AMP CAPITAL

AUTONOMOUS VEHICLES: THE REAL OPPORTUNITY THAT LAYS AHEAD FOR INVESTORS

AMP Capital
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December 2017

INSIGHTS
IDEAS
RESULTS

> During the gold rush it's a good time to be in the pick and shovel business.

Mark Twain

More balance is needed in the conversation about the scale and speed of change presented by autonomous vehicles. It will take much longer before this evolution can solve the growing congestion problem than excited commentary would suggest. Less talked about are the secondary effects of autonomous car adoption such as the vast amount of infrastructure investment that will be needed. So long-dated is the 'tipping point' for this nascent technology that we see no let-up in the requirement for more market-driven twists on traditional infrastructure projects over the next 20 years.

Investors are undoubtedly aware of visions of the future in which cars function free of human input. Innovators grab headlines on a daily basis that relate to driverless car technology and battery development, while traditional automakers play catch up. Investments in this space are subject to fast-moving technological, regulatory and competitive risks, where extrapolating exponential cost curves can lead to wide margins of forecasting risk.

However, a critical analysis of the factors that will drive the rate of adoption and usefulness of this new technology, such as cultural fit, safety matters and monetary policy, reveals interesting implications.

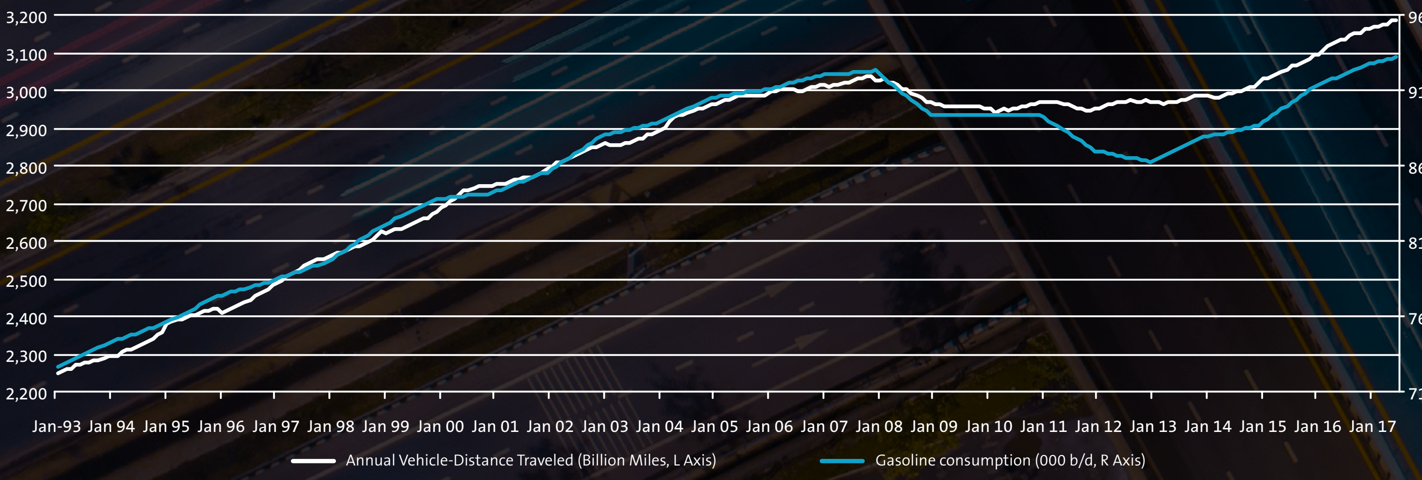
Autonomous cars will, in time, contribute towards solving the very real problem of traffic congestion in the United States and other countries with densely populated urban areas. However, given the slow pace of adoption, more varied solutions are likely to be required in the medium term. This will require vast infrastructure investment and provides opportunities to established players with unique operational expertise.

THE PROBLEM

Road traffic volumes in the US peaked in 2008 and plateaued for much of the following decade. In recent years, however, they have resumed their long term annual growth trend of around 3 per cent as the economy expands, the population grows and the driving cohort expands more quickly.

Much has been documented on millennials shunning car ownership, but little is commented about the biggest part of the population, baby boomers, who are increasingly 'semi-retiring', and thus remain reliant on their car for longer than they would have done 20 years ago. Further, as millennials have delayed starting families until a later stage of their lives, we question whether this may be a trigger for increased car ownership among those in this demographic group.

Road traffic has begun to grow again



Source: US FHWA, BP Statistical Review

Congestion and journey times expand exponentially as traffic increases on a steady basis. Transport analytics company INRIX estimates that the annual financial cost of congestion in the US to be US$1,400 per driver in terms of lost income, wasted fuel and additional maintenance expenses. The annual cost to the US economy is estimated to be US$48 billion.

Traffic congestion carries deeper social and productivity costs beyond the immediate financial impact. Traffic determines journey time, which limits the range of job opportunities available to an individual and the size of the labour pool to a hiring firm. The limitations of public transport in the US along, with planning laws that require new developments to include ample car parking space, further encourage car use.

Top 20 congested US cities

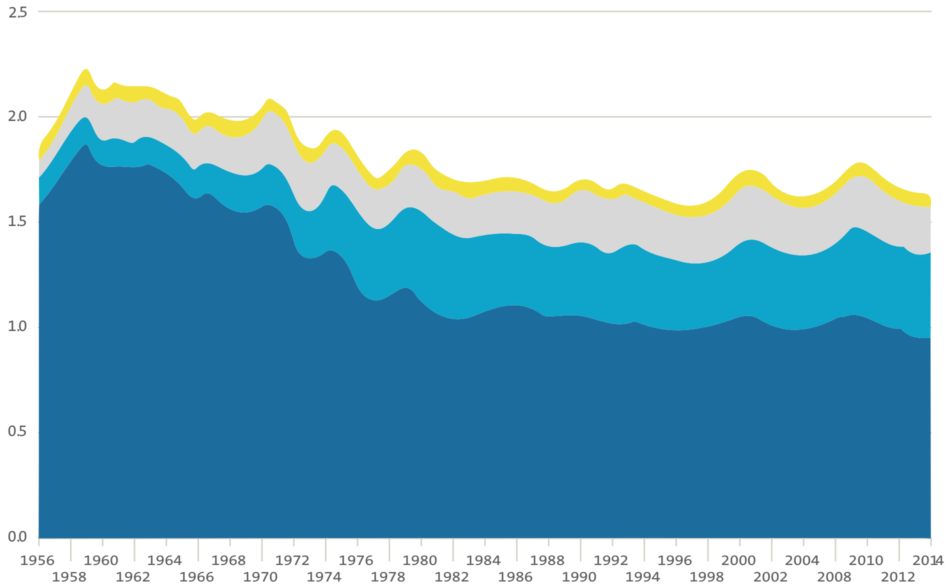
	HOURS SPENT IN CONGRESTION (p.a.)	% OF DRIVING TIME SPENT IN CONGRESTION
Los Angeles, CA	104.1	13%
New York, NY	89.4	13%
San Francisco, CA	82.6	13%
Atlanta, GA	70.8	10%
Miami, FL	64.8	9%
Washington, DC	61.0	11%
Dallas, TX	59.4	7%
Boston, MA	57.6	13%
Chicago, IL	56.6	10%
Seattle, WA	54.8	13%
Houston, TX	51.6	7%
Portland, OR	47.2	10%
Austin, TX	47.2	12%
San Diego, CA	46.2	10%
Minneapolis, MN	39.6	7%
Stamford, CT	39.2	14%
Philadelphia, PA	37.6	8%
Tacoma, WA	37.3	10%
Phoenix, AZ	37.1	6%
Baton Rouge, LA	36.3	11%

Source: INRIX (2016)

Funding for much of the US road network depends upon the gasoline tax, which is charged on each gallon of fuel consumed and has not changed since 1994. The value of funds that are available for road maintenance has therefore been eroded by inflation and the trend towards more fuel-efficient cars. Even amid bipartisan political support for increased investment in US transportation infrastructure, changes to the gas tax appear to be off-limits. The gap between required and available funds continues to grow - US$1.7 trillion of investment is needed for unfunded projects during 2013-20, according to the American Society of Civil Engineers. The road network is already perceived by motorists in the US as being in a state of disrepair.

This US-centric example is an extreme one, but the issues are similar in many countries. Growing demand for mobility requires large investment at a time when governments face high debt/GDP ratios.

US spending on transportation infrastructure (% of GDP)



Source: Congressional Budget Office based on data from the Office of Management and Budget, the Census Bureau, and the Bureau of Economic Analysis

HOW TO FIX IT

Broadly speaking there are three solutions to address the problem of traffic congestion:

1. increase supply
2. decrease demand, or
3. a combination of the two

Increasing supply of roads is the traditional solution, but this requires long term political thinking and substantial capital to invest (either public or private). Forcing citizens to pay to travel from A to B is unlikely to build political capital, and so the 'user-pays' model is underused in many countries.

Urban areas, where congestion is highest, suffer from physical space constraints – there is simply limited space to add more road capacity. Addressing congestion problems through increasing supply can traditionally only be achieved through public policy choices. Despite broad support, the impact on government finances and the long-term nature of the benefits delivered, mean that supply has failed to match demand growth over the past 20 years.

The Game Changer?

Autonomous vehicles have the potential to offer a comprehensive solution to congestion. A system in which cars drive much closer together and with more occupants – ride sharing – can vastly increase the capacity of existing road space by effectively reducing each occupant's overall demand for road space. This is a solution which can be driven almost exclusively by the private sector with appropriate regulatory support.

By 2030, within 10 years of regulatory approval of autonomous vehicles (AVs), 95 percent of US passenger miles traveled will be served by on-demand autonomous electric vehicles owned by fleets, not individuals, in a new business model we call "transport as-a-service" (TaaS).- RethinkX, May 2017

All New Cars Will Be Self-Driving in 10 Years - Elon Musk, Feb 2017

Get Ready for Peak Oil Demand - WSJ, May 2017

We are reaching "peak car" in many developed markets - Bank of America Merrill Lynch, Jun 2017

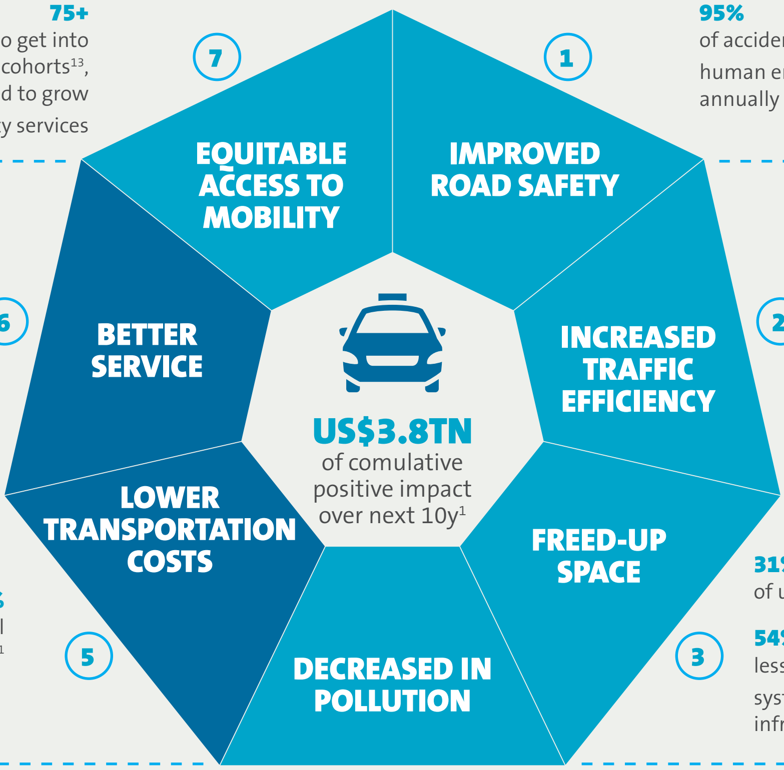
A high tech solution to an age old problem?

Source: Mercedes Benz

Benefits of Autonomous Vehicles

75+
population are 2.5x more likely to get into a fatal car accident vs younger cohorts[13], Average passenger miles travelled to grow **25-86%** through mobility services

95%
of accidents are caused by human error[2], save **US$697bn** annually in crash prevention[3]



500%
higher throughout using AV platooning[4]

40%
lower communte time vs public transport[12]

2x
the average car occupancy can be achieved through ride-sharing[5]

31%
of urban land are parking spaces[6]

40-70%
cheaper than traditional car ownership[11]

54%
less parking spaces in robo-taxi system[7]; save **US$7.5bn** annually in infrastructure spending[8]

4

23%
of emissions are generated by road transport[9]

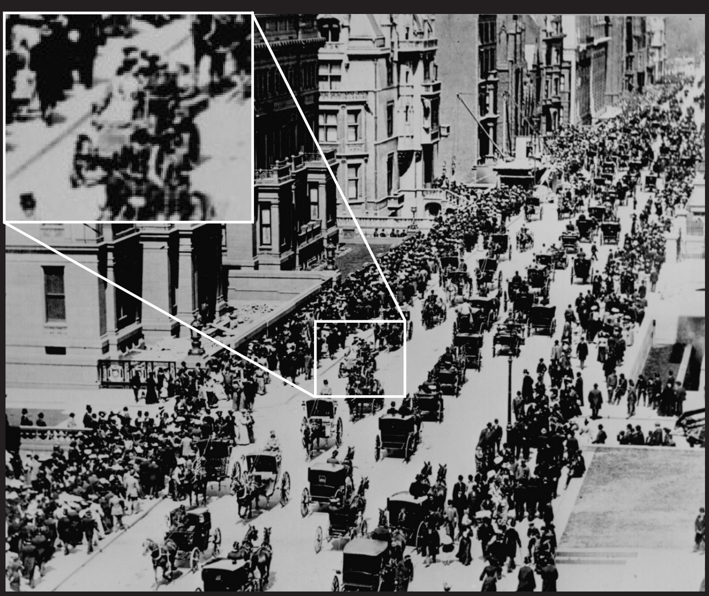
85%
less emissions in robo-taxi system[10]

- Individual benefits
- Society benefits

Sources: 1 Mckinsey; 2 NHTSA; 3 NHTSA; 4 Fernandez and Nunes, 2012 as cited in KPMG and Centre for Automotive Research, 2012; 5 BCG; 6 Kenworthy & Laube; 7 BCG; 8 KPMG; 9 IEA; 10 BCG; 11 Chen et al 2016, BCG 2016, Rock Mountain Institute; 12 BCG 2016; 13 Japan National Police Agency; 14 Bloomberg New Neergy Finance; McKinsey
Source: BofA Merrill Lynch Global Research based on cited sources

Those optimistic that the adoption of autonomous cars will be rapid are looking to the large auto manufacturers' near-exclusive research and development focus on electric vehicles and self-driving solutions. A historic observation of the rapid replacement of horse and cart by the early automobile in the early 1900s is revealing:

5th Avenue, New York: 5 April 1900
Where is the car?



5th Avenue, New York: 23 March 1913
Where is the horse?

Source: Bernstein Research, US National Archives

Autonomous vehicle roadblocks

There are strong reasons to suggest that the adoption of autonomous vehicles will be much more gradual than suggested by this earlier technological leap from the horse and cart to the motorised car.

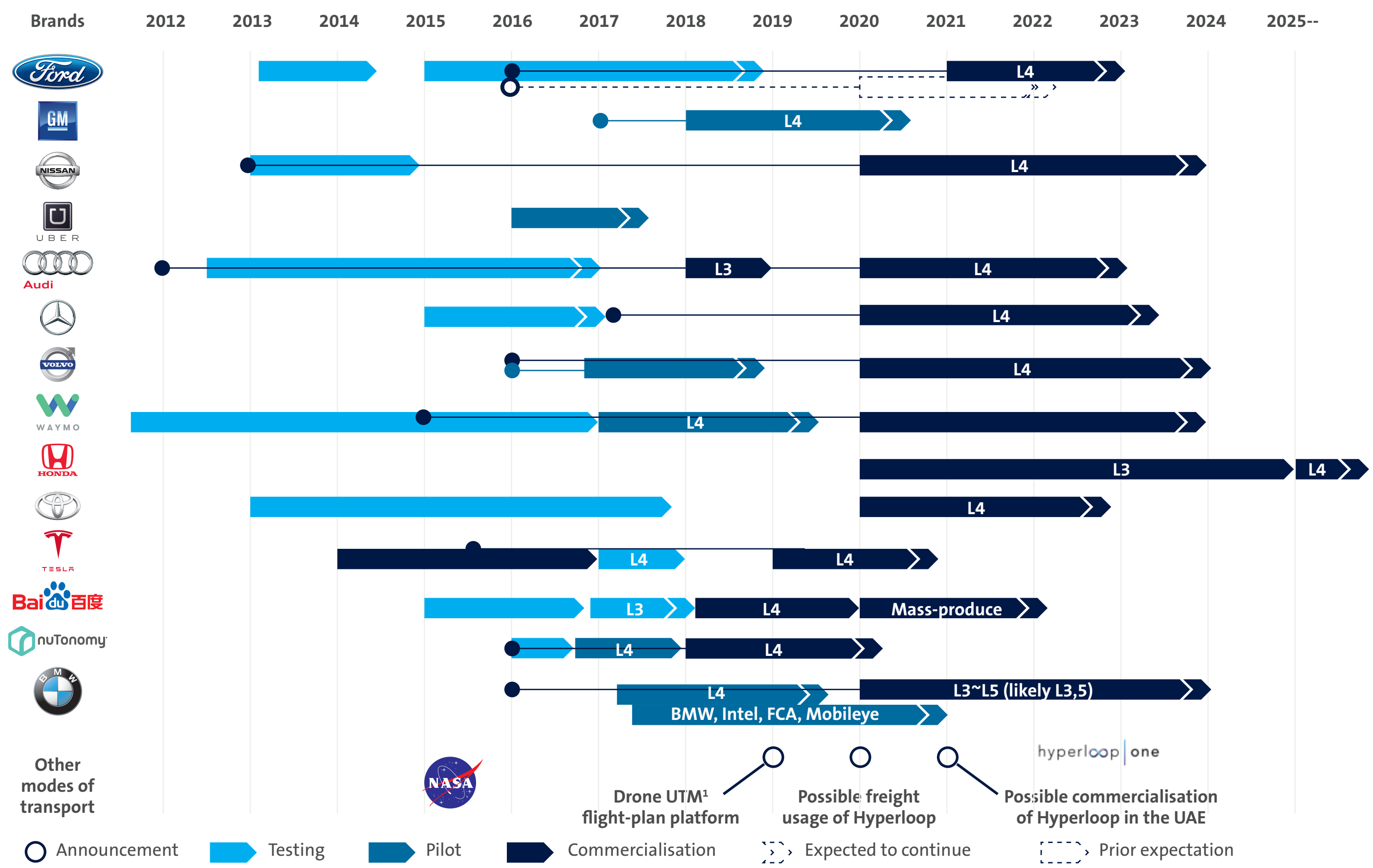
The most significant impediment is that the benefits of greater traffic density can only be achieved when a critical mass of cars are autonomous. Until then they may allow greater convenience to enable the 'driver' to respond to e-mails en route, but won't shorten journey times – which diminishes the incentive to would-be early adopters. Governments could hasten adoption by creating dedicated lanes, but this would result in a significant increase in congestion on the remaining 'human lanes', creating an imbalance for those unable to afford access in the early stages.

Huge initial investment is required to enable autonomous vehicles to function efficiently. Each autonomous vehicle generates a daily amount of data equivalent to 2,700 internet users, and cars will likely also need to communicate with the infrastructure itself. To put this data generation in context, should autonomous vehicles represent 30 percent of total cars on the road, it would be equivalent to 1 trillion people's worth of data usage, every day.

More simple issues such as refreshing road markings and signs so they can be reliably read by cameras will require investment in the tens of billions of dollars. Initial adoption is likely to be confined to well-marked freeways/motorways[1]. A recent study found that even simple graffiti on road signs was able to spur errant behavior in autonomous vehicles[2]. The key question these examples give rise to is who will meet the cost of investment and oversight? Is it a cost for the taxpayer or the transport solution provider? Funding by the taxpayer would be viewed as regressive, while assigning costs to the transport solution provider would substantially increase its overall costs and question its viability.

Autonomous vehicles have different stages of automation. Current automaker investment plans foresee commercialisation of Level 3/4 autonomous vehicles in the mid-2020s. Level 3 means that these vehicles are capable of operating entirely without driver input, in certain environments, while a 'driver' must be available to take over in other environments and in some circumstances. In testing it has been observed that these standby drivers have extraordinarily limited capacity to remain engaged in the task once they can remove their hands from the wheel, taking up to 10 seconds to respond to audible and visual warnings. Such human shortcomings leave some automakers questioning whether evolutionary transition steps to full automation should be skipped altogether, as a number of automakers are now doing.

Automaker Autonomy roadmap



Sources: CLSA

1 http://www.businesscar.co.uk/analysis/2017/uk-roads-deemed-insufficient-for-autonomous-cars
2 http://www.telegraph.co.uk/technology/2017/08/07/graffiti-road-signs-could-trick-driverless-cars-driving-dangerously/

It is highly likely that autonomous vehicles will be electric vehicles. Battery technology has now largely advanced sufficiently to power cars over ranges and at speeds deemed to be acceptable to most users. However, 40 per cent of greenhouse gas emissions from global road traffic in 2015 was due to trucks. The battery power required to provide the load and range required for commercial road haulage may double the weight of the lorry and hence halve its loading capacity. This means that more vehicles would be needed to move the same amount of freight, adding to the problem of wear and tear on road surfaces.

At present, purchasers of electric vehicles receive government subsidies, which bridge some of the cost gap between them and existing petrol/diesel cars. Taxation raised from internal combustion engine vehicles represents approximately 2 per cent of government revenue in the US and 5 per cent in Europe. The adoption of electric and autonomous vehicles will diminish this income, in addition to the increasing cost of subsidies paid to encourage their adoption. At some point, policymakers will need to rebalance their approach, which would have implications for cost relative to that of existing internal combustion engine technology.

Many projections of high rates of autonomous vehicle adoption base their operating model on ride sharing rather than individual ownership of autonomous vehicles. The expected very high rates of asset utilisation assume that users will be willing to collectively stagger their journey timings in order to smooth out the peaks in demand in order to support a very low cost per mile for usage.

It is claimed that extensive adoption and/or government subsidy will eventually lead to autonomous vehicle travel falling to less than 20 US cents per mile[3], assuming that the car is shared. However this cost level is not dissimilar to that produced through efficient bus and long distance rail travel, which in spite of being available for many years, has taken only a fraction of market share from the private car. This is partially due to the convenience factor, since bus/rail does not always get you to exactly where you want to be – but neither necessarily would ride sharing if the user needs to stop 2-3 times on the journey to pick up/drop off other occupants. This is particularly relevant in rural/suburban areas where low population density may mean a higher wait time for a ride share and/or that the ride sharing model is uneconomic. This means continued use of non-autonomous vehicles (and therefore implying an upper limit on adoption below 100 percent).

The implicit assumption in support of the ride sharing model is that it has been caused by underlying societal change. In this, the ownership of goods has now become much less important, rather than being driven by economic circumstance, such as limited real income growth and high youth unemployment. This may well be the present reality, however a 20-year old today may well have a different view as a 35 year old with two children and a dog which enjoys getting muddy!

Finally it is assumed that shared autonomous vehicle adoption will be facilitated by the historically high replacement rate of cars that exists today continuing in the future. There has been a fundamental shift from owning to leasing cars over the past 15 years, at a time of historically low interest rates. Affordability depends upon the monthly cost and hence a relatively small change in interest rates can significantly increase the cost of ownership.

The replacement rate of cars is important. Even if electric - not autonomous - vehicles make up 30 per cent of new car sales by 2030, this will account for only 5 to 6 per cent of cars on the road. This is well short of the 50 per cent tipping point that will deliver the greatest benefits of autonomous car technology.

“Many projections of high rates of autonomous vehicle adoption base their operating model on ride sharing rather than individual ownership of autonomous vehicles.”

3 An Integrated Perspective on the Future of Mobility, Oct 2016. McKinsey & Company, Bloomberg New Energy Finance

A boring solution?

None of this is to suggest that autonomous vehicles will not in time evolve into a widely embraced technology that will significantly impact societies, especially in the US and other industrialised markets. It merely seeks to highlight the very significant financial, practical and cultural barriers that are likely to see a much longer implementation period than most advocates have suggested. Moreover this 'chicken and egg' problem underlines the fact that the immediate problem invites a more near-term solution.

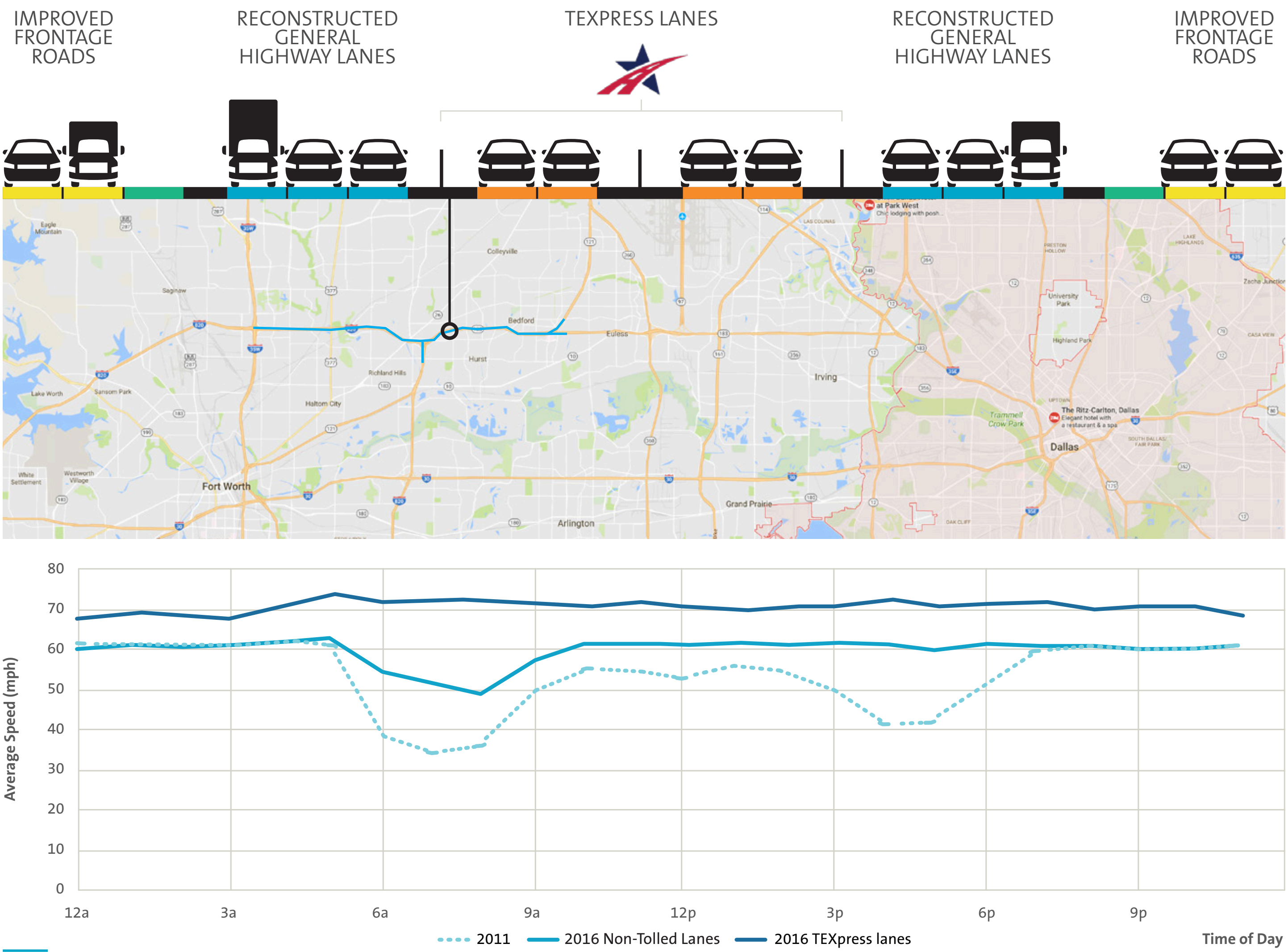
Even with a rapid rate of autonomous vehicle adoption over 30 years (utilising a typical 'S-curve'), a city with 1 per cent annual population growth may see no overall reduction in the demand for road space compared to current levels, hence nearer term solutions are still required. One such example is the managed lane. This is a combination of increasing supply and reducing demand. Whilst it does not solve every issue, it does offer solutions to many of the hurdles encountered when building new free roads or toll roads.

A managed lane is an additional lane built beside or within an existing freeway, saving space compared to the alternative of entirely new road supply. These lanes are accessible to any user willing to pay a toll which varies with demand. The toll is set at a level sufficient to maintain road speeds at a pre-agreed level. This diverts traffic away from the freeway, also benefitting those that do not use the managed lane. In practice, managed lanes have been proven to significantly increase traffic flow, while generating a revenue stream to cover the cost of construction over time.

Managed lanes may be developed either publicly or privately. State transportation departments can design tender packages that achieve specific desired social outcomes, such as including the provision of bus lanes or free transit systems. For private investors, the existence of a known level of traffic in a certain corridor means that the forecast risk is lower than that found in notoriously difficult to model greenfield toll road projects. This lowers the project's risk level and cost of capital. The expertise required to operate a managed lane is still relatively concentrated among few companies and returns can be in excess of those in other toll road operating models.

Managed Lanes – What are they and do they work?

NTE TEXpress (Ft. Worth)
Since Oct 2014



Source: Cintra

What does the future look like?

The demand for mobility in the US and other developed markets will continue to grow over the next 25 years.

However governments' ability to finance increased supply of road space, voter willingness to pay higher taxes, motorists' enthusiasm for compulsory tolls and commuters' acceptance of the higher costs and hassle required to allow change to be implemented, will probably not.

This suggests a future where the road to the widespread adoption of autonomous car technology is to be expected, but much more slowly than foreseen by its enthusiasts, due to the higher than acknowledged societal costs.

Meanwhile more innovative infrastructure models can address traffic bottlenecks through the construction of managed lanes, especially in congested urban areas.

> The demand for mobility in the US and other developed markets will continue to grow over the next 25 years.

The investment opportunity

The investment opportunity lies less in the makers of the autonomous vehicles of the future that currently beguile much of the media. Rather it is in the less glamorous infrastructure that will support the new technologies and which will require investment on a large scale and offer the potential of attractive risk-adjusted rewards.

Historically infrastructure investment depended on 'push' from policy objectives. Now, technological change and experimentation in P3 means investment is 'pulled' by market forces. Regardless of whether autonomous cars take over in 5 years or 25 years, the direction of travel of future mobility solutions paints a clear picture of the investment needed and those infrastructure providers capable of delivering it.

Competitive advantage lies with those transportation infrastructure providers with superior understanding of how different segments of commuters value their time (dynamic road pricing). This implies that first movers in the industry are exceptionally well positioned to capitalise on this trend.

The graphic below highlights what we consider to be the key infrastructure thematics arising from disruptive technology across the main categories of infrastructure. In each instance we believe certain companies within these subsectors possess supportive regulatory frameworks to enable investors to benefit from these themes.

This appears to disprove the perception that listed and core infrastructure firms such as utility, communications and transportation infrastructure operators have growth avenues which are limited. Instead, investors can gain access to growing, inflation-linked and stable cashflows which combined can offer compelling investment opportunities.

Opportunities arising from disruptive technological advancements

TRANSPORTATIONS
- Demand for road space will continue to rise as miles travelled set to increase
- Road network investments are needed and underfunded
- Innovative road pricing capabilities are critical

UTILITIES
- Investments in charging infrastructure are needed
- Reliance on renewable energy and batteries requiring investments in smart grids

COMMUNICATIONS
- Data generated by each AV equivalent to 2,700 internet users, every day.
- Investments in Communication infrastructure (V2I) are critical

ENERGY
- Record-high gasoline demand in short term
- Hybrid vehicles represent a medium term risk for oil demand

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