Why Autonomous Vehicle technology may be better suited to trucks and buses than cars

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ABSTRACT

Significant advances in autonomous vehicle technology have taken place recently, and are expected to continue. Semi-autonomous vehicles are currently on the market, and prototype autonomous cars are being trialled. These offer safer driving features, the ability to take the chore of driving out of each journey, and the potential to alter traffic patterns on our road networks. But is investment in autonomous cars the best option? Given that labour costs typically consist of 70% of bus and truck operating costs, whereas most drivers are driving (in effect) in their own time, autonomous buses and trucks provides the greatest potential to deliver significant cost savings to bus users and the carriage of freight. This paper will explore whether investment in developing autonomous buses and trucks along dedicated corridors such as Busways and disused rail corridors could provide the best financial return. The paper will also consider whether Auckland's Northern Busway could be an ideal test bed to advance this technology.

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INTRODUCTION

Autonomous cars are becoming closer and closer to becoming mainstream vehicle technology. These vehicles are expected to bring many advantages to both drivers and roads including; safer driving by reducing the scope for human error, reduction in travel time costs as passengers are able to use their travel time for other tasks, travel time savings and increased road capacity, etc.

The public demand for these vehicles and their benefits has car manufacturers competing as to who can develop and test this technology first (see JAFFE, Eric, 2015). Yet many of the benefits that we can expect from autonomous cars are probably also applicable to buses and trucks, and these vehicles may offer further benefits, so should we be looking at prioritising the investment of this technology into buses and trucks over the development of autonomous cars?

This paper will look at why investing in autonomous vehicles would provide more benefits on autonomous buses and trucks than on cars. This paper will consider many of the expected benefits that make autonomous vehicles a popular shift in the future, and expand on the advantages that autonomous vehicles are expected to bring and how these would be better served in a bus or truck over a car. This paper will then detail existing trials relating to public transport systems, driverless buses and trucks, as well how other technological advancements have the ability to further impact the benefit of autonomous vehicles. Finally this paper briefly explores some of the moral and ethical issues associated autonomous vehicles.

THE ADVANTAGES OF AUTONOMOUS VEHICLES

For the purpose of this paper, autonomous vehicles can be defined as vehicles that are fully automated and require no human interaction to drive. Some of the main advantages of these vehicles include:

- Driverless vehicles
- Increased road safety
- Increased operating efficiency.

Beginning with the definition outlined above, which specifies what would be one of the most obvious advantages of autonomous vehicles, the ability to be transported from place to place without having to drive. Autonomous vehicles enable people to use their travel time more efficiently. Getting to work need not be as time-constrained if people can begin working on their way to work. Traveling long-distance need not be as great a barrier to families if the entire trip can be spent spending quality time with your family.

Increased road user safety is another key driver for the development of autonomous vehicles. Removing the driver from control effectively eliminates the Human-Error element from driving. Looking at the Crash History information from CAS data to try and get an indicator of what proportion of crashes could be attributed to Human-Error. The review included all crashes classified under the following factors:

- Alcohol
- Too fast
- Failed to Giveway or Stop
- Failed to keep left
- Overtaking
- Incorrect lane or position on road
- Poor handling

- Poor observation
- Poor judgement
- Fatigue
- Disabled, elderly or unwell.

It should be noted that a single crash may be classified under more than one of these factors, however, for the purpose of this review, it serves to provide an indicator of the weighting of involvement of human-error in crashes with injuries. Using these assumptions, the data revealed that 81% of all crashes with injuries fell into at least one of these categories. So the introduction of autonomous vehicles as the potential to make a dramatic impact on deaths and injuries caused from traffic accidents.

Network efficiency is an objective set for many traffic planning tasks, but also has an increasing role in how the 'every-day driver' plans their journey. Google maps enables the feature to check live speed information, or in other words the level of congestion on the network. This means that anyone can plan their journey around live congestion. Autonomous vehicles present the opportunity to expand the level of information available across the network, and increase the reaction time for which up-to-date travel information can be relayed to the passengers, and for re-routing to occur.

THE ADVANTAGES OF AUTONOMOUS BUSES AND TRUCKS

All the aforementioned benefits of autonomous vehicles, can be applied in the same way to autonomous buses and trucks. But in fact, in many cases these advantages can be taken a step further.

Driverless vehicles increase available leisure time to passengers, where previously they would have to drive to work. Bus and truck drivers on the other hand are paid to transport people or products as part of their work. The cost of the drivers services being then incorporated in the operating costs for the bus and truck transport providers, and ultimately to the consumer. (MACKECHNIE, Christopher) stated that employee wages and benefits are approximately 70% of bus public transport operating costs. This suggests that the introduction of driverless public transport buses could have radical implications on the cost of operations and therefore potentially public transport fares.

Other considerations of driverless buses or trucks are the hours of operation. These need not be constrained by available drivers, or restrictions on the number of hours a driver can legally drive for without a rest. This means services can potentially not only run more efficiently (with less breaks), but for longer hours. The same quantity of autonomous buses compared with the existing fleet with drivers, can offer more services during the day, and if run more efficiently, a greater frequency of services as well.

Bus and truck operators are less vulnerable to being affected by staff strikes disrupting their services, or being limited by the number of people available to work less-desirable shifts. (TIMES, Otago Daily, 2015) recently stated that Singapore is looking into a future with a driverless public transport system. "Trying to look for bus drivers, truck drivers - big challenge for us," said Pang Kin Keong, permanent secretary in the ministry of transport. "We don't have a huge population and these are not some of the professions which Singaporeans aspire to,"

When looking improvement of road safety, one need not only measure it by the number of injuries caused (or potentially saved). Road accidents have a large impact on traffic, in particular congestion around a crash. Crashes can cause roads to be closed, and hence delays for thorough-fare traffic. Even if roads are not closed, passers-by will slow down to observe the damage. The scale of these delays and disruptions to road-users is difficult to measure but one can assume that the bigger the vehicle involved in the accident, the bigger the damage is likely to be, and the

greater the effect on traffic. This means the ability to remove human-error in the form of autonomous buses and trucks in particular, stands to gain significant improvements to road operation as well as increased safety to all road users.

When applying network efficiency to buses and trucks, the main advantage to be considered is the operating efficiency. Autonomous buses and trucks have the ability to feed back to a system which can re-route them more effectively as required to meet the demand constraints the dictate the industries in which these vehicles are used, namely public transport and freight deliveries.

AUTONOMOUS VEHICLE TRIALS

Many countries are pursing trials for autonomous vehicles on their roads but for a large variety of reasons. Examples of trials beginning at the moment include Robot Taxis in Japan. (DEMETRIOUS, Danielle, 02) states that Robot Taxi are now poised to test their self-driving taxis with a group of 50 local residents. The vehicles will be autonomously operated, but with two human co-pilots present to take control if required, for safety reasons. Tokyo is hoping to have these operational in time for the 2020 Olympics.

Closer to home, the Ministry of Transport Intelligent Transport Systems Technology Action Plan for 2014-2018 (TRANSPORT, Ministry of, 2014) states that it will be reviewing transport legislation to "identify unnecessary barriers to the continued deployment of ITS technologies in New Zealand." It also identifies the "increasing introduction of advanced driver assistance systems (ADAS) and semiautonomous vehicles." The plan also comments on the potential presented by having fully autonomous vehicles; the implications for road safety and increasing travel opportunities (demographically), and increasing the efficiency of our roading network.

Turning towards autonomous buses, (JAFFE, Eric, 2015) states that although these are under development, they will not arrive on our roads as quickly as autonomous cars.
For the autonomous buses under development, progress is largely determined by need. There are companies in the United States that are investing in driverless shuttles. (WALKER, Alissa, 2015) describes one of these scenarios, where the driverless shuttles transport employees around the Northern California Office park. This case is a pilot programme where the cars will travel at slow speeds along pre-programmed routes.

Further development of autonomous buses, with the particular aspirations of introducing them into public transport are occurring in many different countries, including China and Singapore.
A driverless bus prototype is being developed by Yutong in China. (HARS, Dr. Alexander, 2015) states that Yutong are hoping to improve bus services by offering on-demand-buses over today's mix of scheduled buses, trains and individual cars. These buses are expected to lower the cost, resource consumption and ecological footprint of mobility. Long-term these buses are expected to increased capacity of highways by providing a valid alternative to cars.
Metro Vancouver's transit authority is exploring the possibility of driverless buses guided by computerized maps and laser technology.

As mentioned previously, in Singapore there is a push for autonomous bus trials due to the constraint in bus drivers, as part of a driver to push Public Transport, as reported by (TIMES, Otago Daily, 2015).

Developments in autonomous vehicles are not just limited to cars and buses. Autonomous trucks are in fact already in use. Komatsu (KOMATSU) has developed autonomous trucks for use on mine sites. The targeted advantages around this development, is in line with the targets already

mentioned already, namely:

- Reduce number of drivers working in hostile and remote areas
- Increased safety on mine sites
- Reduced operating costs
- Increased productivity and efficiency.

(RUTKIN, Aviva, 2015) claims that Daimler in the United States, have has been cleared to drive their new self-driving truck on US Roads. At this stage they are not completely driverless. A human driver is still present to take control in case of lane change or unexpected hazard. The truck is not yet available for commercial release but Daimler are now planning to conduct tests to improve the truck further. (RUTKIN, Aviva, 2015)'s article also mentions that the safety benefits of these partially autonomous trucks are still a grey area where drivers may become too reliant on the built-in safety features, or attempt to do things with the truck that it has not been designed for.

Driverless Trains

Driverless trains already exist. Currently only the Docklands Light Railway runs with no drivers in London, although that network still requires a member of staff on each train for safety. London's Victoria Line was constructed in the 1970s to be a driverless system, though the trains have always had a human presence for customer relations reasons.

Nuremberg in Germany has a driverless metro that was opened in 2008. (AG, Siemens, 2014) describes the trains as fully automated, driverless and without conductors, in operation. The systems offers advantages to both passengers and operators. It has enabled reduced dwell time for passengers and increased the overall capacity of the metro service. The system has taken the service a step-further by enabling flexibility in shortening and extending the length of cars as the demand requires to keep up changing capacity constraints. This has helped to avoid overcrowding on trains and further optimised the operating costs by only deploying trains when required, to the necessary capacity.

Nuremberg is not the only example, merely one of the firsts. However if driverless trains are already in operation, how much bigger a leap is it from driverless trains to driverless buses for public transport? We already have Bus-only lanes that can be used to segregate non-autonomous vehicles from proposed autonomous bus services. The train operates in a similar manner, to stop and start at designated stops to allow passengers to board and alight the service. The idea of driverless public transport therefore, is not new to the public, merely the introduction of the technology specific to buses. Given its success in Germany, let along elsewhere that it has already been introduced, is it much more of a stretch to extend autonomous vehicles to autonomous buses and look to introduce these into our public transport operating system?

The Northern Busway, Auckland

The Northern Busway will provide segregated Bus and vehicle lanes to road users. This separation enables a platform to test autonomous vehicles, much like the Driverless Trains mentioned previously. Autonomous vehicles would be able to operate on the road in general traffic conditions, but being in an alternative lane reduces the risk posed to general traffic (or non-autonomous vehicles).

Currently the New Zealand Government has not received any formal requests to test autonomous vehicles (Transport, Autonomous including driverless vehicles, 2015). These is a Technology Action Plan available on the Ministry of Transport NZ website, however, the legal situation will need to be adapted to enable testing and general use of autonomous vehicles on New Zealand roads. The action plan states that the New Zealand Government will monitor international developments on these matters for use in the future when outcomes have progressed further.

Autonomous Vehicles and Phone Applications

Updates in modern technology have already begun to influence the way we use public transport. Uber offers the facility to order taxis at the best price you can find, through the day – and watch them travel to your doorstep. Aps allow us to check what public transport services we can catch to get home, and compare how long these services will take and when they will arrive at the nearest station. Google maps is constantly involving but can now incorporate live speed flows on the roads, so you can see where congestion is developing and what alternative routes are available to you. Given the existing ability to order taxi's, on-demand through phone aps, as-well as the ability to suggest adapt routing for a more efficient travel time, it is not too far-fetched to suggest the possibility that aps have the potential to play an even bigger role in public transportation. One of the key potentials with modern technology and public transportation would be estimating demand based on user-inputs. Autonomous buses would be able to adapt their routing to pick-up the nearest passengers heading in the same direction. There would be the potential to decide when to run additional services, particularly in the off-peak times, based on the demand.

This next step in synchronising phone applications and vehicular technology need not just apply to public transportation either. Freight trucks, for example, could synchronise to a similar server. This could be particularly beneficial not just in optimising which trucks are sent to which pick-ups and deliveries, but also in re-routing. Say one truck were to be held up in traffic delays, or to have an accident, a server linking all trucks would be able to re-assign that trucks pick-up's to another available truck, so that all deliveries have a better chance of being delivered on time.

Earlier in this paper I touched on how public transport and truck freight services will no longer be constrained by working hours with the introduction of autonomous buses and trucks. This in particular has ramifications for the off-peak, in particular the evening shifts. Instead of irregular services that only operate between certain hours, at a certain frequency. Autonomous buses could now operate based on demand for services at various hours during the night – demand for services being an input provided by aps.

THE ETHICS OF AUTONOMOUS VEHICLES

One of the big debates with the introduction of autonomous vehicles is insurance and liability. If an autonomous vehicle has an accident, who is liable? The passenger for buying the car? The car manufacturer for not creating a crash-proof vehicle? The software developer for not developing an all-encompassing software system.

This can be further complicated if one considers how an autonomous vehicle might react to a potentially hazardous situation. (O'CALLAGHAN, Jonathan, 2015) wrote a very interesting article titled "Should A Self-Driving Car Kill Its Passengers In A "Greater Good" Scenario?". The article poses the question how should a self-driving car react in the following situation:

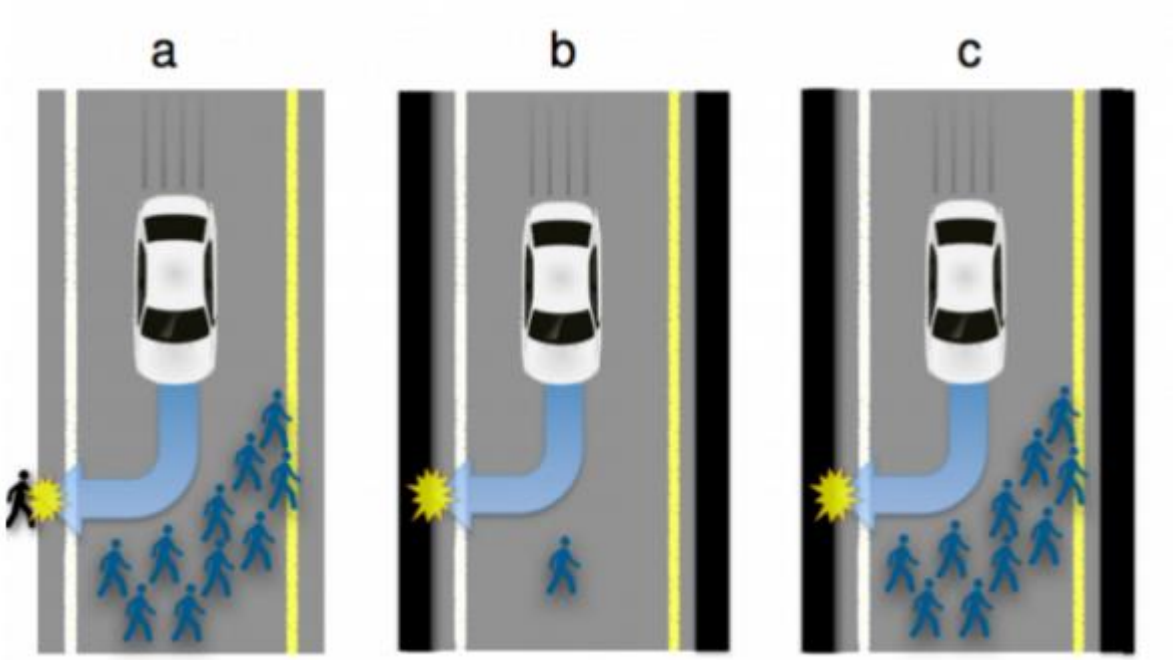

Figure 1: A, B and C represent 3 scenarios where an autonomous vehicle is approaching the following groups of pedestrians, and possible impact scenario's that could take place. A shows the vehicle crashing into a pedestrian on the side of the road (to avoid impact with the group crossing the road). B shows the vehicle crashing the vehicle into a wall, sacrificing the driver, but saving the pedestrian crossing the road. C shows the vehicle again crashing into a wall to avoid injuring the majority (of people) crossing the road, at the risk of injuring the driver.

He poses the question, picture yourself in a self-driving car approaching the situations depicted. Should the vehicle be programmed to swerve to avoid the pedestrian(s), at the risk of seriously injuring the passenger? "The results are perhaps not too surprising; on the whole, people were willing to sacrifice the driver in order to save others, but most were only willing to do so if they did not consider themselves to be the driver. While 75% of respondents thought it would be moral to swerve, only 65% thought the cars would actually be programmed to swerve."

This scenario raises both a moral and ethical dilemma, should a person be punished for purchasing the vehicle that is encouraged by governments around the world as a safer vehicle. And, at the extreme of this situation, what would prevent a pedestrian from deliberately running out in front of an on-coming autonomous vehicle with the intent of causing a crash? How would we distinguish the innocents from the guilty? On the other hand, if you programmed vehicles to prioritise their passengers, and public knowledge of this approach was encouraged, then people would be more inclined to behave responsibly around vehicles, and reduce the case of incidents on the whole.

What if I were to take this example one step further, and substitute the autonomous car shown for an autonomous bus? How then should the vehicle be programmed to react?

CONCLUSION

Autonomous vehicles are expected to bring many efforts to road users including increased road user safety, decreased value of travel time, decreased congestion and increased efficiency on the roads – to name a few. Yet all of these benefits can not only be applied to autonomous buses and trucks, but further value may be added.

Driverless vehicles decrease the value of travel time, a benefit that is very measurable when applied to industries such as public transport and freight where drivers will no longer be required. While this may create a job shortage for drivers, there is already a shortage in availability of drivers, and the dependency on drivers influences the cost of the service they are providing. In public bus transport this is up to 70% of the operating costs of the service.

Services will no longer be constrained by legal driver operating hours, they can continue as regularly as required by demand rather than by driver availability.

Increasing the safety of the road not only reduces the number of crashes, but congestion and road closures caused by these crashes. As trucks and buses cause more disruption, they stand to gain more from these crashes savings, not only in terms of time saved in clearing the incident, but also in lives saved.

Autonomous buses and trucks are already being trialled in various forms. Driverless trains have taken this a step further and are already operating. The service offered by public transport trains to public transport buses is not that different, particularly with the ability to segregate autonomous buses onto bus only lanes, as trains are from the public. Therefore the ability to integrate autonomous public transport is already underway, and presents fewer obstacles than integrating autonomous cars with drivers.

The capability to introduce autonomous buses onto our networks exists, and the technology is not only in demand for autonomous vehicles but being trialled for its numerous potential benefits. The ethics to how these vehicles operate still presents many unanswered questions, particularly in terms of liability. However the demand for this technology will continue to push its development. The only question is why autonomous buses are not being prioritised over autonomous vehicles?

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