Transurban

Industry report

Smart Roads, Smart Trucks trial

May 2025

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1. Trial snapshot

Exploring the role of smart road solutions in advancing autonomous trucks

Transurban's 2024 Smart Roads, Smart Trucks trial built on previous connected and automated vehicle (CAV) trials we've conducted over the past eight years. This trial explored the role advanced road infrastructure technologies – or 'smart road solutions' – may have in improving safety, efficiency and productivity of autonomous (self-driving) trucks in the future.

The on-road trial was originally intended to involve two trucks equipped with automated driving systems (ADS), operating in autonomous mode during overnight periods across an extended route. At all times, a specially trained vehicle supervisor would be in the driver's seat, ready to take over. In response to stakeholder feedback, we adapted our on-road trial approach so professional drivers always maintained control of the vehicles, with the ADS systems collecting data on the technology's performance.

Trial components

ON-ROAD DATA COLLECTED

Drivers completed over 4,100km of data collection with zero safety events.

MULTIPLE SCENARIOS TESTED

Two trucks driving an end-to-end freight route experiencing varying road conditions across time of day, traffic conditions and road classes (for example, local road, managed motorway, highway).

LIVE DATA EXCHANGE

Real-time data exchange between the trucks and Transurban's smart road solution.

SIMULATION DATA

Simulations assessed what the autonomous trucks' performance would have been, both with and without Transurban's smart road solution.

What we learned

ROUTE AND LOGISTICS

The movement of container freight along the trial route seems well suited to autonomous trucks.

SAFETY PERFORMANCE

Indicative results from the on-road phase showed autonomous trucks could safely handle the trial route and conditions without infrastructure support. However trucks' decision making can be enhanced when supported by additional data from the smart infrastructure.

ADVANCED AWARENESS MEANS EARLIER DECISION MAKING

Smart road solutions may assist autonomous truck decision making by providing advanced awareness of dynamic road and traffic conditions. This enables trucks to make earlier decisions which can benefit safety, efficiency and performance.

STAKEHOLDERS

Constructive collaboration across government and industry stakeholders, and building community acceptance and readiness, are both critical to unlock potential benefits of autonomous trucks.

2.The state of road freight

A growing industry under increasing strain

Australia's road freight industry is under significant pressure, with more challenges ahead. As our cities and populations grow, the demand for goods – and associated freight volumes – is increasing. Road freight volumes are expected to grow 77% between 2020 and 2050,[1] alongside overall traffic growth. Road congestion is forecast to cost Australia around $39 billion a year by 2031,[2] which can add to the cost of everyday items through increased fuel, vehicle operating and driver costs, and delivery delays which is an extra cost burden for businesses.

This increasing demand is placing pressure on drivers, resulting in occupational health and safety concerns. Truck driving is one of Australia's most dangerous jobs, with drivers facing a 13-fold increased risk of fatal injury compared to workers in other occupations.[3] And heavy trucks are overrepresented in road death statistics, accounting for just 2% of vehicles on the road in Australia[4] but involved in 15% of all road deaths.[5]

Working in a profession associated with shift work, spending long hours in a sedentary (seated) position, operating under time pressure and in social isolation,[6] truck drivers are at increased risk of injury compared with most other professions, and also experience below-average health outcomes.[7]

A longstanding skilled driver shortage and an aging workforce are further compounding the industry's challenges. The existing driving shortfalls and increasing demand mean one in three drivers are regularly working longer (overtime) hours.[8] And forecast growth in the sector suggests the driver shortfall is poised to increase,[9] at a time when the median age of a truck driver is 48, compared to 39 for all occupations.[10]

[1] Bureau of Infrastructure and Transport Research Economics, *Australian aggregate freight forecasts – 2022 update (Summary)*, bitre.gov.au, November 2022, page 1
[2] Infrastructure Australia, *Urban Transport Crowding and Congestion – The Australian Infrastructure Audit 2019 Supplementary report*, infrastructureaustralia.gov.au, 2019, page 6
[3] T Xia, R Iles, NS, D Lubman, et al, Driving Health Report No 2: Work-related injury and disease in Australian truck drivers, Insurance Work and Health Group, Faculty of Medicine Nursing and Health Sciences, Monash University, 2018
[4] Australian Bureau of Statistics, *Motor Vehicle Census, Australia*, abs.gov.au, 31 January 2021, accessed April 2025
[5] Bureau of Infrastructure and Transport Research Economics, *Road Trauma Involving Heavy Vehicles—Annual Summaries*, bitre.gov.au, January 2023
[6] Ting Xia, Ross Iles, Sharon Newnam, Alex Collie, *National Transport and Logistics Industry Health and Wellbeing Study Report No 2: Work-related Injury and Disease in Australian Truck Drivers*, research.monash.edu, Monash University, May 2018
[7] A Bratanova, C Mason, H Pham, D Evans, E Schleiger, E Grimberg, G Walker and K Bulled, *Challenges and opportunities for the middle-mile road freight workforce in Australia in the era of transport automation*, CSIRO and Data 61, report commissioned by Transurban, 2024, page 10
[8] KPMG, *The Potential Economic Benefit of Middle Mile Autonomous Trucks in Victoria,* report commissioned by Transurban, October 2023, page 28
[9] KPMG, *The Potential Economic Benefit of Middle Mile Autonomous Trucks in Victoria,* report commissioned by Transurban, October 2023, page 10
[10] Jobs and Skills Australia*, Occupation and Industry Profiles – ANZSCO 7331 Truck Drivers*, jobsandskills.gov.au, accessed April 2025

An additional challenge facing the road freight industry is vehicle emissions. Freight transport was responsible for 26% of Australia's transport emissions in 2020, with almost half (12%) attributed to articulated trucks.[11]

These challenges are not unique to Australia. The themes of increasing road freight demand, driver shortages, aging workforces, and striving for improved safety and emissions outcomes are global. We can benefit from progress around the world by applying learnings to our unique sector and conditions.

Read more about the future of road freight in our Transurban Insights: The Future of Freight report

The role of technology

As technology continues to advance globally, we are seeing the freight industry exploring autonomous driving solutions as a key enabler for increasing freight capacity, addressing driver shortages and enhancing safety. Testing and pilots are well progressed in markets such as the United States.

There's no one solution for the complex and wide-reaching challenges facing road freight - but new technology has played a key role in improving the safety and efficiency of our roads – and it will continue to be part of the solution, with autonomous vehicles likely to play an increasingly important role.

Transurban has been an early adopter of on-road technology to improve safety, reduce emissions and keep traffic moving. As vehicle technology and capability advances, so too must our road infrastructure technologies, to help keep our cities moving.

[11] Department of Climate Change, Energy, the Environment and Water, *Australia's emissions projections 2024*, dcceew.gov.au, 2024, page 60. Total articulated truck emissions figure calculated as proportion of total transport emissions

Targeting key trip types with autonomous trucks

The road freight supply chain is complex and involves a wide range of driving tasks, encompassing multiple vehicle types, travel patterns and delivery types, spanning everything from large container trucks travelling to and from ports to suburban deliveries of online shopping orders.

Automated driving technologies are but one tool the freight industry could adopt as both freight demand and pressure on available drivers continues to increase. While automation is not the answer for all driving tasks – for example, it's not suited to tasks where drivers must interact with customers – this tool is being explored in multiple countries around the world, applied in specific trip types.

In Australia, trips that follow repeatable paths along highways and urban motorways – such as between distribution hubs – is where automation could prove beneficial in helping to meet forecast freight demand increases. For example, autonomous vehicles could make these hub-to-hub trips on urban motorways by travelling in a dedicated lane overnight – reducing interfaces with other road users by travelling outside peak travel times.

Hub-to-hub trips along motorways represent approximately 4.6% of all Victorian freight movements.[12] If just 5% of these truck movements were automated by 2040, it could deliver an estimated $2.2 billion of direct economic benefits to the state.[13] This could be achieved by shifting the freight task to overnight, yielding both freight-user benefits (travel time, driver time and vehicle operating cost savings), and community benefits (improved safety, congestion and environmental outcomes).

To date, despite significant trial activity, autonomous trucking has yet to move into commercial operation on public roads and motorways at any significant scale, either here or overseas. This is partly due to the complex and dynamic road environment – challenging scenarios can arise at any time on any road. There's a long list of 'edge cases' (rare, unpredictable scenarios that fall outside normal driving conditions) autonomous trucks need to handle to operate safely and efficiently before they can be commercially viable. Advanced road infrastructure technologies – smart roads – could be well positioned to help solve these edge cases.

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[12] KPMG, *The Potential Economic Benefit of Middle Mile Autonomous Trucks in Victoria*, report commissioned by Transurban, October 2023, page 26, Figure derived from estimated 2020 road freight demands (Table 4.3)
[13] Ibid, page ii

3.Transurban's smart road technology

Transurban is a toll road developer and operator, and we are exploring the role our smart roads can play in solving some of the freight challenges outlined above.

Our roads connect ports, airports and distribution centres with key activity centres and freight routes – an average 383,000 large vehicle trips are taken on our roads every day.[14] And our roads are increasingly relied upon for moving freight: large vehicle numbers on our roads have grown 57% over the past decade.[15]

Alongside this growth in road freight, the technology we use to operate our roads is getting smarter, and connected and automated vehicle (CAV) technologies continue to advance. These technologies have reached the point where smart road solutions can fill automated driving system (ADS) awareness gaps. For example, on-road cameras and sensors can share data with an autonomous truck's ADS, helping the system 'see' what's happening beyond the range of its own sensors, including when sensors are occluded (blocked) and when the truck cannot access a full picture of the road ahead (for example, around corners).

Smart roads and smart trucks working together

Transurban has been testing how our smart roads could support the adoption of CAVs for nearly a decade. Our primary focus throughout has been identifying opportunities to improve safety and efficiency for everyone using our roads.

Our latest Smart Roads, Smart Trucks trial builds on our previous research and trials by expanding trial partners, route and technology capability, and government and industry collaboration. We worked with ADS-software developer Plus and heavy vehicle manufacturer IVECO to develop commercial grade vehicles suited to testing on Australian roads and collaborated with the Victorian Department of Transport and Planning (DTP) to deploy advanced road infrastructure technologies along the route. DTP also supported the operations planning and permitting, and we collaborated with industry stakeholders including the Port of Melbourne, the Victoria International Container Terminal, and Salta, located at each end of the route.

This trial explored the suitability of a 50km hub-to-hub (mostly) urban motorway route for future adoption of self-driving technologies. It also investigated the potential role of smart road solutions to assist autonomous truck operations and performance across a range of scenarios and operating conditions.

Smart truck partners

Plus

Plus is a global Silicon Valley-based autonomous driving software company. Highly automated trucks enabled by Plus technology are already delivering freight in the US. For this trial, Plus provided its state-of-the-art Level 4 autonomous driving software, SuperDrive, along with skilled technical and operational personnel to conduct the on-road trial phase. Plus also undertook the simulation phase modelling and shared its global commercial deployment experience throughout the trial.

IVECO
Drive the road of change

IVECO provided two S-WAY prime-movers (with advanced performance, comfort, and safety features) for this trial. The trucks were custom fitted with Plus sensors at IVECO's Australian Customisation and Innovation Centre, and the automated driving system (ADS) was integrated into the truck's systems.

[14] Average daily traffic (ADT) on Transurban's Australian assets as measured between July 2024 and March 2025 for Light Commercial Vehicles and Heavy Commercial Vehicles
[15] Excludes Westlink M7. Toll roads, including NorthConnex and WestConnex (Sydney), and Airportlink M7 (Brisbane), have been added to Transurban's portfolio since 2015

4. Trial scope, methodology and learnings

Scope

Following the success of Transurban's 2022 trial which saw an autonomous truck drive itself on a limited route over four weeks, the intention of the 2024 trial was to use a more advanced autonomous vehicle, again supervised by on-board safety driver, to expand the route and duration of a self-driving trial.

A key component of the trial was stakeholder consultation, which, while largely positive, identified concerns. In the interest of completing the trial within a reasonable timeframe, and to ensure stakeholder concerns were heard, the decision was made for the trial to be conducted with drivers operating the trucks at all times.

Consequently, the trial approach was adapted to focus on collecting data to evaluate how the truck would perform across a range of on-road scenarios and conditions, had it been operating in fully autonomous mode. The trial also investigated the potential benefits of integrating smart road solutions into a truck's automated driving system and assessed the suitability of this type of end-to-end route for potential future autonomous operations.

The trial comprised on-road evaluation and desktop simulation phases.

On-road evaluation

Method

ACTIVITIES

- Over 4,100 km of on-road 'shadow mode' data collected
- 50km end-to-end route along an urban freight corridor
- Smart road technology deployed along the route
- Real-time smart truck–smart road data exchange
- Level 4 automation capability tested (in shadow mode only)

Shadow mode

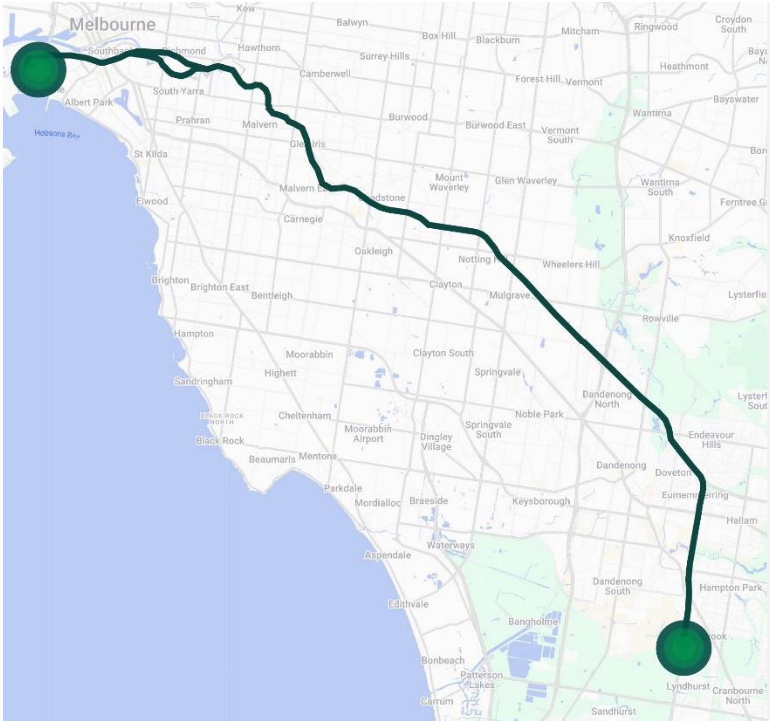
Autonomous vehicles are designed to operate by themselves, with no human behind the wheel, in certain locations and under a range of specific conditions.

However, for this trial, on-road data was collected with the trucks' autonomous systems operating in 'shadow mode'. This means that qualified and licensed drivers were in control of the trucks throughout their journeys – but the trucks' sensors and automated driving system were operating in the background. We subsequently analysed the truck's sensor and system data collected during the on-road phase, to develop an indicative evaluation of how the trucks would have performed (without driver intervention) had they been driving in autonomous mode across a wide range of conditions and scenarios.

Trial route and scenarios

The selected trial route – a 50km freight corridor between Port Melbourne and South Dandenong (Figure 1) – required the trucks to navigate complex manoeuvres including on-ramp motorway merging, mainline merging, travelling through signalised intersections and through both the Burnley and Domain tunnels.

Figure 1. Trial route



Throughout the trial the trucks encountered varied operating conditions including:

- different times of day
- various lighting and weather conditions
- varying congestion levels.

The trucks also encountered dynamic on-road scenarios, including:

- road works
- incidents
- debris on the road
- stopped vehicles
- emergency services

On-road learnings

Data collected during the on-road component was analysed to assess the indicative performance of the automated driving system. This analysis found that the autonomous trucks would have safely handled nearly all the on-road conditions and scenarios encountered. These results are illustrative of the fact autonomous vehicle developers are building vehicles capable of safely navigating all scenarios within a range of specific operating conditions.

However, autonomous vehicles can only react to scenarios, obstacles or conditions they can detect themselves, through their on-board sensors. And detection can be limited by perception range, road layout (such as around corners), and other obstructions (such as passing vehicles).

SMART ROAD SOLUTIONS COULD ASSIST AUTONOMOUS TRUCKS

While the autonomous trucks would have safely handled nearly all on-road scenarios encountered, smart road solutions could assist navigation around road works, debris and when unpredictable (such as speeding or weaving) vehicles are approaching.

Qualitative assessment of the data collected during the trial suggested that automated driving systems could benefit from smart road solutions that provide information on conditions beyond the perception range of a vehicles' onboard sensors, enabling earlier decision making. This could assist with optimising the automated driving system's efficiency and performance. It could also extend the period of time the automated driving system has to react to dynamically changing road scenarios, which means the truck is more likely to remain within the range of conditions where it can safely operate – improving its operational 'up time'.

For example, smart road solutions could help trucks' decision making in planning the best trajectory of travel, potentially reducing or eliminating the need to slow down, stop or restart, or taking action (such as changing lanes) earlier.

The on-road trial results also offer a strong indication that end-to-end freight routes could be a suitable use case for autonomous freight, and that smart infrastructure solutions can play a role in enabling this use case.

Desktop simulation

Method

ACTIVITIES

- Tested operational performance both without and with additional smart-road data
- Targeted challenging manoeuvres, including specific road configurations and conditions

The on-road trial phase was complemented by a range of desktop simulations. Simulation is a computer driven model of a real-world system, and is used to test scenarios, understand behaviour and predict outcomes. In this trial, simulation allowed us to model and test various scenarios and conditions at a scale we could not have achieved via on-road activity alone.

The simulations leveraged Plus's advanced simulation capabilities and enabled deeper analysis and comparison of autonomous truck performance with and without smart-road data under a range of conditions.

Simulating specific scenarios

Simulation was conducted after the completion of the on-road phase and scenarios focused on some of the more challenging manoeuvres, such as navigating through complex road configurations and driving conditions.

Simulations were modelled with both synthetic data (qualitative simulation), and real data (real data re-simulation). Real data was captured from the ADS and smart road solutions deployed at selected locations (on-ramp merge to motorway, and left turn yield and merge) during the on-road phase.

Scenarios tested

- Blocked lane ahead, mimicking real-life situations that can emerge unexpectedly, such as crashes, broken down vehicles and debris in the lane of travel.
- On-ramp merge to motorway, involving high-speed motorway traffic, an obstructed view and a relatively short distance for completing the merge
- Left turn (yield) and merge, entering a high-speed arterial road from a local road. Decision-making challenges in this scenario included: fast-approaching oncoming traffic, a complex intersection layout, a relatively short turning lane that then merges, dynamic traffic conditions and nearby traffic signals.

Our qualitative simulations tested a wide range of artificial scenarios, while our real-data simulation tested specific scenarios encountered during the on-road phase.

Simulation learnings

Both qualitative and real data re-simulation allowed us to evaluate the autonomous trucks' driving behaviour with and without data from the smart road solution.

The qualitative simulation results validated some of the challenges the autonomous trucks could experience and illustrated how smart road solutions could help alleviate these challenges.

Smart road solutions enable earlier decision making

Our simulations demonstrated that smart-road data can provide earlier insights into conditions beyond the perception range of the trucks' onboard sensors. Providing these earlier insights enabled earlier decision making which in turn optimised the automated driving systems' efficiency and performance.

SMART ROAD SOLUTIONS EXTEND INFORMATION AVAILABILITY

Smart road solutions can support more efficient vehicle manoeuvring, such as enabling fluid navigation through dynamic traffic environments, minimising the need to slow, stop and start.

In the real data re-simulation, the trucks' sensor data and smart-road data were fused in the simulation environment to reflect the real traffic conditions. This enabled us to test how the smart-road data would have impacted the autonomous trucks' decision-making process for these specific scenarios.

Some of the results of this real data re-simulation suggested that similar outcomes would occur in the real world as was illustrated in selected qualitative scenarios. This confirmed the challenge for trucks in optimally handling specific scenarios autonomously in certain conditions. It also demonstrated the benefit that could be achieved from smart road solutions (with further development of the solution in some cases).

This is a very encouraging signal that smart road solutions could benefit autonomous trucks through improved decision making and by expanding the range of conditions under which these vehicles can safely operate.

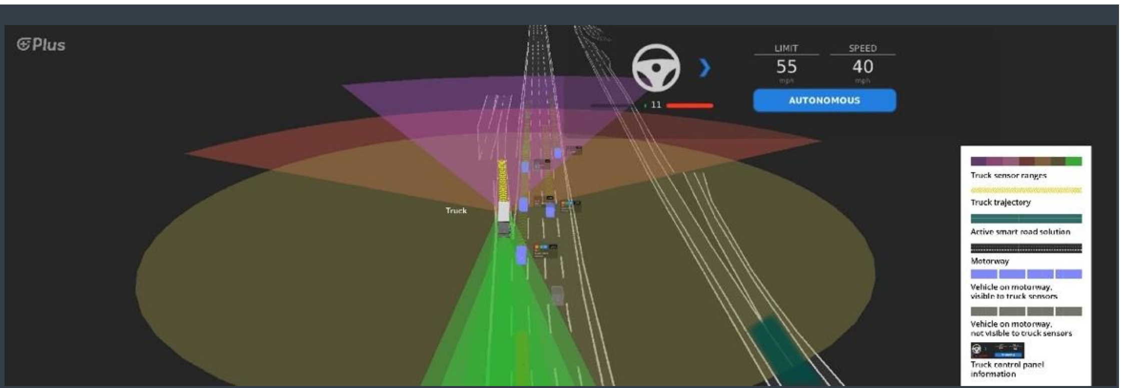
Smart roads can improve handling of specific manoeuvres

The following simulation examples demonstrate the effectiveness of smart road solutions in assisting in autonomous driving decision making.

View the simulation videos

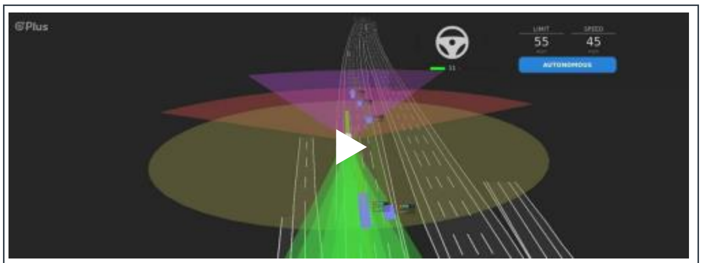
QUALITATIVE SIMULATION VISUALISATIONS

Visualisations provide intuitive understanding of smart road solution impact.



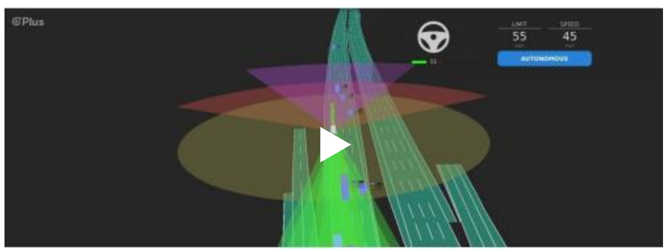
Blocked lane ahead

This simulation illustrates a scenario where the autonomous truck's lane is blocked and the smart road solution helps the truck avoid stopping for an obstacle that otherwise would have forced the truck to stop in the lane.



Without smart road solution

The autonomous truck detects the obstacle and is forced to stop in the lane behind the obstacle. Due to the busy adjacent lanes, by the time the truck perceives the blockage, it has insufficient space or time to change lanes.



With smart road solution

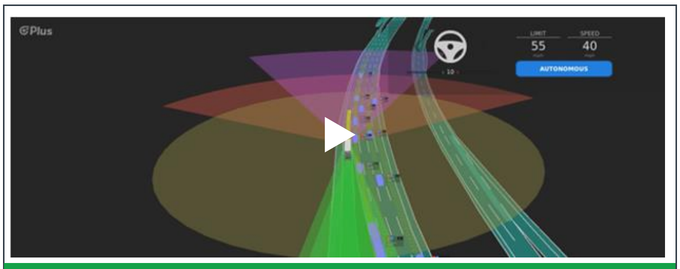
The autonomous vehicle is alerted to the obstacle ahead well in advance of approach, allowing it to perform a successful lane change and avoid a complete stop. This example demonstrates the effectiveness of smart road solutions in assisting ADS decision making.

On-ramp merge

This simulation illustrates an example of the truck merging onto a busy motorway with limited gaps, where the smart road solution helps the truck find a gap and complete the merge when it would otherwise have been unable to do so.

Without smart road solution

The autonomous truck approaches the merge and struggles to find a suitable merge window – its sensors cannot detect any available gaps due to occlusion. The truck is unable to complete the merge onto the motorway successfully and must exit the motorway at the off-ramp, requiring an extended detour to return to its route.



With smart road solution

The autonomous truck approaches the merge with advanced knowledge of the approaching traffic on the motorway, including information on an approaching suitable merge gap that would otherwise be occluded. The truck adjusts its speed to match the arrival of the merge gap and successfully merges onto the motorway.

Left turn (yield) and merge

This simulation illustrates a scenario where the autonomous truck must make a left-hand turn onto a busy arterial, and shows how the smart road solution helps the truck turn without having to first come to a complete stop at the intersection.

Without smart road solution

The autonomous truck approaches the intersection, comes to a complete stop, waits for an appropriate break in the oncoming traffic and completes turn when safe to do so.

With smart road solution

The autonomous truck has advance knowledge of the traffic conditions as it approaches the intersection. This assists the truck in detecting cross-traffic early and it adjusts its turning strategy accordingly. The truck can time its approach to the intersection and avoid coming to a complete stop, improving its manoeuvring efficiency and saving time and fuel.

Quantitative simulation

While the qualitative and real data re-simulations focused on specific scenarios, the trial's quantitative simulations modelled the autonomous trucks' behaviour across a broad range of real-world traffic conditions, both with and without smart-road data.

The simulation model varied parameters such as map topology, autonomous trucks' on-board sensor detection range and braking power, surrounding traffic density and the extent of smart-road data support.

The quantitative simulations assessed performance metrics relating to safety, fuel economy and traffic flow, and demonstrated that smart road solutions could improve autonomous truck performance across all metrics.

SMART ROAD SOLUTIONS COULD ENHANCE PERFORMANCE

The self-driving trucks' safety, fuel economy and traffic flow metrics improved with smart-road data, based on quantitative simulation.

5. The way forward

Autonomous trucks have the potential to address some of the biggest challenges facing Australia's road freight industry, and metropolitan motorways carrying repeatable freight tasks are likely to be well suited for initial adoption of autonomous technologies. Our trial demonstrated that while self-driving vehicle technology appears highly capable, smart road technology can have a valuable role to play.

Solving the challenges together

The automation of targeted freight use-cases – such as hub-to-hub transport – presents an opportunity to improve road safety outcomes, improve freight productivity and provide decongestion benefits to all road users. This could be achieved, for example, by shifting truck movements to less congested overnight periods and to operating within a dedicated lane.[16]

Collectively, these could help unlock the safety, efficiency and economic benefits of autonomous freight as a commercial proposition, helping meet the many challenges the industry faces.

Through this trial and our previous trials, we have encountered broadly positive stakeholder support to explore the role of innovative solutions – such as self-driving technologies – to prepare the freight sector to be fit for the future. A key learning from this trial has been the importance of building eco-system-wide dialogue and support – early and regular stakeholder engagement is encouraged. Trials such as this present an important opportunity for stakeholder voices and concerns to be heard and can galvanise industry and government alike to work together to solve the challenges to achieve a safer, more productive and more sustainable road freight sector.

The environment must be right

Alongside developments in autonomous driving systems and smart infrastructure integration, progress is needed in many other areas to realise the benefits of autonomous trucks in the freight sector.

This includes, in the lead up to any meaningful implementation, the coordinated development of a transition approach that incorporates:

- sufficient regulatory frameworks
- community and road user acceptance and readiness
- industry preparedness
- availability of autonomous driving technologies.

The integration of smart road solutions as a further technological safeguard to support the transition and adoption of autonomous trucks can play a key role to increase comfort levels across stakeholders.

Much can be learned from the automation of other industries, where over time, new and more skilled jobs are created in the sector.[17] Proactive collaboration and engagement with government, original equipment manufacturers, automated driving system developers, industry and impacted stakeholders, and the development of suitable pathways to build future workforce skills, will be essential.

Transurban looks forward to further opportunities to deploy smart road infrastructure solutions to help solve both current and future transport challenges.

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[16] KPMG, *The Potential Economic Benefit of Middle Mile Autonomous Trucks in Victoria,* report commissioned by Transurban, October 2023, page 36
[17] A Bratanova, C Mason, H Pham, D Evans, E Schleiger, E Grimberg, G Walker and K Bulled, *Challenges and opportunities for the middle-mile road freight workforce in Australia in the era of transport automation*, CSIRO and Data 61, report commissioned by Transurban, 2024, page 38

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