Three revolutions in urban passenger travel

Lewis M. Fulton and Junia Compostella

Three revolutions are underway in urban transportation around the world: vehicle electrification, automation, and shared (on-demand) mobility. We do not yet know the manner in which each of these will unfold or how they may interact; the way in which these changes take place will have major implications for cities over the coming decades. Our modelling work suggests a wide range of possible impacts, and a strong need to pursue policies that move these revolutions in sustainable, societally optimal directions. This generally means reducing the numbers of vehicles on the roads, and parked, as well as dramatically cutting energy use and CO_2 emissions. To do this it seems likely that we will need to dramatically increase the extent to which rides are shared, public transit is expanded and used intensively, and active modes (walking/cycling) increase their share of trips. The effects of achieving these conditions under a three revolutions future was the focus of recent research at the University of California, Davis. This commentary summarizes and extends this work.

'THREE REVOLUTIONS ARE UNDERWAY IN URBAN TRANSPORTATION AROUND THE WORLD: VEHICLE ELECTRIFICATION, AUTOMATION, AND SHARED (ON-DEMAND) MOBILITY.'

- As of 2017, battery electric and plug-in hybrid vehicles have reached 1–3 per cent sales shares in most OECD countries (and much higher in a few, such as Norway); some projections see this share rising as high as 30 per cent by 2030, with a hundred million or more EVs in service at that point.
- Automated vehicles are further behind but costs are declining rapidly, regulatory frameworks are emerging, and commercial vehicles are expected to begin appearing as Level 3 or Level 4 (fully autonomous but limited to certain driving modes) around 2018/19, and Level 5 (completely driverless) a few years later.
- Shared mobility, both in terms of ride hailing and car sharing, is now well developed and widespread around the world, though it still represents a low share of trips in most cities. But on-demand ride hailing appears to be increasing rapidly in many places.

Some directions the changes could take

How might these three revolutions co-evolve? There are a number of potential directions, and complex potential dynamics. These include:

1 Automated vehicles in households could increase travel and traffic

A major shift to privately owned driverless cars could result in an increase in travel, since people may be willing to be in their vehicles for longer periods, given the opportunities to be productive and more comfortable if they are not driving them. While automated vehicles should reduce the road space requirements of each vehicle (more compact spacing) and improve traffic flow (for example, there would be fewer accidents), the net effects of possible increased vehicle travel on congestion and energy use are difficult to predict.

2 Automation with or without electrification?

Household automation does not guarantee electrification: for example,

'THE ADVENT OF DRIVERLESS, ELECTRIC, ON-DEMAND RIDE SHARING SERVICES COULD CUT THE COST OF THESE SERVICES BY 70 PER CENT OR MORE.'

early Uber self-driving test vehicles in Pittsburgh were non plug-in hybrids. Many households may not 'demand' that automated vehicles be electric, and may also want these vehicles to be large, comfortable, and powerful (which can be achieved with EVs as well, but these features are not required). Such a scenario would result in substantially more energy use and CO_2 emissions than one combined with electrification, and could lead to an overall increase in CO_2 compared to a 'base' scenario without automation (given additional vehicle miles travelled (VMT) and despite some efficiency gains from automation).

3 The impacts of very low cost on-demand mobility

The advent of driverless, electric, on-demand ride sharing services could cut the cost of these services by 70 per cent or more, since the driver cost would be eliminated while fuel and maintenance costs would also be reduced given those characteristics of EVs. With high mileage driving, the capital cost of cars would also drop, since they could be amortized over many hundreds of thousands of kilometres, potentially bringing the per-km capital cost to very low levels.

4 Could private cars (and other modes) be left behind?

Such low costs could encourage more people to use ride hailing for urban (and even some non-urban) trips, and leave their own cars at home or even

User monetary and non-monetary cost types for different travel choice options

Monetary costs	Non-monetary costs
Vehicle purchase	Travel time (driving)
Vehicle maintenance	Travel time (passenger)
Fuel	Parking search time
Insurance	Walking time
Cleaning	Driving stress
Parking	Shared trips (e.g. lack of privacy)
Driver	EV range, charging anxiety
TNC charges	Car ownership negatives (maintenance, registration, inspections etc.)
Tolls	Car ownership positives (car pride, guaranteed ride, can leave personal belongings in the car)
Registration	Perceived environmental cost

Source: Authors' list.

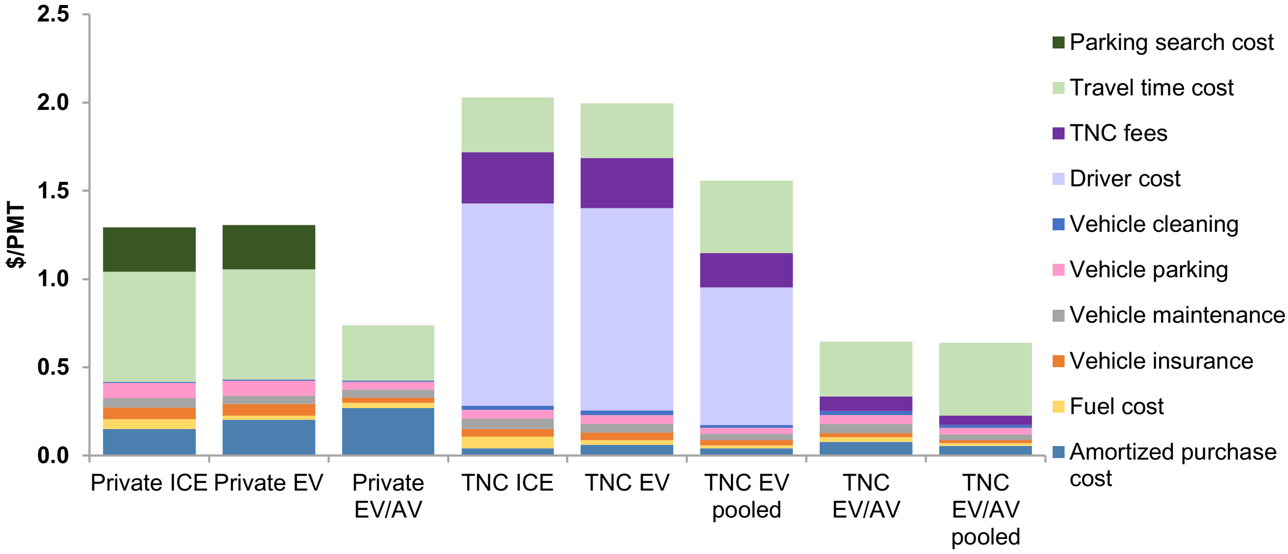
reduce ownership levels. They might even choose door-to-door ride hailing over public transit systems, since costs may become similar. Similarly, very low-cost ride hailing could even reduce the interest of riders in actually sharing rides; what might have been interesting when a $15 ride could be cut to $10 with sharing becomes much less interesting as a $3 ride cut to $2. One of the core concepts of ride sharing services that provides societal benefits is the actual sharing – in principle a shared trip means one less vehicle trip, one less car in use. This benefit could be quite large with substantial sharing – for example, in 2016 the International Transport Forum (see the document 'Shared Mobility: innovation for liveable cities') modelled a hypothetical system for Lisbon that could meet all of the city's trip demands with only 3 per cent of the current vehicle stock, if these were 8 and 16 seat vehicles (vans and buses), intensively shared. But very low-cost services would probably not lead to such an outcome.

Thus there are many dynamics in play here, and it is difficult to gauge their potential net effects on urban travel.

Possible effects of costs

In our research in this area, we have been comparing the costs of choosing among different travel options, to gain some insights into the likely success of both shared mobility and automated vehicles in the household travel market. We have learned that while monetary 'out-of-pocket' costs are important factors among the different options, non-monetary or 'hedonic' costs may be much more important. These hedonic costs may include many different factors, as can be seen in the table above left.

UC Davis has begun to estimate a number of these costs, as shown in the figure below. This figure compares the cost per mile travelled, from the point of view of the consumer, for private and Transportation Network



Midsize vehicles (dollars per passenger mile travelled) in 2025

Source: Authors' analysis.

Company (TNC) trips, and breaks these costs down by cost component. For each situation, it includes internal combustion engine (ICE), electric, and automated vehicle choices. It also includes pooled ride choices for the TNC options, where separate riders share a ride with a discounted price. These costs are built up using the monetary cost categories listed in the table on the previous page, and two of the non-monetary costs: travel time (while driving the vehicle or while being a passenger); and the search/inconvenience time of parking one's car when this applies.

The figure reflects myriad assumptions made, related to costs and prices in the San Francisco area and projected to 2025, particularly for the costs of EVs and automated vehicles. Some of the key assumptions include:

- Battery costs are assumed to decline over time, to under $200/kWh by 2025; AV costs also decline to under $10,000 per vehicle by that year.
- Private vehicles are amortized over 100,000 miles of driving, while TNC vehicles are amortized over much longer distances, since they are driving much more intensively. This causes their per-mile capital cost to be far lower than for household vehicles.
- Insurance, maintenance, and other operating costs are based on a review of such costs in California in 2017, and on estimated costs in the future. Electric vehicles are assumed to have much lower maintenance costs than ICE vehicles; automated vehicles are assumed to have much lower insurance costs than driven vehicles by 2025, given their safety advantage.
- Parking is assumed to cost about $5 per trip, and a trip length of 15 miles is assumed; this makes parking a fairly important cost.

'NON-MONETARY COSTS ARE IMPORTANT, PARTICULARLY WHEN HAVING TO DRIVE AND PARK ONE'S OWN VEHICLE.'

- Driver costs for TNC trips are estimated based on current average costs (and driver revenues) in California. A similar approach is used for TNC overhead costs and resulting fees per PMT.
- The value of time is assumed to be $15/hour when driving and half that when a passenger (whether in a driven vehicle or an AV). The time associated with parking and walking to the destination is assumed to be five minutes, twice per trip.
- Shared or pooled trips provide a 40 per cent discount per rider, but there is an increase in time cost due to additional pickups and drop-offs. This is assumed to be five minutes, twice per trip.

Of course, the costs shown in the figure may vary widely by time, location, trip type, and even across the population, particularly for perceived non-monetary cost levels. But the averages shown here are nonetheless revealing. The figure shows that TNC trips are expensive, whether in ICE or electric vehicles; pooled trips can be considerably cheaper. The non-monetary costs are important, particularly when having to drive and park one's own vehicle. A private automated vehicle may be perceived as far cheaper given the time and parking advantages (this assumes the automated vehicle provides door-to-door service and then parks itself). Meanwhile, the TNC automated vehicle provides services that are quite competitive with a private vehicle, but given even a five minute delay during pickup and dropoff (due to multiple riders), the pooled TNC ride has little advantage over the individual ride, even at a modest time cost. Finally, if one were to neglect the purchase cost of private vehicles (since for existing car owners this is a sunk cost and probably not considered when making the decision each day regarding how to travel), the private EV/AV would actually become the cheapest option (since the 'Amortized purchase cost' would be eliminated).

These comparisons only scratch the surface of what could be investigated in terms of costs. The wide range of non-monetary, hedonic costs shown in the table above could be estimated (though some would be difficult) and included in a figure similar to the one in this article. It may show, for example, that many people would attach an even greater penalty to sharing, if they prefer not to be in cars with strangers, particularly if there is no driver. The variation in valuations of costs may also be considerably affected by location and across the population. This type of analysis could help better understand the likelihood that in the future many or most people will choose TNC vehicle trips, automated vehicle trips, and shared vehicle trips, or not. This in turn will likely be critical in determining whether the future of urban travel will be dominated by household vehicles (and the possible increases in traffic associated with automated household vehicles) or by TNC vehicles, perhaps in conjunction with other modes such as transit. UC Davis continues to work in this area and is collecting travel behaviour data to help answer these important questions.