The Impact of Autonomous Vehicles on Cities

Stelios RODOULIS

Abstract

Autonomous vehicles (AVs) are under active development and they are the hottest topic in transport. They offer enormous potential to improve the safety, efficiency and sustainability of road traffic, especially in cities. Users will experience significant benefits including less time spent in traffic and wasted time looking for parking, more productive in-vehicle time and reduced risk of accidents and delays. AV's can radically change the need and type of infrastructure. Subsequent impacts on land uses are inevitable in the long term. Urban and Transport Planners need to anticipate the impacts, develop enabling legislation and plan for these changes in order to gain the maximum benefits.

Introduction

Autonomous Vehicles (AVs) – cars that drive themselves with little or no human input – are the hottest topic in transport. Self-driving vehicles are undergoing tests on our streets today, and many cars already feature autonomous technology such as auto-braking, automatic parking and adaptive cruise control.

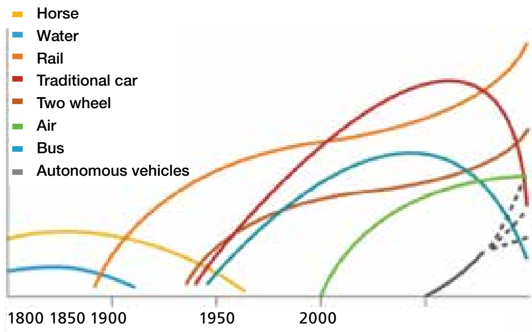
This article is designed to be thought provoking by examining the most significant changes to cities, with impacts anticipated on roads, traffic, parking, infrastructure investments and land use.

Characteristics of AV Technology

Transformative Technology

AVs are poised to be the next transformative technology in transportation. *Figure 1* illustrates the indicative transformative impact of new modes such as rail, cars and aviation in history. A challenge for city planners and managers is to understand how quickly AVs will transform current patterns of mobility and land use, as well as replace or change existing transport modes. Ultimately, AVs will need no input from vehicle occupants other than advising the destination. AVs will communicate with each other and interact with smart infrastructure. They will be able to operate themselves without human occupants, deliver items and park on their own. While travelling in an AV, users will be able to sleep, eat, email, work or even meditate! AVs will become a place of activity rather than just a means of transport.

Figure 1: Passenger mobility trends (indicative)



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AVs promise significantly improved safety, economic efficiency, smarter, faster and more reliable travel, low emissions, increased productivity and enhanced quality of life.

Timeline

Figure 2 gives a possible scenario for AV introduction over the next 30 years or so.

Vehicle manufacturers and other organisations are developing autonomous technology very quickly; some aim to have AVs available by 2020, although their saleability may depend on how jurisdictions adapt traffic regulations to permit their use. Initially they might be limited to certain roads, or with a requirement that a human driver is available to take over control at any time (although this may soon prove to be a retrograde step, from a safety point of view).

As the technology matures, rapid take-up is possible similar to other leaps forward in technology. It may be that transportation authorities find themselves having to respond to the trends much quicker than currently anticipated.

Safety

The World Road Association (2013) estimates that human behaviour is a contributing factor in more than 90% of road accidents. More than one million people are killed every year in road accidents worldwide, with 20-50 million suffering non-fatal injuries. By 2020, under current trends, the World Health Organisation (2013) estimates that annual fatalities will increase to 1.9 million people worldwide.

Figure 2: Potential 30-year AV implementation scenario.

TIMESCALE	POTENTIAL IMPLEMENTATION
Now - 2025	• Increasing automation of driving functions, even on affordable cars • Vehicles park themselves • Vehicle to vehicle communication • Vehicles drive themselves in traffic jams or highways (adaptive cruise control) • Early-adopter entrepreneurs start to hire out AVs • Taxi industry disruption • Standardisation of communication and technology protocols
2025 - 2035	• Car ownership declines - car sharing increases. Demand for parking starts to decline • Bus service disruption - segregated or guided busways become fully driverless bringing costs down • Logistics industry disruption • Vehicle to vehicle, and vehicle to infrastructure communication technology matures • Accidents/collisions significantly reduce
2040 - 2045	• Vehicle size/weight/emissions reduce. New vehicle platforms • Catalyst for alternative mass produced propulsion systems - electric • Catalyst for fiscal incentives (road charging, pay as you go) • Urban road-space optimisation - narrower lanes, tighter intersection etc • Reduced need for urban parking - re-inventing/relocating car parks, on-street parking space for other uses (walking, cycling, market stalls) • Vehicles on demand - no reduction in availability or quality of services
2045 - onwards	• Maturing technology, convergence and standardisation. Artificial intelligence on vehicles 'learns to read' the road • Eradication of congestion on highways • Elimination of accidents/collisions • Significant reduction in urban congestion • Ubiquitous autonomous door to door travel • Increased urban sprawl

AVs could significantly reduce the risk of road accidents through co-ordination between vehicles and infrastructure, faster reaction times and elimination of driver error. Communication between vehicles will also allow AVs to modify their routes, thus avoiding hazards.

Economics

A study by the US Department of Transportation (2010) estimated the economic cost of road accidents in the US for a single year. In 2010 there were 32,999 fatalities, 3.9 million non-fatal injuries and 24 million damaged vehicles, which cost the economy approximately US$277 billion. AVs can greatly reduce this cost by dramatically reducing both the number and severity of accidents.

As future scale is achieved, operating costs such as driver wages and parking will also reduce. By removing the cost of a driver, it would become cheaper and more attractive to summon an AV on demand than to own and drive a car exclusively. Thus, vehicle ownership patterns will change as AVs extend the concepts of personal public transport and car sharing schemes.

AVs will also make the vehicle fleet more efficient through increased utilisation. Shared vehicles will be in use more of the time, which will greatly reduce time spent idle in garages or parked between uses.

Smarter, Faster and more Efficient

AVs will produce smoother, faster traffic flows, reducing congestion. On average, motorists in London spent an average of 82 hours in traffic jams in 2013, 10 hours more than 2012 (British Broadcasting Corporation 2014). According to TomTom's annual Congestion Index (2014), the average driver in Moscow and Istanbul spend 74% and 62% more time behind the wheel respectively, than when traffic is flowing. AVs will adjust speed according to road demand, capacity, environmental conditions and geographic area. This eliminates traffic jams caused by speed inconsistencies and temporary slowing down. AVs will predict traffic changes and alter their routes. They could also analyse conditions before setting out and suggest the optimal time or route to travel.

Productivity will improve because people can use their travel time for working or leisure. AVs would free up peoples' time when travelling unoccupied, for instance carrying out tasks like grocery collection or delivering items unattended.

AVs using efficient, smooth acceleration will enable optimal energy use and reduced emissions. Additionally, their inherent safety will reduce requirements for heavy protective equipment, thus shedding weight. This will generate lower emissions both on the road and during manufacture.

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Improved Quality of Life

AVs can provide a solution by offering additional mobility to people regardless of age, physical or driving ability. People with disabilities, younger people and increasingly older populations would find higher levels of freedom and mobility, especially in cities where traditional solutions like scheduled public transport are not up to standard.

Technological Changes and Impacts

Road Capacity

AVs will significantly affect how roads are organised and used. They will run closer together, increasing highway capacity. They will also collectively calculate the most efficient route selection and synchronise key maneuvres between each other, such as turning and merging.

The Partners for Advanced Transit and Highways [PATH] program (2012) estimated that drivers in California space themselves so that only 5% of the road is occupied. Tientrakool (2011) suggested that AVs could increase capacity by 43% (using sensors alone) to 273% (when using sensors and interacting with other AVs). This would materially affect the way infrastructure is planned, with current transport infrastructure better utilised, and a much-reduced need to build new or widen existing roads.

Road Design and Traffic Management

The design of roads would largely stay the same. However, elements such as traffic signals and signage will change; traffic management will be driven by real time, through shared data rather than by roadside infrastructure. Highways could have smaller corner radii for exits and entries, as well as shorter merge and diverge tapers. Physical traffic management infrastructure such as speed humps and safety measures like guard rails and pedestrian protection can also be reduced as AVs will travel at speeds suited to road environments and will automatically detect and avoid other road users. Traffic signals might eventually be dispensed with altogether, as AVs undertake all required maneuvres without them.

Improved Urban Spaces - Decluttering

Fewer hard traffic management measures, improved safety, lower emissions and noise will create a better utilised and more attractive urban realm. Removing road safety and signage clutter in streets will create more space. Streetscaping and shared space schemes will become more common, especially since fewer cars will park on-street. Housing stock close to traffic, fumes, noise and physical segregation may become more desirable and increase in value.

Parking

Shoup (2006), using sixteen different studies from 1927-2001 has shown that drivers cruise for 8.1 minutes on average, when looking for a parking spot; as a result, up to 30% of all traffic in downtown areas can be attributed to drivers searching for parking. In some cities, up to a third of land is devoted to parking.

AVs would drop and collect passengers when required, decreasing demand for nearby parking. Many will be in continuous operation and will not park at all, or will return to depots in less expensive locations where more land is available. Cars with no drivers can park more closely together. New parking lots will be much smaller and existing parking capacity could be doubled.

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Less off-street parking will be needed on valuable city centre land. On-street parking demand would also diminish, creating more road capacity for AVs or reallocated for other transport modes such as cycling, walking and mass transit. These impacts will vary depending on how car-dependent a city currently is. City authorities need to have a clear appreciation of what land is likely to become available and a strong vision for its re-use.

Public Transport and Taxis

AVs will complement or replace public transport in low-medium density / high car dependency cities. Even with AVs, it will still be important to have metro trains, light rail and trams to cater for high demand concentrations.

AVs would feed commuters to mass transit, thus shortening trips to and from transit stations and reducing the need for car parking. Scheduled bus routes could be replaced by on-demand AVs transporting people door-to-door. Users could choose to share AVs with other passengers, thus paying less. A demand-responsive, driverless service could replace conventional bus services, except where demand is high. Driverless buses will also reduce operating costs significantly as the cost of providing and training drivers will be avoided.

Taxis could arguably be replaced by AVs early on; they would certainly be significantly affected by the new competition from AVs.

Infrastructure Investments

AVs could significantly impact allocation of infrastructure funding. By increasing capacity on existing roads, AVs would reduce the need for new road infrastructure. This would enable funding to be reallocated to alternative infrastructure and amenities.

Given the lifespan of road infrastructure, forecasting and planning for it will need to strike a balance between meeting short / medium term demands and anticipating longer term demand with a predominantly AV fleet.

Urban Sprawl

AVs could induce increased urban sprawl because people would be more prepared to travel greater distances with faster, more efficient and comfortable travel. This would promote lower density development unless controlled through planning provisions.

Road use pricing could be used to help manage this, by charging through a combination of location, vehicle occupancy, time of day and distance travelled. With AVs it will be easier to price individual journeys compared to cordon charging systems (like those used in London and Singapore).

The Challenges

Changing behaviours and culture take time and there are a number of obstacles to overcome before AVs can realise their full capability. Managing this change is critical; planning, legislation and public perception issues require careful consideration.

Planning

The impact of AVs will vary according to a city's age, size, morphology and transport provision. For example, street layouts in central London have remained relatively unchanged since Roman times, whilst New York's street layout in Manhattan is designed as an efficient grid pattern. City authorities will need to carefully consider their city layouts and plan for potential impacts. High density cities with logical perimeters due to natural constraints or ring road infrastructure could be candidates for early adoption, for example Singapore, New York (Manhattan Island) and inner London.

*Figure 3: Senior Minister of State (Finance and Transport), Mrs Josephine Teo inspecting and testing an autonomous vehicle at LTA-A*STAR MoU Signing Ceremony*

Photos by: Land Transport Authority, Singapore

Social Perceptions

People's acceptance of driverless technology is likely to be gradual, improving as they become more comfortable with the experience.

A customer satisfaction survey (Ultra Global 2012) for the driverless Personal Rapid Transport (PRT) system at Heathrow Airport indicates high customer satisfaction; users regard the system like a horizontal elevator. Other research (Rodoulis 2011) shows that public acceptability of driverless trains increases when passengers see the benefits, for example where higher train frequency creates more capacity, less waiting time and better reliability.

An investigation into psychological factors affecting AV technology uptake in the UK by Clough (2013), suggests that enjoyment of driving, lack of trust in AVs and concern about legality are barriers to adoption. Clough also found that dangerous drivers are more willing to adopt the new technology than safe ones, which would accelerate the safety benefits. Interestingly, removing full control from the driver, or automatically intervening in emergency situations, is perceived as better than putting the driver in a supervisory role, expecting them to take over in an emergency.

Individual perceptions of AVs will differ greatly; those who see driving as an inconvenience or chore will look forward to the benefit of technology taking over, while driving enthusiasts will not want to lose the experience.

Safety

Many safety questions need consideration before full implementation of AVs. There are uncertainties around how AVs would respond in particular scenarios. For example how will an AV choose between damaging itself and / or the people in it, or a child in its way? How will they anticipate the sometimes unpredictable behaviour of pedestrians or cyclists? An AV will have vastly improved reaction times but it may not have the instinct or experience of humans. Worst case scenarios need to be developed, for example when AV software or hardware fails, such as through a cyber-attack.

Legislation and Liability

A major barrier to full AV implementation is accident liability. With cars driven by humans there is a high risk of accidents due to human error. When a driver has little, if any, input, responsibility for an accident may rest with the software company or the carmaker. New methods of risk management will be required and the insurance industry will need to adapt to the technology.

The US is an early adopter of legislation for AVs, prompted by Silicon Valley start-ups and Google's fleet of test cars. The National Highway Traffic Safety Administration has issued policy guidance around testing and includes plans for further safety research. Similar policies are being developed in Europe, but not as quickly.

Road to the Future

Despite the significant challenges to be overcome and managed, AVs have the potential to radically transform our cities and the way we move about them. Despite this, their possible impact is largely ignored in current urban and transport planning thinking. AVs represent the biggest change to transport that we will ever see. Cities need to understand and incorporate AVs into their future visions. Inevitably, society will demand city infrastructure that enables full use of these technologies. While the 'tipping point' is some time away, the positive effects on our lives and cities are rapidly becoming clear. Early adoption and preparation will bring substantial rewards.

Acknowledgement

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Stelios Rodoulis is a Development Transport Planner with a research interest in the future of transport and the impacts of driverless vehicles. Stelios works in Jacobs Traffic and Development team in London providing design advice, writing transport assessments and travel plans for public and private sector developments of varying land uses.