## CHAPTER 23

# HYPE OR HOPE – CAN FUTURE TRANSPORT TECHNOLOGIES EASE CONGESTION?

*Yuchao Sun, Laura Gladstone and John Taplin*

## INTRODUCTION

We live in an exciting era of rapid technological innovation. Many emerging technologies and technology-enabled business models look like promising solutions to existing transport and land-use problems. These opportunities also create new uncertainties and unanswered questions. Many technologies in the past have failed to live up to their promise or have taken us two steps forward but one step backward. Are the emerging ones true saviours or will they create more problems than solutions?

There has been much media hype but not much systematic and critical analysis. It is difficult to predict exactly what will happen – which technologies are going to prevail or what their impacts will be. Nevertheless, some rational thinking and thought experiments should help to prepare for the future. This chapter examines possible impacts of key future technologies on road congestion, focussing on urban passenger transport: the movement of people rather than goods.

The estimated annual cost of congestion is on the scale of US$100 billion in the USA (Texas A&M Transportation Institute, 2012) and A$10 billion in Australia (Bureau of Transport and Regional Economics (BTRE), 2007). Different accounting methods give different figures depending on what is counted and how, but these numbers highlight the enormity of the problem.

Although evidence suggests that motorised travel demand has levelled out or even declined – sometimes called 'peak car' (Wee, 2015) – in a number of developed economies, including Australia (Millard-Ball & Schipper, 2011), there is no sign that congestion will decrease.

Future transport technologies will affect us in legal, technical, social and economic aspects. For example, autonomous vehicles (AVs) will likely require different insurance arrangements, as liability will probably shift from the driver to the manufacturer or a third party. More reliance on technology also means increased risks of hacking. How will people adopt and interact with radically new technologies like AVs when first introduced? Will performance of AVs have to be toned down to accommodate or not annoy human drivers? For example, Arnaout and Arnaout (2014) found drivers unwilling to use the shortest gap a vehicle with Cooperative Adaptive Cruise Control was capable of, though they commented that the test period may have been too short for the participants. With ever increasing speed of innovation, governments also face challenges in making the right technology investment decisions to ensure what they commit to will not become obsolete in the near future. These are all important issues to consider and this chapter will only focus on a small subset of problems.

No matter how technologies advance, the relationship between supply and demand applies as long as road space remains a scarce resource. Consumer costs are important in determining the balance between these drivers. The authors' analysis is based on an imaginary future where the combination of future technologies works in consumers' favour to reduce their private costs, as presented in the following sections.

It is important to note changes in many other socio-economic and political factors could affect transport supply and demand, but this chapter assumes everything else remains the same, on an 'other-things-being-equal' basis.

## HOW FUTURE TECHNOLOGIES MIGHT AFFECT CAR USERS' PRIVATE COSTS

Private costs are borne by consumers themselves and external costs are what they impose on others. Many future transport technologies (e.g. AVs, connected vehicles and smart infrastructure) are designed to increase supply through more availability at a cheaper price. This section makes an educated guess as to how they might change car users' private costs, leaving the discussion on external costs to the next section. A road user's private costs include vehicle purchase costs, operating cost, energy cost, time cost, and various fees and taxes (Litman, 2009; Mallard & Glaister, 2008).

Figure 1 gives a general idea of the average cost breakdown of private cars. Importantly, a large part of the cost is variable[1] and mainly related to mileage. An average driver is insensitive to most variable costs, except travel time and possibly fuel cost, which are therefore the only two significantly perceived marginal costs of driving. This section will first discuss how AVs might change private fixed costs. It will then discuss how future technologies might even further desensitise car users from their private variable costs.

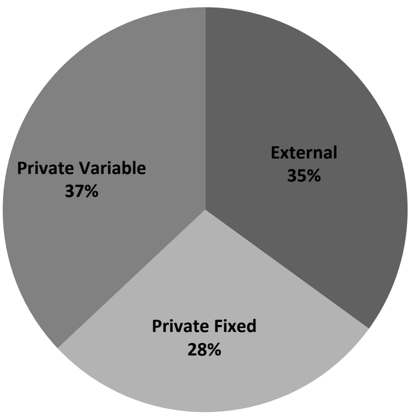


*Figure 1: Average car cost distribution (Litman, 2009)*

### *More Expensive Cars but Reduced Ownership*

Purchase price is the largest private fixed cost. Self-driving and connected vehicles will cost more than conventional ones because of the additional equipment. However, AVs may reduce car ownership because it is easier to share them with family members or other people. In our hoped-for scenario, lessened ownership will offset the increase of vehicle price.

Autonomous taxis and new car-sharing business models may also emerge, allowing people to use cars on-demand (Fagnant & Kockelman, 2014; Folsom, 2012; Greenblatt & Saxena, 2015). Some car-sharing systems have already been practically implemented in Sydney (Dowling & Kent, 2015) as well as other countries (Cepolina & Farina, 2012). These systems could complement private car use or enable people not to have a car. Given that average cars in the USA are only used 10 per cent of the time, there could be a large potential to reduce car ownership (Fagnant & Kockelman, 2014). Note, however, that reduced car ownership does not necessarily mean reduced travel demand, and the latter is more of a concern when it comes to managing congestion. Nevertheless, reduced car ownership will also beneficially reduce the large amount of space currently allocated to garages and parking.

### *Lower Operating Costs*

Future vehicles should be cheaper to operate (Greenblatt & Saxena, 2015). Vehicle service costs will probably decrease as a result of electrification. Electric and hydrogen-powered vehicles are driven by mechanically simpler electric motors probably requiring less maintenance. Manufacturers might charge subscription fees to keep users' in-car software (e.g. maps and operation systems) up-to-date. On balance, however, we think average service cost might decrease.

Despite uncertainties in energy costs, it is probably safe to assume average running costs of future vehicles will fall as more of them will be driven by highly efficient electric motors.

Today's electric cars are already cheaper to run than their petrol counterparts (Hopewell, 2015). For cars that still use fossil fuels, improved combustion engines and better driving of AVs and semi-autonomous vehicles will also result in efficiency gains. Electric vehicles can be recharged by solar panels, especially with the help of home storage batteries. After initial installation costs, solar (or wind) energy has close to zero perceived marginal cost, meaning the vehicles it powers will no longer have their energy cost associated to mileage.

### *Less Time Cost*

Self-driving vehicles will reduce perceived time cost of travelling, because riders can be freed to perform their daily business. This is one of the main value propositions behind many future concept cars. Comfort is a key factor in making passengers productive. There are concerns that lower acceleration and deceleration rates are required to make passengers comfortable, which might sacrifice system performance and reduce infrastructure capacity (Le Vine, Zolfaghari & Polak, 2015). As this chapter imagines an optimistic future for technologies, it assumes travel time in AVs will be more productive, so associated disutility and private cost will be reduced.

### *Larger Infrastructure Capacity*

Improving road capacity is claimed to be one of the main potential benefits of AVs (Folsom, 2012; Le Vine et al., 2015). This would reduce the average travel time if total demand remains constant. Fully autonomous vehicles will almost certainly surpass an average human driver in the future. With shorter reaction time, they have potential to increase traffic density by reducing gaps between vehicles (Folsom, 2012). Theoretically, these intelligent driving machines will be capable of fixing many problems caused by imperfect human drivers, although, as mentioned in the introduction, users might choose to tone down the parameters for their own comfort. Concerns on the trade-off between capacity and passenger comfort aside, AVs should be able to reduce traffic shock waves caused by small disturbances such as sudden or unnecessary braking, which lead to so called 'Phantom Jams'.

Forecast increases in road capacity will be significant only when the adoption rate of appropriately equipped vehicles reaches a critical level, as a simulation of Cooperative Adaptive Cruise Control has shown (Arnaout & Arnaout, 2014). A combination of proactive government policy and road safety lobbying could assist in reaping the benefits of technology more quickly. However, as it is not possible to force people to buy new cars, there may be quite a delay before achieving maximum benefit.

Other factors may also decrease the likelihood of realising the benefits of future technology. Vehicles equipped with varying systems that behave differently could compromise system performance (Townsend, 2014). It is to be hoped current work by international committees on connected vehicles and other technologies will help to avoid this outcome by standardising vehicle parameters.

Connected vehicles will be able to communicate with each other and with infrastructure. Possible legal, privacy and security concerns (such as hacking) aside, better communication should improve system efficiency. For example, it will be easier to have more efficient traffic lights by knowing vehicle destinations. By talking to each other, AVs should be able to negotiate better at freeway weaving and merging points, which are often bottlenecks.

### *Didn't History Prove that Lower Private Costs Induce More Travel Demand?*

In our optimistic scenario, future technologies are likely to reduce travellers' private costs but this is based on the assumption that demand does not increase, which is often not the case. History has proven increasing supply is not the solution to congestion. Despite continuous road building and improvement, congestion persists or has even worsened (Maddison et al., 1996). It is well known to economists that more supply induces more demand in transport. Lower private costs that future technologies might bring, especially lower time costs and lower marginal operating costs, will reduce impedance to travel so people might travel further or more often.

The government's goal of having a 'more compact' city (Western Australian Planning Commission, 2010) could, with future technology, be even harder to achieve. If a family owns a car, the temptation to use it will persist. What stops people from living even further from their workplace to seek cheaper property prices or desirable lifestyles? Townsend (2014) has projected a dystopia including commuters leaving home at 4am and going back to sleep at the wheel of their fully autonomous cars for a three-hour commute. It is to be hoped that work-life balance concerns would prevent this outcome, but it is possible. Fully automated vehicles could provide 'mobility freedom' for people who are not able to drive (KPMG, 2012). They increase equality in transport provision but could also generate more demand for private car use.

The ability of AVs to drive by themselves is a blessing but also a potential source of additional traffic. For example, a shared AV may well run empty between pickup points, creating the dead running problems seen in public transport. It is less a problem for a publicly shared AV than a private one shared between family members. However, modelling suggests even the former would produce longer total travel distances (Fagnant & Kockelman, 2014).

Driverless capacity might also render parking policies an ineffective instrument for travel demand management. Why would a car owner pay a $30 parking fee in the CBD, when he/she can simply send the car home because access to roads is free, especially if it is running on 'free electricity' as discussed previously? Another point to consider is that parking and parking fines are sources of government revenue. If these sources are reduced, alternative forms of revenue may be needed.

One may argue that future technologies are more about better utilising the existing infrastructure than the expansion of the network. The authors agree that there are benefits in this but, on the other hand, increasing supply is likely to induce more demand. It is possible that fewer but highly utilised AVs might eventually generate more traffic.

## HOW MIGHT FUTURE TRANSPORT TECHNOLOGIES AFFECT EXTERNALITIES?

An external cost (negative externality) is a cost imposed by an economic entity on a third party where the imposing entity does not consider consequences (Mallard & Glaister, 2008). Transport generates significant external costs to society (Jakob, Craig & Fisher, 2006; Maddison et al., 1996). Many of our current transport problems are the results of market failure where consumers do not pay for their full external costs. External costs in transport are commonly divided into three main categories: environmental damage, accident costs and congestion costs. The latter two are mostly variable costs while the first has both fixed and variable components. The fixed environmental damage occurs during the manufacturing process and the variable is produced during the life of the car.

### *Less Environmental Damage*

Environmental damage includes greenhouse emissions and other forms of pollution (including noise) causing human health problems, environmental degeneration and building damage (Maddison et al., 1996).

Greenblatt and Saxena (2015) claim self-driving taxis could cut greenhouse pollution by about 90 per cent by 2030. Many things need to happen for this to become true, particularly more reliance on clean energy. Despite current hurdles for carbon pricing, we are hopeful the clean energy mix will increase and future vehicles in general will pollute less.

### *Less Accidents*

Accident costs are both internal and external. Examples of the latter include clean-up costs, policing and traffic jams caused by accidents (Jakob et al., 2006; Maddison et al., 1996).

Although still subject to programming errors, machine malfunctions and hacking, it is not unreasonable to predict that AVs will be generally safer than human drivers so externalities caused by accidents and internal costs will be reduced (Folsom, 2012; National Highway Traffic Safety Administration, 2013). Currently driver error is believed to be the primary cause of over 90 per cent of crashes (Main Roads WA, 2015).

### *How About Congestion?*

Fewer accidents also mean more reliable roads and less congestion (National Highway Traffic Safety Administration, 2013). Nevertheless, to what degree future technologies can ease congestion is unclear.

Congestion costs include increased time delays and fuel consumption. As traffic builds up, not only do additional vehicles experience higher costs themselves, but they also inflict higher costs on other road users. In our future scenario, consumers bear less private costs and, if they still only pay part of the external costs, their total costs of travel go down. As discussed earlier, reduced costs are likely to induce more travel demand, contrary to the goal of easing congestion.

Individuals put their own interest ahead of their collective interests, even if achieving the latter would make everyone better off (Olson, 1971). This leads to depletion of a common resource, known as ‘tragedy of the commons’. One simply cannot hope private car users will voluntarily restrain themselves from driving (or riding in the case of full AVs) while others enjoy their right to drive as much as they wish (Maddison et al., 1996). Economists argue the most effective way to avoid ‘tragedy of the commons’ in transport is to create social marginal cost-based charges.

The current peaking of passenger vehicle travel mentioned in the introduction may be a result of congestion affecting people's time budget. If so, once the marginal cost of car travel is largely reduced by AVs and clean energy, it is hard to guarantee demand will not increase again until it overwhelms supply.

One may argue congestion may not be such a problem in future because time spent travelling becomes more productive, so congestion will not cost society as much. That argument has three problems.

- Congestion will stop vehicles with the need to travel fast (e.g. emergency vehicles) reaching destinations in time;
- Congestion will cost commercial vehicles extra money, even if they are fully autonomous;
- As discussed, there is a trade-off between personal comfort and transport system performance as a whole (Le Vine et al., 2015). If future governments mandate parameter settings to seek optimal system performance, time spent in AVs might not be as productive as car manufacturers envisage due to discomfort, so reduction in time wastage may be less significant.

A congested road network is ineffective and never desirable. Most people will probably agree that empty AVs running around on streets causing congestion is not a pleasant future.

## ROAD PRICING IS NEEDED EVEN MORE FOR FUTURE TRANSPORT

Many of our existing transport problems are caused by market failure, which refers to situations where the free market fails to achieve desired social and economic efficiency in the absence of government intervention (Mallard & Glaister, 2008). A major market failure in transport is revealed in the lack of proper pricing mechanisms for charging users their full external costs. Estimates based on UK figures show the average marginal road user only

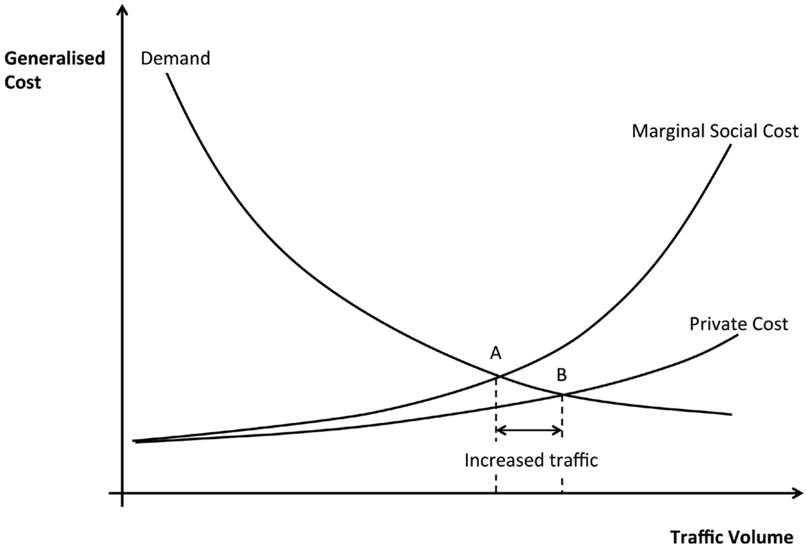


*Figure 2: The deviation of marginal social cost of road travel from private cost.*

pays one third of the marginal external costs he or she imposes (through tax collected by the government (Maddison et al., 1996)).

Figure 2 shows when external costs are not borne by road users who impose them, demand increases from the efficient equilibrium at A to the inefficient one at B, producing extra traffic on the road (Maddison et al., 1996). Figure 2 also shows the gap between marginal private cost and marginal social cost increasing as traffic builds up, which is based on flow studies of single roads and has also been modelled for a network (Sun & Taplin, 2006).

New technologies will not fix market failures because they are not technological problems. They might help reduce some negative externalities but, in the absence of a proper pricing scheme, inefficiency of the market remains. Many if not most transport researchers argue road pricing might be the only way to reduce traffic congestion (e.g. King, Manville & Shoup, 2007; Moriarty & Honnery, 2008).

The theory of road pricing has long been established (Ministry of Transport – Great Britain, 1964; Vickrey, 1963; Walters, 1961). Since future technologies might reduce private marginal costs of travelling and induce more traffic, it is even more important to impose a pricing scheme reflecting the true marginal social cost. An effective road pricing system should consider both traffic conditions and distance.

The existing fees and taxes such as fuel excise recover some of the external costs. Fuel excise is the only existing marginal cost-based charge in Australia. It is ineffective because it relates to distance but not traffic conditions, which are important in determining external costs. Marginal charges which do not reflect scarcity of road space at the time of driving do not help ease congestion.

A proposed indirect and equitable method of charging for – and thus rationing – the use of cars at peak times in critical locations would allocate a limited quantity of free but tradeable travel credits to eligible recipients (Grant-Muller & Xu, 2014). A commuter could use these credits to drive in the peak while someone not in a hurry might sell credits. The system could be extended to cover connected AVs.

A dilemma for the government is that clean energy and improved efficiency will make fuel excise even less effective. Additionally, they will shrink government revenues collected from fossil fuels, adding another practical reason for marginal cost based (pay-as-you-go) road pricing (Hibbs, 2003; Johnson, Leicester & Stoye, 2012). Johnson et al. (2012) also suggest that increasing tax on fossil fuels or even electricity is unwise. The UK Department of Transport estimated a well-designed national road pricing scheme that targeted marginal social costs could result in annual time savings worth £10 billion (Devereux et al., 2004).

One cannot assume public support for an economically efficient solution so there are severe political barriers to overcome (King et al., 2007). What new technologies can help with is to bring down the cost of implementing wide pricing schemes, an important factor in determining their acceptance and feasibility (Mallard & Glaister, 2008). The authors argue that is where future technologies are likely to have a large impact in establishing an efficient market for transport.

## PUBLIC VS PRIVATE

Proper road pricing will also help public transport compete with private. Since the 1940s, total passenger travel in Australian urban areas has increased ten-fold and the share of private car use has more than doubled to about 90 per cent (BTRE, 2007). Can new technologies stop this trend?

Autonomous technologies may make public-transport systems more competitive. Automation will likely reduce the operating cost of public transport, since drivers' salaries make up a significant part of running cost. Advanced technologies might also make public transport more or less on demand and dispatch vehicles according to customers' requirements (Greenblatt & Saxena, 2015). This would partly solve one of the biggest challenges of public transport, dead running, which makes many current bus services less fuel efficient than private cars (Folsom, 2012). Technology could also help reduce disutilities such as waiting time and service disruptions.

The distinction between public and private transport might become less clear if publicly shared autonomous vehicles become a feasible business model (assuming problems such as how to prevent passengers' malicious behaviour in an unwatched environment can be solved).

The real question is whether AV-driven public transport can compete with private AVs with low running costs. Folsom (2012) claims they will but with no substantial backing. It would be helpful if as technology advances, financial modelling could be done to show that public transport would still be competitive. Even with a more optimistic scenario for technology, and assuming future public transport becomes very attractive, it would require a dramatic change of attitudes for a large number of families to decide to give up car ownership altogether.

Cost recovery is another challenge. Governments cannot continue subsidising public transport if most people use it. With increased patronage and, hopefully, reduced empty running, cost recovery could improve, but how and when is uncertain. For privately run car-sharing businesses, licensing fees the government will probably charge will add extra cost burdens.

Public transport could also suffer from crowding and congestion if patronage increases dramatically. Shared AVs may be convenient but they need to use space more efficiently. Smaller vehicles, such as Personal Rapid Transit (PRT) systems made up of AVs, have been proposed as a solution (Folsom, 2012; Greenblatt & Saxena, 2015).

## HOW ABOUT DEMAND?

Most modern economists hold that demand leads to supply (Mallard & Glaister, 2008). Transport demand is derived demand, therefore most demand-side technologies are not actually transportation technologies but Information and Communications Technologies (ICTs) – telepresence being the most promising. The hope is that telepresence combined with advanced IT infrastructure will enable more flexible working arrangements such as working-from-home or co-working.

Current telepresence solutions are not capable of replacing physical interaction and maintenance of working relationships through co-location. A drawback to working from home is a lack of structure and social interaction. Co-working might offer a middle ground where people could share and rent a desk from a professionally managed office close to their home instead of going to their own office.

More flexible working arrangements might help spread the peak or reduce commuting traffic. However, they might also enable people to live further from their work-place and increase the number of non-work trips (Hensher, 2007), especially when they are equipped with autonomous vehicles. Houses in fringe areas are cheaper than they should be because of current practice to subsidise the required infrastructure. If this continues, together with reduced travel costs and the need for commuting, urban sprawl is encouraged.

## CONCLUSION

Solving congestion by increasing supply has never worked and probably never will. Technology has enabled people to travel further and is likely to continue doing so in future. Future technologies such as clean energy and AVs are expected to reduce the two major components of a driver's private marginal cost: energy and time cost. Although these have benefits they might also induce more travel demand.

Future technologies are likely to render two of the major instruments (taxes on fuel and parking) ineffective. Governments will have fewer tools available to manage travel demand. That combined with lessened revenue will make it even more important to implement road-pricing schemes that target marginal social cost. These might include restricted travel credits.

There are many pathways future technologies could take. Predicting the future is hard, if not impossible, because of the complex dynamics of change (Hibbs, 2003). However, what we can do is drive change towards a desirable future rather than waiting for a magical technical solution. No matter what advanced technologies we have, implementing proper pricing schemes will always be necessary to create an efficient market for transport, at least for the foreseeable future.

Many of the promising technologies, such as AVs, will take decades to mature and reach a critical mass. Only then can we get their full benefits. In the meantime, market failures will continue to cost society billions of dollars. With mounting pressure caused by congestion, waiting and hoping for miracle technologies can only cost more. The same is true for waiting and hoping that people's attitudes to car ownership will change.

Although the authors are passionate about what the technologies are capable of, we should also be aware they are not miracle cures for structural faults. The old criticism about technology determinism has to be repeated here – without a proper government policy framework, technologies alone are unlikely to create an efficient transport market. We should see technologies as enablers, not determiners. Ultimately, the solution should be political and economic as well as technical.

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## NOTES

1 The next section will discuss the breakdown of external costs. Only one of its three categories has the fixed components.

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