. This will impact how much, when and why people travel, and the infrastructure needed to support the transport task.
- **A lighter footprint.** Geopolitical pushes towards electric vehicles, shifts in consumer preferences and emerging shared mobility models offer significant opportunities to reduce the environmental and safety burden of transport. However, Queensland lags behind global trends in some of these areas.
- **Empowered consumers.** Transport users increasingly expect personalised, on-demand services that cater to their specific needs. The evolution of more individualised transport services could encourage new models of freight distribution and pay-as-you-go charging models for transport users.

The scenarios

The megatrends point to opposing forces that can have different implications for present-day strategy and policy decisions. To what extent will new digital and mobility technologies penetrate the Queensland market, and will Queenslanders be willing to adopt new these technologies and service models? Moreover, where will people live, work and study, and how will this influence the way they travel? Taking these uncertainties into account, four scenarios for the future of Queensland's transport system out to 2048 were defined:

New technologies & business models are rapidly adopted

Off-Peak, On-Demand	Cruise Control
Digital technologies have advanced significantly, enabling a virtual presence for work, study and other activities, and improving costs of transportation. The transport task is serviced by more on-demand, personalised services.	Mobility patterns concentrate around peak times and/or destinations and this demand is better managed by intelligent technologies. Ridesharing and point-to-point services can better connect people and freight to mass transit systems.
Mobility options for people living in regional areas improve, but what happens to transport infrastructure in urban areas?	*High technology uptake and concentrated populations enable transport efficiencies, but how are revenue challenges managed?*

People's travel is non-routine and dispersed ← **Variability in mobility patterns** → **Travel continues to concentrate around peak times**

Level of technology transformation

Suburban Streets	Bumper to Bumper
Urbanisation pressures drive people to live in more regional areas. Many own a car but do not need to travel to a central location as frequently. However, the freight sector must service a more dispersed population without the aid of new technologies.	Increased population density in South East Queensland, combined with low technological innovation and uptake in the transport sector, continues to strain the transport network. Commutes grow longer, congestion worsens and emissions increase.
Peak demand and congestion both reduce, but could this coincide with a rise in passenger and freight transportation costs?	*If other jurisdictions see significant changes in their transport system, what impact will this have on the quality of life for Queenslanders?*

Uptake of new technologies and business models is slow

The areas of impact

To quantify the impact of these scenarios on Queensland's transport system, a set of transport-related fundamentals were modelled under each scenario. These reflected key areas of economic, safety, and environmental impact for Queensland's transport system, and included:

- Size and fuel mix of the vehicle fleet
- Vehicle kilometres travelled
- Road crash fatalities and hospitalisations
- Transport-related infrastructure expenditure
- Registration revenue
- Public transport patronage
- Household expenditure on transport
- Cost of freight mobility
- Cost of excessive congestion
- Greenhouse gas (CO_2) emissions
- Automation impacts across the transport and logistics sector

The policy implications

These scenarios raise a number of key risks, challenges and opportunities for Queensland's transport system and TMR's future operating environment. This report explores the implications of the scenarios on future strategic and policy decisions, in both the short and long term. These policy implications include:

- Alternative charging models for vehicle and road users
- Shared mobility solutions for transport
- Ensuring equal and fair access to transport
- A shift from government as a service provider to service broker
- Setting the direction for climate transition strategies
- Security and safety considerations for physical and virtual assets
- Maximising existing and to-be-developed infrastructure and assets

These megatrends and scenarios provide a narrative for the future of Queensland's transport system, and will facilitate discussion around how the transport sector may respond to these changes. Moving forward, it will be important to establish strategies for monitoring signals that point towards particular scenarios so that TMR can respond proactively. By understanding and anticipating these potential futures, TMR will be in a strong position to leverage opportunities and mitigate risks for Queensland's transport system.

INTRODUCTION
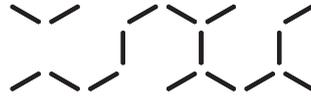
Transport is a key enabler that moves and connects people, places, goods and services. From the commute to work or school to the distribution of freight across urban regional centres, the transport system is essential to the day-to-day functioning of Queensland's economy.

Queensland's transport system has changed significantly over the past few decades, with new technologies, innovative business models and changing consumer preferences opening up novel ways of travelling. For example, app-based ride services like Uber and Lyft allow consumers to travel on-demand without needing their own vehicle.

Queensland's transport system will likely face further changes over the next 30 years, driven by continued advances in digital and mobility technologies, population growth, urbanisation pressures and rising environmental concerns. Certain transport options will grow in popularity whereas others may become obsolete. Where people choose to live, work and study will also influence how, when and where they choose to travel. Queensland's transport system will increasingly need to service a growing passenger and freight task safely, efficiently and effectively through streamlined, convenient and high-quality options.

The Queensland Government Department of Transport and Main Roads (TMR) is responsible for planning, managing and delivering an integrated transport environment for Queensland. Through this, TMR is committed to ensuring Queensland's transport system contributes to people's quality of life, a vibrant economy and a sustainable environment. But, like many other industry and sectors, TMR is experiencing a period of rapid change. Shifts in Queensland's transport system present potential operating risks for TMR, but also new opportunities to better service the transport task.

This report explores future changes in Queensland's transport system out to 2048 and their impact on TMR's operating environment. The aim of the report is to identify and understand the critical risks, challenges and opportunities that Queensland's transport system will face over the next 30 years, and provide input into the development of policy and strategic responses to these changes. This project also aims to provide a shared starting point that can be used and communicated within TMR and to its external stakeholders in discussions around Queensland's future transport sector.

CSIRO's Data61 was commissioned to conduct this strategic foresight project as part of the Q-Foresight program – an initiative under the multi-year Queensland Government and Data61 Strategic Partnership Agreement. This initiative is designed to provide state government agencies with improved information for decision-making about future trends, risks and scenarios. The intention is to support the development of improved policies, service delivery strategies and outcomes for the people of Queensland.

This report first provides a snapshot of Queensland's current transport system (Chapter 2) and five 'megatrends' (i.e. overarching patterns of changes) shaping the future of Queensland's transport system (Chapter 3). Chapter 4 illustrates the key uncertainties arising from these megatrends and four plausible scenarios for the future of Queensland's transport system out to 2048. These qualitative scenarios are complemented by quantitative modelling of impacts across key areas of TMR's operating environment. Finally, the report concludes with a set of policy considerations for future decision-making (Chapter 5), highlighting opportunities to deal with future challenges and risks.

While change is inevitable, the future destinations are not and there is a significant degree of uncertainty around what the future will hold. By understanding the future patterns and drivers impacting Queensland's transport system, and the range of plausible ways these trends could unfold in the future, stakeholders in government, industry, and the community will be in a better position to anticipate and respond to these changes.
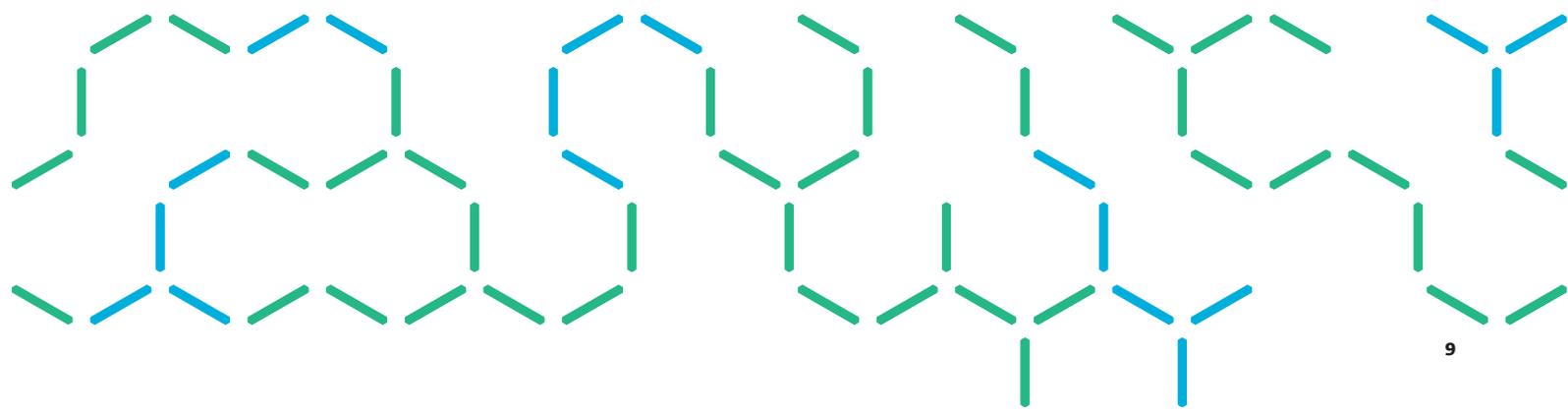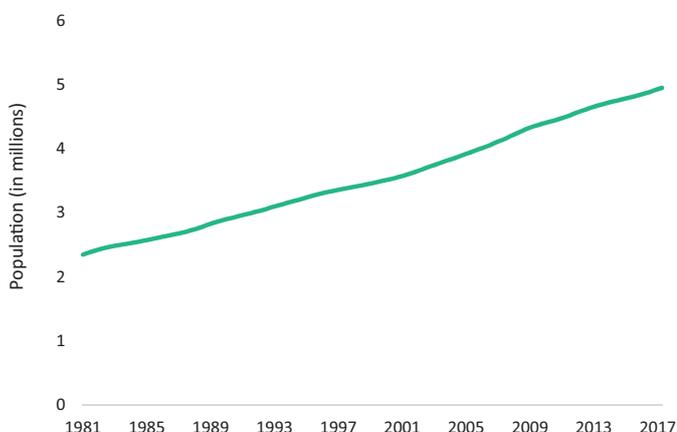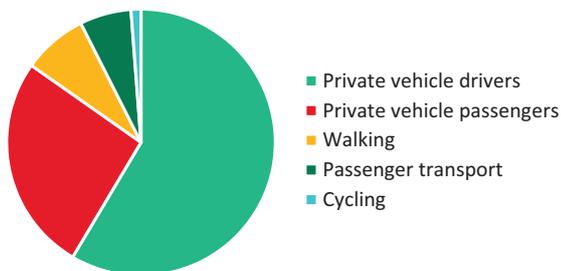
CURRENT PROFILE OF TRANSPORT IN QUEENSLAND
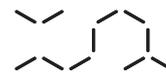
Queensland's population is growing steadily (see Figure 1) and much of the growth is concentrated in South East Queensland (SEQ).[5] As the population grows so does the demand for transport. Data from 2011 show that every day, Queenslanders across the state make a combined average of 10,795,880 passenger trips and travel 101,979,656 kilometres.[6] Work (26.0% of trips), shopping and personal errands (25.6%), and accompanying others (23.8%) are the top reasons to travel.[6]

in 2016 (see Figure 3). Public transport patronage in 2016 was unusually low relative to trends over the decade prior. When it comes to active transport, statewide trends show a long-term decline, but rates of active transport have been relatively stable in Brisbane (see Figure 4). Infrastructure improvements have benefited rates of active transport in Brisbane. Major upgrades and expansions saw an increase of 63% in weekday cyclists and 30% in weekday walkers between 2004 and 2010 following.[12]

Figure 1. Population growth in Queensland
Data source: Australian Bureau of Statistics[7]
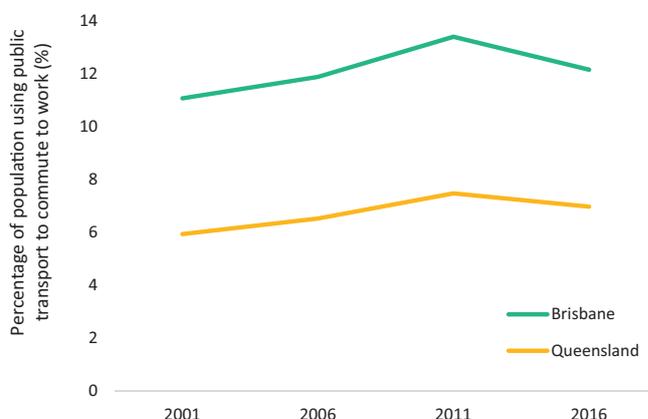
Figure 3. Rates of public transport commutes in Brisbane and across Queensland
Data source: Australian Bureau of Statistics[9,10,13-16]

Despite the range of travel modes (e.g. car, bus, train, ferry, bike or foot), most trips use private vehicles (see Figure 2). People prefer private vehicles for their efficiency and convenience: private vehicle trips take an average of 1.8 minutes/km compared with 3.1 minutes/km for public transport and 6.9 minutes/km for active transport (i.e. walking or cycling between destinations).[8] The number of people in Brisbane commuting to work solely via car has remained relatively stable over the past decade, increasingly marginally from 64.2% in 2006 to 65.9% in 2016.[9-11]


Figure 2. Modal share across all trips in Queensland
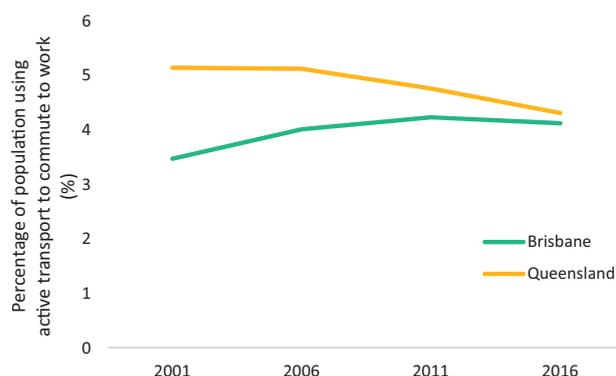Data source: Department of Transport and Main Roads[6]

In Brisbane and across the state, the percentage of commuters using public transport to commute to work has grown steadily from 2001 to 2011, with a slight drop off

Figure 4. Rates of active transport commutes in Brisbane and across Queensland
Data source: Australian Bureau of Statistics[9,10,13-16]

When fewer people use mass transit systems it creates inefficiencies during periods of peak demand. The effects of these inefficiencies go beyond inconvenience – congestion imposes significant social costs, including longer journeys, poorer air quality, and increased vehicle operating costs.[17] Projections by the Bureau of Transport and Regional Economics show that Brisbane's social congestion costs (calculated as the quantity of travel for which the total societal costs exceed the benefits)

are set to grow at a faster rate than in any other capital city out to 2020 (see Figure 5). These trends, combined with population growth, could place increasing stress on Queensland's transport system.
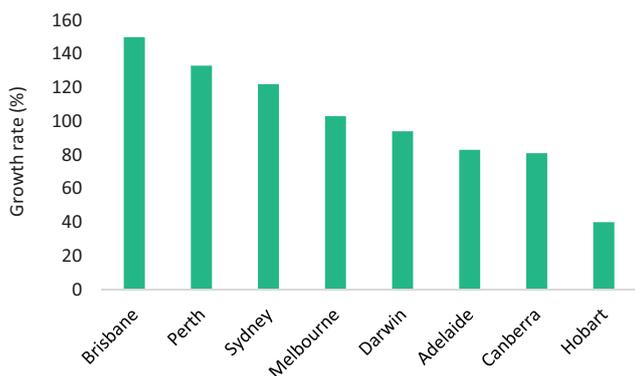
Figure 5. Growth rates of capital city congestion costs from 2005–2020
Data source: Bureau of Transport and Regional Economics[17]
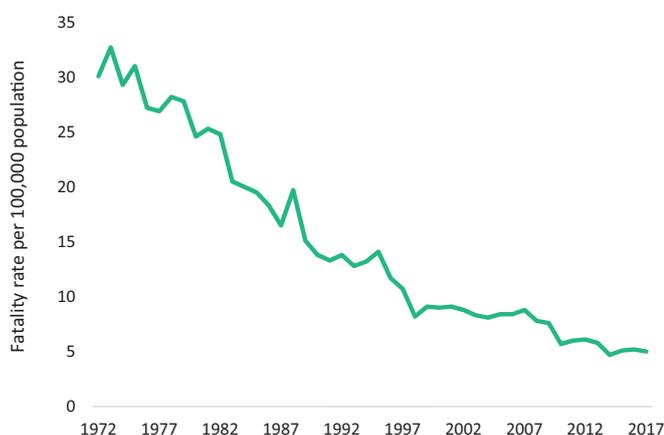
Figure 6. Number of road crash fatalities in Queensland per 100,000 population
Data Source: Bureau of Infrastructure, Transport and Regional Economics[18] and TMR estimates[i]

The long-term trend in total road fatalities in Queensland has shown a steady decline, with the lowest road fatality rate (4.7 per 100,000 population) occurring in 2014 (see Figure 6). Since then, fatality rates have remained relatively stable, on par with the national average of 5.0 per 100,000 population in 2017.[ii] Most fatalities are car drivers (44.2% of road crash fatalities in Queensland in 2017) given they are the most frequent road users.[iii] However, motorcyclists are the most vulnerable to fatal crashes, accounting for 21.9% of Queensland's fatal road crashes in 2017[iv] despite making up only 5.1% of the fleet.[19,20]

For several reasons, rural and regional areas are the most disadvantaged when it comes to transport in Queensland. First, the tyranny of distance means that people have to travel further and pay more in transport costs to access employment and basic services. Second, the size and dispersion of these communities means there are fewer transport options in regional and rural areas than metropolitan areas, such as public transport and app-based ride services. Indeed, the 2011 Household Travel Survey found 8.9% of trips in Brisbane are by public transport, but this drops to 6.2% in the rest of Queensland.[6]

TMR has developed a mobility disadvantage index (MDI) that takes into account the need for assistance, number of dependents, income, employment and number of vehicles in regions across Queensland.[v] On a scale of 1–10, where 10 represents the highest disadvantage, the rest of Queensland had consistently lower MDI scores (6) relative to the Greater Brisbane area (4) from 2006 to 2016.[9,15,16] The stability in this MDI trend could indicate no real change in mobility disadvantage across Queensland, or there could be limitations in the sensitivity of this measure (e.g. it does not account for public transport accessibility).

When it comes to moving goods, Queensland has an extensive freight transport network, covering 13,600 km of road, 9,550 km of rail line, 15 trading ports, three international airports, multiple domestic airports, three key intermodal rail freight terminals, and multiple smaller freight terminals and rail sidings.[21] Queensland's total freight task roughly doubled from 1995 to 2013,[22] and freight transport is expected to continue to grow across all parts of Queensland over the next 10 years, particularly in areas with high population growth, major mining developments and agricultural production.[23]

i.   Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.
ii. Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.
iii. Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.
iv. Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.
v.   The MDI was developed using a principal component method drawing on ABS Census data. The variables used in calculating the MDI were 'need for assistance', 'many dependents', 'low income', 'unemployment' and 'no vehicles'. The MDI was then calculated across Queensland by postcode area, as per the methodology developed by TMR.

A key challenge for transport is its impact on the environment: in 2014 Queensland's transport sector was the second largest source of greenhouse gas emissions in the state, accounting for 14.3% of Queensland's total emissions, or 21.1 million tonnes (see Figure 7). Cars are the main source of these emissions.[24] Across the world, there has been a global commitment to keep global temperatures below two degrees Celsius above pre-industrial times and as close to 1.5 degrees as possible.[25] The Queensland Government has a goal of net zero emissions by 2050, and there is a key role for the transport sector in meeting these objectives.[26]

Queensland's transport system has also seen significant changes in vehicle uptake. An increasing number of people are registering 4-cylinder vehicles over larger engine types (see Figure 8). The majority of these vehicles are petrol (84.7%) or diesel (13.8%). This market shift has key implications for TMR's future revenue streams from registration fees. As registration fees are currently calculated based on the size of a vehicle's internal combustion engine, in the absence of a change in the current funding model, a shift towards smaller vehicles and electric vehicles (EVs) could pose a future revenue risk for TMR.
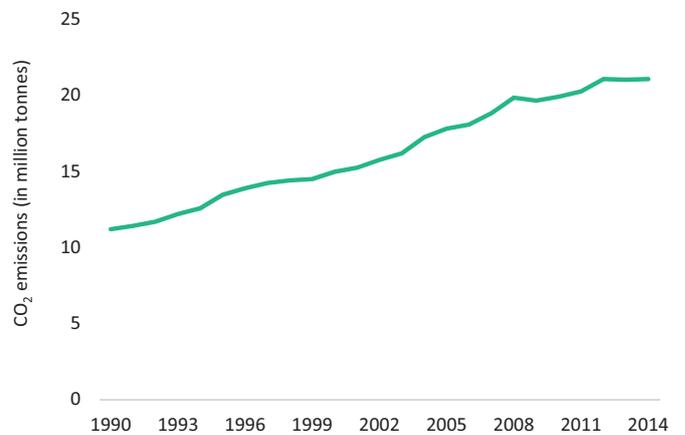
Figure 7. Transport-related carbon dioxide (CO_2) emissions in Queensland
Data source: Department of Environment and Heritage Protection[24]
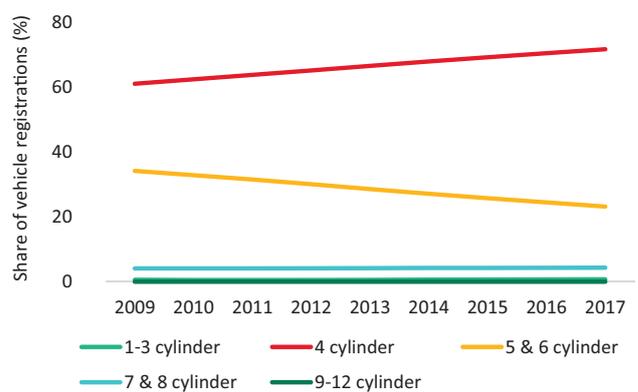
Figure 8. Number of registered vehicles on the Queensland register by cylinder group
Data source: Data provided by TMR and Data61 estimates
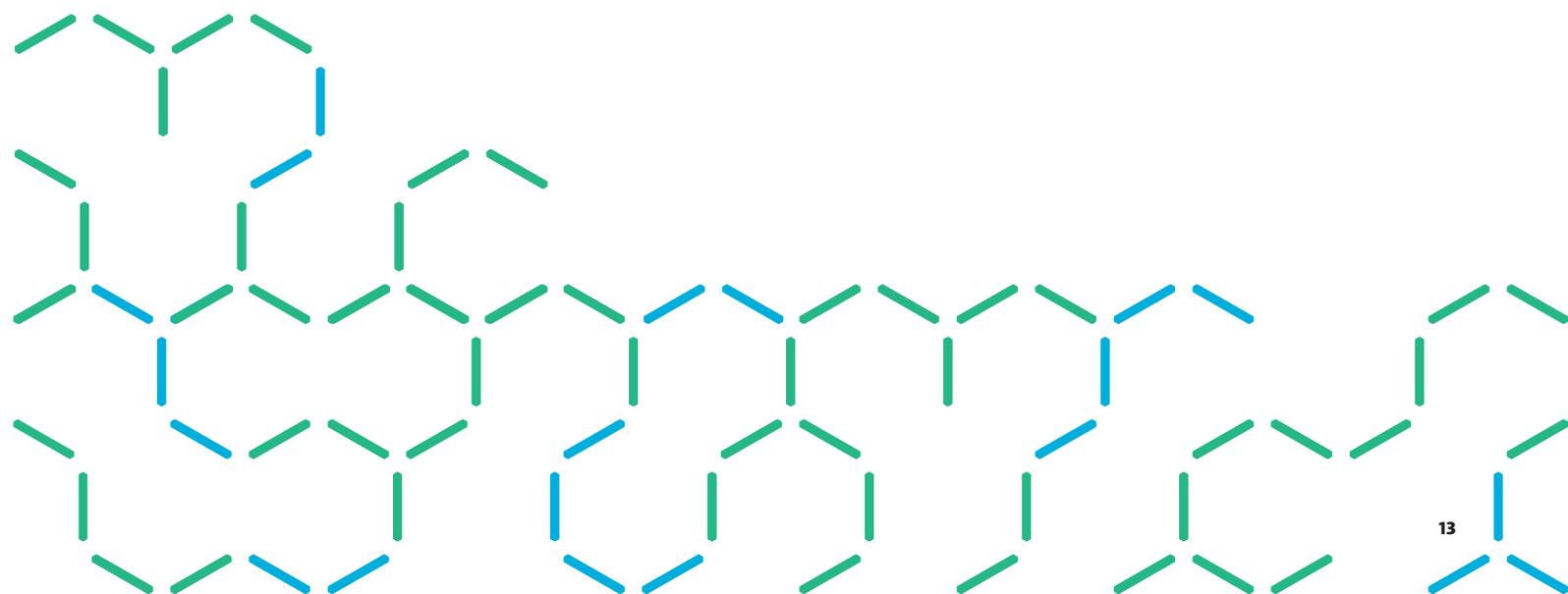
MEGATRENDS FOR QUEENSLAND'S TRANSPORT SYSTEM

A megatrend is a deep-set pattern of change that will impact the operating environment for government, industry and/or society over the coming decades. It is made up of a cluster of geopolitical, economic, social, technological and environmental trends. CSIRO originally applied this approach in its *Our Future World* report, which identified a series of global megatrends impacting a broad spectrum of businesses, sectors and communities across the world.[27]

This project extends these global megatrends, identifying five megatrends impacting Queensland's transport system over the next 30 years (see Figure 9). These megatrends provide the underlying evidence for scenario development (see Chapter 4).

Virtually There

Empowered Consumers

On the Move

A Lighter Footprint

Digital Dividends

**Figure 9. Five megatrends for Queensland's transport system out to 2048**

On the move

Demand for transport has risen consistently over the past few decades as people and goods travel more frequently. This increase is a derived demand; that is, consumers are using transport services for the indirect benefits (e.g. visiting friends or relatives) rather than the specific benefits these services provide. Population growth and the increased accessibility and efficiency of different transport options are the key drivers. This growth in demand is likely to continue over the coming decade, fuelled by further innovations around mobility services.

Population growth and urbanisation is driving up demand for transport. Queensland's population is projected to grow from 4.5 million people in 2011 to 8.1 million by 2048 (medium series).[28] Much of this population growth will be concentrated in SEQ. The Greater Brisbane area is expected to remain the most populous region in Queensland, followed by the Gold Coast, the Sunshine Coast and Wide Bay (see Figure 10). With more people living in more densely populated urban areas, there will be more concentrated demand for movement of people and goods in the future.

Commuter flows are increasing and pushing up travel time. Every weekday, Queenslanders make over two million work trips. Work commutes are the longest of all trip types in Queensland and over 20% of all trips are work related.[8] The most recent analyses of commuting flows in SEQ show an increase of 3.6% per annum from 2001 and 2006, with 60% of this growth coming from Brisbane.[31] On average, SEQ and Brisbane residents travel 15.7 km and 15.1 km to work respectively, double the distance travelled for any other purpose.[31]

An ever-expanding list of mobility options will continue to drive demand for mobility. Digital and mobility technologies have widened the range of passenger transport options, including EVs, electric bikes, scooters and skateboards.[32] Shared mobility options also enable consumers to effectively share rides, cars and bikes, reducing the need for individually owned bikes or vehicles. On the horizon, even more sophisticated developments have been suggested — such as fully connected and autonomous vehicles (AVs), flying vehicles or high-speed mass transport tunnels — which could further transform mobility options and drive demand over the coming decades.[33-35]
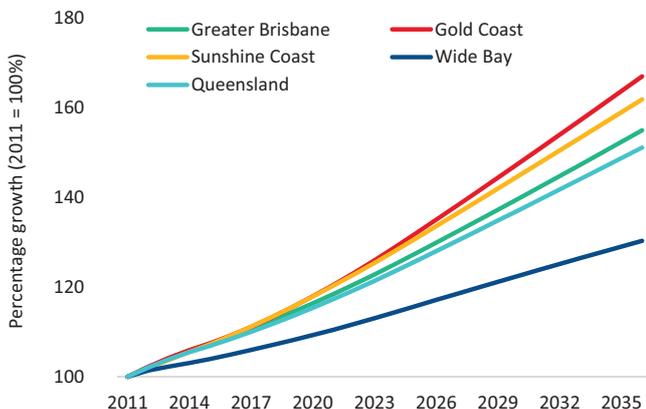
Figure 10. Projected medium series population growth as percent of resident population (index base, 2011 = 100%)
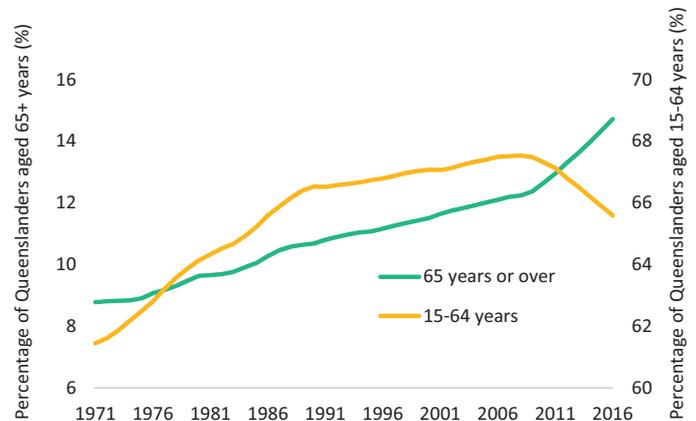
Data source: Australian Bureau of Statistics[29] and Queensland Government Statistician's Office[30]

New technologies could enable cheaper transport. As new mobility technologies come online, transport costs could reduce, fuelling further demand for mobility. Research suggests that AVs could reduce travel costs by between $2,600 and $5,200 per annum per vehicle through reduced cost of crashes, travel time, fuel and parking.[36] In addition, while EVs are still expensive to buy, the maintenance is significantly cheaper than for combustion vehicles.[37,38] Internet-of-Things (IoT) applications could also reduce mobility costs for freight in the future through capacity sensing, planning and reporting, route optimisation, energy management, and fault detection and resolution.[39]

An aging population will shift transport demand. In 2011, 13.0% of Queensland's population was 65 years or over and this is projected to reach up to 21.8% by 2048.[40] This has coincided with a reduced proportion of the population being of working age (see Figure 11). However, with higher life expectancy, many older workers are choosing to stay longer in the workforce.[41] These demographic changes could affect transport demand in different ways; for example, increasing demand for off-peak travel, or demand for mobility options that cater for those with sensory, cognitive or mobility impairments. Initiatives such as the National Disability Insurance Scheme could similarly add to demand for special needs transport options, as more people with a disability enter, or return to, the workforce.[42]

Air travel is increasingly popular. Airline ticket prices have decreased steadily over the past few decades.[44] In 2011, 19.9 million people landed in Brisbane — the third largest receiver of passengers in Australia — and current trends project this to reach 45.1 million by 2031 (see Figure 12). As airline ticket prices continue to fall, demand for air travel will continue to rise. This is driven by growth in the 'experience economy' which is characterised by increased consumer demand for experiences over physical goods. Part of this growth could be driven by business travel too, as more people travel for work outside of SEQ.

Greater flows of people into Queensland is driving growing visitor activity. In 2017, Queensland saw a 4.9% increase in domestic visitors and a 4.3% increase in international visitors.[46,47] The largest share of international visitors now come from China,[48] with Queensland welcoming 503,000 Chinese visitors in 2017.[46] Queensland is also becoming more culturally diverse. In 2017, 28.9% of its was population born overseas, compared to 24.8% in 2006.[49,50] A growing tourism market and an increasingly diverse population will continue to fuel travel for holidays, business and visiting friends and relatives.

Figure 11. Percentage of Queensland population of working age (15–64 years) and 65 years and over
Data source: Australian Bureau of Statistics[43]
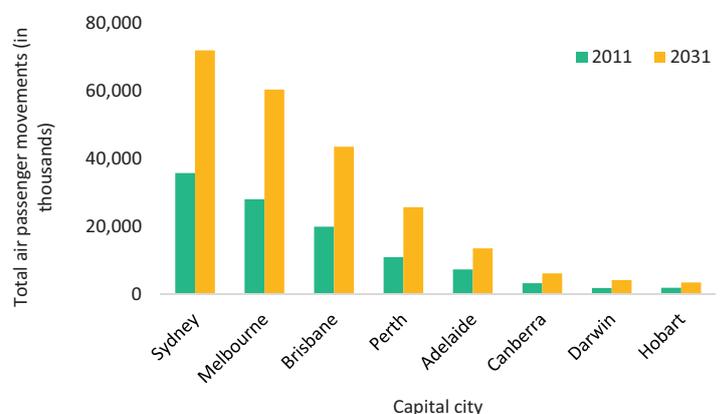
Figure 12. Total air passenger movements (in thousands) in Australian capital cities
Data source: Department of Infrastructure and Transport[45]

Digital dividends

Queensland's transport system is likely to change significantly as emerging technologies become increasingly capable, affordable and widespread. Automated vehicles, digitally enhanced infrastructure and drones all have the potential to reduce infrastructure costs and the impact of transport in the environment, and better utilise the existing freight and passenger fleet. Other applications of big data analytics could similarly enable a transport system that can more effectively respond to demand. These advances will ultimately improve the quality, safety and reliability of Queensland's transport system.

Using building information modelling to reduce transport infrastructure costs. Building information modelling (BIM) could help lower expenditure on future transport infrastructure projects. This technology digitally models construction projects in three or more dimensions quickly and with a high level of precision and accuracy. BIM has been used extensively in construction projects across the United Kingdom.[51] Although BIM has a high upfront cost, it delivers cost savings regardless of the size of a construction project, with returns on investment varying from 16% to 1,654%.[52] Data61 is working with the Queensland Government to use BIM in the Cross River Rail infrastructure development.

Sensory systems and drones could be used to better monitor existing transport infrastructure. Systems that monitor structural health can provide infrastructure planners with early warning signs about physical damage and potential weaknesses.[53] This can reduce costs through preventive maintenance, limit disruption to road users and extend asset life without drastically increasing expenditure.[54] Similarly, drones can inspect infrastructure more cheaply and more precisely, to inform maintenance needs and enable more accurate forecasts.[54,55] Drones can also provide a viable, unobtrusive and less time-consuming alternative to traffic monitoring and management.[56,57]

Big data analytics can better understand, manage and shift peak traffic demand, and target solutions. Big data analytics can identify times and locations of peak demand, thus improving public transport planning and delivery.[59] For private vehicle drivers, big data analytics can also identify congestion and predict future traffic conditions, allowing drivers to use the most efficient routes.[60,61] When these 'active demand management' systems are combined with reward schemes for off-peak travel and the use of less congested routes, travel time can be reduced by 20%.[61] Big data can also be applied to design transport solutions (e.g. for land-use patterns or demand management) using precise, real-time information.[62]

Cooperative intelligent transport systems could optimise the transport network. Cooperative intelligent transport systems (C-ITS) enable vehicles to communicate with each other and with connected infrastructure (e.g. traffic signals). This can alert drivers to upcoming road hazards and significantly improve road safety and traffic efficiency.[63] Moreover, the fatal Tesla accident in 2016 could have been prevented if the vehicle was fitted with C-ITS capabilities.[64] There is a multiplicative effect of these technologies. One study estimates that highway capacity increases by 1.4 when AVs are equipped with sensors only, but increases by 3.7 when vehicles are equipped with both sensors and communication devices (see Figure 13).

Autonomous heavy vehicles could reduce freight costs and emissions. Experts suggest that autonomous electric trucks could reduce the cost of trucking by 75% over the next 5 to 10 years (see Figure 14). This is the result of higher utilisation rates and reduced labour costs associated with drivers.[65] Albeit, these vehicles are unlikely to replace human drivers on all freight corridors. Heavy vehicle automation will allow trucks to 'platoon' (i.e. drive cooperatively at less than one second apart), enabling lower fuel consumption, greenhouse gas emissions and congestion, and improved travel times and road safety.[66] Autonomous trucks have already been used in the mining industry: Rio Tinto estimates that over the course of a year, its autonomous trucks operated for around 700 hours more, and at 15% lower load and haul unit costs, than conventional trucks.[67]
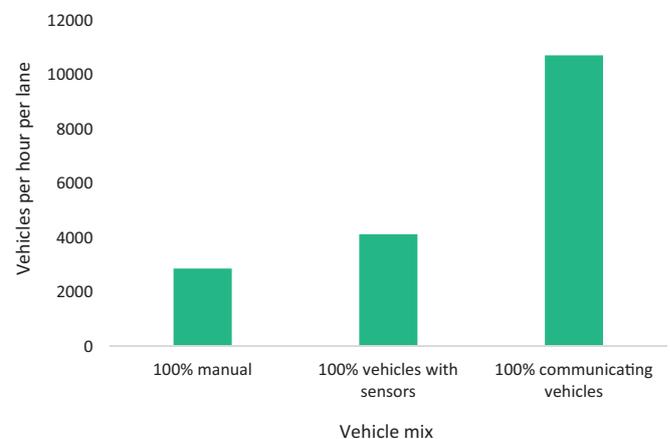

Figure 13. Highway capacity under full-adoption scenarios for manual, sensor-equipped and communicating vehicles

Data source: Tientrakool, Ho, and Maxamchuk[58]
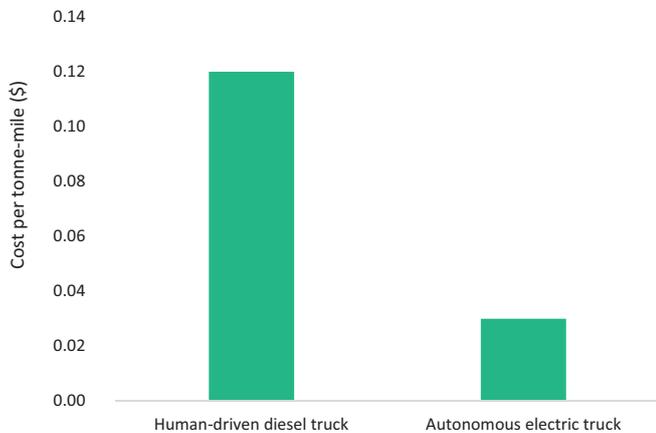
Figure 14. Cost per tonne-mile for human-driven and autonomous trucks

Data source: ARK Invest[65]

Autonomous vehicles could come online but there are uncertainties around when this will happen. There is much commercial interest around AVs and cumulative investments in AVs are on the rise (see Figure 15). Moreover, AV sales are predicted to reach 1 million by 2027 and 10 million by 2032.[68] In Australia, transport ministers have agreed to a phased reform program to support the safe and legal operation of fully automated vehicles from 2020.[69] Despite this interest, the affordability, capability and accessibility of AVs, along with privacy concerns, could impact future uptake.[70] Modelling projections for Queensland estimate that anywhere from 87% (high-uptake scenario) to 26% (low-uptake scenario) of the fleet could be autonomous by 2046, depending on when AVs reach 100% fleet share (i.e. year 2048 versus 2058).[71]
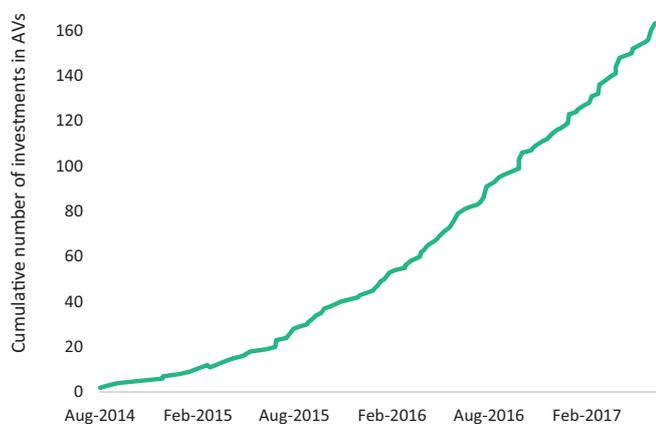
Figure 15. Cumulative number of investments in autonomous vehicles (AVs)

Data source: Brookings Institution[72]

Virtually there

Advances in digital technologies are opening up new ways of accessing goods and services, such as online banking, shopping, education and training programs, and government services. This reduces the physical travel to meet these everyday requirements and has implications for traditional brick-and-mortar centres. Many knowledge workers already telecommute or work from home, which can reduce pressure on the transport system during times of peak demand. In the future, less of people's travel 'budget' might be spent on trips to work, education and retail centres, opening up the capacity to travel more for leisure and tourism.
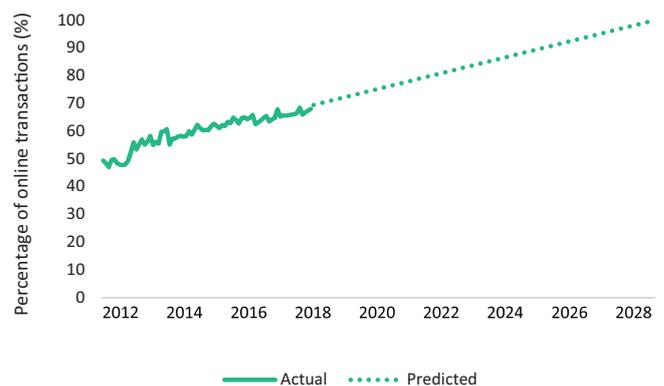
Figure 16. Percentage of Queensland Transport and Main Roads transactions performed online out of total available online transactions

Data source: Data provided by TMR and Data61 estimates

Note: Actual data are shown until April 2018 with subsequent estimates based on a linear projection of historical data.

Access to online goods and services impacts passenger and freight transport. Online shopping deliveries across Queensland increased by 9.8% from 2016 to 2017.[73] While this growth is stronger in more populated areas, regional growth was stronger for purchases from department and variety stores (7.9% for regional vs. 6.6% for metropolitan areas), and specialty food and liquor purchases (1.8% vs. −1.2%).[73] TMR has also seen growth in the share of customer transactions performed online (see Figure 16). Based on the current growth trajectory, Data61 estimates that the percentage of TMR service transactions done online will plateau at 99% by 2028 (see Figure 16). As people access more goods and services online, the transport task will shift from moving people to goods, to moving goods to people.

Workers are increasingly able and willing to do their work remotely. Teleworking and flexible working arrangements are becoming more popular. In 2015, 4.2 million people in the United Kingdom (13.7% of the workforce) worked from home,[74] and up to 50% of their workforce could be working remotely by 2020.[75] In Australia, more people are working regularly from home, but Queensland lags behind the national average (see Figure 17). A survey of Queensland workers in 2014 found about 30% were able to work from home, but only about 25% did so regularly.[76] Greater uptake of teleworking can improve workers' productivity and job satisfaction,[77] and ease peak demand on the transport system.

The average Australian work week is getting shorter. As automation substitutes or augments human labour across the workforce, and part-time and causal work arrangements become more common, the average work week could get shorter. In Australia, the average number of hours worked has decreased significantly (see Figure 18). This has coincided with more people working part-time. In 1997, about 25.6% of the workforce were employed part-time which grew to 31.6% by 2017.[84] Workplaces in some countries such as Sweden and New Zealand have even trialled six-hour work days or four-day work weeks.[85,86] With people working fewer hours, there could be changes to the nature of peak demand and the variability in this demand for the transport system.

Figure 17. Percentage of employed persons working regularly from home in Australia and Queensland
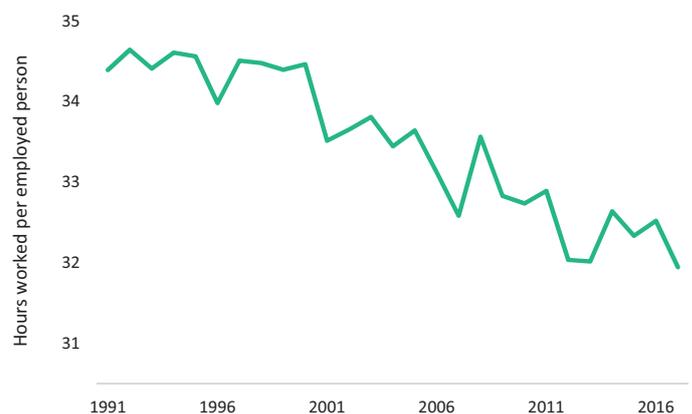
Figure 17. Percentage of employed persons working regularly from home in Australia and Queensland
Data source: Australian Bureau of Statistics[78,79]

Figure 18. Hours worked per employed person in Australia
Data source: Australian Bureau of Statistics[84]

Workforce automation will emphasise the non-physical aspects of work. There is great uncertainty around the extent to which technology will impact the workforce, with estimates that 9%[80] to 47%[81] of it is at high risk of future automation. Recent estimates suggest that automation will have a disproportionate impact on the manufacturing and agricultural industries, as well as low-skilled service sectors, such as postal and courier services, land transport and food services.[82] Increased use of artificial intelligence and robotics in the workforce will likely reduce the time workers spend on physical tasks, and increase time spent on higher value intellectual tasks the can be done remotely.[83]

The service sector is growing. The top-employing industries in Queensland in 2018 were healthcare and social assistance, retail, construction, and education and training, making up 14.2%, 10.2%, 9.6% and 8.2% of the workforce in May 2018 respectively.[87] Service-related sectors are also the fastest growing industries, with administrative and support services, arts and recreation, and healthcare and social assistance showing the strongest growth from 1985 to 2018 (see Figure 19). This growth in the services sector in Queensland mirrors national and global trends and reflects the state's transition to a more knowledge-based economy.
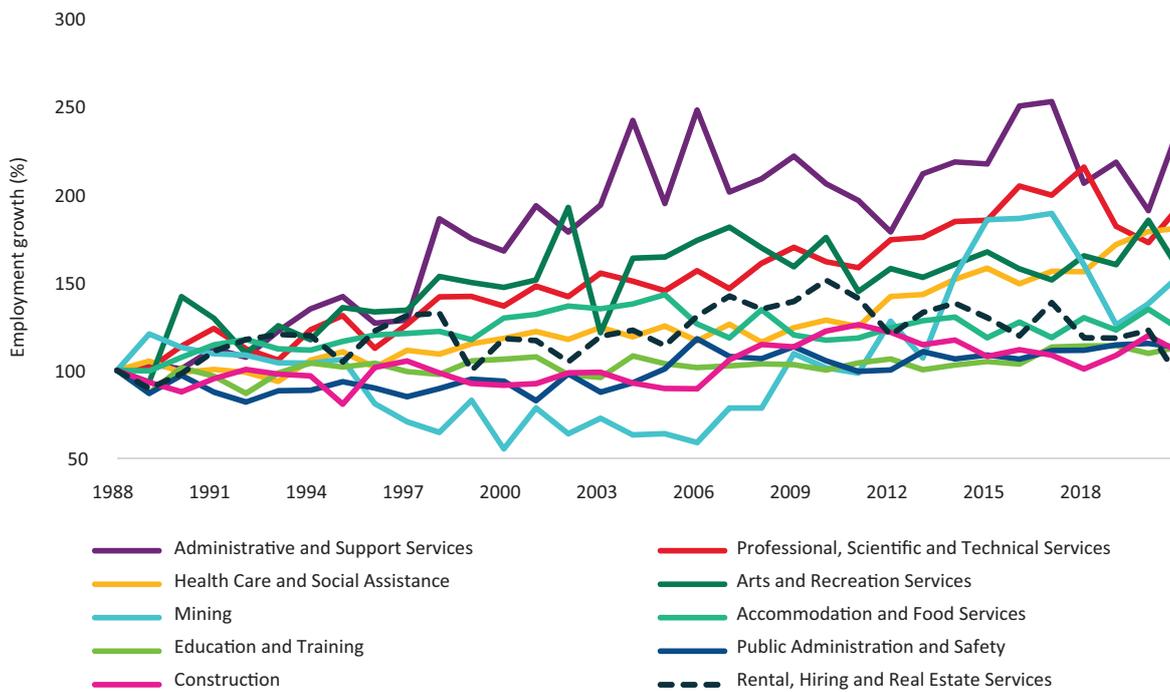
Figure 19. Employment growth across the ten fastest growing industries in Queensland (index base, 1985 = 100%)

Data source: Australian Bureau of Statistics[87]

3D printing may alter the freight task. There are critical uncertainties around the impact of 3D printing on freight transport. Some experts have hypothesised that 3D printing will give rise to more dispersed and flexible distribution networks, with production occurring in city hubs, either with or without home-based printers.[88] While raw materials will still be needed as inputs to the 3D printing process, these could be delivered in bulk and lead to more efficient freight movements.[89,90] However, experts are divided on whether 3D printing will increase or decrease overall transport volumes.[88]

More time online can have negative health impacts. People are spending more time online. Medibank estimates that Australians are sedentary for 77% of the working day, and spend an average of 9.5 cumulative hours looking at a screen.[91] The average adult in Queensland spends 38.5 hours per week on sedentary activities for work or leisure (e.g. sitting on transport, watching television or using a computer).[92] A lack of physical activity has been associated with increased risk of obesity, diabetes, cardiovascular disease and premature mortality.[91] There are therefore opportunities for the transport system to provide public health benefits through initiatives and infrastructure that encourage active transport.

A lighter footprint

The transport sector has a significant impact on the environment and on public safety. A rise in demand for transport, in the absence of changes to vehicles, therefore has the potential to increase transport-related greenhouse gas emissions and road traffic fatalities and injuries. Innovations around vehicle technologies such as AVs and EVs, however, are providing greener, more efficient and safer mobility options. There are also strong geopolitical pushes towards more environmentally friendly vehicles. These combined trends point towards a 'lighter' future for Queensland's transport system.

Battery costs are projected to decline if sufficient access to raw materials continues. Lithium-ion battery prices have been on the decline (see Figure 20). This trend is expected to continue, with EV battery pack prices projected to drop to approximately $255/kWh by 2020 and $134/kWh by 2030.[93] Cheaper batteries, simultaneous with government incentives for EVs, could make EVs more accessible for consumers in the future. However, availability and cost of raw materials (e.g. cobalt – a rare metal required for lithium-ion batteries) might halt future developments and price reductions in the EV industry.[94] Furthermore, battery production can cause significant environmental damage caused by mining for raw materials and toxic waste from batteries that are not recycled.[95]

Global macro-level transport policies are increasingly focused around EVs. There has been a global geopolitical shift away from vehicles powered by non-renewable energy sources. For instance, China, India, France, Britain and Norway have committed to a ban on selling petrol- and diesel-powered vehicles over the coming decades.[97] Austria, Denmark, Ireland, Japan, the Netherlands, Portugal, Korea, Spain and parts of the US have similarly all set targets for electric car sales.[98] As EV technologies become cheaper and current generations of fuel-powered vehicles reach end of life, more governments may adopt similar targets. While EVs produce fewer tailpipe emissions than petrol or diesel vehicles, the energy efficiency of completing the mobility task will also be an important factor to consider in the future.

Queensland lags behind growing global demand for electric transport. Global EV sales have been on the rise, up from 540,000 units in 2015[101] to 2 million units in 2016.[101] Estimates reveal that up to 54% of new car sales and 33% of the global car fleet will be electric by 2040.[102] Under a high-adoption scenario, the International Monetary Fund estimates that up to 90% of passenger vehicles in the developed world will be electric by 2042, resulting in a reduction of 3.2 billion tonnes of CO_2 emissions per year.[103,104] Despite these trends, the uptake of fully electric vehicles in Queensland, and indeed Australia, is low (see Figure 21), likely due to limitations in vehicle capacity and the selection of affordable models in the market.[99]
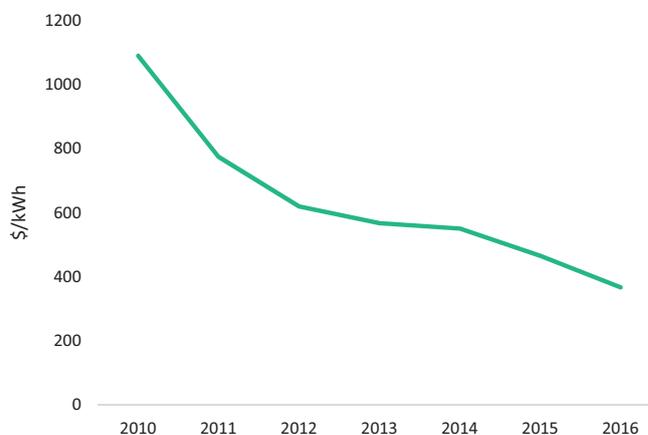
Figure 20. Global lithium-ion battery prices ($/kWh)
Data source: Bloomberg New Energy Finance[96]

Figure 21. Number of electric vehicles (EVs, excluding hybrid vehicles) purchased across each Australian state from 2011–2016
Data source: ClimateWorks Australia[99]

Vehicles are becoming more fuel efficient. The average level of emissions from vehicles manufactured between 1994 and 2007 has reduced significantly, driven largely by tougher emission standards set by the Australian Design Rules.[105] A 2015 Australian study found that the national average carbon emissions from new passenger and light commercial vehicles was 184 g/km, representing a 26.9% reduction since records began in 2002 (see Figure 22). Despite vehicles becoming more efficient, the number of vehicles on the road has increased, resulting in a 2.7% average annual increase in greenhouse gas emissions from Queensland's transport sector.[24] Vehicle sharing, a reduction in distances travelled alone and increased fuel efficiencies are needed to improve transport-related greenhouse gas emissions.

Uptake of alternative fuel sources is growing, yet remains uncertain. Total biofuel production grew from 27,848,000 tonnes oil equivalent in 2006 to 82,306,000 in 2016.[107] The International Energy Agency predicts that by 2050, biofuels will provide 27% of the world's transport fuel.[108] Alternative fuel sources are beneficial as they can help mitigate greenhouse gas emissions and air pollution without the need for restrictive measures, such as road pricing.[109] There are uncertainties around alternative fuel sources though, as they rely on consistently high oil prices and/or substantial policy initiatives to encourage uptake.[109]

AVs could have both positive and negative environmental impacts. Research suggests that even a single AV can ease a congested traffic flow and reduce fuel consumption by around 40% (averaged across all vehicles).[110] Modelling by the Organisation for Economic Cooperation and Development (OECD) has also found that shared self-driving cars when combined with high-capacity public transport can service the current passenger task with 10% of the car fleet.[62] However, the additional convenience and mobility offered by AVs could translate into greater demand for private vehicle travel over public transport, walking, or cycling. Modelling of transport in Queensland estimate that by 2046, demand for car travel will increase by 4.6% under a high-AV-uptake scenario and decrease by 1.9% under a low-AV-uptake scenario.[71]

The shift from six- to four-cylinder vehicles continues. The share of 4-cylinder vehicles in Queensland's vehicle fleet is growing in tandem with a declining share of 5-/6-cylinder vehicles (see Figure 23). The majority of passenger cars registered in Queensland in 2018 are 4-cylinder vehicles (73.2%).[vi] Vehicles with smaller engines consume less fuel: in 2016, vehicles with four cylinders consumed 10 litres per 100 km, compared with 11.7 litres for 6-cylinder vehicles and 12.9 litres for 8+ -cylinder vehicles.[111] Despite the environmental benefit, this market shift could pose future revenue risks for TMR, as 4-cylinder vehicles incur a smaller registration fee than 5-/6-cylinder vehicles.
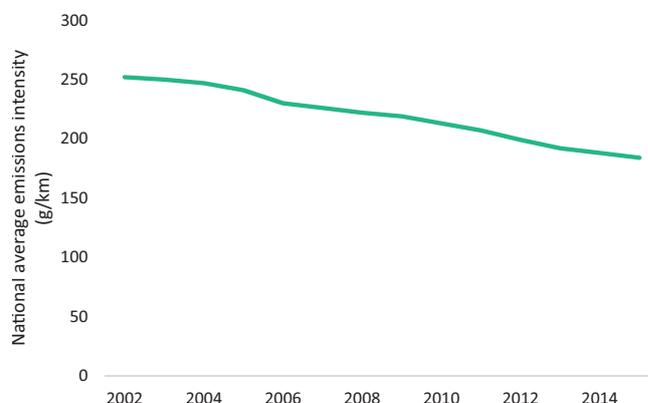
Figure 22. National average emissions intensity for new passenger and light commercial vehicles in Australia
Data source: National Transport Commission[106]
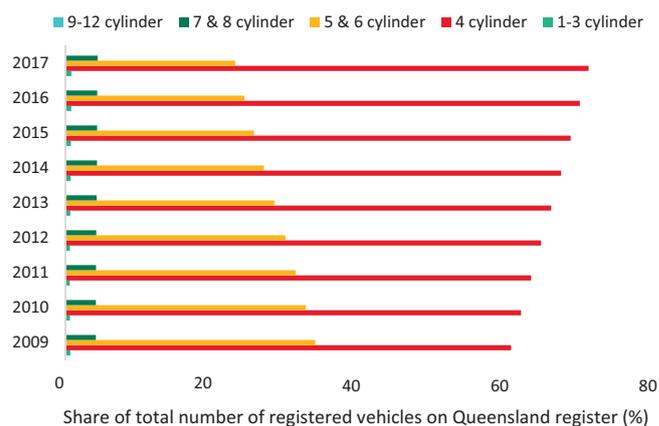
Figure 23. Share of total number of registered vehicles on Queensland register by cylinder type
Data source: Data provided by TMR and Data61 estimates

AVs could improve the road toll which is disproportionately high in rural and regional areas. The number of road traffic fatalities dropped to an all-time low in 2014 (4.7 per 100,000 population),[112] and rates have gradually risen since then, reaching 5.0 per 100,000 population in 2017.[vii] The majority of the road toll (85.4%) is accounted for by regional and remote areas in Queensland.[viii] AVs would lead to radical improvements in safety, with over 90% of car crashes in the US resulting from human error,[113] and 40% of fatal crashes caused by distraction, intoxication or fatigue.[36] Some estimates suggest that full vehicle automation could reduce traffic accidents by up to 90%.[114]

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vi. Estimates based on registration data provided by TMR.

vii. Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.

viii. Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.

Empowered consumers

Across the globe, there is growing consumer demand for on-demand, personalised, convenient and streamlined transport services over traditional schedule-based models that cater to the masses. Enabled by growth in digital connectivity and access to data, new platform businesses that better connect passengers and freight to mobility services have emerged. As alternative mobility services become more responsive, reliable and integrated, there will be less need for individuals to own a vehicle to travel, and new travel options for those who are most mobility disadvantaged.

Transport is becoming more personalised. Enabled by the proliferation of smartphones and access to data, personalised transport services have grown in popularity. Mobility-as-a-service (MaaS) schemes that integrate public and private transport services into a single fare and are being trialled around the world.[115,116] Examples include the Whim app, released in the Helsinki region in 2016, which integrates taxi, public transport, car services and bike sharing into a single monthly user access plan. Vehicle automation will likely fuel further personalisation of transport services, and may give rise to a hybrid model of vehicle sharing and private ownership.[117,118] MaaS schemes could provide more options to consumers and improve access to transport across Queensland, particularly for those who are unable to drive or who have limited access to public transport.

Bike-sharing schemes are becoming more popular. The number of trips taken via bike-sharing schemes in the US has risen (see Figure 24). In 2010, there were approximately 125 bike-sharing programs that used docking systems across cities around the world, providing more than 139,300 bikes.[119] This had risen to 325 cities and 278,057 bikes in 2018.[120] Dockless bike-sharing programs that operate via smartphone have become more popular too, with large companies operating tens of millions of bikes worldwide and in Australia.[121] Bike-sharing can improve mobility, flexibility of travel, public transit use, individual health and environmental awareness, and reduce travel costs, congestion and fuel.[119]
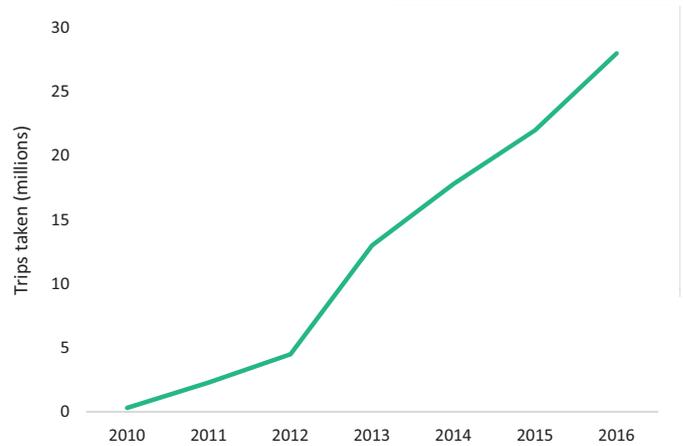

Figure 24. Trips taken via bike-sharing schemes in the US
Data source: National Association of City Transportation Officials[122]

Different types of shared mobility models can lead to different impacts. A range of emerging app-based ride services are allowing people to share assets.[124-127] These include 'ride-sourcing services', like UberX and Lyft, which enable one or more passengers to travel from a single point-to-point, and 'ride-pooling services', like Uber Pool and Lyft Line, which allow multiple passengers to be picked up and dropped off at different locations en route. While it is unclear how ride-pooling services impact congestion, a preponderance of ride-sourcing services have been associated with an increase in the number of vehicle trips and kilometres travelled.[128] How people use app-based ride services and the impact of these services on congestion likely depend on how they compare to the availability and attractiveness of other mass transit and active travel modes.[128]

Younger generations are embracing new forms of transport. Millennials (i.e. those born between 1982 and 1996) own fewer cars than older age cohorts, drive less and have a more favourable view of public transport.[129-131] Consistent with global trends,[132] licensing growth rates for Queenslanders aged under 25 have dropped from 3.1% in 2006–2007 to 1.2% in 2016–2017.[133] The percentage of 18- to 34-year-old licence holders with a registered vehicle has declined from 2008 to 2018, while the percentage of those aged 56 or older with a registered vehicle has remained stable or increased.[ix] Queenslanders aged 18–34 years also have fewer registered vehicles per person (see Figure 25) and are more likely to use app-based ride services (33.6%) compared to all other age groups (25.1% or lower).[134]

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ix. Data61 estimates based on licensing and registration data provided by TMR.

On-demand freight services are emerging.

Freight and logistics sectors worldwide suffer from significant inefficiencies associated with empty loads. Estimates from 2012 show that 23.2% of all kilometres travelled by heavy vehicles were with empty loads.[135] To deal with this, in 2017 Uber launched Uber Freight, a smartphone app that connects truck drivers with freight loads in the US. Similar services are emerging in Australia too (e.g. FreightExchange). However, challenges around truck driver shortages can make it difficult for these platforms to scale in a shipping market already crowded with freight brokers.[136]

Drones could help fill last-mile delivery gaps for freight.

Drones could provide novel ways of servicing last-mile delivery, with Amazon and Google announcing plans to use drones to deliver small parcels directly to households.[138,139] Drone delivery could be particularly beneficial for people in rural and remote areas, where same-day delivery via vehicle transport is extremely costly.[139] Widespread commercial drone use for last-mile delivery will be subject to regulatory conditions around drone safety and privacy, and drone capabilities around flight time and weight-carrying capacity.
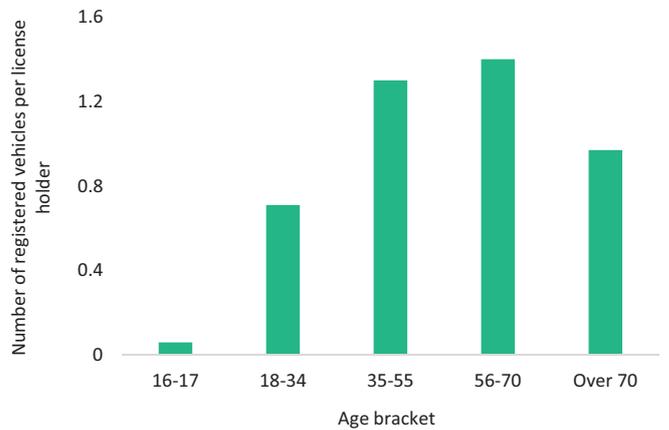
Figure 25. Average number of vehicles registered to Queensland licence holders by age bracket

Data source: Estimates provided by TMR
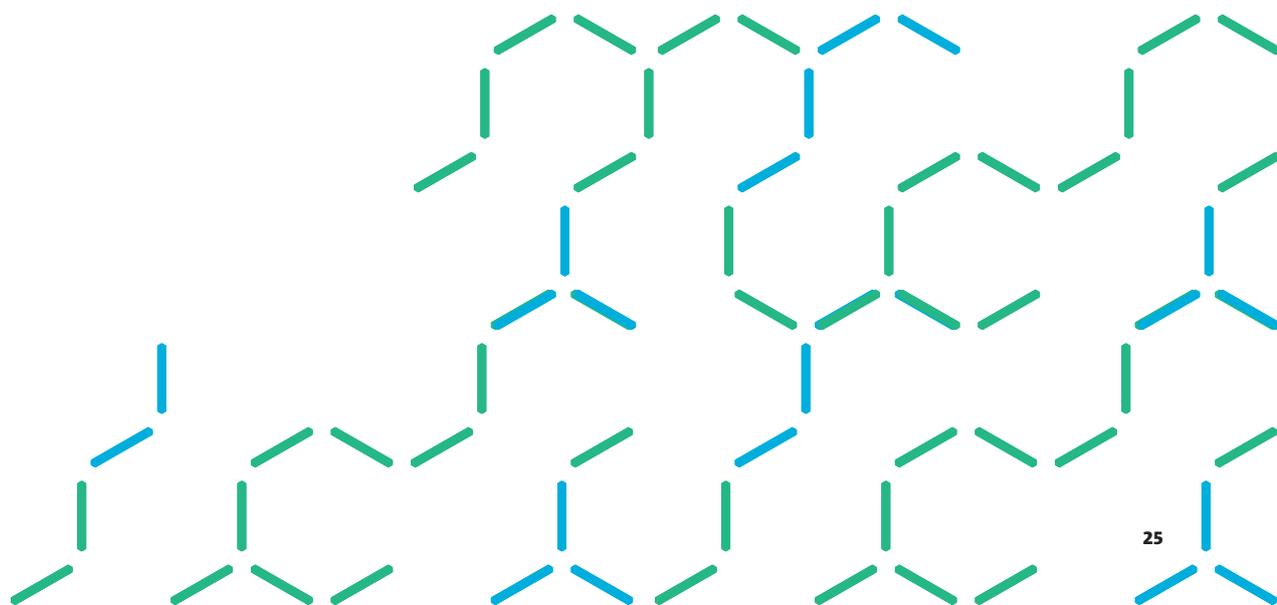
SCENARIOS FOR QUEENSLAND'S TRANSPORT SYSTEM
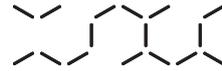
The megatrends presented in Chapter 3 are based on emerging transport trends, some of which will continue along their current trajectory, with others tapering off or changing direction. A set of four scenarios has been developed to understand the uncertainties around these future trends and their implications for TMR's operating environment (see Chapter 5).

Complementing these qualitative narratives are quantitative forecasts for a set of key transport-related fundamentals (see Appendix B and C for modelling details and Appendix D for more granular time-series plots).

Scenarios do not aim to predict the future; rather, they are intended as evidence-based stories about plausible future changes. The scenarios are defined by the intersection between two continuums of uncertainty: variability in mobility patterns and level of technology transformation. Both ends of these continuums (i.e. axes) of uncertainty must be supported by existing trends and drivers, and have a strong potential for impact in the future.

These two axes give rise to four plausible scenarios for the future of Queensland's transport system (see Figure 26). This chapter outlines key uncertainties around mobility patterns and technology transformation, and the narratives emerging from these. This chapter also presents modelling results that estimate the quantitative impacts under each scenario. These estimates provide more granular insights into the key economic, safety and environmental impacts on Queensland's transport system under each scenario.

New technologies & business models are rapidly adopted

Level of technology transformation

Off-Peak, On-Demand

Digital technologies have advanced significantly, enabling a virtual presence for work, study and other activities, and improving costs of transportation. The transport task is serviced by more on-demand, personalised services.

Mobility options for people living in regional areas improve, but what happens to transport infrastructure in urban areas?

Cruise Control

Mobility patterns concentrate around peak times and/or destinations and this demand is better managed by intelligent technologies. Ridesharing and point-to-point services can better connect people and freight to mass transit systems.

High technology uptake and concentrated populations enable transport efficiencies, but how are revenue challenges managed?

People's travel is non-routine and dispersed

Variability in mobility patterns

Travel continues to concentrate around peak times

Suburban Streets

Urbanisation pressures drive people to live in more regional areas. Many own a car but do not need to travel to a central location as frequently. However, the freight sector must service a more dispersed population without the aid of new technologies.

Peak demand and congestion both reduce, but could this coincide with a rise in passenger and freight transportation costs?

Bumper to Bumper

Increased population density in South East Queensland, combined with low technological innovation and uptake in the transport sector, continues to strain the transport network. Commutes grow longer, congestion worsens and emissions increase.

If other jurisdictions see significant changes in their transport system, what impact will this have on the quality of life for Queenslanders?
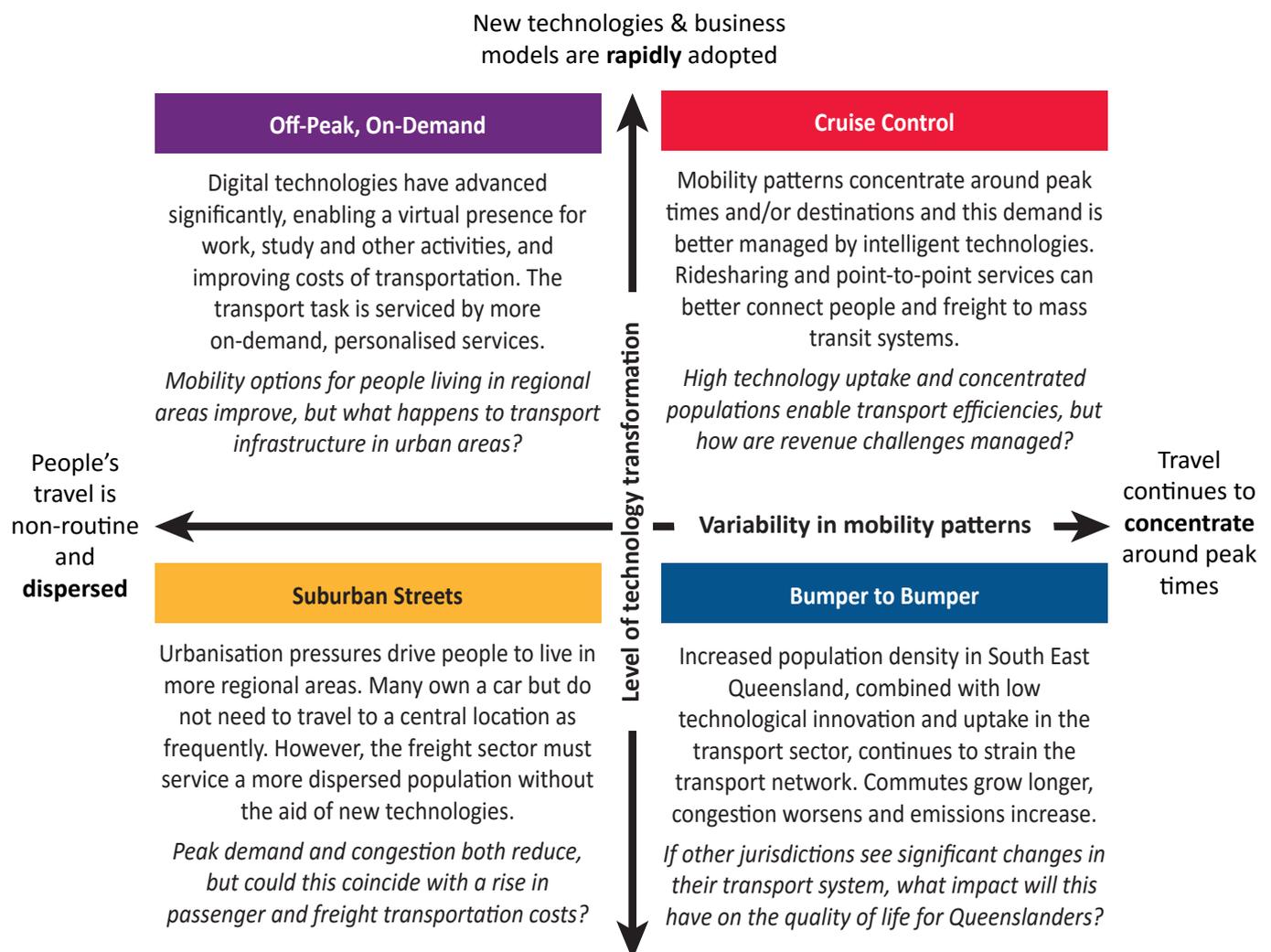
Figure 26. Scenarios for Queensland's transport system in the year 2048

Horizontal axis: Variability in mobility patterns

The horizontal axis describes mobility patterns and how concentrated or dispersed they are based on temporal and spatial dimensions. This axis captures key uncertainties around employment models, consumer behaviour and land-use patterns in response to advances in technology, urbanisation pressures and/or demographic shifts. At the high end, land use and commuting patterns continue along the current trajectory, but at the low end, we see more people moving to regional centres, driven by urban pressures and/or a shift towards telecommuting.

CONCENTRATED MOBILITY PATTERNS

At the concentrated end of the axis, the Queensland population continues to cluster in major centres, largely in SEQ. Under these scenarios, population trends would fall in line with current projections out to 2036, with the most populous regions being the Greater Brisbane area, followed by the Gold Coast, Sunshine Coast and Wide Bay region.[28] Queensland has already seen strong migration from the regions to SEQ, with all areas outside of these key growth regions showing declining populations (see Figure 27). As more people live in a concentrated location, there is increased pressure on the transport system in managing peak demand.
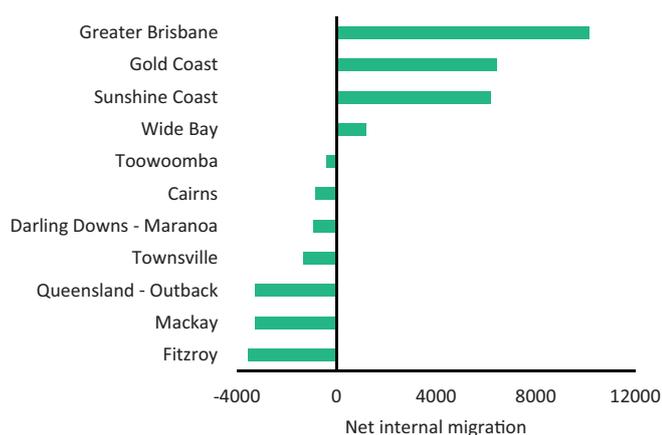
This concentration of people is driven by a desire to live and/or work in a central office, or study in a central school or educational institution. Currently, 50.3% of Queensland's workforce is employed in the Greater Brisbane area (49.7% in the rest of Queensland), and this has increased from 48.4% in 1998 (51.6% in the rest of Queensland).[84] At this end of the continuum, we see little change in the current institutional models around employment and education, with people continuing to physically travel to work. The current low rates of regular teleworking in Queensland would also continue.[78,79]

Telepresence systems will likely improve from what we have today, but the inability of teleworking systems to simulate 'real-world' working or learning experiences could limit uptake. There could also be cultural resistance around teleworking, as concerns around productivity, cost, security, career progression, work/life balance and team coherence have been identified as factors deterring large-scale adoption of teleworking.[141] Furthermore, concerns around wages and working conditions could limit participation in the peer-to-peer workforce.[142-145]

Increasingly concentrated mobility patterns will have a negative impact on traffic congestion in the absence of better ways of managing peak demand. As demand increases, there is increased pressure to build more roads and other traffic infrastructure to better manage demand. This will likely incentivise private vehicle travel though,[146] which consequentially worsens congestion around central hubs. Aided by technologies such as intelligent, connected vehicles, responsive traffic monitoring and alternative mobility models that connect to mass transit systems, this concentrated demand could be effectively managed.

Figure 27. Net internal migration in Queensland from 2006 to 2016 by region

Data source: Australian Bureau of Statistics[140]

DISPERSED MOBILITY PATTERNS

The dispersed end of the axis captures a future where Queensland's mobility patterns have become more variable, devoid of the typical peaks and troughs in demand. Queensland is already the most dispersed state in Australia, with 51.7% of the population living outside the capital city in 2016, compared to 35.5% in New South Wales and 24.3% in Victoria. Some regional hubs outside of Brisbane are projected to be some of the fastest growing regions, such as Ipswich (up 184.3% from 2016 to 2036), Logan (72.0%) and the Scenic Rim (68.2%).[147] This growth could expand to more regional and remote areas as mobility patterns become less dependent on commutes into the Brisbane CBD.

Housing affordability is a key factor that could drive more people to live further from the city. Between 2011 and 2017, residential property prices in Brisbane grew by 24%, while Sydney and Melbourne saw much steeper growth (see Figure 28). Out of the 12 regions with the fastest growing housing prices, 11 of these are located in SEQ.[148] Another motivator for moving out of the city is to avoid lengthy commutes – this is one of the main reasons why Australians move house or change jobs.[149] Indeed, people living in lower-income areas that are distant from the city drive longer and further, have higher travel costs and suffer the associated poor health outcomes.[150,151]

People could also choose to live in more dispersed locations as new employment models give them the flexibility to work remotely. Rather than traveling to work, the work now comes to people. Here we could see greater alignment between the Queensland workforce and that of other countries, such as the United Kingdom,[75,153] with stronger uptake of teleworking. A third of Queensland respondents in 2014 reported that their jobs already enable them to work from home,[76] and the cost of videoconferencing is on the decline.[154] Younger generations also value greater flexibility in their working lives.[155] These trends all point towards the potential for greater uptake of teleworking in the future.
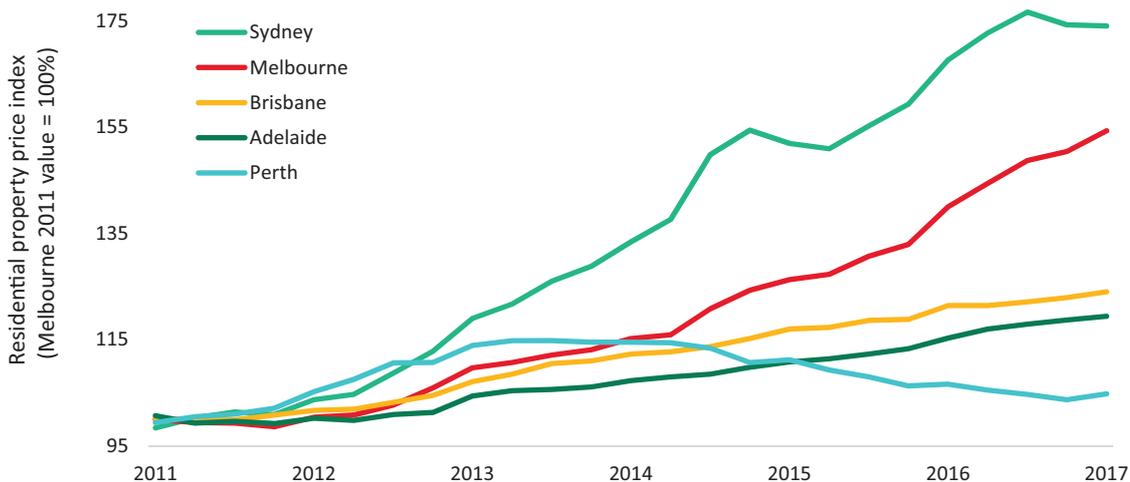

Figure 28. Residential property price growth in major capital cities (index base, Melbourne 2011 value = 100%)

Data source: Australian Bureau of Statistics[152]

Vertical axis: Level of technology transformation

The vertical axis captures the extent to which technology has transformed Queensland's transport sector, reflecting the level of uptake of digital and mobility technologies, and new service delivery models. Both ends of this continuum would see improvements in current capabilities around vehicle efficiencies, device connectivity, computer power and artificial intelligence. At the low technology transformation end though, this progress would be sluggish and incremental, with the level of innovation capped by concerns such as privacy, safety or cost. On the contrary, the transport sector under high technology transformation scenarios would be more intelligent, connected, reliable and efficient.

LOW TECHNOLOGY TRANSFORMATION

The low technology transformation end of the axis illustrates a future in which the promises of new technologies for the transport sector have failed to have a significant impact. Fully autonomous technologies (i.e. Level 5 automation) have been slow to develop, as many artificial intelligence experts warn today.[156-159] There is a paucity of rigorous empirical research on the social, economic and environmental impacts of AVs, making reliable projections difficult.[158] Under these low technology scenarios, the utopian view for AVs would bear little resemblance to reality.

A handful of high-profile accidents involving AVs, similar to the very high-profile incident in 2018 when an AV hit and killed a pedestrian,[161] have damaged the public's trust in the technology and further delayed development and deployment. Cybersecurity is another area of concern, with the 2015 hacking of a Jeep Cherokee further damaging the public's trust in digitally connected and intelligent cars.[162] As cyberattacks are on the rise in Australia (see Figure 29), concerns around public safety could slow the adoption of new vehicle technologies and mobility services.

The development of EVs has been constrained by the accessibility and cost of raw materials. The competition between EV manufacturers has fuelled increasing demand and competition for raw materials, many of which (e.g. cobalt) are difficult and costly to extract.[94] As such, EVs remain expensive in Australia. The high price and the need to drive long distances prevents many Queensland consumers from buying an electric car.[163]

In low technology transformation scenarios, most cars would be powered by petrol or diesel and driven by humans. The transport-sharing economy in Queensland has also remained a niche market, restricted largely to ride- and bike-sharing applications for non-routine trips. The use of

ridesharing apps could even decrease in the future, as has been seen in response to high-profile scandals,[164,165] and concerns over wages[143] and worker surveillance.[144]

HIGH TECHNOLOGY TRANSFORMATION

At the high technology transformation end of the axis, AVs, EVs, drones, connected transport systems and other technological innovations have improved the efficiency of freight and passenger movements. These innovations have significantly transformed Queensland's transport sector, and people benefit from new on-demand and shared mobility services that are well integrated with other transport options. There has been significant investment by technology companies and vehicle manufacturers into AV technology,[74] which could accelerate future developments around these technologies.

There are already signs of this through IoT applications (e.g. global positioning system trackers) in public transport systems and ridesharing apps to provide real-time vehicle tracking.[166,167] In the freight and logistics sector, blockchain technologies have been integrated with the IoT to better manage and track transactions along the supply chain.[168] These applications would become mainstream under the high-technology transformation scenarios. Initial drone delivery trials by Amazon and Google in 2017[138] would be expanded for large-scale last-mile delivery of small goods.

The price of lithium-ion batteries is already on the decline,[96] and this would continue, making EVs more affordable for more people. As EVs become more mainstream, investment in EV-charging infrastructure would likely also increase, along with improvements in battery capacity. These advances would make it feasible for people to travel longer distances in EVs. There is a 'rebound effect' though: the improved efficiency of EVs[169] and convenience offered by AVs[170-172] could translate into increased demand and congestion in densely populated areas.

Enabled by technology, MaaS schemes have become the preferred model for passenger transport. Younger generations of adults are already following this trend in being less likely to own a vehicle and more likely to use ride-sourcing apps than their older conterparts.[129,131,134,173] Subsequent generations could follow these behavioural trends. A high technology transformation scenario would also see MaaS schemes extend beyond the urban setting, with increased uptake in more regional and remote areas. These new on-demand services might better service a more dispersed population than traditional, scheduled services.
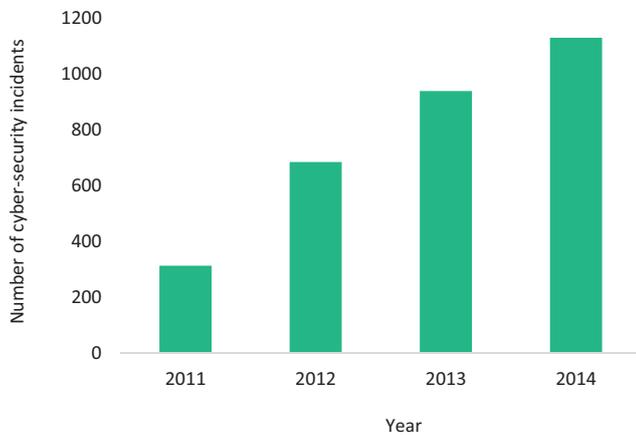
Figure 29. Number of cybersecurity incidents reported in Australia

Data source: Australian Cyber Security Centre[160]

General assumptions

The development of these scenarios and their underlying axes of uncertainty are based around a set of general assumptions. These assumptions are based on trends and drivers for which there is a greater degree of certainty and thus, will likely continue along their current trajectory over the next 30 years. For details on the scenario-specific assumptions, refer to the individual scenarios below and Appendix C. The general assumptions are:

- The Queensland population will continue to grow at its current average annual growth rate of roughly 2.0%,[29] with an increasing proportion of the population aged 65 years or older.

- The policy settings governing transport will remain constant. In particular, vehicle registration will continue to be charged based on the current cylinder-based revenue model,[x] and drivers will still be required to hold a licence to operate a non-autonomous vehicle.

- Knowledge-intensive and service industries, which are among the top employing industries in Queensland,[87] will continue to grow and be a key driver of economic growth.

- Digital and mobility technologies will be a key driver of new service models and will be a necessary precursor, but not sole determinant, of broader social changes around shared mobility.

- Most AVs will be electric due to the environmental benefits of EVs and the continued geopolitical push to reduce the impacts of the transport sector on the environment.

The scenarios

OFF-PEAK, ON-DEMAND: HIGH TECHNOLOGY TRANSFORMATION AND DISPERSED MOBILITY PATTERNS

A window out to 2048

This scenario describes a future where the promises of autonomous, connected, and intelligent transport systems have been fully realised. At the same time, technologies enabling virtual presence have advanced to the point where the need for a physical presence in the workplace, classroom, retail store or doctor's surgery is reduced. Most workers have more flexibility in where and when they work and benefit from shorter work days. Work is more focused on the provision of knowledge and services, thanks to the use of automation technologies which now take care of many manual, routine tasks.

There is a wealth of personalised, on-demand and point-to-point services now available for end users, meaning that fewer people own a vehicle. Many instead rely on autonomous taxi services, electric bikes and scooters and other small-scale, demand-responsive vehicle services. This sees a decrease in road fatalities. This is particularly beneficial for regional and remote communities where the road toll is concentrated. However, there is also an increase in hospitalisations among vulnerable road users. Public transport services ›››››››become more reliable and responsive, but the demand for these services is limited to non-routine long-distance trips (e.g. for leisure/tourism) where other modes of transport would be more costly.

New regional business and community hubs emerge as the population spreads outside of SEQ, which increases economic activity in many regional communities. Mobility disadvantage improves in regional communities too as employment and access to services become less dependent on physical proximity. Congestion in urban areas improves and the variability in local trips helps offset the transfer of congestion to more regional areas. Greenhouse gas emissions are radically reduced, driven both by declines in the vehicle kilometres travelled and positive uptake of EVs. However, the convenience offered by new mobility options decreases active transport, raising concerns around the health and wellbeing outcomes for Queenslanders.

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x. Trends such as a declining share of 5/6-cylinder vehicles in Queensland may encourage TMR to consider alternative funding models for registration in the future. Indeed, the topic of revenue resilience was commonly mentioned in stakeholder consultations conducted as part of this project. For the purposes of these scenarios though, Data61 has assumed no change in the funding model so that they can be used to demonstrate the impact on registration revenue in the absence of any policy changes. The scenarios demonstrate futures where a change to the current registration funding model might be needed more so than others.

Government revenue streams are at risk, as the shift away from private vehicle ownership results in a steep decline in registration revenue. There is rising pressure for government to consider alternative models of charging road users. There has also been a high capital expenditure on new infrastructure to support emerging technologies and services, which has placed an initial strain on government budgets. The ongoing operating costs are reduced, however, by more efficient and connected systems. The costs associated with this infrastructure mean the rollout is not uniform across Queensland and some regions benefit ahead of others. Parts of the transport network which are underutilised, such as major corridors into SEQ, have been repurposed.

The freight network has shifted from a hub-and-spoke to a node-to-node model, enabled by greater use of AVs, drones and sensor technologies. Distribution has become more decentralised with growth in 3D printing applications. Freight is delivered quicker, more efficiently and through streamlined services, which reduces mobility costs and incentivises more people to buy their goods online. Brick-and-mortar retail stores instead focus on providing an experience factor for customers that cannot be replicated online.

A day in the life of 2048

Cassidy is 35 years old and owns a highly successful online business, selling boutique food products across Australia and internationally. She does so based out of her home office in Cairns. Occasionally she'll work at a local co-working hub, but this is more for the social engagement this provides than a need to go into a physical office. With the convenience of high-speed internet and quality teleworking systems, Cassidy can connect with her team, clients and suppliers across the country without having to leave her home. The tyranny of distance is lessened for people living in rural or regional areas in Queensland.

Technology has also radically changed the workforce. Workers who used to do many of the manual, repetitive and routine tasks have been replaced by robots and other automation technologies. A large proportion of work now focuses around knowledge and service delivery, and the retail sector is among many industries that have experienced this shift. In Cassidy's business, her team's work is focused on maintaining brand loyalty, improving customer interactions and providing more personalised and streamlined shopping experiences online.

The improved logistics of the freight network has dramatically improved the quality of service that Cassidy can provide to her customers. She is able fill her online orders, use online platforms to identify spare capacity in existing loads and pool her freight delivery with other businesses.

Her orders are delivered by a mixture of autonomous trucks, light commercial vehicles and drones, depending on where the goods are travelling to and the availability of transport options. Delivery times are also shorter, so customers can get the products they want on-demand.

In her local area, there are endless options for Cassidy to get around, none of which warrant the expense of owning a private vehicle. A few of Cassidy's friends and neighbours prefer to own cars, but they mainly use them for the occasional long-distance trip to other regional centres. When she does need to travel, Cassidy relies on local ridesharing services or demand-responsive buses that pick her up from her doorstep. These services can be easily booked and tracked through her smartphone, and are well integrated with other connecting services, such as public trains, for longer distances. The convenience of the personalised services offered by these transport options means that active transport is a rarity for Cassidy.

Signals for the evolution of Off-Peak, On-Demand

- Geopolitical events lead to a decline in global oil supply, which strengthens a push towards renewable sources of energy.

- The trend towards greater vehicle sharing and reduced vehicle ownership increases, with current youth passing on similar values around mobility options to the next generation.

- There is a cultural shift to move away from larger cities in favour of a more regional lifestyle. The feasibility of this for many Queenslanders is enhanced by the ability to work remotely.

- A period of high road fatalities drives a push for safer mobility options, which helps build the case for AVs in the community.

- Population growth in regional and rural areas in Queensland increases, along with declines in SEQ population growth and reduced net internal migration to SEQ.

- The capabilities of automation and digital technologies improve at an accelerated rate, and businesses increasingly implement these technologies to replace workers for manual, routine tasks.

- Environmental concerns are heightened as the impacts of climate change are increasingly felt across the state. This drives more people towards more sustainable, environmentally friendly transport options.

Measuring the impact of Off-Peak, On-Demand

Fleet composition. There are fewer cars in the fleet (i.e. the number of registered vehicles on the Queensland register) due to the increased use of mode sharing, autonomous taxis and demand-responsive services (see Figure 30). This reduction in the car fleet is less than what would be expected in a scenario with more concentrated mobility patterns though (i.e. 10% of the projected fleet servicing the passenger task[174]). The variability in travel times and destinations means that some people might still prefer to own a car for rare occasions where they have to travel long distances. The motorcycle fleet also increases as these vehicles are a more popular option for short, local journeys.[175]

The bus fleet has also shrunk as demand for public transport has been shared across other mobility services, and the actual demand for travel for work or education has lessened. The freight fleet is smaller too, with fewer light commercial vehicles and trucks (particularly the largest heavy vehicles). The remaining fleet is more intelligent, connected and efficient, and drones have aided first- and last-mile delivery. As with the car fleet though, this reduction is less than what would be observed in a more concentrated mobility scenario (i.e. 50% of the projected fleet servicing the freight task).[176]

The share of the fleet that is electric or hybrid grows as more AVs are added, and there is a stronger uptake of EVs for passengers and freight. Vehicle purchase and operating costs weigh in favour of EVs and the battery life and infrastructure supporting these vehicles has improved, meaning that they can handle long distances. However, uptake of these new vehicle types is likely to be slower in regional areas than what would be seen in a more urban population.[177] This means that the growth trajectory for EVs is reduced relative to the current baseline projection (see Figure 31).

We assume that electric and hybrid car uptake will follow the current trajectory of increased uptake experienced across other vehicle types. This would result in 63.1% of the total fleet being electric or hybrid vehicles. A proportion of this electric share could be hydrogen-powered vehicles, but the uncertainties around the onset and level of uptake makes this difficult to estimate as a separate fuel type category (see Box 1). We also assume that the share of each vehicle will decline, with a marginal reduction in the declining petrol share from baseline.

Box 1. Uncertainties around hydrogen fuel cell vehicles

Hydrogen fuel cell vehicles use hydrogen gas to power an electric motor. Fuel cell vehicles are considered to be EVs, as they are powered entirely by electricity, but the distance they can travel is comparable to cars with internal combustion engines.[1] The refuelling process of a hydrogen fuel cell car is also similar to conventional cars, taking around ten minutes to refuel, much faster than charging an EV.[1]

There is limited charging infrastructure for hydrogen cars and hydrogen stations cannot currently produce and store enough hydrogen to charge large numbers of hydrogen cars.[2] However, this may be resolved with new technology. For instance, CSIRO has developed membrane reactor technology which allows hydrogen to be transported in the form of ammonia and then reconverted back to hydrogen at the point of use.[3]

Hydrogen is also difficult to produce without generating emissions. The cheapest and easiest way of producing hydrogen is to extract it from methane, but this process also produces carbon dioxide.[2] Hydrogen can also be produced via the electrolysis of water, but this is a very energy-intensive process and to avoid generating emissions this energy has to come from a clean source (e.g. solar or wind power).[2]

Producing hydrogen is complex and expensive. In addition to the practical difficulties in providing charging infrastructure, there could be significant barriers to uptake of hydrogen fuel cells in the future. The absence of a coordinated strategy for refuelling infrastructure also creates uncertainty around future uptake.[4] There are significant benefits of hydrogen through reduced tailpipe emissions. If there was significant uptake of hydrogen fuel cells, it would likely be in trucks and buses first, followed by cars.
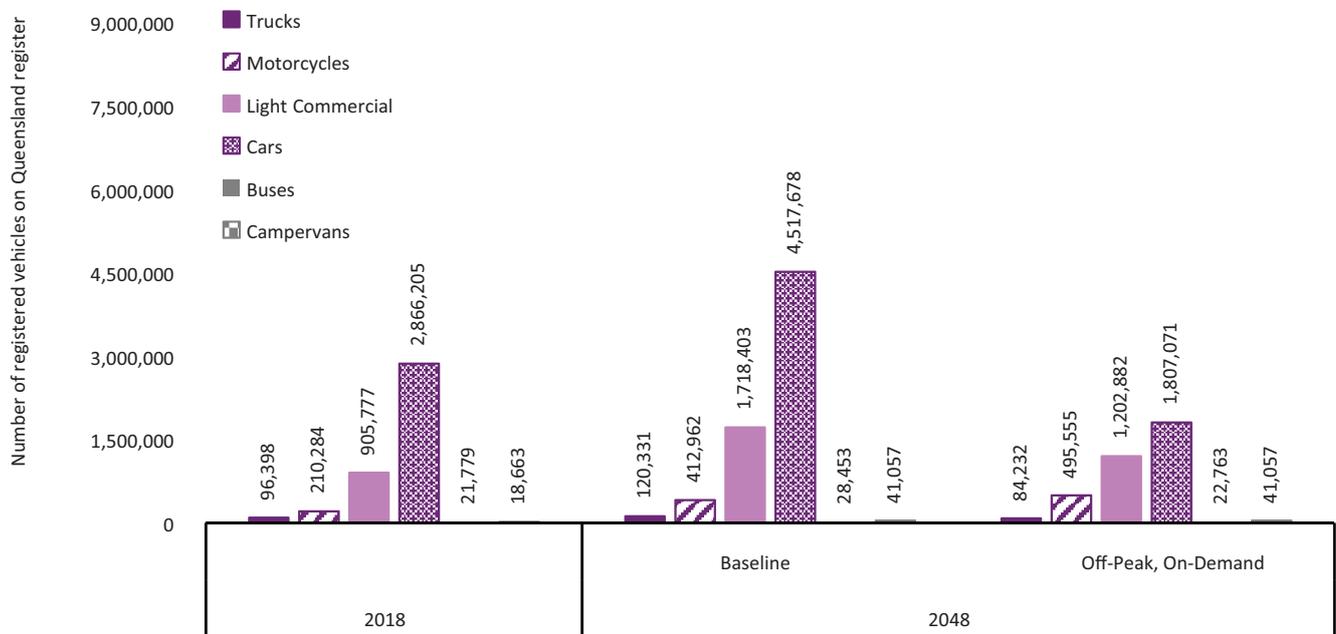
Figure 30. Modelling projections of number of registered vehicles in the fleet by vehicle type in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Data provided by TMR and Data61 estimates
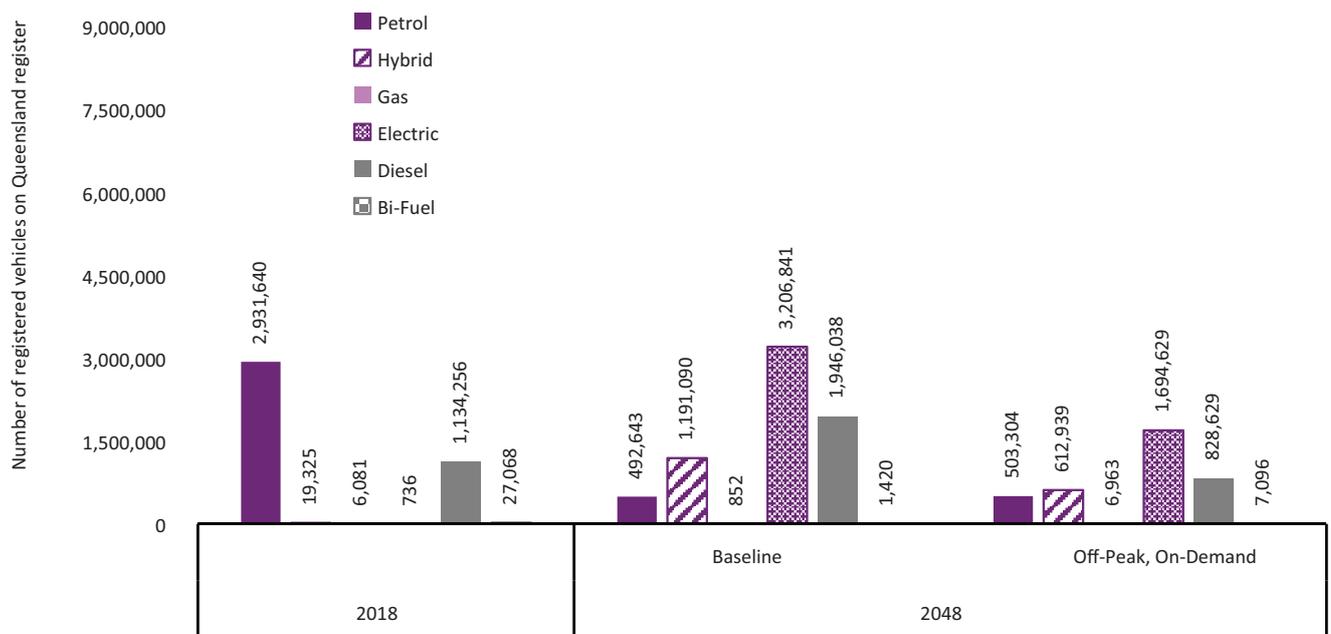
Figure 31. Modelling projections of number of registered vehicles in the fleet by fuel type in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Data provided by TMR and Data61 estimates

Vehicle kilometres travelled. In this scenario, people generally work virtually from their home office, local co-working centre or other convenient places. This greatly reduces trips, travel time and distance. Access to education, shopping and routine medical services can similarly be done remotely, reducing the tyranny of distance for people in more regional communities. When people do travel, they tend to make shorter trips within their local regional hub, rather than going into the CBD. There is therefore a significant decline in growth of passenger vehicle kilometres travelled (see Figure 32).

A 2011 analysis of teleworking mobility patterns in Sydney found that those who worked from home travelled 42.5% fewer kilometres than those who went into the office.[178] The evolution of technology in both transport and everyday life, combined with the localisation of workplaces and other services, means that Off-Peak, On-Demand sees the greatest growth reduction in vehicle kilometres travelled across the car fleet in all four scenarios. This reduction will exceed the benefits of teleworking alone (i.e. as seen under Suburban Streets).

There is little change in the growth in vehicle kilometres travelled for light commercial vehicles due to opposing effects. The dispersed population means that freight vehicles have to travel longer distances. However, this is partially offset by technology-enabled efficiencies within the freight sector, which optimise routes and cut down on empty loads. Using drones for last-mile deliveries also reduces the frequency of shorter trips by freight vehicles.

Road safety. The rates of both road fatalities and hospitalisations drop significantly under Off-Peak, On-Demand due to the safety benefits of AVs and the greater temporal and spatial dispersal of road users (see Figure 33). Assuming that AVs will eliminate accidents caused by human error – with speeding, drink driving and/or fatigue contributing to 55% of all fatalities in 2017[xi] – we anticipate up to a 40% reduction in fatalities and hospitalisations.[36] The safety benefits of AVs are noticeable in regional and remote communities, where the road toll is typically higher.[xii]

Furthermore, under Off-Peak, On-Demand, the dispersed mobility patterns and a smaller car fleet would also reduce the rate of accidents. Fewer road users converging in the same space at the same time mean that crashes are less likely to occur. It is estimated that 15% of road fatalities are accounted for by work-related crashes,[180] which would presumably reduce if fewer people need to travel for work. This is particularly beneficial for vulnerable road users such as pedestrians, cyclists and motorcyclists, who are less likely to encounter cars under this scenario.
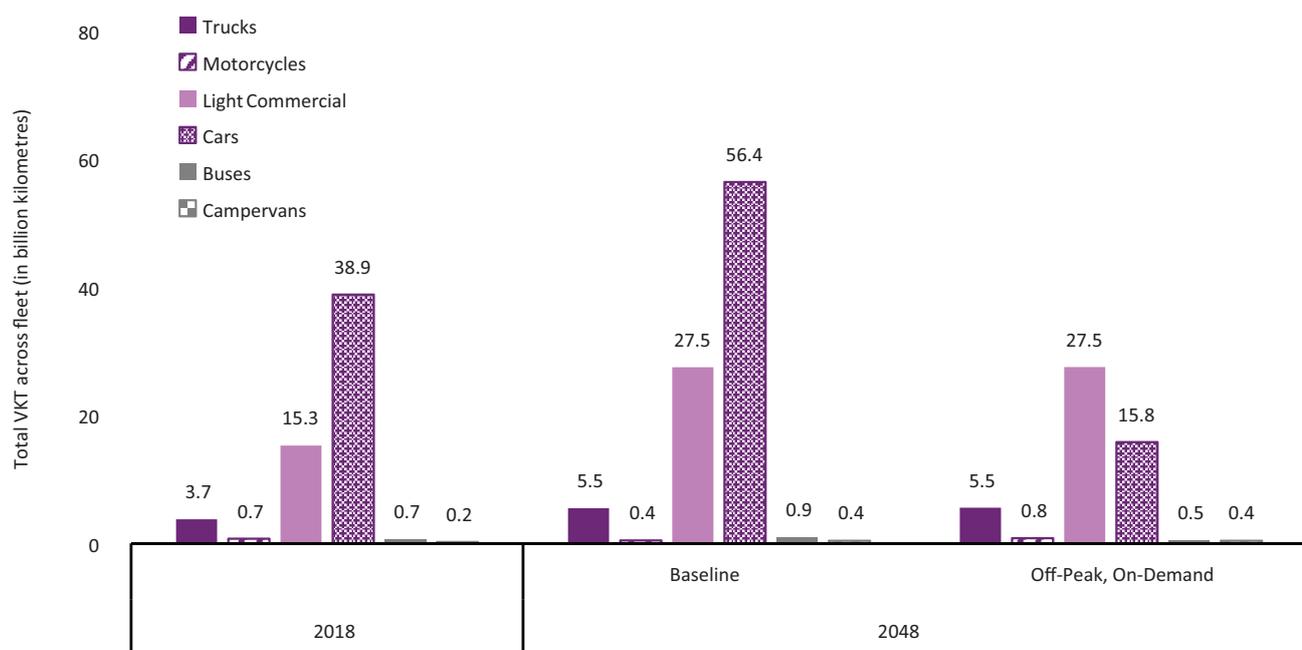
Figure 32. Modelling projections of total vehicle kilometres travelled (VKT) across the fleet (in billion kilometres) in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Australian Bureau of Statistics[179] and Data61 estimates

xi. Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.

xii. Estimates based on Queensland Road Crash Weekly Report (17 April 2018) provided by TMR.

Infrastructure expenditure. While an initial increase in government spending will equip Queensland with the infrastructure to support an autonomous, connected vehicle fleet, with this averaged over time, we anticipate an overall decline in the expenditure growth rate (see Figure 34). This assumes that greater uptake of more efficient mobility services (e.g. AVs and shared vehicles), a smaller passenger and heavy vehicle fleet, and an absence of peak demand will all contribute to reducing infrastructure maintenance and operational costs. Much of the infrastructure for conventional vehicles, such as parking garages, will no longer be needed.[123]

Furthermore, cost-saving technologies will enable infrastructure projects to be completed for less, relative to the present day. There are, however, significant uncertainties around this. For instance, using BIM alone could result in returns on investment anywhere from 16% to 1,654%.[52] We anticipate that the reduction in infrastructure expenditure growth will not be as great as under a high-tech concentrated scenario (i.e. Cruise Control). This is because the major corridors need to maintained between the regional hubs to service a dispersed mobility pattern.

Registration revenue. Growth in registration revenue declines under this scenario due to the drop in rates of private car ownership (see *Fleet composition* section and Figure 35). This decline is not as pronounced as in other scenarios (e.g. Cruise Control) as some people still choose to own a vehicle for the occasional long-distance trip. Most of these vehicles are electric, however, and those with internal combustion engines tend to have four cylinders, in line with current trends.
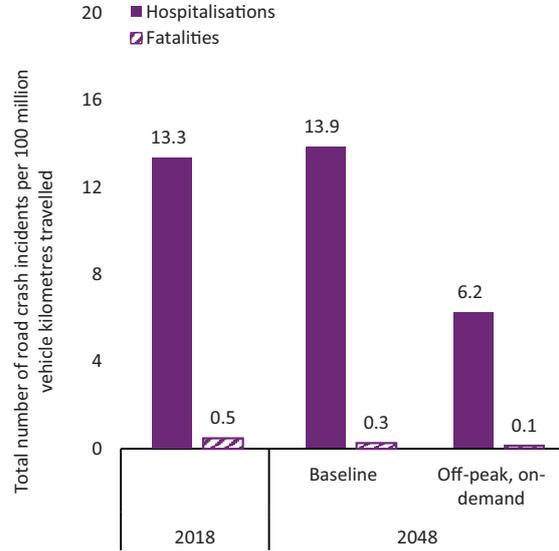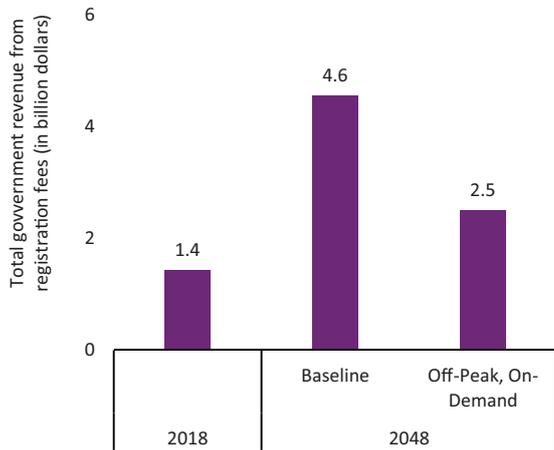

Figure 33. Modelling projections of number of road crash fatalities and hospitalised casualties in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Data provided by TMR and Data61 estimates

Figure 34. Modelling projections of total government expenditure (in billion dollars) in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios
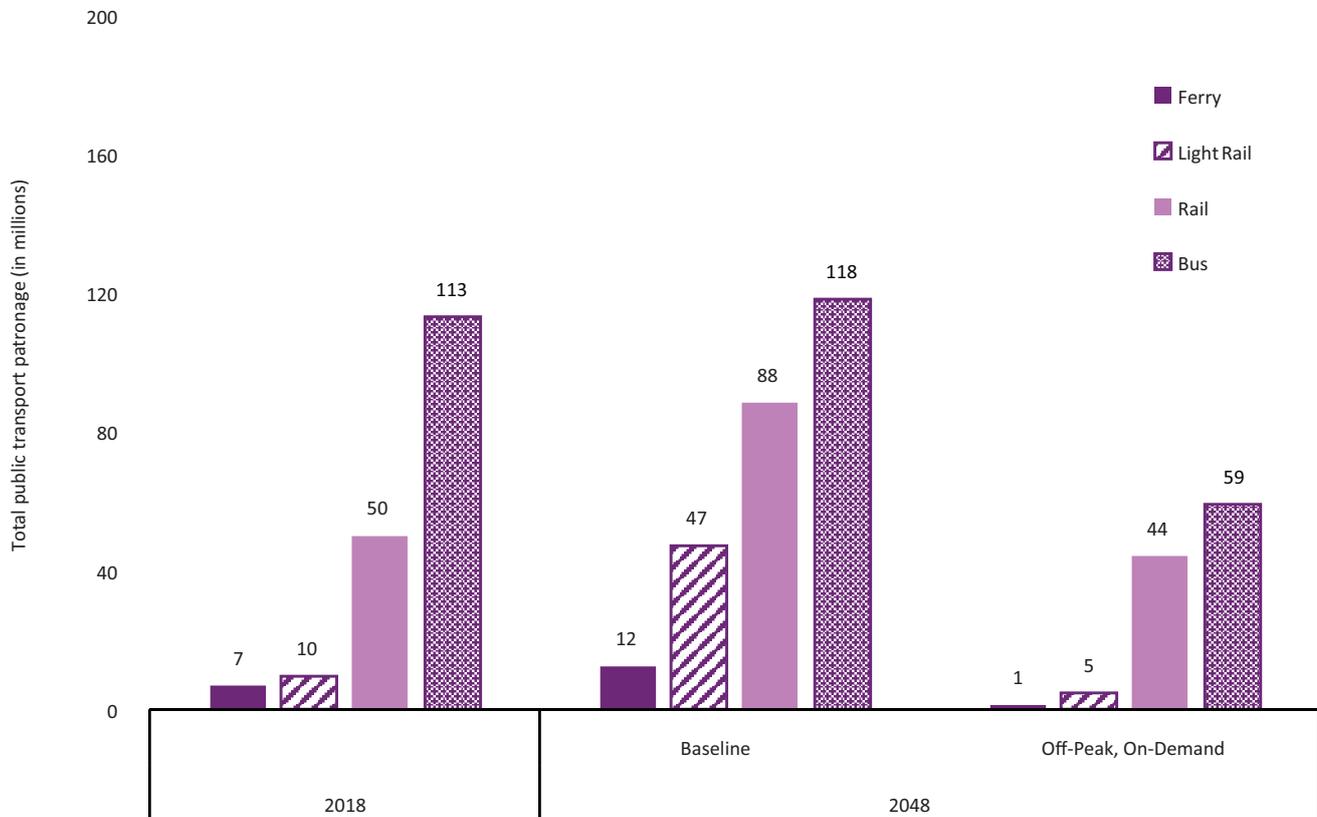
Data source: Data provided by TMR and Data61 estimates

Public transport patronage. This scenario sees a considerable reduction in public transport patronage growth rates, particularly for ferry and light rail as fewer people live in SEQ (see Figure 36). Point-to-point autonomous taxis are the most convenient mode of transport and replace many public transport trips.[71] We anticipate that, unlike under Cruise Control, mass transit systems lose their appeal due to their inability to adequately service a dispersed population with highly varied and irregular travel times and destinations. This is in addition to the reduced need to travel to work via public transport, which made up 37.7% of all public transport trips in Queensland in 2011.[6] Regional areas benefit from a greater breadth of transport options other than private vehicles and public transport.

Figure 35. Modelling projections of total government revenue from registration fees (in billion dollars) in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Data provided by TMR and Data61 estimates
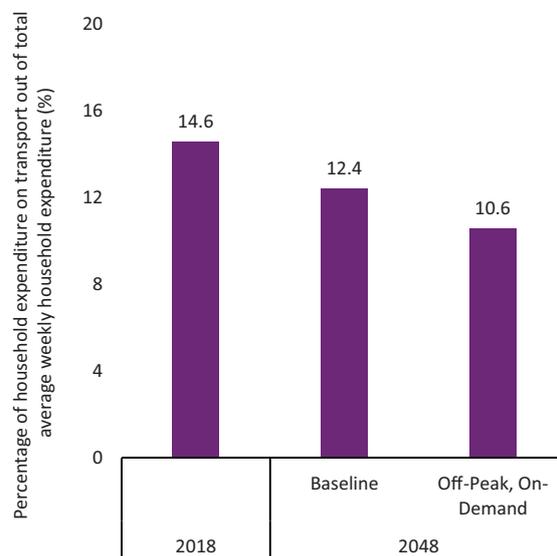

Figure 36. Modelling projections of total public transport patronage (in millions) by mode type in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Data provided by TMR and Data61 estimates

Household expenditure on transport. The growth rate of household expenditure on transport declines (see Figure 37) as fewer people choose to own a car. For those who own vehicles, average whole-of-life maintenance costs go down due to the higher proportion of EVs as they have lower ownership costs.[37] Moreover, it is estimated that total annual mobility costs incurred by shared, on-demand mobility services will be up to 50% less than services requiring a human driver.[181] Under this scenario, private car ownership and its associated costs will be higher than Cruise Control. However, these mobility services might not be a complete solution for passenger transport.

Cost of freight mobility. This scenario sees a moderate increase in the growth of freight mobility costs for light commercial vehicles due to the need to travel longer distances to deliver freight (see Figure 38; see Figure 120 for projections at various fuel prices). This is partially offset by technological improvements that automate driving functions, reduce fatigue-induced down-time, and improve transport logistics. There is also a greater selection of freight options for local deliveries (e.g. drones), which efficiently assist with last-mile deliveries. Overall, growth in total freight mobility costs decreases, but not as much as it would if the freight task was more concentrated (i.e. Cruise Control).

Cost of excessive congestion. Growth in the cost of excessive congestion – which arises through more accidents, increased fuel and labour costs, increased pollution, reduced reliability of travel times and longer commutes[184] – declines sharply in urban areas under this scenario (see Figure 39). This is due to the fact that people are working remotely or are commuting locally at various times of the day. The high variability in travel times and destinations mean that demand for travel rarely outstrips road capacity, and there is little change in current levels of peak demand in more regional areas.
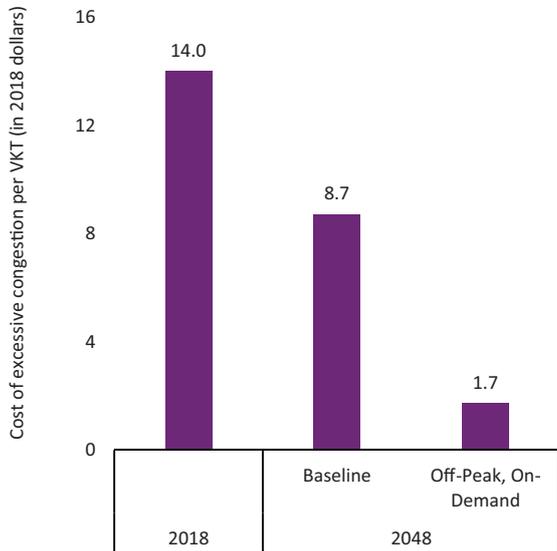
Figure 37. Modelling projections of average weekly household expenditure on transport in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: ABS Household Expenditure Survey[182] and Data61 estimates
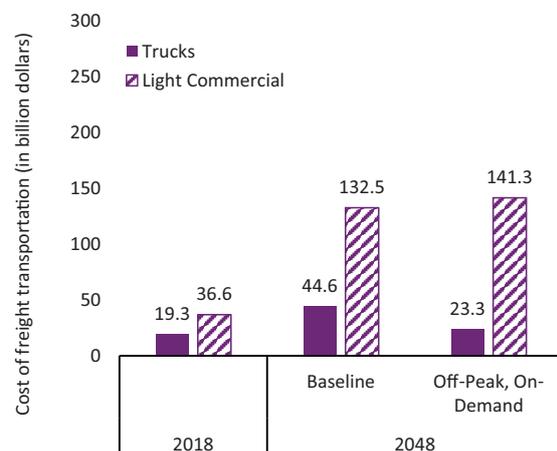
Figure 38. Modelling projections of cost of freight transport (in billion dollars) in 2018 and projected out to 2048 at a fuel price of $2.00/L under the Baseline and Off-Peak, On-Demand scenarios
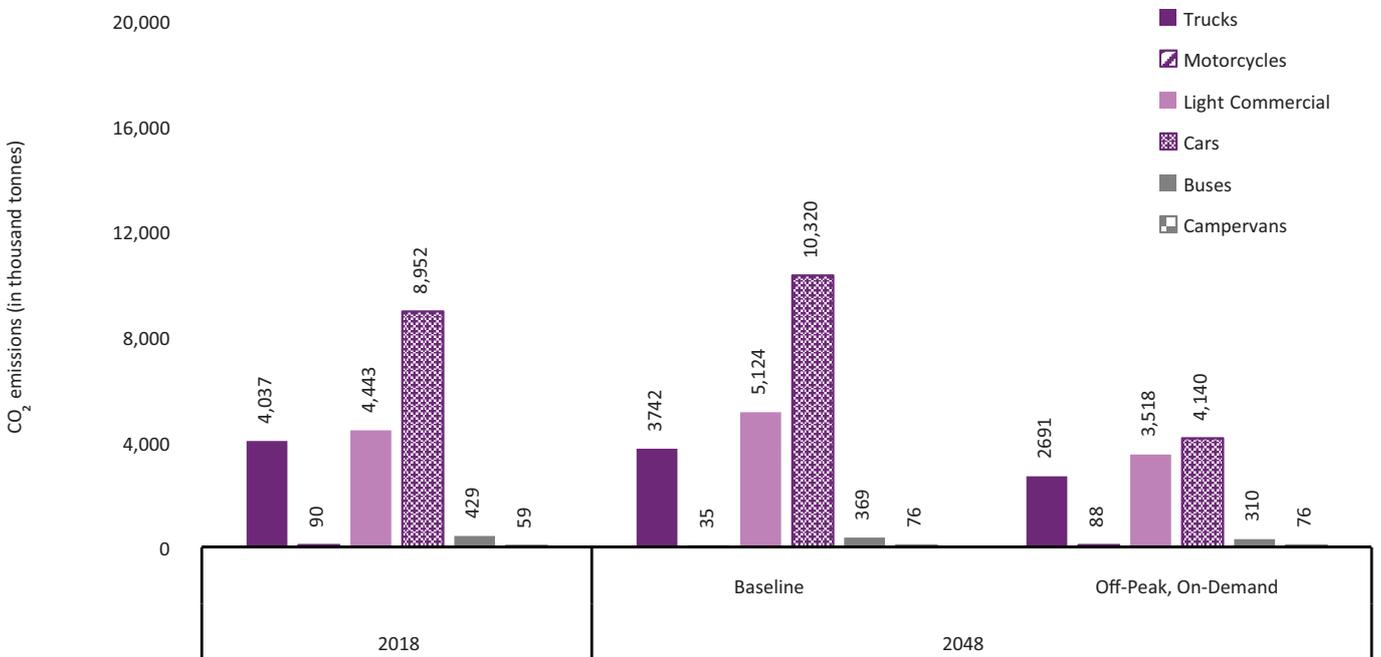
Data source: CSIRO TraNSIT model[183] and Data61 estimates

Greenhouse gas emissions. Changes in the size of the passenger and freight fleet and how much the fleet travels drives down greenhouse gas emissions in this scenario (see Figure 40 and Figure 41). People make fewer and generally shorter trips, and are more likely to switch to hybrid vehicles or EVs. There is also an increase in vehicle occupancy via the move toward shared mobility schemes, which helps keep the total number of trips down, and consequently reduces emissions.[172] This reduction is somewhat offset by more people making a switch from public transport to private vehicles than might be expected for more concentrated mobility patterns.

Figure 39. Modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT; in billion dollars) in Greater Brisbane area in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Data provided by TMR and Data61 estimates

Figure 40. Modelling projections of CO₂ emissions of road transport by vehicle type in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates
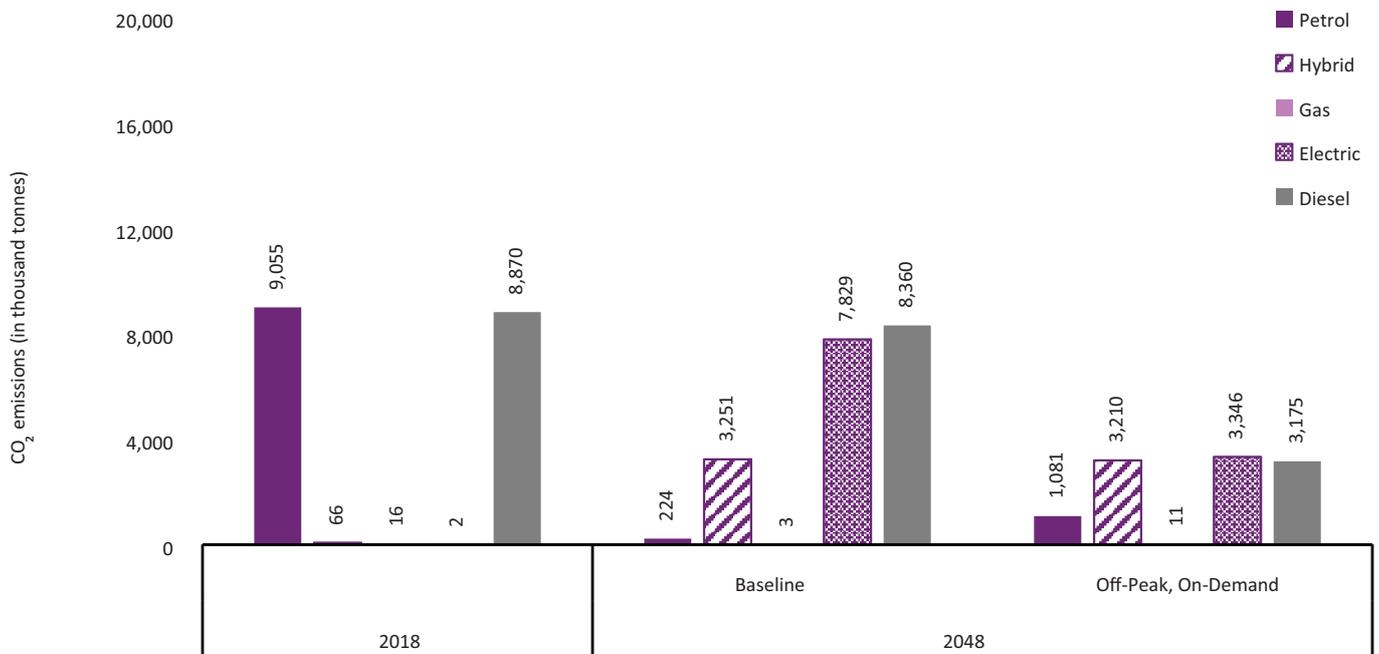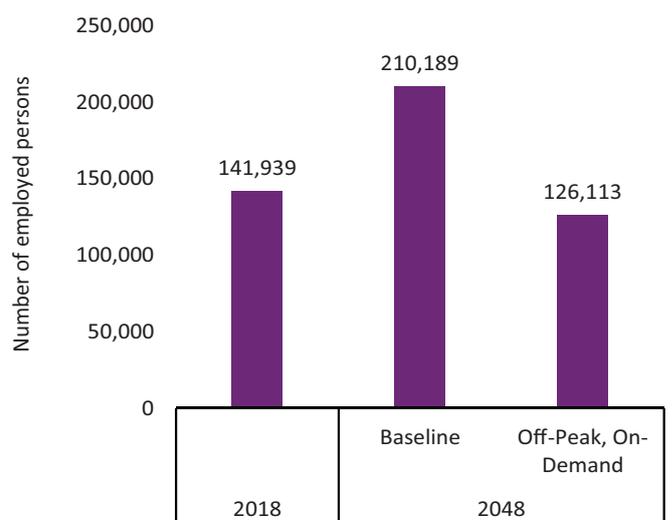
Figure 41. Modelling projections of CO_2 emissions of road transport by fuel type in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Automation impacts across the transport and logistics sector. The transport and logistics sector would be at high risk of automation under Off-Peak, On-Demand due to strong uptake of autonomous trucks and trains for freight transport and AVs, taxis and buses for passenger transport. There is likely to be less need for a human driver in many of these routine transport tasks. New, higher skilled job opportunities will likely emerge in logistics data and analytics and counteract some of the displaced workers.

To represent a high-automation impact scenario, we project that 40% of jobs in the transport and logistics sectors will be susceptible to computerisation by 2048. This probability is based on previous work that has modelled high-automation impact across the labour market in Australia[187] and the US.[80] Based on the high technology development and uptake under Off-Peak, On-Demand, we predict a decline in the number of people employed in the transport and logistics sector out to 2048 (see Figure 42).

Figure 42. Modelling projections of number of employed persons in transport and logistics sector in 2018 and projected out to 2048 under the Baseline and Off-Peak, On-Demand scenarios

Data source: Australian Bureau of Statistics[188] and Data61 estimates

CRUISE CONTROL:
HIGH TECHNOLOGY TRANSFORMATION AND CONCENTRATED MOBILITY PATTERNS

A window out to 2048

Mobility patterns remain concentrated around peak time windows and/or destinations, but new vehiclC-ITSnologies and mobility models enable better management of peak demand. This scenario describes a world in which significant advances in digital technologies and strong uptake of new mobility models revolutionise Queensland's transport network. AVs, EVs, drones for freight, C-ITS and other technologies improve the efficiency and cost of freight and passenger movements. As a result, the government's role shifts from being the provider to the enabler of mobility services, and ensuring a safety net for passengers.

The urban concentration of work, education and services continues to drive people's desire to live close to the city. As a result, peak-hour traffic remains the norm and each day sees large flows of people to and from the city and surrounding areas. To deal with the increased costs of urban living, many people choose one of two options.

Some choose to live close to the CBD in apartments without a car park and therefore don't own a car. These individuals meet their travel needs using various shared mobility services that are well integrated with mass transit systems, autonomous taxis, small electric scooters, bikes or walking.

Other people prefer to live away from the CBD and commute longer distances to work. They do so using autonomous taxis, sharing, or small-scale, on-demand transport services that seamlessly connect them to public transport. The quality of services has improved for commuters, enabling them to work or study while they travel, reducing the burden of commuting. People spend less time behind the wheel and have a more enjoyable and productive commuting experience. Limited travel 'budgets', however, deter many from living outside of SEQ, impacting the sustainability of regional communities.

Passenger transport is more intelligent, and electric, connected AVs now make up a significant share of the fleet. People enjoy the convenience of on-demand and personalised transport options as a sole source of transport, or as a first- and last-mile connection to mass transit systems. Increased use of EVs has radically reduced transport-related emissions, and Queensland is well on its way towards its zero-net emissions target by 2050. The road toll has also improved, thanks to more people using

public transport or AVs, but these benefits concentrate in more urban areas where the technology has had its greatest impact.

The convenience of on-demand AVs does entice more people to use them as private taxis. This adds to the number of vehicle kilometres travelled and reduces the drop in congestion in the CBD. Strong uptake of new mobility technologies has not necessarily come with a complete cultural shift towards shared mobility, with some people using AVs as their private taxi, thereby adding to existing congestion and environmental challenges. Congestion is tempered by technology though, with improved traffic management systems better able to flexibly respond to peak flows and increased use of public transport.

Peak demand in urban areas continues to strain parts of the transport network, which generates the need for more transport infrastructure and fuelling future demand. Other assets outside of major centres are under-utilised. The cost of developing, maintaining and monitoring the network is reduced due to the cost efficiencies provided by BIM and sensor technologies. This helps reduce budget pressures for TMR, which had already been tightening due to drops in revenue from vehicle registration, as more people shift to EVs, or choose to go without a private car.

Population growth in the rest of Queensland continues to lag behind SEQ, which is still the hub for economic activity in the knowledge and services industries. Consequently, regional and remote areas in Queensland see little expansion of their public transport systems and shared mobility models. The reliability and quality of these existing services has improved though: greater use of sophisticated data analytics and sensor technologies for transport logistics helps provide greater certainty around travel times and encourages increased use of public transport. This helps reduce the mobility disadvantage for regional communities through greater access and breadth of options.

The freight network is faster and more efficient. Autonomous trucks are used extensively along major freight corridors to SEQ and major distribution hubs, with drones used for urban freight delivery. These improvements, combined with enhanced logistics systems, lower the cost of freight mobility and enable faster delivery of goods on-demand. The reduced need for human drivers also decreases the amount of downtime between trips (e.g. due to driver fatigue), meaning that a smaller fleet can be used to service the freight task more efficiently.

A day in the life of 2048

Veronica is 66 years old and is no longer working full time. She lives in a retirement village in Logan with her partner and spends her time volunteering for local organisations, visiting family and friends and attending social engagements. Veronica no longer has her licence due to a recommendation from her doctor that she stop driving. She therefore doesn't own a car and relies on other shared and public mobility services.

The absence of a private vehicle has not had a noticeable impact on Veronica's mobility. There are a range of app-based ride services that she can access conveniently through her smartphone. She can compare the cost and time of options depending on where and when she wants to travel, and she can pick the mode that best suits her trip needs. For instance, she can schedule her travel request with a local on-demand bus service which customises its route based around the travel needs of other passengers in similar proximity. These services can connect Veronica to local train services into the Brisbane CBD.

Other times Veronica travels around using an autonomous taxi. She is surprised by how comfortable she feels in these vehicles which have become so mainstream that she doesn't even question the lack of a driver. She is comforted knowing the safety benefits of driving in an AV. She tries to avoid taking autonomous taxis when she needs to travel into the city though, as their numbers in the CBD during peak work hours can create congestion.

Veronica has noticed that her area has become more densely populated over the past decade as more people choose to live in SEQ. Her children and their families have also moved closer, now living in the outer suburbs of Brisbane, as their school and work requires them to be close to the CBD. They too have foregone owning a car and rely heavily on electric bikes to connect them to mass transit lines into the CBD. Veronica has noticed the her travel needs have reduced, as she can increasingly get more of what she needs online — from her groceries and household items, to regular check-ups with her GP.

**Signals for the evolution of Cruise Control**

- There is an increased focus on integrated land use and planning, and the centralisation of decision-making concerning future transport operations. As a result, future investments in infrastructure corridors are concentrated around urban centres.

- Current pricing models are updated to reflect network use and end users are incentivised to use particular options (e.g. public transport, vehicle sharing or alternative travel times etc.) to better manage rising peak demand.

- There is an accelerated shift towards renewables for power generation, which improves cost and accessibility of power for EVs.

- Competition between different private sector mobility models intensifies, leading to the development of new and innovative business models which offer improved cost, convenience and reliability for consumers.

- There is an increase in the number of EV manufacturers in Australia, opening up a wider selection of EVs and creating competition among existing manufacturers.

Fleet composition. Across the board, both the passenger and freight task are served by a smaller, more efficient fleet with less idle capacity (see Figure 43). The passenger fleet has shrunk due to an increase in the use of public transport, AVs and taxis, and moderate amounts of vehicle sharing, with estimates close to those modelled in Lisbon, Portugal: 10% of the car fleet serving the passenger task.[174] The bus fleet has grown to cater for the rise in public transport patronage for travel to and from the CBD for work and study. More people ride motorcycles as they are more efficient in congested areas.

The light commercial fleet is smaller as more urban freight is delivered by alternatives. The introduction of autonomous trucks means that half the projected truck fleet can service the freight task,[16] with the biggest reductions seen for the largest heavy vehicles (e.g. A-doubles, B-doubles and road trains). Autonomous trucks have fewer empty loads and can deliver freight more efficiently with less down time between trips (e.g. due to driver fatigue).

Consistent with projections from the Australian Energy Market Operator's high EV uptake projections,[189] the electric/hybrid share of the fleet grows to 90%. Consequentially, the share of the petrol and diesel fleet reduces (see Figure 45). Strong uptake of EVs is seen across the fleet, most notably in passenger cars, but also in buses, trucks, light commercial vehicles and motorcycles. Similar to the Off-Peak, On-Demand scenario, a proportion of this electric fleet may be powered by hydrogen fuel cells, but this share is not specified as there are significant uncertainties around their onset and level of uptake.
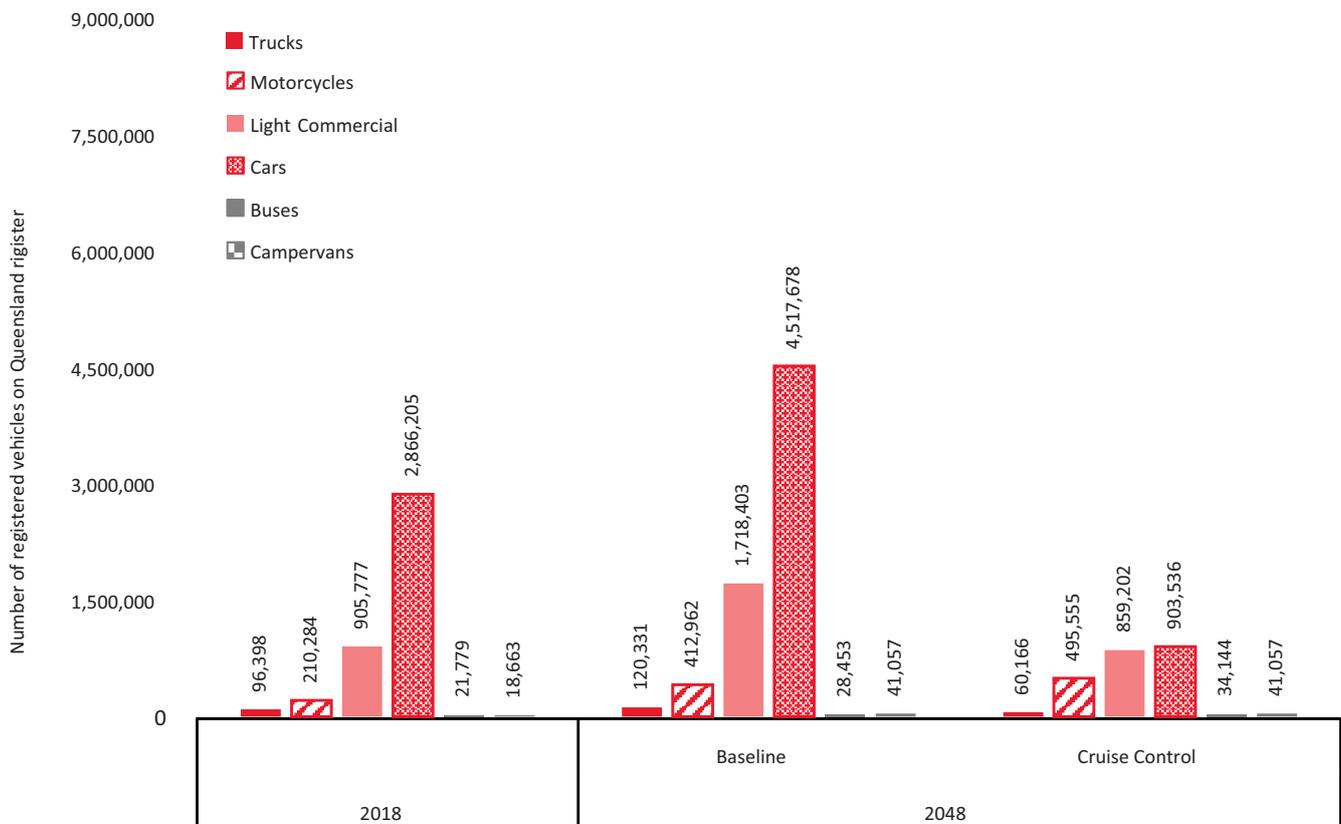
Figure 43. Modelling projections of number of registered vehicles in the fleet by vehicle type in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Data provided by TMR and Data61 estimates
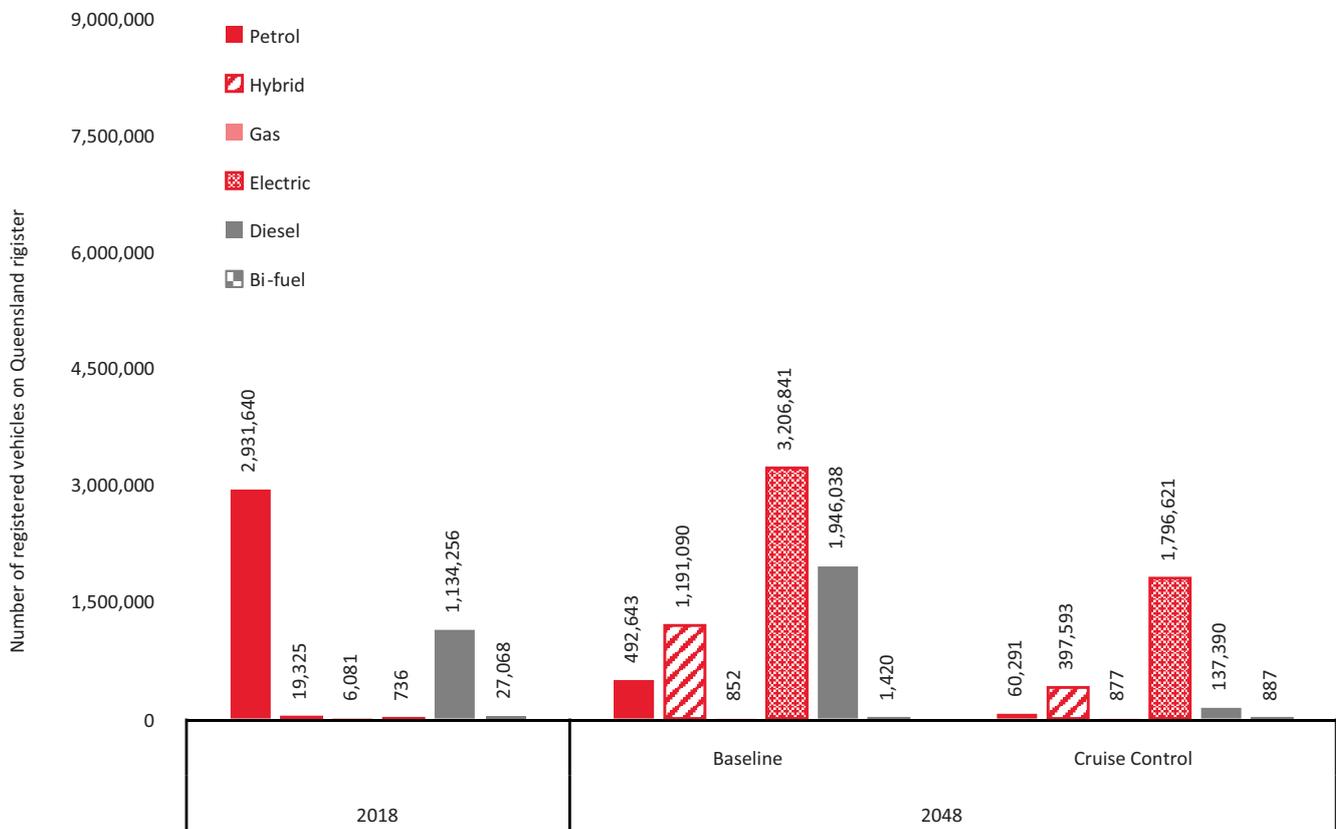
Figure 44. Modelling projections of number of registered vehicles in the fleet by fuel type in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Data provided by TMR and Data61 estimates

Vehicle kilometres travelled. This scenario sees considerable disparity in commuting distances and vehicle kilometres travelled. Those living close to the CBD have very short commutes and are more likely to travel by active transport, significantly reducing their vehicle kilometres travelled. However, those living further out from the CBD due to cost, space, or amenity still face long commutes. Those living in rural and regional communities will likely see little change in vehicle kilometres travelled as the transport network becomes increasingly optimised around the Brisbane CBD.

Some people choose to make these journeys by car, as the convenience of autonomous taxi services (shared and individual) makes this an attractive option. This is particularly true for those who were previously unable to drive themselves (e.g. older drivers, children, or people with disabilities). The added convenience and accessibility of these new mobility services leads to an increase in car

trips that might otherwise have been made by bike, by public transport, or on foot — anywhere from 1.9% to 4.6% of trips.[71] Rising vehicle use in conjunction with a declining fleet size brings an initial increase in vehicle kilometres travelled (as a sizeable share of vehicles increase their travel frequency), but this drops off as 2048 approaches and the fleet becomes more optimised (see Appendix D, Figure 95).

More people are also using public transport, as new mobility services (e.g. autonomous taxis) assist with first- and last-mile connections to public transport hubs. This increases the vehicle kilometres travelled by the bus fleet (see Figure 45). The freight task continues to grow along the current trajectory, resulting in little change in the vehicle kilometres travelled by trucks, but these trips are covered by a more efficient fleet. However, light commercial vehicle kilometres travelled reduce, as drones are increasingly used to deliver small parcels.
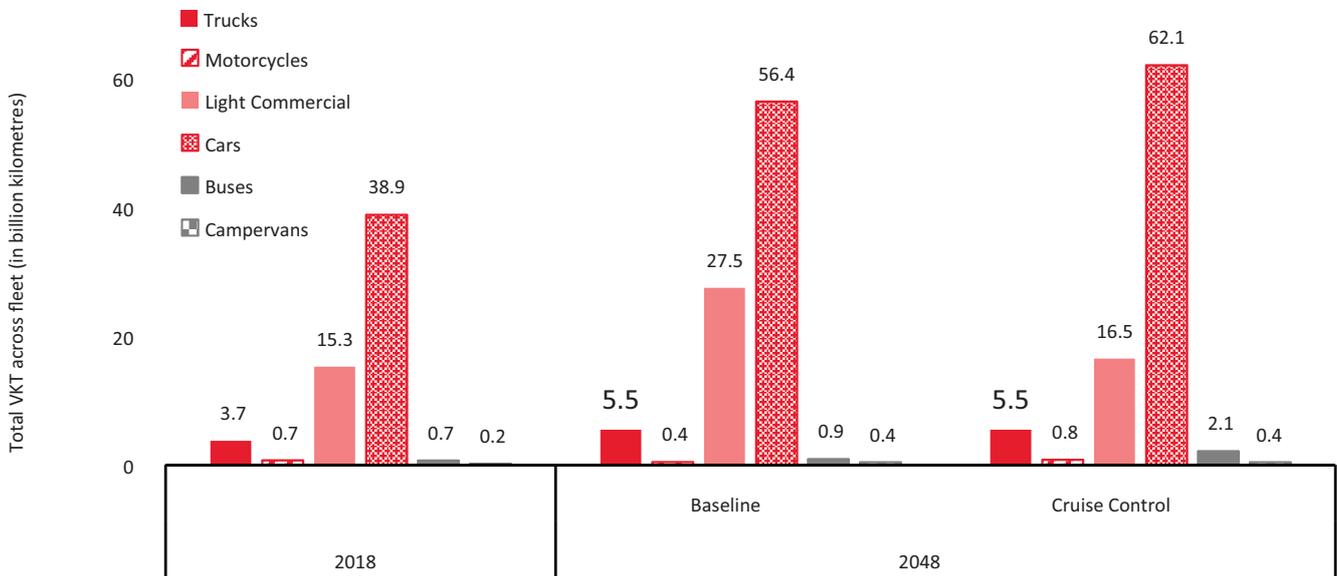
Figure 45. Modelling projections of total vehicle kilometres travelled (VKT) across the fleet (in billion kilometres) in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Australian Bureau of Statistics[179] and Data61 estimates

Road safety. Under this scenario, we anticipate considerably slower growth in both fatalities and hospitalisations in urban areas, primarily due to the safety benefits offered by AVs (see Figure 46), but little change in the regional road toll. Research from the US shows the potential for at least a 40% reduction in the fatal crash rate as crashes involving drink driving, fatigue, distraction or drugs are eliminated.[35] Greater public transport patronage will also help reduce the road toll even further.

This reduction in fatalities will coincide with a marginal decline in crashes involving vulnerable road users — pedestrians, cyclists and those who use electric bikes, scooters, segways or motorcycles for either part or the whole of their journey. Even though more road users along the main routes and at peak times increases the potential for accidents, more of these vehicles are autonomous thereby reducing the risk. The actual impact of concentrated mobility patterns on the road toll will be highly influenced by investment in pedestrian and cycling infrastructure.[190]
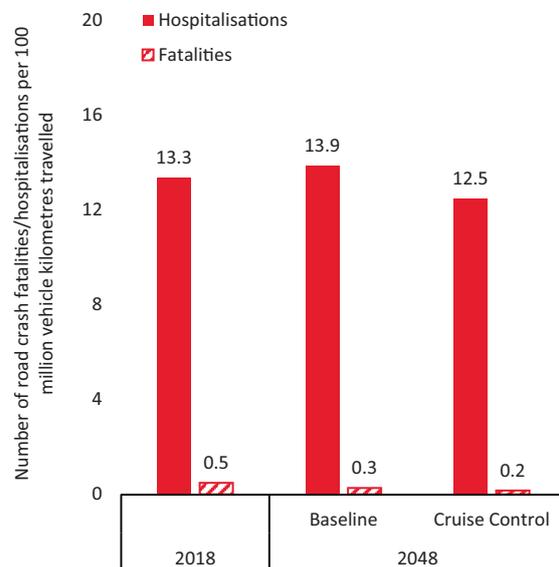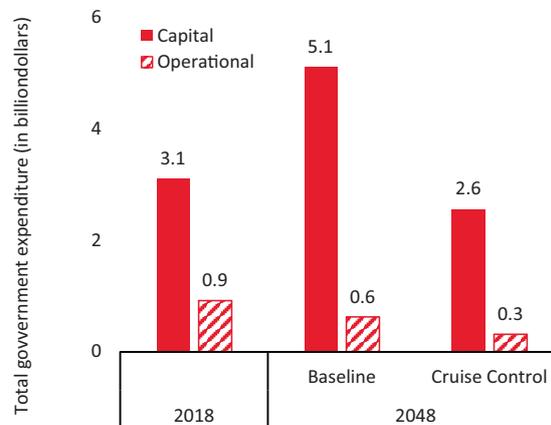

Figure 46. Modelling projections of number of road crash fatalities and hospitalised casualties in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Data provided by TMR and Data61 estimates

Infrastructure expenditure. The high uptake of vehicle sharing combined with increased public transport patronage leads to in increases in fleet use. More efficient use of the fleet reduces the toll on road-related infrastructure, and consequently the costs of maintenance and repairs. While this scenario sees an increase in expenditure on public transport infrastructure, due to a significant increase in demand, digital technologies (e.g. BIM) significantly reduce the capital expenditure required for these projects. Overall, we anticipate a significant decrease in the growth of infrastructure expenditure under Cruise Control — greater than under any other scenario (see Figure 47).

Registration revenue. Private vehicle ownership has declined because mobility services, such as point-to-point autonomous taxis, and improved public transport reduce people's need to own a car in urban areas (see *Fleet composition* section). The transport sector has been significantly transformed by advances in technology as those who own cars have an EV because the necessary charging infrastructure is accessible and convenient. The remaining internal combustion engine fleet is dominated by 4-cylinder vehicles. While those living in rural and regional areas are still likely to drive petrol or diesel vehicles, they hold a minority share of the fleet. Given these factors, we anticipate a sharp decrease in government revenue from registration, with little change from 2018 levels of revenue (see Figure 48).

Public transport patronage. Under Cruise Control, there is significant growth in public transport patronage in urban and regional areas (see Figure 49). This applies in particular to bus and rail as they become key modes of transport for a concentrated population travelling in and out of the CBD at peak times. Digital technologies make public transport more reliable and responsive, which makes for a higher quality service. These projections assume that app-based ride services are operated by private providers (in much the same way as Uber and Lyft operate today), with public transport operated and subsidised by the government. Shared and on-demand mobility schemes are mainly used for short trips, such as connecting commuters to local bus or train stations, and provide a complete end-to-end journey through MaaS schemes.
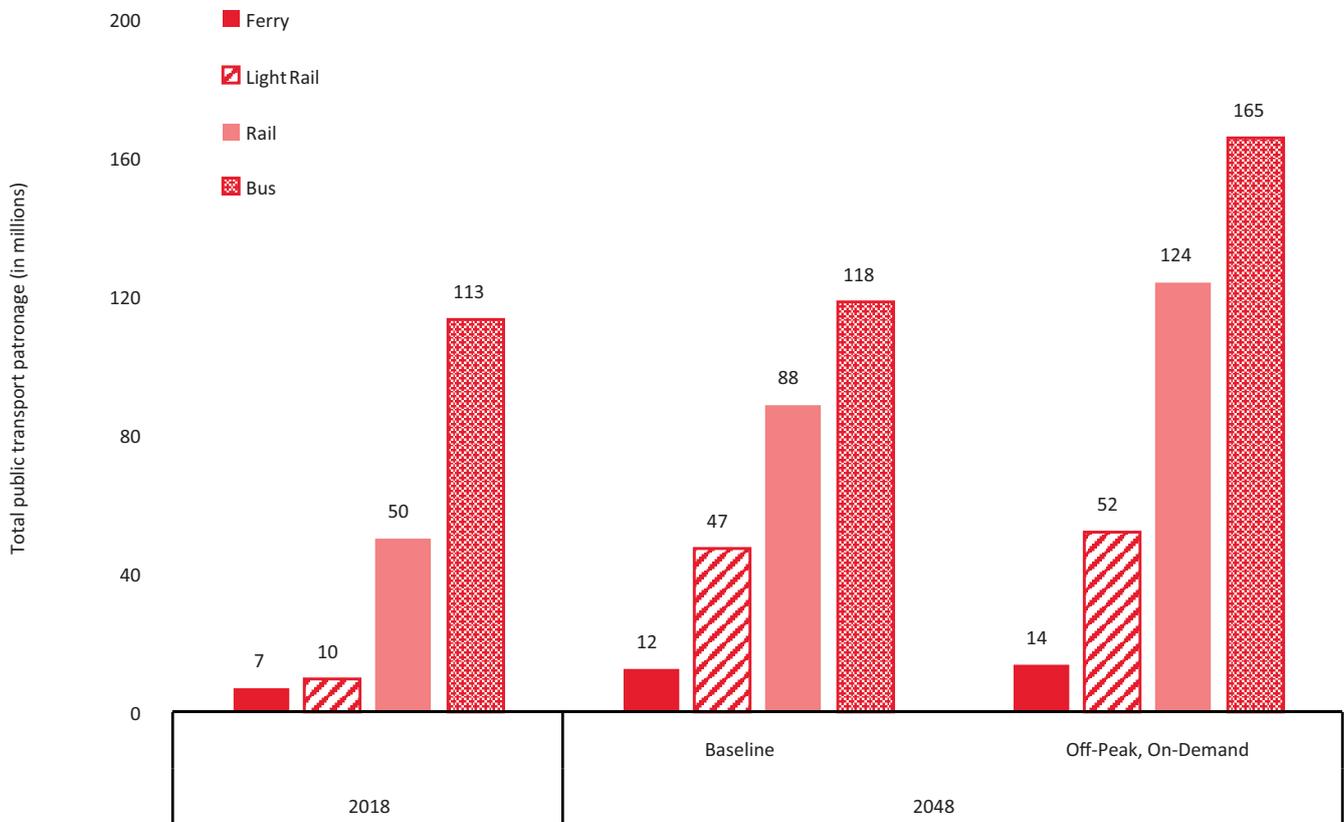

Figure 47. Modelling projections of total government expenditure (in billionv dollars) in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Data provided by TMR and Data61 estimates
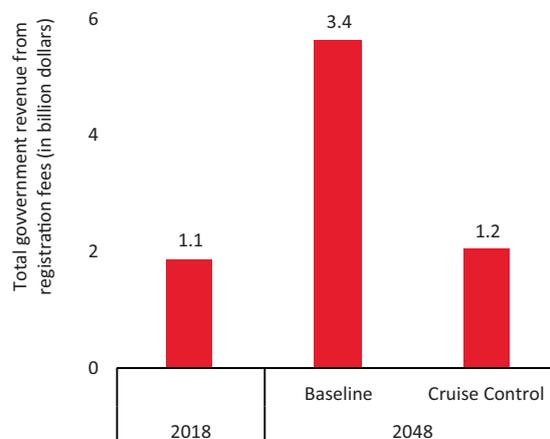
Figure 48. Modelling projections of total government revenue from registration fees (in billion dollars) in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Data provided by TMR and Data61 estimates

Figure 49. Modelling projections of total public transport patronage (in millions) by mode type in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Data provided by TMR and Data61 estimates

Household expenditure on transport. There is a significant decrease in the growth in expenditure on transport among urban households, due mainly to lower private vehicle ownership. Based on 2016 figures, Queensland households spent $194.20 per week in owning and operating private motor vehicles,[191] an expense which disappears for many people under Cruise Control. Even among those who do own a vehicle, the average cost of ownership goes down, as most vehicles are electric and thus cheaper to maintain and register.[37] Regional and remote households would see little change in transport costs.

Instead of spending money on car ownership, people are spending it on shared and point-to-point mobility services, as well as public transport. Research estimates that future 'robo-taxis' will be 50% cheaper than car ownership.[181] Hence we assume that even those who use AVs as personal taxis will see their spending decline. Those who only use AVs as first- and last-mile connections to public transport and for occasional trips will save even more. Based on this combination of factors, household expenditure on transport is estimated to be the lowest out of all the scenarios (see Figure 50).
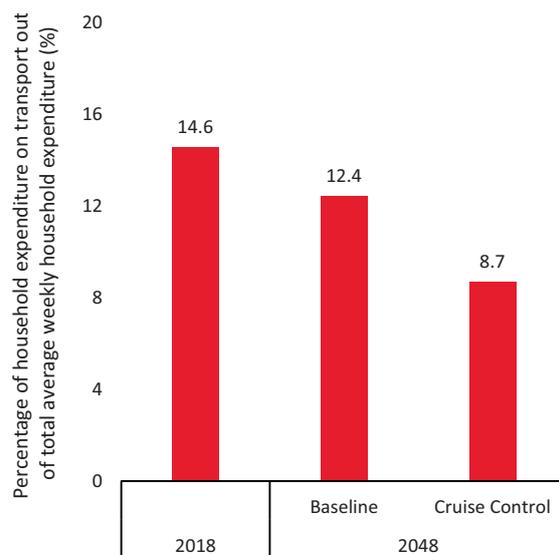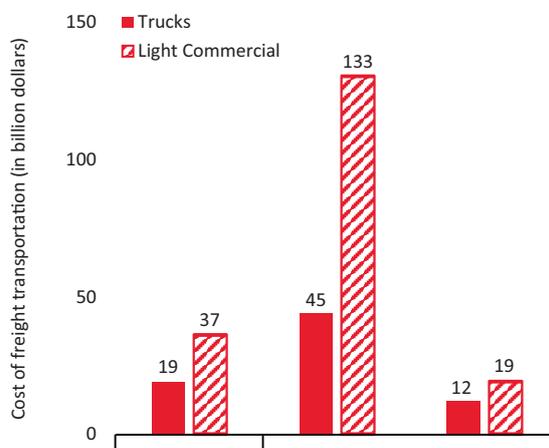

Figure 50. Modelling projections of average weekly household expenditure on transport in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: ABS Household Expenditure Survey[182] and Data61 estimates

Cost of freight mobility. The cost of freight mobility is strongly linked to fuel costs and cost of labour.[192,193] Under Cruise Control, we expect a sharp increase in the fuel price either due to the transition to EVs and the subsequent incentive for the government to increase the fuel excise, or to demand outstripping supply. As an increasing share of the truck fleet is electric though, mobility costs are less impacted by this price increase (see Figure 51; see Figure 121 for projections across variable fuel prices). Cost of freight mobility drops significantly due to labour savings for AV trucks, increased vehicle use due to improved logistic systems and efficient travel (e.g. through platooning).
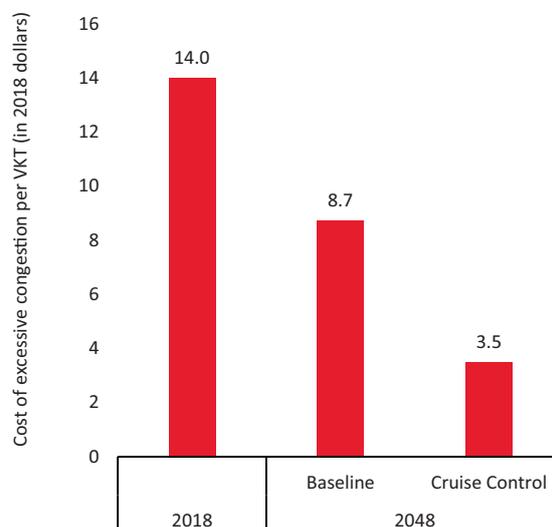
Cost of excessive congestion. Under Cruise Control, excessive congestion is reduced due to the popularity of vehicle sharing and public transport, as well as the efficiencies from new technologies. For instance, an autonomous bus can carry about 25,000 people in the space of one road lane per km per hour on a freeway, compared to 15,000 based on current bus capabilities.[194] OECD modelling of a city serviced by shared taxis and taxi-buses found that congestion disappeared.[123] Some people will still drive private cars during peak periods or use fully connected and AVs as private taxis. So although we do not anticipate the total elimination of excessive congestion in urban areas we do assume significant decreases (see Figure 52).

Greenhouse gas emissions. Research has found that a city serviced entirely by shared mobility models could decrease emissions by one-third, even with current internal combustion engines.[123] We estimated that adding high EV and public transport uptake in urban areas under Cruise Control would reduce emissions even more (see Figure 53 and Figure 54).[xiii] Emissions will also reduce significantly in the freight sector due to the uptake of electric trucks. While there will be a major drop in the growth trajectory of emissions under this scenario, we do not assume zero emissions. Unless 100% renewable energy sources are available, charging EVs will still contribute emissions.

Figure 51. Modelling projections of cost of freight transport (in billion dollars) in 2018 and projected out to 2048 at a fuel price of $2.00/L under the Baseline and Cruise Control scenarios
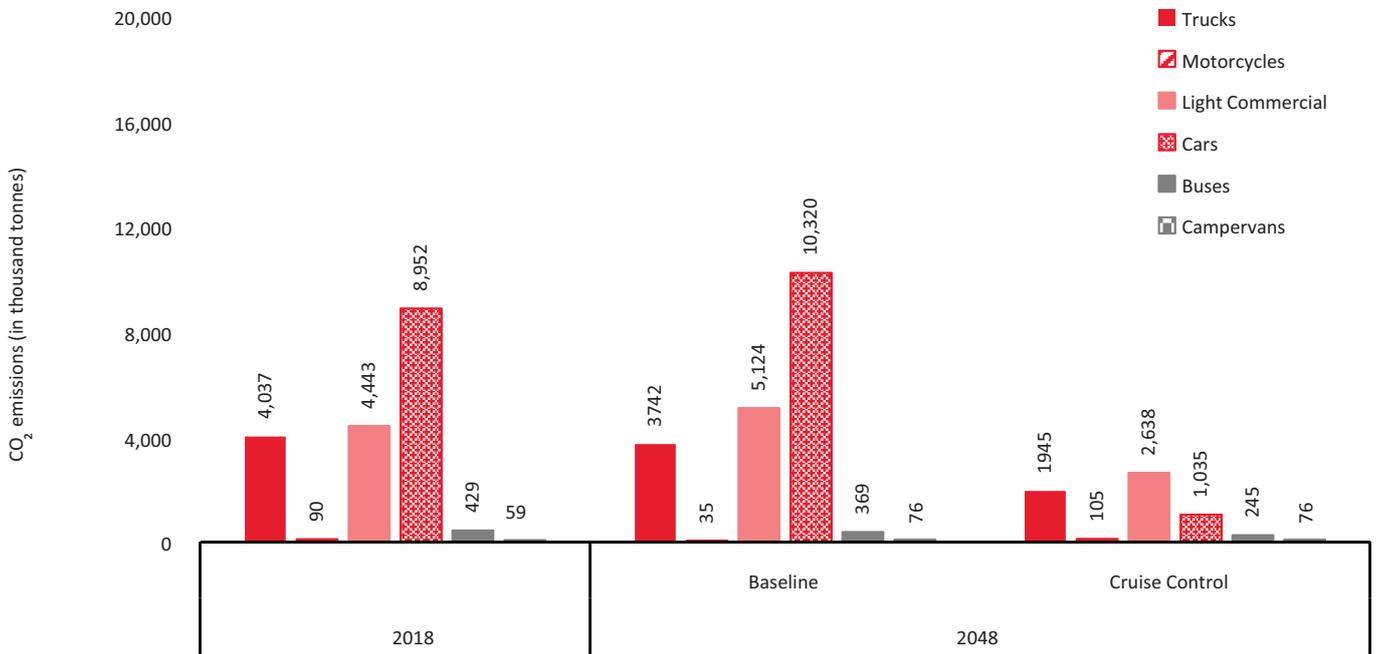Data source: CSIRO TraNSIT model[183] and Data61 estimates

Figure 52. Modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT) in Greater Brisbane area in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios
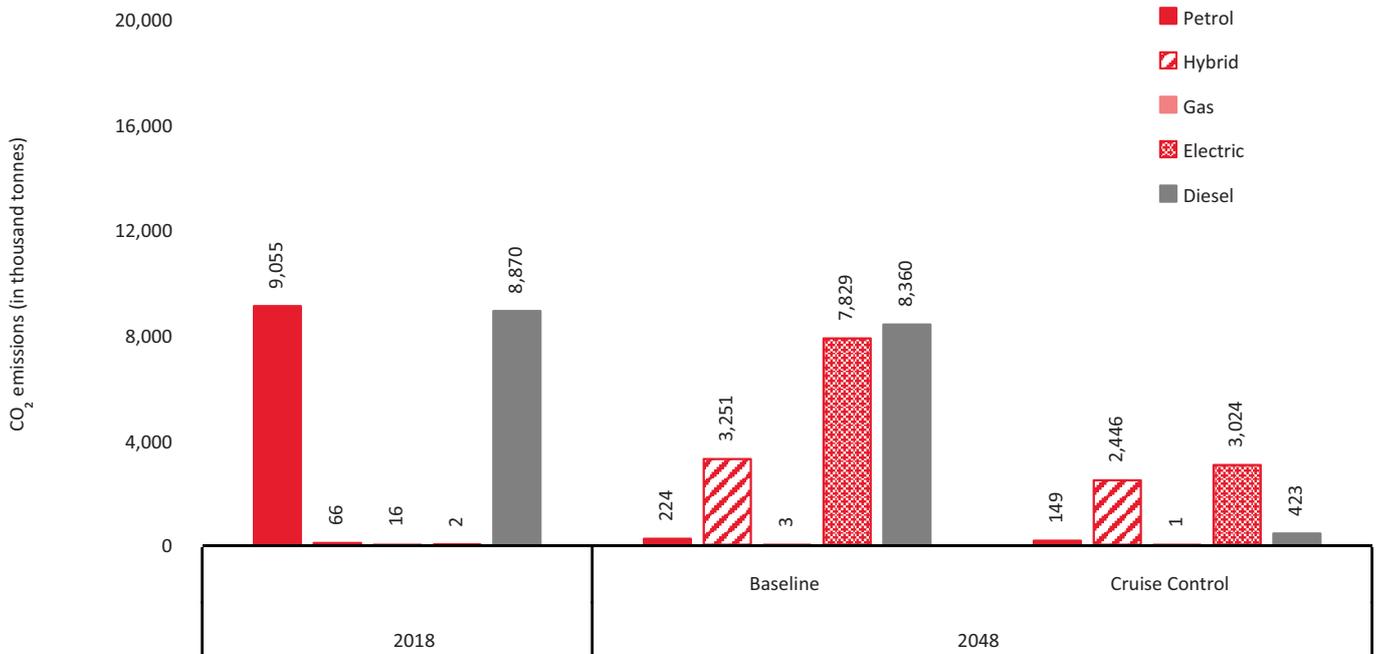Data source: Data provided by TMR and Data61 estimates

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xiii. Based on preliminary results from TMR's Transport Abatement Modelling, the state is expected to deliver on roughly half of its 2050 abatement targets (results from Pekol Traffic & Transport provided by TMR). The Cruise Control scenario would see these contributions grow closer to 90–100%, driven by an accelerated increase in the efficiency of the vehicle fleet and fewer high-emission vehicles on the roads.

CO₂ emissions (in thousand tonnes)

20,000

16,000

12,000

8,000

4,000

0

Trucks
Motorcycles
Light Commercial
Cars
Buses
Campervans

2018
4,037
90
4,443
8,952
429
59

Baseline
3742
35
5,124
10,320
369
76

Cruise Control
1945
105
2,638
1,035
245
76

2048

Figure 53. Modelling projections of CO₂ emissions of road transport by vehicle type in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

CO₂ emissions (in thousand tonnes)

20,000

16,000

12,000

8,000

4,000

0

Petrol
Hybrid
Gas
Electric
Diesel

2018
9,055
66
16
2
8,870

Baseline
224
3,251
3
7,829
8,360

Cruise Control
149
2,446
1
3,024
423

2048

Figure 54. Modelling projections of CO₂ emissions of road transport by fuel type in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Automation impacts across the transport and logistics sector. Similar to Off-Peak, On-Demand, this scenario will likely see significant automation of freight and passenger transport. This will lower the number human workers required to move people and goods in occupations such as drivers, loaders and operators. This may be compensated for by new job opportunities in the sector for roles in logistics data and analytics.

We project that 60% of jobs in the transport and logistics sector will be at future risk of automation (see Figure 55). This automation impact is greater than that proposed in previous modelling across the workforce in Australia and US,[81,187] as it may be easier to automate more transport processes and vehicles in more concentrated, and presumably more structured, environments. For example, autonomous trucks could be used to transport freight down major freight corridors, with drones and other small-scale AVs servicing urban freight delivery. Implementing this type of network for a more dispersed population may be challenging.
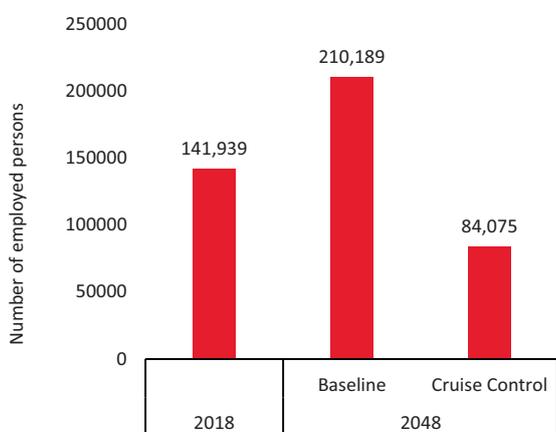
Figure 56. Modelling projections of number of employed persons in transport and logistics sector in 2018 and projected out to 2048 under the Baseline and Cruise Control scenarios
Data source: Australian Bureau of Statistics[188] and Data61 estimates

SUBURBAN STREETS: LOW TECHNOLOGY TRANSFORMATION AND DISPERSED MOBILITY PATTERNS

A window out to 2048

The promise of new technologies has not delivered on cost and/or capability. Consequentially, uptake of digital and mobility technologies has been slow and incremental and this has limited the expansion of mobility service models in Queensland. Australia's economic position globally has remained stable, but government policy has failed to adequately respond to changes in land use and mobility patterns. Pressures of urbanisation and high costs of living have driven many people to move away from urban areas, and new regional business hubs have emerged.

Many knowledge workers work at least part of the week at home or local co-working hubs, and passenger trips have become more localised and variable (i.e. different days of the week, times of day or destinations). Gaps in teleworking technologies make it difficult for Queensland to realise a truly virtual workforce, and many people still own a private vehicle for the occasional trip into the city. SEQ's urban footprint has expanded and a broader selection of subregions have emerged, with regional areas enjoying a well-needed boost in population and economic activity.

The increased variability in region-to-city trips has significantly reduced peak demand, congestion and pressure on transport infrastructure in urban areas. Rates of active travel across the state increase slightly as trips become more local. The low uptake of EVs means that transport still makes an increasing contribution to Queensland's total greenhouse gas emissions. EVs remain a niche market as they are expensive, their battery life cannot handle long distances and there are too few charging stations to support their use. Many Queenslanders instead continue to 'squeeze' as much life as they can out of their existing vehicles.

The divide between the 'haves' and the 'have nots' widens, as those who can afford to live close to the city benefit from lower congestion on the roads and greater access to transport options. Government expenditure on roads, public transport systems, bikeways and walkways is prioritised around regional centres, but this distributed network is more expensive to service. Reduced expenditure on maintenance makes mass transit systems less efficient and reliable over time and deters people from using them. Government is forced to maintain public transport in regional communities as a social service provision.

The workforce behind the transport and logistics sector has not been significantly impacted by automation. Autonomous trucks are not a reality due to challenges around legislation, safety and infrastructure requirements, and human drivers remain a key component of the freight distribution network. The decline in public transport use poses potential risks for this workforce. As fewer buses are needed in the fleet to service demand, there is less need for public transport drivers and service staff to manage this fleet.

There is increased pressure on the freight system to deliver more goods across longer and more variable distances. The demand for direct freight to the consumer has increased, with more people choosing to order their goods online rather than travelling to retail centres. Without the cost and efficiency gains of a more intelligent and connected freight network, long-distance freight deliveries are slower and more expensive than under a more concentrated scenario. To compensate for the high costs of freight mobility, freight distribution networks become more decentralised and regional warehouses re-emerge.

A day in the life of 2048

Ethan is 32 years old and moved to Toowoomba from Brisbane several years ago. The lack of housing affordability and long commutes took its toll on his quality of life. He earns a good salary and works for a large financial company that offers flexible working arrangements. He works at least part of the week from home or at a local co-working hub in Toowoomba. For the other 1 to 2 days of the week, he commutes into his central office in the CBD for team meetings and other engagements that are difficult to do virtually — teleworking systems are no substitute for human interactions.

On the days he works at a local co-working hub, Ethan drives his own car or travels via bike. He doesn't do this every day as he still has concerns around his safety on the roads. Other days when he works from home, his main travel is via foot to the local café. On the days that Ethan travels into Brisbane, there's little option but to drive. There are some public transport options between Toowoomba and Brisbane, but these are slow, unreliable and lack the comfort and convenience of a private vehicle.

On his commute to Brisbane, Ethan shares the road with a large number of heavy vehicles. He has noticed an increase in the number of trucks, and the quality of the road conditions has declined; he suspects the two are linked. Ethan drives the same 4-cylinder petrol vehicle he's had for

almost 12 years. It gets him from A-to-B and there's little reason for him to upgrade. Electric cars are still well outside his price range and if he did need to get a new car, he'd probably opt for another similar car second hand. While Ethan is concerned about rising greenhouse gas emissions, he's not willing to pay the price of going electric.

Many of Ethan's friends and family have similarly chosen to move to more rural or regional towns in Queensland. Some work for organisations that have based their headquarters in the outskirts of SEQ, or in coastal regional hubs like Cairns or Townsville, so they have the option to work and live in smaller, less densely populated areas. Ethan is more willing to travel longer distances on the weekend for leisure and travel as his commuting time each week is less.

Signals for the evolution of Suburban Streets

- There is a social shift towards lifestyles that have a lower impact on the environment, with more people (both in Queensland and abroad) choosing to go 'off-grid' to varying extents.

- Similar housing pressures that have been felt in Sydney and Melbourne become evident in Brisbane.

- There is a major crash in the oil price, which further incentivises people to move away from EVs in favour of petrol and diesel vehicles that have lower operating costs.

- Tiers of government are expanded to better manage land use across a dispersed population. The role and influence of regional local governments increase as a result.

- In an attempt to boost regional populations, new immigration policies are introduced which encourage newly arrived migrants to live in a regional or remote area in Queensland.

- Uptake of AVs and other new mobility technologies are significantly delayed due to public concerns around safety and security, or technical barriers in their development.
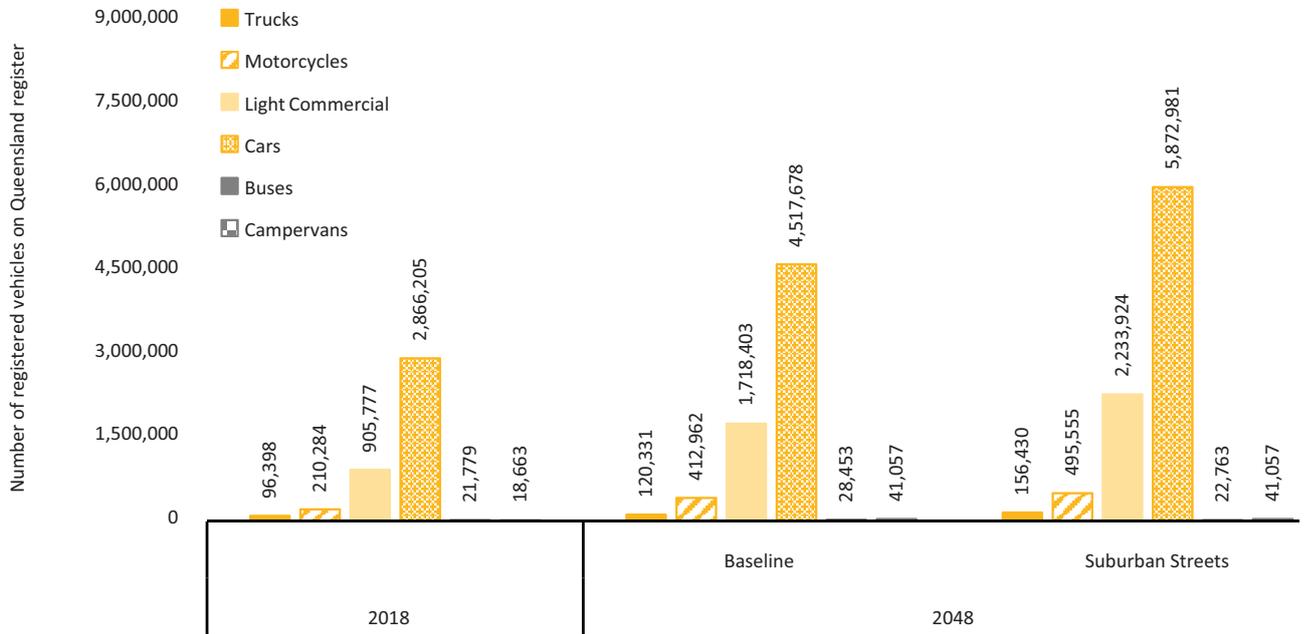
Figure 56. Modelling projections of number of registered vehicles in the fleet by vehicle type in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Data provided by TMR and Data61 estimates
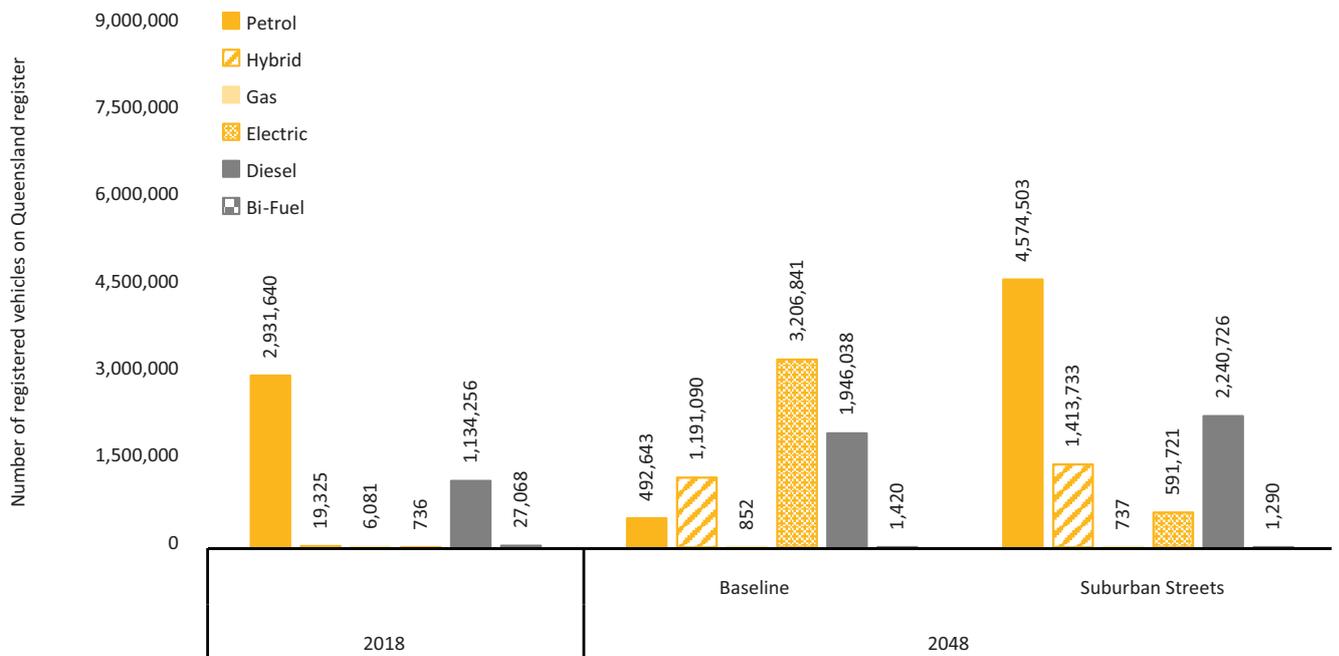
Figure 57. Modelling projections of number of registered vehicles in the fleet by fuel type in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Data provided by TMR and Data61 estimates

Measuring the impact of Suburban Streets

Fleet composition. In the absence of alternative mobility options that offer the same level of comfort and convenience, the passenger car fleet continues to grow at an accelerated rate (see Figure 56 and Figure 57). Private vehicles remain the go-to mode of transport for most passenger trips. In the absence of peak demand, fewer buses are needed. Motorcycles become more popular as an alternative way of travelling, particularly for local trips.

The truck and light commercial fleets have grown at a faster rate due to the larger freight task associated with servicing a more dispersed population. The existing fleet operates less efficiently due to the lost gains that could have resulted from greater adoption of AVs, sensor technologies and improved logistic analytics. A larger, underutilised fleet therefore services the passenger and freight task, with limited sharing or optimisation of transport.

Uptake of EVs has slowed across the board relative to current trajectories, with 22.7% of the fleet being electric or hybrid. Hybrids are preferred over fully EVs as they can better handle the long distances people still occasionally need to travel. This share is consistent with the Australian Energy Market Operator's low EV uptake projections.[189] The low EV uptake is due to high vehicles costs and the limited capacity and infrastructure available to support these vehicles when travelling long distances. Similarly, freight vehicles tend to be petrol- and diesel-powered to cover the long distances between dispersed regional hubs.

Vehicle kilometres travelled. Queenslanders' travel behaviour has changed, with long commutes into the CBD becoming less frequent for most people. Passenger vehicle kilometres are thus expected to reduce (see Figure 58); it is estimated that teleworking alone leads to a 42.5% reduction in passenger kilometres travelled.[178] Teleworking trials in the US have also found participants reduced their average annual travel by 2,850 km each year.[195] Without vehicle sharing and sophisticated teleworking capabilities, however, this reduction in car vehicle kilometres travelled would be less than Off-Peak and On-Demand.

As the population is more dispersed, trucks and commercial vehicles must travel longer distances to meet the freight task. Unlike in Off-Peak, On-Demand, this cannot be offset by technology-enabled efficiencies. Suburban Streets therefore sees an increase in the growth of vehicle kilometres travelled in the freight sector, including increases in both light commercial vehicles and trucks. The bus fleet also travels less as fewer people are using these services and fewer scheduled trips are offered.
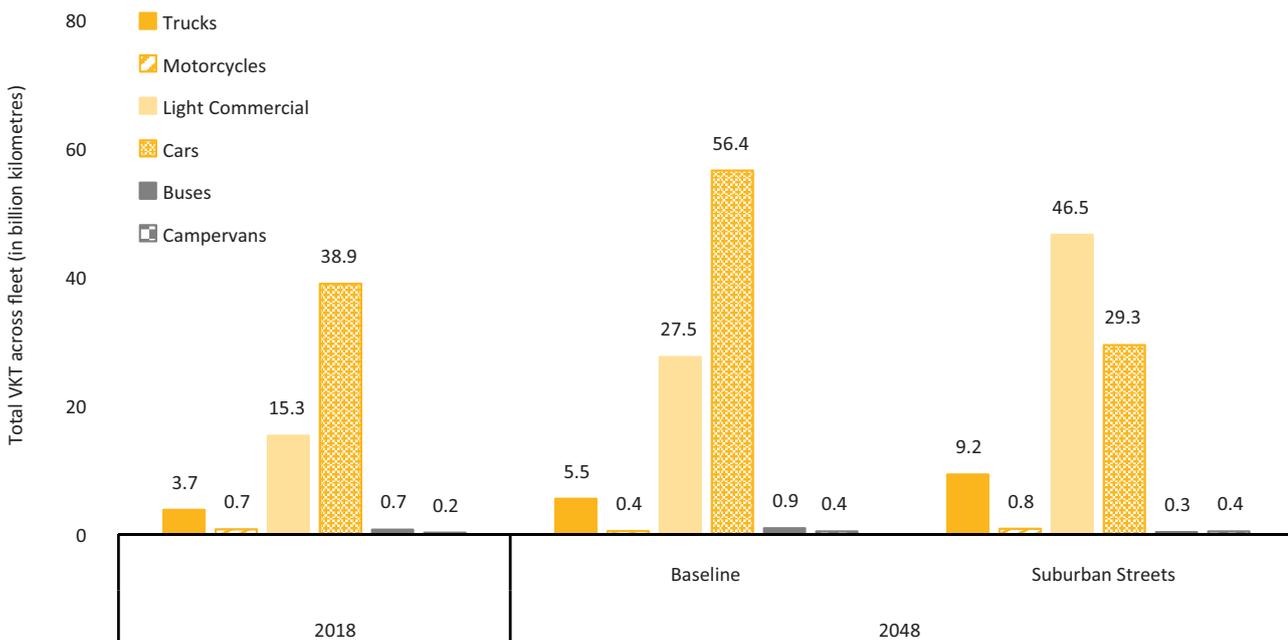

Figure 58. Modelling projections of total vehicle kilometres travelled (VKT) across the fleet (in billion kilometres) in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Australian Bureau of Statistics[179] and Data61 estimates

Road safety. As the fleet under this scenario is made up of non-automated vehicles, the population does not see the safety improvements of AVs. Accidents caused by human error, distraction, fatigue, or intoxication continue to drive an increase in road traffic crash fatalities.[113,37] Even though people undertake more regional and remote travel, another risk factor in fatal crashes,[112] this is mitigated by workplaces and services being more localised and therefore these trips are fewer and shorter. As such, there is a slight reduction in the current growth trajectory for road crash fatalities and hospitalisations (see Figure 59).

Infrastructure expenditure. Due to the prevalence of shorter, more localised commutes, there is a significantly reduced need for government expenditure on upgrading and maintaining major commuter corridors in and out of the CBD. Similarly, maintenance and operational costs for public transport infrastructure decrease as, fewer people use these services. They instead work or study from home, or drive or walk to their local co-working centre or café to work/study.

However, these savings are offset by the increased demand for regional transport options. While Queensland's transport system can draw on existing regional networks, this infrastructure is travelled more frequently, particularly by heavy and light commercial vehicles, and therefore requires more regular maintenance and upgrades. Regional roads now also require appropriate traffic management systems to cope with the increased traffic flows. This drives up operational costs (see Figure 60). There is little change in capital costs, with existing funding for metropolitan projects instead redirected to regional parts of the network.

Registration revenue. In this scenario, private car ownership is the preferred passenger transport solution for most people. This is due to the lack of technology-enabled alternatives (e.g. autonomous taxis or shared mobility schemes) and the irregularity in travel times and destinations. Car ownership, and consequentially government revenue from registration fees, therefore follows a steeper growth trajectory than the present, with a decreased rate of EV uptake (see *Fleet composition* section). Similar to today, most vehicles are 4-cylinder engines, but the growing fleet size mean that registration revenue streams continue to grow (see Figure 62).
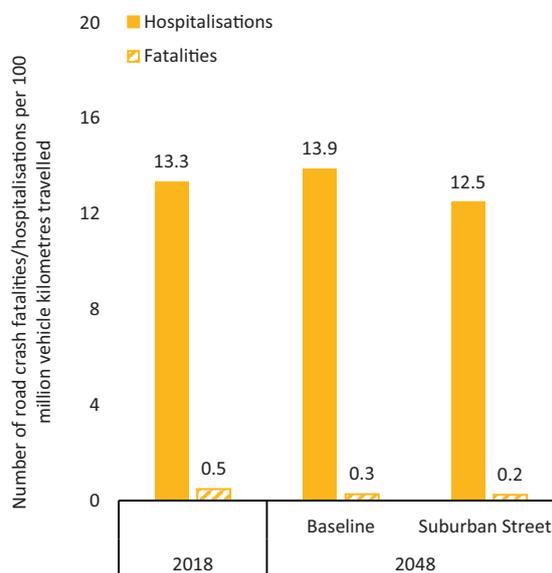

Figure 59. Modelling projections of number of road crash fatalities and hospitalised casualties in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Data provided by TMR and Data61 estimates
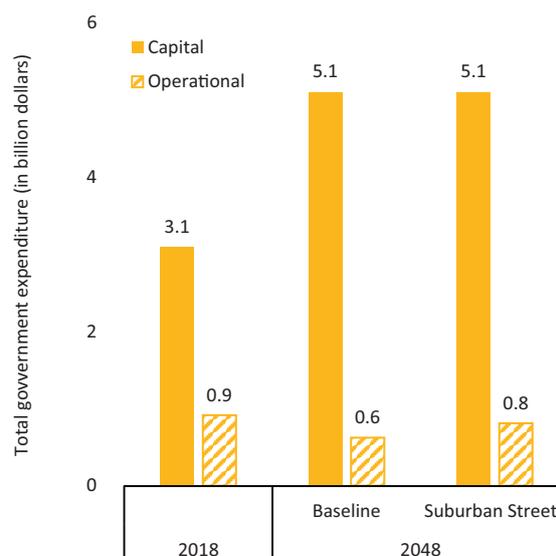
Figure 60. Modelling projections of total government expenditure (in billion dollars) in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios
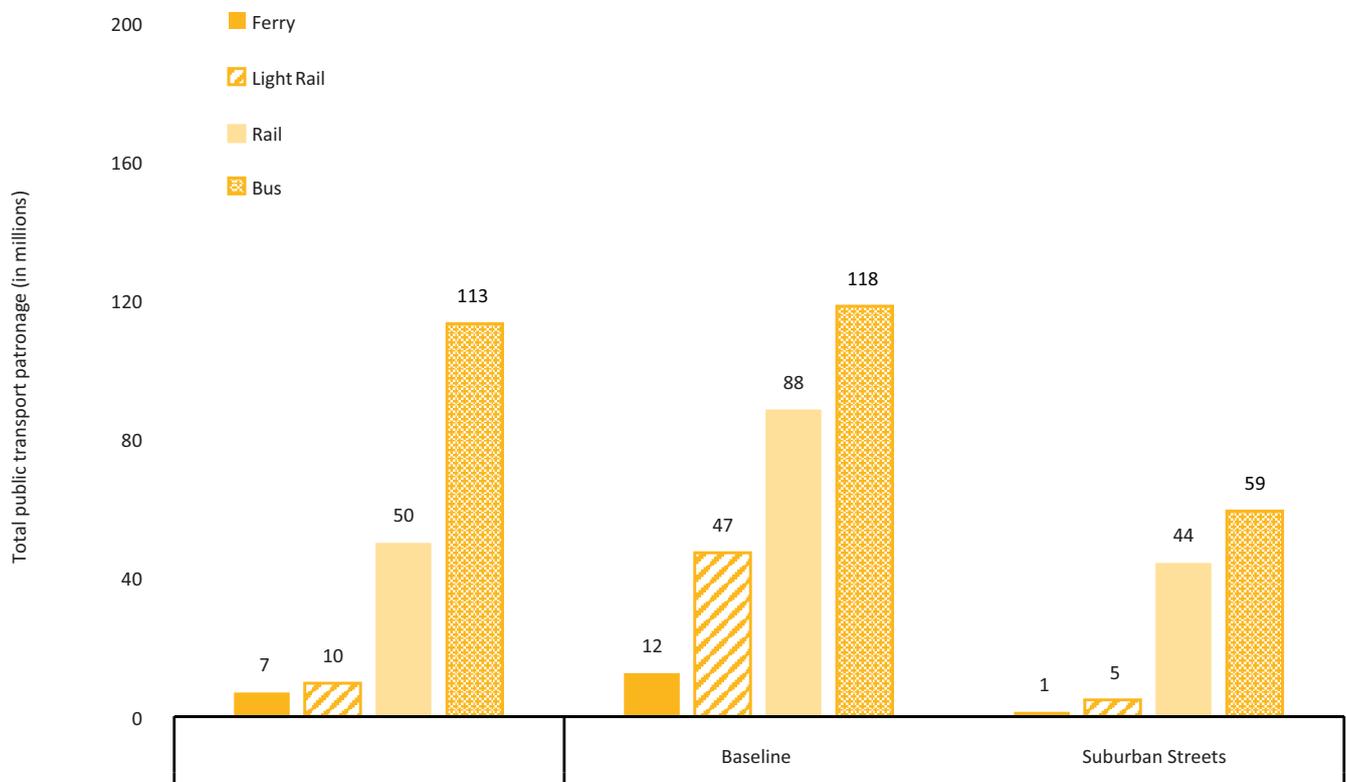
Data source: Data provided by TMR and Data61 estimates
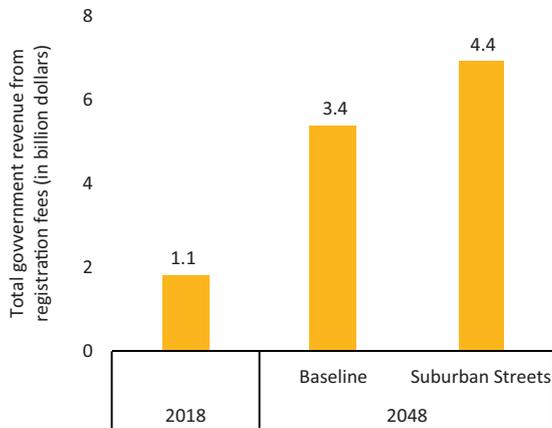
Public transport patronage. In the absence of technology-enabled, on-demand services that can better connect people to local train stations and busways, public transport patronage is expected to decline (see Figure 62). A dispersed population with highly variable mobility needs is not well-serviced by a traditional, scheduled mass transit system. Patronage levels are similar to Off-Peak, On-Demand, yet this shift has come with an increase in private car ownership rather than uptake of shared mobility. Travelling via a private vehicle is seen as a more attractive and convenient option for most people living in regional areas.

Figure 61. Modelling projections of total government revenue from registration fees (in billion dollars) in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Data provided by TMR and Data61 estimates

Figure 62. Modelling projections of total public transport patronage (in millions) by mode type in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Data provided by TMR and Data61 estimates

Household expenditure on transport. With higher levels of private car ownership and a lack of more affordable and viable transport options, weekly household expenditure on transport grows at an accelerated rate (see Figure 63). People have to spend more money on maintaining and operating their own vehicle, even if they do not need it to commute to work or school every day. Those who would have previously used public or active transport in a more densely populated area must instead budget for private car costs. This is somewhat counteracted by the fact that people may take fewer and shorter trips and travel by foot or bicycle in their local area, reducing day-to-day operational costs.

Cost of freight mobility. With a more dispersed population and a lack of AV uptake, the freight task grows significantly along with the costs of maintaining and running the freight fleet (see Figure 64; see Figure 122 for projections across variable fuel prices). However, this is partially offset by the creation of regional warehouses and hubs that enable more localised production and distribution, and reduce the costs associated with peak congestion on major freight corridors. Overall though, the task of servicing a more dispersed population means the cost of freight mobility grows at an accelerated rate relative to the current trajectory.

Cost of excessive congestion. Current standard commuting patterns (i.e. concentrated flows of commuters in and out of a central area at peak times) produce peak-hour congestion. Under Suburban Streets, this urban congestion could be offset by structural shifts in standard work and commuting practices, including greater uptake of teleworking.[17] This scenario thus sees a significant drop in excessive urban congestion (see Figure 65). This trend is supported by research in the US which found that part-time teleworking significantly reduced congestion on two major highways during peak hours.[195] Region-to-city trips for work and study will not be eradicated, but significantly reduced and more variable.
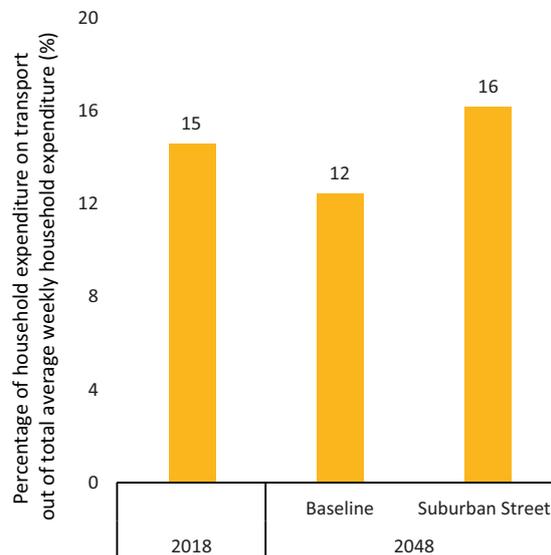

Figure 63. Modelling projections of average weekly household expenditure on transport in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: ABS Household Expenditure Survey[182] and Data61 estimates
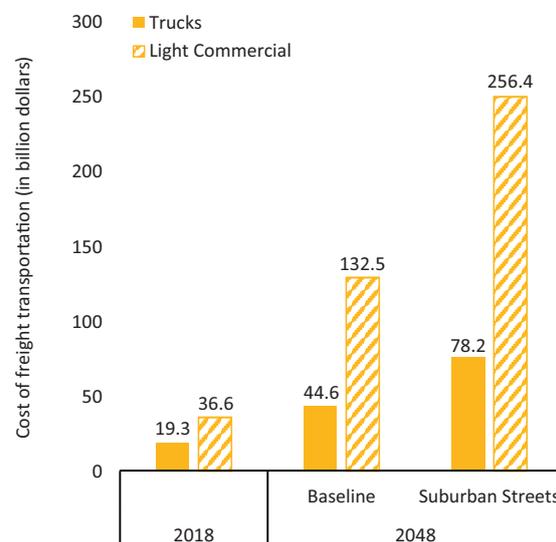
Figure 64. Modelling projections of cost of freight transport (in billion dollars) in 2018 and projected out to 2048 at a fuel price of $2.00/L under the Baseline and Suburban Streets scenarios

Data source: CSIRO TraNSIT model[183] and Data61 estimates
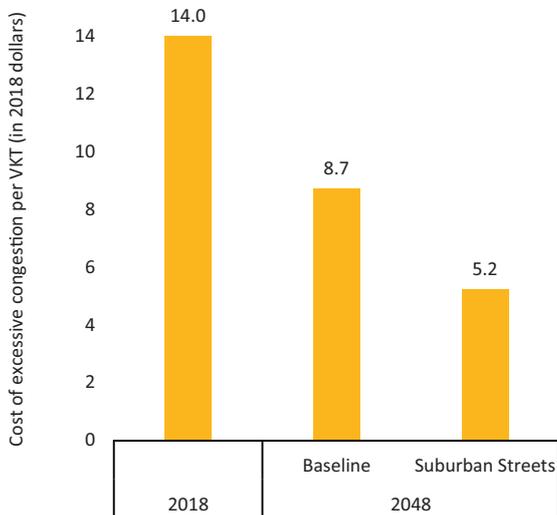
Greenhouse gas emissions. In this scenario, EV uptake failed to grow at the expected rate due to the high cost of EVs and limitations in EV capacity to travel long distances. Emissions from the freight sector increase due to increased vehicle kilometres required to service the freight task (see Figure 66 and Figure 67). Most trucks and cars have internal combustion engines and the transport sector continues to be a major contributor to the greenhouse gas emissions. People travel less due to telecommuting and spend less time idling in congestion,[195,196,197] which slightly offsets the growth in greenhouse gas emissions resulting from cars.
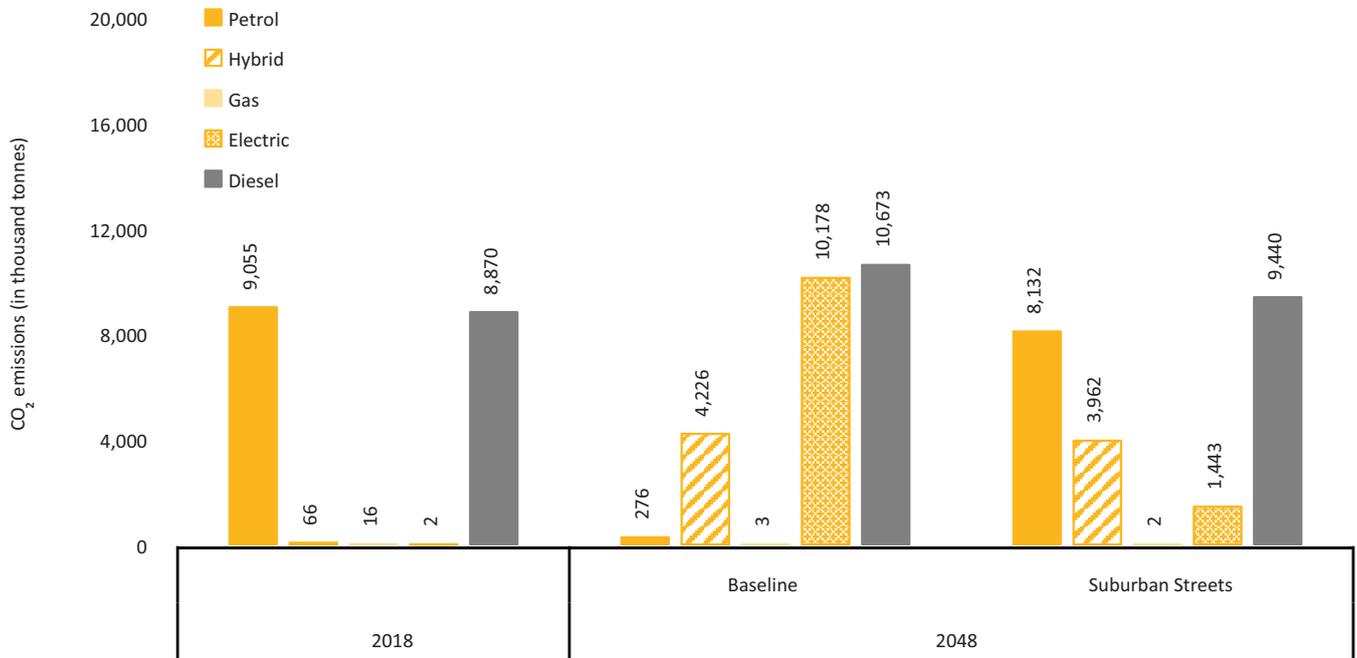
Figure 65. Modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT) in Greater Brisbane area in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios
Data source: Data provided by TMR and Data61 estimates
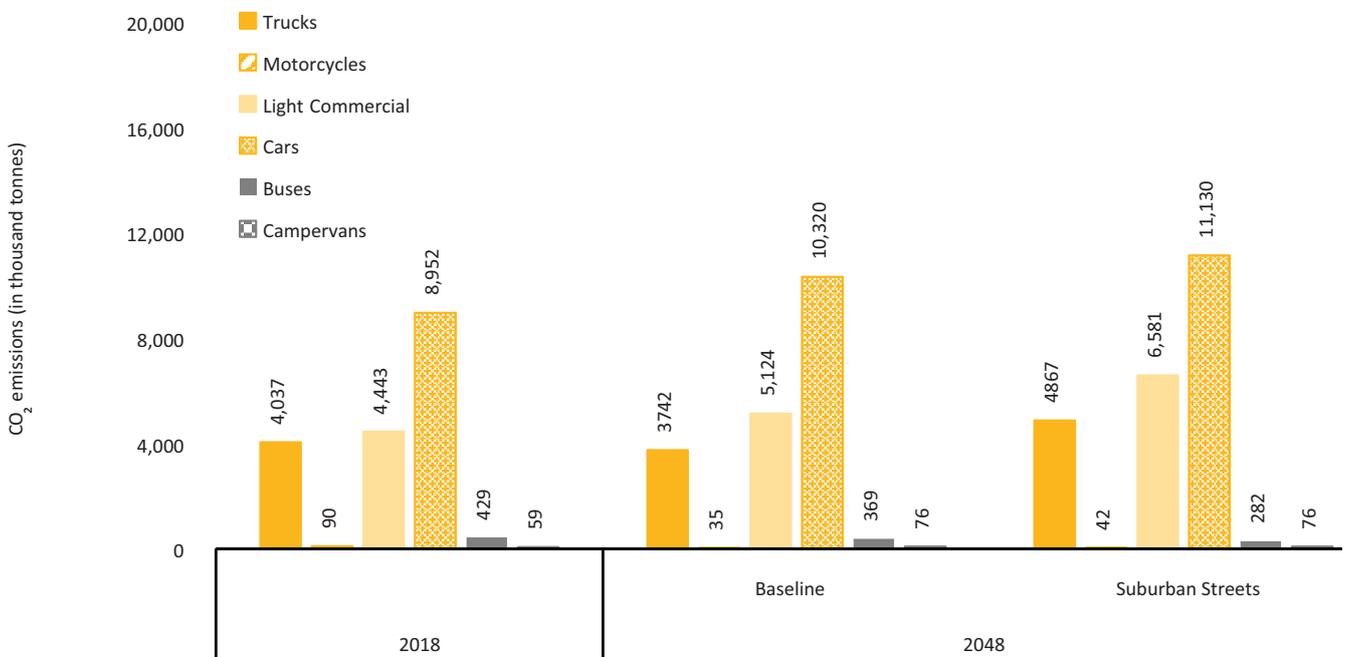
Figure 66. Modelling projections of CO₂ emissions of road transport by vehicle type in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios
Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates
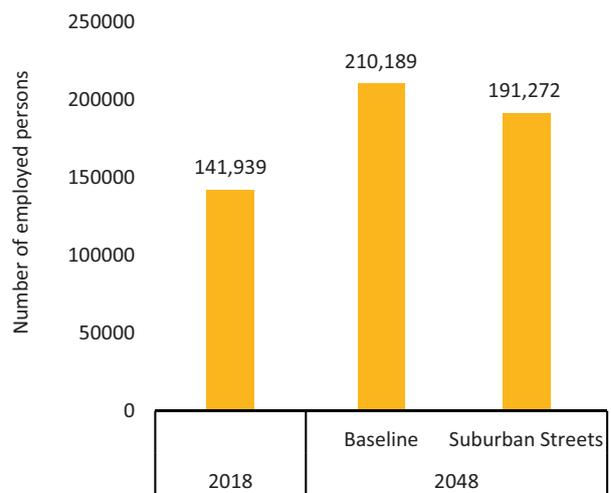
Figure 67. Modelling projections of CO_2 emissions of road transport by fuel type in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Automation impacts across the transport and logistics sector. Under this scenario, due to the limited and slow uptake of new mobility technologies, we estimate that automation will have a low impact on the number of people employed in the transport and logistics sector. AV use will be restricted to special circumstances (e.g. autonomous trucks used on mining sites) amidst fears around their safety and security limiting greater adoption across the transport and logistics sector.

Previous modelling estimates from the OECD in 2017 suggest that around 9% of jobs in the US are at risk of future automation.[80] These estimates were lower than the original estimates provided by Frey and Osborne,[81] as this approach assumed that automation will likely impact specific tasks rather than displacing entire occupations. Under Suburban Streets, innovations around technology are likely to incrementally augment existing occupations in the transport and logistics sector, but there will be minimal disruption of the existing transport and logistics workforce (see Figure 68).

Figure 68. Modelling projections of number of employed persons in transport and logistics sector in 2018 and projected out to 2048 under the Baseline and Suburban Streets scenarios

Data source: Australian Bureau of Statistics[188] and Data61 estimates

BUMPER TO BUMPER:
LOW TECHNOLOGY TRANSFORMATION
AND CONCENTRATED MOBILITY PATTERNS

A window out to 2048

Queensland has continued to see modest growth in digital technologies, but there has been limited transformation of the transport sector. Many futuristic predictions have not eventuated. Much of this progress has been slowed by the high costs of new mobility technologies, a lack of sufficient investment in infrastructure for these new technologies and/or safety, cybersecurity or regulatory concerns around AVs. A handful of accidents or public relations disasters have damaged public trust in these new mobility options. Consumers prefer to be in 'control' behind the wheel rather than be in the 'hands' of a machine.

The lack of technology uptake has slowed productivity levels in Queensland. As a result, many government departments and corporations have become more concentrated to improve operating efficiency. Tele-presence systems are a poor substitute for an office or classroom environment, making it challenging for people to work and/or study remotely. As a consequence, many commuters still travel daily during peak time periods into the CBD and other densely populated parts of SEQ. The bulk of the state's internal migration is concentrated in SEQ, as many people want to live closer to where they work. The quality of the transport network in other parts of Queensland suffers as a result of low population growth.

The mass concentration of commuters does enable greater efficiencies in the public transport system, and people increasingly choose to travel via bus, train or ferry. Public transport services are designed around meeting peak demand, with high-frequency services scheduled for the morning and afternoon commute and greater bus lane prioritisation. To handle peak congestion in the CBD, private car access is limited to a 5 km radius from the CBD, with commuters forced to park 'n' ride via public transport for the remainder of their journey. The public transport system is under increased strain, particularly during peak hours, with any breakdown or incident in a major CBD public transport corridor causing significant delays.

While personalised app-based ride services have gained some popularity, the main users are young people, or those living close to the CBD. Shared mobility models supplement rather than replace trips via private vehicles and public and active transport. Many people still own a car for travel during off-peak times and non-routine locations. Regional and remote communities in Queensland do not have a strong demand for ride- and vehicle-sharing services. For regional and remote communities, access to transport options outside of private vehicles are few and far between.

Greenhouse gas emissions associated with transport continue to rise due to low EV uptake and poor utilisation of existing vehicles in the fleet. Congestion also worsens as many people use major commuter corridors during peak hours to travel into the CBD. Without the efficiency gains of AVs or other intelligent transport technologies, strain on road infrastructure during peak hour continues to rise. Government is under increased pressure to invest in new road and public transport infrastructure, but this only results in increased demand, rising levels of congestion and emissions, and the need to increase road-user tolls.

Vehicle safety features improve but rates of road-related hospitalisations accelerate. The number of road fatalities continues to increase in line with the current trajectory, but with most of these incidents occurring in regional communities. Those who are able to live close to their workplaces or places of study are able to travel more via foot or bike, which benefits their health and wellbeing, and reduces the need to own a vehicle. But few have this luxury. Most people have little choice but to drive and/or travel via public transport. This widens the mobility divide between regional and urban households.

Household expenditure on transport goes up, as there are few options besides private vehicle ownership, and long work and education commutes push up the amount of time people spend travelling during peak hours. To compensate, consumers feel more inclined to do their shopping online instead of having to make an extra trip to a retail store. This puts increased demand on urban freight and logistics, and the lack of efficiency-enabling technologies means that deliveries are slow and expensive.

A day in the life of 2048

Greg is 47 years old and works as a self-employed electrician. His ute is his sole option for getting to and from work. Each morning he travels from The Gap to inner city construction sites, battling the early morning peak-hour traffic into the CBD. Greg has noticed the roads getting busier and busier over the past couple of decades, and regularly sees accidents between motorcyclists and other cars as drivers get impatient waiting in traffic. His wife and children work and go to school in the city too, but they get public transport as they are a one car family.

Greg often reads online about AVs and flying drones being used in other countries, but he's yet to see any being used in Queensland, nor does he think it will be a reality anytime soon. These new types of mobility technologies seem to be more hype than anything else. Greg buys a lot of the things he wants online and has these delivered straight to his door. These delivery services are poor quality and there are often delays in the estimated delivery time. As a result, Greg sometimes opts to go to the retail store directly to get what he needs.

While Greg cares about the environment, the idea of owning an EV does not come on his radar — not when he's got a vehicle that runs perfectly well that will likely last him for many years to come. The cost of petrol has also remained reasonable. He wishes he could live further away from the city, but it is a challenge to find work elsewhere, since most new construction sites, particularly new apartment blocks, are in Brisbane's CBD. Plus, Greg's commute already maxes out his daily travel budget and he couldn't imagine travelling further each day.

In his leisure time, Greg often travels with his family to the Gold Coast or Sunshine Coast. He does so in the family car, mainly because it's easier and more convenient than using public transport. Greg is worried about the amount of time he spends driving around, but is glad he has an active job that helps keep him physically fit. The same can't be said for some of his fellow office workers though; Greg has noticed his white-collar friends and colleagues spend an increasing amount of time driving to work or sitting down, which is negatively impacting their health.

Measuring the impact of Bumper to Bumper

Fleet composition. Private car ownership increases due to the lack of alternatives that offer the same level of convenience (see Figure 69 and Figure 70), and those that do remain tend to be 4-cylinder vehicles. This increase is tempered relative to what the increase would be under more dispersed mobility patterns (i.e. Suburban Streets), as many people in urban areas live close enough to access public transport, bikeways or walkways. Those in regional

and rural areas depend solely on their private vehicles for travel. A greater share of drivers also ride motorcycles as an alternative way of getting to and from the city during congested peak times.

The size of the bus fleet increases to cater for the rise in peak demand on the public transport network, as does the truck and light commercial fleet due to the increased freight task in urban areas. Heavy vehicles deliver freight down major corridors to dispatch centres, where the load is picked up and distributed to more urban areas via light commercial vehicles. The freight supply chain is still inefficient due to frequent empty loads and restrictions to prevent driver fatigue; the growing fleet is not utilised to its full capacity. People in regional and rural areas are the most impacted by the rise in freight costs that come with these inefficiencies.

Uptake of fully EVs slows relative to current growth trajectories for several reasons (see Figure 70). First, EVs are not capable of travelling the long distances that people occasionally want to travel. Second, they are costly, and many prefer to 'sweat' their existing assets for as long as possible before upgrading to a lower emissions vehicle. Similarly, the long distances that heavy vehicles need to travel in the freight sector mean that EVs are not feasible. As a result, 34.2% of the total fleet is electric or hybrid — a middle ground between the Suburban Streets and Off-Peak, On-Demand scenarios.

Signals for the evolution of Bumper to Bumper

- Improvements in AVs and EVs begin to slow or plateau, along with investment in the infrastructure (e.g. charging stations) needed to support these new types of vehicles.

- There is a significant event, or series of events, that damage the public's trust in AVs, drones and other emerging technologies.

- Urban congestion continues to rise at an accelerated rate, as does the amount of government expenditure on transport infrastructure in SEQ versus the rest of Queensland.

- Changes in immigration policies encourage greater net overseas migration to Queensland, which further adds to the rising population in SEQ.
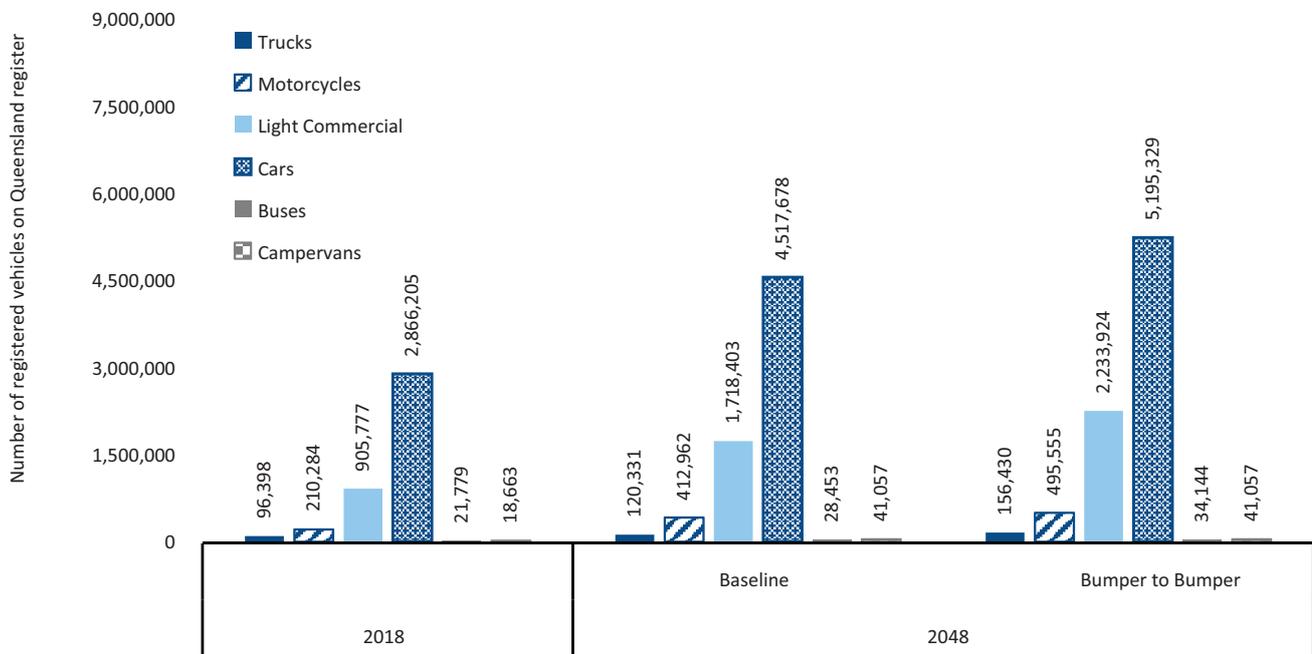
Figure 69. Modelling projections of number of registered vehicles in the fleet by vehicle type in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

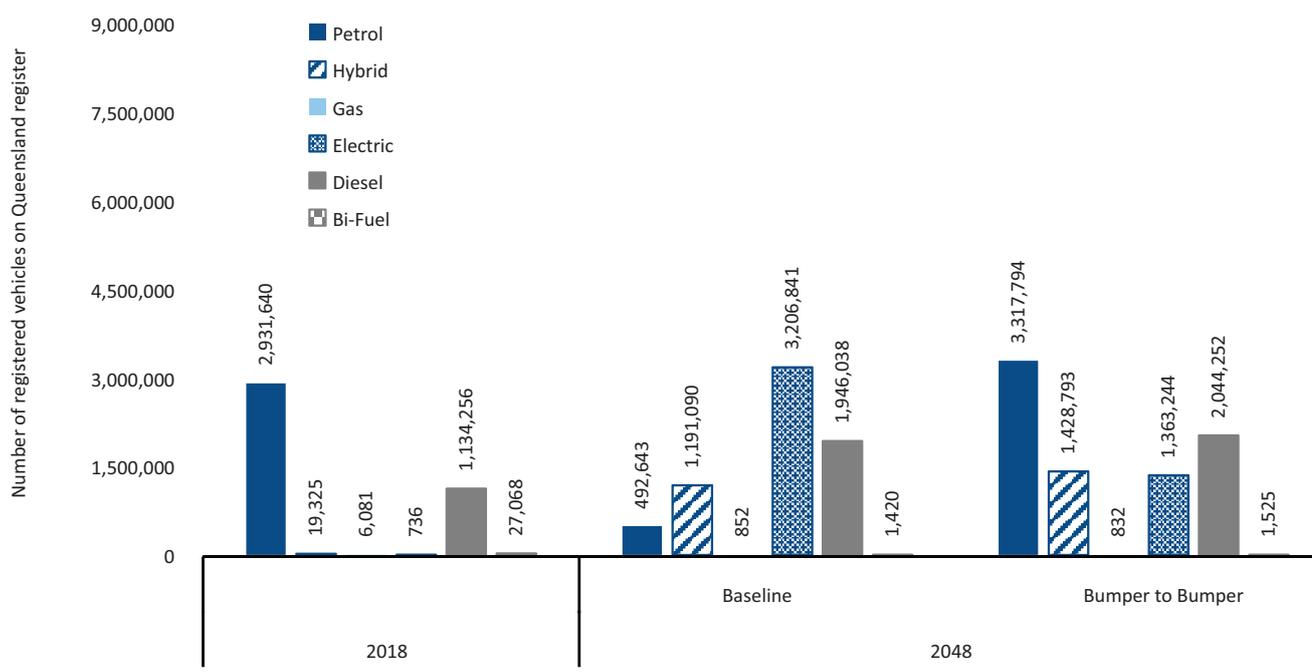Data source: Data provided by TMR and Data61 estimates

Figure 70. Modelling projections of number of registered vehicles in the fleet by fuel type in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Data provided by TMR and Data61 estimates

Vehicle kilometres travelled. As people continue to live clustered around metropolitan areas and travel to the city for work, education and other services, we anticipate that vehicle kilometres travelled under this scenario will continue to grow (see Figure 71). Unlike other scenarios, there are few options for people to work or access services remotely, so they must travel physically. Many communities across Queensland still suffer from the tyranny of distance. Bus kilometres travelled rises, but the lack of first- and last-mile connections for public transport systems mean that private vehicle kilometres go up too.

We also expect that current growth trajectories will continue for heavy vehicles based on the assumption that demand for small freight deliveries via online shopping will continue to increase,[298] along with population growth. Under this scenario, the freight sector sees incremental improvements in efficiencies, but none are significant enough to substantially change how freight is delivered. Growth in the freight task is likely to be less than under a more dispersed scenario (i.e. Suburban Streets) as it is more efficient to deliver freight centrally than between regional hubs.

Road safety. Vehicle safety improves incrementally but not enough to have a major impact on Queensland's road toll. Without the enhanced safety improvements that could come with new mobility technologies (e.g. the ability of AVs to reduce road vehicle crashes[36]), the growth rate for fatalities increases from baseline (see Figure 72). More

people now commute via motorcycles and bicycles to avoid higher fuel costs and long periods stuck in traffic.[199] This, combined with busy roads during peak times, accelerates growth in road crash hospitalisations.

Infrastructure expenditure. Spending on infrastructure increases considerably, due to both the rise in the number of vehicles on the roads and the lack of shared mobility leading to poor fleet utilisation. This increase is greater than Suburban Streets (see Figure 73), with expenditure concentrated in SEQ and minimal investments in more regional areas. Investment in infrastructure for roads and public transport is prioritised towards the congestion challenge, but this only serves to fuel further demand.[146] Without the aid of technology (e.g. autonomous buses and big data analytics), the public transport system struggles to efficiently manage and shift peak commuter demand.

Registration revenue. This scenario anticipates that registration revenue will continue to follow a similar but accelerated trajectory as today (see Figure 74). This assumes that vehicle ownership growth rates will continue to rise as private vehicles are increasingly preferred over lower grade public transport options (see *Fleet composition* section). Similar to today, most vehicles are internal combustion engines with four cylinders. Electric uptake has been slower than anticipated too, and as such, does not represent a major threat to registration revenue growth.
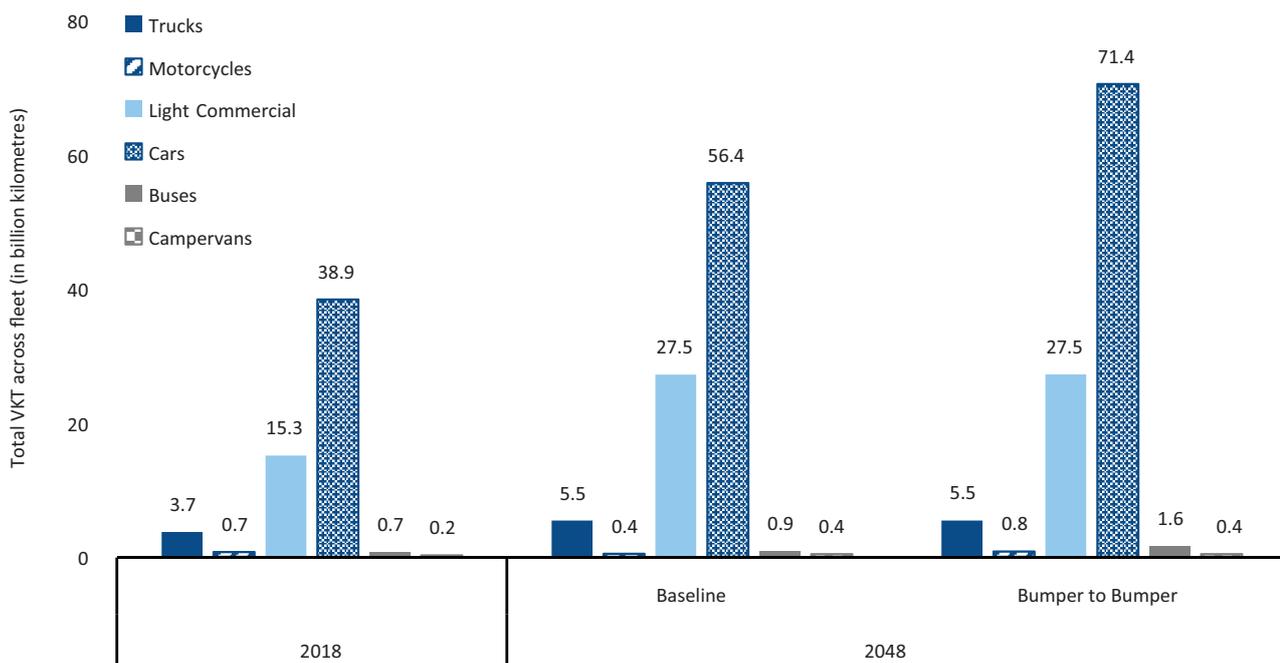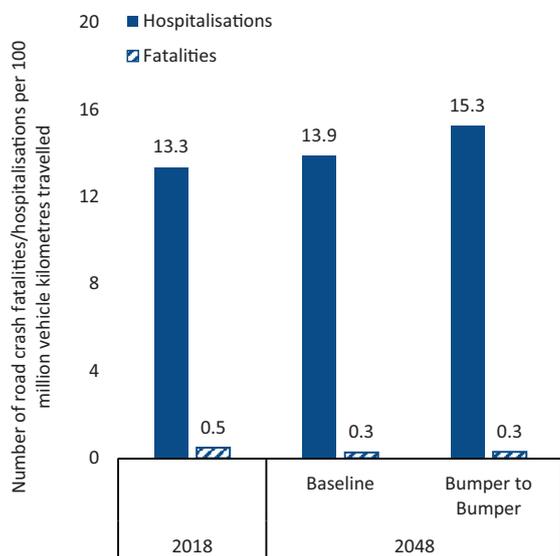

Figure 71. Modelling projections of total vehicle kilometres travelled (VKT) across the fleet (in billion kilometres) in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

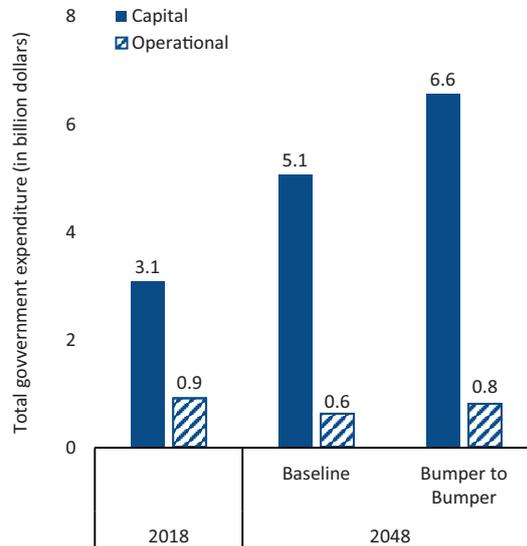Data source: Australian Bureau of Statistics[179] and Data61 estimates

Public transport patronage. This scenario assumes that the current rate of public transport patronage continues (see Figure 75), as roughly the same proportion of people use public transport to commute to the inner city for work, education and other services. The rate of public bus patronage increases slightly due to increased bus prioritisation on the roads, as does that for public rail services, which are better suited for people commuting from outer regional areas. Mass transit models present a reasonable solution for people in urban areas, but not those in regional areas where there isn't sufficient demand to support an efficient system.

Many people continue to use private vehicles as their first- and last-mile connection to public transport hubs. Moreover, public transport services lack the technology-enabled efficiencies present under other scenarios (e.g. Cruise Control),[194] meaning that commuters experience little improvement in the accessibility and functionality of bus, train, ferry and light rail services. Those who can travel in their own vehicle at a similar cost to public transport do so, and are willing to sacrifice extra time out of their daily travel budget in traffic congestion in favour of comfort and convenience.

Figure 73. Modelling projections of total government expenditure (in billion dollars) in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

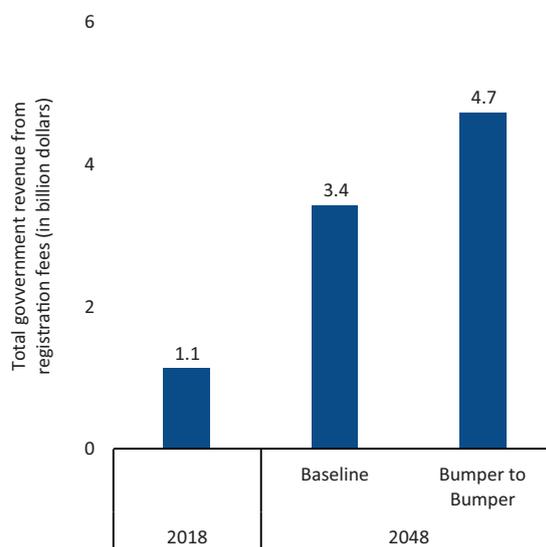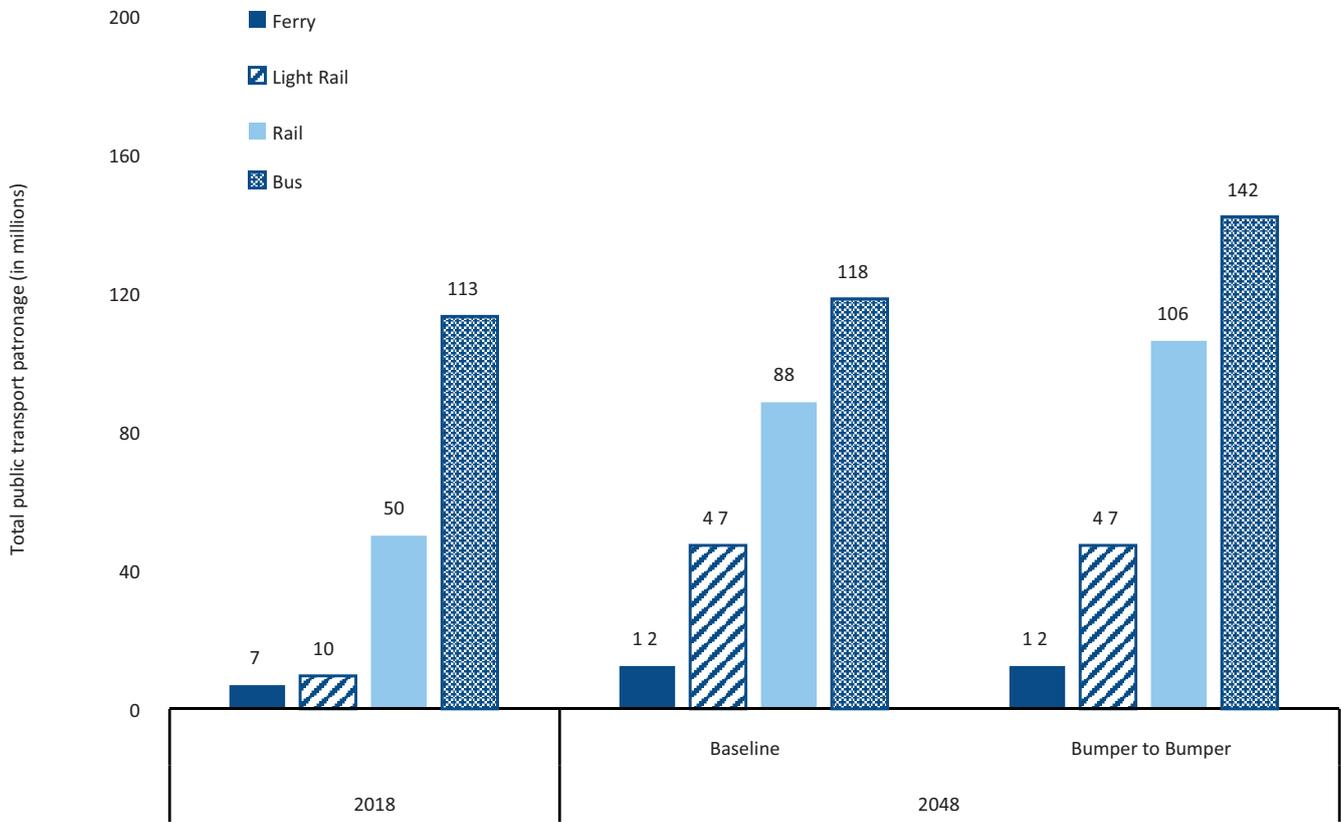Data source: Data provided by TMR and Data61 estimates

Figure 72. Modelling projections of number of road crash fatalities and hospitalised casualties in 2017 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Data provided by TMR and Data61 estimates

Figure 74. Modelling projections of total government revenue from registration fees (in billion dollars) in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Data provided by TMR and Data61 estimates

Figure 75. Modelling projections of total public transport patronage (in millions) by mode type in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Data provided by TMR and Data61 estimates

Household expenditure on transport. Due to increased demand during peak hours, high car ownership and low uptake of EVs, growth in household expenditure on transport increases. Those who live close to the CBD or near public transport hubs see their household expenditure on transport decline, as they are able to take active or public transport to work. However, they are in the minority. For most people, particularly those living outside of SEQ, the cost of fuel, vehicle maintenance, parking, registration and insurance, which make up 93.4% of total weekly household expenditure on transport (based on 2016 figures),[182] drive up transport costs (see Figure 76).
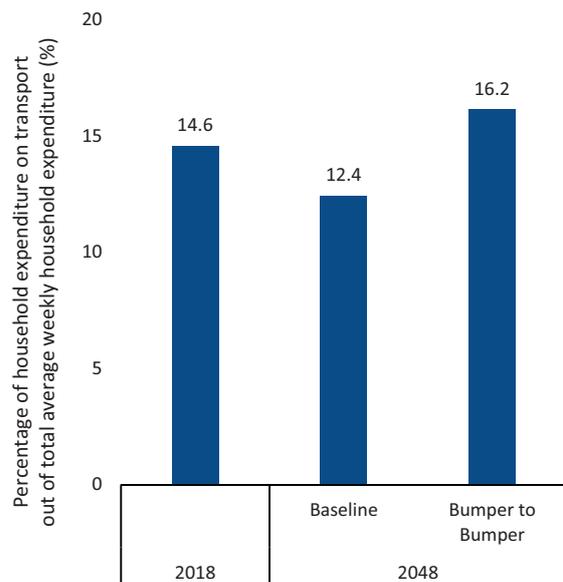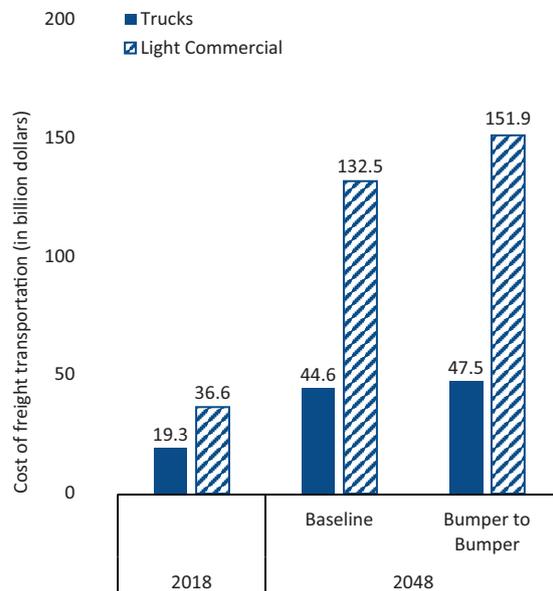

Figure 76. Modelling projections of average weekly household expenditure on transport in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: ABS Household Expenditure Survey[182] and Data61 estimates

Cost of freight mobility. The growth rate of the cost of freight mobility in Bumper to Bumper increases (see Figure 77), as fuel prices rise and the growing freight demand requires more trucks and light commercial vehicles. Added congestion on the roads further drives up fuel and labour costs, as delivery vehicles spend much of their time sitting in traffic. Without technology aids (e.g. automated trucks or data-driven logistics), the freight sector operates relatively inefficiently; trucks drive empty loads and must stop frequently for driver fatigue breaks.
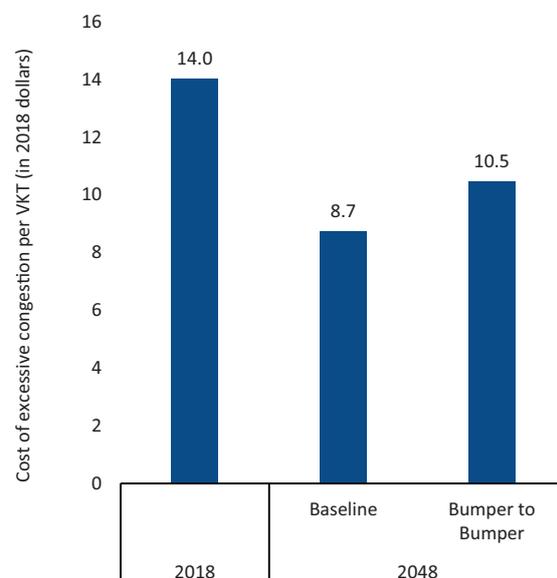
Cost of excessive congestion. Congestion presents a major problem in urban areas under the Bumper to Bumper scenario; excessive congestion is largely non-existent in other part of the state. Because most people still choose to commute to a central location at peak times in a private car with low levels of sharing, the cost of excessive congestion grows at an accelerated rate (see Figure 78). This scenario does not see the benefits of technologies in better managing traffic flows,[60,61] or optimising distances between vehicles (e.g. through platooning AVs).[65] Bumper to Bumper is therefore the only scenario for which the current decline in costs of excessive congestion is reduced.

Greenhouse gas emissions. Greenhouse gas emissions grow slightly above baseline under Bumper to Bumper as most people own and drive their private vehicle, and a large proportion of the fleet is made up of cars with internal combustion engines (see Figure 79 and Figure 80). This rise in emissions is further reinforced by the increase in vehicle kilometres travelled. Although Cruise Control has similar concentrated mobility patterns, the emissions associated with this travel were offset by high levels of sharing and EV uptake, and a well-connected public transport system (see Figure 53 and Figure 54). Short of these factors, greenhouse gas emissions rise more steeply under Bumper to Bumper than Cruise Control.
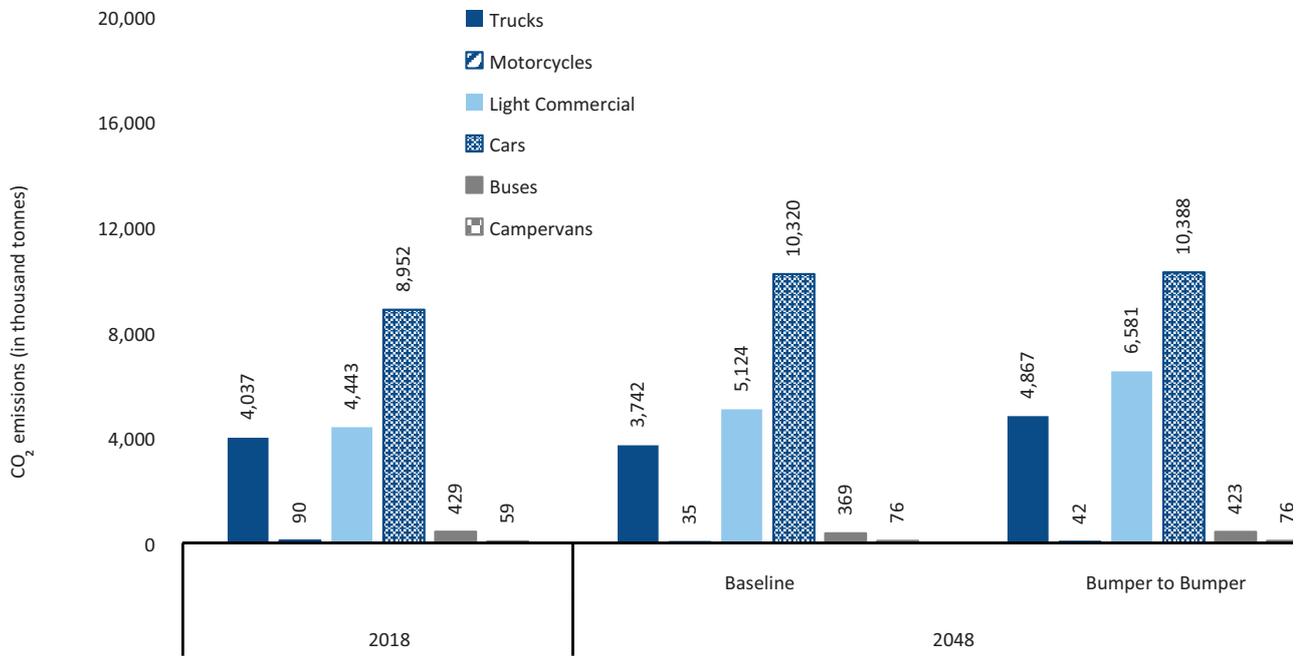

Figure 77. Modelling projections of cost of freight transport (in billion dollars) in 2018 and projected out to 2048 at a fuel price of $2.00/L under the Baseline and Bumper to Bumper scenarios

Data source: CSIRO TraNSIT model[183] and Data61 estimates

Figure 78. Modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT) in Greater Brisbane area in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Data provided by TMR and Data61 estimates

Figure 79. Modelling projections of CO$_2$ emissions of road transport by vehicle type in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates
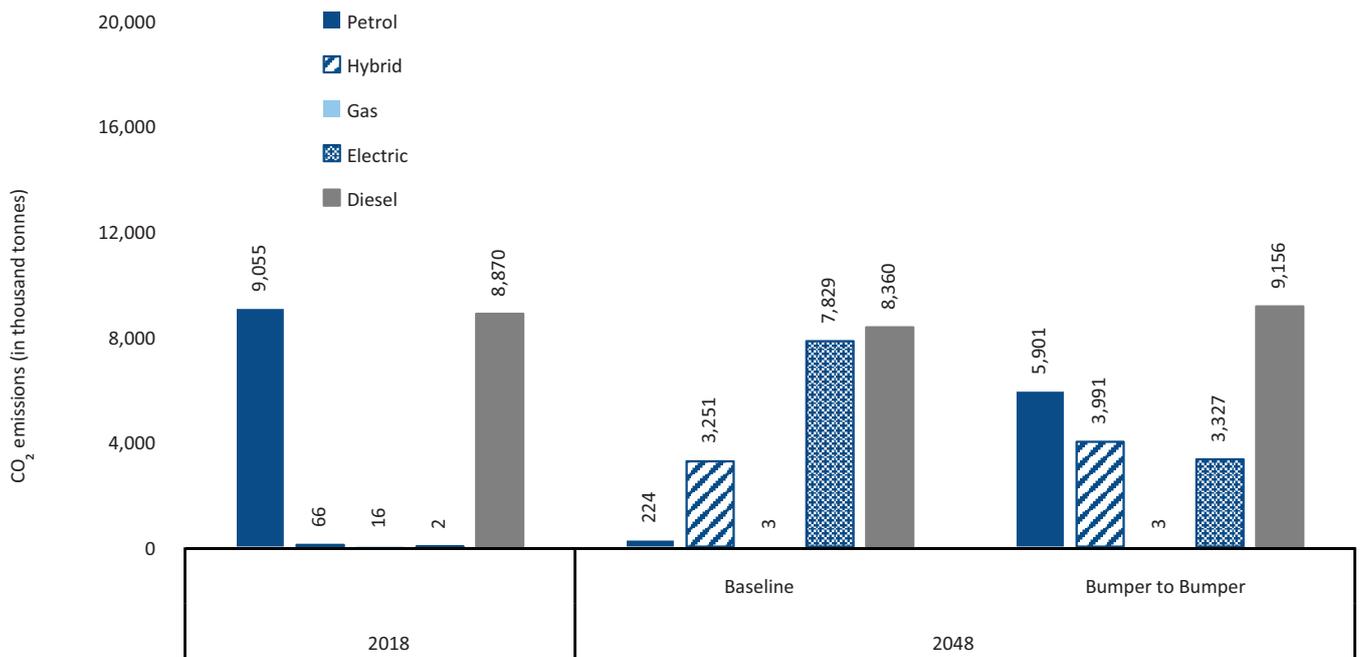
Figure 80. Modelling projections of CO$_2$ emissions of road transport by fuel type in 2018 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Automation impacts across the transport and logistics sector. Similar to other scenarios with low technology transformation, there will likely be a low risk of future computerisation of the transport and logistics sector under the Bumper to Bumper scenario. Applications of AVs are restricted to specialised domains, such as the mining industry, where there are clear safety and productivity benefits. In other domains, the lack of public trust around AVs arising from recent high-profile incidents means they have limited uptake. Tasks associated with moving goods and people are largely done by human workers.

Under this scenario relative to Suburban Streets, the automation impact for the transport and logistics sector will be slightly higher (see Figure 81). In a more concentrated scenario, there may be more ways to integrate and streamline existing services if incremental improvements in digital connectivity replace some manual tasks. This scenario assumes a 14% reduction in the transport and logistics workforce, based on 2018 estimates from the OECD.[81] These estimates were derived from a more fine-grained analysis of automation impacts on work tasks than the OECD's previous 2017 estimates.[79,81]
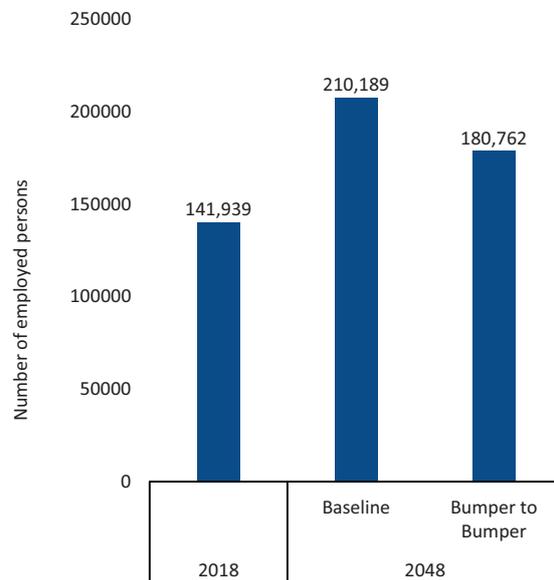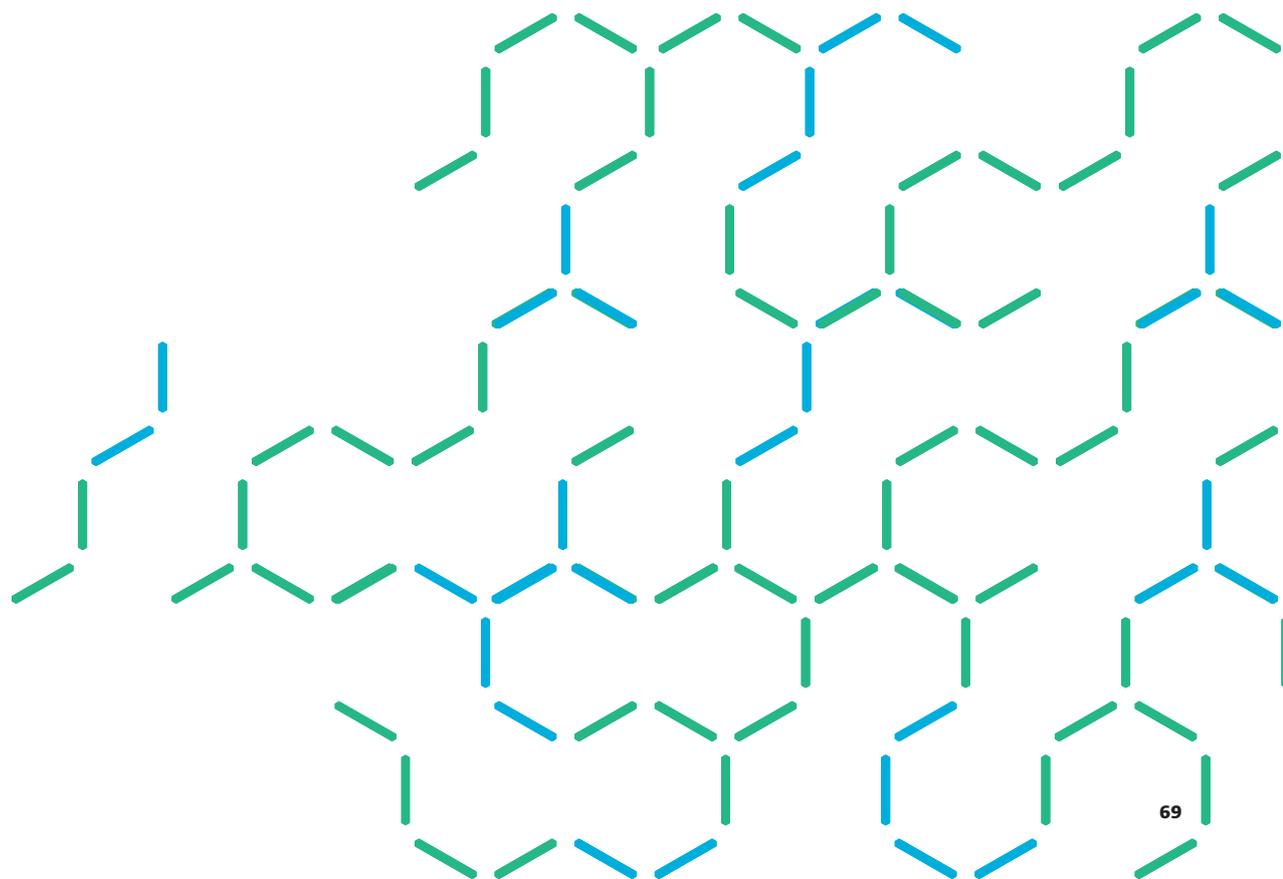

Figure 81. Modelling projections of number of employed persons in transport and logistics sector in 2017 and projected out to 2048 under the Baseline and Bumper to Bumper scenarios

Data source: Australian Bureau of Statistics[189] and Data61 estimates
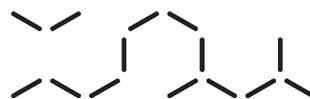
TO **M1** BRUCE HWY
Brisbane ⬆

M1 | BRUCE HWY
⬅ Sunshine Coast

POLICY IMPLICATIONS

The megatrends and scenarios for Queensland's transport system raise a number of key risks, challenges and opportunities for the Queensland's transport system and TMR's future operating environment. Informed by consultations with key internal stakeholders of TMR, this chapter explores the policy implications of future changes in Queensland's transport system and identifies important policy considerations for TMR over the next 30 years. These policy implications refer to existing relevant domestic and international initiatives and approaches.

The significance of the megatrends and scenarios to TMR is discussed under the following headings:

- Alternative charging models for vehicle and road users
- Shared mobility solutions for transport
- Ensuring equal and fair access to transport
- A shift from government as a service provider to service broker
- Setting the direction for climate transition strategies
- Security and safety considerations for physical and virtual assets
- Maximising existing and to-be-developed infrastructure and assets.

Alternative charging models for vehicle and road users

There have already been significant changes to Queensland's vehicle fleet, as seen in the decline in vehicle ownership among younger road users[xiv] and the market shift from 5/6-cylinder to 4-cylinder vehicles.[xv] These changes have significant implications for TMR's future revenue streams from vehicle registration fees, as vehicles with smaller engines incur lower registration fees. For instance, in 2018/19, renewal fees for 4-cylinder vehicles were $377.40 versus $546.90 for 5/6-cylinder vehicles.[xvi] If more vehicles are 4-cylinder vehicles, there is less revenue generated from similar use of the road network.

In some of the future scenarios for Queensland's transport system, particularly those with more significant technological transformation of the transport system, these revenue challenges could be further exacerbated. The first relates to an increase in vehicle sharing and AVs, which could reduce the fleet size needed to service the passenger and freight task. For instance, in line with previous work suggesting that 10% of projected passenger fleet could service the task,[174] we project a reduction in the car fleet out to 2048 under the Off-Peak, On-Demand and Cruise Control scenarios relative to baseline.

The second is related to greater uptake of EVs. EVs are currently charged at a lower registration renewal rate ($308.75, based on 2018/19 figures) than internal combustion engines ($377.40 or higher).[xvii] Similar to the trends around vehicle cylinder types, a significant market shift to EVs, in the absence of any changes in the current registration funding model, would pose significant revenue risks in the future. Based on global trends that suggest strong uptake of EVs out to 2050,[189H] we project that the share of the electric fleet would increase under Off-Peak, On-Demand and Cruise Control scenarios. Such projections would further reduce government revenue from registration fees.

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xiv. Estimates on rates of vehicles register to Queensland licence holders provided by TMR.
xv. Estimates on share of total number of vehicles on Queensland vehicle register provided by TMR.
xvi. Registration renewal fee amounts provided by TMR.
xvii. Registration renewal fee amounts provided by TMR.

With these trends in the vehicle fleet, there is a heightened need to explore alternative models for charging vehicles and road users. One option is congestion pricing, which was introduced in London in 2003,[200] and subsequently adopted in Singapore, Stockholm, Gothenburg and Milan.[168] Congestion pricing charges private vehicle users who drive in certain lanes, facilities (e.g. bridges) or congestion-prone zones during peak times.[201] While fuel excise was not modelled in this report, changes to the size and use of the fleet also has implications for this and other transport-related revenue sources.

In Australia, the Productivity Commission has suggested that most government road fees and charges could be replaced with a single charge based on how much and when drivers use roads.[202] Today's technologies already make it feasible to track vehicle movements within the network, making this charging model feasible under all future scenarios.[202] Many countries that have introduced road user charging models have invested excess revenue into public transport services, and the Productivity Commission proposed that such funds would need to be primarily invested in providing road services.[202]

Shared mobility solutions for transport

The level of technology transformation that can occur in Queensland's transport system is uncertain and is primarily dependent on two key factors: the capability, access and uptake of both new digital technologies and new mobility services. While we assume that technology development will be a necessary prerequisite for uptake of shared mobility services (e.g. app-based ride services like Uber draw on existing geolocation, routing, mapping and payment services), the reverse does not necessarily hold true. The development of new mobility services does not guarantee people will be willing to share rides, vehicles and other assets.

As illustrated in Off-Peak, On-Demand and Cruise Control, there are key benefits to be gained from shared mobility. First, it can reduce the need to own a private vehicle, much in the same way that AVs are estimated to reduce the number of vehicles needed to service the passenger fleet down to 10% of the current fleet size.[174] Second, it can improve fleet utilisation, thereby reducing CO_2 emissions, congestion and the land use dedicated to public parking.[122] Both these impacts can lower transport costs incurred by consumers and government.[181]

Conversely, a lack of shared mobility can hinder efforts to reduce the environmental and economic impact of the transport sector. For instance, although vehicles are becoming more efficient, the quantity of greenhouse gas emissions produced by Queensland's transport sector continues to rise as there are more vehicles on the road.[24] Similar impacts of EV uptake on congestion levels could be expected in the absence of broader behavioural changes around mobility and sufficient access to renewable energy sources. Improving efficiencies in the vehicle fleet through sharing are therefore a necessary component in dealing with issues such as congestion, emissions and transport costs.

Not all emerging app-based mobility services are equal. For example, app-based ride services that allow users to source rides probably have different impacts to those that allow users to pool their trips with other passengers. As ride-pooling services are an emerging business model, it is unclear how they will impact existing mobility patterns. However, ride-sourcing services, in the absence of other changes in the quality, reliability and integration with other mass transit and active modes, can exacerbate existing congestion challenges.[127] To meaningfully decrease congestion, app-based ride services need to be integrated in a way that complements, rather than competes with, mass transit and active travel modes.

Ensuring equal and fair access to transport

Indices of mobilty disadvantage have remained stable in Queensland over the past decade, with the rest of Queensland consistently poorer than the Greater Brisbane area.[xviii] While the sensitivity of this mobility disadvantage measure could be limited, this trend suggests little change in mobility services outside of Queensland's most populous region. Under the low technology transformation scenarios, the mobility divide between regions in Queensland could widen due to relative differences in the accessiblity and quality of transport options.

For instance, under Suburban Streets, urbanisation pressures could push the poorest households to live in regional areas where public transport services are more expensive to operate and maintain, and therefore, of poorer quality. Conversely, higher income households may be able to live closer to the city, benefiting from the reduced peak demand for existing transport services in these areas.

xviii.   Data61 estimates based on TMR Mobility Disadvantage Index methods and 2006, 2010 and 2016 Census data available through the Australian Bureau of Statistics Table Builder.

Future investment decisions surrounding public transport services and infrastructure could be particularly challenged in servicing the needs of a more dispersed population.

As in other cities, the 10 km radius surrounding Brisbane contains the most expensive housing and most employment opportunities.[203] Those outside this radius have lower levels of employment and access to services, and have to travel further, and thus pay more, to access services, work and education.[149,204] Emerging app-based ride services operate most effectively in more densely populated areas. Thus, if the technology and the market for these services exists (e.g. as in Off-Peak, On-Demand), more regional communities could see a wider range of mobility options.

Technology could also improve access to transport for people with sensory, cognitive or mobility impairments. People with disabilities make up about 18.3% of the Queensland population,[205] and this proportion is likely to increase as the population ages. People with disabilities who use wheelchairs are unable to access train stations that do not have a ramp or lift, and those with hearing problems may struggle to hear announcements, buy tickets or make enquiries.[204] New mobility options, like AVs and app-based ride services, could improve the independence and quality of life of those with a disability.

Access to transport services needs to consider digital inclusion. The Australian Digital Inclusion Index is a 100-point measure where higher scores indicate greater digital inclusion. According to this index, Queensland was placed sixth in Australia in 2017.[206] The digital inclusion gap between Brisbane and rural Queensland still exists, but declined from 6.3 to 5.1 points from 2016 to 2017, largely driven by improved access to the internet.[206] Closing gaps in digital connectivity in regional and remote areas in Queensland will be a key prerequisite for more sophisticated mobility options.

There is also the risk that new transport models and services could introduce new challenges to mobility disadvantage. Research from the US found evidence of racial discrimination on ride-sharing apps, with African-American passengers experiencing wait times up to 35% longer for Uber rides than white passengers.[207] Although it is unclear whether similar discrepancies occur in Australia, as Queensland's population becomes more culturally diverse,[49,50] there is a potential risk of unequal treatment of passengers using new app-based ride services.

A shift from government as a service provider to service broker

Across the Queensland economy, there has been a shift towards more service-based industries over the provision of physical goods, and TMR is not immune to these changes. As consumers demand more personalised services, there will be an increasing need for TMR to adapt the way it serves its customers. TMR services are already becoming increasingly digital, with the number of transactions performed online expected to reach its ceiling by 2028.[xix] The proliferation of smartphones and access to mobile data now make online transactions easier and more convenient for many consumers.

While this shift towards more digital and personalised services will likely continue under all future scenarios, high technology-uptake scenarios may push towards more individualised options. In particular, Off-Peak, On-Demand and Cruise Control could see a greater emphasis on MaaS schemes that provide an end-to-end journey that is suited to individual needs. This rise in MaaS schemes could see a shift in TMR's role from a service provider to a service broker, enabling a growing ecosystem of equitable and sustainable mobility solutions. These schemes also provide an opportunity for TMR to fulfil its vision of, 'creating a single integrated transport network accessible to everyone'.[208]

Current MaaS schemes in Europe are operated by private companies, transport service providers and public agencies.[209] TMR's Demand Responsive Transport trial in Logan is an example of an integrated public–private transport service, with local taxis connecting commuters to public transport services. Under MaaS schemes, the government will play a key role in facilitating public–private partnerships and striking the right regulatory balance that fosters private sector innovation and investment and protects public interest.[210] In some cases though, these services may be better delivered by the private sector.

MaaS schemes could change the traditional role of TMR service centres in the future. As transactions become increasingly digital, the focus of TMR service centres could shift from routine transactions (e.g. licensing and registration) to more complex customer service needs. For example, TMR could play the role of a collaborator between businesses, providing bespoke services, such as insurance and registration bundles that are based on the customers' need (e.g. a one-off month subscription). The nature of these services will depend on other changes (e.g. changes in the registration funding model), but this future would see TMR focus more on business-to-business than business-to-customer services.

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xix. Data61 estimates based on online service transaction data provided by TMR.

Setting the direction for climate transition strategies

The Queensland Government, like many other governments around the world, has committed to a climate transition strategy out to 2050. The goal is zero net greenhouse gas emissions by 2050, with at least a 30% reduction in emissions by 2030.[26] As part of this strategy, the Queensland Government is developing a Net Zero Emission Transport Roadmap, which will consider better integration of transport policy with land-use planning to lessen demand for mobility, improve public and active transport infrastructure and services, and reduce the emissions across the transport sector.[26]

The four scenarios illustrate potential challenges and opportunities for Queensland Government in meeting these climate transition objectives. For instance, Cruise Control sees the greatest reduction in CO_2 emissions, driven by the high uptake of shared mobility options, public transport and EVs through an integrated and responsive transport network. On the contrary, Bumper to Bumper and Suburban Streets both present challenges in meeting these emission targets, as movement of people and goods continues to rely on an inefficient and high-emitting fleet.

The scenarios also illustrate how climate transition strategies need to consider factors beyond vehicle efficiency, technology and fuel shifts. As discussed in the *Shared mobility solutions for transport* trend, the quantity of greenhouse gas emissions produced by Queensland's transport sector has risen despite improvements in the fuel efficiency of vehicles.[24] A critical component which could be considered in climate transition strategies is shared mobility, which can enable more efficient movement of people and goods, and in turn, reduce emissions produced by the transport sector.

Queensland's climate transition strategies also need to consider economic and social impacts, as well as environmental factors. Transport is a derived demand, in which the value the transport system provides is in its ability to move people and goods, rather than services themselves. For this reason, there are complementary policy settings outside of the transport domain that will influence TMR's capacity to meet its objectives around transport-related emissions. As illustrated in the scenarios, changes in employment models, land-use patterns and public safety concerns could impact future transport patterns and decisions on climate transition policies.

There could also be opportunities for Queensland's transport decarbonisation strategies to provide social, economic and environmental co-benefits. For one, improving access to active and public transport infrastructure and services (as in Cruise Control) could provide lower emission transport options, but also promote better health outcomes for Queenslanders through increased physical activity. Policies and incentives that encourage greater uptake of EVs could fuel demand for these vehicles, providing new opportunities to create and grow new low/zero emission industries too.

Security and safety considerations for physical and virtual assets

Increased uptake of digital and mobility technologies come with potential risks around cybersecurity. Indeed, concerns around public security and safety are implicated as key barriers that could limit uptake of technologies and service models under the Suburban Streets and Bumper to Bumper scenarios. National trends show a rise in the number of cybersecurity attacks in Australia,[159] and there have been significant public incidents, such as the remote hacking of a Jeep Cherokee in 2015.[161] These have raised concerns around future developments in autonomous and connected vehicles.

The megatrends demonstrated significant benefits of new mobility technologies and their associated service models: improved road safety[112] and fleet efficiency,[174] reduced congestion[60,61] and (potentially) transport-related environmental impacts.[110,211,212] These benefits, however, rest upon these technologies becoming mainstream and widely adopted across Queensland. As vehicles become increasingly sophisticated and connected, cybersecurity risks will similarly rise, raising the need for appropriate systems to protect these physical and virtual assets.

The responsiveness of legislative change could slow uptake of new digital and mobility technologies if it lags behind the pace of these developments. Despite Uber being illegal to operate in Queensland until 2016,[213] a 2015 survey found that 4.8% of Queenslanders had travelled via the ride-sharing service in the previous three months, with this increasing to 17.0% by 2017.[134] This demonstrates that people, albeit a minority, are willing to use new mobility services even before appropriate regulation is in place. It will be important for government to monitor future technology trends to ensure it can respond in a timely manner.

A key area for future legislation could be the commercial use of drones for delivering small parcels. In the high technology transformation scenarios (i.e. Off-Peak, On-Demand and Cruise Control), it is predicted that drones service a significant share of the urban and last-mile freight task, which could require future changes to the regulatory framework. In addition, drone legislation for recreational use would also need to be considered, either as part of, or separate from that for commercial use. In line with this, in late 2017 the Queensland Government released their Queensland Drone Strategy for consultation.[214]

Maximising existing and to-be-developed infrastructure and assets

As new mobility technologies come online, so will demand for new types of transport infrastructure, such as electric charging stations for EVs or hydrogen refuelling stations for vehicles powered by hydrogen fuel cells. The level and type of infrastructure investment will differ across each scenario, and this can encourage new mobility behaviours.[12] Overcoming the 'force of habit' in individual travel behaviours, permanently changing travel behaviour without a very compelling reason, can be challenge. It will require customer-led infrastructure that is able to flexibly cater for a diverse set of users.[215]

There are also regional considerations for future infrastructure developments. Norway is a world leader for EV uptake, with 15.7% of its vehicle fleet being electric and 13.4% hybrid in 2016.[216] By 2030, it is predicted that 100% of new car sales in Norway will be zero-emission vehicles.[216] The Norwegian Government has invested heavily in EV infrastructure, with around $11 million invested in constructing charging stations in 2009–2010.[216] This investment likely contributed to strong EV uptake in Norway, along with its bold targets for CO_2 emissions reduction by 2020.

The current and future geographical distribution of Queensland's population could reduce the generalisability of these European trends. For instance, 81.5% of the Norwegian population is urban,[216] yet only 63.7% of the Queensland population lives in a major city.[217] While a more dispersed population has its advantages, such as reduced peak demand and congestion, the initial infrastructure investment and ongoing operational costs needed to support new mobility technologies can be expensive.

Based on plausible uptake of AVs and shared mobility in urban and rural areas,[218] we predicted uptake of new mobility options would be less in more dispersed scenarios than concentrated scenarios.

Changes in technology could also raise implications for how new and existing infrastructure is maintained and managed. For example, in much the same way that pedestrians, bicycles, animals and agricultural machinery are not permitted on motorways, parts of the network could be limited to fully connected and AVs due to the infrastructure needs of these vehicles or safety considerations. Moreover, sensor technologies and other digital infrastructure will be subject to considerations around the security and management of the data produced by these services. This data will be valuable for managing and shifting peak demand[59] as well as for designing targeted transport solutions.[62]

Under-utilisation of existing infrastructure is another risk emerging from the scenarios, particularly in those where mobility patterns become more dispersed. The city of Davis, California has faced similar challenges with approximately 23.3% of residential parking spaces under-utilised following strong uptake of cycling.[219] This space could be repurposed in various ways (e.g. as accessory dwelling units to private properties to address a housing shortage), or it could be replaced with bioswales, landscaped parklets, or trees to capture rainwater and run-off and reduce pressures on the stormwater management system.[219] Strategies concerning asset utilisation will need to be considered under each scenario.

CONCLUSIONS
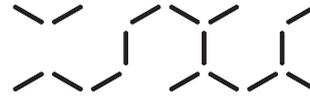
This strategic foresight project was designed to explore plausible emerging trends and scenarios for Queensland's transport system and to understand the impact of these changes on TMR's operating environment. The objective here is not to predict the future out to 2048, but rather to understand what changes could be on the horizon and the different ways TMR could be affected. Through this process, decision-makers can better understand the future opportunities, challenges and risks for Queensland's transport system and TMR, and use this knowledge to make better strategic and policy decisions.

The megatrends identified in this report highlight major geopolitical, social, economic, environmental and technological trends facing Queensland's transport system over the coming decades. These include an ever-growing population, advances in technology, shifts in consumer preferences and increasing concerns around the environmental impact of the transport sector. These changes come with significant opportunities, such as reduced road fatalities from the introduction of AVs, as well as challenges around managing peak demand and encouraging uptake of new mobility technologies and services.

But what will Queensland's transport system look like in 30 years? The four scenarios proposed for Queensland's transport system out to 2048 aim to provide an evidence-based view of the future, and illustrate how the key uncertainties around technology and mobility patterns could unfold out to 2048. They allow us to explore the impacts of unknowns. For instance, where will people live

and work, how willing will Queenslanders be to adopt new mobility technologies and service models, and how will changes in the transport system impact congestion, emissions and transport costs?

The scenarios demonstrate the interplay between technology, service models, land-use patterns and consumer behaviour. Off-Peak, On-Demand presents a world where people live, work and study across dispersed locations and access to on-demand and personalised transport options. While this provides more transport options for regional communities, it could leave parts of the transport network under-utilised. Cruise Control similarly benefits from a technology-enabled and responsive transport system designed for concentrated travel, but this scenario raises questions around the sustainability of current revenue models.

In the other scenarios, Suburban Streets and Bumper to Bumper, the uptake of new digital and mobility technologies is halted by vehicle capabilities, access or public safety concerns. In Suburban Streets, people increasingly adopt more flexible work and study arrangements, which eases urban congestion, but challenges mass transit systems. On the contrary, the public transport system maintains consistent patronage in Bumper to Bumper, but the quality and reliability of transport declines, congestion worsens and emissions rise under increasing pressure to meet demand without the aid of new mobility options.

From this combined quantitative and qualitative scenario analysis, we identified key implications for future strategic and policy decisions concerning Queensland's transport system. A significant area of consideration is future revenue streams for TMR: if people are less likely to own their vehicle, travel less and are more likely to travel via EVs or shared mobility services, what changes need to be made to existing charging models for vehicles and road users? Other areas included the challenges in providing equitable access to transport and mitigating the environmental impact of the transport sector.

Queensland's transport system in 2048 will likely reflect aspects of one or more of the scenarios identified in this report. They are designed to challenge current perspectives and encourage proactive discussions about the future. Moving forward, it will be important to establish strategies for monitoring signals that point towards particular scenarios so that TMR can respond proactively. In doing so, TMR can identify strategies that are robust under each plausible scenario and ensure it is in a strong position to respond to future challenges and opportunities for Queensland's transport system.

APPENDIX A: STRATEGIC FORESIGHT METHODS

This project employed a range of strategic foresight methods to understand future trends and scenarios for Queensland's transport system out to 2048. Strategic foresight is an emerging field that draws on economics, management science, operations research and planning theory. CSIRO's Data61 has developed its generic strategic foresight process, which incorporates international research and practical experience. This process was adapted for the present study (see Figure 82). The CSIRO Social Science Human Research Ethics Committee approved this research protocol.

The first stage consisted of background study and scope definition. Rather than looking into the future, this phase is concerned with current status and historic conditions, where the scope defines the stakeholder groups, time frames and issues to be investigated. This stage included a scoping workshop with the general managers of TMR to identify key trends impacting Queensland's transport system and to develop a set of transport fundamentals that would be quantitatively modelled under each scenario.

The second stage consisted of a horizon scan and included desktop research and investigative interviews with internal stakeholders of TMR. The goal here was to cast a wide net over all potentially relevant trends and identify data sources that could be used in the quantitative modelling. In the third stage, these trends were classified, validated and prioritised. This screening process ensured that the remaining trends were supported by evidence and were relevant to the project's scope.

In the fourth stage, the trends were collated to identify a set of megatrends — overarching trajectories that occur at the intersection of multiple trends, and have a time frame of 10 years or longer. These smaller trends might be specific to a particular point in time, industry or issue. In this stage, a set of uncertainties were also identified (i.e. continuums showing evidence of trends moving in both directions). The two that would have the greatest impact on Queensland's transport system in the future were isolated.

These continuum (or axes) of uncertainty were used to define four plausible scenarios. Scenarios are evidence-based narratives of the future that estimate how the megatrends could unfold. Because the future is uncertain, there are multiple plausible scenarios. To ensure plausibility and relevance, these scenarios and the megatrends were then tested and refined in a validation workshop with TMR's general managers. In the final stage, the research findings were further refined and applied to the quantitative modelling (see Appendix B for method details).
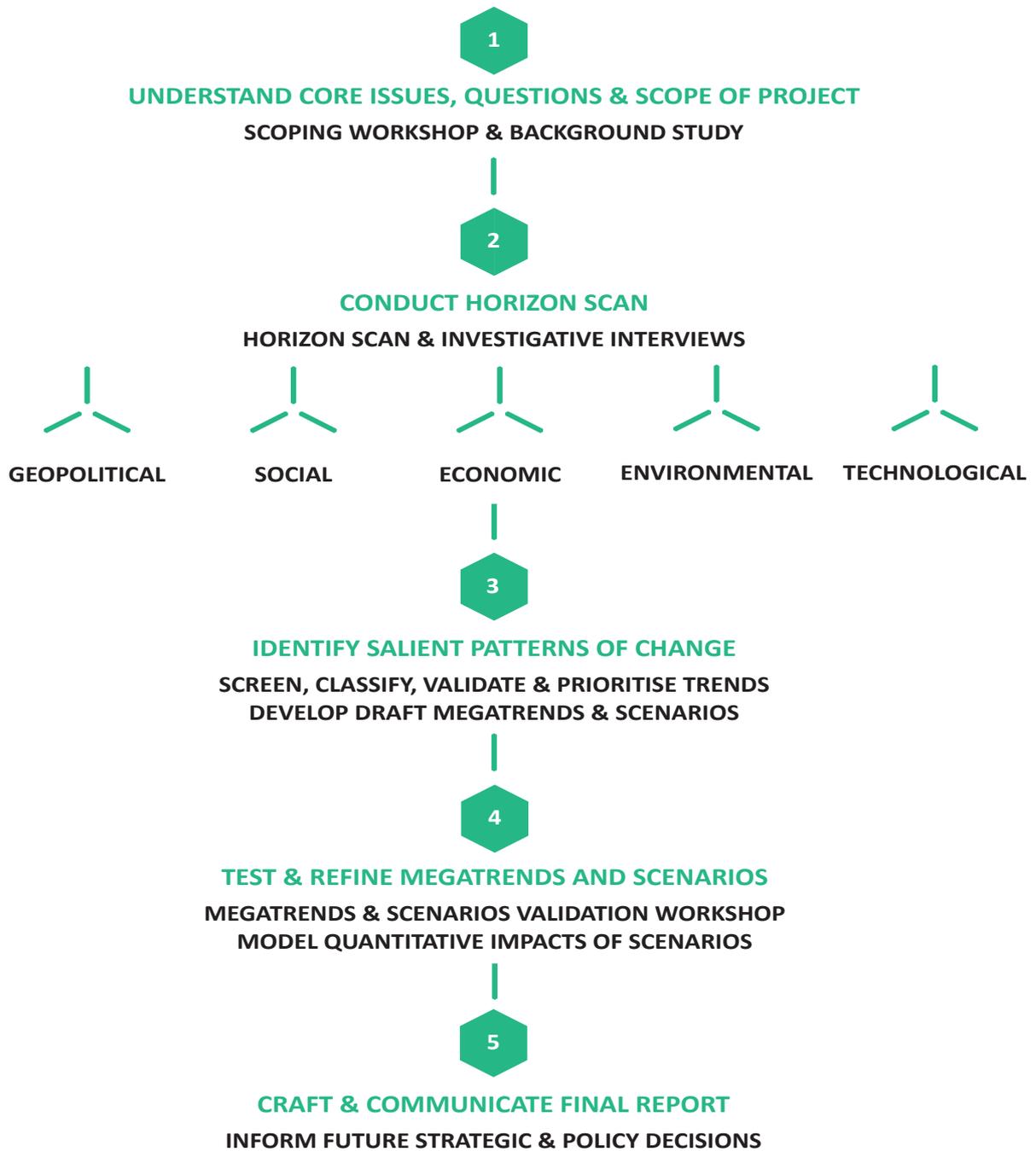
1

UNDERSTAND CORE ISSUES, QUESTIONS & SCOPE OF PROJECT

SCOPING WORKSHOP & BACKGROUND STUDY

2

CONDUCT HORIZON SCAN

HORIZON SCAN & INVESTIGATIVE INTERVIEWS

GEOPOLITICAL   **SOCIAL**   **ECONOMIC**   **ENVIRONMENTAL**   **TECHNOLOGICAL**

3

IDENTIFY SALIENT PATTERNS OF CHANGE

SCREEN, CLASSIFY, VALIDATE & PRIORITISE TRENDS
DEVELOP DRAFT MEGATRENDS & SCENARIOS

4

TEST & REFINE MEGATRENDS AND SCENARIOS

MEGATRENDS & SCENARIOS VALIDATION WORKSHOP
MODEL QUANTITATIVE IMPACTS OF SCENARIOS

5

CRAFT & COMMUNICATE FINAL REPORT

INFORM FUTURE STRATEGIC & POLICY DECISIONS

Figure 82. Generic foresight process developed by CSIRO's Data61

APPENDIX B: STATISTICAL MODELLING METHODS ⟩⟨⟩⟨⟨

Fleet composition

The fleet was defined as all registered vehicles on the Queensland register and was based on road vehicle registration data provided by TMR. These data were provided from June 1999 to March 2018, and fleet composition was broken down across vehicle type, fuel type and cylinder type.

We aggregated data across multiple vehicle types, giving rise to the following five categories: cars, trucks, buses, light commercials, motorcycles and campervans. Vehicle types included in each category were as follows.

VEHICLE TYPES PROVIDED BY TMR	VEHICLE TYPES USED IN DATA61 PROJECTIONS
Ambulance	Cars
B Doubles	Trucks
B Triples	Trucks
Buses	Bus
Campervans	Campervans
Conditional Vehicles	-
Light Commercials	Light Commercials
Mini Buses	Bus
Mobile Machinery	-
Motorcycles	Motorcycles
Motorhomes	-
Motorised Wheelchairs	-
Passenger Cars	Cars
Prime Movers	Trucks
Rigid Trucks	Trucks
Road Trains	Trucks
Tractors	-

Similarly with the fuel types, we aggregated data across multiple fuel types, giving rise to the following six categories: bi-fuel, diesel, electric, gas, hybrid and petrol. Here 'bi-fuel' refers to a mixed fuel type (e.g. diesel and gas) rather than other biofuels, such as ethanol. Fuel types including in each category were as follows.

FUEL TYPES PROVIDED BY TMR	FUEL TYPES USED IN DATA61 PROJECTIONS
Diesel	Diesel
Diesel/Electric	Hybrid
Diesel/Gas	Bi-fuel
Electric	Electric
Gas	Gas
Kerosene	-
Petrol	Petrol
Petrol/Electric	Hybrid
Petrol/Gas	Bi-fuel
Steam	-

With these exclusions, the remaining vehicle fleet used in the projections covered 95.9% of the registered vehicles on the Queensland register as of March 2018. This resulting fleet was used in a linear autoregressive model to project values out to 2048. The growth rate observed across the Queensland fleet was highly correlated with the near linear population growth (r = 0.98, with population estimates taken from the Queensland Government Statistician's Office medium series).[30]

Vehicle kilometres travelled

Data for the vehicle kilometres travelled were sourced from the ABS Survey of Motor Vehicle Use, with data available from 1998 to 2016.[179] Data were aggregated across ABS fleet categories to correspond to the fleet projections. The specific vehicle type included in each category were as follows.

VEHICLE TYPES USED BY ABS	VEHICLE TYPES USED IN DATA61 PROJECTIONS
Passenger vehicles	Cars
Motor cycles	Motorcycles
Light commercial vehicles	Light Commercials
Rigid trucks	Trucks
Articulated trucks	Trucks
Non-freight carrying trucks	Trucks
Buses	Buses

The reported ABS figures were then used in a linear autoregressive model to project the vehicle kilometres travelled for each of these vehicle types (i.e. cars, motorcycles, light commercials, trucks, and buses) to 2048.

Road safety

Road safety data on total fatalities and hospitalisations as a result of road crashes in Queensland were obtained from TMR. These data, spanning 1990 to 2017, were aggregated across all transport modes and projected out to 2048.

Data on fatalities showED a persistent trend towards fewer fatalities. Applying a linear autoregressive model to the fatality data would have resulted in near zero fatalities by 2048. We therefore applied a non-linear autoregressive model which reduced the fatalities at a lower rate and projected that about half the fatalities observed in 2018 would occur in 2048. Similarly, hospitalisations have increased at a much lower rate over the last 10 years than in the years before. We therefore applied a non-linear growth model to best reflect the most recently observed trend.

Infrastructure expenditure

These projections were based upon on TMR data on total actual capital and operating expenditure on transport infrastructure in Queensland from 2013 to 2018 plus TMR projections until 2022. These data were projected out to 2048 using non-linear autoregressive models.

Registration revenue

Registration revenue forecasts were based on historical and forecasted registration fees, combined with fleet composition forecasts across different cylinder passenger and light commercial vehicle types. TMR provided vehicle registration fees from 2009 to 2017, broken down by cylinder category (i.e. 1, 2 or 3 cylinder or electric; 4 cylinders; 6 cylinders; 8 cylinders; 9–12 cylinders; and motorbikes). Trailers and other vehicle types were not included as a vehicle in these registration revenue projections.

The traffic improvement fee and compulsory third-party insurance fee were excluded from the registration fee, and the value remaining was then multiplied by 81.44%. This reflects the share of registration fees which is received as registration revenue by TMR. Forecasted fees post-2017 were based on an average annual consumer price index (CPI) increase from 2008 to 2018 (2.4%),[220] and registration revenue forecasts were indexed to the fleet composition projections (see *Fleet composition* section).

The registration revenue projections also included changes to the qualifying age of pensioner concession holders which on July 1 2017 was 65 years and 6 months. This will steadily increase to 67 years by July 2023. For the projection of the share of pensioner concession holders (paying 50% of the registration fee) until 2048, current TMR data were aligned with long term ABS projections for Queensland for the age groups above 65.

Public transport patronage

Data on public transport patronage were provided by TMR from 2009 to 2018, with data broken down across different transport modes (i.e. buses, ferry, light rail and rail). Forecasts for patronage from 2018 to 2048 across all these modes were calculated using linear autoregressive models.

Household expenditure on transport

Data on total weekly household expenditure on transport were taken from the ABS Household Expenditure Survey.[182] Data were available for 1999, 2004, 2010 and 2016. These data were aggregated across all transport-related spending categories to produce a single value of average weekly household expenditure on transport. Weekly expenditure on transport was modelled as a percentage of total weekly household expenditure and projected to 2048 using a linear autoregressive model.

Cost of freight mobility

Cost of freight mobility data were derived from the CSIRO Transport Network Strategic Investment Tool (TraNSIT) model[183] and applied to trucks and light commercial vehicles. The cost of freight transport included cost for loaded and unloaded trips, wear and tear, driver cost, depreciation, repair and fuel. With the fuel price being highly volatile, projections for freight mobility costs were performed in two steps.

First, the base cost component (excluding fuel prices) was projected until 2048 using the same average CPI (2.4%)[220] as applied in the registration revenue projections. Second, fuel prices over the projection time frame were estimated separately by assuming a fuel price for the year 2048 (e.g. $2.00/L) and projecting this value linearly backwards to the year 2018. The base fuel price as of 2018 was assumed to be $1.40/L. This fuel cost component was then added to the aforementioned base cost component.

The fuel cost per kilometre travelled was only applied to the share of the truck/light commercial fleet with an internal combustion engine. For EVs that do not need any petrol/diesel, only the base cost component per kilometre was applied. For hybrid vehicles, the cost per kilometre was calculated using the base cost plus half the fuel cost component (i.e. assuming that 50% of kilometres travelled would be powered by petrol/diesel). To deal with the high uncertainty associated with future fuel prices, we projected freight mobility costs across a range of plausible fuel prices (i.e. $1.30, $2.00 and $3.50/L). The full set of freight mobility cost projections are displayed in Appendix D.

Cost of excessive congestion

Data on cost of excessive congestion per vehicle kilometre travelled were provided by TMR from January 2012 to July 2016. These costs of excessive congestion were based around average costs for vehicles travelling in the metropolitan, North Coast and South Coast regions of Queensland. Costs were averaged across these three SEQ regions and from 7am and 6pm (corresponding to peak period).

These estimates were calculated using data from TMR's traffic management platform (STREAMS) and the Australian Road Research Board method, which uses components for travel time, vehicle operations and emissions to calculate the added cost of travel when speed falls below a set congestion speed threshold.[221] This is calculated separately for arterials and motorways, where the threshold for congestion is set to 55% and 70% of the posted speed, respectively.

For our projections, congestions costs were collapsed across road types and linearly extrapolated out to 2048. Given the short time series that was used as a baseline for these projections, we caution the reader around the reliability of these projections. We recommend that future updates of this work include a longer baseline time series to provide more robust and reliable projections.

Greenhouse gas emissions

CO_2 projections for the road vehicle fleet[xx] were based upon fleet composition and vehicle kilometre travelled projections. Other inputs to this model were fuel efficiency estimates and emission factors associated with different fuel types. Emission factors were sourced from the Australian National Greenhouse Accounts.[186] Since no values for fuel consumption were provided for hybrid vehicles, this was taken as 50% to the average consumption rate for diesel and petrol vehicles across each vehicle type. Values for fuel consumption were as follows.

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xx. Please note that Data61's projections only account for CO_2 emissions across road vehicles, and do not include non-road forms of transportation (e.g. rail). CO_2 emission projections for the rail fleet will be included in the final version of this report, pending the data being available to Data61.

FUEL EFFICIENCY IN 2016 (L/100KM)				
VEHICLE TYPE	PETROL	DIESEL	GAS	HYBRID
Buses	14.2	27.6	29.2	20.9
Cars	10.2	9.8	9.1	10.0
Light Commercials	12.8	11.4	10.4	12.1
Motorcycles	5.6	N/A	N/A	2.8
Trucks	52.9	41.2	49.9	47.1

The fuel efficiency estimates listed above were based on fuel consumption data from the ABS Motor Vehicle Survey 2016 and from a previous work by CSIRO.[179,222] The data sources for fuel consumption by vehicle type are as follows.

DATA SOURCES FOR FUEL EFFICIENCY IN 2016 (L/100KM)			
VEHICLE TYPE	PETROL	DIESEL	LNG
Buses	ABS Motor Vehicle Survey, 2016	ABS Motor Vehicle Survey, 2016	Reedman and Graham, 2013
Cars	ABS Motor Vehicle Survey, 2016	ABS Motor Vehicle Survey, 2016	Reedman and Graham, 2013
Light Commercials	ABS Motor Vehicle Survey, 2016	ABS Motor Vehicle Survey, 2016	Reedman and Graham, 2013
Motorcycles	ABS Motor Vehicle Survey, 2016	N/A	N/A
Trucks	Reedman and Graham, 2013	ABS Motor Vehicle Survey, 2016	Reedman and Graham, 2013

It was assumed that fuel efficiencies will have their own improvement trajectories for which a value of 1.55% improvement per year was assumed.[185]

Automation impacts across the transport and logistics sector

The data in this analysis included the number of employed persons in sector of Transport, Postal and Warehousing, and the number of employed persons in Queensland's labour force. The data were available quarterly from 1989 to 2017 and were obtained from the ABS Labour Force Survey.[188]

Data were transformed into employment rate to ensure the stationarity of the forecasts accounting for the growth of Queensland's workforce. Employment rate is defined as a change in the proportion of employed persons in sector of Transport, Postal and Warehousing over the total employed persons in Queensland's labour force.

We used an autoregressive model to forecast the employment rate out to 2048. The predicted employment rate was then transformed back to the number of employed persons in sector of Transport, Postal and Warehousing.

The predicted value served as the forecast in the base case where Queensland's economy in 2048 is relatively similar to the current state.

The calibrated probability of automation discussed in four scenarios (i.e. ranging from low to high automation: 9%, 14%, 40% and 60%) was used to calculate the number of jobs at risk. This was the product of the predicted number of employed persons in the sector and the probability of job automation. Note that the data used to generate this risk probability estimate were based on a single point in time and therefore cannot be used to forecast time series changes in automation impact. Hence, there is no time series data associated with this transport fundamental in Appendix D.

APPENDIX C: MODELLING ASSUMPTIONS
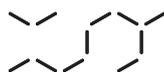
For each transport fundamental, we modelled the plausible trajectory under the four scenarios. As referred to in Chapter 4, a set of general assumptions was used to frame this modelling exercise.

Each transport fundamental was modelled in two stages. First by projecting the baseline trajectory using historical data (see Appendix B for details). Next, the end state of the baseline trajectory associated with each transport fundamental (i.e. the value at 2048) was increased or decreased by a fixed value. This end state was then projected backwards over the 30-year time period.

Where possible, these adjustment assumptions were based on estimates from other published sources. Where such estimates were not available, best guess estimates were informed by subject matter expertise from TMR. Future work could expand on these initial insights, providing a more granular account of the impacts of these scenarios on each fundamental using a wider selection of available data sources.

The following table displays the specific values that were used to adjust the 2048 baseline value for all transport fundamentals, with the exception of fleet composition, which is described separately below. The justification behind each assumed value for each scenario/transport fundamental is outlined with the presentation of the results in Chapter 4.

TRANSPORT FUNDAMENTAL	LEVELS	OFF-PEAK, ON-DEMAND	CRUISE CONTROL	SUBURBAN STREET	BUMPER TO BUMPER
Vehicle kilometres travelled	Buses	-30%	100%	-60%	50%
	Campervans	0%	0%	0%	0%
	Cars	-30%	450%	-60%	10%
	Light Commercial	43%	20%	30%	-23%
	Motorcycles	50%	50%	50%	50%
	Trucks	45%	100%	30%	-23%
Road safety	Fatalities	-55%	-40%	-10%	40%
	Hospitalisations	-55%	-10%	-10%	10%
Infrastructure expenditure	Capital	-20%	-50%	0%	30%
	Operational	-20%	-50%	30%	30%
Registration revenue	Based on outputs of fleet composition projections				
Public transport patronage	Bus	-50%	40%	-50%	10%
	Ferry	-90%	10%	-90%	0%
	Light Rail	-90%	10%	-90%	0%
	Rail	-50%	40%	-50%	10%
Household expenditure on transport		-	-15%	-30%	30%	30%
Cost of freight mobility	Based on outputs of vehicle kilometres travelled projections				
Cost of excessive congestion			-80%	-60%	-40%	30%
Greenhouse gas emissions	Based on outputs of fleet composition projections				
Automation impacts across the transport and logistics sector		-	-40%	-60%	-9%	-14%

The approach for modelling the fleet composition projection differed slightly from other transport fundamentals. This was necessary given that the direction of the baseline trajectory deviated from what was proposed in some scenarios. For example, the petrol share of the car fleet is currently on the decline and the electric share is showing strong growth based on historical trends (see Figure 84). However, the low technology transformation scenarios (i.e. Suburban Streets and Bumper to Bumper) foresee a world where EV uptake is halted and share of petrol/diesel vehicles continues to grow with the electric share declining.

To accommodate these alternative projections, we applied a two-stage adjustment to the fleet projections. First, the overall size of the fleet was increased or decreased based on the assumptions around fleet size under each scenario. Second, the trajectory of each fuel type was then adjusted to reflect the assumed level of uptake of each fuel type under each scenario.

For instance, under Suburban Streets, which assumes a growing share of diesel and petrol vehicles, negative petrol trajectory values were replaced with the trajectory value for diesel vehicles under each mode type (or vice versa if petrol was increasing but diesel was declining). Furthermore, the positive trajectory associated with EVs and hybrid vehicles were reduced to obtain an electric/hybrid share close to the Australian Energy Market Operator's low EV uptake projections (i.e. 22.7%).[189]

This approach was applied to all scenarios. The values used to adjust the fleet size and rate of change in each fleet projection are displayed in the following table. Here each vehicle by fuel type cell displays the percentage increase/decrease that was applied to the overall fleet size and the rate of change used for the trajectory. Where the baseline trajectory was used, this is denoted as 'base'.

VEHICLE TYPE	FUEL TYPE	OFF-PEAK, ON-DEMAND	CRUISE CONTROL	SUBURBAN STREET	BUMPER TO BUMPER
Buses	Bi-fuel	-20% / Base	20% / Base	-20% / Base	20% / Base
	Diesel	-20% / -0.0181	20% / -0.0182	-20% / Base	20% / Base
	Electric	-20% / 0.2000	20% / 0.4500	-20% / Base	20% / Base
	Gas	-20% / Base	20% / Base	-20% / Base	20% / Base
	Hybrid	-20% / 0.2000	20% / 0.3005	-20% / Base	20% / Base
	Petrol	-20% / Base	20% / Base	-20% / 0.0049	20% / 0.0049
Campervans	Bi-fuel	0% / Base	0% / Base	0% / Base	0% / Base
	Diesel	0% / Base	0% / Base	0% / Base	0% / Base
	Electric	0% / Base	0% / Base	0% / Base	0% / Base
	Gas	0% / Base	0% / Base	0% / Base	0% / Base
	Hybrid	0% / Base	0% / Base	0% / Base	0% / Base
	Petrol	0% / Base	0% / Base	0% / Base	0% / Base
Cars	Bi-fuel	-60% / Base	-90% / Base	30% / Base	15% / Base
	Diesel	-60% / Base	-90% / -0.0089	30% / Base	15% / Base
	Electric	-60% / Base	-90% / Base	30% / 0.3500	15% / 0.4100
	Gas	-60% / Base	-90% / Base	30% / Base	15% / Base
	Hybrid	-60% / Base	-90% / Base	30% / 0.2400	15% / 0.2600
	Petrol	-60% / Base	-90% / Base	30% / 0.0873	15% / 0.0873
Light Commercial	Bi-fuel	-30% / Base	-50% / Base	30% / Base	30% / Base
	Diesel	-30% / -0.0586	-50% / -0.0586	30% / Base	30% / Base
	Electric	-30% / 0.2000	-50% / 0.4500	30% / Base	30% / Base
	Gas	-30% / Base	-50% / Base	30% / Base	30% / Base
	Hybrid	-30% / 0.2000	-50% / 0.3005	30% / Base	30% / Base
	Petrol	-30% / Base	-50% / Base	30% / 0.0493	30% / 0.0493
Motorcycles	Bi-fuel	20% / Base	20% / Base	20% / Base	20% / Base
	Diesel	20% / Base	20% / Base	20% / Base	20% / Base
	Electric	20% / 0.2000	20% / 0.4500	20% / Base	20% / Base
	Hybrid	20% / 0.2000	20% / 0.3005	20% / Base	20% / Base
	Petrol	20% / -0.1111	20% / -0.1111	20% / Base	20% / Base
Trucks	Bi-fuel	-30% / Base	-50% / Base	30% / Base	30% / Base
	Diesel	-30% / -0.1007	-50% / -0.1007	30% / Base	30% / Base
	Electric	-30% / 0.2000	-50% / 0.4500	30% / Base	30% / Base
	Gas	-30% / Base	-50% / Base	30% / Base	30% / Base
	Hybrid	-30% / 0.2000	-50% / 0.3005	30% / Base	30% / Base
	Petrol	-30% / Base	-50% / Base	30% / 0.0019	30% / 0.0019

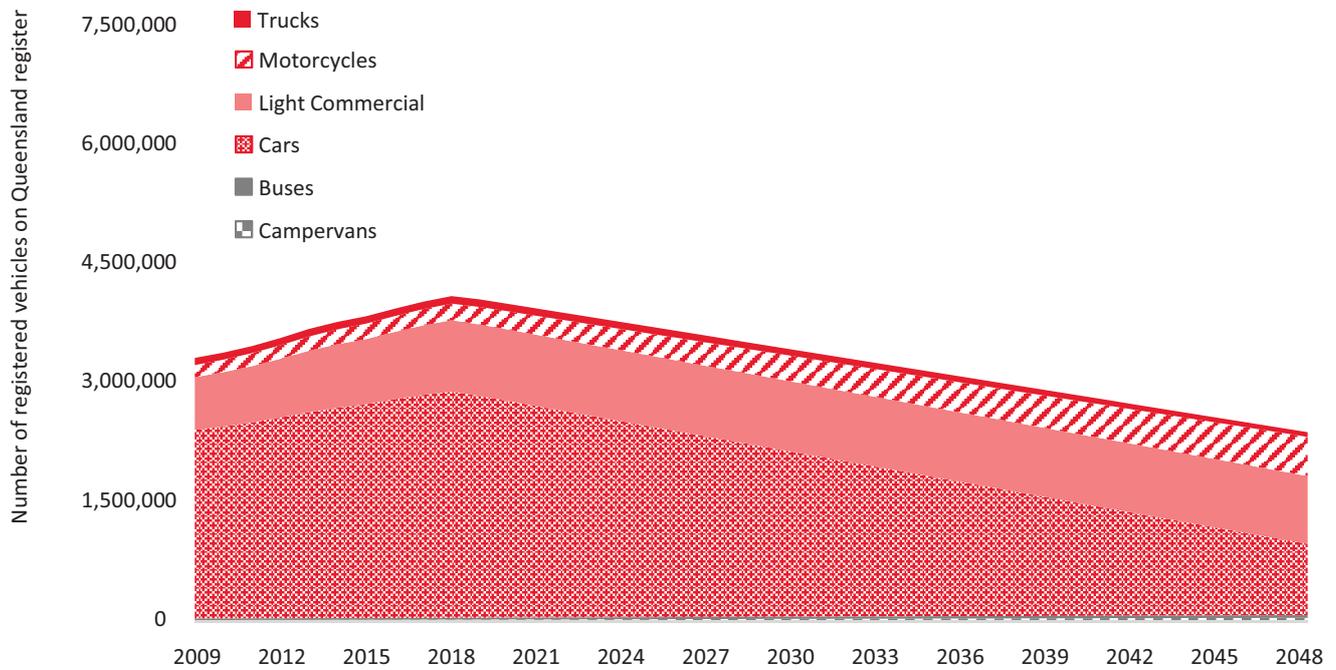# APPENDIX D: SUPPLEMENTARY MODELLING RESULTS
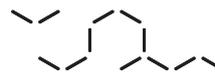
Fleet composition

Baseline
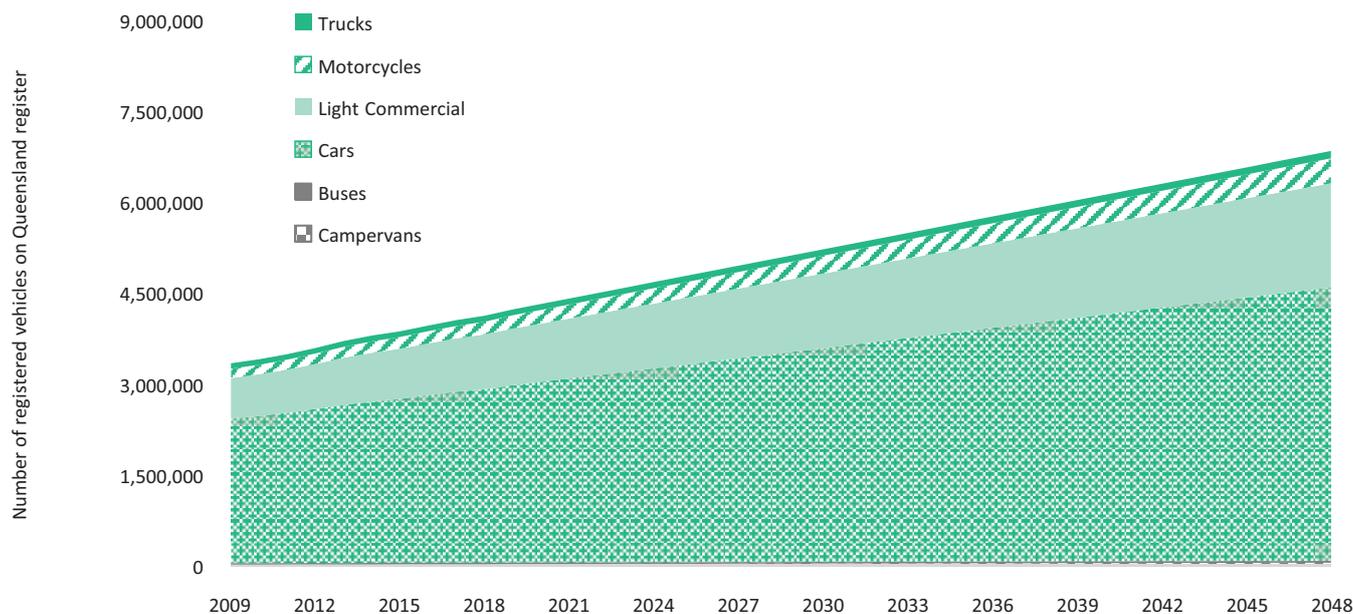
Figure 83. Time series of modelling projections of number of registered vehicles in the fleetby vehicle type projected out to 2048 under Baseline scenario
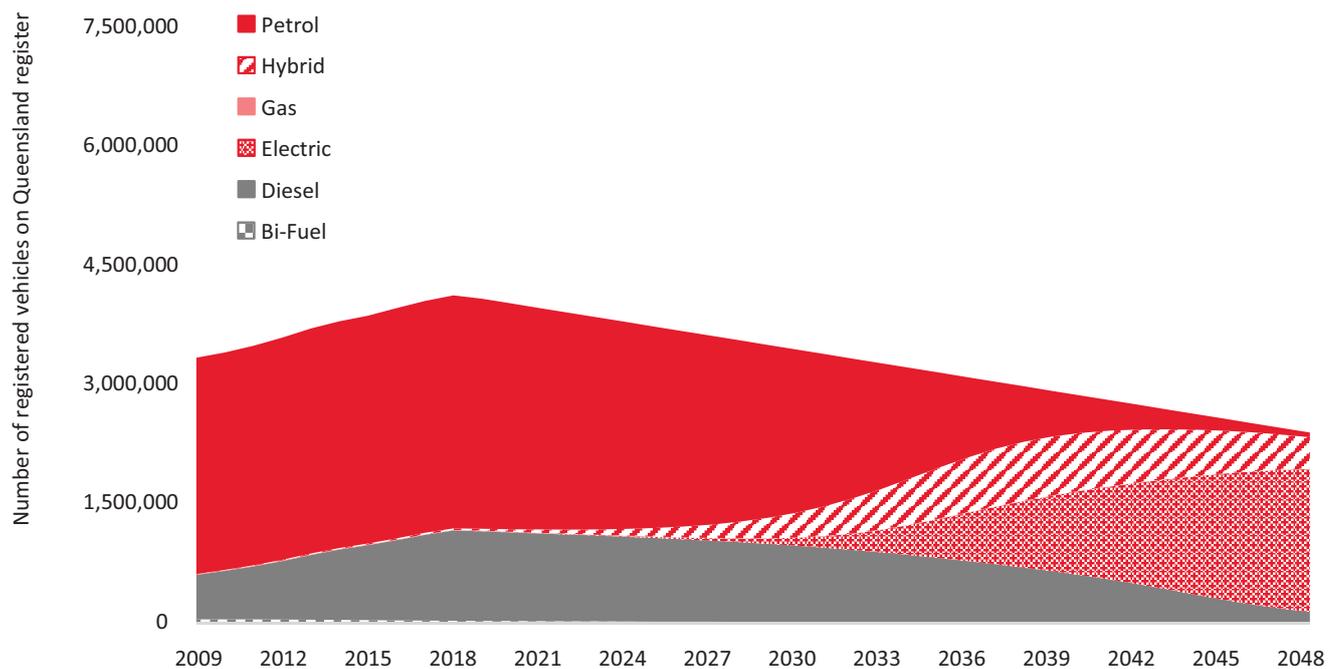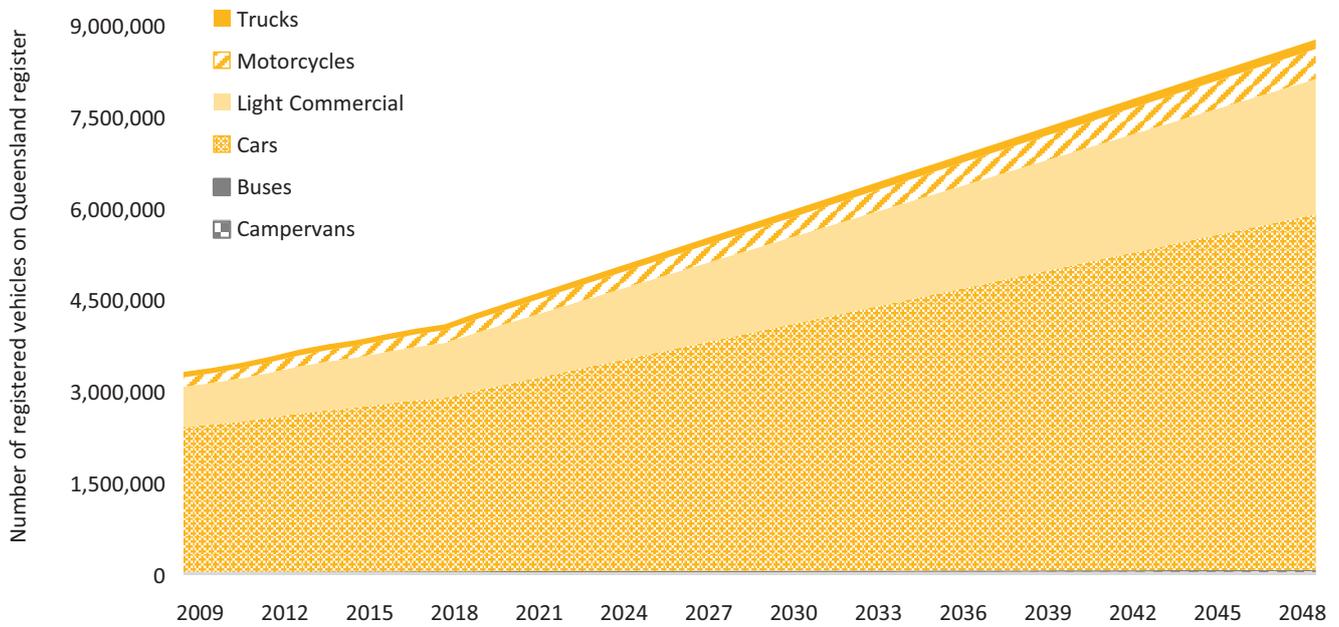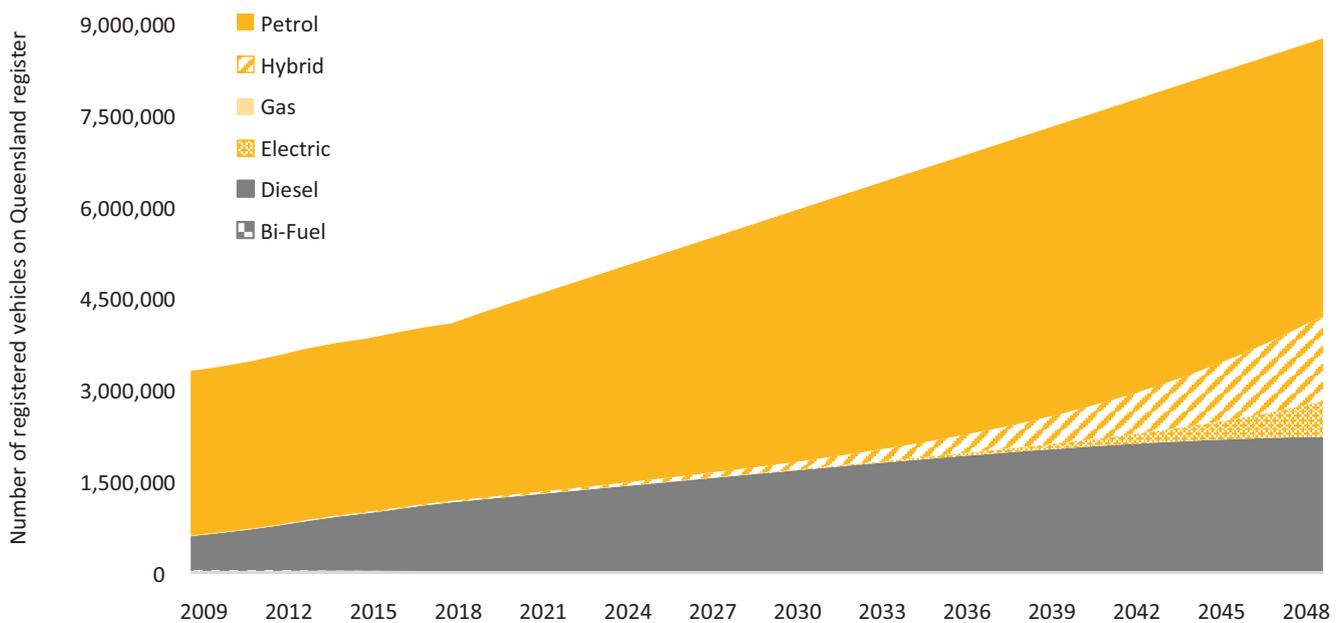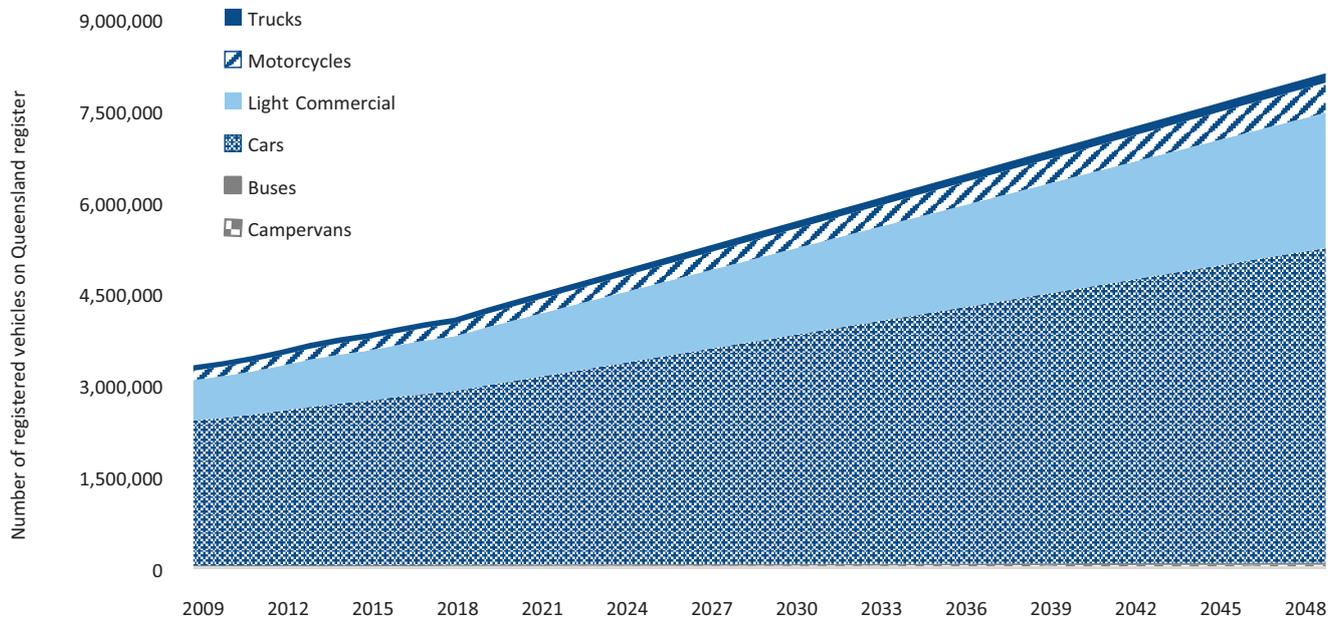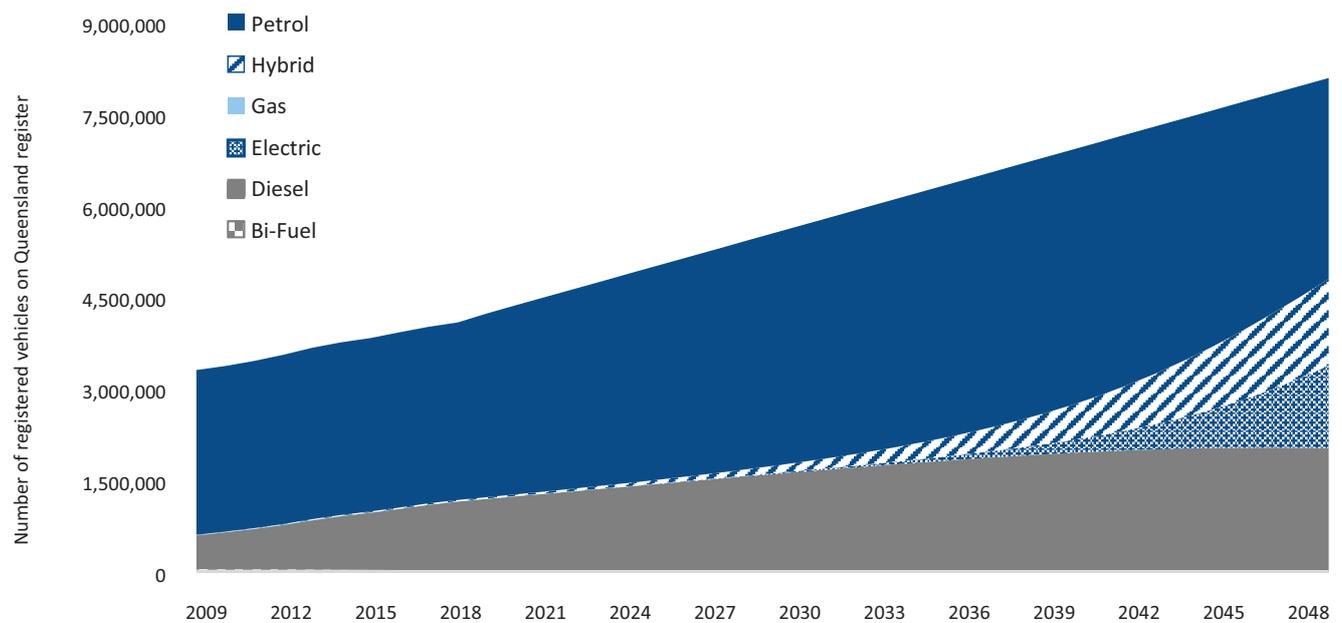
Data source: Data provided by TMR and Data61 estimates
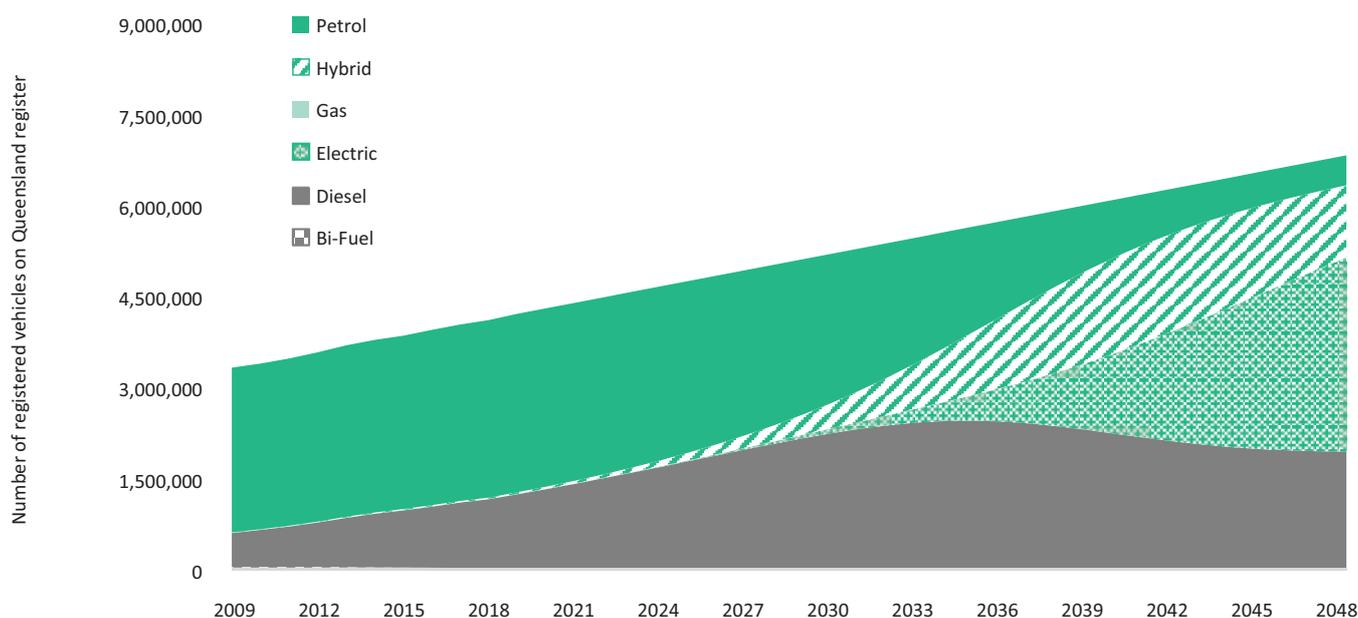
Figure 84. Time series of modelling projections of number of registered vehicles in the fleet by fuel type projected out to 2048 under Baseline scenario

Data source: Data provided by TMR and Data61 estimates
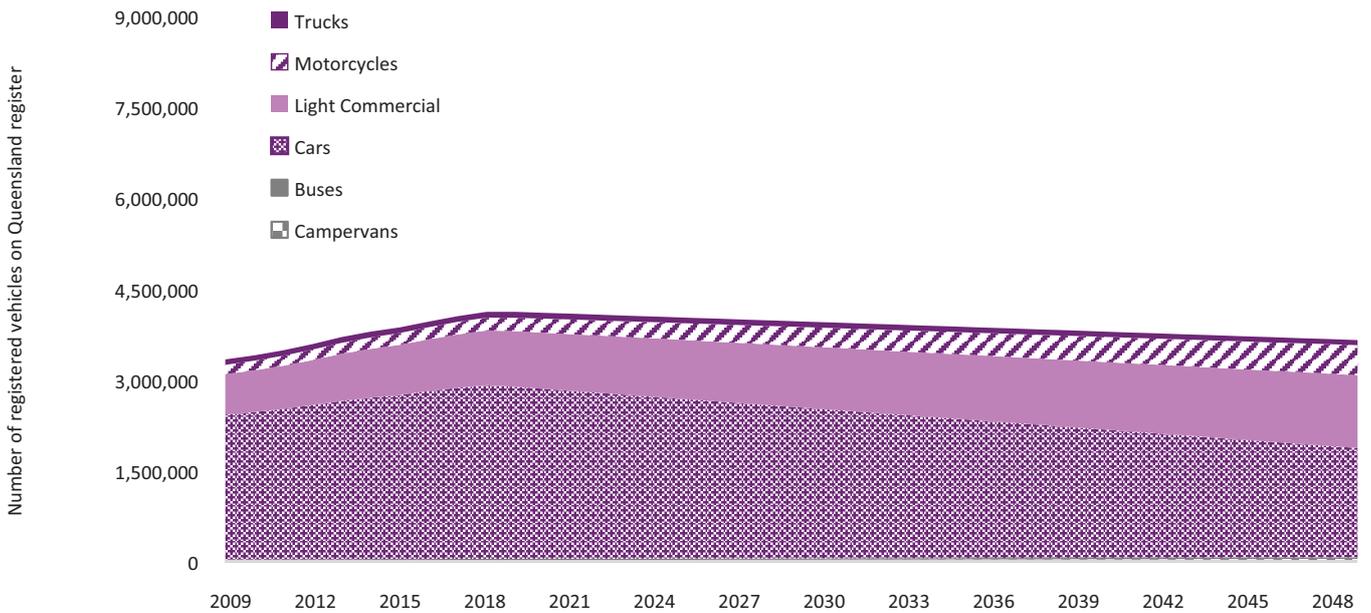
Off-peak, on-demand

Figure 85. Time series of modelling projections of number of registered vehicles in the fleet by vehicle type projected out to 2048 under Off-Peak, On-Demand scenario

Data source: Data provided by TMR and Data61 estimates
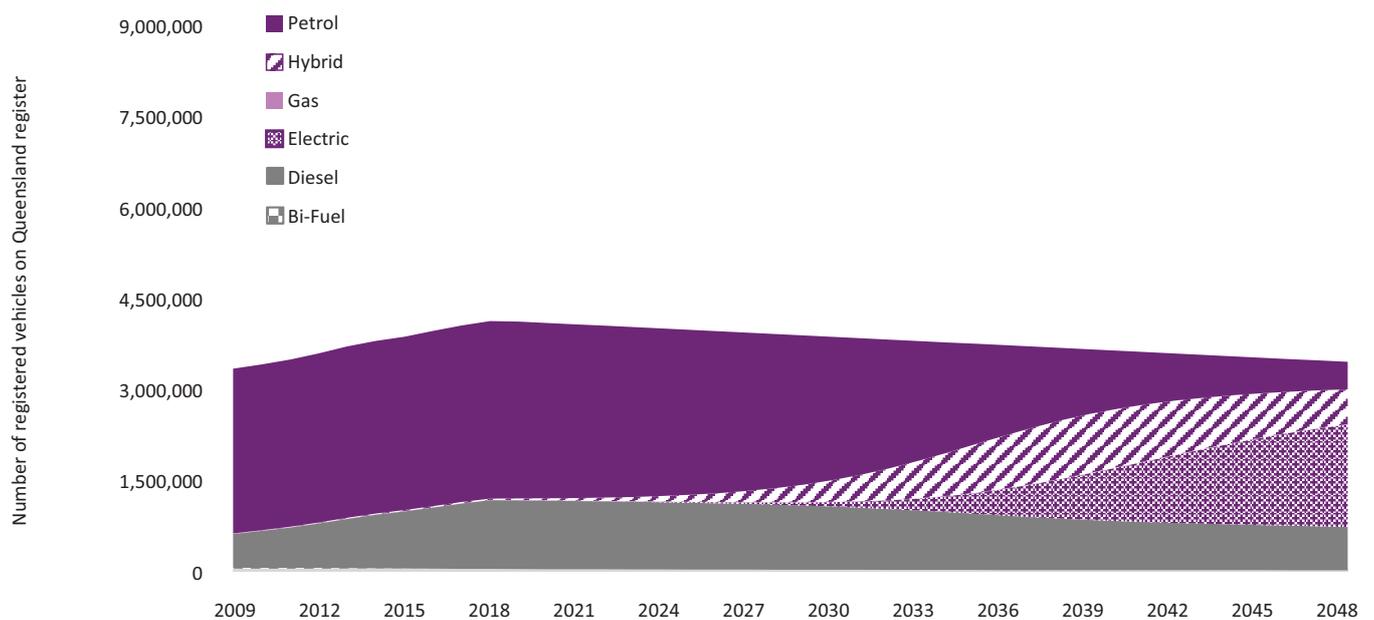
Figure 86. Time series of modelling projections of number of registered vehicles in the fleet by fuel type projected out to 2048 under Off-Peak, On-Demand scenario

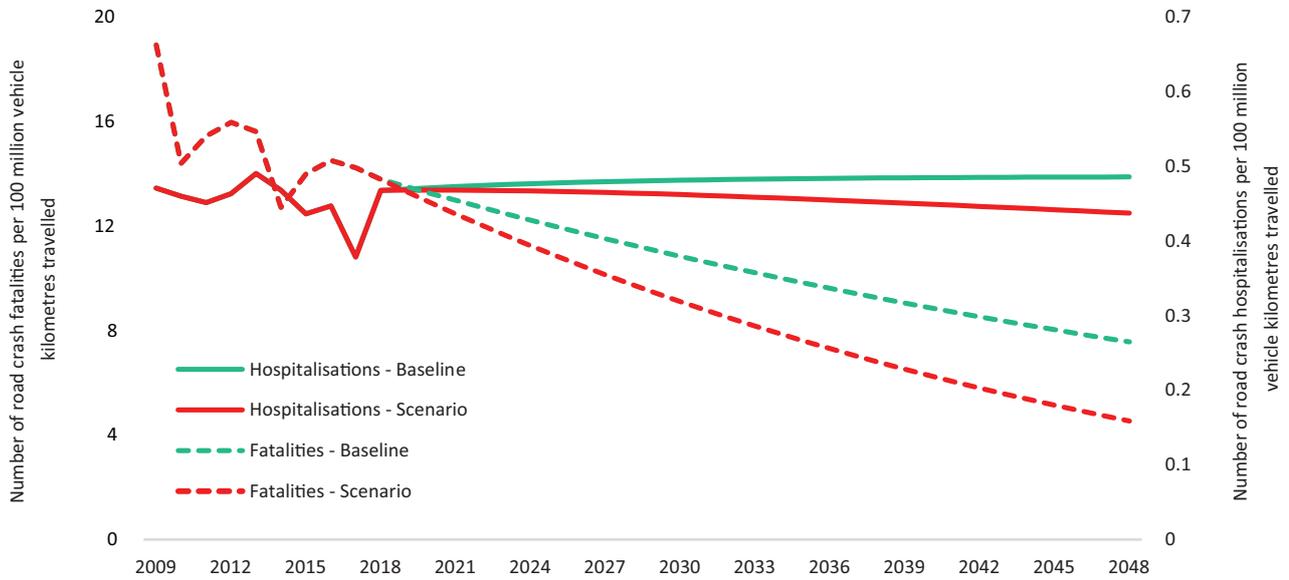Data source: Data provided by TMR and Data61 estimates

Cruise control

Figure 87. Time series of modelling projections of number of registered vehicles in the fleet by vehicle type projected out to 2048 under Cruise Control scenario

Data source: Data provided by TMR and Data61 estimates

Figure 88. Time series of modelling projections of number of registered vehicles in the fleet fuel type projected out to 2048 under Cruise Control scenario

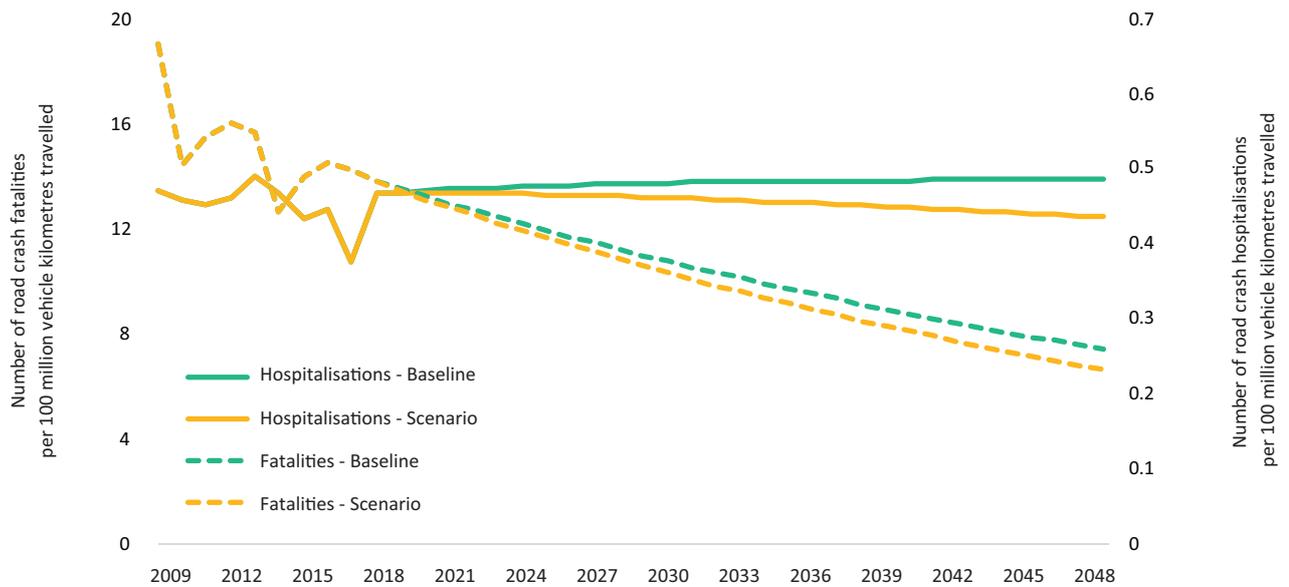Data source: Data provided by TMR and Data61 estimates

Suburban streets

Figure 89. Time series of modelling projections of number of registered vehicles in the fleet by vehicle type projected out to 2048 under Suburban Streets scenario

Data source: Data provided by TMR and Data61 estimates

Figure 90. Time series of modelling projections of number of registered vehicles in the fleet by fuel type projected out to 2048 under Suburban Streets scenario

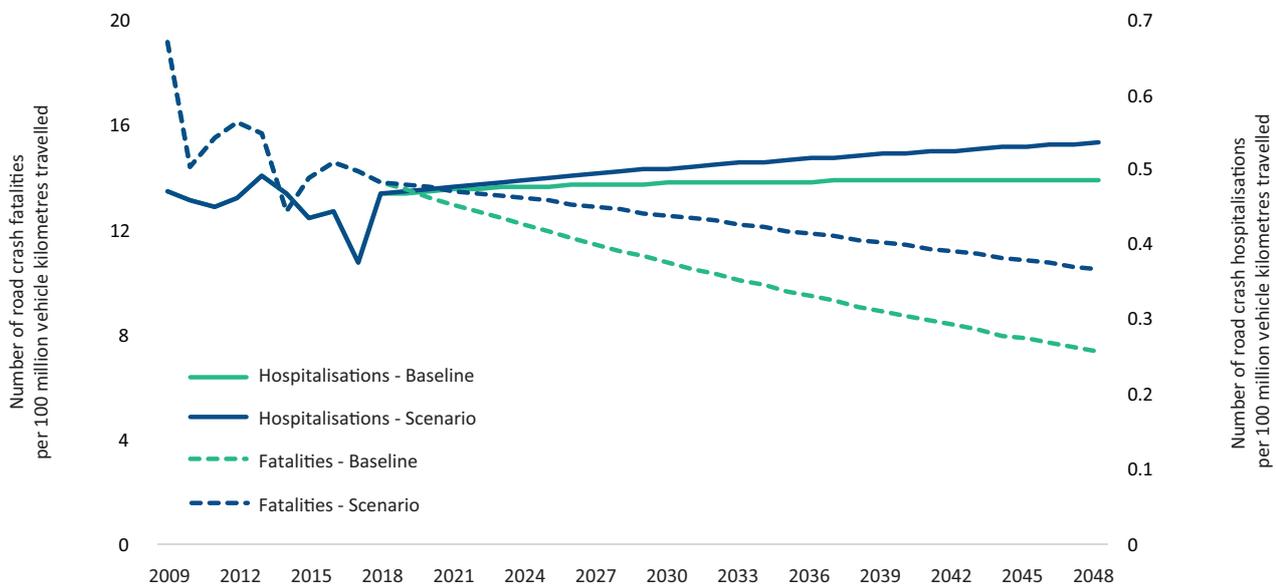Data source: Data provided by TMR and Data61 estimates

Bumper to bumper

Figure 91. Time series of modelling projections of number of registered vehicles in the fleet by vehicle type projected out to 2048 under Bumper to Bumper scenario

Data source: Data provided by TMR and Data61 estimates

Figure 92. Time series of modelling projections of number of registered vehicles in the fleet by fuel type projected out to 2048 under Bumper to Bumper scenario

Data source: Data provided by TMR and Data61 estimates

Vehicle kilometres travelled

Baseline
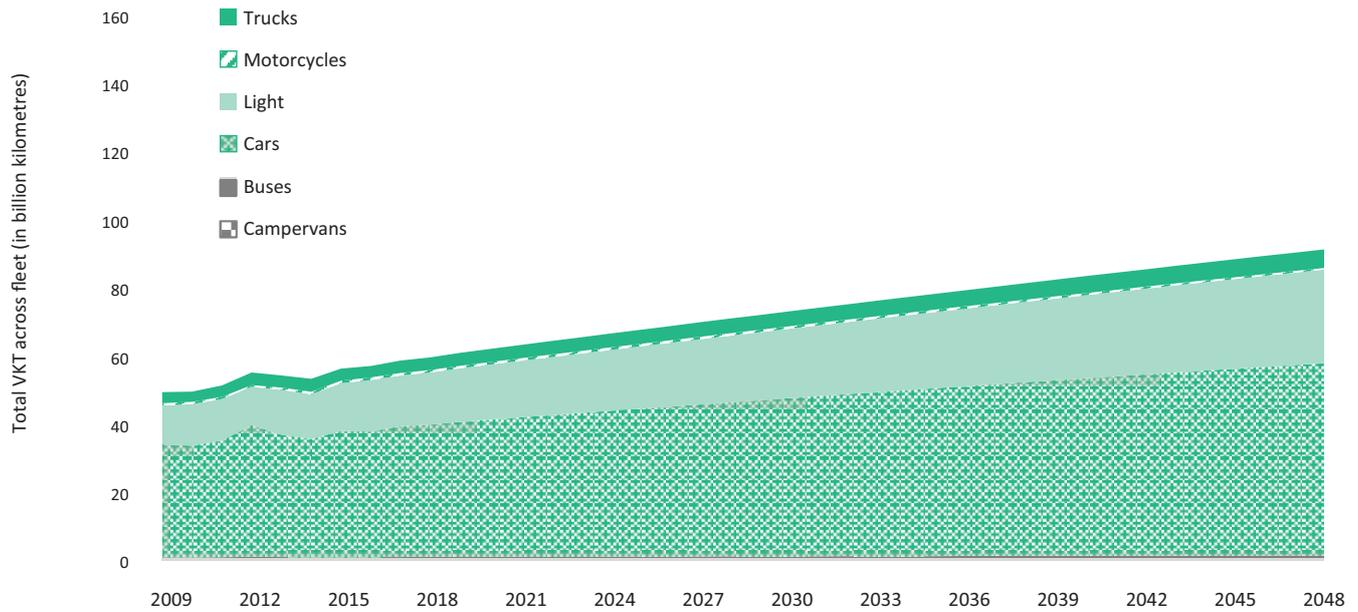
Figure 93. Time series of modelling projections of total vehicle kilometres travelled (VKT) projected out to 2048 under Baseline scenario
Data source: Australian Bureau of Statistics[179] and Data61 estimates
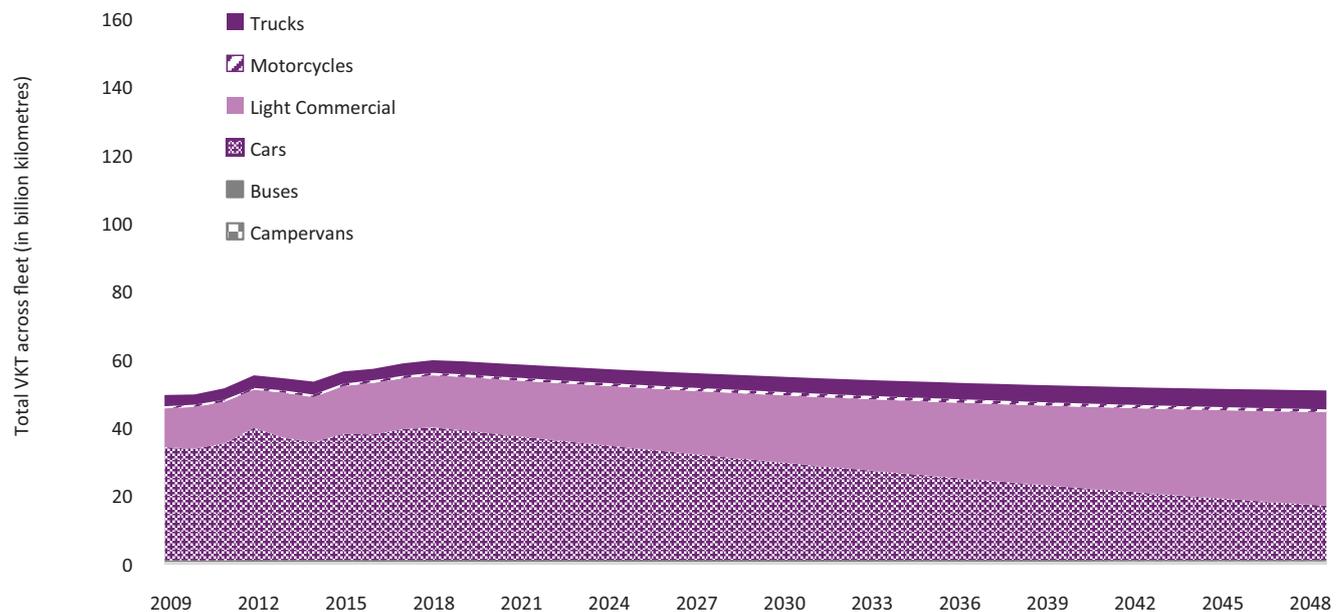
Off-peak, on-demand

Figure 94. Time series of modelling projections of total vehicle kilometres travelled (VKT) projected out to 2048 under Off-Peak, On-Demand scenario
Data source: Australian Bureau of Statistics[179] and Data61 estimates
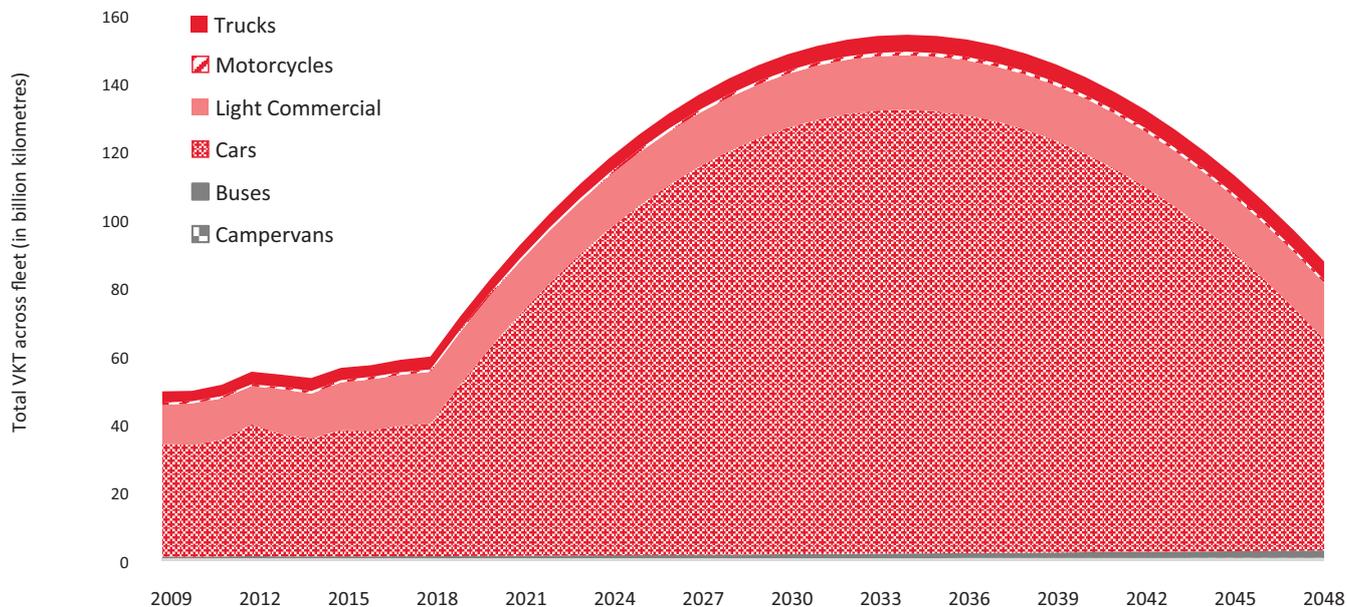
Cruise control

Figure 95. Time series of modelling projections of total vehicle kilometres travelled (VKT) projected out to 2048 under Cruise Control scenario
Data source: Australian Bureau of Statistics[179] and Data61 estimates

Note: Please see "Measuring the Impact of Cruise Control" section (p. 43-44) for a further explanation around this pattern of results.

Suburban streets
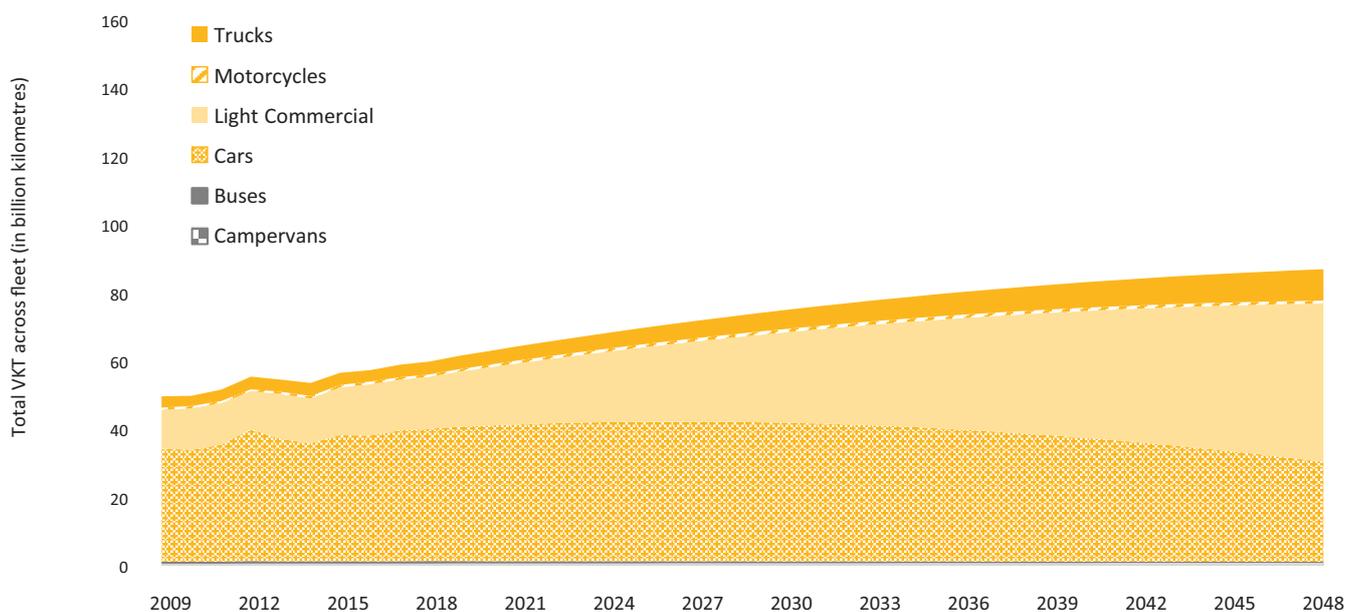
Figure 96. Time series of modelling projections of total vehicle kilometres travelled (VKT) projected out to 2048 under Suburban Streets scenario
Data source: Australian Bureau of Statistics[181] and Data61 estimates
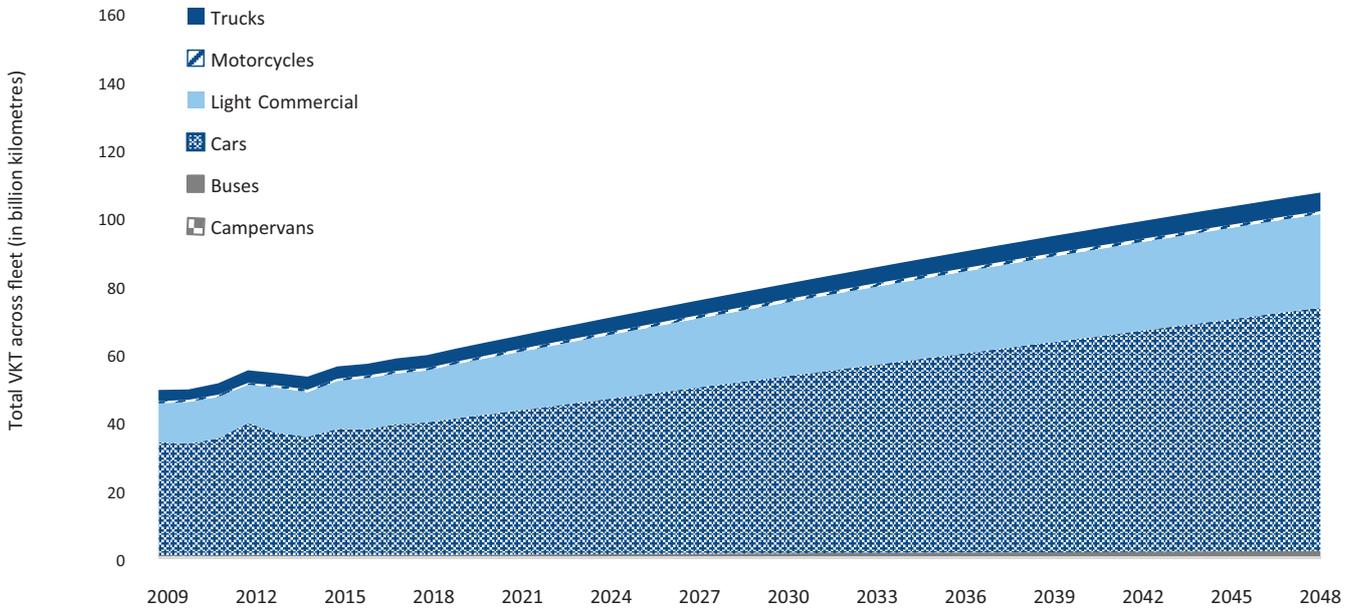
Bumper to bumper

Figure 97. Time series of modelling projections of total vehicle kilometres travelled (VKT) projected out to 2048 under Bumper to Bumper scenario

Data source: Australian Bureau of Statistics[179] and Data61 estimates

Road safety

Off-peak, on-demand
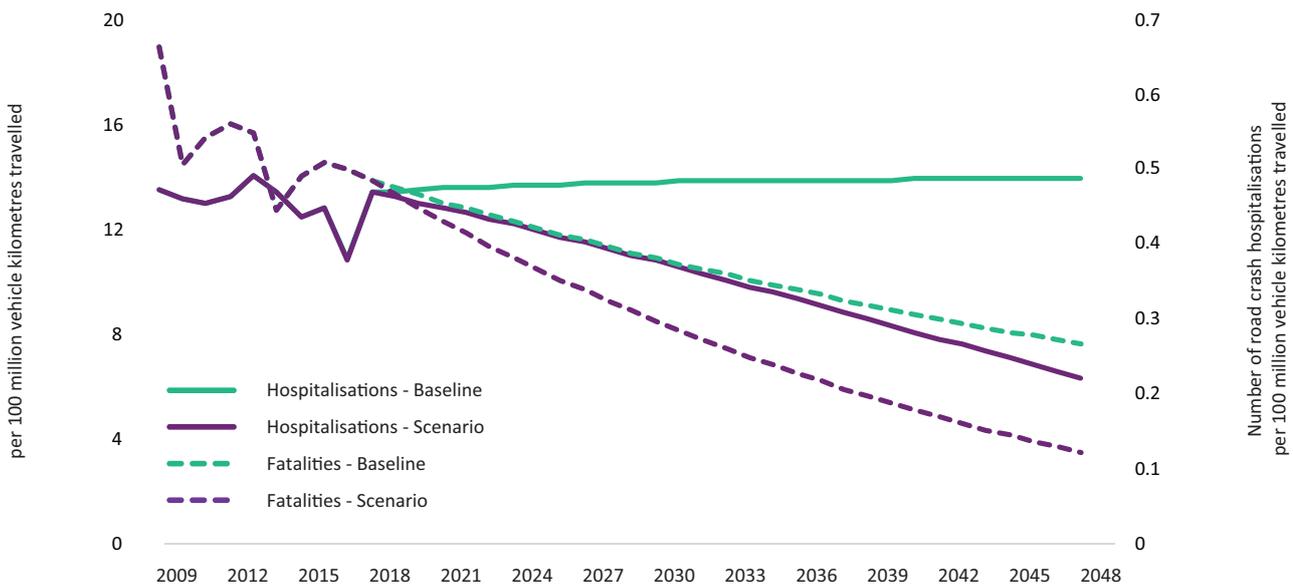
Figure 98. Time series of modelling projections of road crash fatalities and hospitalisations projected out to 2048 under Off-Peak, On-Demand scenario

Data source: Data provided by TMR and Data61 estimates

Cruise control

Figure 99. Time series of modelling projections of road crash fatalities and hospitalisations projected out to 2048 under Cruise Control scenario
Data source: Data provided by TMR and Data61 estimates

Suburban streets

Figure 100. Time series of modelling projections of road crash fatalities and hospitalisations projected out to 2048 under Suburban Streets scenario
Data source: Data provided by TMR and Data61 estimates

Bumper to bumper

Figure 101. Time series of modelling projections of road crash fatalities and hospitalisations projected out to 2048 under Bumper to Bumper scenario

Data source: Data provided by TMR and Data61 estimates

Infrastructure expenditure

Off-peak, on-demand
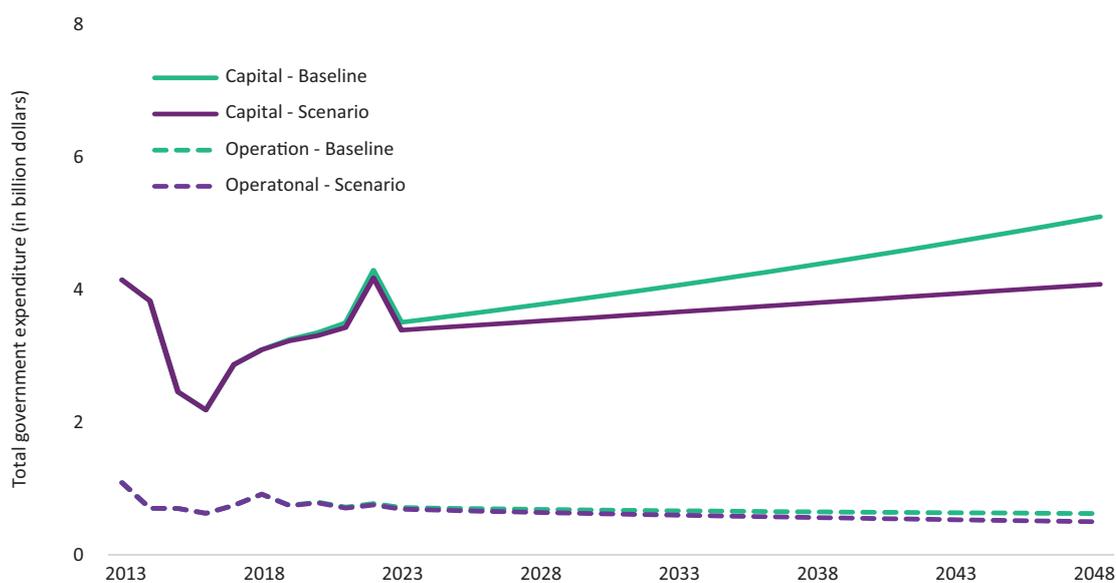
Figure 102. Time series of modelling projections of total capital and operational government expenditure projected out to 2048 under Off-Peak, On-Demand scenario

Data source: Data provided by TMR and Data61 estimates
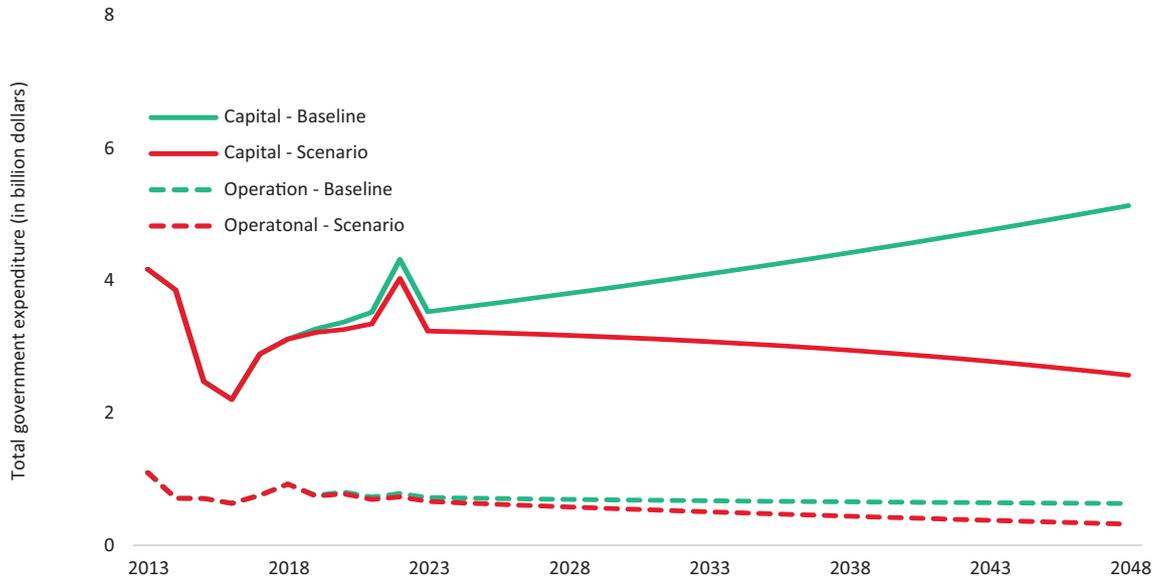
Cruise control

Figure 103. Time series of modelling projections of total capital and operational government expenditure projected out to 2048 under Cruise Control scenario

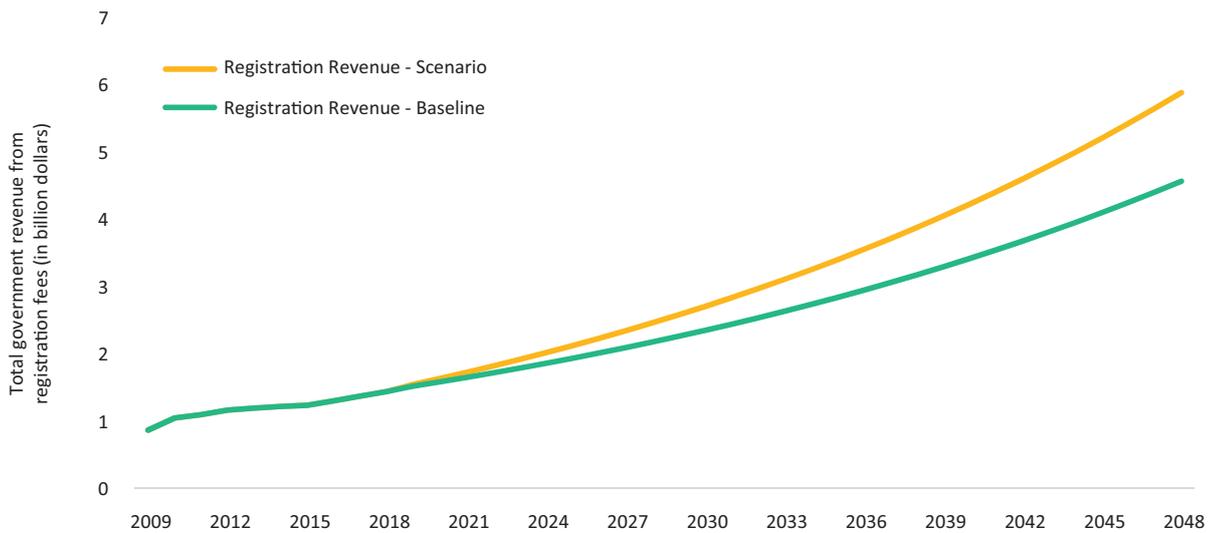Data source: Data provided by TMR and Data61 estimates
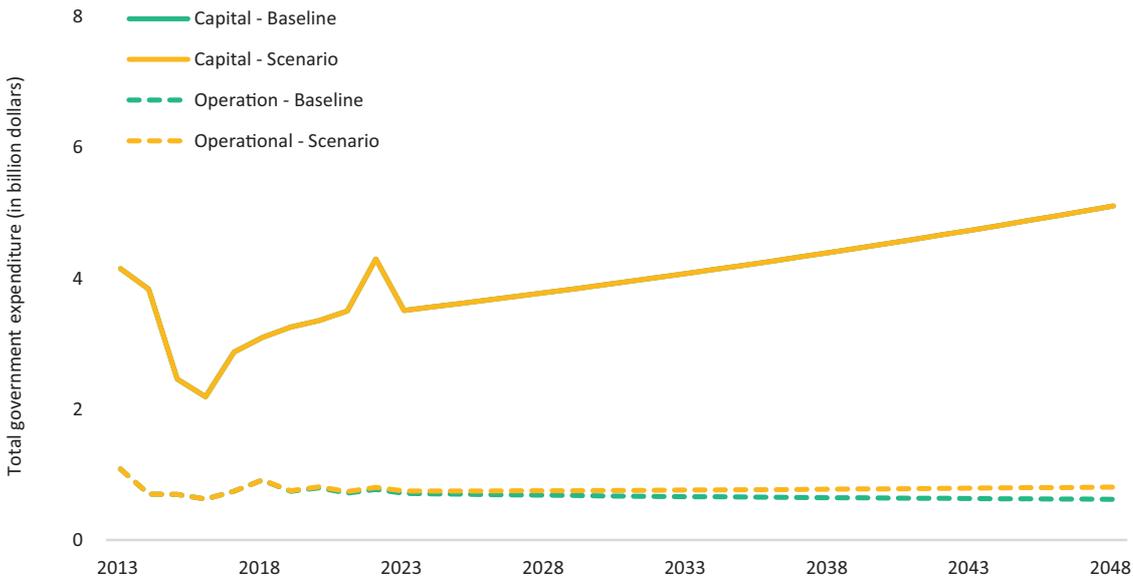
Suburban streets

Figure 104. Time series of modelling projections of total capital and operational government expenditure projected out to 2048 under Suburban Streets scenario

Data source: Data provided by TMR and Data61 estimates
Note: The baseline projection was used for the capital costs estimates under Suburban Streets.
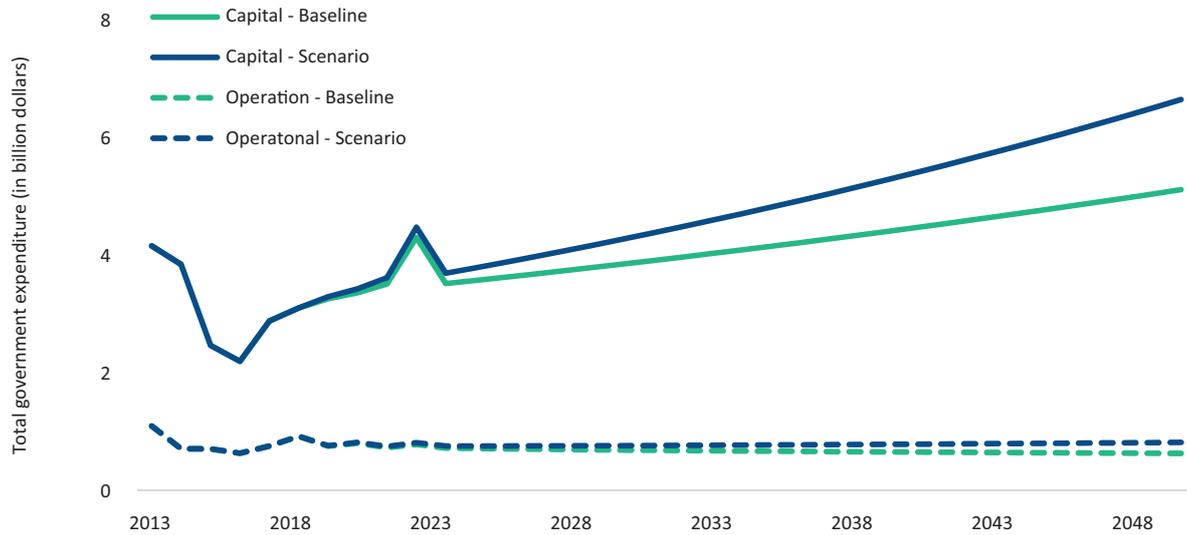
Bumper to bumper

Figure 105. Time series of modelling projections of total capital and operational government expenditure projected out to 2048 under Bumper to Bumper scenario

Data source: Data provided by TMR and Data61 estimates
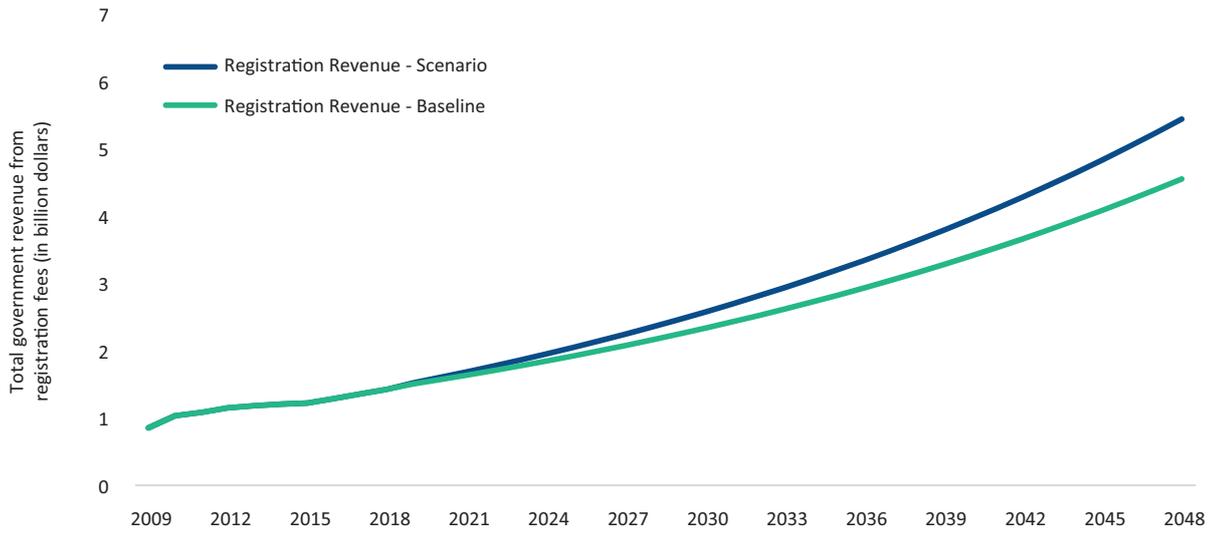
Registration revenue

Off-peak, on-demand
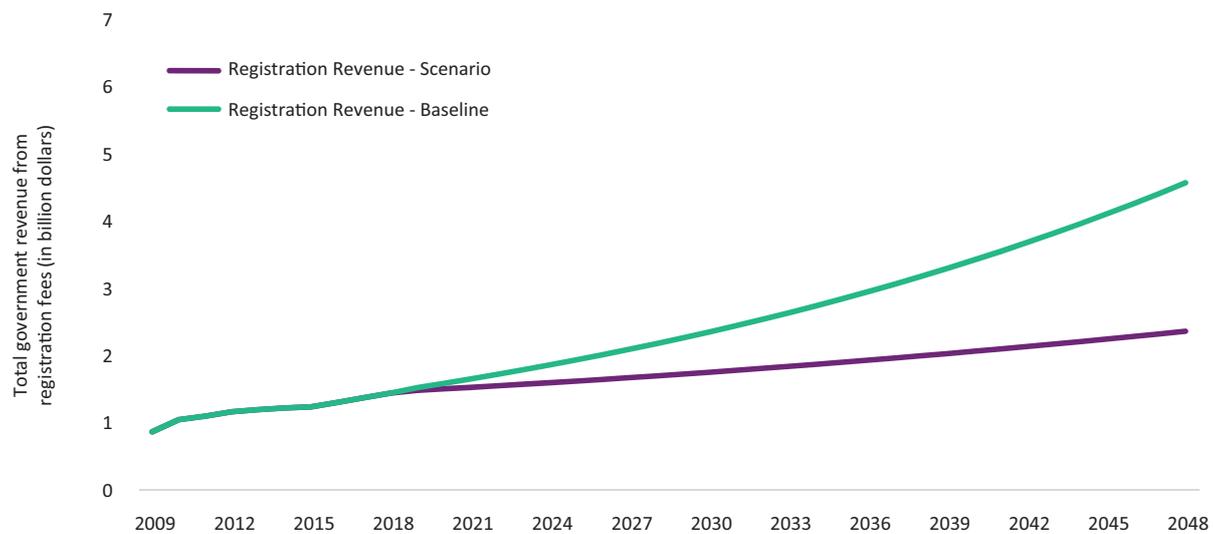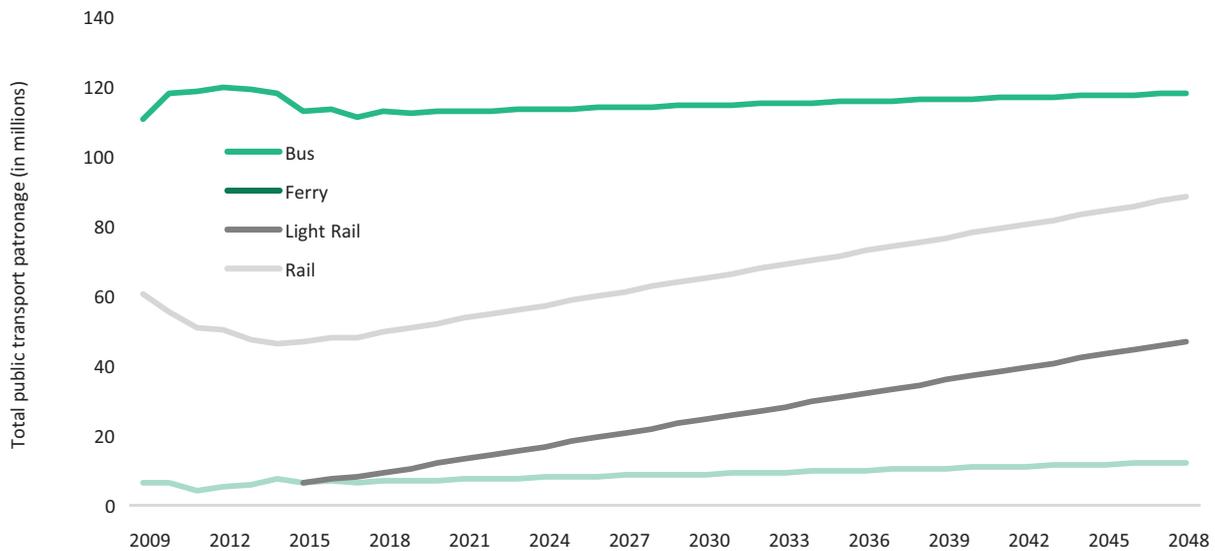

Figure 106. Time series of modelling projections of total government revenue from registration fees projected out to 2048 under Off-Peak, On-Demand scenario

Data source: Data provided by TMR and Data61 estimates
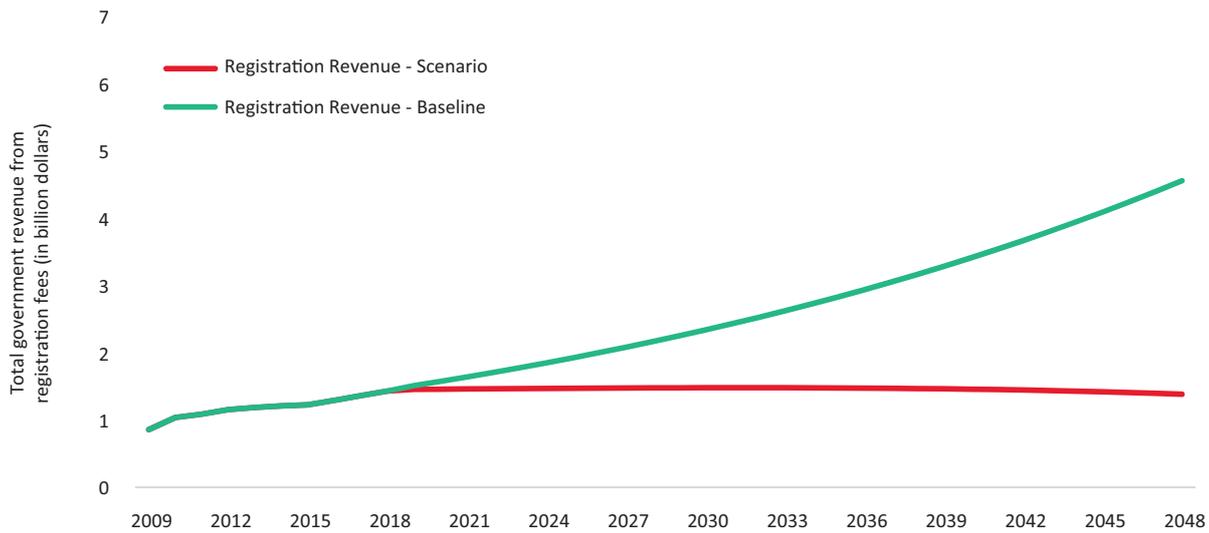
Cruise control

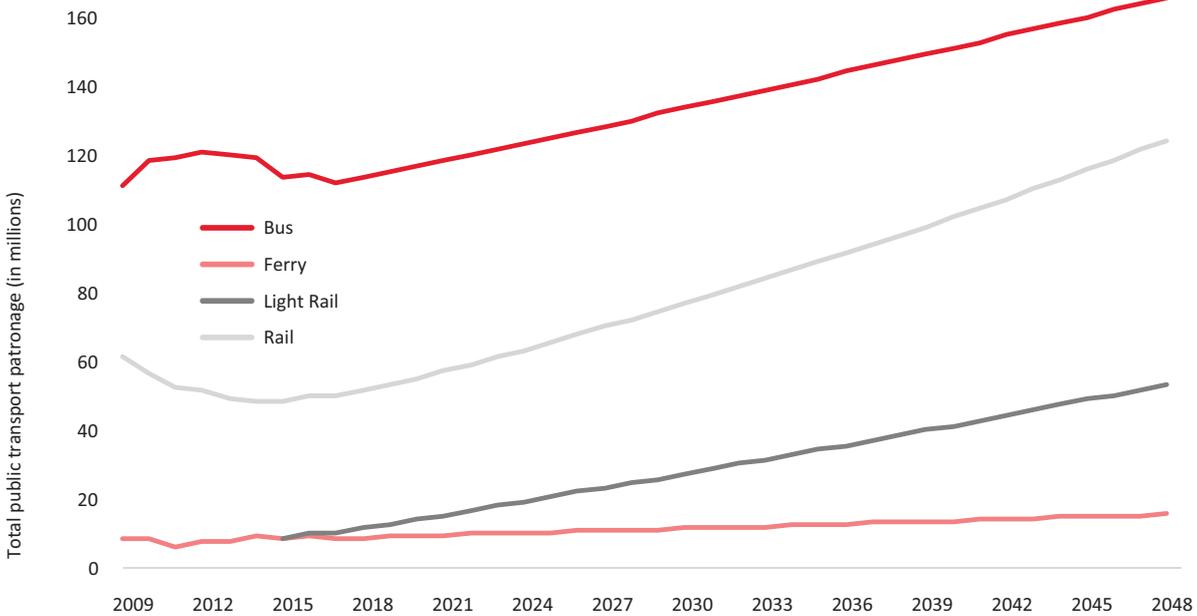**Figure 107. Time series of modelling projections of total government revenue from registration fees projected out to 2048 under Cruise Control scenario**

Data source: Data provided by TMR and Data61 estimates

Suburban streets

Figure 108. Time series of modelling projections of total government revenue from registration fees projected out to 2048 under Suburban Streets scenario

Data source: Data provided by TMR and Data61 estimates

Bumper to bumper

Figure 109. Time series of modelling projections of total government revenue from registration fees projected out to 2048 under Bumper to Bumper scenario

Data source: Data provided by TMR and Data61 estimates

Public transport patronage

Baseline

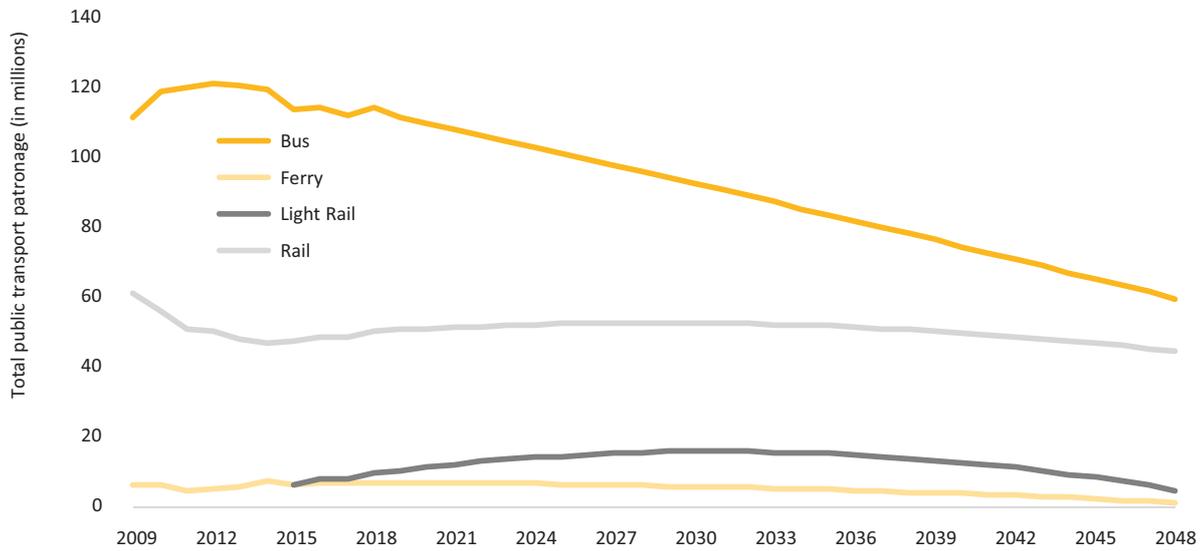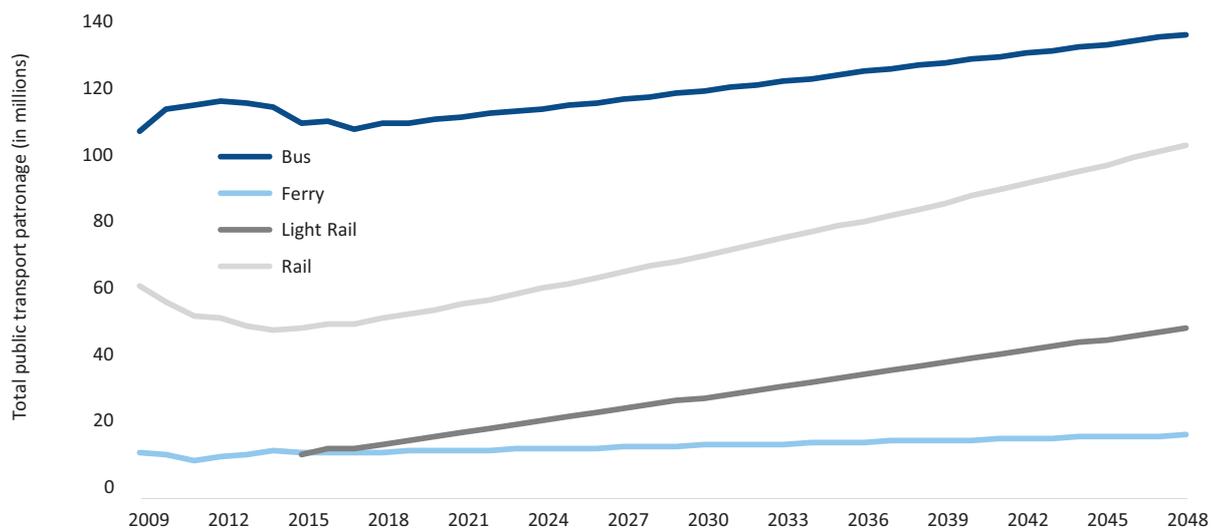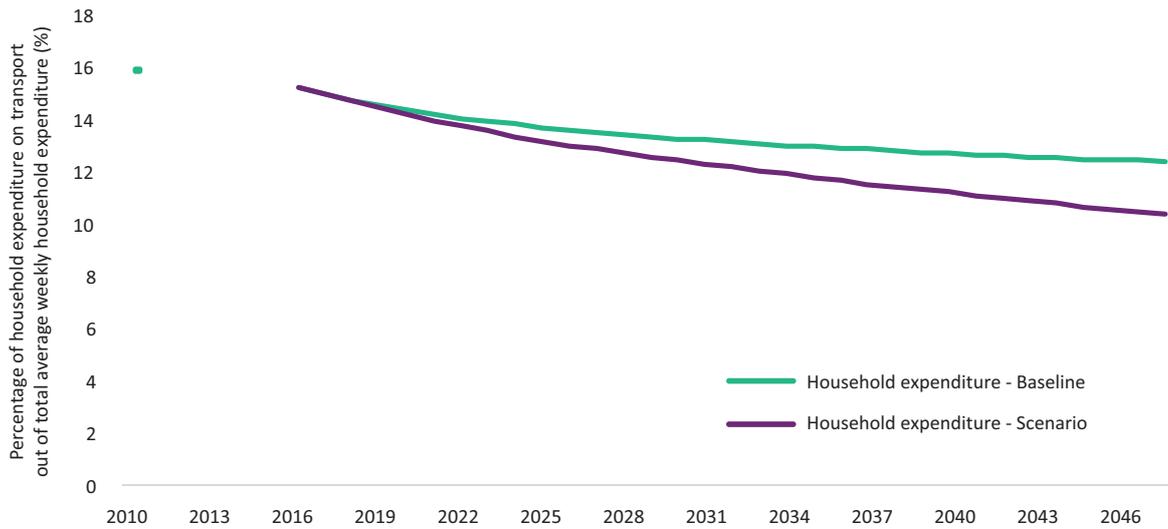**Figure 110. Time series of modelling projections of public transport patronage by mode type projected out to 2048 under Baseline scenario**

Data source: Data provided by TMR and Data61 estimates
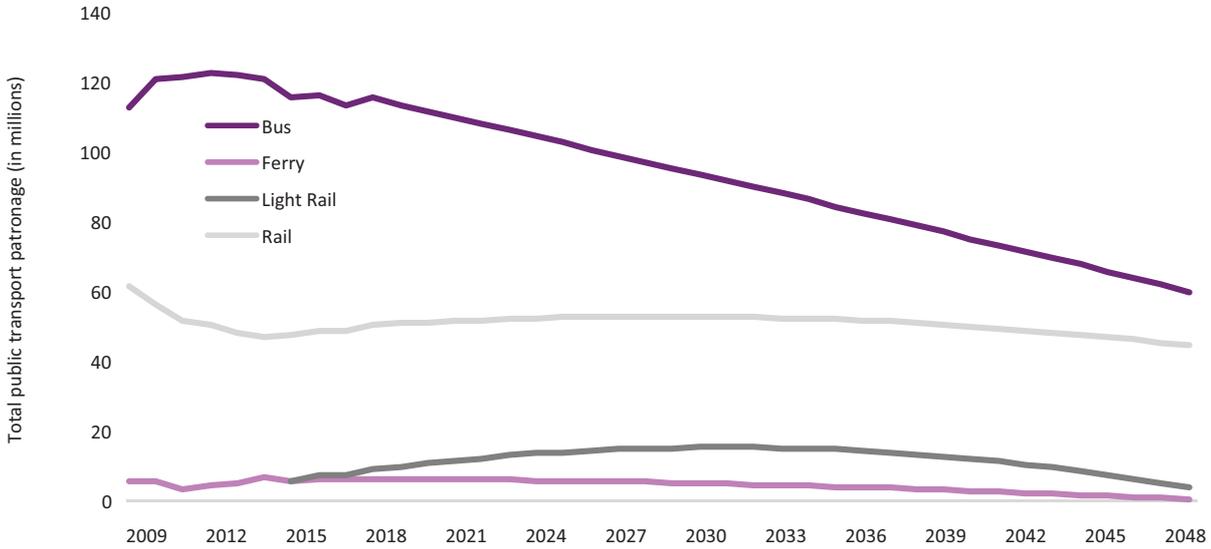
Off-peak, on-demand

Figure 111. Time series of modelling projections of public transport patronage by mode type projected out to 2048 under Off-Peak, On-Demand scenario
Data source: Data provided by TMR and Data61 estimates

Cruise control

Figure 112. Time series of modelling projections of public transport patronage by mode type projected out to 2048 under Cruise Control scenario
Data source: Data provided by TMR and Data61 estimates

Suburban streets

Figure 113. Time series of modelling projections of public transport patronage by mode type projected out to 2048 under Suburban Streets scenario
Data source: Data provided by TMR and Data61 estimates

Bumper to bumper

Figure 114. Time series of modelling projections of public transport patronage by mode type projected out to 2048 under Bumper to Bumper scenario
Data source: Data provided by TMR and Data61 estimates

Household spent on transport

Off-peak, on-demand

Figure 115. Time series of modelling projections of average weekly household expenditure on transport projected out to 2048 under Off-Peak, On-Demand scenario

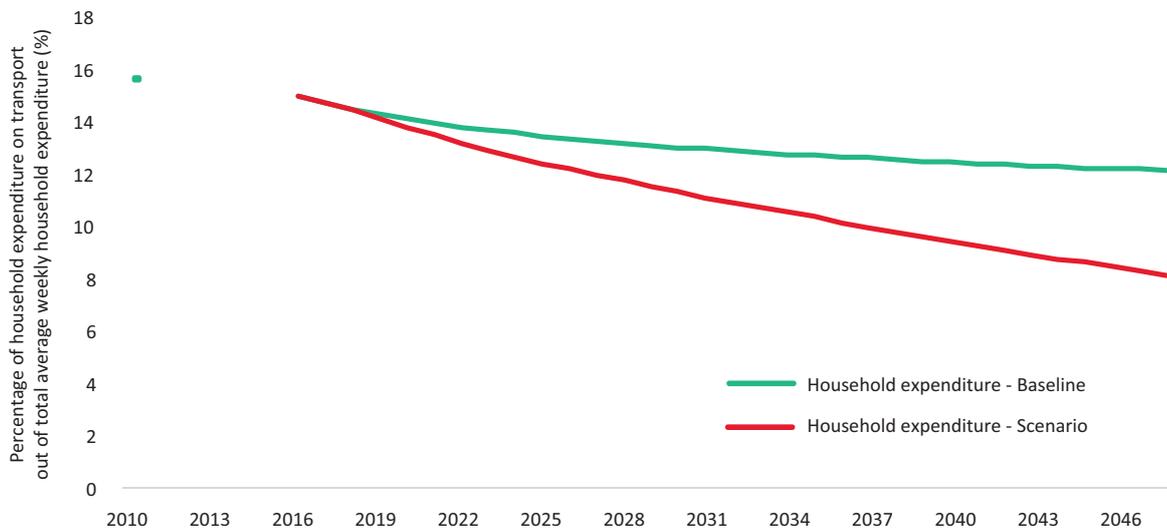Data source: ABS Household Expenditure Survey[182] and Data61 estimates

Cruise control

Figure 116. Time series of modelling projections of average weekly household expenditure on transport projected out to 2048 under Cruise Control scenario

Data source: ABS Household Expenditure Survey[182] and Data61 estimates
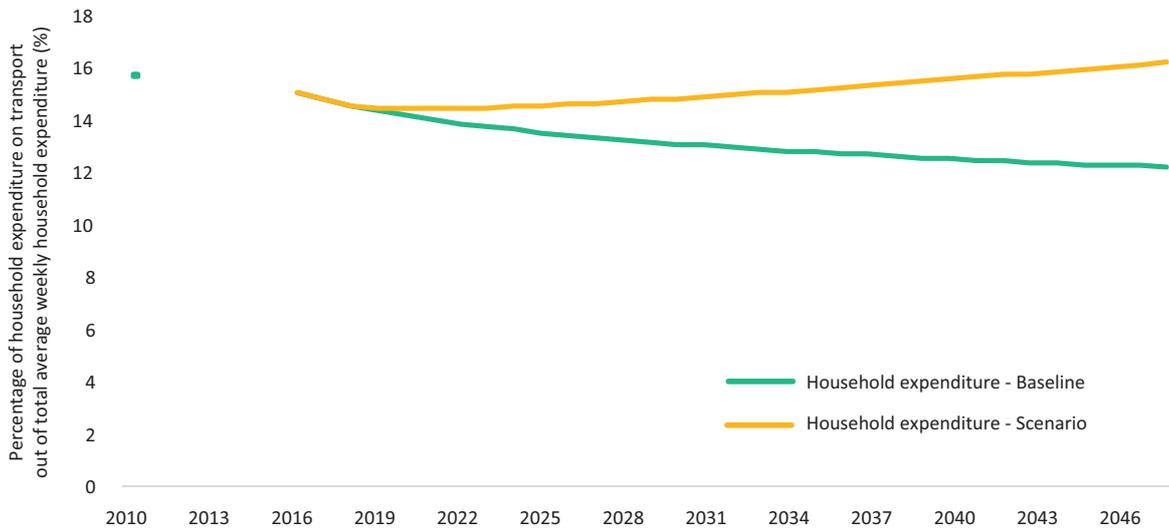
Suburban streets

Figure 117. Time series of modelling projections of average weekly household expenditure on transport projected out to 2048 under Suburban Streets scenario

Data source: ABS Household Expenditure Survey[182] and Data61 estimates
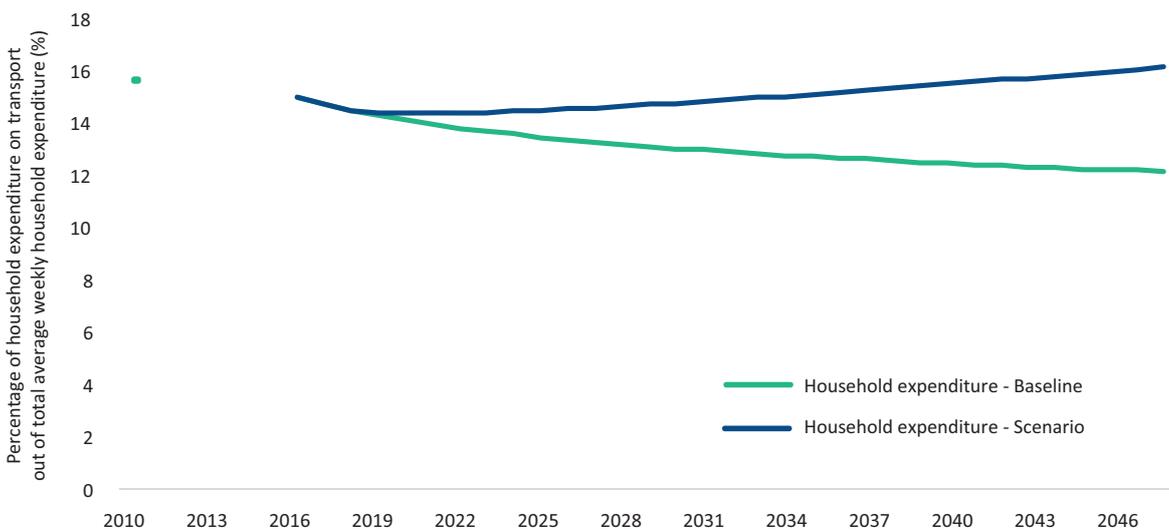
Bumper to bumper

Figure 118. Time series of modelling projections of average weekly household expenditure on transport projected out to 2048 under Bumper to Bumper scenario

Data source: ABS Household Expenditure Survey[182] and Data61 estimates

Cost of freight mobility

Baseline

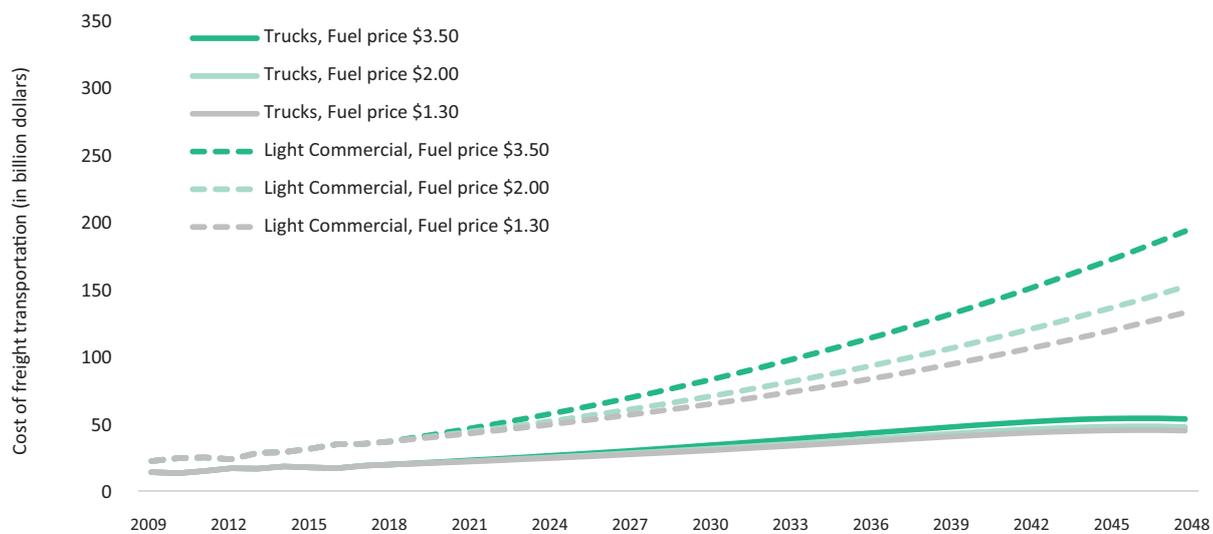**Figure 119. Time series of modelling projections of cost of freight transport projected out to 2048 by fuel price per litre under Baseline scenario**

Data source: CSIRO TraNSIT model[183] and Data61 estimates
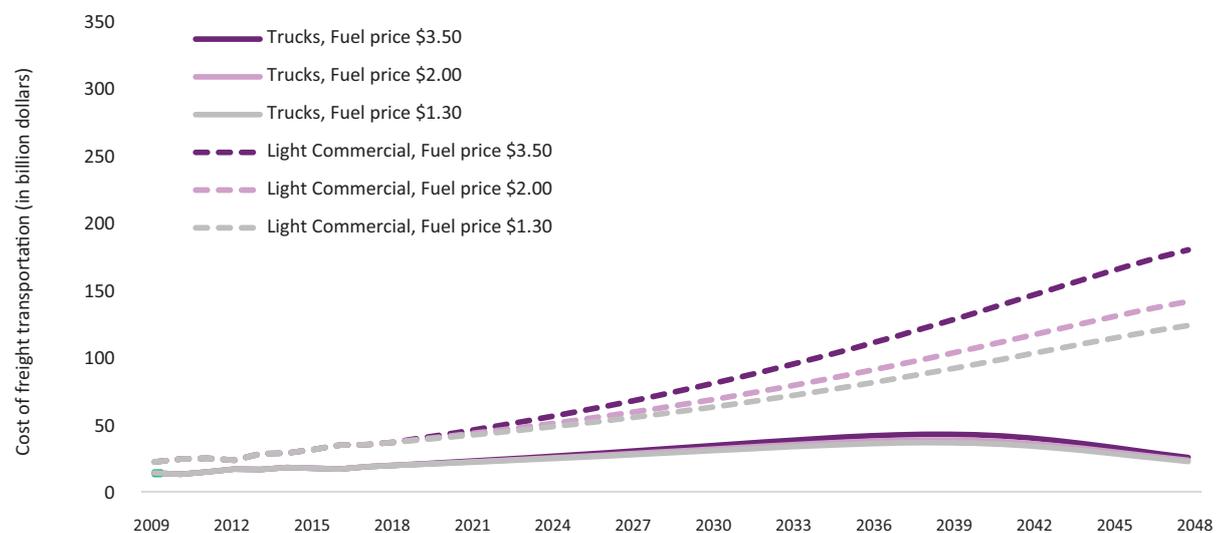
Off-peak, on-demand

Figure 120. Time series of modelling projections of cost of freight transport projected out to 2048 by fuel price per litre under Off-Peak, On-Demand scenario

Data source: CSIRO TraNSIT model[183] and Data61 estimates
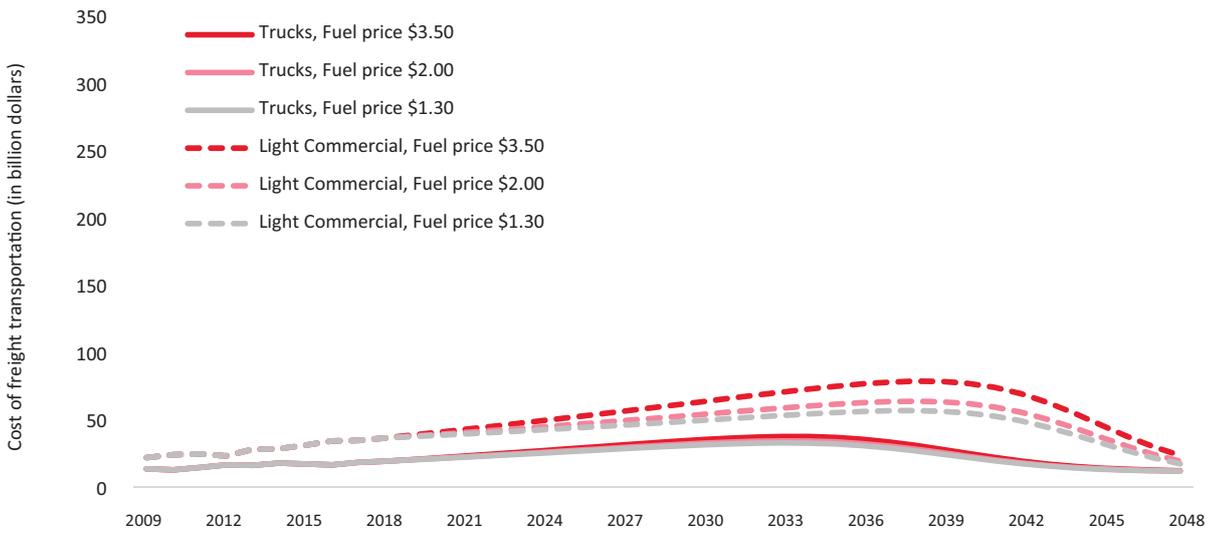
Cruise control

Figure 121. Time series of modelling projections of cost of freight transport projected out to 2048 by fuel price per litre under Cruise Control scenario
Data source: CSIRO TraNSIT model[183] and Data61 estimates
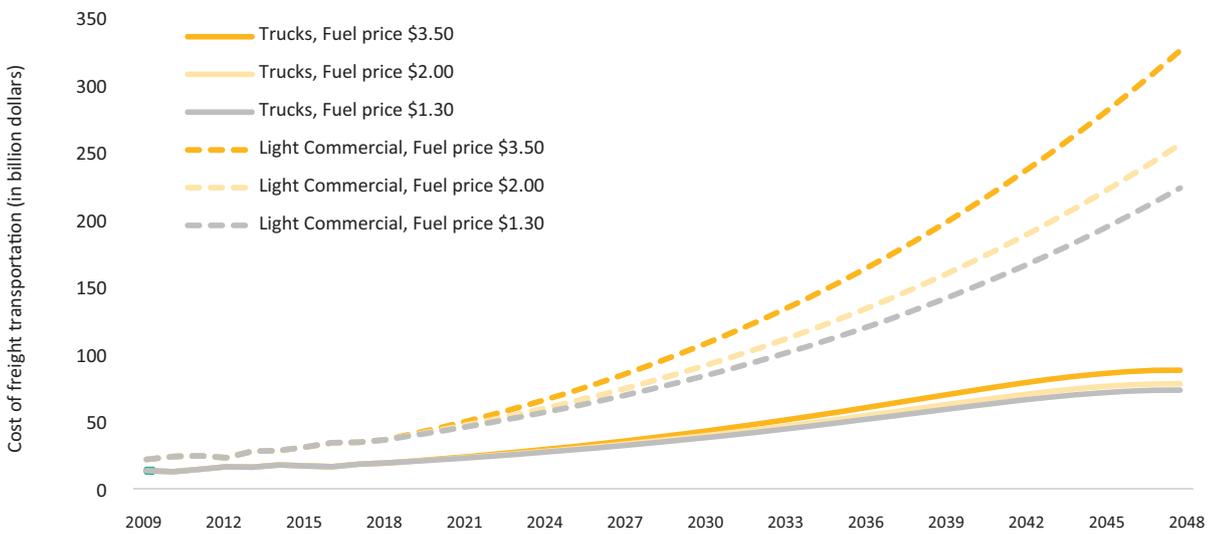
Suburban streets

Figure 122. Time series of modelling projections of cost of freight transport projected out to 2048 by fuel price per litre under Suburban Streets scenario
Data source: CSIRO TraNSIT model[183] and Data61 estimates
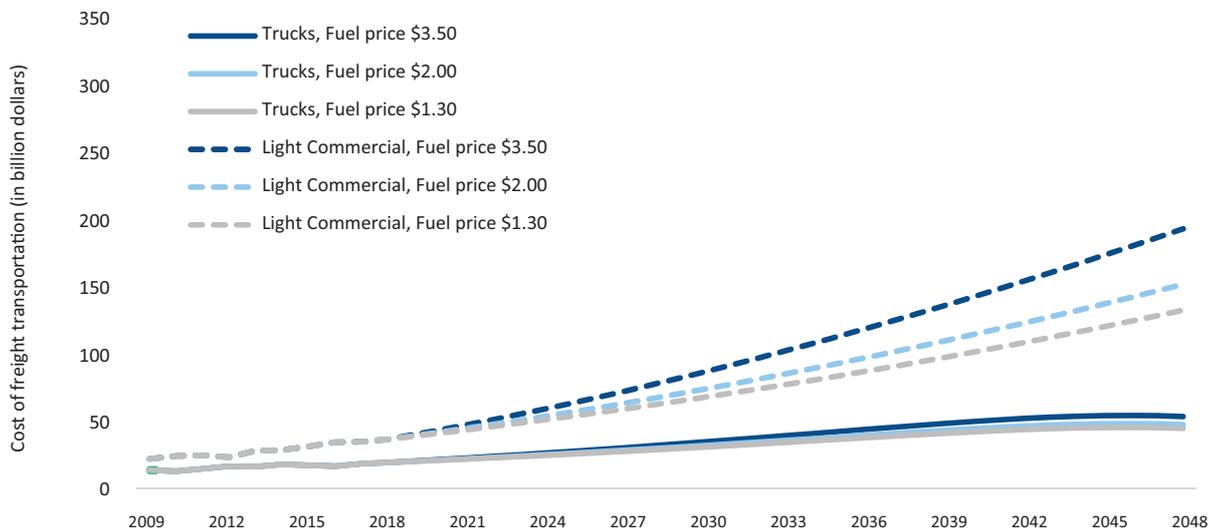
Bumper to bumper

Figure 123. Time series of modelling projections of cost of freight transport projected out to 2048 by fuel price per litre under Bumper to Bumper scenario

Data source: CSIRO TraNSIT model[185] and Data61 estimates

Cost of excessive congestion

Off-peak, on-demand

Figure 124. Time series of modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT) in Greater Brisbane area projected out to 2048 under Off-Peak, On-Demand scenario

Data source: Data provided by TMR and Data61 estimates

Cruise control

Figure 125. Time series of modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT) in Greater Brisbane area projected out to 2048 under Cruise Control scenario

Data source: Data provided by TMR and Data61 estimates
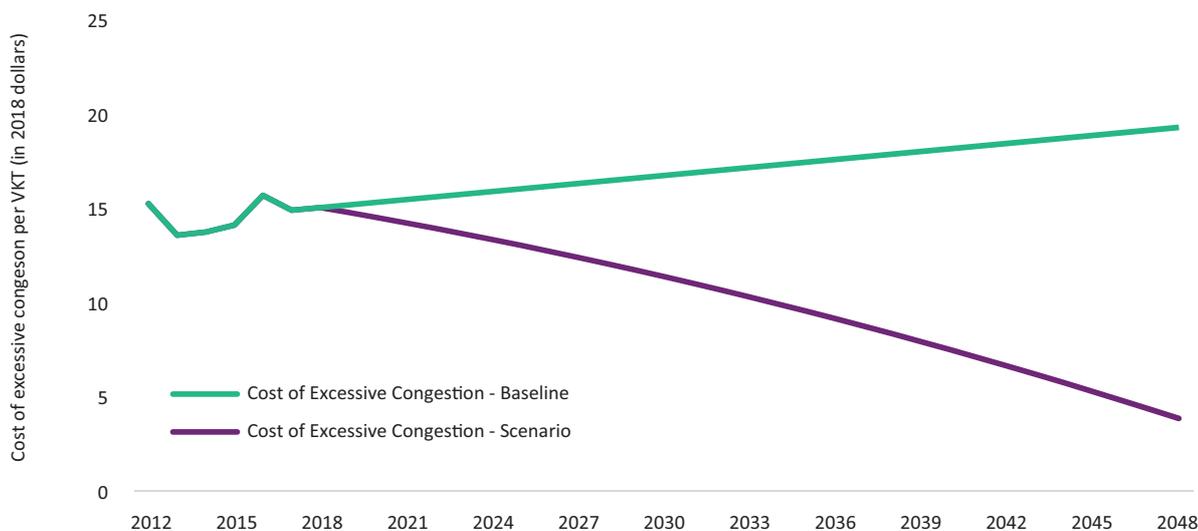
Suburban streets

Figure 126. Time series of modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT) in Greater Brisbane area projected out to 2048 under Suburban Streets scenario

Data source: Data provided by TMR and Data61 estimates
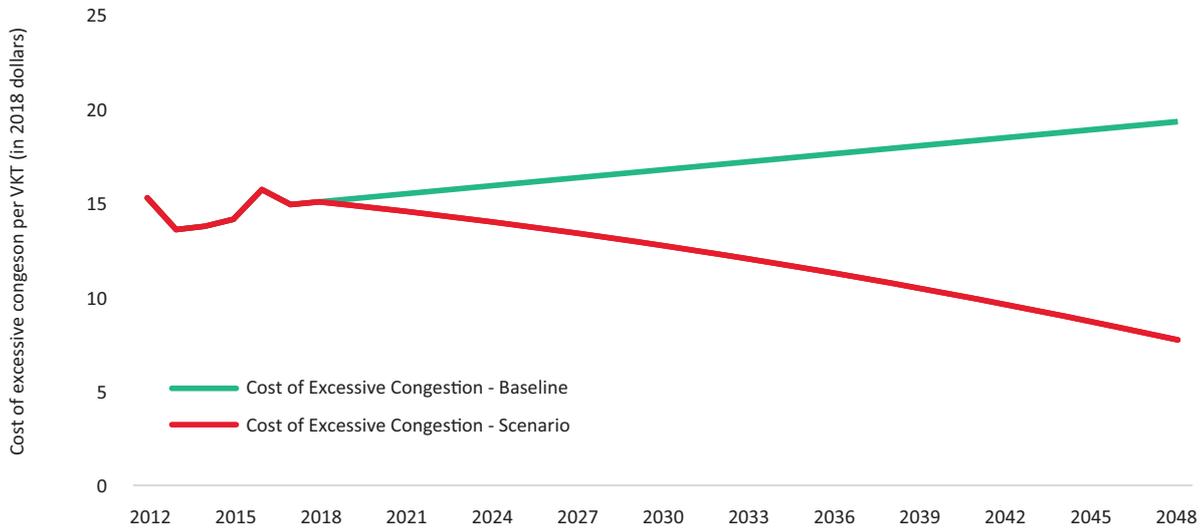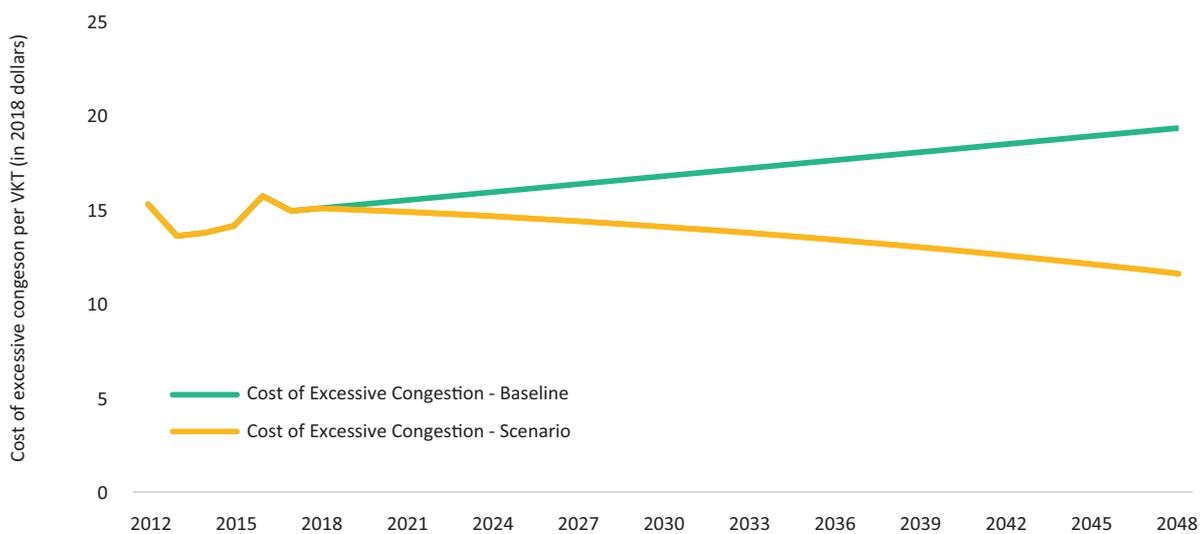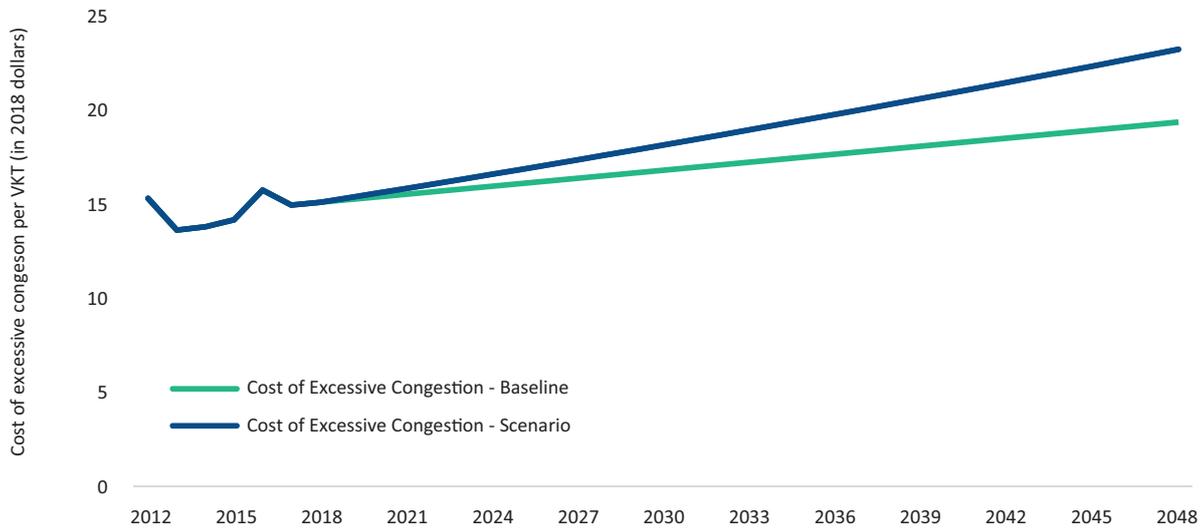
Bumper to bumper

Figure 127. Time series of modelling projections of cost of excessive congestion per vehicle kilometre travelled (VKT) in Greater Brisbane area projected out to 2048 under Bumper to Bumper scenario

Data source: Data provided by TMR and Data61 estimates

Greenhouse gas emissions

Baseline

Figure 128. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by vehicle type projected out to 2048 under Baseline scenario

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Figure 129. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by fuel type projected out to 2048 under Baseline scenario

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Off-peak, on-demand

Figure 130. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by vehicle type projected out to 2048 under Off-Peak, On-Demand scenario

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates
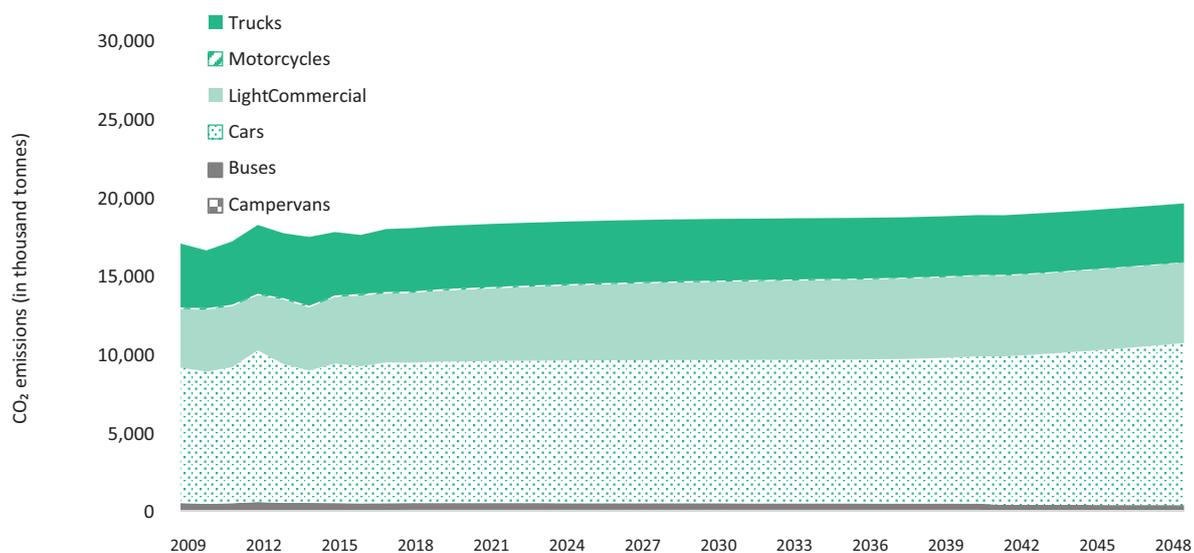
Figure 131. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by fuel type projected out to 2048 under Off-Peak, On-Demand scenario

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[15] Department of Environment and Energy;[186] and Data61 estimates
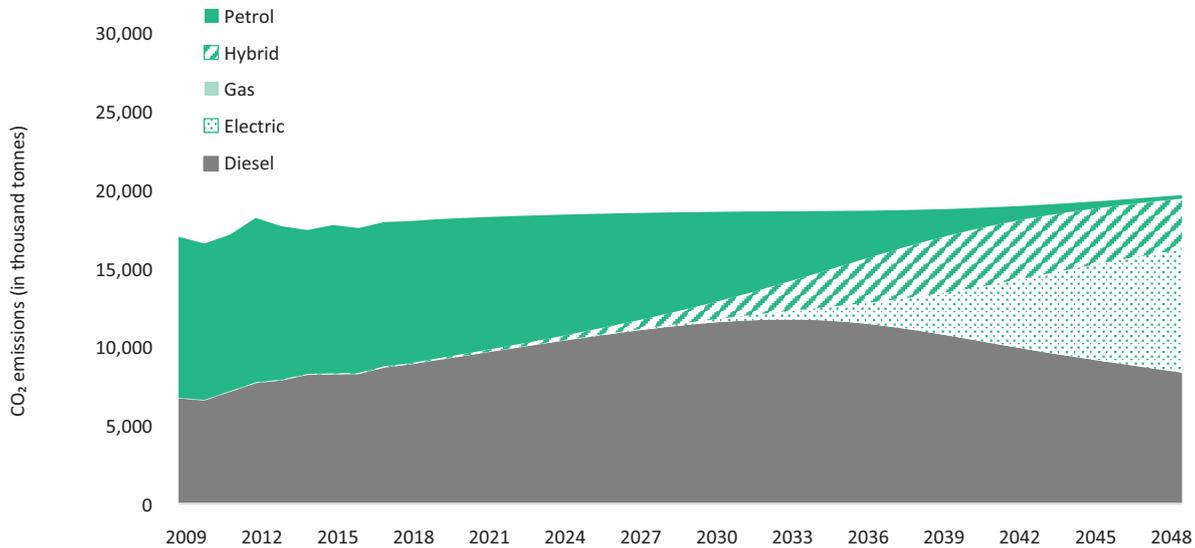
Cruise control

Figure 132. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by vehicle type projected out to 2048 under Cruise Control scenario
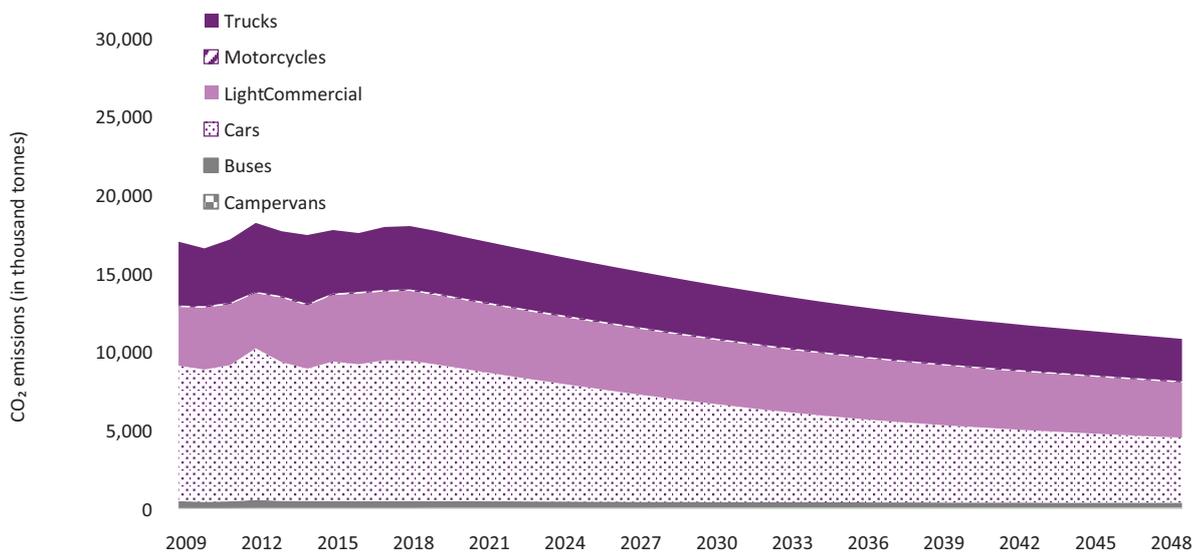
Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Figure 133. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by fuel type projected out to 2048 under Cruise Control scenario
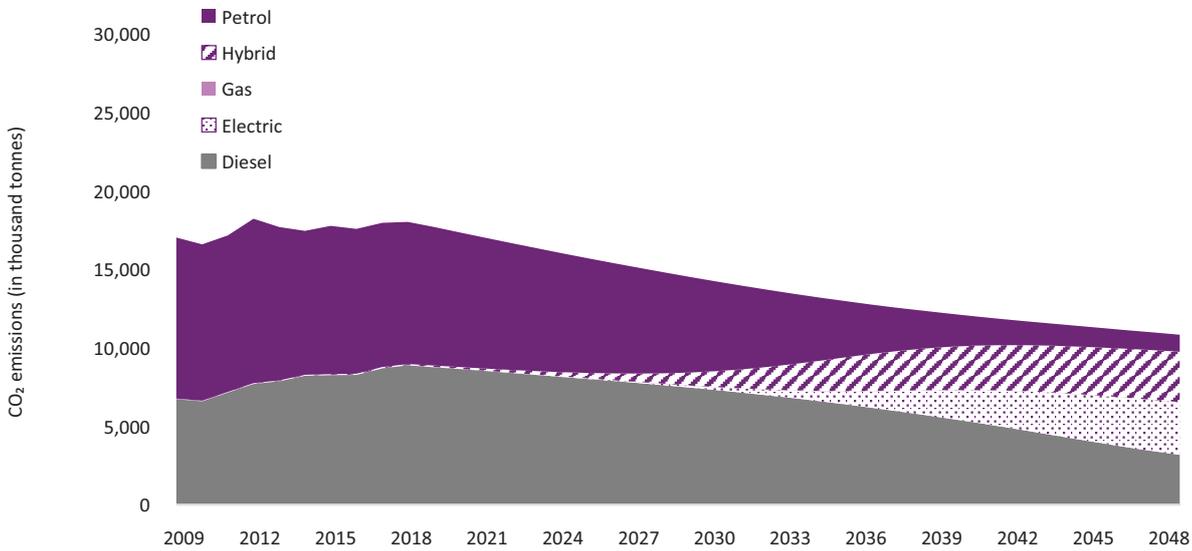
Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Suburban streets

Figure 134. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by vehicle type projected out to 2048 under Suburban Streets scenario

Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Figure 135. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by fuel type projected out to 2048 under Suburban Streets scenario
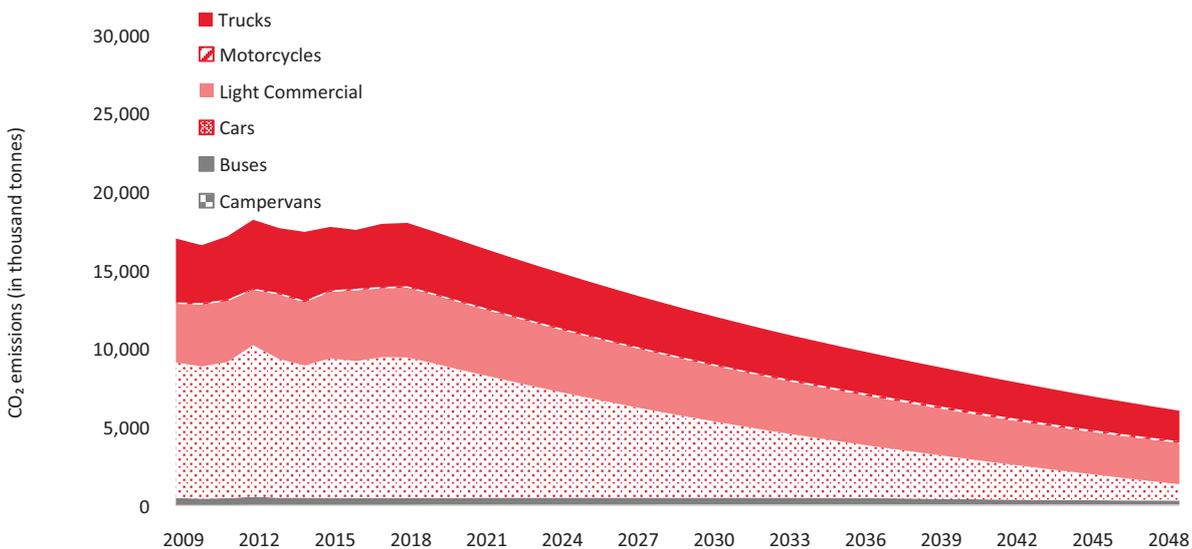
Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Bumper to bumper

Figure 136. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by vehicle type projected out to 2048 under Bumper to Bumper scenario
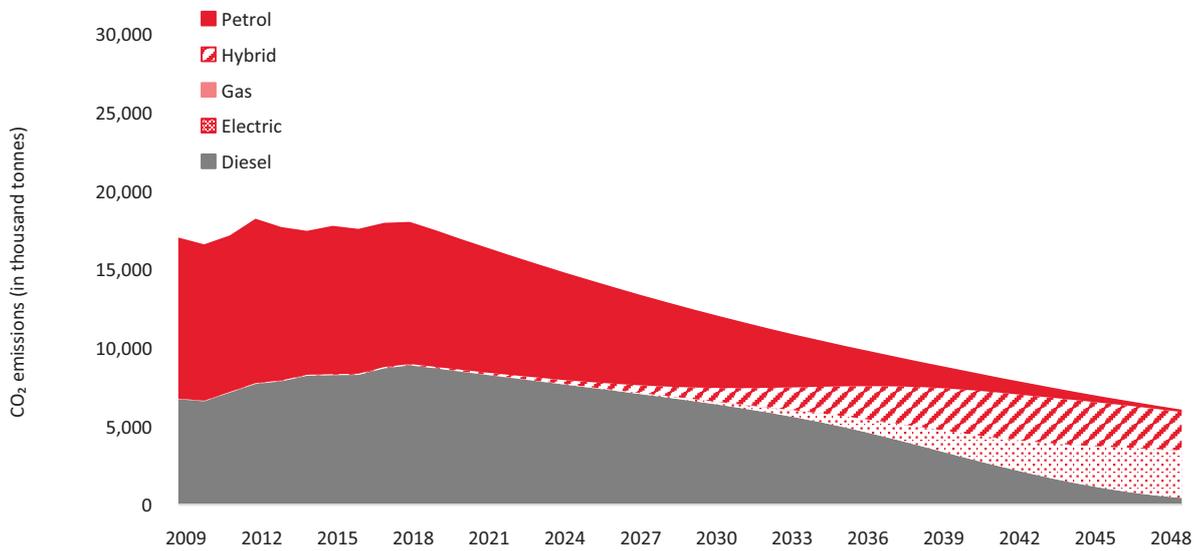
Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

Figure 137. Time series of modelling projections of greenhouse gas emissions across the road vehicle fleet by fuel type projected out to 2048 under Bumper to Bumper scenario
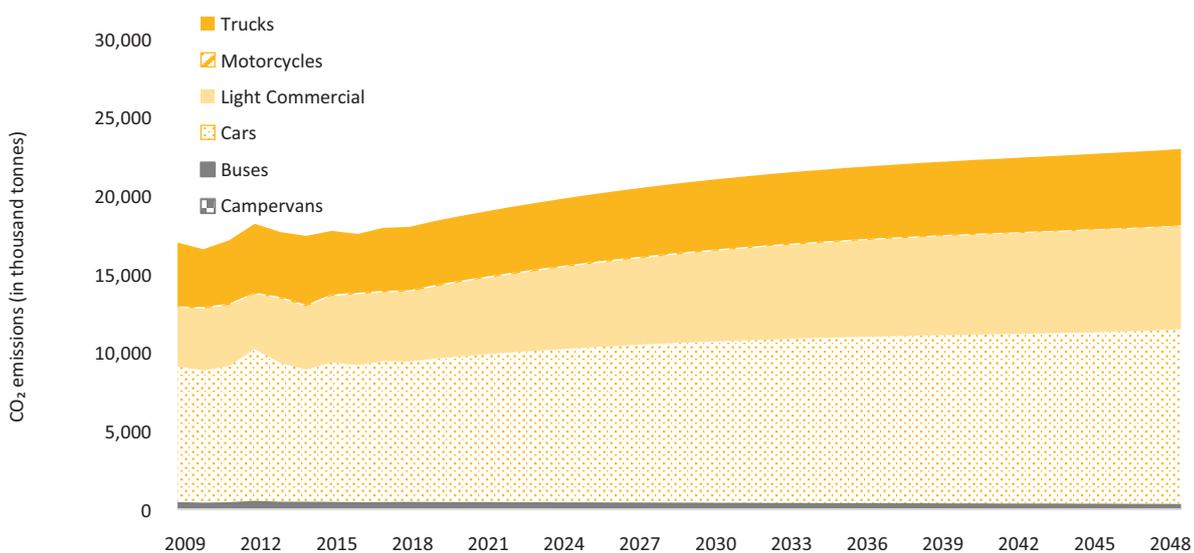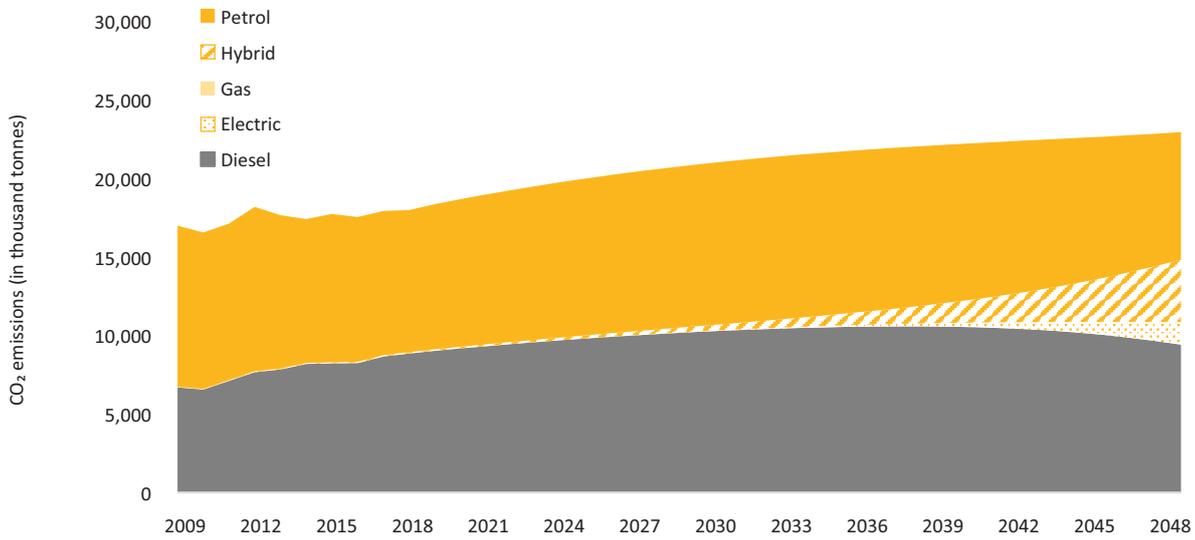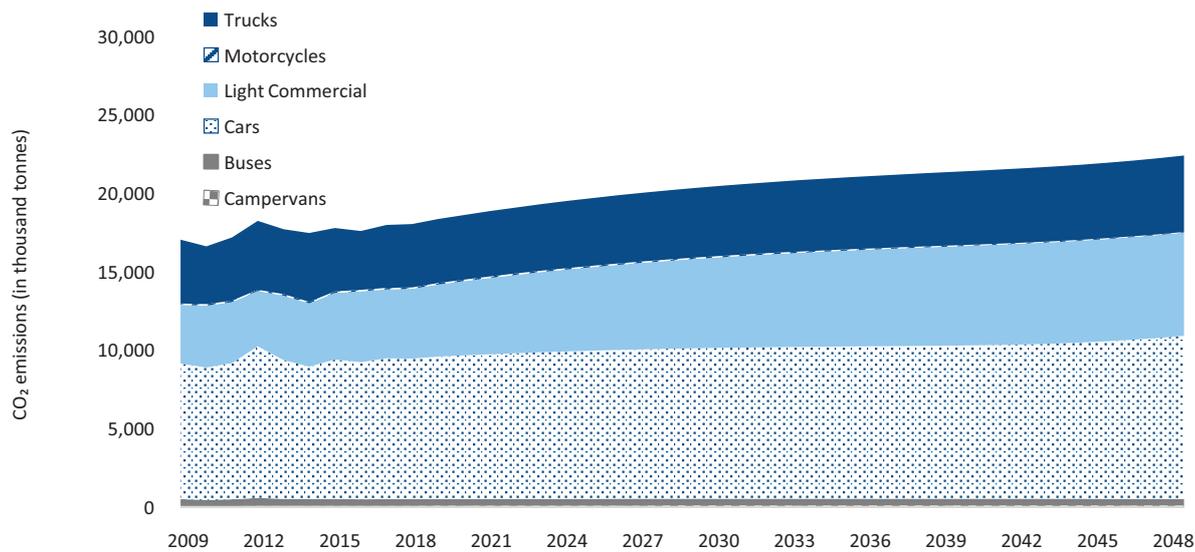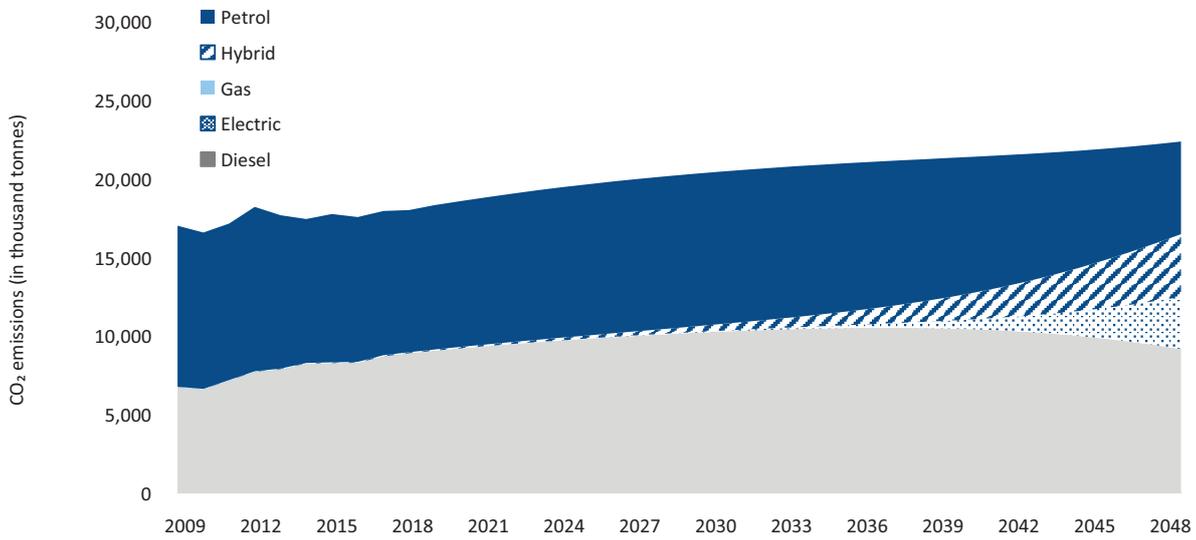
Data source: Queensland Department Transport and Main Roads; Australian Bureau of Statistics;[179] Reedman & Graham;[185] Department of Environment and Energy;[186] and Data61 estimates

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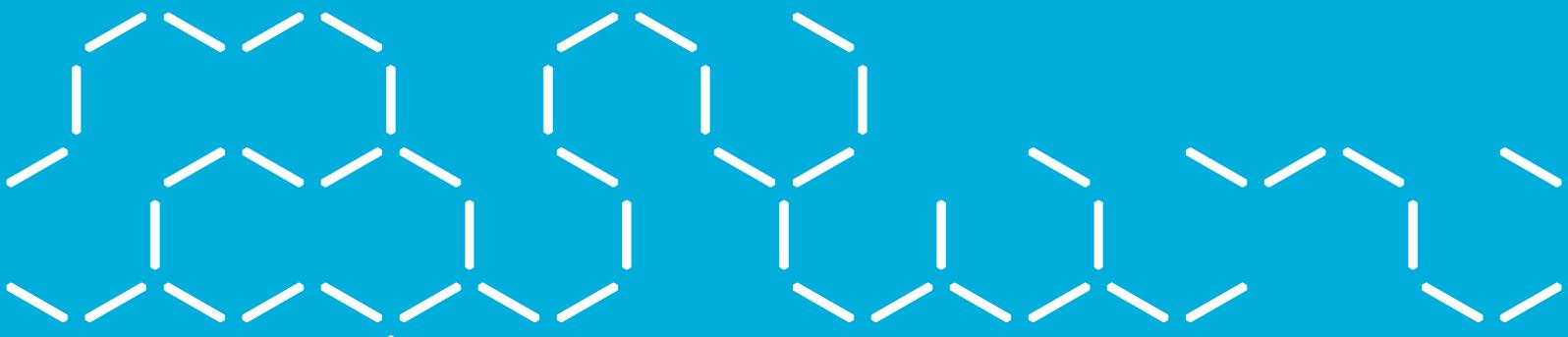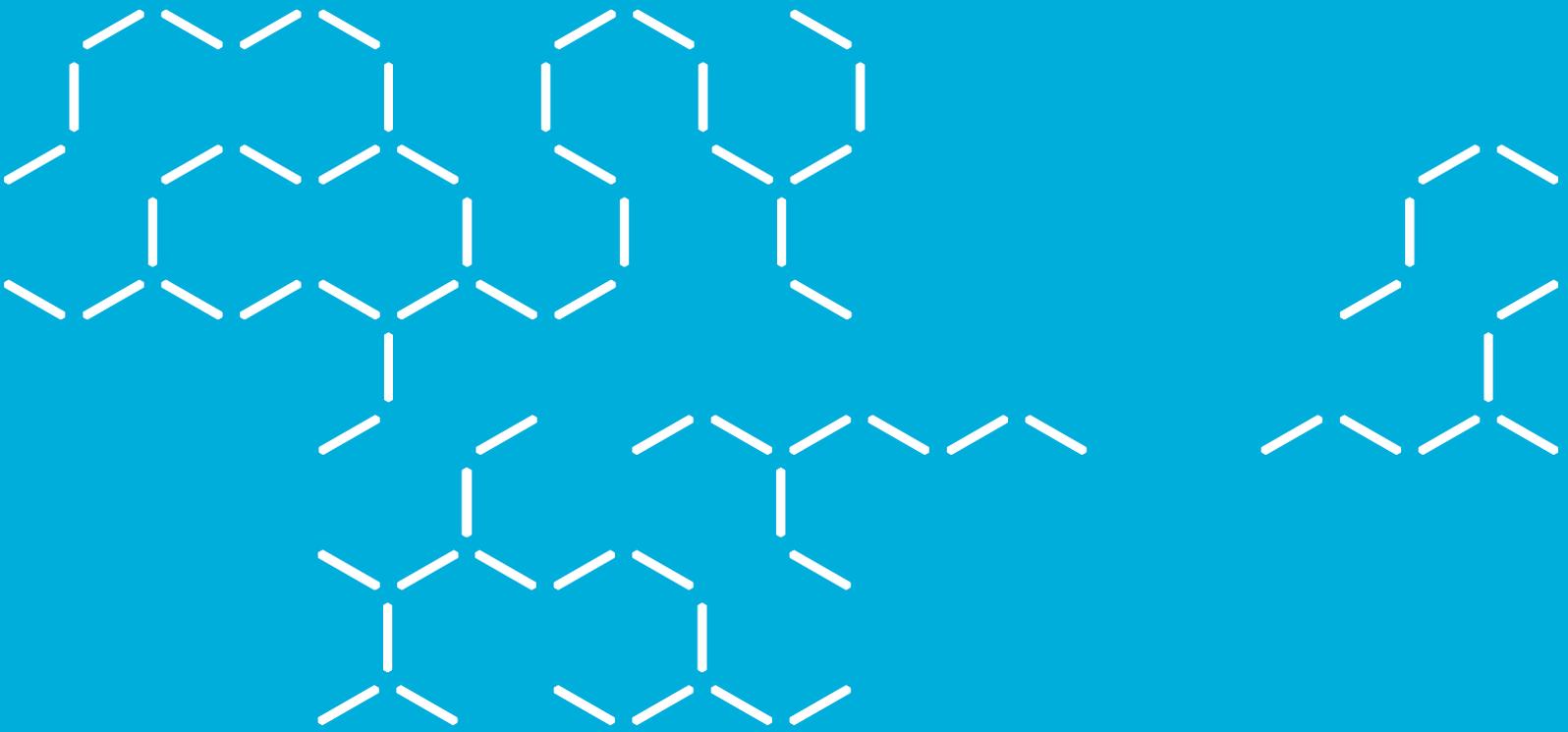
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