DRIVERLESS CARS:

Reducing Congestion on Expressways, but Increasing Congestion in City Centres

There has been much recent talk of driverless cars, with high profile companies such as Google joining a number of leading car manufacturers in developing systems to enable driverless cars to take to the road. **Richard Di Bona** argues that whilst such cars may reduce congestion on segregated highways through increasing effective capacity, within city centres they may be more likely to increase congestion.

It was not that long ago when driverless cars were the stuff of science fiction. But given the relentless pace of development in computing systems, both in terms of increased speed and reduced cost, as well as in visual recognition, such driverless cars are now deemed largely feasible.

Indeed, there has been ever-growing press coverage of advances in automating cars, such that they can navigate and drive without any interaction from humans. This either for driving with automatic collision avoidance on highways or even to control a full journey, with humans merely stipulating the trip's destination and perhaps also the time to make the trip. There has also been substantial commentary on how autonomous cars might improve road safety, road capacity and road environments in general. Whilst there are indeed grounds for optimism, there remain challenges to be addressed, including some possible negative outcomes, which appear to have attracted less media coverage. This article is thus intended to provide some balance.

How long have driverless cars been in development?

Whilst the Google™ driverless car is perhaps the most publicised, it is by no means the only, nor indeed the first driverless car under development and testing. The first autonomous demonstration vehicles appeared in the 1980's, though these were not used on ordinary roads with other road traffic. It was with the advent of cheaper and faster sensors and computers in recent years that autonomous cars, potentially capable of mixing with other traffic became a reality.

In the United States, the National Highway Traffic Safety Administration (NHTSA) proposed a formal classification system to describe the level of vehicle autonomy/ self-driving capability, as follows:

- Level 0: the driver completely controls the vehicle at all times
- Level 1: individual controls are automated, such as automatic braking
- Level 2: at least two controls can be automated together, such as adaptive cruise control and lane keeping
- Level 3: the driver can leave all functions to the car under certain situations, but the driver remains on-hand, with the car sensing when control should be returned to the driver
- Level 4: the vehicle can perform all navigation and safety functions on its own, including parking; the vehicle can operate without a driver being present

Progress with driverless cars now makes Level 4 autonomy realisable. The question then becomes what are the likely impacts of such full autonomy for vehicles? As will be argued, the impacts are likely to vary between segregated highways and mixed traffic in urban areas.

Increasing Capacity on Highways

Considering the potential impact of driverless cars on highways as opposed to city streets, i.e. on roads without pedestrians potentially crossing, kerbside parking or frequent junctions (potentially requiring vehicles to turn against opposing traffic), driverless cars have the potential not only to reduce accidents, but also to increase road capacities and decrease congestion.

Driverless cars would have collision avoidance algorithms, which could perform braking or evasive manoeuvres more quickly than humans could react. However, over-and-above this is the potential for platooning behaviour.

Under traditional, human-controlled driving, the capacity of a highway in terms of cars per hour or cars per lane per hour can be described using the Fundamental Diagram of Traffic Flow, as illustrated below. Figure 1(i) shows the notional relationship between traffic speed and the density of vehicles, reflecting the greater typical spacing between cars as speed increases. The consequence of this relationship on traffic flow versus traffic density is shown in Figure 1(ii) and on the resultant relationship between speed and traffic flow in Figure 1(iii).

Figure 1: The Fundamental Diagram of Traffic Flow (for Human-Controlled Vehicles)

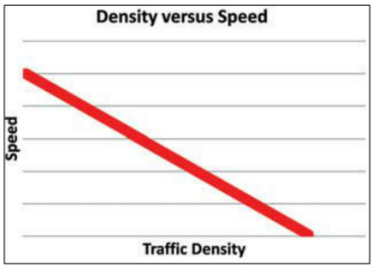

Figure 1(i): Speed versus Traffic Density

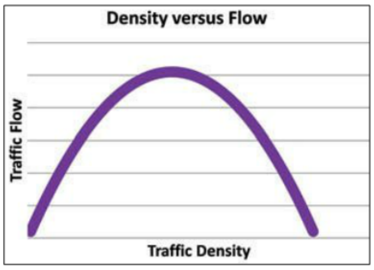

Figure 1(ii): Traffic Flow versus Traffic Density

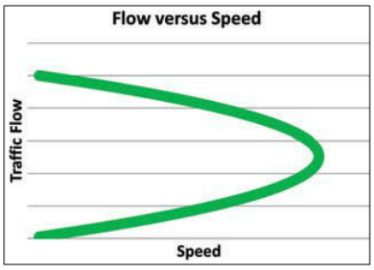

Figure 1(iii): Speed versus Traffic Flow

What the Fundamental Diagram of Traffic Flow shows is that above a certain speed, the capacity of a highway starts to decline. As such, there are two ways to increase a highway's capacity, either:

- Attempt to manage traffic speeds to always be around that level which maximises capacity; or,
- Find some method to safely allow vehicles to follow one another more closely at higher speeds

Driverless cars, which are not only continuously sensing their surroundings, but which moreover communicate with one another may enable the second of the above possibilities. Under computer control, ensuring that the speeds of vehicles travelling in a platoon or convoy are kept virtually identical, it becomes possible for cars to be spaced far more closely than would be deemed safe under human control. The effects of this on attainable traffic speeds and highway capacity are shown in Figure 2, with equivalent values for human control shown in lighter shades.

Figure 2: How Driverless Cars Might Change The Fundamental Diagram of Traffic Flow (Driverless Vehicles shown Bold; Human Controlled Vehicles shown faint)

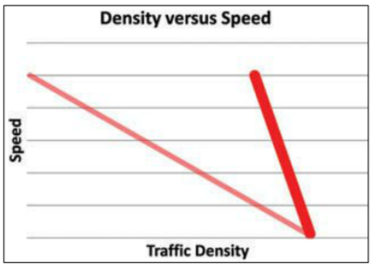

Figure 2(i): Speed versus Traffic Density

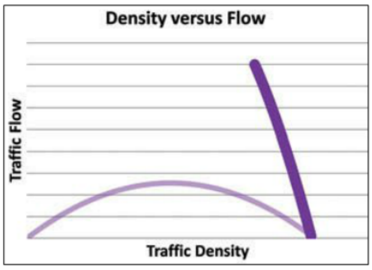

Figure 2(ii): Traffic Flow versus Traffic Density

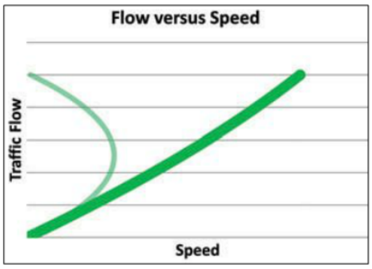

Figure 2(iii): Speed versus Traffic Flow

Figure 2 therefore shows just how much capacities and speeds might increase with a deployment of driverless vehicles able to communicate and coordinate with one another.

Figure 2 assumes a lane or lane(s) of traffic given over to the exclusive use of driverless vehicles. In mixed traffic, i.e. a combination of driver-controlled vehicles and computer-controlled vehicles, the scope for platooning is likely to be substantially reduced.

Nevertheless, this still shows the potential for driverless vehicles to boost capacity and speeds on highways in an inter-urban context, e.g. for expressways and the like.

But these benefits do not necessarily apply to urban environments!

Some commentators have claimed that similar benefits could arise from the deployment of driverless cars in urban environments, i.e. with respect to speeds and capacities. However, this ignores the reality that the speed of driverless cars in mixed traffic would be constrained by the speeds and behaviour of other road users, such as human-controlled cars, other vehicles and also pedestrians crossing the road. Also, in many urban environments, the critical determinants of road network capacities and journey times are likely to be delays at junctions more than journey speeds between junctions.

In fact, there are a number of other issues with driverless cars in urban environments which also need to be considered.

Potentially doubling vehicle kilometres travelled

One of the benefits of driverless cars touted is that they could either drop their owner at their workplace then go and park themselves, or could drive home, so as to reduce the spacetake in city centres devoted to car parking. Whilst reducing landtake for parking could be beneficial, such claims ignore one consequence of this: namely that cars would end up driving twice as far a day: as instead of one round-trip from home to a city centre car park and then back again, they would now drive from home to the owners' workplace then back to home and then repeat this journey when it is time to collect the owner.

This would increase pollution (unless all driverless cars were electrically powered and all power generation was from pollution-free, renewable sources). Moreover, it would roughly double traffic levels on city streets, hence likely resulting in increased congestion.

Problems for traffic control systems

In fact, congestion levels could more than double. At present, traffic signals take advantage of what is termed "tidal flow." Put simply, in the morning peak there is more traffic travelling to the city centre than in the reverse direction; whilst in the evening peak there is usually more traffic flowing out of the city centre.

As such, optimised traffic signals tend to give more green time to those movements with the greatest flows. If driverless cars were to return home after dropping their owner at work and then drive back into the city to collect them, then not only would overall traffic levels increase, but even more critically, traffic flow would no longer have the same level of tidality. Consequently, average delays at junctions would increase for all vehicles. And where city networks are close to capacity (as is often the case) this also raises the danger of traffic queues at intersections blocking back to their other junctions upstream. There becomes a larger danger of gridlock.

Increased Vehicle Circulation

A further problem is likely to arise, whether cars return home during the day or whether they park themselves downtown and then come to collect their owners when their owners wish to return home. Unless and until the forecourts and/or other vehicular circulation facilities of buildings are overhauled there is unlikely to be sufficient capacity for vehicles to wait to collect their owners. Such remodelling of buildings' facilities is likely to be quite time-consuming and costly, even where retro-fitting is possible. And more likely, the space requirements for this would likely undo a large proportion of mooted landtake savings from reducing downtown parking spaces.

Consequently, it is highly likely that vehicles would need to circulate in the vicinity of their owners' workplaces whilst awaiting their owner's arrival for collection. Such vehicular circulation would of course further increase traffic congestion levels!

A Possible Paradox of Increased Vehicle Collisions ("Car Crashes")

Whilst collision avoidance mechanisms built into driverless cars would make them safer, there is also a paradoxical danger of such vehicles increasing overall accident rates on urban road networks.

A human driver would quickly realise that driverless cars are programmed to avoid collisions. As such, a human-controlled vehicle is likely to be able to squeeze computer-controlled cars more effectively than cars driven by other humans, for instance when wishing to change lanes or to turn onto a road. The computer controls in the other car would prioritise collision avoidance and so would cede space to more aggressively (human) driven cars.

The problem is this: a human driver becoming conditioned to being able to squeeze in front of computer controlled vehicles may well assume that a vehicle is computer-controlled, only to discover too late that it was under human control. And the human driving the other car, with slower reaction times than the computer and likely also having a more aggressive mindset than a "robot" car, may well end up in a collision. After all, there could still be someone in the driver's seat when a car is under computer control, so it would not be readily apparent which cars are being actively driven by their occupant and which are being driven by computer.

Pedestrian safety and a collapse in traffic speeds and road capacities

Another related problem pertains to the interaction between pedestrians and driverless cars. Driverless cars would need to be programmed to avoid collisions with pedestrians, including any who might jump off of the pavement/ sidewalk and into traffic with little or no warning. Consequently, driverless cars will need to respond instantaneously to any such instances of pedestrians stepping into the road.

This raises a number of possible problems. Firstly, pedestrians are likely to quickly realise that driverless cars would allow them to cross the road. Pedestrians are likely to take advantage of this; so urban traffic speeds could collapse as pedestrians make a habit of stepping into traffic more often than they currently do. As such, traffic may become very frequently interrupted, thus resulting in far lower effective capacities on roads.

However, bearing in mind that for some time to come after the introduction of driverless cars, that they would be sharing the road with human-controlled vehicles, there is an increased risk of a human controlled vehicle rear-ending a computer-controlled vehicle which comes to a sudden halt to avoid hitting a pedestrian. On this last point, it might be argued that the human controlled car could have some collision avoidance technologies; however, this presupposes that all vehicles would quickly switch to such technologies.

It could be argued that the presence of human controlled cars, and the danger of jaywalking pedestrians being sued when a human controlled car rear-ends a driverless car due to the jaywalking pedestrian stepping into the road, would tend to mitigate against such accidents happening. However, in many jurisdictions this could require a change to how insurance liability is apportioned, possibly itself requiring a change in legislation.

Indeed, it has been argued that driverless cars are likely only to widely feature in society, not only after a raft of legislation has been revised, but also following a number of legal test cases.

Cities for Pedestrians or for Cars

There is little doubt that over recent decades the trend in most cities has been to prioritise the motor car, in terms of allocating not only road space, but also parking space; often resulting in pedestrians being forced onto footbridges or underpasses.

However, in some cities, primarily though not exclusively in Europe, a counter-trend is now emerging. Many cities are now looking to increase the pedestrianisation of areas, so as to improve the urban environment. Also in many cities, both in Europe but moreover also in much of the rest of the World, including India, there is an increased emphasis on promoting public transport; this often combined with demand management measures for car usage. Given such trends, one also has to question whether or not cars, even under computer control, would continue to be accepted in great numbers in city centres.

Bear in mind that should a time come when the overwhelmingly majority of cars are fully computer controlled, then so as to avoid issues with pedestrians stepping out into the road at will, there would need to be a massive step-up in legislation and enforcement against jaywalking, even on minor roads. In many cities, this would require a social shift to accept such prohibitions on freedom of pedestrians to cross roads; and in many places such a social shift would be greater than that required to accept driverless cars *per se*.

Based on the above, I would contend that driverless, or fully computer-controlled cars:

- Are likely to have a substantial role in increasing the safety and capacity of segregated highways, such as expressways and motorways; but,
- Are unlikely to have a substantial and widespread role within city centres (excepting any segregated highways passing through urban areas).

(Richard Di Bona is a Hong Kong-based transport consultant with over 20 years of consultancy experience gained from projects in over 30 countries. He has undertaken a wide range of transport planning, demand forecasting, economic appraisal and transport policy projects).