Practitioner papers

Let's get real about self-driving cars: The transition will take a significant amount of time

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Abstract   Today, driverless/autonomous/self-driving cars are a hot topic in conversations about the future of our urban areas. Many people reasonably expect that some variant of driverless cars will dominate our future urban transportation scene. However, there are strong reasons to have uncertain expectations about what exactly that transportation scene will finally look like, how long it will take to complete and how it will evolve over the intervening years. The analysis in this paper suggests that the path will be neither quick nor easy, and that the toughest issues will not be technological, but psychological, sociological and perhaps most importantly, political.

Keywords: *autonomous cars, self-driving cars, driverless cars, urban future, urban environment, technology and urbanism.*

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INTRODUCTION

Today there is a lot of hype, puff and unrealistic expectations associated with the coming transition to self–driving cars in our nation. For example, in September 2016, Lyft's president and co–founder, John Zimmer, made the astonishing claim that the coming 'driverless car revolution' will 'all–but end' car ownership in our cities by 2025.[1] Zimmer had no concept of the massive scale and complexity of the 'car revolution' he was both advocating for and predicting its success. It is one thing to have driverless cars that work, another for them to be manufactured, bought and used by the public on a massive scale.

Unrealistic expectations about driverless cars are often also infusing more everyday discussions. For example, in a recent LinkedIn discussion thread that was initiated by a post about how dense residential development in a neighbourhood had created a big on–street parking problem, someone, who seemed to be a planner, suggested that driverless cars could solve the problem. Are driverless cars really that well developed that they can be recommended as viable corrections for today's problems? Or even tomorrow's? Can they be implemented now or even soon enough to be relevant to current project, programme or policy decisions? Or do we wait to solve many important problems until the transition to driverless cars is completed?

Many people reasonably expect that by 2037, or maybe 2047, some variant of

driverless cars will dominate our urban transportation scene. However, there are strong reasons to have uncertain expectations about how that transportation scene will evolve over the intervening years. Three things are undeniable right now:

- There is a lot of advocacy going on and that means marketing and PR puff. Discussion about self-driving cars is certainly good for both the public and policy-makers, but its value declines with puffery and inaccurate statements. Let the discussion be passionate and visionary, but also reasoned and factual;
- The changeover to driverless cars will be a huge techno-socio-economic phenomenon, so large that its intended and unintended consequences — both positive and negative — are hard to foresee with any great reliability. Yes, discerning *potential* consequences is possible, but that is quite different from knowing with great confidence what the consequences will be. Prudence consequently directs that we should expect the unexpected;
- There are *three — not just one — interrelated revolutions* unfolding around our use of automobiles:
  - 'Electrification: a shift from internal combustion engine (ICE) vehicles to electric vehicles (EVs)'.[2] Electrification will probably account for most of any reductions in CO_2;
  - 'Automation: a shift from human-piloted vehicles to automated vehicles (AVs) that drive themselves'.[3] Automation will probably account for most safety improvements;
  - 'Ride-sharing: a shift from privately owned, often single-occupant vehicles to fleets of shared cars, vans and small and large buses'.[4] Ride-sharing is the revolution that is needed to effectively reduce the number of cars in our urban areas

and thus reap the benefits of greater walkability with less space used for the storage of vehicles. Moreover, ride-sharing probably means the use of vans with 12 to 18 passengers, not simply the ride hailing services of Uber or Lyft.

At this point in time, the most certain aspect of the coming 'car revolution' is that it will involve a fairly long and very complicated transition period — perhaps 20 to 30 years — that has the potentials for being both very beneficial and very harmfully disruptive.

THE EMERGENCE OF THE AUTOMOBILE AS OUR DOMINANT TRANSPORTATION MODE TOOK DECADES TO HAPPEN

The past is neither determinant nor predictive, but much can still be learned from it. Looking at the transition to gasoline powered vehicles is a case in point.

Horses were the early autos' prime initial competition as a transportation mode. They were not a very large or strong force to contend with. In 1900, there were about 13m horses in the US. That equine population grew to a peak of about 25m by 1920, partly due to increased demand generated by the armies in the First World War.[5] However, the vast majority of the horses were used for non-transportation purposes, mainly in agriculture. Their numbers declined significantly after 1920 as the war-generated demand disappeared and the use of tractors on farms soared.

As Dave Feehan has pointed out, one of the major reasons that the public went for cars was public health: horse manure and dead carcasses had reached levels endangering public health on city streets.[6] Today, the emissions, especially CO_2, of our gasoline engine auto fleet also

pose a strong public health risk, but the electrification of the fleet's engines could help resolve that issue and that would not require a complete transition to the most automated driverless cars.

Still, depending on how you look at it, going from horses to autos took about 20 years, if you just look at the cars, or well over 50 years if you also take into consideration the road system needed to make car use flourish. Here are some major milestones:

- As far back as the 1880s, Europeans were developing horseless carriages;
- In 1901, Mercedes produced the first really modern automobile, designed by Wilhelm Maybach;
- In 1908, Ford introduces its Model T and General Motors is formed;
- In 1913–14, Ford introduces the revolutionary moving assembly line;
- In 1915, Ford built its one millionth car and had 25 assembly plants;[7]
- By 1929, 80 per cent of auto production was accounted for by the Big Three — Ford, GM, and Chrysler;[8]
- The Dwight D. Eisenhower National System of Interstate and Defense Highways System were initiated by the Federal Aid Highway Act of 1956;
- The US population was 76m in 1900, 106m in 1920 and 152m in 1950.

THERE ARE STRONG REASONS TO BELIEVE THAT THE TRANSITION TO SELF-DRIVING VEHICLES WILL BE NEITHER SHORT NOR EASY

While driven cars only had probably fewer than 10m horses to replace, driverless vehicles must replace hundreds of millions of existing units. For example, in 2015, about 263m passenger cars, motorcycles, lorries, buses and other vehicles were registered in the US.[9] The highest rate of annual vehicle sales reported monthly over the past two decades was 22.1m units/yr in October of 2001. At that rate, it would take 11.9 years for the driverless cars to completely replace the non–autonomous inventory.[10] A more recent annual vehicle sales rate is about 17.9m. That would convert into 14.7 years for the inventory turnover to be completed. Of course, the implicit assumptions behind these calculations are that everyone will want the driverless cars and manufacturers will be all tooled up to produce desirable products. Negatives on either of those points would mean a much longer transition period.

There now are over $1tn invested in people driven cars

There are not only many cars on the road today, they are also worth a lot of money. Not all cars are associated with a loan, but the total value of car loans in 2016 was $1.2tn, with the average amount financed about $28,000.[11] Many of the vehicles not associated with car loans will also be worth thousands of dollars each, so the $1.2tn loan total is a minimum of the total dollar value of the US vehicle inventory.

Question: If Americans change over to driverless cars, then how will they get back some of the money their non–autonomous cars are worth? How would they react if they could not do so because the resale market is being been killed off? Talk about the potential for brutal politics.

It will be impossible if they opt for participating in the pay–by–the–ride option *a la* Uber or Lyft. Will GM or Ford or Tesla take trade-ins? If so, how will the auto manufacturers recoup those trade–in dollars besides selling the vehicles for scrap, because they are killing the resale market? This will be a huge problem for car manufacturers.

In 2014, the average household in the US had 2.09 vehicles.[12] That means that

the dollar value extraction from existing vehicles will be a very salient problem for a huge portion of the potential addressable market for driverless cars. It will make building a wave of individual conversions really tough to achieve, except among those who are not current car owners.

Of course, with safer, fewer and electrified cars, there also will be many companies that will be forced out of business, eg body shops, gas stations.

PRYING THE STEERING WHEELS FROM THEIR COLD, DEAD HANDS

Then there's the 'cold, dead hands' problem. Americans' love of guns is well known.[13] So is our love of our cars. An NRA slogan made famous by the actor Charlton Heston is: 'I'll give you my gun when you pry (or take) it from my cold, dead hands'. Will Americans feel the same way about their cars and steering wheels?[13] One bet is that many Americans would appreciate having the cars they drive made considerably safer through the addition of computerised car safety features, but they will strongly oppose giving up their steering wheels.

Certainly, today, Americans are against banning human driven cars, even if the completely automated self-driving versions were shown to be safer. For example, a survey done for Vox in 2016 found that only 30 per cent of the population would support a legal ban on human drivers, while 54 per cent would oppose such a ban. However, the respondent's ages made a significant difference: for those under 30, 43 per cent would favour a ban and 42 per cent would oppose it. In sharp contrast, among those 65+, 58 per cent opposed such a ban and only 22 per cent supported the idea.[15] Even if one assumes that opposition to a ban on human driven cars will 'age out', such a process will likely take quite a bit of time.

WHAT WILL THE SELF-DRIVING CAR PRODUCT REALLY BE?

Many of the companies, eg Waymo (the Google offshoot) and Apple, that are developing the electronic systems that will operate our autonomous cars, have decided that the driver must be taken out of the equation if the desired high levels of safety are to be attained. Others, that also manufacture the cars, eg Tesla, have a vested interest in keeping a potential for humans, especially car owners, to drive their vehicles when they want to.

At this point in time, it is difficult to determine what the world of self-driving cars will look like at either the vehicle level or at the aggregate system level. At the vehicle level, units could be privately owned, have the traditional range of passenger capacity, and have an operating system that either takes complete control of the vehicle's operations or allows a human to drive with computerised features that enormously increase vehicle and passenger safety. On the other hand, humans could be banned from driving vehicles, legislation could incentivise the production of the van–type vehicles needed for ride sharing while discouraging the type of individual ownership we have today.

There also might be some mix of these two scenarios. I am sure other scenarios are possible. The main points here are that:

- The type of self–driving cars that will win out and the transportation system they will operate in are products that are yet to be defined along many important dimensions. For example, will autonomous vehicles be privately owned? Or will dedicated roads with sensors and/or beacons be required?;
- Most importantly, the definers of those products will be less and less the minds and hands of technologists in the labs of Waymo, Apple, Tesla, GM, Ford, etc.,

and more and more in the decisions and behaviours of consumers and their politicians;

• To date, the companies working on driverless cars have shown themselves to be gizmo smart, consumer ill–advised and politically naïve.

THE ABSOLUTELY CRITICAL IMPORTANCE OF HUMAN BEHAVIOURS AND PREFERENCES: RIDE-SHARING

Computer simulations have shown that very high levels of ride-sharing will be needed if the number of cars on the road is to be significantly reduced and associated societal benefits achieved.[16] Instead of one or two people travelling in a car, 12–18 might have to be carried in a mini–bus/van-like 'module'.

Uber and Lyft: Ride-hailing, vehicle-sharing or ride-sharing services?

Before proceeding, let us try to clarify how these auto service companies fit into the scheme of things. They are certainly trying to establish themselves as aiming to use driverless cars to provide pay-by-ride services for the public. They prefer the truly driverless model of automated vehicles since it significantly reduces their need for drivers and their associated labor costs. They definitely are ride-hailing firms — you can use their apps to get them to pick you up and tell them where you want to go. They can even be called vehicle–sharing services, since over the course of the day, much like traditional taxis, multiple parties of one or more people will ride in their vehicles with each party paying separately and each able to have different pickup points and destinations. However, they have often been referred to as ride-sharing companies/services. That, unless they significantly change their operating model, is probably a misnomer. Ride-sharing, conventionally, has been associated with multiple parties (of one or more persons) sharing the use of a vehicle. Though Uber and Lyft now provide economy services that involve carrying more than one party at the same time, those ride-sharing services do not account for significant portions of their activities or revenues. Moreover, their current vehicles' passenger capacities are not large enough to bring about the desired reduction in the number of cars on the road and its associated other benefits. One might also ask if Uber's and Lyft's services will retain their current allure when their vehicles are larger, carry many passengers unaffiliated to each other and may have numerous pickup and drop off stops. Sounds more like a good bus system, than a high tech car service for which you pay premium prices.

Some current indicators of the potential for substantial growth in ride-sharing

One might doubt that those whose steering wheels will have to be pried from their cold, dead hands are good prospects for ride-sharing, though they might occasionally do so.

One good benchmark for the current attractiveness of ride-sharing is the use of public transit systems such as buses, subways and commuter rail systems. In some areas, private vans and formal ride–share programmes are also present. The number of personal trips that involve the use of a private vehicle vastly outnumber those that utilise public transit: in 2009, for example, about 327,118,000,000 person trips were done by private vehicles compared to just 7,520,000,000 using transit.[17]

Obviously, the presence and size of public transit systems will affect use levels. However, even in NYC, with the largest

public transit system in the US and the most riders, auto use remains significant. For instance, 44 per cent of the households in both the Bronx and Brooklyn have cars, while 64 per cent do in Queens. Even in Manhattan, where garage spaces can cost $700+ per month and in several of its zip codes over 40 per cent of the residents walk to work, 23 per cent of the households own cars.[18] The car-owning residents in Brooklyn, the Bronx and Queens tend to be tri-modal from a transportation perspective. They walk a lot to local destinations — perhaps longer and more frequently than anywhere else in the US — and use subways, buses and even commuter rail to get to work. But they are extremely likely to use their cars to travel to any other types of destinations. Uber, Lyft and a myriad of private car services are present for trips to these other destinations, but car owners do not use them unless their vehicles are inoperable.

The data on the current use of transit modes strongly suggests that significantly growing the ride-share customer base will be a real challenge. However, those data cannot assess, one way or another, the possibility that if ride-share vehicles were more accessible and/or more attractive, they then would attract more users.

Opinion surveys are another indicator of ride-sharing's current attractiveness to American consumers and they can provide some insight on this issue. Here are some recent relevant findings:

• A 2016 survey for Vox found that 61 per cent of its respondents reported they were unlikely to use an Uber-style self-driving car service if it becomes available in their area.[19] That is a lot of people who do not want to use the largest wannabe self-driving car ride-share service;
• A survey done for the AAA in 2017 found that: 'Three-quarters of U.S.

drivers would be afraid to ride in a self-driving vehicle, while 19 percent would trust the vehicle and 4 percent are unsure'. Baby Boomers were more afraid (85 per cent) than Millennials (73 per cent), but the latter's percentage is still very high.[20] If people are afraid to ride in self-driving vehicles, then they surely will not be ride-sharing in them.

Ride-sharing, if it is to grow to the level needed to have substantial environmental benefits, will have to be much more attractive than it is today or how it is being presented in scenarios for the future.

HUGE TECHNOLOGICAL ISSUES REMAIN TO BE SOLVED

The technological aspects of the transition to driverless cars will probably be the easiest to achieve. According to Bran Ferren, the co-founder of Applied Minds, the transition to driverless cars will take these 'five miracles', some of which have already been achieved:

• 'You need to be able to know exactly where you are and exactly what time it is. (Thanks GPS.);
• You need to know where all roads are and what the rules of driving on them are. (Check, in-car navigation systems.);
• You need near-continuous communications with other vehicles nearby. (Ferren says that current wireless technology, with modifications, could get us there.);
• You need restricted roadways that people agree are safe to use. (We could start with HOV lanes.);
• And you need the ability for machines to recognise people, signs and symbols. (For this a car might need to wake up to ask its passenger a question, the answer to which it could then share with all other vehicles.)'.[21]

To get an honest look at what has been achieved and how rigorous the work can be, see Madrigal, 'Inside Waymo's Secret World for Training Self‑ Driving Cars'.[22] Particularly striking is Madrigal's description of how the Waymo autonomous car could handle entering a one‑lane roundabout, but was absolutely flummoxed about entering a roundabout having two lanes. That is an important tell indicating that the programming for the cars still requires a lot of work. On the other hand, Madrigal's article demonstrated that a lot of very impressive technological progress already had been accomplished.

HUGE NON-TECHNOLOGICAL ISSUES, BESIDES RIDE-SHARING, STILL NEED RESOLUTION

Regulations

The private companies involved in developing self-driving cars seem to be acting like politically privileged teenagers when it comes to government regulation. They have already been actively complaining and we can expect more in the future. Their complaints sound like expressions of creative entitlement. The whole business community suffers from over‑regulation, so why on earth should the new kids on the block be an immediate exception? Do they want, on their way to developing a driverless car society, to revolutionise our regulatory system, too? Good luck with that and its potential for sidetracking the primary venture, the transition to autonomous vehicles.

Uber and Airbnb provide an invaluable lesson. Both have encountered significant amounts of regulatory conflict at the municipal level. These overwhelmingly occurred after they made a significant entry into a market area. One might argue that, similarly, the full brunt of

the pressures to regulate driverless cars will not be felt until they, too, gain a significant amount of market penetration — when the public will be more aware of driverless cars and what they can and cannot do, people will be more likely to start demanding regulation. A few multi‑car, multi‑injury accidents could unleash strong vocal public concerns and demands for more regulation. Tesla's recent experience shows that the possibility of such incidents should not be ignored until the technology advances quite a bit more.

In addition, we know that state and local regulatory environments vary considerably with geography. The highly urban, densely populated areas where driverless cars will supposedly have the easiest adoption and largest positive societal impacts are also those with political cultures most favourable to government regulation.

Furthermore, if Waymo, Apple and other driverless car companies want fully automated, no steering wheel cars to be dominant, then they might only succeed if local or national regulations make that a legal requirement. These companies then may actually solicit such regulation.

Possible disruptions

Many may be hard to discern at this point in the development and adoption of driverless cars. However, here are some of the disruptions that are already being discussed:

- Taxi, Uber and Lyft drivers losing jobs;
- Goods transport and bus industry revenue and job losses. The public is already concerned about these potential losses. For example, a 2016 survey found that '53% of respondents predict that self-driving cars will take away jobs from professional taxi and truck

drivers, compared to just 29 percent of Americans who say that won't happen';[23]

• Lower public rail transit ridership use and devalued infrastructure investments;

• Reduced parking structure use, incomes and investments. The need to repurpose many existing parking facilities. The way we design real estate projects, districts and communities could be significantly altered.

The types of cautious decisions that might be needed now

Until the transition to self-driving cars is much closer to completion, most ordinary consumers and citizens, as well as landlords and developers and policy-makers at all levels of government, will be acting in an uncertain situation. We will have to guard against making wrong decisions even more than usual, especially about how we invest our money, time and political capital

A good example of this is provided by AvalonBay Communities Inc., a major-league real estate developer. It 'is designing a downtown residential complex for a future time when ride-sharing services and driverless cars whittle down car ownership and parking places become "expendable"'.[24] The project's garage, for example, will not have the traditional inclined floor, and its level floors could be converted to other uses such as retail, a gym or a theatre. Numerous electric car charging stations and ride-sharing drop-off points will be key amenities of the apartment complex.[25] See also Feehan's advice about building conventional parking structures today.[26]

SOME FINAL COMMENTS

Holly Whyte made an enormous contribution to the way we revitalise our public spaces and downtowns. The foundational idea behind his approach was that improvements will only succeed if they merge with the preferences and behaviour patterns of potential users. That idea can also be rephrased to stand as a basic axiom for the marketing of any new product — such as self-driving cars. Whether you are creating a great new public space or developing a revolutionary new car, one thing you certainly do not want to do is to design a product that requires potential customers to change strongly ingrained preferences or behaviour patterns in order to accept the product. Such personal changes are hard to accomplish and likely to require a lot of time and resources to induce. When a product needs social engineering for acceptance it is unlikely to succeed.

What is astounding, is that for all the attention companies such as Waymo, GM and Apple have given to developing the many technologies required for self-driving cars to work, how little attention they have paid to the actual preferences and behaviour patterns of potential consumers. As a result, it looks as if they are developing products that will require substantial changes in the attitudes and mindsets of potential users.

Far too many urbanists have had their heads in the clouds about driverless cars. They eagerly accepted and then advocated for driverless cars because of their potential environmental, safety and urban design benefits. However, in so doing, they have failed to look at any of the many non-technological issues at the individual and political levels that might impede adoption of a range of possible driverless car features. Nor have many of them realised that some of these benefits can be realised without going to completely automated, no-steering wheel vehicles. Some maintain that those wanting to still drive cars can go to private tracks, avoiding the issue that many of

those still wanting to drive may be wealthy and very accustomed to having and using political clout.

The above failures in what might be termed social and political engineering will contribute significantly to a potentially drawn out transition period for driverless cars. It will be akin to a multi–decade long inflection point for America's quality of life.

Increasingly, though, it will be the decisions of ordinary citizens, as consumers and voters, as well as our politicians — not our technological wizards or our industrial moguls — that will determine the directions of those paths.

Given that the coming self-driving car transition will be a long and arduous process, ardent urbanists and enthusiastic technologists should guard against suggesting a system of highly automated cars as an immediate solution to our current problems, or even those arising over the next decade or so.

References

1. Carson, B. (September 2016), 'Lyft president: Car ownership will "all–but end" in cities by 2025', Business Insider, available at http://www.businessinsider.com/lyft-president–car-ownership–will–all–but–end–in–cities–by–2025-2016-9 (accessed 15th December, 2017).
2. Robert, D. (July 2017), 'Unless we share them, self-driving vehicles will just make traffic worse', Vox.com, available at https://www.vox.com/energy-and-environment/2017/5/18/15604744/self-driving-cars–cities (accessed 15th December, 2017).
3. *Ibid.*, note 2.
4. *Ibid.*, note 2.
5. Equine Heritage Institute (2013), 'Horse Facts', available at http://www.equineheritageinstitute.org/learning–center/horse-facts/ (accessed 15th December, 2017).
6. Feehan, D private email to N. David Milder.
7. History.com (n.d.), '1915: Ford builds its 1 millionth car', available at http://www.history.com/this-day-in-history/ford–builds-its-1–millionth-car (accessed 15th December, 2017).
8. History.com (n.d.), 'Automobile History', available at http://www.history.com/topics/automobiles/print (accessed 15th December, 2017).
9. Statistica.com (n.d.), 'Number of vehicles registered in the United States from 1990 to 2015 (in 1,000s)', available at https://www.statista.com/statistics/183505/number-of-vehicles-in–the–united–states-since-1990/ (accessed 15th December, 2017).
10. The data are from the Bureau of Economic Analysis, The Federal Reserve Bank in St Louis (November 2017), 'Total Vehicle Sales (TOTALSA)', available at https://fred.stlouisfed.org/series/TOTALSA (accessed 15th December, 2017).
11. Guilford, G. (February, 2017), 'American car buyers are borrowing like never before—and missing plenty of payments, too', Quartz Media, available at https://qz.com/913093/car–loans-in-the-us-have–hit-record-levels-and–delinquencies-are-rising-fast-too/ (accessed 15th December, 2017).
12. Statistica.com (n.d.), 'Number of vehicles per household in the United States from 2006 to 2014', available at https://www.statista.com/statistics/551403/number-of-vehicles–per–household-in-the-united-states/ (accessed 15th December, 2017).
13. See https://www.washingtonpost.com/opinions/americans-love-of-guns-part-of-our-culture/2012/12/25/f301f326-4ddd-11e2-950a-7863a013264b_story.html?utm_term=.d3b8695bd62a (accessed 20th February, 2018).
14. See https://www.youtube.com/watch?v=5ju4Gla2odw (accessed 13th February, 2018).
15. Lee, T. B. (August 2016), 'We polled Americans about self-driving cars. Here's what they told us', Vox.com, available at https://www.vox.com/2016/8/29/12647854/uber-self-driving-poll (accessed 15th December, 2017).
16. *Ibid.*, note 2; Madia, E. (May 2017), 'How Autonomous Cars and Buses Will Change Urban Planning (Industry Perspective),' available at http://www.govtech.com/fs/perspectives/How–Autonomous-Cars-Buses-Will-Change–Urban-Planning-Industry-Perspective.html (accessed 15th December, 2017).
17. US Department of Transportation (2015), 'Passenger Travel Facts and Figures 2015', available at https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/PTFF_Complete.pdf (accessed 15th December, 2017).
18. StasBee (April 2012), 'New Yorkers and Cars', NYCEDC, available at https://www.nycedc.com/blog-entry/new-yorkers-and-cars (accessed 15th December, 2017).
19. *Ibid.*, note 13.
20. Stepp, E. (2017), 'Americans Feel Unsafe Sharing the Road with Fully Self-Driving Cars: AAA Fact Sheet: Vehicle technology Survey — Phase II. 2017', Newsroom/AAA.com, available at http://newsroom.aaa.com/2017/03/americans–feel-unsafe-sharing-road-fully-self-driving-cars/ (accessed 15th December, 2017).
21. Bajarin, T. (March 2014), 'Why Bran Ferren's TED Talk Is Required Viewing for All Techies', PC News, available at https://www.pcmag.com/

article2/0,2817,2455647,00.asp (accessed 15th December, 2017).

22. Madrigal, A. C. (August 2017), 'Inside Waymo's Secret World for Training Self-Driving Cars', *The Atlantic*, available at https://www.theatlantic.com/technology/archive/2017/08/inside–waymos–secret–testing–and–simulation–facilities/537648/ (accessed 15th December, 2017).

23. *Ibid.*, note 13.

24. Graves, B. (May 2017), 'Driverless Cars and the Disruptions They Will Bring', FutureStructure, available at http://www.govtech.com/fs/perspectives/Driverless-Cars-and-the-Disruptions-They-Will-Bring.html (accessed 15th December, 2017).

25. *Ibid.*, note 22.

26. Feehan, D. (July 2013), 'Suddenly it's 1900 again', Parking Today, available at http://www.parkingtoday.com/articledetails.php?id=1463 (accessed 15th December, 2017).