The impact of technological change on the infrastructure sector

AUGUST 2016

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Executive summary

Technological breakthroughs require intelligence, diligence and, perhaps, a dash of divine inspiration. But, before revolutionary technologies experience broad societal adoption, there is often another requirement: Infrastructure.

As an investment manager investing in global listed infrastructure companies, we are focused on the effects of technological change. While advances in infrastructure and its usage may not garner widespread public attention, they are a key ingredient in the successful implementation of new technologies. In this paper, we have focused on three infrastructure sectors experiencing meaningful technological change.

Communication infrastructure

What happens when more and more of the population use smartphones? How do mobile phone networks adjust to exponential growth in data usage and rising demand for faster connectivity speeds? As demand soars, the companies which supply the necessary infrastructure for telecommunications companies will face new challenges and significant opportunities.

Rail

Railroads were a breakthrough technology in the 19th century. But, the 21st century is seeing meaningful improvements focusing on two types of advancements: train size and train signalling. We discuss the company which operates the tunnel connecting London to Paris and the ways that it is at the forefront of implementing these technologies to improve service.

Toll roads

Once relegated to science fiction, driverless cars are becoming a reality. As technology advances, automakers will not be the only industry to experience significant changes. The advent of autonomous vehicles will impact the toll road sector. We have focused our discussion on potential changes regarding road safety, road capacity, and freight traffic.

IN THIS PAPER, WE HAVE FOCUSED ON THREE INFRASTRUCTURE SECTORS EXPERIENCING MEANINGFUL TECHNOLOGICAL CHANGE.
Section 1:
The impact of technological change on telecommunication towers

Author: NATASHA THOMAS, analyst in the Global Listed Infrastructure team
Since its invention, wireless technology has undergone constant evolution. From the first mobile phone to the current generation of smartphones and tablets, technology continues to provide consumers with a new level of accessibility and convenience that makes it hard for consumers to imagine life without it.

As consumers have embraced the mobile environment, data usage has exploded. With experts forecasting ongoing and escalating demand for mobile bandwidth through at least 2020, continued capital investment by the carriers will be required, which in turn should support continued leasing growth for the Tower companies.

What role do towers play in the telecommunication process?

Tower companies own and operate communications sites and lease space on these sites to tenants such as wireless service providers, radio and television broadcast companies, and government agencies. The Tower companies own the tower structure and either own or lease the land underneath the tower, while the tenants own the antennas, base station equipment and coaxial cables. In order to lease space on the tower for their communications equipment, tenants are charged rent based on the location of the site, square footage of tower space leased and the weight placed on the tower from the transmission equipment.

The contracts between a Tower operator and its tenants typically include an initial term of 10 years with multiple renewal terms of 5 to 10 years at the option of the tenant, and contain limited termination rights for the tenant. In the US, the contracts include annual lease escalators on the rental price of approximately 3 per cent, while in international markets the contracts include annual lease escalators that are based on local inflation rates. These escalators help Tower operators to recover increases in their operating costs, which are largely fixed but tend to increase at the rate of inflation.

Due to the high scarcity value of tower assets, largely because of the zoning approval required for new sites, Tower operators rarely compete against each other and have been able to achieve steady increases in the rent they charge their carrier tenants. Towers provide a critical service to their tenants, so typically contract terminations are low at around 1–2 per cent per year.

As the demand for and use of wireless services grows around the world, continued capital investment by the wireless service providers will be required – whether it be to build out additional spectrum or capacity, densify current networks, or overlay new technologies – in order to improve their existing networks and expand their network coverage. Any increase to the equipment mounted on the Tower or held in the base station by the tenant requires an amendment to the existing contract, usually resulting in higher rental revenue for the Tower operator. As Tower operators add new tenants, they generate high incremental returns due to the relatively fixed operating costs, resulting in incremental margins of over 90 per cent.

*Source: CCI Presentation March 2016*
What’s happening in the US wireless industry?

Since the early 2000s, wireless carriers in the US have invested nearly US$350bn in wireless capex to build out their nationwide mobile networks. First it was to support the conversion of fixed line to mobile telephony; then the transition from 2G to 3G which enabled mobile internet on consumer devices. More recently, the transition from 3G to 4G has offered users access to faster data speeds and lower latency rates, kicking off the social media and entertainment trend.

Consumers have shifted more and more of their daily activities to a mobile environment – from buying a cup of coffee in order to skip the line at the coffee shop, to booking hotel rooms, requesting an Uber pick-up, or paying a bill through online banking – and as a result data usage has exploded.

US data traffic was 1.6x higher in 2015 compared to 2014, and Cisco estimates it will grow a further 6x – a 43 per cent compound annual growth rate – by 2020 primarily driven by an increase in the level of video streaming by customers on smartphones and tablets.

US wireless industry trends

Over the last decade, advancing technology, rising device penetration and ramping data usage have led to increased levels of carrier capital expenditures.

In 2020, Cisco projects that 77 per cent of total mobile data traffic will be mobile video, up from 61 per cent in 2015.
Are there opportunities in international markets?

Internationally, the wireless networks in developing and emerging markets are typically less advanced than those in the US and other developed markets. As an example, smartphone penetration in India is less than 25 per cent with the vast majority of the population still on 2G. A fundamental shift towards more advanced wireless technology is now underway in India with 3G and 4G networks being rolled out concurrently.

As the younger population in these markets embrace wireless, the availability of cheaper smartphones globally is expected to drive mobile traffic growth, with carriers in markets such as Nigeria and Uganda investing significant capital in their networks in order to take advantage of this shift.

As an example of this, US Tower company, American Tower, is positioned to benefit from the advancement of wireless networks in a number of emerging and developing markets around the world through the towers it owns and operates in these regions. This technological advancement should support continued double-digit margin growth in American Tower's international business for the foreseeable future.

**International markets poised for smartphone growth – wireless penetration vs mobile broadband (3G/4G) penetration**

Size of bubbles = number of mobile subscribers

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We’re a vital provider of communications real estate in vibrant markets like Mexico, where aggressive 4G rollouts are ramping up; and Brazil, where significant 3G network augmentation is continuing; and in India, where the transition from 2G is only now getting underway for a majority of the population.

Tom Bartlett, American Tower CFO, on a call to the investment community, 29 April 2016

What’s next – evolution from 4G to 5G and beyond

While 5G technology is still in its early stages of evolution, it is expected that it will provide ultra-fast speeds, have lower latency than 4G and thus provide the network infrastructure required for the next wave of products and services over the next decade which need connections to work everywhere, all the time.

**Machine to machine (M2M) connectivity:** there is already a vast array of applications using M2M such as smart meters and smoke detectors in a “connected” home system, and healthcare monitoring, however the possibilities are almost endless as technology and networks advance. Perhaps your alarm clock will one day have a button to press that sends a signal to your coffee machine to start brewing? Or a friend’s surgery may be performed by a robot that is controlled by a doctor on the other side of the world?
Autonomous driving/connected cars: In order for the safe operation of autonomous cars, a connection to a network incorporating a traffic management system with a command response time close to zero is crucial for their safe operation. This type of response time is currently envisioned in the specification for 5G networks.

Fixed wireless broadband access is expected to be the first application of 5G in the US, with US carrier Verizon planning initial deployment as early as 2017. The next phase will then be to expand 5G capabilities to their mobile network, currently expected in the 2020+ time-frame while telecom operators in South Korea have targeted the 2018 Winter Olympics for its deployment of mobile 5G.

Once fully deployed, 5G is expected to support the increased demand for wireless data through 2030-35. Since the 1980s, approximately once a decade the world has seen a “generational” evolution in the wireless sector; a trend that will likely continue as technology continues to advance and demand for wireless globally continues to grow.

Implications for the Tower sector

We expect wireless carriers will continue to invest in their networks as they take advantage of the predicted increase in mobile data usage between now and 2020.

As overall network usage increases, the additional demand can overload the capacity of a cell site. In order to relieve congestion, carriers are adding new infrastructure to existing macro sites as well as adding more capacity in high traffic areas, such as sports stadiums and universities, with small cells.

Small cells are an important compliment to traditional towers – they help increase capacity in areas where demand outstrips the capacity of a macro tower. Small cells can be placed in specific locations and offer network densification to improve the quality, speed and reliability that is needed to handle increased traffic.

These small cells are largely an opportunity for the carriers to offload some of the data traffic off of a macro site onto a small cell, which improves and enhances the value of the macro site to cover a larger geography.

Ben Moreland, Crown Castle President, on a call to the investment community, 22 April 2016

What are small cells?

Small cells enable wireless carriers to add much needed coverage and capacity to relieve congestion on their networks.

Source: CCI Presentation

Tower companies, such as Crown Castle in the US, are increasingly investing in small cell networks to complement its existing macro towers.

Small cells share the same economic model as towers.
Similar to macro tower sites, the small cell business can accommodate multiple carriers and other customers, resulting in relatively high incremental margins as additional customers are deployed on existing fibre.

As the wireless service providers compete based on the quality of their networks, incremental investment in networks by the providers is required in order for them to maintain or improve network performance in an effort to improve customer satisfaction. Providers continue deploying additional equipment across their existing sites while also adding new cell sites to alleviate strains on existing networks. In many cases, this requires the addition of physical equipment such as antennas and connecting cables deployed on macro towers.

Longer term, we expect the deployment of 5G will drive growth for Tower operators as carriers look to densify their networks to provide the coverage, capacity and speed needed to support mobile video, increased machine-to-machine connectivity (the “internet of things”), fixed wireless broadband, and other products not yet envisioned.

Conclusion

We anticipate that consumers will continue to embrace future technological advancements in the mobile environment.

In order to satisfy consumer demand and take advantage of the predicted increase in mobile data usage between now and 2020, continued capital investment by telecommunication carriers will be required.

This should support continued leasing growth for the Tower companies through the addition of new sites and amendments to equipment on existing sites, requiring the tenant to sign a new lease or an amendment to their existing lease with the Tower operator, and resulting in incremental operating margins for the Tower companies.

Historically as technology has improved, the Tower companies have not seen significant levels of churn from the removal of old equipment because in most cases the new technology supplements the existing network.

As a result, Tower companies should continue to benefit from the continued investment in networks by the carriers as wireless technology continues to advance.
Section 2: The impact of new train technology on rail infrastructure operators

Author: DOUGLAS HAYES, analyst in the Global Listed Infrastructure team
Although not glaringly obvious, technology is set to have a big impact on the rail market in Europe.

Rail network operators in general and Eurotunnel, in particular, should be well positioned to benefit from these changes. Eurotunnel has the monopoly right to operate the tunnel between the UK and Europe under a concession agreement that lasts until 2084, and the company generates revenues from a mixture of passenger and truck shuttle trains. In this review we will discuss how upgrades to both train sets and train signalling will impact the usage of this tunnel.

Train set technological improvements

For the first time since the introduction of rail services in the tunnel over 20 years ago, the actual carriages for the passenger trains are being upgraded.

These new trains, the Siemens Valero e320 (British Rail Class 374), offer a significant upgrade over the existing Eurostar trains, which are Alstom TGV TMST (British Rail Class 373). These new Valero train sets have a seat capacity of over 900 passengers (depending on configuration), versus the current capacity of just over 700 for the TGV TMST trains. Even though the length of the trains is broadly the same (about 400m), the additional capacity on the Siemens trains is achieved by several innovations. First, the company has removed the need for a separate Locomotive engine to provide power, by moving the power sources directly to the wheels. The “engine” units are now placed underneath the floor of the carriages, with 50 per cent of axels driven directly by these motors. This has in effect added almost two extra cars to the train. Second, the technological hardware has also been moved into the floors of the train, rather than in the vestibules. This increases the amount of room for passenger seats.

The net impact of these changes puts the centre of gravity closer to the ground and spreads the weight more evenly over the length of the trainset. Additionally, it reduces the stress on the axels, since train traction is provided on all bogies (there are 2 axels per bogie), helping to smooth out the ride, especially when accelerating from a standstill. This in turn helps improve stability and reduce maintenance costs. In addition to the increased seat capacity, these new trains can also travel at faster speeds (320km/h versus 300 km/h for the existing trains), allowing for slightly shorter journey times.

Cost-effectiveness thanks to maximum seating capacity

By increasing the length of the cars and moving equipment into the floor, Siemens has increased the amount of floor space available for seating. Moving traction power to the floors, too, has removed the need for large locomotives to power the train.
SECTION 2: The impact of new train technology on rail infrastructure operators

However, these new train sets are not the only improvement to come. Although not currently in the pipeline, the opportunity exists to add double-decker trains to the fleet, which will instantly almost double the capacity of a train, helping to further increase potential passenger growth. The new Siemens trains do not yet have double-decker passenger carriages, however there are examples of high speed trains running with such carriages. In France, the TGV has operated bi-level carriages (the Duplex train manufactured by Alstom) since 1995. These increased the effective capacity of the trains by 45 per cent. The incremental EBITDA benefit for Eurotunnel would be significant. Double-decker trains can already pass through the tunnel so there would be little additional capex for Eurotunnel (bar the additional maintenance that larger, heavier trains may bring) and almost no additional opex. The biggest issue with these larger trains will be ensuring that the larger number of passengers (1,200–1,500 per train) could safely evacuate the tunnel in an emergency. In Japan, they also used to operate double deckers on certain Shinkansen lines, and these could in theory increase the capacity per car by as much as 75 per cent, depending on the train. However, the experience in Japan has resulted in a preference for faster speeds over double deckers as a means to increase capacity on existing rail infrastructure. We continue to monitor the evolution of rail carriage technology in Europe but given the mixed results globally we do not yet have sufficient conviction to conclude that double deckers will be used in the tunnel.

Train signalling technological improvements

With the tracks and catenary already able to handle bigger trains (thanks to the larger, heavier shuttle trains), the next investment involves upgrading the signalling systems in the tunnel.

This upgrade, to European Rail Traffic Management System (ERTMS) Phase 3 standard, will allow for less time between trains and better regulated speeds, increasing the number of available paths per hour.

Currently, the tunnel uses the same signalling system used in France for the TGV lines. While this allows for a certain degree of automation, such as the display of signals in the cab, rather than on the side of the track (as it can be difficult to view trackside signals at speed) and automatic braking, the line is still operated in a traditional way. This means that it is divided in sections, or blocks (about 1 mile long), and train spacing is determined by the number of blocks between trains (the number of blocks is dependent upon variables like the speed of the train and the safety stopping distance). As a train enters a block, it crosses over a transponder at track level, which then closes that block to other trains (meaning another train would have a red signal and cannot enter that stretch of track). Only once the original train crosses the transponder at the end of the section (and thus enters another block) can a new train enter that stretch of track. This can result in an uneven train speed, especially if the second train is faster than the first, as a train may need several blocks in order to completely stop (in an emergency).

Dealing with different speeds is of particular focus for Eurotunnel, given that the tunnel handles both freight trains and passenger trains. Currently, freight trains travel at 100–120km/h, while passenger trains can reach up to 160km/h. As a result of the speed differential and the existing block system, Eurotunnel controllers need to leave longer intervals between trains. If necessary, Eurotunnel can modify the schedule, so that slow trains go through in the evening and fast trains during the peak times. This does help to partially offset the speed issues.

Although not currently in the pipeline, the opportunity exists to add double-decker trains to the fleet, which will instantly almost double the capacity of a train, helping to further increase potential passenger growth.
Ultimately, though, improved signalling should make it easier to manage the tunnel (and the broader European rail network). Under the new ERTMS Phase 3 system, trains will continuously report their position to a central controller, thus by-passing the need for controlled sections of track and eliminating the need for static blocks. This new system is referred to as “moving blocks.” Using GSM-R technology, the trains continuously send their position and speed to the main control centre. The control centre can then determine the safest distance of space needed behind that train, and allow a second train to run in that position. This distance will take into account variables such as the speed of the trains, the weight of the trains and the conditions on the track. By actively managing the distance between trains, this should increase the effective capacity of the rails. Although trains may take several kilometres to stop (especially when travelling at top speed) this system allows the train to travel at a constant speed, rather than having to slow down and speed up as blocks ahead open/close.

**Current signalling systems**

Under current signalling systems, trains are monitored in blocks. In the example below, Train 1 cannot go past Signal 2 until Train 2 clears Signal 6.

![Current signalling system diagram](image)

Source: Macquarie

**New “moving block” system**

However, with the “moving block” system, trains 1 and 2 can continue to move together and keep a constant, safe distance apart.

![New moving block system diagram](image)

Source: Macquarie

In a sense, this system is similar to some of the technology already seen in cars (such as automatic cruise control and distance warnings). However, the technology has still been deemed too immature for roll out across the European rail networks. Moving block systems are in place in some areas in Europe, mostly across the urban transit systems, such as certain lines on the London Underground. These trains tend to run at maximum speeds of 100 km/h, though, versus high speed rail (HSR) speed of close to 300km/h. The European Union is trying to help fund investments in this type of technology for HSR (initially providing €770mn from 2007–2013 for countries to upgrade their signalling), however, given the number of legacy signalling systems across Europe, it is proving very challenging to create a new system that is compatible with the existing set-up and still able to achieve its targets of eventually replacing the static block system. Additionally, the EU has only identified 6 key corridors across the continent where they want to roll this out, focused mainly on central Europe. The corridors have been brought up to ERTMS Phase 2 standards; however, the next step requires more research into the technology behind the train management system.
New developments in Japanese rail carriages

The challenges facing Japanese rail due to demographic changes are well known due to the aging of their population.

On a recent research trip to Japan we were impressed by JR East’s ability to generate significant demand for their new “Shiki-Shima” train service which is essentially a high end tourism related train service that is proving popular in Japan with 50 to 60 year old customers. The most expensive ticket which is for 3 nights and costs JPY 950,000 (US$9,500) per person, is where the company is seeing the most demand.

Whilst it is still very early days with the new Shiki-Shima services set to launch in 2Q17, we wanted to highlight the potential for not only cutting edge technological developments but also really just smart use of existing technology, which could lead to better than expected demand for rail services from an ageing population. Given that Europe may face a similar demographic challenge as Japan, this type of train service could provide another lever for rail transport demand.

Conclusion

A key conclusion is that most rail infrastructure assets should benefit from continuing improvements in train set and train signalling technology. For example, the recent shift to the new e320 has resulted in an over 25 per cent increase in capacity for Eurotunnel without the need for any significant capital expenditure. The new trains will bring additional passengers without any investment from Eurotunnel.

Improvements to the signalling system should increase the capacity of the tunnel without requiring significant amounts of investment in physical expansion of the tunnel. However, although improvements to the signalling systems will require investment in new technology, it will also increase the overall capacity of the tunnel, allowing for more passenger, freight, and shuttle trains to pass through. Improved networks across Europe should lower transit times, and help passenger trains continue to gain market share versus airplanes, increasing the catchment area for Eurostar, and continuing to support structural growth in passenger numbers.

Although the exact impact on travel times is unknown, faster train times have a clear correlation with increased market share (versus air travel). This could be especially relevant for destinations that are in the 3–4 hour journey time, and so are on the cusp of the rail vs air market share battle. Research from the OECD suggests that reducing a train journey from four to three hours can result in a significant increase in market share for rail. Additionally, a reduction in travel times of 30 minutes can add 10–15 per cent market share for rail if the journey is less than four hours.

Source: Macquarie.
SECTION 2: The impact of new train technology on rail infrastructure operators

Journey time versus rail market share: exponential curve
Data suggests that the shorter the distance train journey, the more market share it can gain versus air.

![Journey time versus rail market share](chart.png)

Source: OECD, PriceWaterhouseCooper

With the improvements to the trains and the improvements to the signalling system, we see scope for a reduction in transit times across the European rail network. This could not only increase the market share for existing routes, but also allow new markets to be considered. All of this growth would benefit Eurotunnel, and incremental EBITDA margins on the additional passengers should be high given the large amount of fixed costs. We currently assume that direct rail passengers services are rolled out to cities like Amsterdam, Frankfurt and Geneva, as these would all be within 3–5 hour train journey based on the existing networks (see the table below for market share and passenger estimates).

### Increased track speeds

If track speeds are increased on the new routes, it could help to expand train travel market share, which could add over 5 per cent of additional revenue based on our current estimates, which should have a high drop through to EBITDA and FCF.

<table>
<thead>
<tr>
<th>Additional routes</th>
<th>Startup year</th>
<th>Air mkt (2014)</th>
<th>Rail mkt share</th>
<th>Target passengers</th>
<th>Market share</th>
<th>Target passengers</th>
<th>% Difference</th>
<th>Additional revenue (£ mn)*</th>
<th>% of 2016 revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amsterdam</td>
<td>2017</td>
<td>3,411,188</td>
<td>35%</td>
<td>1,193,916</td>
<td>45%</td>
<td>1,535,035</td>
<td>29%</td>
<td>29</td>
<td>2.3%</td>
</tr>
<tr>
<td>Frankfurt</td>
<td>2020</td>
<td>1,739,429</td>
<td>25%</td>
<td>434,857</td>
<td>30%</td>
<td>521,829</td>
<td>20%</td>
<td>10</td>
<td>0.8%</td>
</tr>
<tr>
<td>Geneva</td>
<td>2020</td>
<td>2,332,304</td>
<td>25%</td>
<td>583,076</td>
<td>40%</td>
<td>932,922</td>
<td>60%</td>
<td>18</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

* Based on current Eurotunnel per passenger fee charged to Eurostar of about 19 per passenger.
Source: PWC for improved track speed market share, Macquarie estimates.

Because the shortest journey time is likely 4 hours, we do not assume a market share greater than 35 per cent. Although there is scope for further reductions in the transit time on these routes, we do not currently model this in our estimates. This is mainly due to the difficulties that the EU is having in implementing the signalling improvements across the EU network, thanks to the many legacy signalling systems in each country along the route. Eurotunnel may be able to upgrade its own signalling as capacity dictates, however the tunnel is only 50km of the journey (versus a distance of about 600km from London to Amsterdam). In the long-term, if the European rail infrastructure builds out improved signalling and faster trains are deployed by the operators, new routes should open up to larger markets, such as Zurich, Munich, Milan or even Barcelona. If trains can safely travel at 300km/h for the whole journey, these destinations will suddenly only be a 4–5 hour train ride from London.
Section 3:
The impact of driverless cars on toll roads and beyond

Author: NEVILLE SWINFIELD, analyst in the Global Listed Infrastructure team
Transport infrastructure is very important to our quality of life and the productivity of our cities.

As populations continue to grow, building more roads and adding lanes will not be enough to meet the growing demand for transport infrastructure. Technology will need to play an increasing role and one technology which is likely to revolutionise transport infrastructure and how we travel is autonomous vehicles.

Driverless vehicles or CAVs (Connected and Automated Vehicles) will be the most significant change to personal transport since the invention of the car itself. CAVs have the potential to dramatically improve road safety, reduce congestion, optimise road network capacity, lower emissions and increase mobility for the population. Autonomous technology is not only likely to be the biggest disruptor to the automotive industry but it could also have major implications for future infrastructure investment, travel choices, parking needs, land use and the movement of freight.

**Connected and autonomous vehicles (CAVs)**

**What are CAVs?**

In 2013, the U.S. Department of Transportation’s National Highway Transportation Safety Administration (NHTSA) issued its preliminary policy on automated vehicles and outlined 4 levels of autonomous vehicles:

- **Level 1 – Function-Specific Automation:** automation of specific control functions such as cruise control, lane guidance and automated parallel parking.
- **Level 2 – Combined Function Automation:** automation of multiple and integrated control functions such as adaptive cruise control in combination with lane centering.
- **Level 3 – Limited Self-Driving Automation:** drivers can cede full control of all safety-critical functions under certain conditions and rely on the vehicle to monitor for changes in those conditions that will require transition back to driver control.
- **Level 4 – Full Self-Driving Automation**

**When will CAVs be a reality?**

The confluence of three technological advances in recent years has made the evolution of CAVs much faster than many had expected:

1. **Sensor technology** – has matured to the point that cars can now understand and sense their environment.
2. **Processing power** – has improved so much that it is now at the levels required for autonomous vehicles.
3. **High definition digital mapping** – is critical to autonomous vehicle technology and has improved dramatically in recent years.

There are already more than one hundred types of autonomous vehicles being tested legally on public roads today\(^1\). Tesla’s Autopilot function is a high profile example of self-driving technology available in cars today, however it is important to remember that driving with no hands on the steering wheel is still illegal in most countries.
Car manufacturers around the world are recognising they need to transform from being traditional manufacturers into becoming “mobility providers”, with all major manufacturers forecasting they will have a level of autonomous vehicle by 2020. Technology companies are also moving aggressively into this space. In 2014 Google created a fully functioning driverless car and it has now driven more than 1.5 million miles. There are also plenty of examples of increased partnership between car manufacturers and technology companies, such as BMW’s recently announced plans to partner with Intel and camera-software company Mobileye to roll-out autonomous cars by 2021.

It is likely that autonomous vehicle technology will be adopted in stages and the reality of mass adoption of completely self-driving cars is still many years away. Apart from the technological challenges there will be economic, legal and social constraints that will affect the pace of adoption. Vehicle innovations also tend to be adopted more slowly compared to other technological changes, due to legal and safety considerations as well as the slow fleet turnover.

It appears that many in the industry are confident that autonomous vehicles will be available on the market within 5 to 10 years, with mass adoption likely in around 25 years. The following chart from the 2016 Transurban Investor Day illustrates one forecast from the University of Minnesota on the timing of vehicle automation in the USA.

１Road safety

About 1.25 million people die globally each year as a result of road traffic crashes. There are around 1,200 deaths on Australian roads each year. Human error is estimated to be the cause of over 90 per cent of road accidents. Autonomous vehicle technology has the potential to dramatically reduce the number of road casualties by eradicating human error and emotional behaviour behind the wheel. Where collisions do occur, CAVs are expected to reduce the severity rate by being able to brake and take evasive action quicker than a human driver.

CAV technology will also drastically reduce the economic impact from road accidents. The Australian government estimates that road trauma costs the economy around $27bn each year, which equates to around 1.8 per cent of national GDP.

Conclusion: Up to one million lives per year could be saved once CAVs reach critical mass on roads around the world. The rapid development of automation technology in vehicles is already resulting in many new vehicles coming equipped with significant sensor and monitoring technology, which should reduce the amount of accidents and improve the flow of traffic over time.

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2 Transurban, AFR Infrastructure Summit, June 2016
4 Australian Government, Department of Infrastructure, Transport and Regional Development “Road Deaths in Australia, December 2015”.
SECTION 3: The impact of technological change on toll roads and beyond

Road network capacity

A typical highway with all human drivers has a maximum throughput of around 2,000 vehicles per hour per lane. According to our financial models quite a few of the toll roads we cover will face capacity constraints before the end of the concession which limits the cash flows from these assets. Hence, any increase in the capacity and efficiency of roads resulting from the adoption of CAVs could increase valuations. Some research predicts that road capacity could even double to 4,000 vehicles per hour per lane following full market penetration of CAVs\(^5\).

Transurban expects that the introduction of autonomous vehicles will improve the efficiency of its roads and potentially increase lane use capacity by 10–25 per cent within the next 20 years. The following chart from the 2016 Transurban Investor Day highlights how the combination of CAVs and infrastructure connectivity could potentially increase throughput during a typical workday, highlighting the potential increase in capacity during peak periods in particular.

This also highlights how road efficiency improvements will flow not just from advances in vehicle technology but also from advances in infrastructure technology and the level of connectivity between vehicles and road infrastructure.

<table>
<thead>
<tr>
<th>Hour Ending</th>
<th>Current capacity</th>
<th>Potential technology enabled capacity</th>
<th>Technology enabled throughput</th>
<th>Theoretical throughput</th>
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</table>

Source: Transurban 2016 Investor Day

We need smart infrastructure to support smart vehicles.\(^6\)

It is likely that when CAVs are initially rolled out they will not provide a material boost to road network capacity. It will only be in the long term when CAVs reach a high penetration of the vehicle fleet that efficiency and capacity improvements will be realised.

One simulation analysis by Princeton University\(^7\) suggests capacity benefits are likely to occur only on freeways when the fleet mix is at least 75 per cent autonomous. This study concludes that at that point, likely post-2035, the CAV fleet mix is likely to achieve traffic flow benefits of 25–35 per cent. Beyond that, when regulations, liability concerns and driver comfort allow much more aggressive car-following algorithms, vehicle delays may be reduced by 45 per cent or more.

Conclusion: Capacity and efficiency improvements from the introduction of CAVs should benefit toll road operators which are already facing congestion concerns on their roads.

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\(^6\) Transurban, AFR Infrastructure Summit, June 2016

\(^7\) Jane Bierstadt, Aaron Gooze, Chris Gray, Josh Peterson, Leon Raykin and Jerry Walters, 2014, “Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity”.
The automation of vehicles will enable cooperative adaptive cruise control or “platooning” of vehicles which will reduce the space between the front and back of vehicles. A combination of radar, cameras, GPS and vehicle to vehicle communication allow the platoon to accelerate and brake simultaneously which potentially has significant implications for the movement of freight.

The “platooning” of trucks is already being tested, which involves two or three trucks driving in a column, with the first truck determining the speed and route. This enables shorter gaps between the trucks which can result in fuel efficiency benefits by taking advantage of the slipstream created by the truck in front. Traffic could also flow better given the trucks drive together at constant speeds, the smoother speed changes of platoons and the shorter distance between trucks means more space left for other vehicles on the road. Truck platooning can improve traffic safety as the following trucks brake immediately.

Tests by Scania have shown that convoy driving using truck “platoons” can reduce fuel consumption by up to 12 per cent.8 The European Truck Platooning Challenge was held earlier this year, which involved several brands of automated trucks driving across Europe, on public roads, from several cities and all finishing at the Port of Rotterdam.

Last year Daimler’s Freightliner Inspiration Truck became the first licensed autonomous commercial truck to operate on an open public highway in the United States9. The Freightliner Inspiration truck is considered a Level 3 autonomous vehicle. The vehicle includes a camera and radar system, called Highway Pilot, that keeps the truck in its lane, avoids collisions, controls speed, braking and steering and presents information to the driver via a dashboard display. Freightliner stressed that its autonomous truck is not a driverless truck and a qualified truck driver is still required to be in the cab and at the controls.

Conclusion: Autonomous vehicle technology and truck platooning is likely to have significant impacts on the movement of freight by improving traffic safety, reducing fuel consumption and reducing operating costs. For those toll roads which have exposure to significant truck traffic there is potential for higher traffic as this technology rolls out. Whilst it is in its early stages, the improved efficiency of road freight transportation from CAV technology has the potential to improve the competitive position of road vs rail for freight transportation.

Broader implications of CAVs for the economy and society

Impact on Parking and Urban Areas
CAVs have the potential to significantly reduce the need for parking. For example, once your CAV has taken you to work in the morning you can instruct it to go back home for the day, or even to go to another destination to pick up someone else. This could revolutionise urban planning by reducing the need for car parks next to offices and retail areas. The space currently used for car parks could be used for something else.

Time and Productivity Impacts
The UK Department of Transport found that the average driver in England spends 235 hours, or the equivalent of 6 working weeks, driving each year10. Autonomous cars will allow drivers to use their time in the car as they choose – relaxing or working as desired. The car could become an extension of the office or perhaps even provide a chance to catch up on sleep.

Impact on traffic volumes
It is unknown at this stage how the adoption of CAVs will impact traffic volumes and the number of trips. The topic of whether autonomous vehicle technology will lead to more trips could be an entire thought piece by itself.

One view is that CAVs will reduce the number of vehicles on the road given the technology will facilitate more ride sharing, which is clearly a risk to the toll road sector. Another view is that it will increase the number of trips given CAVs will improve the mobility for those that are unable to drive currently. Also, if CAVs significantly enhance the user experience for drivers then people may travel more.

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8  http://www.scania.com/group/en/platooning-saves-up-to-12-percent-fuel/
9  http://www.freightlinerinspiration.com/
Conclusion

As we have shown, technological change is impacting many of the global listed infrastructure companies that we analyse.

These changes are likely to be far reaching and in some cases, as with driverless technology, are likely to impact many listed infrastructure sectors.

Our approach to this is to seek to understand, at a company level, the impacts, opportunities and threats of these changes and position our investments accordingly. This paper has highlighted how technological change is impacting and driving opportunities in the Listed Infrastructure investment world.

Infrastructure investing provides investors with a number of benefits, including the long-term, and often inflation-protected nature of the underlying cash flows. By focusing on companies that deliver real economic benefits for their shareholders and customers we hope to be able to understand and avoid the disruption and pain that can result from technological change, whilst taking advantage of the investment opportunities that come from the technological innovation in infrastructure (assets).
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