Auckland Transport Alignment Project

Technology Report

Role of emerging technologies

Contents

Preface

This is one of a series of research reports that were prepared as inputs to the Auckland Transport Alignment Project (ATAP). It is one of a number of sources of information that have been considered as part of the project, and which have collectively contributed to the development of the recommended strategic approach. The content of this report may not be fully reflected in the recommended strategic approach, and does not necessarily reflect the views of the individuals involved in ATAP, or the organisations they represent. The material contained in this report should not be construed in any way as policy adopted by any of the ATAP parties. The full set of ATAP reports is available at www.transport.govt.nz/atap.

1. Executive summary

The purpose of the technology workstream of the Auckland Transport Alignment Project (ATAP) is to understand the potential impacts of three specific areas of transport technology on Auckland's transport system and their implications for transport over the next 30 years. The three areas of transport technology are:

- Intelligent network management;
- Emerging vehicle technology
- Shared mobility.

These technologies were selected because they are expected to have the greatest potential impact on the performance of Auckland's transport system.

This report was prepared by officials from the Ministry of Transport, the New Zealand Transport Agency, Auckland Council and Auckland Transport. Analysis was peer reviewed by AECOM experts in the United States and New Zealand.

Intelligent Network Management

Intelligent network management encompasses a wide variety of distinct interventions designed to enable a comprehensive real-time understanding of network use, the ability to intervene to dynamically manage travel demand, and the associated data processing capability to perform these functions. Examples include: provision of sensors on the network to monitor traffic movements; adaptive traffic signals; dynamic lanes or information provision to manage demand; and staff capable of using advanced analytical tools to manage the transport network in real-time.

Benefits of intelligent network management include: improved optimisation of existing transport infrastructure (for example by managing traffic flows in response to congestion or incidents); better targeting of maintenance and renewals expenditure; and better planning of new infrastructure investment.

The current state of network management in Auckland is comparatively mature but there is still significant opportunity for improvement. Over the next ten years, the New Zealand Transport Agency and Auckland Transport have tentatively forecast investment of around $350 million in intelligent network management. Initial analysis indicates that additional investment of around $200 million would provide good value for money, enabling Auckland to take better advantage of the latest advances in transport technology and prepare the network for the roll-out and management of connected and automated vehicles (see below).

Emerging Vehicle Technology

Connected automated vehicles (CAVs) is a term used to describe vehicles that are both 'connected' and 'automated' – two distinct areas of vehicle technology. Connected vehicles enable communication between vehicles, infrastructure and other connected devices. Automated vehicles are equipped with technology which enables self-driving features, ranging from partial automation (like single-lane motorway autopilot, closely monitored by the driver), through to fully autonomous vehicles (which require no driver monitoring). Connected and automated vehicles have the potential to significantly improve network performance by increasing lane capacity (through shorter following distances and mitigation of start-stop shockwaves), improving safety (by removing human error, the cause of around 80% of traffic accidents), and improving travel time reliability.

However, the extent of these impacts will depend on what proportion of the fleet are CAVs, and the degree to which efficiency benefits are offset by induced demand. For example, fully autonomous vehicles may stimulate demand by making travel easier for certain groups (e.g. the elderly, people with disabilities or children) or they may encourage more travel as time spent in the vehicle can be used for other purposes. In addition, fully autonomous vehicles could add to congestion through re-positioning trips to pick up new users or park.

While it is difficult to estimate the uptake and impacts of CAVs in Auckland given a high degree of uncertainty, we anticipate that it could be at least 10 years before they start to make a significant difference to network performance. When they do arrive in significant numbers, their impact on increasing lane capacity will be much more prominently felt on the motorway network than on local roads (due to the effect of intersections and more complicated vehicle movements on local roads).

Based on synthesising findings from a comprehensive literature review and taking into account Auckland’s particular characteristics, we have made the following estimates for the uptake of CAVs and their corresponding impact on lane throughput. The broad ranges reflect uncertainty regarding the speed at which the technology will become commercially attractive and the extent of any potential central or local government interventions to accelerate uptake.

	2026	2036	2046
CAVs (proportion of fleet)	6 - 11%	22 - 52%	60 - 90%
Increase in motorway throughput[1]	+0.7 – 1.3%	+3.8 – 16.3%	+21.3 – 65.3%
Increase in local road throughput	+0.2 – 0.4%	+1.3 – 5.4%	+7.1 – 21.8%

Shared Mobility

Shared mobility is the shared use of transport modes other than public transport. Examples include car sharing, ride sharing and bicycle sharing, often facilitated by websites or smart phone apps.

Potential benefits of shared mobility include: reducing congestion by increasing vehicle occupancy at peak times; extending public transport catchment areas through better first and last leg connections; and providing greater access and choice to users of the transport system.

In the long run, shared mobility may extend to the widespread use of shared fleets of CAVs if they present a more cost-effective travel option than private vehicle ownership for the public.

[1] Measured as vehicle/lane/hour.

The elimination of most labour costs with driverless vehicles may result in shared CAVs providing a compelling alternative to private vehicle ownership and some public transport services.

Shared mobility is also key to uptake of ‘mobility as a service’ – the concept that urban travel can be consumed as a service, rather than provided through personally owned modes of transportation. Mobility as a service could work by combining public transport and shared mobility options through a single system (for example a smart phone app), which recommends, manages and pays for the trip.

More work is needed to further investigate the behavioural drivers behind decisions to share transport and what both central and local government could do to facilitate a widespread shift.

Combined impact of technologies

In the long-term, shared fleets of CAVs supported by intelligent network management have the potential to dramatically improve travel time, accessibility and congestion outcomes for Auckland. The impact on traditional public transport is unclear with the potential that patronage could increase or decrease, depending on the extent to which shared CAVs compete against or complement services. Investment in these emerging transport technologies is likely to deliver good value for money for central and local government given the scale of potential benefits and their relatively low cost to implement in comparison to traditional infrastructure.

Further work is required to better understand the potential implications of emerging technology on demand for transport infrastructure. However the need for additional motorway capacity and the provision of lower-demand public transport services appear particularly sensitive to changes in vehicle technology and shared mobility.

Recommendations

- Further investigate the case for increased investment in intelligent network management of around $200 million over the next 10 years (in addition to what is already tentatively forecast by the New Zealand Transport Agency and Auckland Transport over this period).
- Undertake detailed research into the drivers of shared mobility and what central and local government could do to facilitate a widespread shift; including the provision of enabling and flexible regulation, development of an open data policy, and conducting shared mobility trials.
- Further investigate how to best prepare for and potentially accelerate the uptake of connected and automated vehicles.
- Ensure transport agencies involved in Auckland build staff capability in intelligent transport systems and work collaboratively to deliver outcomes.
- Ensure that potential changes in transport technology are taken into account when planning future infrastructure to reduce the chance of stranded investment.

2. Purpose and approach to analysis

2.1. Purpose and scope

The purpose of the technology workstream of the Auckland Transport Alignment Project (ATAP) is to understand the potential impacts of three specific areas of transport technology on Auckland's transport system over the next 30 years. The three areas of transport technology are:

- Intelligent network management;
- Emerging vehicle technology
- Shared mobility.

These technologies were selected because they are assumed to have the greatest potential impact on the performance of Auckland's transport system.

Road pricing is dealt with elsewhere in ATAP, while initiatives to encourage the uptake of electric vehicles and provision of supporting infrastructure is national in scope, with work taking place outside of ATAP.[2]

2.2. Approach to analysis

Preface

Cities around the world are grappling with how to make best use of existing transport technology and plan for the introduction of emerging technology that could significantly alter the nature of urban transport.

The degree to which existing technology is utilised to enable better network management varies considerably city by city, but there is broad international agreement that further investment can yield significant benefits and is value for money.

What is less certain is the timing and impact of emerging technologies, particularly connected and automated vehicles (CAVs) and changes in behaviour towards shared mobility. Very few cities have attempted to forecast the impacts of these technologies on their urban transport systems, yet many acknowledge the potential for a paradigm shift in performance. In response to this uncertainty, a number of jurisdictions are prioritising enabling regulation and trials of CAVs.

Approach

Given the high degree of uncertainty inherent in assessing the potential uptake and impact of transport technology over a 30-year horizon, the work adopted a scenarios-based approach to the analysis, informed by a comprehensive literature review. Projected impacts

[2] In May 2016, the Government announced its Electric Vehicles Programme, which aims to increase the uptake of electric vehicles in New Zealand. More information can be found on the Ministry of Transport's website at: http://www.transport.govt.nz/ourwork/climatechange/electric-vehicles/

were tested using the Auckland Regional Transport (ART) Model to better understand how these technologies could impact on Auckland's transport system.

Given time and modelling constraints, two scenarios were developed for the rate of technological development, utilisation and associated behaviour change over the next 30 years. One scenario reflects relatively conservative estimates for the uptake of new technology, while the other assumes uptake increases faster than expected, strongly supported by a concerted effort across central and local government.

Analysis was peer reviewed by AECOM experts in the United States and New Zealand. Drafts were shared with AUSTROADS and Dr Marcus Enoch (Senior Lecturer in Transport Studies at Loughborough University, England).

3. Intelligent network management

3.1. What is it?

Intelligent network management encompasses a wide variety of distinct interventions designed to enable a comprehensive real-time understanding of network use, the ability to intervene to dynamically manage travel demand, and the associated data processing capability to perform these functions. Examples include: provision of sensors on the network to monitor traffic movements; adaptive traffic signals; dynamic lanes or information provision to manage demand; and trained professionals using advanced analytical tools to manage the transport network in real-time.

Benefits of intelligent network management include: improved optimisation of transport infrastructure (for example by managing traffic flows in response to congestion or incidents); better targeting of maintenance and renewals expenditure; and better planning of new infrastructure investment.

3.2. Current state in Auckland

The current state of transport network management in Auckland is comparatively mature, but there is still significant room for improvement. Notable features of the system include: a relatively small sensor network, two transport network operations centres, the use of an adaptive traffic light control system (planned to be significantly upgraded soon), motorway ramp signalling, traveller information systems (variable messaging signs and websites), and an electronic card-based integrated ticketing system for public transport. Toll charging is carried out on one motorway section (the Northern Gateway). Real-time data analysis and dynamic management of the network are in their infancy.

3.3. Emerging technology and trends

Data collection and analysis

Data collection, analysis and distribution is at the heart of intelligent network management. Without a clear picture of network use, better investment decisions and real-time management of travel demand is not possible.

Closed circuit television cameras and various types of sensors are commonly used to gather information about network use, however their coverage is limited (typically only to key corridors). Extending the reach of sensors across more of the network enables a more comprehensive view of network performance and provides the data necessary for better travel demand management and investment decisions. Sensors however have significant capital and operating cost implications, and a cheaper alternative in third-party data is rapidly gaining prominence.

Data sourced from third parties is likely to play an increasingly important role in intelligent network management. Smart phones, wearable devices and connected vehicles provide a platform for data collection and distribution that does not directly rely on the provision of road-side sensors. Benefits of data sourced from third parties include; reduced cost to central and local government, faster technological upgrade and greater network coverage (assuming relative ubiquity of traveller connectivity). However, commercial sensitivity issues can limit the level of detail and therefore usefulness of third-party data for investment and network management decisions. Targeted investment in developing a more comprehensive sensor network, while actively exploring and leveraging third-party data, may therefore be the most prudent course of action going forward.

Data collected from various sources is most useful if it is available in a form that stakeholders in both the public and private sectors can easily use. Common data standards, aligned to emerging international standards, which take into account accuracy, reliability and privacy requirements, will be necessary to enable this.

Various types of software can be used to interpret and analyse transport data to help inform decision-making. There are three broad types of analytical tools; 'descriptive' (what is happening), 'predictive' (what will happen) and 'prescriptive' (what should the response be). Software to enable descriptive analytics is commonly used in network management today, whereas the more advanced predictive and prescriptive tools have yet to be widely employed (due to data and cost constraints). Once implemented, predictive and prescriptive analytics should enable a faster and more effective response to congestion and incident management.

In addition to data collection and analytical tools, a skilled workforce capable of managing a smart transport network will be needed. All transport agencies involved in Auckland will need to ensure adequate capability.

Dynamic management of the network

Understanding what is happening on the network in real-time is only half of the equation. The other half is the ability to dynamically manage travel demand. Provision of traveller information through radio, variable messaging signs, smart phones, and in the future connected vehicles, is one key way to enable transport users to make better route or mode choices in response to congestion or incidents. Other means involve dynamic physical infrastructure to manage traffic flows such as: adaptive traffic signals, motorway on-ramp signals, dynamic lane and speed control, and enforcement technology.

Preparation for the roll-out of CAVs

In addition to investment to better manage today's transport network, central and local government agencies will need to look ahead for what will be required to support the roll-out of CAVs. Upgrading road marking, connected traffic signals, augmented satellite positioning and/or digital maps (for fully autonomous vehicle navigation) and a radio spectrum for connected vehicles (for vehicle to vehicle communication), will all likely be necessary.

Balancing risks of implementation

It is important not to lose sight of the risks of implementation as new technologies are investigated. Technology changes rapidly and care must be taken to avoid being locked in to particular applications or providers. Waiting for a commercial off-the-shelf solution and being a fast follower can reduce the risk of wasted time and money. On the other hand, deploying new technology early gives network operators the chance to test more creative solutions and form collaborative relationships with suppliers.

The key will be harnessing the benefits of new technology as soon as possible while minimising early implementation risk.

3.4. Key findings

Over the next decade, the New Zealand Transport Agency and Auckland Transport have tentatively forecast around $350 million for investment in intelligent network management. This includes investment in the following broad areas.

Investment	Description	Cost (millions)
Dynamic management of the network	Traveller information provision and tools required to manage traffic movements in real-time such as; adaptive traffic lights, ramp signals, variable message signs, dynamic lane and speed control and incident management systems.	$285
Data collection	Systems to collect, transfer, store and manage data on network use.	$37
Transport Operations Centres	Staffing and other operational costs.	$22
Data analysis	Real-time analysis of performance of the network including limited applications of 'predictive analytics' (what will happen) and 'prescriptive analytics' (what should the response be).	$10

Initial analysis indicates that further investment of around $200 million in intelligent network management over the next decade (2016-2026) is likely to deliver good value for money. Additional investment would also better prepare Auckland to take full advantage of emerging technology, including CAVs, in subsequent decades.

The following interventions and indicative costs are recommended as a basis for a higher investment package (noting substantial further work post-ATAP will be required to develop detailed business cases).

Investment	Description	Cost (millions)
Data analysis	Additional investment would provide comprehensive real-time analysis of system wide performance, enabling more advanced applications of ‘predictive analytics’ (what will happen) and ‘prescriptive analytics’ (what should the response be). This investment could also support communication and data transfer with vehicles.	$86
Data collection	Additional investment in information gathering devices (and supporting communication network) to cover more of the transport system.	$38
	Development of an open-source data platform (including both public sector and third party data) to enable a more accurate view of system performance and encourage private sector development of effective transport apps.	$35
Dynamic management of the network	Additional investment in dynamic network management tools to enable rollout on parts of the network not covered by new capital projects.	$8
	Further investment in more comprehensive traveller information provision and tailored services for the freight sector.	$4
Transport Operations Centre	Expansion of the operations centre to manage a larger and more complex intelligent network, and enable better cross-agency response to incidents.	$10

Estimating what intelligent network management investment will be needed for the second and third decades is challenging given a high degree of uncertainty. However, some investment in the following areas is likely to be needed; provision of new forms of sensors, continued development of data integration (including data from third parties which is likely to be more prominent) and infrastructure / initiatives to support the widespread use and management of CAVs.

4. Emerging vehicle technology

4.1. What is it?

Connected vehicles enable communication between vehicles, infrastructure and other connected devices. Automated vehicles are equipped with technology which enables self-driving features, ranging from partial automation (like single-lane motorway autopilot, closely monitored by the driver) through to fully autonomous vehicles (which require no driver monitoring). Connected automated vehicles (CAVs) is a term used to describe vehicles that are both connected and automated.

Emerging vehicle technology has the potential to significantly improve network performance by increasing lane capacity (through shorter following distances and mitigation of start-stop shockwaves), improving safety (by removing human error, the cause of around 80 percent of traffic accidents), and improving travel time reliability. However, the extent of these impacts will depend on what proportion of the fleet adopt new technologies, the provision of supporting infrastructure and regulation, and the extent to which efficiency benefits are offset by induced demand (for example from increased trips by the elderly, children or disabled).

4.2. Current state in Auckland

Auckland has the youngest light passenger vehicle fleet in New Zealand (12.5 years compared to the national average of 14.3). However, this is still relatively old by OECD standards. The makeup of Auckland's fleet points to both the likely delay between introduction to the market of new vehicle technologies and their comprehensive adoption. New vehicles tend to be purchased by companies while individuals typically buy older second-hand vehicles from Japan. Currently very few vehicles have advanced driver assistance systems.

4.3. Emerging technology and trends

Automated vehicles

Vehicle automation is commonly classified into different levels, based on the degree to which human involvement is necessary in driving functions. The Society of Automotive Engineers (SAE) has developed one such classification system, which is widely recognised internationally and is used for this report.

SAE classification system

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Advanced driver assistance systems (ADAS) which are currently on the market foreshadow the more advanced automated technology currently under development. ADAS systems include the following:[3]

Feature	Introduced	Automation level	Description
Adaptive Cruise Control	2006	1	Automates vehicle speed to keep a set following distance from preceding vehicle using sensors (no communication with other vehicles or infrastructure).
Parallel-park assist	2006	2	Uses cameras and ultrasound to guide the vehicle into a parking space.
Automatic emergency braking[4]	2008	1	Activates itself when the vehicle risks collision with another object.
Lane-keeping technology	2014	1	Warns the driver when the vehicle risks drifting out of its lane and in some versions prevents the vehicle from doing so.

More advanced automated features will to come to market over the next decade, with timing depending on the validation of technology by manufacturers and regulation in various jurisdictions (particularly large key markets). Based on likely readiness of technology and manufacturer announcements, the following timeframes for commercial introduction of automated features are estimated:[5]

[3] *Revolution in the driver's seat, the road to autonomous vehicles.* The Boston Consulting Group. April 2015.
[4] The Government's Safer Journeys Action Plan 2016-2020 has an action to undertake initial investigation by December 2017 on the value of mandating automatic emergency braking for all vehicles except motorcycles.
[5] *Revolution in the driver's seat, the road to autonomous vehicles.* The Boston Consulting Group. April 2015.

Feature	Expected introduction	Automation level	Description
Single-lane highway autopilot	2015/16	2	Enables a vehicle to drive itself in a single lane on a highway.
Traffic jam autopilot	2017	2	Takes control of vehicle functions in low-speed stop-and-go traffic conditions.
Automated valet parking	2017	3	Enables the vehicle to park and retrieve itself when summoned (however, the vehicle cannot independently find a vacant parking space).
Highway autopilot with lane changing	2018	3	Enables the vehicle to drive itself on highways, including changing lanes.
Urban autopilot	2022	4	Allows the vehicle to drive itself in virtually all urban environments at low speed.
Full automation	2025	5	Enables the vehicle to drive itself in almost any environment without driver intervention or constant monitoring (limitations of operation in severe weather conditions are yet to be determined).

Connected vehicles

In addition to automated features, a number of connected features are likely to be introduced commercially over the next decade.

These features will enable vehicles to:

- communicate with other vehicles;
- communicate with roadside infrastructure; and
- communicate with transport control centres for real-time data exchange.

These capabilities will facilitate traveller information and navigation, safety alerts and warnings, improved maintenance diagnostics, infotainment, software updates, and potentially provide a platform for road pricing in the future.

Most importantly, connected vehicles (particularly when coupled with vehicle automation) have the potential to significantly improve the efficiency of urban roading networks. This is achieved through vehicle-to-vehicle communication features like Cooperative Adaptive Cruise Control (which enables shorter following distances and mitigation of start-stop shockwaves) and dynamic management of traffic flows.

Retrofitting connected and automated features

While increasing numbers of new vehicles will be equipped with connected automated features, a significant after-market industry is also likely to emerge in the decades ahead to enable older vehicles to be upgraded to various levels of connection and automation. One such application which may hold some promise in the medium term is ‘here I am’ communication units. These relatively inexpensive, after-market units (estimated at around US $100-200) could be installed in older vehicles to enable some of the capacity benefits of higher level connected vehicles to be realised in advance of fleet turnover (as well as potentially providing a platform for road pricing).[6]

4.4. Key findings

Uptake

Projections for uptake of emerging vehicle technologies vary widely. For example, some studies predict as high as 75 percent fleet penetration of fully autonomous vehicles by 2040 (Institute of Electrical and Electronics Engineers) while others only predict 50 percent penetration by 2055 (Todd Litman, Victoria Transport Policy Institute).

Making projections is difficult given the diverse nature of challenges to the widespread uptake of emerging vehicle technologies, chief among which include issues around; safety, liability, reliability, cyber security, privacy, cost, licensing, the need for digital mapping and other supporting infrastructure, public acceptance and consumer demand, and potentially incompatible communication standards for vehicles sourced from Europe, Japan and the United States. In addition, the extent and nature of potential central and local government interventions to accelerate uptake will have a significant impact.

As emerging vehicle technology will be a key component in the development of Auckland's transport system over the next 30 years, it is necessary to estimate a plausible rate of uptake to inform decision making. To this end, a comprehensive literature review has been undertaken to provide the best possible foundation for forecasts. Estimates were developed by combining analysis on: when vehicle technology is likely to be introduced to the market globally; the additional cost of automated features; willingness to pay surveys; historical trends for uptake of similar vehicle technology; Australian uptake estimates; and Auckland-specific fleet turnover characteristics.

The table below shows the proportion of the vehicle fleet estimated to be automated (according to level) and connected, with broad ranges reflecting uncertainty about the speed of technological development/commercialisation and the degree to which central or local government interventions could accelerate uptake. Note that the table shows that as higher levels of automation enter the vehicle fleet, the proportion of vehicles equipped only with lower levels of automation declines as older technology is updated.

[6] *Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow.* Shladover, S. California PATH Program, University of California, Berkeley. January 2012.

Technology	2026	2036	2046
Vehicle automation			
Level 0 – No Automation	59 - 79%	15 - 38%	5 - 15%
Level 1 – Driver Assistance	15- 30%	33 - 40%	5 - 25%
Level 2/3 – Partial/Conditional Automation[7]	5 - 8%	10 - 20%	10 - 35%
Level 4 – High Automation	1 - 2%	7 - 17%	N/A[8]
Level 5 – Full Automation	<1 - 1%	5 -15%	25 - 80%
Vehicle communication (connected)			
Cooperative Adaptive Cruise Control[9]	6 - 11%	22 - 52%	60 - 90%

Road capacity

To estimate road capacity (or throughput) effects for motorways, the above fleet uptake estimates were matched with results from micro-simulation modelling studies which assess the impact of CAVs as fleet penetration increases. One such study (Shladover, 2012) is used as the basis for road capacity projections in this report because it attempts to incorporate the interaction between humans and technology to provide a more realistic estimate of capacity effects (time-gap settings were selected by members of the general public).

The potential impact of CAVs on local road throughput is less well understood, with literature indicating it to be around one third of motorway throughput impacts due to more complicated vehicle movements (e.g. more lane-changing and intersections).[10]
Shladover's modelling results below show how motorway throughput (measured as vehicles/lane/hour) increases as the proportion of vehicles in the fleet equipped with Adaptive Cruise Control (non-communicating vehicles) and Cooperative Adaptive Cruise Control (communicating vehicles) changes. Remaining vehicles are assumed to be manually driven.[11]

		Percentage of CACC Vehicles								
		10%	20%	30%	40%	50%	60%	70%	80%	90%
Percentage of ACC Vehicles	10%	2065	2090	2170	2265	2389	2458	2662	2963	3389
	20%	2065	2110	2179	2265	2378	2456	2671	2977	0
	30%	2077	2127	2179	2269	2384	2487	2710	0	0
	40%	2088	2128	2192	2273	2314	2522	0	0	0
	50%	2095	2133	2188	2230	2365	0	0	0	0
	60%	2101	2138	2136	2231	0	0	0	0	0
	70%	2110	2084	2155	0	0	0	0	0	0
	80%	2087	2101	0	0	0	0	0	0	0
	90%	2068	0	0	0	0	0	0	0	0

[7] Given level 2 and level 3 automation is likely to come to market within a couple of years, we assume the same rate of uptake by 2026 and beyond.
[8] Due to software updates this feature is assumed to be no longer distinguishable from fully automated vehicles by 2046.
[9] We assume all vehicles with level 2 automation or above are equipped with the ability to perform cooperative adaptive cruise control.
[10] *Preparing a nation for autonomous vehicles.* Eno Centre for Transportation. October 2013.
[11] *Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow.* Shladover, S. California PATH Program, University of California, Berkeley. January 2012.

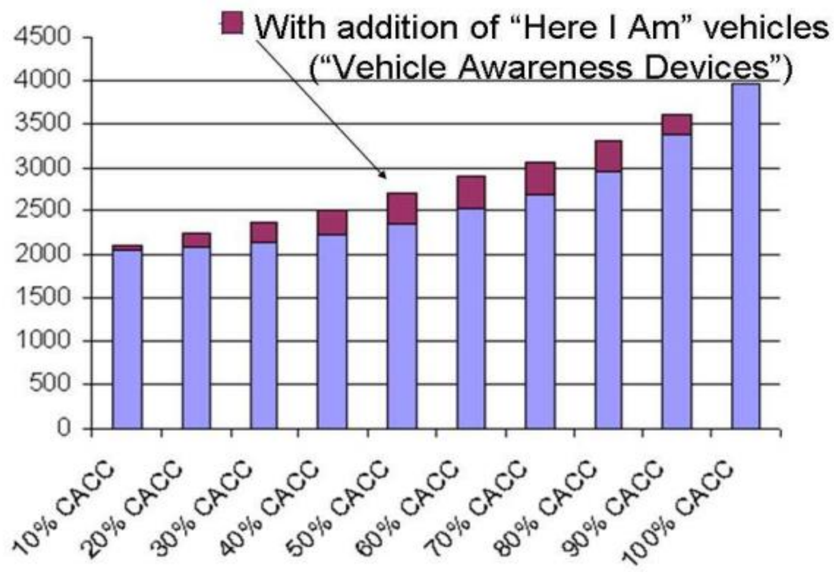
Note that Adaptive Cruise Control is not assumed to significantly improve throughput as driver preference indicates similar following distances to manual vehicles. This contrasts with Cooperative Adaptive Cruise Control where throughput increases dramatically once fleet penetration thresholds are met (around 50-60 percent of fleet). This is because the shorter following distances that Cooperative Adaptive Cruise Control allows over Adaptive Cruise Control are only possible when both the lead and following vehicle are communicating.

Given average throughput on Auckland's motorway network is assumed to be around 2050 vehicles/lane/hour, and using figures from Shladover 2012, we estimate the following road capacity increases on motorways and local roads.

Change in throughput	2026	2036	2046
Motorways	+0.7 - 1.3%	+3.8 - 16.3%	+21.3 - 65.3%
Local roads	+0.2 - 0.4%	+1.3 - 5.4%	+7.1 - 21.8%

It may also be possible to bring forward some of the throughput benefits of vehicle-to-vehicle communication ahead of fleet turnover by equipping non-communicating vehicles with after-market 'here I am' units. These units communicate with Cooperative Adaptive Cruise Control vehicles, enabling them to safely follow closely behind (thus allowing higher throughput at lower Cooperative Adaptive Cruise Control fleet penetration).

The graph below shows the estimated impact of 'here I am' units.



Induced demand

Induced demand from CAVs may well offset some of the capacity benefits outlined above. Additional demand may stem from fully autonomous vehicles making travel easier for certain groups (e.g. the elderly, people with disabilities or children), or it may encourage more travel as time spent in the vehicle can be used for other purposes. In addition, fully autonomous vehicles could add to congestion through re-positioning trips to pick up new users or park.

It is very difficult to estimate to what degree this technology will stimulate demand, however some predict at 50 percent fleet penetration, vehicle kilometres travelled could increase by between 5 and 20 percent. At 95 percent fleet penetration, vehicle kilometres travelled could increase by as much as 35 percent on parts of the network.[12]

Potential interventions to accelerate uptake

Both the central and local government have a number of potential interventions available if increasing uptake of CAVs is deemed desirable. Options include:

- Carrying out trials of CAVs to test impacts
- Investing in supporting infrastructure (e.g. fitting out road-side infrastructure with Direct Short Range Communications capability)
- Ensuring the network is digitally mapped
- Mandating 'here I am' communication units or new vehicle sales being at least level 3 automated
- Creating financial incentives to stimulate uptake (e.g. through tax breaks, subsidies, or free parking)
- Enabling CAVs to use express lanes
- Replacing some low capacity public transport services with fleets of shared CAVs, which likely would either be provided by the private sector under contract to local government, or in free competition.

[12] *Effects of next-generation vehicles on travel demand and highway capacity.* FP Think. Bierstedt. J, Gooze. A, Gray. C, Peterman. J, Raykin.L and Walters. J. January 2014

5. Shared mobility

5.1. What is it?

Shared mobility is the shared use of transport modes other than public transport. Examples include car sharing, ride sharing and bicycle sharing, often facilitated by websites or smart phone apps. In the long run, shared mobility may extend to the widespread use of shared fully autonomous vehicles.

Shared mobility is also key to uptake of ‘mobility as a service’ – the concept that urban travel can be consumed as a service, rather than provided through personally owned modes of transportation. Mobility as a service could work by combining public transport and shared mobility options through a single system (for example a smart phone app), which recommends, manages and pays for the trip.

5.2. Current state in Auckland

The current extent of shared mobility in Auckland is limited, evidenced by the average car occupancy being 1.45[13] in the morning peak. While ride-sharing and car-sharing schemes exist, they have had little traction to date. The same is true of car-pooling despite Auckland Transport operating a website and conducting promotional campaigns. Auckland has a few small-scale and independent bike-sharing schemes, and websites or apps to enable the public to compare travel options are relatively limited.

5.3. Emerging technology and trends

The ‘internet of things’

The internet of things refers to everyday objects being equipped with network connectivity, enabling them to send and receive data. For transport, this means smart phones, private vehicles, public transport, bicycles and infrastructure.

Internet connectivity is important because it enables the location and status of transport networks and services to be monitored and, through smart phone apps or websites, trips to be organised in real-time for users. Ubiquity of connectivity is therefore necessary to enable easy and seamless access to shared mobility options as well as transfers with public transport (thus enabling mobility as a service).

Rise of the sharing economy

Many sectors have been disrupted by the rise of the sharing economy - or peer-to-peer renting of goods or services (e.g. finance and accommodation). Transport is not immune to this trend, with car-sharing and ride-sharing services projected to experience significant growth in some overseas markets.[14]

[13] Household travel survey data for Auckland (average of 2009-2014).
[14] What’s Ahead for Car Sharing?: the new Mobility and its impact on vehicle sales, Boston Consulting Group, February 2016

Both the public and private sectors have sought to take advantage of an increasing propensity for transport users to share with varied results. One key lesson from trials of ride sharing services conducted overseas is the importance of achieving sufficient size to enable economies of scale and convenient levels of service for customers.[15]

Shared fully autonomous vehicles

The introduction of fully autonomous vehicles has the potential to facilitate a widespread shift to shared mobility. Fully autonomous vehicles shared between many users would likely significantly reduce the cost of travel as labour costs associated with taxis and public transport could be eliminated. As a result, these shared vehicles could provide a mode of transport which offers the door-to-door level of service of private vehicle travel, at a similar cost to traditional subsidised public transport. However, scale will likely be important to achieve an economically viable and attractive service.

Projections for uptake of shared mobility

While limited evidence exists to make projections for uptake of shared mobility in Auckland (in part due to the complex behavioural drivers behind sharing), Auckland Transport have tentatively estimated the following rates of uptake over the next 30 years.

	2026	2036	2046
Proportion of trips shared	<2 - 5%	5 - 10%	15 - 50%

5.4. Key findings

Potential benefits of shared mobility include:

- Fewer private vehicles on the road during peak travel times as a result of higher average vehicle occupancy, with consequential positive impacts on accessibility and congestion. Results from transport modelling support this, but also show a significant decline in public transport patronage. While mode shift away from public transport towards ride-sharing would be likely to occur in some circumstances, the effect may be much less pronounced in reality, with literature indicating that shared mobility could also support access to public transport spines.
- Increasing public transport catchments areas through better first and last leg connections as a result of greater access to car share, ride share and bicycle share options and mobility as a service apps facilitating transitions. The effect on patronage may be most pronounced for public transport trips on the periphery. Greater use of shared mobility to feed into rapid transit spines also has the potential to reduce the need for feeder public transport services, with resulting implications for public transport subsidies.
- Greater access to transport for those who do not own a private vehicle. Improved shared mobility options give the public more flexibility and choice in how and when to travel. If at sufficient scale and priced appropriately, shared mobility may also improve access to transport for lower income groups.

[15] *Why Helsinki's innovative on-demand bus service failed*. Citiscope. March 2016

In addition, widespread uptake of shared mobility may reduce the need for parking (thus allowing land to be re-purposed) and reduce transport related greenhouse gas emissions by decreasing average vehicle kilometres travelled.

However, any widespread shift to shared mobility involves significant changes to behaviour that, despite advances in technology, have not been observed to date. Comprehensive research will be needed to better understand current attitudes towards shared mobility in Auckland, what the key behavioural drivers for sharing are, and what central and local government could do to facilitate a widespread shift.

Based on actions taken in other jurisdictions, central and local government could investigate the following initiatives to help facilitate uptake:

- Provision of enabling and flexible regulation to support a range of shared mobility business models.
- Development of an open data platform, drawing on sources from across the public and private sectors and provided in a standardised, anonymous and user-friendly way. Doing so would provide the data necessary to aid private sector development of shared mobility business models and mobility as a service apps.
- Conducting trials of shared mobility services to determine what works, what doesn't, and why.
- Communication strategies promoting the service offerings of shared mobility and links with the public transport network.

In addition, land use and demographic patterns will affect what shared mobility services are likely to be available and sustainable in Auckland. Higher densities and restriction of parking availability in particular would likely be conducive to enabling shared mobility services to succeed.

6. Combined effects of technologies

While intelligent network management, emerging vehicle technologies and shared mobility could each individually improve transport outcomes in Auckland, when combined their effects are likely to be more pronounced.

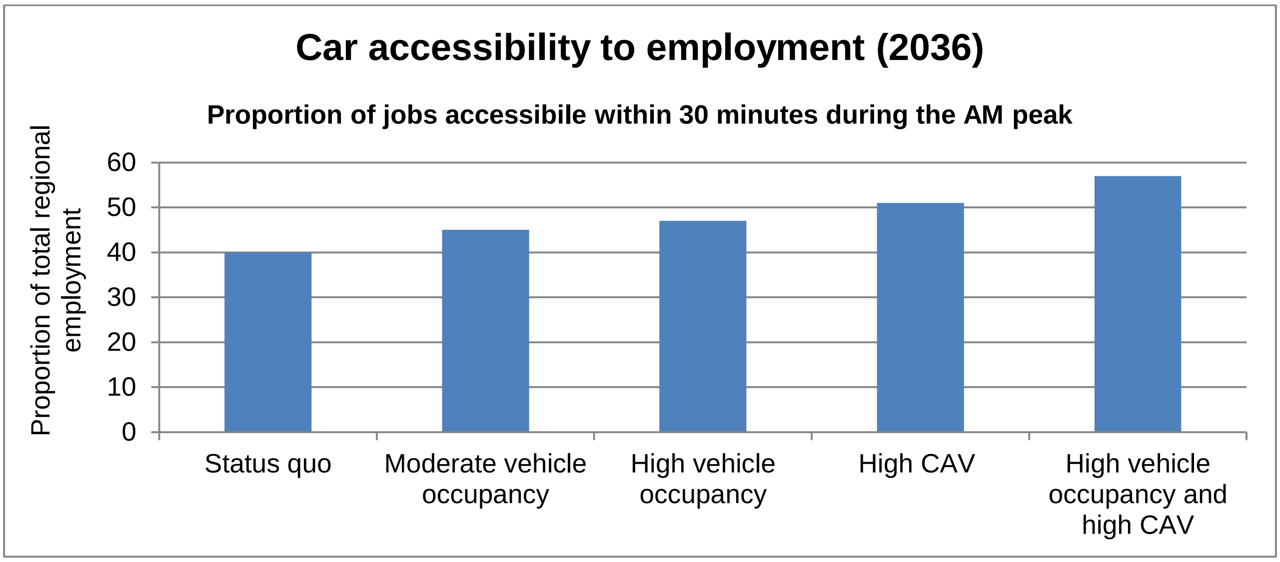
To assess the potential contribution of these technologies towards the core ATAP objectives, literature from a wide range of sources and results from the Auckland Regional Transport (ART) Model were used.

6.1. Modelling

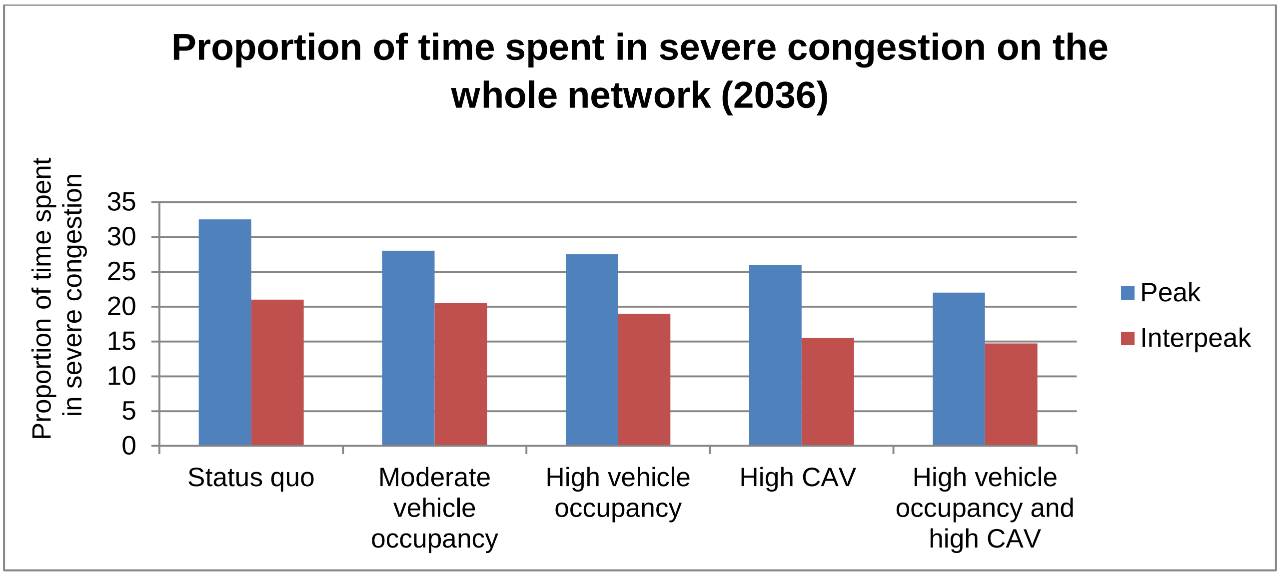
Four 'what if' modelling scenarios were tested for 2036 that reflect a reasonably aggressive increase in vehicle occupancy (to simulate shared mobility) and uptake of CAVs. The four scenarios were:

- Moderate vehicle occupancy – assumed a 50 percent increase in vehicle occupancy for commuter trips with a smaller increase for other trip types (like shopping or business trips), reflecting that rates of ride-sharing are likely to vary by trip purpose. Overall, average peak-time occupancy was assumed to increase from 1.36 to 1.61.
- High vehicle occupancy – assumed a 100 percent increase in vehicle occupancy for commuter trips with a smaller increase for other trip types. Overall, average peak-time occupancy was assumed to increase from 1.36 to 1.73.
- High CAV – assumed 75 percent of the fleet are CAVs, resulting in a 29 percent increase in lane capacity for motorways and a 10 percent increase on other roads. Capacity of signalised intersections was also assumed to increase by 15 percent as a result of supporting intelligent infrastructure.
- High vehicle occupancy and high CAV – assumed both a 100 percent increase in vehicle occupancy for commuter trips and 75 percent of the fleet being CAVs.

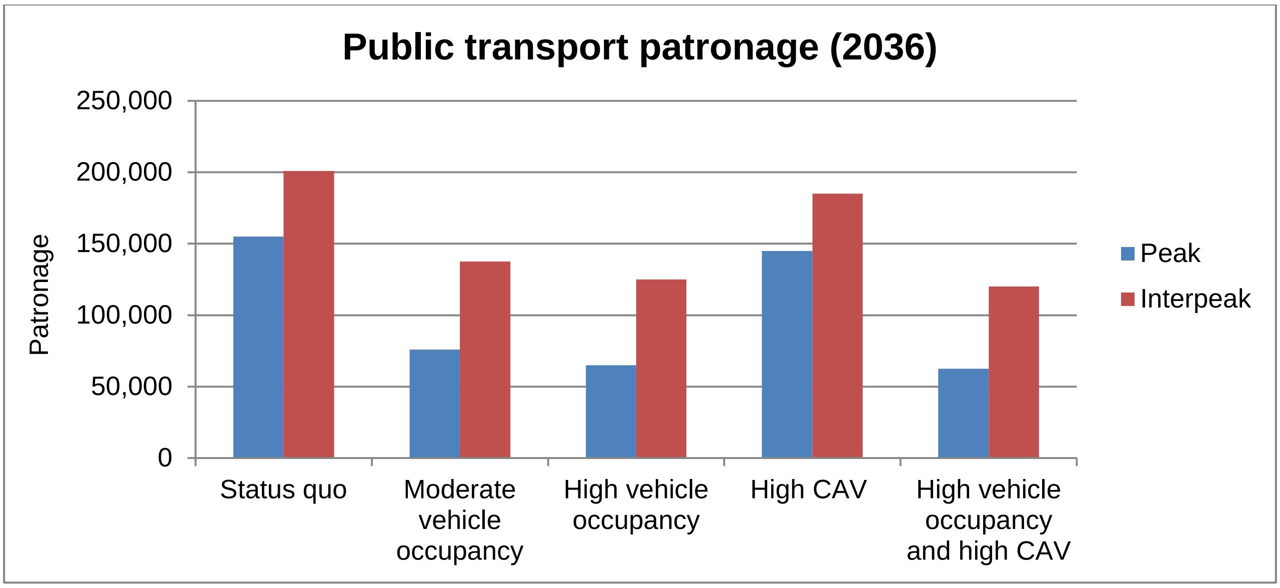
Results



All scenarios showed a considerable improvement in car accessibility to employment, particularly the high vehicle occupancy and CAV scenario, where the proportion of jobs accessible within 30 minutes increased by 45 percent in comparison to the status quo.



Time spent in congested conditions during the peak decreased under all scenarios, but particularly the high vehicle occupancy and CAV scenario, where it reduced by around 33 percent in comparison to the status quo. Interpeak congestion improved more as a result of CAVs than higher vehicle occupancy.



Under scenarios where vehicle occupancy increased, public transport patronage decreased by over 50 percent in the peak, with smaller but still significant declines in the interpeak. CAVs alone did not appear to have a significant impact on patronage.

6.2. Limitations of modelling

While useful for gaining a sense of the scale of potential impacts stemming from these changes in transport technology, the nature of the model used means a number of simplifying assumptions are necessary. These include: vehicle occupancy changes being uniform across the region whereas different locations and urban densities may be more or less conducive to ride sharing; user preferences regarding mode choice not being accurately reflected in the model (meaning that public transport patronage results should be treated with caution); and induced travel demand stemming from technology changes not being incorporated (meaning accessibility and congestion results probably reflect a 'best case'). To more realistically estimate the effect of shared mobility and CAVs on Auckland's network, the Ministry of Transport, with the support of Auckland Transport, have partnered with the International Transport Forum (the transport branch of the OECD), to investigate developing a purpose-built transport model.

6.3. Summary of impacts

In the medium-term, better intelligent network management could aid accessibility results by managing incidents and congestion more effectively through more comprehensive traveller information incentivising users to choose alternative routes, modes or times to travel. It may also support public transport patronage due to greater provision of real-time travel information for users and better prioritisation of bus services through emerging vehicle-to-infrastructure communication technology.

In the longer-term as uptake of CAVs increases, accessibility and congestion results could improve considerably because of higher lane capacity, particularly on motorways, and mitigation of start-stop shock waves. Shared mobility could further improve accessibility and congestion results as average vehicle occupancy increases and proportionally fewer private vehicles travel during peak periods.

If shared fully autonomous vehicles become widely adopted, the impact on public transport demand could also be material. Research indicates that the cost per passenger kilometre of fully autonomous vehicles could potentially be similar to that of traditional subsidised public transport and significantly cheaper than taxis, while offering a broadly equivalent level of service to private vehicle travel (in urban environments).

This suggests that shared fully autonomous vehicles may provide an attractive alternative to both private vehicle travel and some public transport services – particularly those that do not experience corridor constraints or very high demand (where traditional public transport is likely to remain relatively attractive). Alternatively, fully autonomous vehicles may increase catchment areas for public transport spines by making it easier to get from home to the station.

Further research and analysis is required to better understand the potential infrastructure implications of emerging transport technology. However, the need for additional motorway capacity and some public transport services appear particularly sensitive to changes in vehicle technology and shared mobility.

7. Conclusions

There is a growing international consensus that transport is on the cusp of disruptive change driven by new technology. However, the timing and detailed impacts of these technologies are very uncertain.

While investment in intelligent transport systems is already planned for Auckland over the next decade, preliminary analysis indicates that additional targeted investment would likely deliver good value for money and better prepare Auckland to take advantage of new technologies in subsequent decades.

Shared mobility, particularly if average peak-time vehicle occupancy increases significantly, has the potential to greatly improve accessibility and congestion results due to proportionally fewer vehicles on the road. More work will be needed to understand the behavioural drivers behind shared mobility and what both central and local government could do to facilitate a widespread shift.

Once uptake is sufficiently high (around 50-60 percent of the fleet) CAVs have the potential to significantly increase vehicle throughput on motorways by enabling shorter following distances and mitigation of start-stop shockwaves. While still material, their effect on local road capacity is expected to be much lower as a result of intersections and more complicated vehicle movements. Traffic accidents are also likely to decline as uptake of CAVs increases.

In the long run, shared fleets of CAVs supported by intelligent infrastructure have the potential to greatly improve the performance of Auckland's transport system and change the nature of public transport as we know it. However, the degree to which changes in technology may stimulate additional travel demand remains uncertain, with the possibility that efficiency benefits may be offset to some extent.

Given a high degree of uncertainty and the scale of potential impacts of these emerging transport technologies, a flexible approach to infrastructure planning and funding decisions is crucial, particularly for investments in the second and third decades of ATAP's 30-year horizon.

8. Recommendations

- Further investigate the case for increased investment in intelligent network management of around $200 million over the next 10 years (in addition to what is already tentatively earmarked by the New Zealand Transport Agency and Auckland Transport over this period).

- Undertake detailed research into the drivers of shared mobility and what central and local government could do to facilitate a widespread shift; including the provision of enabling and flexible regulation, development of an open data policy, and conducting shared mobility trials.

- Further investigate how to best prepare for and potentially accelerate the uptake of connected and automated vehicles.

- Ensure transport agencies involved in Auckland build staff capability in intelligent transport systems and work collaboratively to deliver outcomes.

- Ensure that potential changes in transport technology are taken into account when planning future infrastructure to reduce the chance of stranded investment.

9. References

Intelligent network management

As A Cohort of Bus Startups Emerge, Chariot Looks To Source New Routes Through Crowdfunding Kim-Mai Cutler, Techcrunch. November 2014 http://techcrunch.com/2014/11/10/chariot/

Analyst questions DSRC-based V2V communications for vehicle safety, points to LTE Advanced and 5G instead Mike Dano Fierce Wireless news, http://www.fiercewireless.com/tech/story/analyst-questions-dsrc-based-v2v-communications-vehicle-safety-points-lte-a/2015-08-06 (Accessed December 16, 2015)

Apps for transport maps: connecting the dots in a complex ecosystem. Chris Lo. railway-technology.com http://www.railway-technology.com/features/featuretransport-apps-key-trends-and-innovations-4323893/ (Accessed 30 November 2015)

An Open Door for Travel Apps. Transport for London "https://tfl.gov.uk/info-for/media/news-articles/an-open-door-for-travel-apps" (Accessed 30 November, 2015)

Advanced parking management systems cost between $250 and $800 per parking space to install. US Department of Transportation, Office of the Assistant Secretary for Research and Technology, http://www.itscosts.its.dot.gov/its/benecost.nsf/ID/EE8CCECEAD836EB6852573E2006BC427?OpenDocument&Query=Home (Accessed December 1, 2015)

A typical signal timing project in Portland saves over 300 metric tons of CO2 annually per retimed traffic signal. US Department of Transportation, Office of the Assistant Secretary for Research and Technology, http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/56D8C4668F1A07C685257DB3006C652A?OpenDocument&Query=Home (Accessed November 30, 2015)

Congestion Management Plan 2014-2018. City of Toronto, https://www1.toronto.ca/City%20Of%20Toronto/Transportation%20Services/TMC/Files/PDF/Congestion%20Management/Congestion%20Management.pdf (Accessed January 15, 2016)

Cruising for Parking. Donald Shoup *Transport Policy* 13, no.3 (2006) http://shoup.bol.ucla.edu/Cruising.pdf (Accessed November 30, 2015)

Gartner terms Prescriptive Analytics as the "Final Frontier" of Analytic Capabilities. John Rynn globys https://www.globys.com/2013/06/gartner-terms-prescriptive-analytics-%E2%80%9Cfinal-frontier%E2%80%9D-analytic-capabilities (Accessed December 14, 2015).

LINZ's responsibilities. Land Information New Zealand, http://www.linz.govt.nz/about-linz/our-organisation/linzs-responsibilities (Accessed December 16, 2015).

MATOC Benefit-Cost Whitepaper. Metropolitan Washington Council of Governments https://www.mwcog.org/uploads/committee-documents/Yl5ZVlZc20100607114406.pdf (Accessed January 14, 2106)

"Monroe County New York ITS Camera Deployment & Systems Integration. US Department of Transportation Intelligent Transportation Systems, http://ntl.bts.gov/lib/30000/30200/30232/14416.htm (Accessed December 1, 2015)

Monroe County, NY, deployed five CCTV cameras at high priority intersections at a cost of $279,338. US Department of Transportation, Office of the Assistant Secretary for Research and Technology, http://www.itscosts.its.dot.gov/its/benecost.nsf/ID/50592D9262D54F95852575C5005C7165?OpenDocument&Query=Home (Accessed December 1, 2015)

More than 99 percent of surveyed users said they benefited from information provided by an advanced transportation management system and traveller information system serving northern Kentucky and Cincinnati. US Department of Transportation, Office of the Assistant Secretary for Research and Technology http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/114EA878F88DE555852569610051E2D8?OpenDocument&Query=Home (Accessed December 1, 2015)

Tackling Urban Mobility with Technology. Google Europe Blog, http://googlepolicyeurope.blogspot.com.es/2015/11/tackling-urban-mobility-with-technology.html (Accessed November 27, 2015).

The bright side of sitting in traffic: Crowd sourcing road congestion data. Google Blog, https://googleblog.blogspot.ca/2009/08/bright-side-of-sitting-in-traffic.html (Accessed 11 December 2015)

The Transport Data Revolution. Transport Systems Catapult https://ts.catapult.org.uk/documents/10631/169582/The+Transport+Data+Revolution/99e9d52f-08a7-402d-b726-90c4622bf09d (Accessed 11 December 2015).

Transit signal priority in the Portland metro area can reduce transit delay by 30 to 40 percent and improve travel times 2 to 16 percent. US Department of Transportation, Office of the Assistant Secretary for Research and Technology, http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/*E2AC4192CEEA55D985257DB300693E91*?OpenDocument&Query=Home (Accessed November 30, 2015)

The overall cost to implement a region-wide Traffic Management System in Portland Oregon was estimated at $36 million. US Department of Transportation, Office of the Assistant Secretary for Research and Technology, http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/14D29D98399B21C585257DC500534E2F?OpenDocument&Query=Home (Accessed November 30, 2015).

Traffic Watch. National ICT Australia https://www.nicta.com.au/category/research/machine-learning/projects/traffic-watch/ (Accessed November 30, 2015).
Update on vehicle technology for fleets. Rocco Zito, University of South Australia. http://www.aecgroupltd.com/npsfmc/files/Update%20on%20Vehicle%20Technologies%20for%20Fleets%20-%20Dr.%20Rocco%20Zito%20(University%20of%20South%20Australia).pdf (Accessed November 30, 2015).
Why Europe Implemented SBAS. European GNSS Agency. https://www.thalesgroup.com/sites/default/files/asset/document/day_1_-_10.50_gsa_-_why_egnos_v0_8.pdf (Accessed December 8, 2015).
Why a new website but no app? Part 1. Transport for London http://blog.tfl.gov.uk/2014/03/12/why-a-new-website-but-no-app-part-1/ (Accessed 30 November 2015).

Vehicle technology

Autonomous cars, self-driving the new auto industry paradigm. Morgan Stanley Research Global. November 2013.
Automated vehicles: Are we ready? Mainroads Western Australia. January 2015.
Connected & autonomous vehicles, introducing the future of mobility. Atkins.
Connected vehicles: Are we ready? Mainroads Western Australia. June 2015.
Disruption on the road ahead! How auto technology will change much more than just our commute to work. New Zealand Institute of Economic Research. November 2014
Effects of next-generation vehicles on travel demand and highway capacity. FP Think. Bierstedt. J, Gooze. A, Gray. C, Peterman. J, Raykin.L and Walters. J. January 2014
Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance. Department of electrical engineering, Columbia University.
Highway capacity increases from automated driving. California PATH program. July 2012
Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow. Shladover, S. California PATH Program, University of California, Berkeley. January 2012.
Preparing a nation for autonomous vehicles. Eno Centre for Transportation. October 2013.
Potential impacts of connected and autonomous vehicles. Synergine Group Limited. October 2015.
Revolution in the driver's seat, the road to autonomous vehicles. The Boston Consulting Group. April 2015.
Recent International Activity in Cooperative Vehicle–Highway Automation Systems. US Department of Transportation – Federal Highway Administration. 2012.
Safer Journeys Action Plan 2016-2020. New Zealand Government, 2016.

Towards implementation: technology and policy implications of connected and autonomous vehicles. Synergine Group Limited. November 2015

The New Zealand vehicle fleet: fact and fiction. Ministry of Transport. March 2015.

Urban mobility system upgrade, how shared self-driving cars could change city traffic.

Shared mobility

A car club strategy for London – growing car clubs to support London's transport future, Transport for London and others, 2014

Accessibility in Cities, Transport and Urban Form. The London School of Economics and Political Science, Philip Roade, Graham Floater et al, November 2014

Connecting low-income people to opportunity with shared mobility, ITDP for Living Cities, Michael Kodransky & Gabriel Lewenstein, December 2014

Moving Together in the 21st Century: How Ride-sharing Supports Liveable Communities, U.S. Department of Transportation, Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center, June 2013.

Nice rides for all neighbourhood: equity efforts in Minnesota's Bike Share, PeopleforBikes, Emily Wade, 2015

Shared Use mobility reference guide, Shared use mobility centre, Chicago 2015

The Impact of Carsharing on Household Vehicle Holdings: Results from a North American Shared-Use Vehicle Survey, 2010. Martin, Shaheen, Lidicker

The future of urban mobility – where are we going from here? Trends and challenges in Personal Mobility seminar class, Dr Sevn A Beiker, Stanford University, 2014

The new transportation planning paradigm ITE Journal (www.ite.org), Vol 83, No 6 pp 20-28, 2013: at www.vpti.org/paradigm.pdf, T Litman, Victoria policy Institute, 2013

The Metro Vancouver Care Share Study – technical report, Metro Vancouver, November 2014

The Impact of Carsharing on Household Vehicle Holdings: Results from a North American Shared-Use Vehicle Survey, 2010. Martin, Shaheen, Lidicker

What's Ahead for Car Sharing? - the new Mobility and its impact on vehicle sales Boston Consulting Group, February 2016

Why Helsinki's innovative on-demand bus service failed. Citiscope. March 2016