



Autonomous,
connected,
electric and
shared vehicles

*Reimagining transport to drive
economic growth*

ARUP

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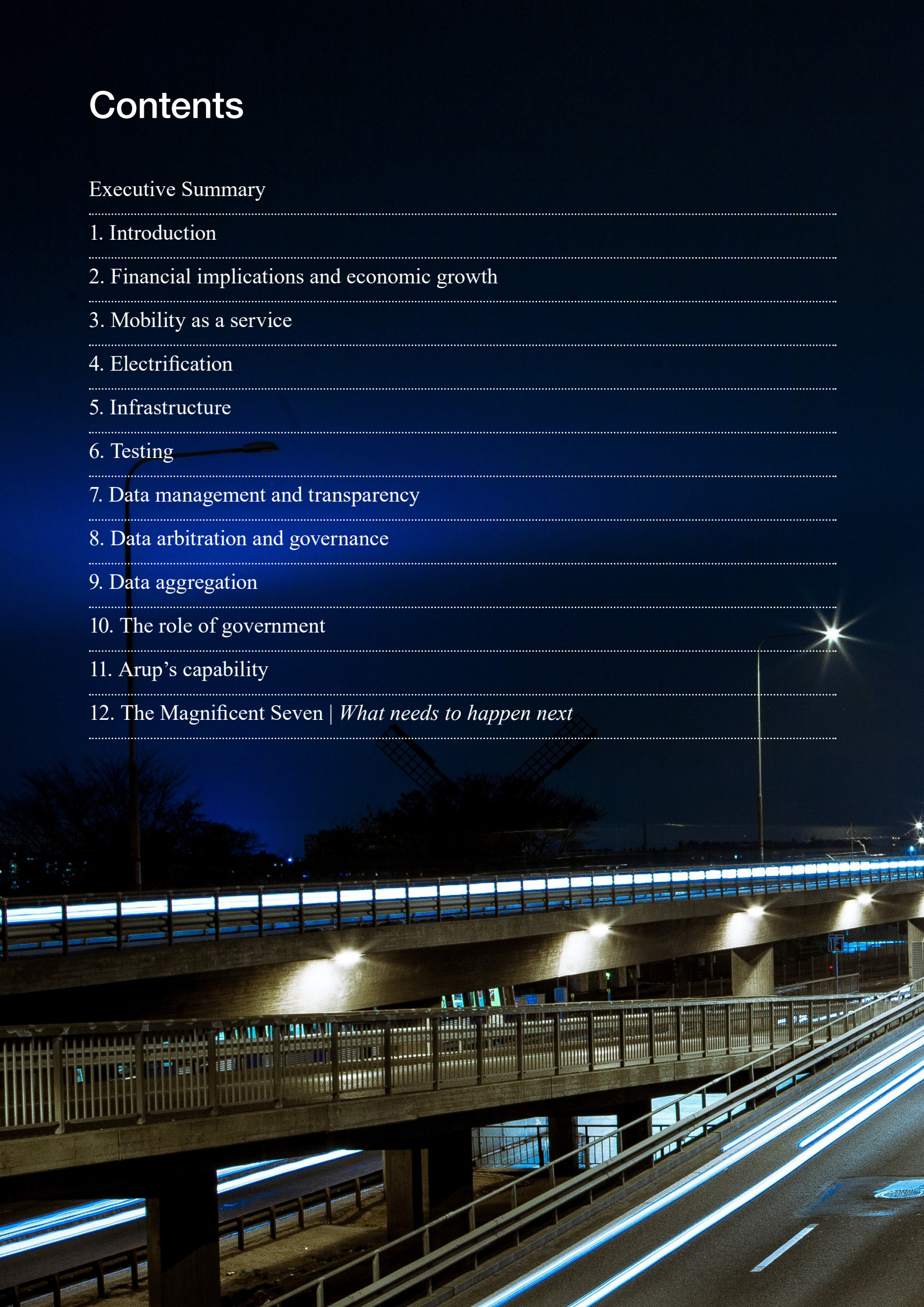
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Executive Summary

Ireland's opportunity for high-calibre job creation in a global market

A new mobility revolution is sweeping the globe. The introduction of disruptive technologies such as connected and autonomous vehicles (CAVs) is compelling us to reimagine how transport is delivered and promising a new era of safe, secure and enjoyable transport. CAVs are already being tested and used worldwide, with both traditional players and new automotive entrants, such as Apple and Google, looking to have production-level vehicles deployed by 2021.

This presents us with a significant challenge. What was once the future is now a reality, putting Ireland under real pressure to consider how we manage and take advantage of this new technology.

On the upside, this revolution also creates a huge opportunity. The global market for CAV technologies is predicted to be worth €70bn^[1] by 2035. This does not include ancillary electric and mobility services, for which staggering growth is forecast. As this market will be underpinned by the availability of reliable, quality-assured and trustworthy data and information, it is clear that jobs will be created not only in hardware manufacturing but also in data services that support CAV technologies.

This means that the technology sector in Ireland is ideally placed to play a leading role in this burgeoning market.

'TII is keenly aware of the need to understand the impact new technologies, such as Connected and Autonomous vehicles, could have for the road network, the travel patterns of people and the movement of goods. The potential implications of CAVs are important to consider when assessing Ireland's current and future transport infrastructural needs.'

*Helen Hughes, Director of Professional Services,
Transport Infrastructure Ireland*



1. Introduction

Most of us are familiar with the concept of autonomous and electric vehicles, but fewer are aware of technologies relating to sharing mobility services and connecting data between vehicles and their environment. Many of these innovations, known collectively as autonomous, connected, electric and shared (ACES) technologies, are in early stages of development and commercialisation.

Ahead of the pack are connected and autonomous vehicles (CAVs), which are likely to become a common feature of Irish roads within the next decade. As these vehicles have enormous implications for our transport system in the short term, we concentrate in this paper on the connected and autonomous, rather than electric and shared, aspects of ACES technologies.

1.1 Autonomous vehicles

90% of all traffic collisions are caused by human error ^[2]: the vehicle's driver taking the wrong decision at the wrong time, resulting in disastrous and, all too often, life-ending collisions. These events can have a catastrophic impact not just on the individuals involved and their families but also on the wider community. With up to 190 people killed every year in traffic collisions on the Irish roads, not to mention over 5,000 collisions causing injury and those that go unreported ^[3], there is a huge incentive to eliminate the errors leading to these events. Coupled to the human cost is the economic impact, where collisions cause significant delay to the travelling public, create congestion and tailbacks, and impede the delivery of goods and services.

What if there was an alternative? What if technology and the use of driver-assisted systems could eliminate 90% of traffic collisions by removing human error? That is the possibility offered by autonomous vehicles (AVs).

An AV is a vehicle capable of deciding on and taking a course of action, such as steering or braking, without the need for human intervention. Different levels of autonomy exist, reflecting the technology available on the market and the mixture of features deployed. The diagram opposite outlines these levels and what they mean from a human driver's perspective. Current technology has matured to somewhere between 2.5 and 4.

AVs are receiving a huge amount of attention globally, with both countries and companies investing billions in delivering infrastructure and data services to ensure their success. Accelerated developments are ongoing and test sites are springing up across the globe, from the UK to the Netherlands, Scandinavia to New Zealand and Australia to the US, as companies seek real-world environments in which to test the latest versions of these vehicles. Timelines associated with AV deployment are varied but a large number of manufacturers are focused on delivering vehicles by 2021 ^[4]. This means that, in under five years' time, AVs will be coming off the production line ready for use on our road network. Ireland is on the cusp of major change.

The question is whether we as a country are positioned to take advantage of AVs to manage our road network more safely and efficiently than ever before while, at the same time, delivering superior customer service to the travelling public.

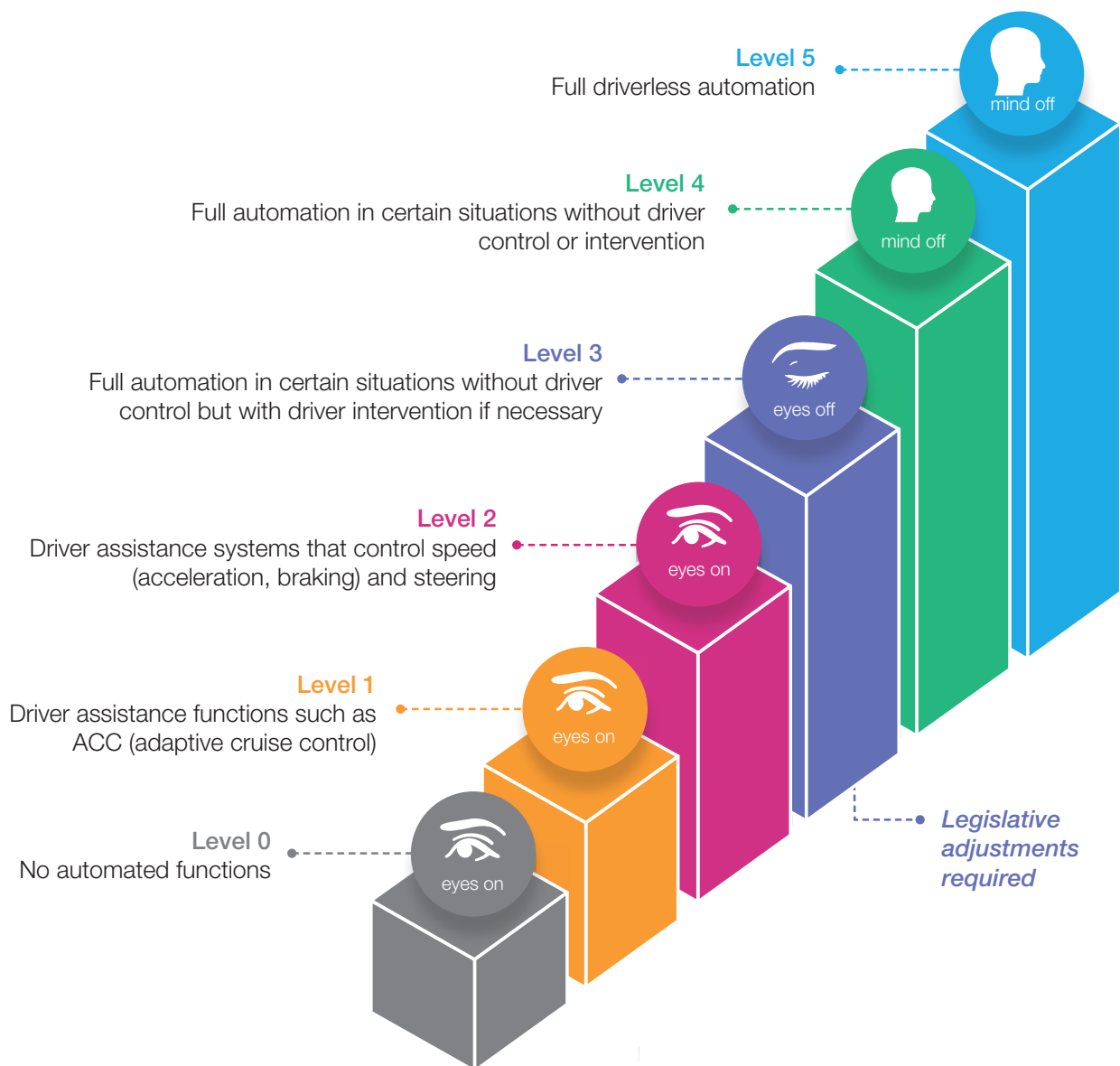


Figure.1 The five levels of automation

1. Introduction (*Contd.*)

1.2 Connected and autonomous vehicles

With all of the attention given to AVs, people often forget about the “connected” part of the vehicle: the part through which it can share information with other vehicles and its environment. This technology is, by and large, more mature than that for AVs and a number of international standards reflect this maturity.

For example, we are all familiar with variable-message signs advising us of roadworks and traffic conditions. These signs are relatively limited in their connectivity: they are restricted by their physical location, by the type of information they can display, and in their ability to respond quickly and proactively to changes in the road network.

By contrast, in the near future, infrastructure providers will be able to share information with moving vehicles using technology linked to the vehicle dashboard or integrated mobile phone services such as apps or Twitter. This will allow them to provide timely and relevant information to the travelling public and, conversely, receive information back that allows the network to respond proactively to changes in movement.

Although transport authorities have yet to take full advantage of the connected part of CAVs, we will soon see the creation of environments where people, organisations and service providers (from parking bays to coffee shops to charging points) are all engaged in supporting a user-centric system that services these technologies.

In the meantime, a range of information-sharing services could be introduced now and in the near term, as follows.

Day 1 services (immediate-term)

Hazardous location notifications:

- Slow or stationary vehicle(s) and traffic ahead warning
- Road works warning
- Weather conditions
- Emergency brake light
- Emergency vehicle approaching
- In-vehicle signage and speed limits
- Traffic signal priority request by designated vehicles

Day 1.5 services (short- to medium-term)

- Information on fuelling and charging stations for alternative fuel vehicles
- Vulnerable road user protection
- On-street parking management and information
- Off-street parking information
- Park & Ride information
- Connected and co-operative navigation into and out of the city (first and last mile, parking, route advice, co-ordinated traffic lights)
- Traffic information and smart routing

“TII recognises that Connected and Autonomous vehicles represent an as yet unknown challenge to management of our network but at the same time may offer significant benefits around safety and improved journey experience. However, this requires an understanding not only of the technology and what that means from a road management perspective, but also the policy and guidelines that will be required to safeguard road users’ needs.”

Pat Maher, Director of Network Management, Transport Infrastructure Ireland



safety



efficiency



mobility



productivity

Figure.2



1 Introduction (Contd.)

ACES technology is moving at different speeds in different directions, with some technologies evolving and maturing faster than others. As a result, timelines for deployment are difficult to ascertain. However, with a date of 2021 being used by nearly all vehicle manufacturers, it is clear that the presence of CAVs (Connected and Autonomous Vehicles) on the Irish road network is just a few years away.

This raises a number of questions around issues such as safety, management policy and insurance, and a review of legislation needs to be put in place to make this a safe reality.

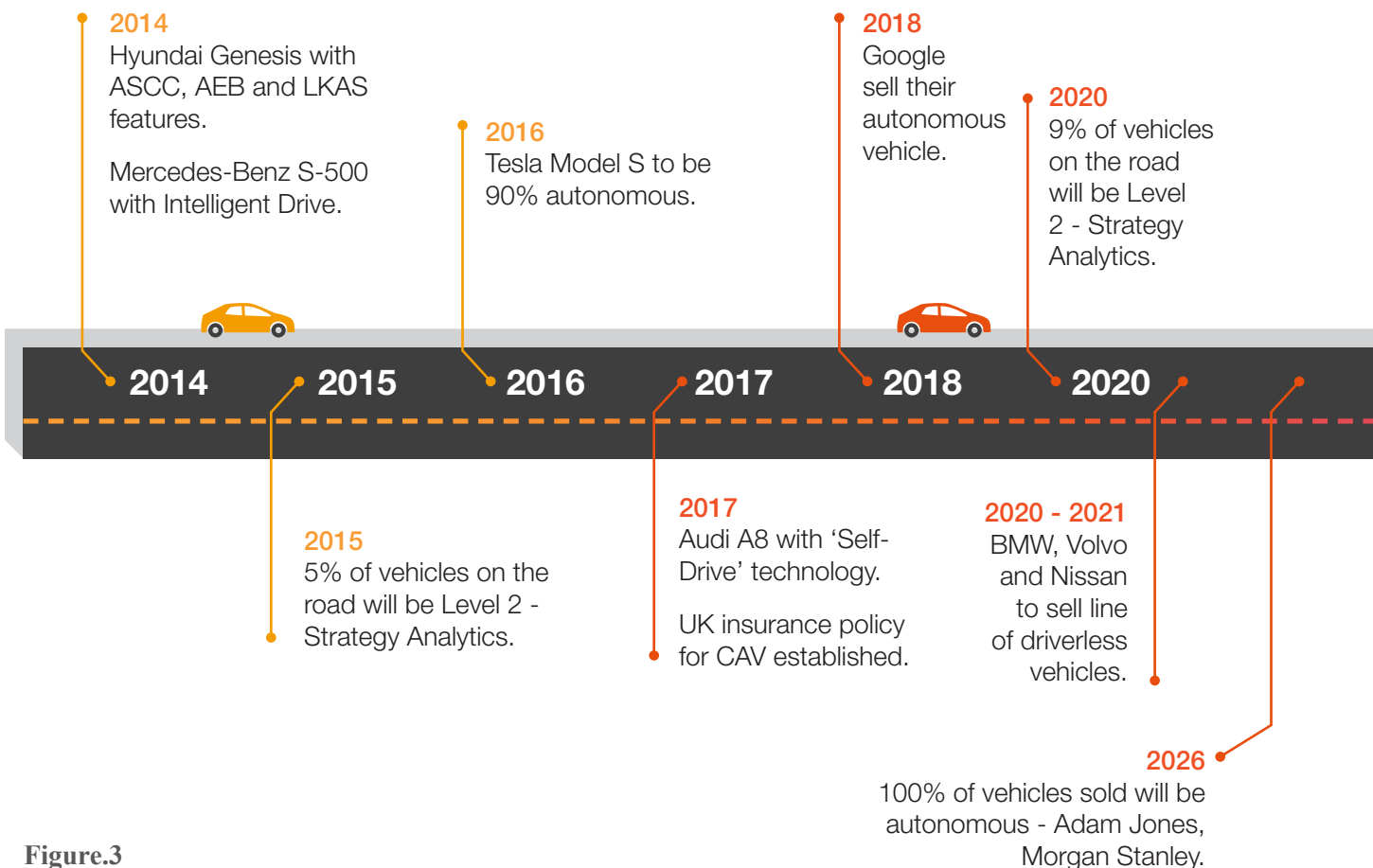
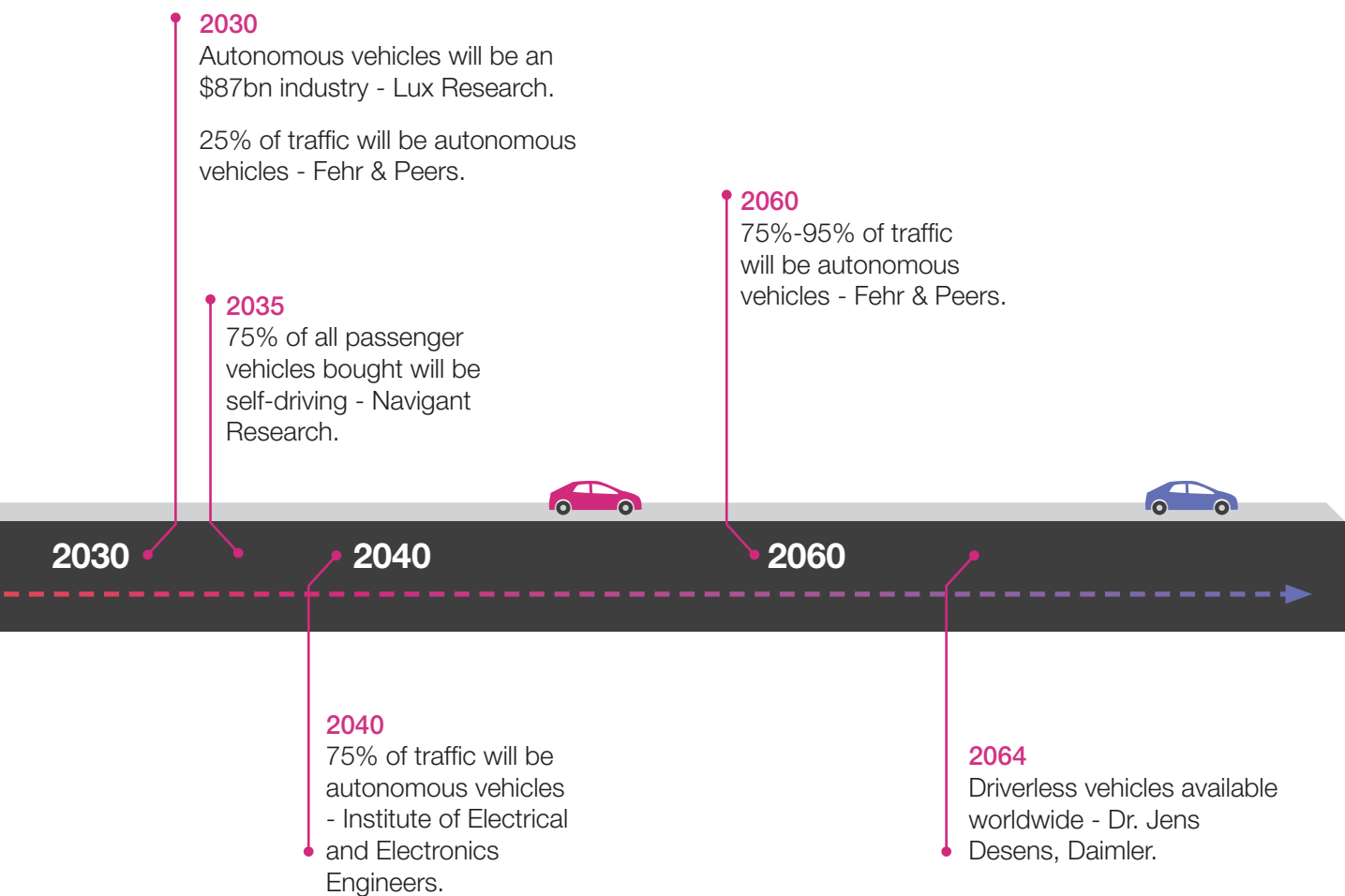


Figure.3

“Across the SFI Research Centres, but particularly in Lero, where we have a strong research focus on Autonomous and Adaptive Systems, we are seeing a growing demand for research expertise in the technical challenges related to CAV particularly in relation to the more immediate ‘blended’ autonomous environment that’s likely to exist in the near to medium term as we continue to have a mix of CAV and non-connected vehicles operating side-by-side on our roads and in our cities. Ireland’s ultimate success with CAV will depend very much on how quickly we respond to its unique challenges and opportunities, from both OEM, tier-one suppliers and indigenous Irish companies.”

*Joe Gibbs, Autonomous Vehicle Spokesperson, Lero,
Irish Software Research Centre, University of Limerick*



2. Financial Implications and Economic Growth

CAVs have the potential to drive economic growth and job creation. They also have significant financial implications in terms of both savings to the exchequer and revenue loss. From an Irish perspective, three areas deserve particular mention:

- savings to the exchequer in terms of collisions and their associated cost to the economy;
- the loss of revenue through existing pricing and tax schemes built around current mobility solutions and approaches; and
- job creation based on our existing capabilities.

Collisions

As mentioned above, CAVs offer the potential to reduce the 90% of collisions currently caused by human error. The use of these vehicles could drastically reduce the numbers of deaths on Irish roads, which have run at between 150 and 190 people per annum over the last five years ^[5].

Collisions also create significant economic costs. Data examined by Global Positioning Systems Inc from a variety of sources, including the WHO Global Report on Road Safety 2015 ^[6], the World Bank DataBank Gross Domestic Product 2015 ^[7] and McKinsey & Company (2016), indicates that 0.6% of Ireland's national GDP, that is €11.87bn, is lost to the Irish economy due to traffic collisions. Huge potential exists to reinvest this otherwise "lost" money back into the road network or into areas such as healthcare, education and job stimulation to reinvigorate the Irish economy.

Revenue

The deployment of CAVs and other ACES vehicles will also radically alter the tax system for land transport. At present, budget income from vehicle registration tax, road tax, excise duties on carbon fuels and VAT amounts to approximately €4.8bn – virtually all of which is from road transport. Reinvestment in land transport amounts to less than 30% of that – a historically low figure and way below that of our peers ^[8]. The arrival of disruptive technologies will cause a major hole in this tax base.

Fundamental changes in fiscal policy will be necessary to account for reductions in this income and incentives for road users to move away from conventional vehicles. The significant financial challenges posed to the transport network may be addressed through investment of savings enabled by the reduction in collisions, although these savings are more likely to be spread across other services than invested back into the road network.

In addition, it has been estimated that parking fine revenues will be significantly reduced, if not removed entirely, as intelligent, connected and automated technology and vehicles work together to make sure these vehicles are not sitting idle. This will remove an important revenue source from local authorities, which collected nearly €100m per annum from parking fines in 2014 ^[9]. National and local policies and strategies will have to be in place to counter this budget loss.



2. Financial Implications and Economic Growth (*Contd.*)

Job creation

“Ireland has a long heritage and pedigree in technology. It is home to the biggest global tech companies, a vibrant start up ecosystem and recently ranked Ireland 10th in overall global scientific research. Companies are developing world class innovations and solutions across industries. With regards to the emerging global opportunities companies are looking to Ireland for skills and innovations needed to enable a connected autonomous vehicle future in technologies such as A.I., vision processing, machine learning, big data analytics and many more underpinning technologies needed to enable the CAV evolution.”

Ken Finnegan, Chief Technologist, IDA

There is a misconception that if a country does not have an existing vehicle manufacturing capability, then there is little point in developing a position on the testing, use and deployment characteristics of CAVs. However, it is clear that as automobiles develop into “supercomputers on wheels”, most jobs created around the development of CAVs and the services they can deliver will be in data creation and interpretation. This is in addition to the creation of new markets in providing intelligence and experiences to the travelling public.

Indeed, there is a misstated belief that Ireland has no automotive sector at all. It is true that we have no manufacturing base for the production of vehicles but it is important to remember that the vehicle itself is made up of components, hardware and software that power its performance and capabilities.

This is where Ireland has a proven knowledge base and excellence. In fact, Ireland already has a track record in the design of key components linked directly to the auto sector, with significant employment already in existence across a wide geographical base spanning Galway, Kildare, Limerick and Cork ^[10]. Additionally, OEM research and development teams exist in the main universities and research centres across the country, from Waterford to Belfast, and are growing rapidly as they look

to develop cutting-edge analytics and tools in the area of CAVs. Dublin, in particular, hosts leading global data companies that are directly or indirectly involved in the CAV market through research and data management solutions. As such, significant employment already exists in the automotive ecosystem, beyond that of mere chassis and shell development.

Huge potential exists in this market. The global connected car market is expected to grow in the next five years to over \$180bn ^[11] and this will be underpinned by the delivery of software and hardware services such as eCall, park/motorway assist, sign detection and entertainment services. Intel suggests that self-driving cars could lead to the creation of another \$7 trillion in economic activity provided by a new wave of software and hardware solutions for both the travelling public and the overall knowledge economy.

With over 5,000 companies and several thousand jobs already in Ireland in the combined digital, ICT and financial services sectors ^[12], Ireland is ideally positioned to take a leading role in the creation of new high-end employment opportunities linked both directly and indirectly to the CAV market.

Action needed

Grasping these job opportunities will require the creation of a suitable infrastructure for backbone development and testing and also the development of high-calibre expertise in a range of areas, from artificial intelligence to video analytics. “Ireland Plc” is uniquely positioned to accelerate job creation across a number of related areas, including:

- cybersecurity;
- data centres and management;
- video analytics;
- infotainment;
- autonomy systems (hardware and software);
- communications networks; and
- detection sensors.

Economic impacts linked to CAVs are estimated at anywhere between 1% and 8% of GDP growth. Linking this growth back into the various sectors involved and using a variety of growth trajectories^[13, 14, 15], from low to ambitious, we estimate that it is entirely possible that Ireland could create approximately 100,000 new jobs in direct and indirect services for CAVs by 2030.

“Tyndall National Institute, one of Europe’s leading ICT Research and Innovation centres, fully supports the need to harness the content of this paper, where the expert building blocks of Government, Academia and Business ensure that Ireland is part of the Autonomous Connected Electric and Shared vehicles (ACES) wave of innovation, thus keeping Ireland’s technology sector at the forefront of innovation.”

Carlo Webster, Senior Strategic Business Development Executive, Tyndall Institute

2. Financial Implications and Economic Growth (*Contd.*)

2.1 Fintech/digital payment

The field of financial technology (fintech) and digital payment deserves a special mention, as it is an area of enormous potential for Ireland.

Payments for services delivered to CAVs will be enabled by ongoing advances in digital payment technology, particularly bitcoin and blockchain. This technology will allow for seamless, stress-free payment mechanisms that are secure, scalable and robust while, at the same time, offering integration with payment services outside of the vehicles themselves – for example, one integrated payment system covering mobile phone usage, fuel costs, online shopping and in-vehicle services.

Account-based payment systems are undergoing a resurgence due to the evolution of technology, with “tokens” used to protect both payment and user. These systems could be used in a personal cloud for CAV users that supports payment services for all parts of daily life, not just transport. Such a development would inevitably raise questions about the maturity of the payment technology, the integration of different pay channels, the back-end systems and clearing houses needed, transparency and governance across the whole payment digital chain, and security across the systems and links to the vehicle itself. In addition, privacy concerns regarding location services linked to payments and/or the individual would need to be considered.

Significant investment is underway, with companies such as Toyota and university partners such as MIT working to understand the applications of blockchain ledgers in the payment and monitoring aspects of CAVs, including in insurance models. The banking sector has already identified and trialled the ability of a connected vehicle to make payments from the vehicle itself, such as at fuel stations. Companies including US Bank, U.S. Bancorp, FIS Payments and Visa are already exploring what this means for existing business models and the technologies required at their end to help these seamless payments take place.

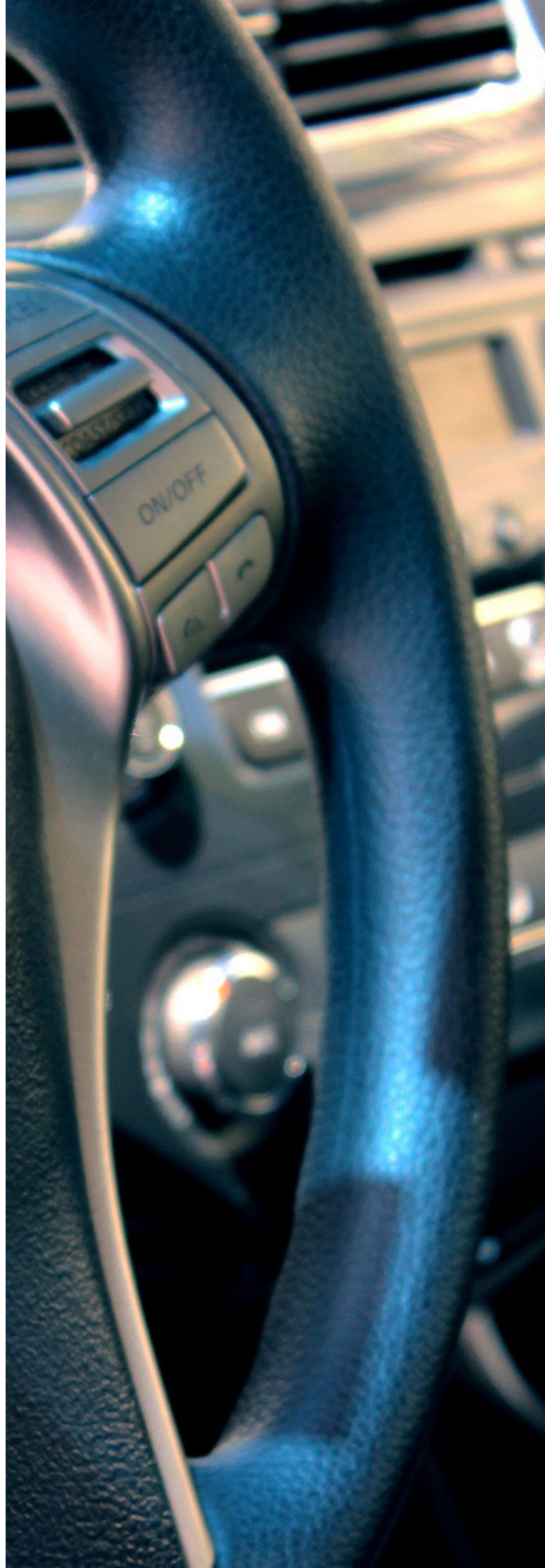
Other possibilities in financial services include direct provisioning of underwriting from the vehicle, financing on the go (migrating the mobile app into the vehicle itself) and provisioning of mobility as a service, as well as consultancy services from the financial sector aimed at start-ups and institutions in the CAV space:

- closed-loop payment networks;
 - credit institutions;
 - mobile and e-commerce payments;
 - prepaid cards and e-money institutions;
 - foreign exchange brokers;
 - in-store point-of-sales technology;
 - acquirers;
 - card networks; and
 - supporting technology.
-

Action needed

Ireland, with over 40,000 people^[16] working directly in the financial services area and many more thousands indirectly linked to this sector, possesses both a large risk exposure to changes in the industry and significant growth potential in new sectors linked to disruptive technologies. With CAVs expected to cause huge changes to current banking models and the financial services sector already working to understand new business opportunities and routes to market, there is a huge role for government to stimulate this area and encourage CAV-based fintech services to be led from Ireland.

The government will also have a prime role in ensuring that regulated policy and guidelines are in place to protect individuals and optimise the service industry and, in turn, drive job creation and innovation.





3. Mobility as a service

The ownership model for vehicles is changing, as is the approach to mobility. Car manufacturers and automotive leasing and rental companies are increasingly positioning themselves as providers of mobility services. Combining transport services, for example ride sharing, ride hailing, bike and scooter sharing, car pooling and demand-responsive transport (not to mention high-quality, real-time information about walking and cycling options and conditions), has the potential to bring huge benefits to our transport network by complementing classic fixed-route, timetabled public transport.

Ride sharing, for example, involves the sharing of a mode of transport to allow multiple users to benefit from a single resource. Each vehicle shared removes about 9 to 13 vehicles from the road, taking hundreds of thousands of vehicles out of circulation. Ride sharing is not yet a reality in Ireland, where a lack of clarity on policy and legislation has limited its deployment. What is clear is that the market is providing solutions that encourage the adoption of ride sharing and short-term vehicle usage.

This evolution towards mobility as a service (MaaS) reflects a massive change in philosophy driven by advances in technology and changes in people's values and approach to mobility. People are now less focused on ownership and are looking for services that are personalised, convenient and easy to use. MaaS is an innovative way of fulfilling these mobility needs by providing a single platform from which to access and pay for a range of on-demand transport services.

With an emphasis on individual needs and preferences, MaaS can give customers instant access to transport services ranging from trams and buses to taxis and vehicle-share schemes. Essentially, MaaS is a new data-driven, user-centred paradigm that aims to make cities more accessible and less vehicle-centric.

What MaaS means for Ireland

Irish cities and authorities are attempting to do more with less – offering a larger number of services using the same or reduced levels of funding. This dilemma calls for the introduction of innovative mobility solutions that use existing and emerging transport modes to alleviate pressure on the transport network.

MaaS could become a key tool in helping us address this problem. It aligns with several of our transport strategic objectives, in particular the development of a more resilient, less congested and more sustainable road and light rail network.

For example, by improving the convenience and comfort of modes of transport other than private vehicles, MaaS incentivises the use of these alternative options, promoting long-term sustainable travel patterns. MaaS can reduce both vehicle traffic and demand for parking spaces, leading to a less congested road network. It can also help us achieve transport goals with less public spending and without the need to prohibit vehicles from the roads. Furthermore, MaaS is data-centric and will provide public agencies with tools to better manage the transport network and enable all transport providers to reach efficiencies and plan future investment in the system.

MaaS also offers an alternative to current transport provision in rural communities by exploiting technologies to provide more demand-driven transport and shared services that create a sustainable business model.

The benefits MaaS can bring to Irish cities, users, transport providers and local authorities can be summarised as follows:

- Cities – no need for major investment in new road and rail infrastructure to deal with increasing congestion
- Individuals – improved mobility options for users
- Transport network – the blurring or elimination of boundaries between different modes
- Transport authorities – rich data to help optimise the management of transport systems
- Policy makers – changes in travel behaviour and more efficient management of demand

3. Mobility as a service (Contd.)

Implications for data

MaaS is about placing the customer at the centre of all transport choices and providing a seamless, stress-free, intuitive mechanism for providing the right transport choice at the right time for the right purpose.

For transport providers, MaaS offers new sales channels, access to untapped customer demand, and advanced user account and payment management systems, as well as richer data on travel demand patterns and dynamics.

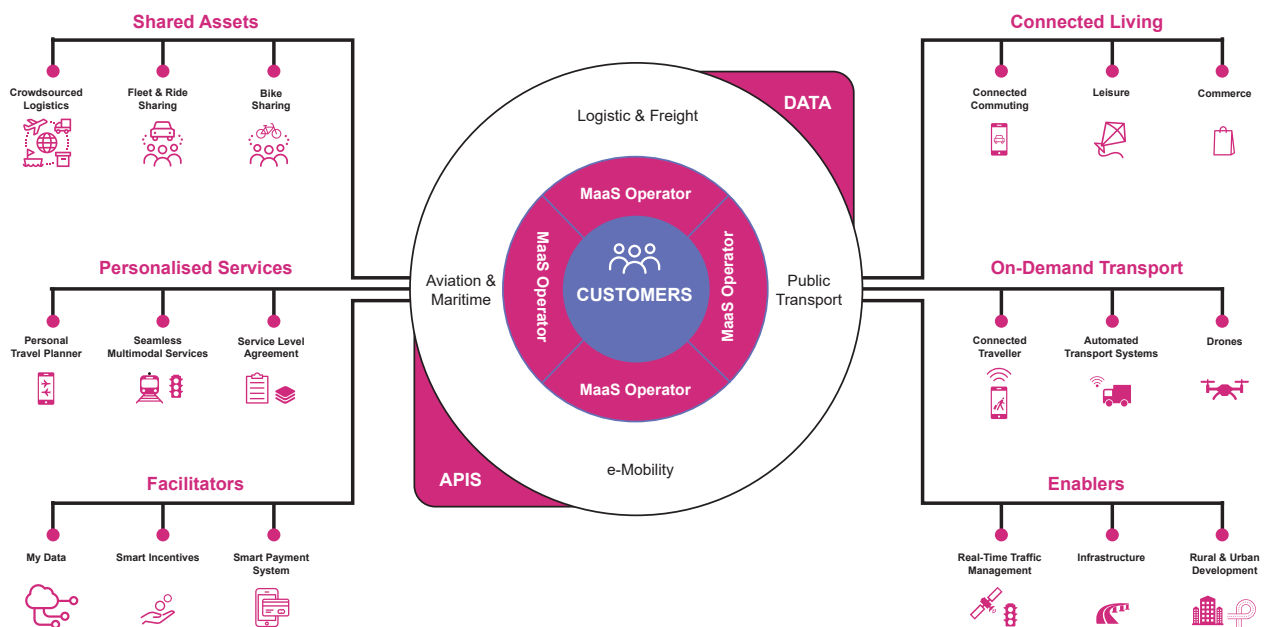


Figure.4 Mobility as a Service [17]

The technologies involved of course, have implications in terms of the amount of data being generated, shared and interpreted across providers and backboned through the use of mobile phone services and apps. As with all new technologies linked to data, questions around the safeguarding of that data and protecting the anonymity and rights of the travelling public will have to be fully understood at a local, national and international level.

One positive is that data on customer movement could be used to understand system performance in greater detail, identifying blockers and challenges in real time, rather than historically, and creating an information-rich mobility tapestry across all transport solutions that enables improved journey time reliability, reduced congestion, and more effective use of the urban space.

Action needed

Although there are many potential benefits to the implementation of MaaS in Ireland, there are also many unknowns due to the infancy of MaaS technologies and processes. The impact of ride-sharing and related business models on promoting sustainable transport choices for all must be considered more fully.

Early government involvement and policy are needed to encourage the development of a system where public transport is always the favourable option, encouraged by the development of seamless connection and improved reliability of services. Also required are engagement and collaboration across multiple stakeholders and the travelling public.

The migration to shared services is developing rapidly and Ireland can look to take advantage of this for both rural and urban mobility needs.

4. Electrification

There has been a recent series of high-profile announcements relating to electric vehicles (EVs). Volvo has announced that all new vehicles produced from 2019 will be EVs or hybrid. City of Paris officials have stated that by 2040 all petrol and diesel vehicles will be banned from the streets; traditionally strong OEM-based cities such as Munich and Stuttgart look set to follow suit. In addition, China has stated that at least one-fifth of all vehicles sold in that country will be EVs by 2025. The UK has also looked to install a range of charge points across the network, with London alone investing £18m to support the rollout of EV traditional black cabs as standard. This global investment and activity around EVs has a direct impact on the infrastructure requirements in Ireland for the travelling public.

EVs offer significant value from both an environmental and a cost perspective. Reductions in emissions and the ability to undertake journeys at a fraction of current prices, due to the disparity in pricing between petrol/diesel and electricity, make EVs a viable option for widespread deployment. This has not taken place to date due to ongoing concerns about mileage, the length of time it takes to power the vehicles and the lack of charge points across the country. However, with the upsurge in advancements around this technology, in both the development of superfast charge points and the efficiency of the engines themselves, it is clear that EVs will begin to dominate our road network in the near future.

Action needed

The power requirements for the EV network will have to be carefully weighed against the existing use of power networks, and supplementary power from sources such as wind will need to be considered as part of a coordinated and long-term approach to the rollout of EVs. This will require policy, strategic direction and investment in alternative power sources that could position Ireland at the forefront of this environmental revolution.

EVs will also offer the option of sharing power back into the network should this be desired. This will require regulation, a vision around sharing and dispersion of power into the network, and consideration of power as a service through privately held automobiles.

Although timelines are yet to be defined, it is clear that AVs and EVs will begin to converge within the next five years. This means we need to consider the related implications for the design, installation and planning of our road network, as well as approaches to mobility in cities and rural areas. Both elements (AV and EV) must be considered as part of a systematic approach to network management. That will require development of a cohesive policy and regulatory position, along with the creation of a skills network to support job creation and growth and to allow Ireland to be at the forefront of knowledge creation.





5. Infrastructure

Infrastructure, not surprisingly, is traditionally viewed in terms of structures such as roads, bridges and pavements that we can look at and touch. However, CAVs will depend not just on physical but also on digital infrastructure. It is critical that we begin to understand required changes to planning and infrastructure design – including roadway widths, street-lighting, safety barriers, signage, parking and intelligent transport systems. We also need to consider what the future road network and landscape will look and feel like, and the role of the person within this.

In a world of CAVs, vehicles will interact and share data with each other, as well as sharing data with infrastructure such as traffic lights and pedestrian countdowns. For this sharing to be reliable, we must fully consider both the data required and its transmission. This makes up the digital infrastructure, effectively the dotted line in the diagram below.

Figure.5



V2V: Vehicle to Vehicle

Each vehicle is a node with the ability to send and receive critical safety + mobility information to other vehicles.

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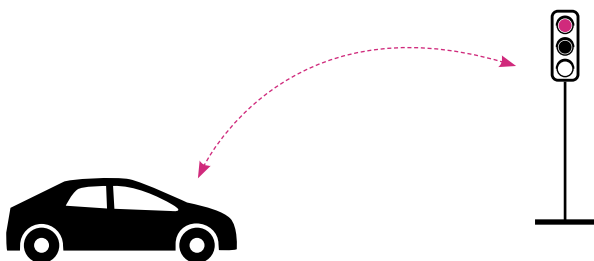
Action needed

It is vital that public bodies establish their position around the digital infrastructure needed for CAVs and requirements for both the data they share with the travelling public and the data and information they expect to receive. Any data management system will depend on robust policy and guidelines around governance, data sharing and the management of data-sharing activities, and public bodies must be involved in this area as they look to create a fair and equitable transport network.

In a CAV model underpinned by the flow and analysis of data leading to personalised information services, we will also need to address the public-sector revenue potential of this new connected age. If the government can create an environment in which each data transmission from a public body has a low-level monetisation associated with it, then, as volumes of data increase, so too will the revenue potential that can then be invested in areas outside of transport.

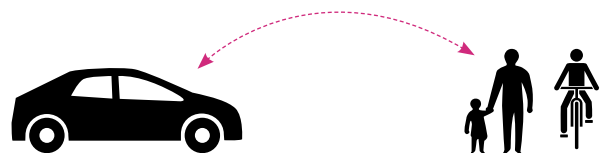
“CAVs will require us to reimagine our approach to building design, use of space and integration of facilities, including traditional parking requirements. The potential to free up valuable land space currently used by vehicles in a range of ways such as on street parking, deliveries, multi storey car parks and suburban driveways is game changing. Certainly, basic long-held principles around the design of land and building use must evolve with the adoption of EVs, CAVs and Shared services, and that is an exciting development in the built environment in Ireland.”

Eloise Heron, Director, Murphy Mulhall



V2I: Vehicle to Infrastructure

Vehicles are able to send and receive information to surrounding infrastructure such as traffic signals and road sensors.



V2X: Vehicle to Everything

Vehicles can communicate with other vehicles, infrastructure and other users of the public right-of-way for a safer, more efficient transportation network.

5 Infrastructure (Contd.)

5.1 Planning

CAVs must not be just about the technology. They must also be about the user and the environment in which they operate. As such, CAVs will play a central role in the planning and design of both our road network and the fabric of movement in rural and urban environments.

In the short term, the deployment of such technology, as has been the case to date, will involve the running of relatively small-scale pilot projects that planning teams will need to factor into their transportation improvement plans. This will require the relevant agencies to have sufficient technical knowledge to evaluate these investments and to educate their board members and stakeholders on the benefits and costs of the technology.

In the medium to long term, CAV deployments are likely to become part of standard strategy, with large-scale investments over multiple funding cycles. It is important to note that, for both initial CAV pilots and longer-term investments, ongoing maintenance and operations funding must be provided if the project is to continue after initial funds run out.

CAV technologies provide a great opportunity for agencies to enrich their sources of planning data, particularly in traffic and asset management. This may require new skills in data science and the development of relationships with new stakeholders to address issues of privacy and data ownership.

CAV technologies may also enhance the mobility and safety of non-automobile users, including transit riders, cyclists and pedestrians, by providing improved information and enhancing motorist awareness of vulnerable users. Planning agencies will want to identify these opportunities, evaluate their effectiveness and facilitate implementation where beneficial.

Road network

CAVs should allow for changes to design of the road network, including:

- the creation or use of smaller new roads for CAV usage as vehicles move closer together and required passing distances change;
- the placing of integrated charge points at repeatable distances across the road network, following the example of the UK;
- reconsideration of physical elements such as crash barriers and the use of variable message signs in the hard shoulder in terms of both their form and function as technology evolves and offers alternative solutions; and
- dedicated CAV lanes on interurban roads linked to booking slots for journey time reliability.

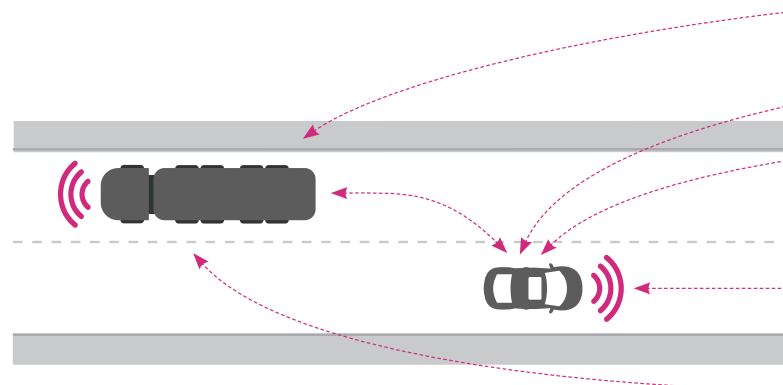


Figure.6

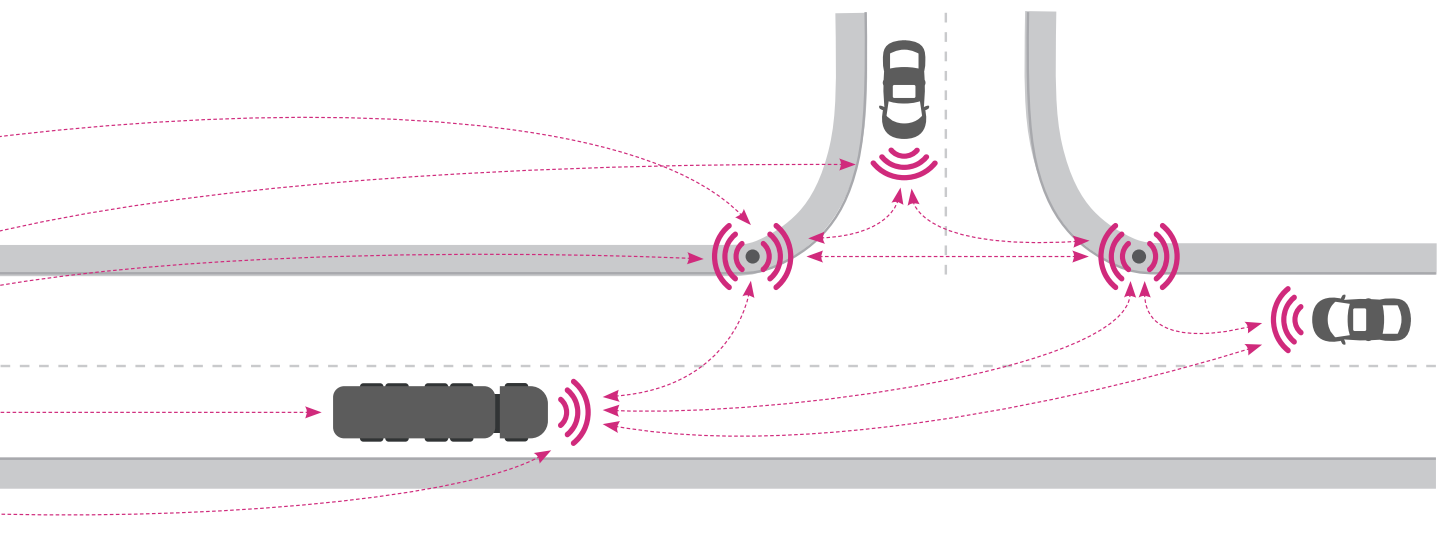
Urban landscape

- The urban landscape, where walkers, cyclists and pedestrians currently compete and fight for space and priority, will have to be approached differently when CAVs begin to fully penetrate the road network.
- Integrated mobility solutions linked to safe, secure and reliable delivery of goods and people will form the heartbeat of design as technology allows for shared surfaces, reduced dwell times for vehicles, improved emissions reductions and significant reductions in street-based furniture currently used for managing the transport network.
- Loading bays and parking, both in car parks and on-street, will evolve towards a hub-and-spoke design as vehicles are continuously used and shared across the day. Current occupancy levels of car park bays will be reduced dramatically, which has revenue implications for cities and private enterprises. The size of bays themselves will also change, as vehicles will have improved parking provision with the driver having been dropped off before the vehicle parks itself.

Rural landscape

- The rural landscape will have to be designed to deliver dynamic, on-demand mobility solutions that are accessible for all, with wait times of under 10 minutes for the travelling public.
- Accessibility to jobs will have to be at the foreground of mobility design, matching the on-demand features of CAVs to peak and trough demands across the day.
- Depots of CAVs linked to defined geographic areas will have to be put in place to allow a managed service to be defined and delivered.

Testing of the digital infrastructure, and an understanding of the impact on the road network and on the efficient, safe and reliable movement of people and goods, is critical in all of this.



6. Testing

A huge amount of activity is taking place across the globe in testing and validating CAV technologies. Most of this activity is underway in areas where there is a strong and traditional vehicle manufacturing industry. The US has created 10 designated sites that test vehicles in a variety of circumstances. The UK, meanwhile, has invested hundreds of millions of pounds to become the test site centre of the world, creating a living lab test bed for OEMs to develop the latest range of equipment and validation tools. Countries such as the Netherlands and New Zealand are also positioning themselves to be test sites of choice and to attract OEMs. These countries have exploited meaningful policy and legislative positions that allow for testing and deployment on their roads. Ireland is not in a financial position to create a bespoke test site facility. With other countries taking the lead in the creation of new-wave CAVs, it is perhaps useful to look at alternative models where we might play a leading or fast-adopter role.

Australia, for example, has a relatively small population from a global perspective and no traditional OEM capability, although indications are that it could become a CAV producer in the future. In the meantime, it is undertaking a number of tests based on three criteria as follows:

- targeting vehicles in the marketplace now with limited connectivity and/or autonomy;
- deploying vehicles on real roads under defined national safety test guidelines; and
- capturing and defining the infrastructure changes needed to support these vehicles.

Action needed

Ireland can adopt the same position as Australia in allowing the services linked to job creation in CAV technologies to be bundled with testing. This would create a two-prong benefit, namely:

1. informing road operators and government agencies about the technical requirements, both physical and digital, necessary to interact with the latest consumer vehicles; and
2. creating a framework for testing high-level AVs as they become available.

“Australia has taken a leading role in the development of pragmatic and practical approaches to the deployment of Connected and Autonomous vehicles. Even though there is no automotive manufacturing industry in the country, Australia has developed a number of test and evaluation programs. Arup continues to assist in this area, particularly in understanding the implication of models that are already in the market place offering limited connected and/ or autonomous elements, in order to identify the implications both now and in the future in terms of physical and digital infrastructure.”

*Russell Whale, Arup Associate Principal, SMART
Mobility & Connected Infrastructure*





6. Testing (*Contd.*)

6.1 Cluster of excellence and connected corridor

Arup believes that to position Ireland at the forefront of CAV technology development, and to bring all the facets of CAVs together to enable high-calibre, high-value job creation, it is vital that we create a “cluster of excellence”.

A cluster of excellence would bring together different groups and research departments in a centralised physical location and enable a concentrated focus on CAV activity in Ireland, in turn allowing government agencies to showcase activities and drive foreign investment funds. Arup proposes the adoption of a hub-and-spoke approach similar to that in the UK. This would involve linking areas that already have a physical presence across the country to an independent, impartial hub that provides a centralised focus to activities.

The cluster must be linked to existing capabilities in Ireland, such as ICT and OEM software and hardware development, and underpinned by government actively identifying existing skills and market forces to drive focused job creation. It should bring together a number of elements that can work independently, such as a dedicated test track for CAVs or a software-driven data analytics engine that links into a number of providers and capabilities.

.....

The cluster, which will need to have strong backing from industry, supported by government investment, will allow for the showcasing and validation of a variety of sectors, such as:

- future infrastructure requirements (including physical and digital);
- virtual networks and testing facilities;
- data governance protocols and algorithms;
- communications networks, including vehicle-to-everything requirements;
- smart energy management;
- sensing devices and systems;
- shared-services application development; and
- fintech data management systems and devolution of payments.

Arup also proposes the creation of a “connected corridor” between two Irish cities adjoining the cluster of excellence. This corridor, again based on existing global models, will allow for testing and validation to be explored in real-life conditions and for technology readiness to be raised to market standards. The corridor will build on the cluster by taking outputs from research and validating them in a real-life environment before bringing the results back to the cluster for final updates prior to product release to the global market.

Action needed

Ireland should create a cluster of excellence linked to existing CAV-related capabilities supported by a connected corridor for testing technologies in a real-life environment. This is necessary to develop the required infrastructure and physical deployments that characterise CAVs and other mobility solutions. Understanding the infrastructure investment is critical in developing a fully integrated, customer-centric connected corridor solution, where real-life conditions, test cases and situations are developed in a realistic and risk-managed environment. The connected corridor will inherently link to the cluster of excellence to develop a co-ordinated, multi-capability approach to CAV development and benchmarking on our Irish roads.

7. Data management and transparency

Data is the new gold. It is one of the reasons global companies and service providers are operating in this market. The data captured through the use of CAVs will drive the creation of revenue-generating services, such as in-vehicle Netflix, traffic updates, discounted coffee and dynamic pricing. As such, it is important to break down this data and understand the role the government can play in job creation, data privacy and revenue generation.

1 | External Data

CAVs will receive, and possibly share, huge volumes of data and information between vehicles themselves and between vehicles and infrastructure (such as traffic lights and road pavements).

Public bodies will need to understand:

- what services can be created through the sharing of data;
- what data they can share and receive between their assets and the private sector and what they might want to share;
- what data they have available now and in the future;
- the value of data and its revenue potential;
- where the data will be stored; and
- who is responsible for it.

2 | Internal Data

A CAV is powered by the use of sensors to create a view of the world that requires action and decision. These sensors generate vast (trillions) levels of data. This data will relate not only to the road itself and in-vehicle diagnostics but also to the user and their personal requirements.

Public bodies will need to understand:

- how data ownership is interpreted;
 - what data between the vehicle and the user/operator is shared/owned;
 - what resiliency needs to be put in place; and
 - how data safety requirements are to be put in place.
-

3 | Collision Data

As stated earlier, 90% of collisions are caused by human error. CAVs offer the potential to greatly reduce these errors and, with them, the unacceptable number of collisions and deaths that take place on our road network. However, collisions with CAVs will still take place, particularly in the early stages and while the road is shared between existing and CAV deployments. This raises significant questions about access to data from the vehicle itself for personal insurance and liability reasons and about liability relating to the road and the network as a whole.

Public bodies need to understand:

- how this data will be accessed;
 - what protocols exist;
 - what responsibilities and ownership exist on the State's part; and
 - how data is governed and what the audit trail entails.
-



7. Data management and transparency (*Contd.*)

In the world of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, data will be exchanged between different organisations. This communication will take place over a number of channels, via private sector bodies. This necessitates the creation of an environment where private bodies share information with each other based on data that is potentially sensitive in nature or private and protected by intellectual property.

Action needed

Irish public bodies need to assess the implications of CAV technologies on the sharing of external, internal and collision data and to plan accordingly. Creation of the roles of data arbiter and data aggregator will offer vital support in this area. This is necessary to allow all parties access to data at critical times, create clarity on roles and responsibilities and, fundamentally, position local and national bodies to play an important role in the governance, risk and compliance (GRC) around data sharing among different technologies and businesses.

At present, we lack two key components in the delivery of safe and trustworthy data services between organisations:

These are:

- an independent **Data Arbiter with responsibility for Governance**
- a transparent **Data Aggregator**

“CAVs present an unprecedented opportunity to revolutionise our quality of life by enabling universal safe mobility, eliminating congestion and making commute time productive. Key challenges remain in the appropriate technologies, incentives and regulation for these societal benefits to be realised for everyone.”

Dr. Melanie Bourroche, Assistant Professor, Future Cities Research Centre, Trinity College Dublin



Figure.7

8. Data arbitration and governance

To enable the delivery of data enabled services in a public environment, we must ensure that the data itself is fit for purpose and conforms to the relevant policy guidelines established by local and government agencies. This data must be continuously checked, managed and governed to ensure a consistent and auditable data trail in the event of an emergency or other scenarios where the data flow needs to be established. Checks and balances need to be put in place through an independent body to ensure trust for the travelling public and to safeguard the privacy and ownership concerns of the relevant bodies.

A governance framework in the era of ACES vehicles will contain three important elements.

- **Governance** – ensuring that the overall goals and objectives of traffic management are supported by V2V and V2I communications. These objectives may involve ensuring better traffic flows and congestion management. As V2V and V2I communications are a means to that end, this will help build trust between the organisations sharing information. Key performance indicators (KPIs) can be developed to help track progress, with improvements in KPIs acting as a trigger for changes to V2V and V2I communications processes.

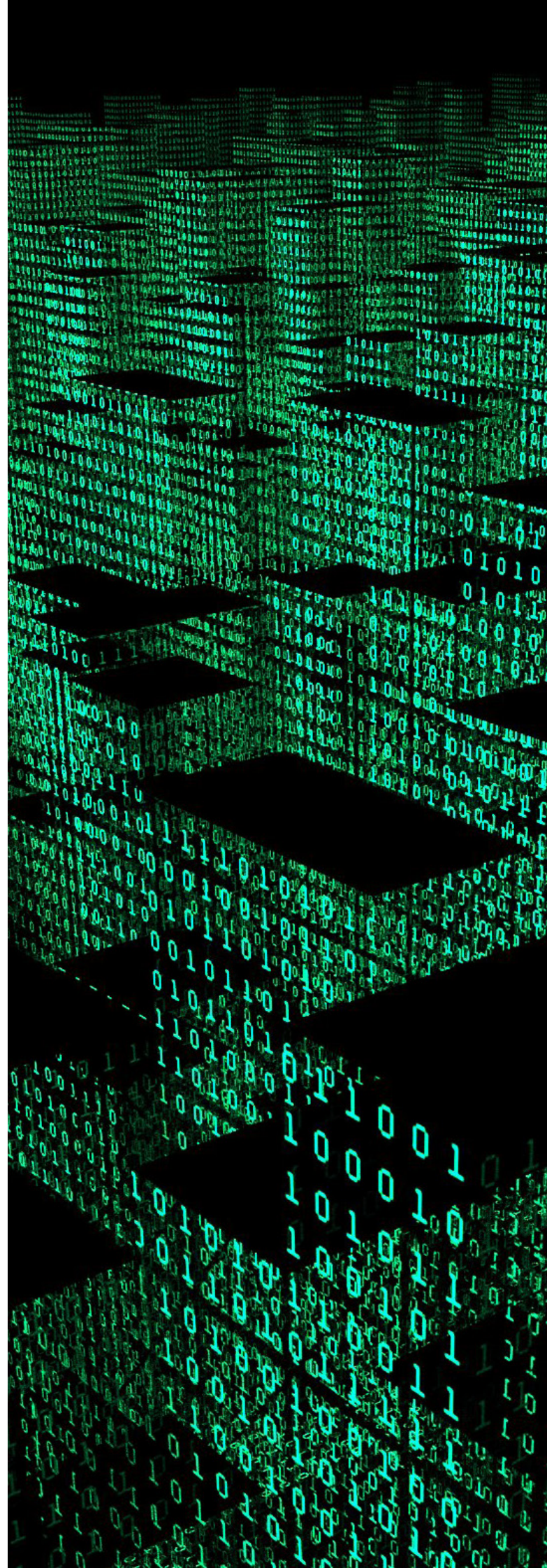
- **Risk** – involving the application of an appropriate risk management process linked to governance and compliance needs to manage relevant risks. The application of these measures will be appropriate to the impact and probability of each risk.
- **Compliance** – involving, similar to any business and technical infrastructure that shares information, adhering to relevant European and local regulations such as those on data protection. As with governance, KPIs can be developed to demonstrate and track compliance.

The data arbiter is an important part of this GRC framework and could be regarded as having the role to manage the framework. Data arbitration is vital to ensure close partnerships between rival organisations and to guarantee that privacy and ownership between companies is protected.

The function and activity of the data arbiter role sits as a governance layer above the data aggregator's technical role in the provision of data for V2I and V2X. The role should also include technical sublayers to provide an independent assessment of the quality and reliability of data being exchanged between rivals, as well as validating that any such exchange aligns itself to an agreed set of guidelines established by the relevant body.

Action needed

The appointment of an independent data arbiter and governance validation is necessary to create an intermediary between public and private entities. This will help to establish the necessary transparency around the movement of data between bodies, as well as helping to define the required operating model to facilitate pass-through of ownership between competing bodies. This is needed to ensure that, at a minimum, we deliver solutions for all parts of society and comply with requirements such as the General Data Protection Regulation (GDPR) and other national and international policies.



9. Data aggregation

As alluded to previously, data aggregation is the technology layer that looks to take data from various entities, be they public or private, fixed or virtual sensors, and link it together under an agreed set of guidelines and protocols as established through the GRC. The aggregation layer will be tasked with aligning data sets with different time stamps, structures and metadata as well as temporal and spatial discrepancies and with creating insight and awareness around the data linked to a “data-to-information” activity.

The aggregation layer functions by accessing data sets, possibly through open or closed application programming interfaces; establishing a service-level engagement linked to the push and pull of data to and from devices; and running data analysis algorithms linked to required outcomes (such as journey time reliability linked to vehicle availability, optimised journey times, reduced dwell times etc).

The success of data aggregation depends on a number of factors. It requires availability of the data itself and ease of continuous access within required time frames, as well as the development of knowledge-led algorithms linked to understanding of both the operator’s and travelling public’s requirements.

Action needed

Data aggregation is necessary to underpin the trust between the travelling public and the public and private bodies that use its data (ensuring anonymity etc). It is also required to develop a quantitative understanding of road network use and the elasticity of that use in order to develop services that can add value and be truly sustainable.


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10. The role of government

Government has an essential role to play in both facilitating the smooth and safe introduction of CAVs onto our roads and helping ensure we reap the maximum economic benefit from these technologies. We look at some key facets of this vital groundwork here.

Accessibility, interoperability and transparency

CAVs have the potential to engage with the environment by sharing data from infrastructure and other vehicles. There is, however, no guarantee that this will take place. Government action is needed to help make this a reality.

A potential scenario exists in which CAVs operate independently of both the local environment and each other. CAVs from one manufacturer may communicate only with other CAVs from that manufacturer, and not with rival CAVs on the network. The prospect of an unstructured future exists in which CAVs do not share their information with road network operators and choose instead to share information only with a private data centre controlled by a commercial third party looking to add value to customers. This would mean that the road network would not be optimised and in fact would be stretched even further. We will have missed the opportunity to adopt a “system-wide” approach to the operation of roads, reduction of congestion, improvement of all journeys, and social and affordable mobility for all.

Should this become a reality, it will mean that islands of CAVs will exist, operating independently of the needs of the overall network and mitigating the value-add in the use of such technology.

Therefore, to establish a desired future scenario in which all CAVs provide a defined, minimum level of information both to each other and to road operators, it is important that government establish a policy on accessibility, interoperability and transparency across the CAV ecosystem.

Ireland can take a lead here and look to become a global leader in defining the GRC requirements for CAVs on the road network.

Skills network creation

Considering CAVs are likely to be deployed in mainstream transport from 2021 onwards, a huge amount of development and research still needs to be undertaken, from both a policy and a technical standpoint. If Ireland decides to allow the market to dictate, these jobs will be filled by graduates and employees from countries that are already investing in the CAV domain.

A job creation opportunity exists now for mobility skills that are transferrable across markets due to the common currency of data’s key role. If we fail to identify the skills and capability already in the Irish marketplace and the market’s requirements, we will lose an opportunity to become a centre of high-calibre excellence in a variety of sectors linked to CAV. As such, we need to invest in secondary and tertiary education linked to a market analysis of skills growth. At first glance, it appears that a number of roles will be required in the areas of:

- data science;
- artificial intelligence;
- cybersecurity;
- Big Data management;
- wireless communications;
- cloud hosting; and
- fintech and payments.

Reducing our exposure

CAVs are going to become a reality, whether we like it or not. Therefore, it is far more palatable to be in a position to control, influence and regulate than to be reactive to developments and deployments from third parties. It is important to note the following:



Figure.8

10. The role of government (*Contd.*)

EV deployment

The challenge also exists to design an infrastructure capability allowing for the deployment of EVs on a large-scale in the marketplace.

Questions that will have to be resolved include the following.

- Where and when will installation take place?
- What role do institutions play in managing the power network?
- How will power be provided – through traditional or wind-based technology?
- Will the existing power network operate within agreed tolerances, and what are these?
- How will charging be managed and what policy will exist around this?

Insurance

Clarity on the insurance aspects of CAVs is vital in terms of incident resolution and division of responsibilities. Clarity is required to ensure that, when CAVs are deployed on the road network, a payment mechanism is already established with clear guidelines and instructions to all partners. The model adopted in the UK is that less change around insurance is the easiest and most effective approach to take when it comes to dealing with CAVs on our roads. However, this is part of an ongoing rolling regulation review being undertaken by the UK government.

This reflects the need in Ireland to start working now with stakeholders to establish the most effective, pragmatic steps forward and avoid the creation of legislative barriers that will result in costly and ambiguous resolutions.

The insurance and underwriting of a CAV will depend on both the technical ability of the system to provide relevant information and the national guidelines that cover management and deployment of such vehicles on the road network. Insurance must be considered as part of the data management and audit trail, in terms of clarity of payment and responsibilities, and be linked to the guidelines and policies required for cybersecurity and accident prevention purposes.

Insurance is also linked to the dependency, or not, on roadside infrastructure and the related service levels this provides as part of the connected ecosystem. What this means is that insurance must now be considered not only in terms of traditional risk underwriting but also as part of the technical delivery of services. This requires multiple parties to understand the interoperability requirements across the various digital systems, as well as the governance and audit trail that links the digital infrastructure to the physical one.

Ireland must develop an understanding of the insurance implications linked to CAVs, review the work undertaken elsewhere, and identify the immediate outcomes and challenges. We must then develop an appropriate technical and policy position on insurance that will allow us to provide market guidelines on transparency and data availability from a national requirements perspective – while, at the same time, providing leadership and direction to a global audience.

Action needed

Government action is critical to the success of job creation for the CAV market. Government also has a direct role in the development of suitable policy and guidelines to enable the road network and the travelling public to take full advantage of the introduction of this new wave of mobility solutions.

Arup urges the government to examine current and future infrastructure plans and ensure it is cognisant of the imminent introduction of CAVs into the road network. Arup also recognises that CAVs are but one of the elements around new mobility solutions and proposes the development of a roadmap and strategic vision to create a preferred scenario for the travelling public that is inherently linked to Irish-based capabilities.

Policy and legislation

Policy and legislation are central to the successful deployment of vehicles on the road. Without these, there is no co-ordinated mechanism to either manage or take advantage of new technologies and routes to job creation for a trillion-euro industry.

The Irish government needs to define a clear policy and regulatory position around the use, testing and deployment of CAVs. In the absence of such a position, the new wave of vehicles will hit our roads in the next five years without any co-ordinated approach to their use and safety – and the role of government in creating jobs and generating revenue will be lost.

Though Ireland has not been hugely involved in the CAV sector to date, it is in a position to benefit hugely from the work undertaken elsewhere in the world and can take a giant step forward using the learning and knowledge from other investments globally.

In this context, we need to address a number of important points as follows.

- How can the road network benefit from the deployment of this new technology?
- What do the network operator and road owners need to do now to answer the question raised above?
- What policy positions are in place around the handling and ownership of data?
- Is there transparency of data exchange when a collision occurs?
- What legal changes are needed to allow driverless vehicles to be used in mixed and isolated modes?

- What communications are required, and linked to what standards?
- How is open data handled and linked to transparency?
- What is the likely impact of the GDPR and elements such as Brexit for cross-border movement of CAVs?
- When will private vehicles be allowed to support the power network?

In Europe, the use of AVs is effectively governed by the Vienna Convention on Road Traffic of 1968. Seventy-two countries signed the convention but not all have ratified and enforced it.

Article 8 stipulates that a vehicle must have a driver and Article 13 states that a driver must be in control of his or her vehicle in all circumstances. An amendment to those articles will be made this year but, as with the UK, Ireland has not signed the convention or ratified its implementation. This means a legislative barrier exists here until we create guidelines equivalent to those produced in the UK on the testing and deployment of AVs on the road network.

Arup was part of the conversation with the UK Department for Transport in the creation of these guidelines and would welcome the opportunity to share experience and perspectives on how they may be implemented in Ireland. Without such guidelines, the auto market will not be allowed to deploy AVs on Irish roads.

11. Arup's Capability

Our goal is to create environments where more people can enjoy integrated and seamless journeys. To achieve this, Arup works with governments and seeks to influence policy and strategy on the smart application of intelligent transport systems. We work with the private sector to reimagine business models and identify value through innovative use of data.

Our mobility experts fully understand urban transport networks and the challenges facing authorities who are responsible for managing, operating and maintaining the transport system network that will carry ACES. We are heavily involved with the intelligent transport industry around the world and have been appointed to provide research and consultancy services for traffic management technology under national frameworks that promote mobility solutions.

Arup recognises, however, that the ability to deliver new mobility solutions is not just linked to the transportation side of the business but also reaches across other Arup expertise, such as planning, design, digital services and customer behaviour. As such, we have been developing our in-house capability to position ourselves as the leading consultancy in Ireland for the provision of expert knowledge in this area.

We recently appointed Dr. John McCarthy to lead our Intelligent Mobility capability. Dr. McCarthy works in the Digital Services team under David O'Keeffe to provide world-class strategic, technical and policy advice to our growing client base.

To support this, we have invested in developing the team's skills and capability to provide end-to-end advisory services for clients in this field.

These services span:

- transport planning;
- CAVs, EVs and MaaS;
- data analytics, protection and privacy;
- economic and policy considerations;
- ITS, C-ITS, telecommunications networks and standards;
- network operations and customer behaviour;
- business transformation; and
- cybersecurity and information security.

“Arup recognises that Ireland can play a leading role in the development and growth of intelligent mobility. Through the introduction of disruptive technologies such as ACES, we see transport is migrating towards a customer-centric mobility-based solution, and one in which our core strengths of advisory services, planning and design can play a fundamental role. We are delighted to author this paper reaffirming our commitment as a global leader in engineering consultancy.”

Eoghan Lynch, Managing Director, Arup Ireland Group



12. The Magnificent Seven | *What needs to happen next*

The world in which we live is changing daily, with technology introducing new choices and options, as well as challenges to existing services and capabilities. Customer experience will drive the adoption and use of these technologies but policy and legislation linked to strategic plans for exploiting them must be in place.

ACES technologies offer potential for high-calibre job creation and significant economic growth. Although Ireland does not have an automotive manufacturing base, it is still well-positioned to play a leading role in developing the technology underpinning ACES vehicles and their operation (spanning hardware, software, data hosting and analysis).

Over the next five years, CAVs will become more mainstream and relevant to our lives. They will be available to run on our roads, whether we are prepared or not, forcing the question: what do we need to do now to prepare for their arrival?

This paper has outlined a number of actions, it is our opinion that our government should act on these now to reduce our exposure to risk when these vehicles arrive and to ensure alignment ourselves with public demand and sentiment. To this end, we believe it is of utmost importance that government do the following:

ONE

Establish a capability map for industries aligned to the CAV sector and identify areas of focus and growth as well as gaps in our skills base.

TWO

Develop an understanding of the requirements needed for cost-effective and sustainable infrastructure, both physical and virtual, to support the deployment of CAVs.

THREE

Review existing capital projects underway, assess the implications of projected technology developments and user scenarios, and tease out the related roadmap.

FOUR

Deliver a technology-driven policy position that protects the needs of the travelling public and encourages economic growth and diversity linked to the creation of a systems-based approach to CAV deployment and job creation.

FIVE

Examine the data already in existence within public bodies linked to CAV markets to help generate relevant services and identify relevant data catalogues to enable growth and exploitation of commercial opportunities.

SIX

Identify the fundamental requirements for the creation of a viable national intelligent mobility cluster of excellence that facilitates indigenous growth and foreign investment to bring together CAV-based services and technologies and enable a centralised approach to research and development.

SEVEN

Create an environment for collaboration between public and private bodies in the development of CAV-based requirements and spearhead the creation of Ireland's unique selling points in this field to be used in foreign investment and partnership creation at a local and global level.

Figure.9

Glossary

ACES

Autonomous, Connected, Electric and Shared

AEB

Autonomous Emergency Braking

ASCC

Advanced Smart Cruise Control

AV

Autonomous Vehicle

CAV

Connected and Autonomous Vehicle

C-ITS

Co-operative, Intelligent Transport System

EV

Electric Vehicle

ICT

Information Communications Technology

ITS

Intelligent Transport System

LKAS

Lane Keeping Assistant Systems

MaaS

Mobility as a Service

MIT

Massachusetts Institute of Technology

OEM

Original Equipment Manufacturer

SFI

Science Foundation Ireland

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