Urban Foresight

Summary Publication

Market Needs for Connected and Automated Road Transport

PREPARED FOR:

ICT4CART
(ICT Infrastructure for Connected and Automated Road Transport)
Research Consortium

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768953

ICT4CART

The ICT4CART project is an EU-wide research and development project that aims to design, implement and test in real-life conditions a versatile ICT infrastructure for the needs of higher levels of vehicle automation. The project was awarded through the European Commission Horizon 2020 funding program.

The project draws on expertise and technologies from across different industries, including telecommunications, ITS, automotive and IT. The consortium is comprised of 21 organisations from across the EU-28, working to combine, adapt, and improve technology applications for CAV infrastructure.

The technology solutions underpinning the project will be trialed, demonstrated, and validated in four specific use cases. These real-world and challenging environments encompass a range of urban and highway applications with varying degrees of complexity. The test sites are located in Germany, Austria, Italy and the Italy-Austria border.

Secondary outcomes from the project include analysis of the market, business model development, and an open cloud platform. This platform will aggregate data from across the IT environment and provide analytics services. It will be open for integration and exchange to allow third parties to develop and deliver innovative digital services in the CAV space.

ict4cart.eu

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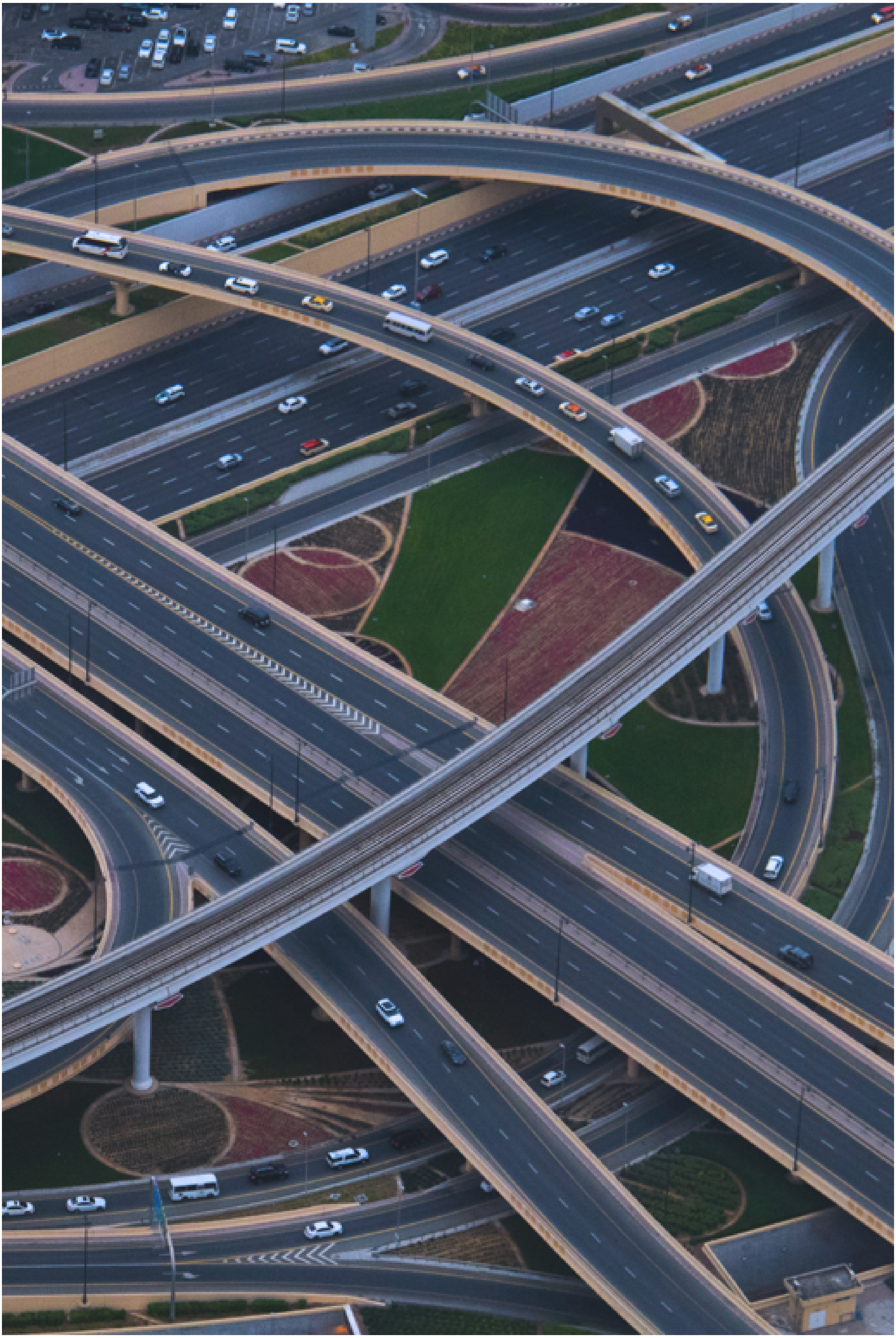


Connecting Road Transport

This report summarises research undertaken to understand what services highly automated and connected vehicles will need from their supporting infrastructure. It offers a valuable framework for anyone seeking to make informed and impactful investment decisions in relation to this emerging market.

Safer, more efficient and more comfortable journeys are being enabled by the ability to communicate with other road users, infrastructure and external systems.

The European Commission has recognised the value of introducing these benefits to Europe's road network and have funded various public-private consortia to undertake research projects to progress the definitions, protocols and equipment needed to roll-out connected and automated road transport. The latest of these research programmes is ICT4CART, which is looking to build, test and evaluate the infrastructure required for vehicle connectivity.

Urban Foresight is leading on the market research, costing and business models analysis for the project. This has so far comprised of researching, analysing and compiling in this report information on the market needs that this infrastructure will meet. Our extensive programme of research included a literature review, interviews with 19 sector experts and a participatory workshop. We handled this research using proprietary analysis frameworks on the market contents, performance requirements and structures.

This analysis is the first in this technology space to take a technology-agnostic, user-focussed approach to the value that connectivity will bring users of road networks and transportation. It seeks to move the thinking in connectivity of road transport away from technology and processes, and towards effective service delivery and commercially sustainable business models.

This summary publication presents our findings and recommendations on future actions, which includes continuing to apply the analysis frameworks and this user-centric approach in further research and development of connected and autonomous vehicle technology.

The Connectivity Market

Before investing in infrastructure solutions, the needs of the market need to be understood.

The Need for Connectivity

The driving task is being increasingly supported through connectivity, whether through the vehicle's on-board systems or through connected devices used by the vehicle's occupants.

This is only likely to increase as more and more of the driving task is automated and vehicle connectivity will move from an optional extra to a key enabler for ensuring that these increasingly automated vehicles interact safely and effectively with each other, other users and the surrounding infrastructure.

The capability of telecommunications and data management infrastructure is improving, making new levels of vehicle connectivity increasingly possible. The advantages of connectivity are recognised across the industry, with acknowledgement that the full benefits of vehicle automation can only be realised with this additional capability.

The exploration of the ICT infrastructure solutions that can be deployed to realise this connectivity is currently underway by various public-private research consortiums and private enterprises. However, to fully validate the commercial viability of these solutions, the market needs that they are serving need to be fully understood.

The Market Services

To date, much of the work in the Connected and Autonomous Vehicle (CAV) technology space on defining the services that ICT infrastructure could offer has been relatively narrow in its focus. When reviewing for the purpose of our analysis we found that:

1. While there has been a significant amount of research and development work carried out in relation to the technology options for the ICT infrastructure, there has been little work on understanding the future demand for this infrastructure in a systematic way.

2. Considerations around the demand for CAV ICT infrastructure has been strongly linked with the capabilities of particular technology architectures, and not the value of the services that they are enabling.

To have a reasonable chance of understanding the value for CAV ICT infrastructure, therefore, there is a need for a holistic, value-based, technology-agnostic assessment of the potential demand for information services for CAVs. Our analysis hopes to achieve this.

Our Analysis Methodology

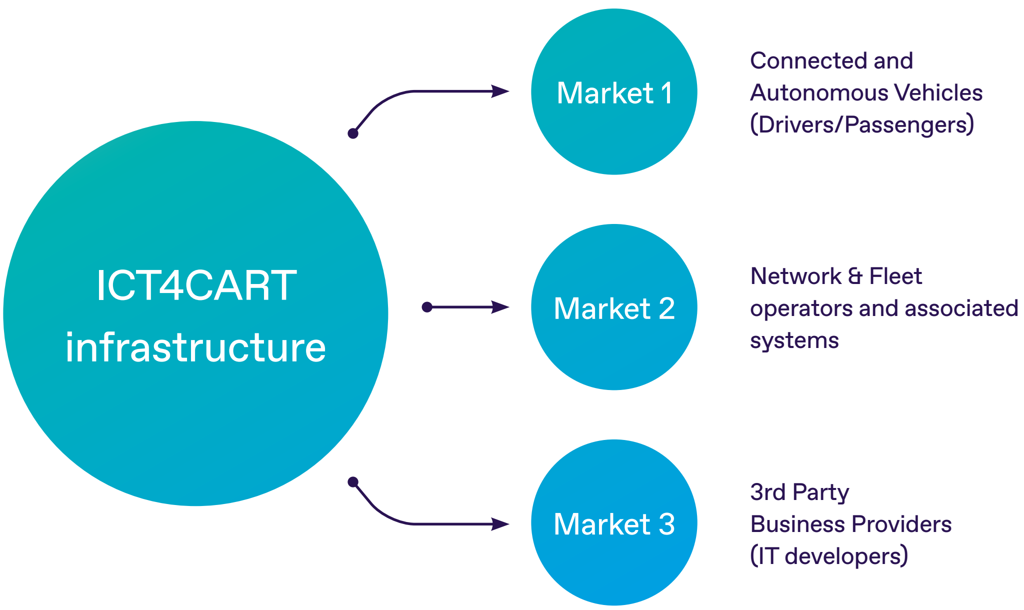
A research method was developed to structure the profiling of the CAV services market through its user-value exchanges.

Step 1

Model the market

The CAV ICT market consists of a number of sub-markets, from mobile network operation to roadside Vehicle to Infrastructure (V2I) solutions. To enable a strong focus on end-users and to avoid the distraction of the various technology options configurations available, this study has deliberately simplified the CAV ICT infrastructure into a single "system" used by vehicles, drivers, passengers and operators for various goals.

By focusing on the three sub-groups of users that interact with the ICT infrastructure, the research was able to focus on the inputs and outputs of that system – i.e. the data and information services communicated through, and partly generated by, that system – rather than the technological design of it.



The transactions between these markets and the infrastructure as a whole were considered as services where value is delivered to the recipient, regardless of whether they are directly commercial services. These transactions provide actionable insight or other information of subjective value to a user, operator or system within the CAV industry.

This information could be generated by any another entity within the framework, or from other external sources. That is, some services will use data generated by CAVs for use by other parties, and others will be services for CAVs using data from other CAVs or other parties.

Step 2

Wide reaching desk study

The desk research aimed to ascertain the material in the public domain both within academic and grey literature. The information found formed the basis for the following interviews; it informed the questions that were asked, focusing on areas without consensus.

The purpose of the literature review aimed to cover the scope of the project, including:

1. Evaluating the size of the current CAV market
2. Mapping the products and services, and their providers in the market
3. Identifying emerging technologies that may impact on the market
4. Identifying products and services that are using or could use this technology in CAVs
5. Reviewing the potential impact of these products and services on the market

Step 3

In depth interviews with expert representatives

To build upon the desk research, we conducted interviews with the consortium members and industry experts. The selection of experts interviewed provided specialist insight into the three sub-markets, their status and developments. As the European market is of primary concern for this research, interview participants mostly represented public authorities, automotive manufacturers, technology OEMs, start-ups and transport lobby groups from the EU nations. A US CAV expert was interviewed to provide comparable information on that market. In total representatives from 19 organisations were interviewed, where 16 of these were ICT4CART consortium partners.

The interviews were conducted within a framework of questions with the overall aim of investigating the perceived need, benefits and requirements of connectivity infrastructure, and the information services that could emerge.

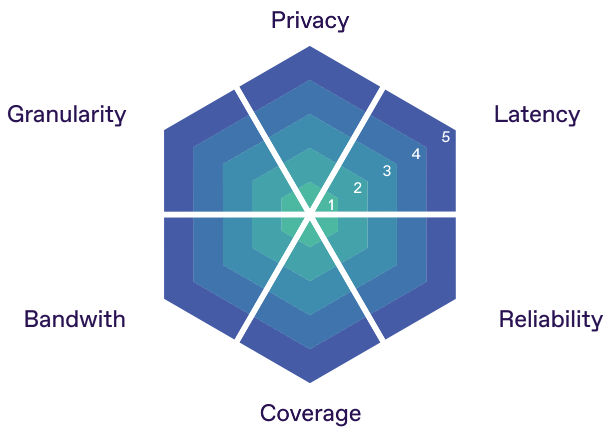
Interviewees were aligned against the sub-market from the simplified market structure model (above) that they best represent. All question sets had a common structure, covering the following areas:

1. The role of their sub-market in the operation of CAVs.
2. The information that will be transferred in order to fulfil this role.
3. Whether there are any information transaction services that will be required to operate continuously.
4. What particular services will require communication to or from road vehicles.
5. Whether any services will require supporting ICT infrastructure to be completed.
6. Whether they anticipate the supporting ICT infrastructure being used for services other than those that enable automated driving (AD).
7. The perceived levels of consistency in views on the information discussed within that market.

Step 4

Develop analysis frameworks

The services that were raised in interviews were grouped into the operation that they support. The potential performance levels of each of these operations was defined against a ratings framework that was defined from the aggregate research.



Privacy

Privacy is judged in this context by the type of information being transferred, specifically if it is personally identifiable and at risk of a security breach.

1 No private or sensitive information used

2

3 Individual and private user information is transferred as part of these services but is not intrinsic to the operation of them and could be anonymised with correct handling

4

5 Private user information is intrinsic to some of the services within this market and there is a significant risk of security breach present

Latency

Latency in this context refers to the time interval between a signal being instructed to transfer across a network and the network's devices receiving it.

1 Information services could generally be communicated within timescales of days or weeks and still be effective

2

3 Information services are in real-time but are not safety-critical, so need to be delivered within timescales of around 1 to 2 seconds

4

5 Information services are in real-time and are safety-critical, so need to be delivered within timescales of less than 100ms to be effective

Reliability

The accuracy of the data transferred across the network. This is predominantly defined by the source of the data, rather than the design of the ICT infrastructure, but the two may be dependent on each other.

1	2	3	4	5
Information services need to communicate accurate information more than 60% of the time to be effective		Information services need to communicate accurate information more than 80% of the time to be effective		Information services need to communicate accurate information more than 99% of the time to be effective

Coverage

The geographical area that the connectivity is enabled in and the consistency of the connection at that location.

1	2	3	4	5
Information services can be available intermittently and covering the local area only and still be effective		Information services need to be available consistently within certain operating areas to be effective		Information services need to be available consistently over an entire road network to be effective

Bandwidth

The size and the rate of the data packages that are being transferred will determine the bandwidth required in the network.

1	2	3	4	5
Information services require only a very small amount of data to be transmitted over a short period of time (typically less than 1Kbps) to be effective		Information services require a medium amount of data to be transmitted over a short period of time (typically greater than 10Mbps) to be effective		Information services require a large amount of data to be transmitted over a short period of time (typically greater than 100Mbps) to be effective

Granularity

The granularity of a data set characterises the level of detail that is held in it. The higher the granularity, the larger the information set.

1	2	3	4	5
The level of detail of the data sets required to support this service is low. For example, on a scale of 1 km		Data sets are on a scale of 10m		The level of detail of the data sets required to support this service is high. For example, on a scale of 1 cm

Step 5

Our research was verified with the consortium's experts.

Market structures workshop

A workshop held with the ICT4CART consortium members was intended to test, verify and expand the information collected through our desk research and expert interviews. The main workshop activity aimed to explore the attendees' understanding and opinions on how the various market players will be acting in a number of future scenarios.

The consortium members reviewed a series of possible future scenarios for the operation of CAVs on road networks. The workshop took place after the stakeholder interviews; therefore, it was used as a sounding board for the preliminary findings.

The workshop moved on from defining the market services to considering the funding options.

Funding is two-fold: paying for the enabling architecture and for the services themselves. Five scenarios on the provision of this funding from the private or public sectors were explored (see figure opposite).

The scenarios differed on connectivity levels and payment structures. In groups loosely arranged by the market that the consortium members represent, the attendees explored how realistic these scenarios are, the opportunities they could present and potential positive and negative outcomes.

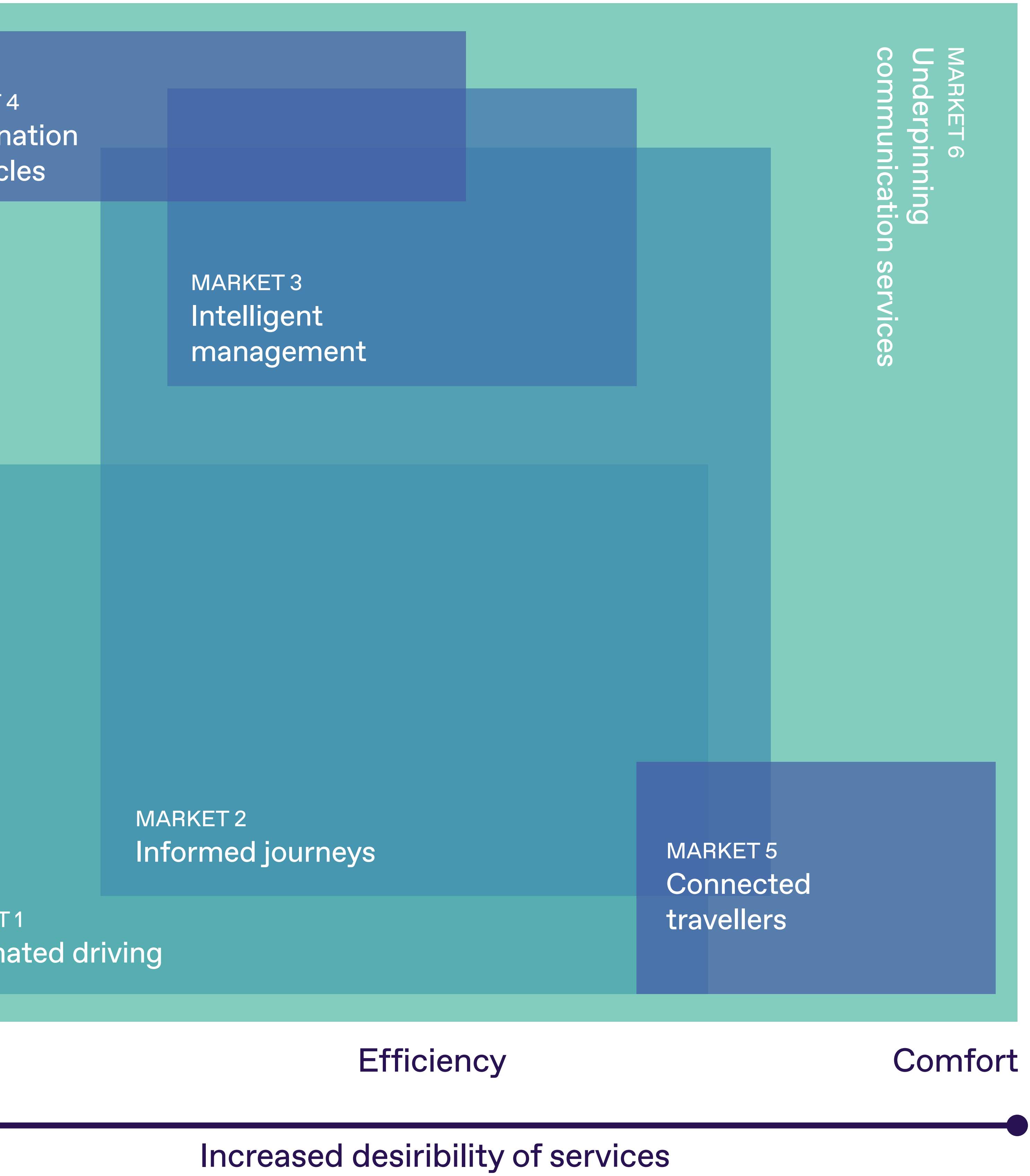
The workshop was not intended to gather new information or views, but to explore and compare standpoints and consistencies in the consortium's views on the ICT infrastructure market for the CAV industry.

Funding is two-fold: paying for the enabling architecture and for the services themselves. Five scenarios on the provision of this funding from the private or public sectors were explored.

		Services are paid for by	
		Public provision	Private provision
Investment is paid for by	Public investment	Scenario 1	Scenario 2
	Private investment	Scenario 3	Scenario 4
Scenario 5 some combination of the above			

Our Findings

We amalgamated our research findings into a framework that categorises each potential service by its user-value configuration.



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MARKET 6
Underpinning
communication services
MARKET 3
Intelligent
management
MARKET 2
Informed journeys
MARKET 5
Connected
travellers
T 1
nated driving
Efficiency
Comfort
Increased desiribility of services

Automated Driving

MARKET 1

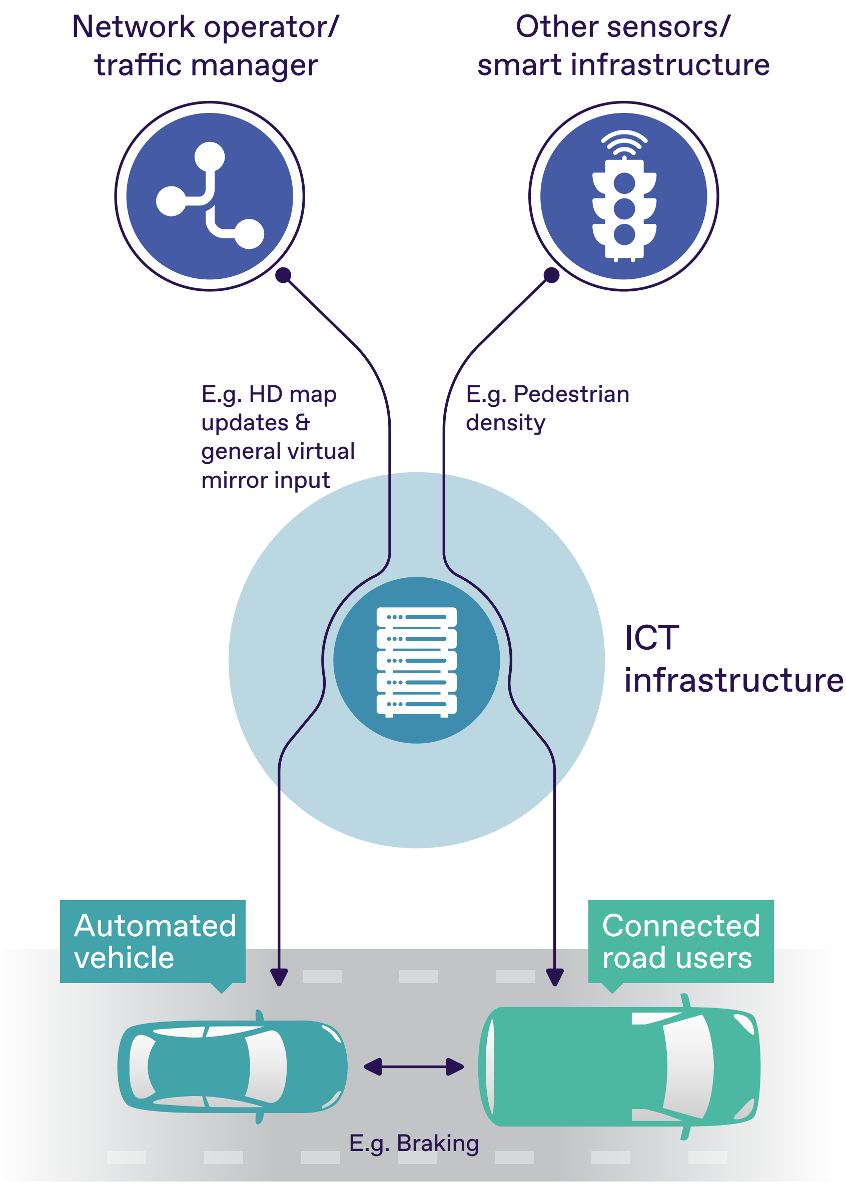
Increasing the vehicle's awareness to reduce the risk associated with driving decisions, allowing smoother, safer and more efficient manoeuvres and journeys.

Vehicles will be connected to the infrastructure and other connected road users, providing them with live information on the surrounding environment.

Connectivity can be used to directly support the operation of automated vehicles.

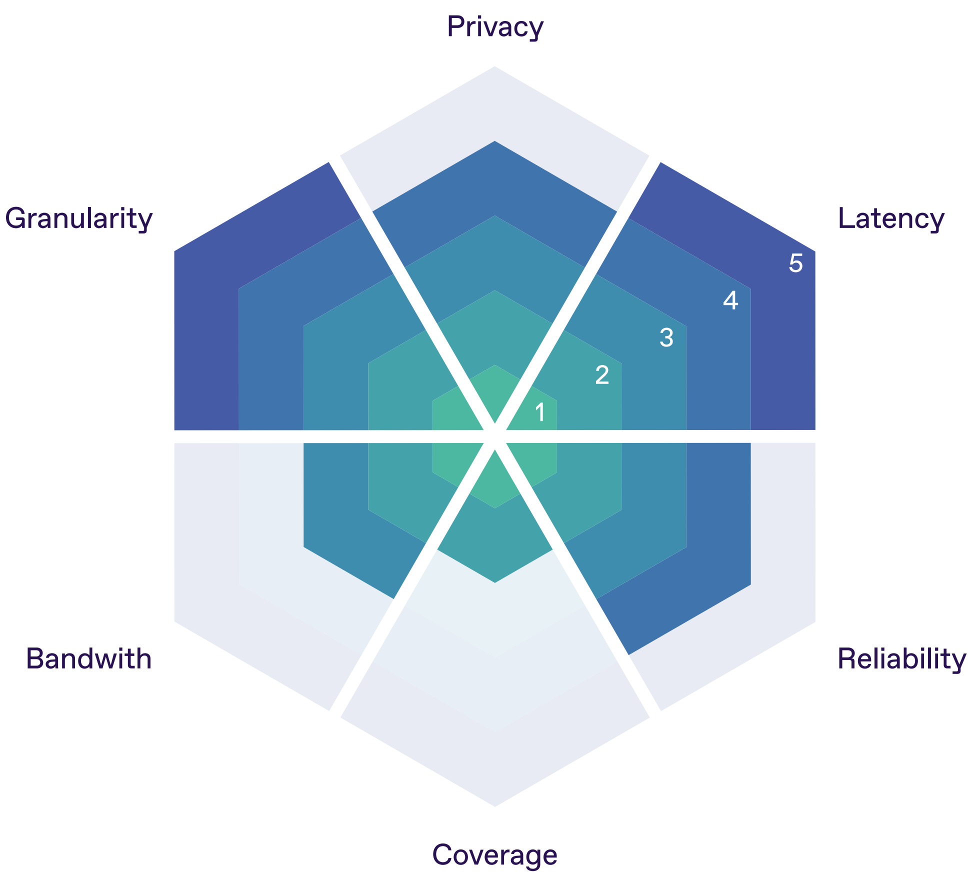
Transmitting proximity information directly to the vehicle can increase its awareness of its environment beyond the capability of its sensors and, hence, reduce the risk associated with vehicle decision making including:

- Collisions with other road users.
- Collisions with road infrastructure.
- Infringement of traffic legislation.



Performance Requirements

The performance requirements for this market sector are high, primarily due to the safety-critical nature of the AD functions that it is enabling. Coverage is rated as relatively low as the scale of infrastructure required to roll out this connectivity is large; full coverage will not be designed for several technology generations.



Automatic Driving

MARKET 1

These services all support the tactical operation of AVs; how a vehicle moves on second-by-second and metre-by metre basis rather than route choice or longer term behaviours.

Services

1. Environmental information

These services supply CAVs with information on infrastructure, road layout, fixed signage and environmental conditions in their immediate vicinity and the route immediately in front of them.

2. Smart system information

These services supply CAVs with information about the status, behaviour and intentions of infrastructure-based technology systems, such as smart city systems and Intelligent Transport Systems (ITS).

With CAVs, traffic management information that is currently communicated only visually can be – and is being - directly transmitted to the road vehicles via connectivity.

3. “Sensed” road user information

These services supply CAVs with information on the other road users in their immediate vicinity – or likely to enter their immediate vicinity within a short period of time. This would include information such as the location, speed, trajectory and type of road user within a limited geographic range.

4. Platoon coordination

Motorway platooning is a key use case for future CAVs on long journeys where potential efficiency gains for all road users are significant. Using a connected network to coordinate them, vehicles would be grouped together to travel as a unit.

5. Predictive quality of connectivity

On determining the route that it is intending to take, a CAV can use connectivity to verify the status of the network through the route. The operating system is then informed of where it will be unable to rely on connectivity to support AD along its future journey.

CASE STUDY

Virtual Mirror Input

An AV's Virtual Mirror is the digital rendering of the surrounding environment that is used to inform driving and vehicle control decisions. The road layout and other road users are captured on it. It is resolved from two primary inputs; the vehicle's onboard HD map and the vehicle's sensors, including positioning systems.

Where connectivity is available, inputs from external sources can be used as an additional layer of information to inform the Virtual Mirror. This data can be generated from other vehicles, in-situ sensors and any other connected devices.

In this context the main value to be captured by connectivity is in the provision of information that is out of the line-of-sight of the vehicle's onboard sensors and in the efficiency of information transfer. It can also increase certainty about objects it is detecting via its sensors.

OEMs are developing automated vehicles under the assumption that they can't rely on external data sources to generate and maintain a Virtual Mirror which it can use to drive safely. However, additional layers of complementary information could be used to compare and confirm against the vehicle's own sensor inputs; supporting the accuracy of the Virtual Mirror. It can also expand the field of perception of the mirror.

Informed Journeys

MARKET 2

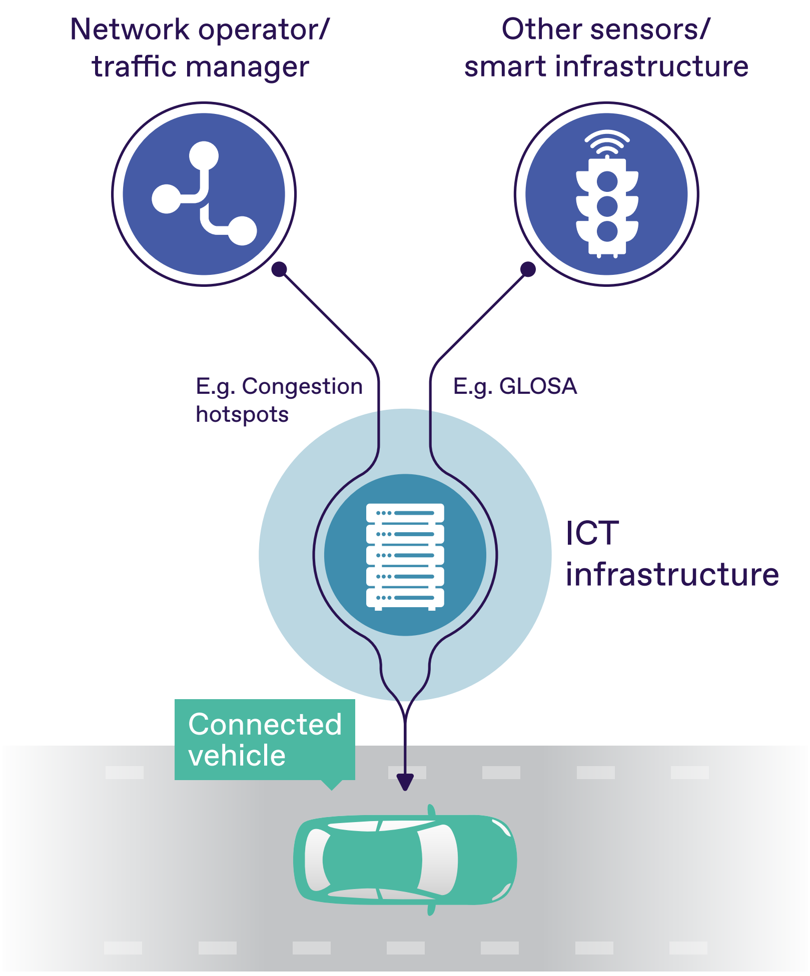
Drivers – whether human or a machine system – make the most effective, safe and efficient decisions in terms of route choice and driving behaviour.

Connectivity has been used extensively for many years now to provide drivers with information on their journey ahead.

This market consists of information services communicated to sat nav systems, smart devices, fleet telematics or any other connected system as part of or within the vehicle. These information services are used to improve driving safety, efficiency and experience regardless of how automated the vehicle is.

In the case of automated vehicles, connectivity can increase the vehicle's awareness of its environment beyond the capability of its sensors and, hence, improve the decision making of the vehicle, mainly, in terms of route choice and driving behaviour. When enabled to, CAVs will bypass the human processing of this information, to receive information on the surrounding environment, process it and use it to inform driving decisions in one system.

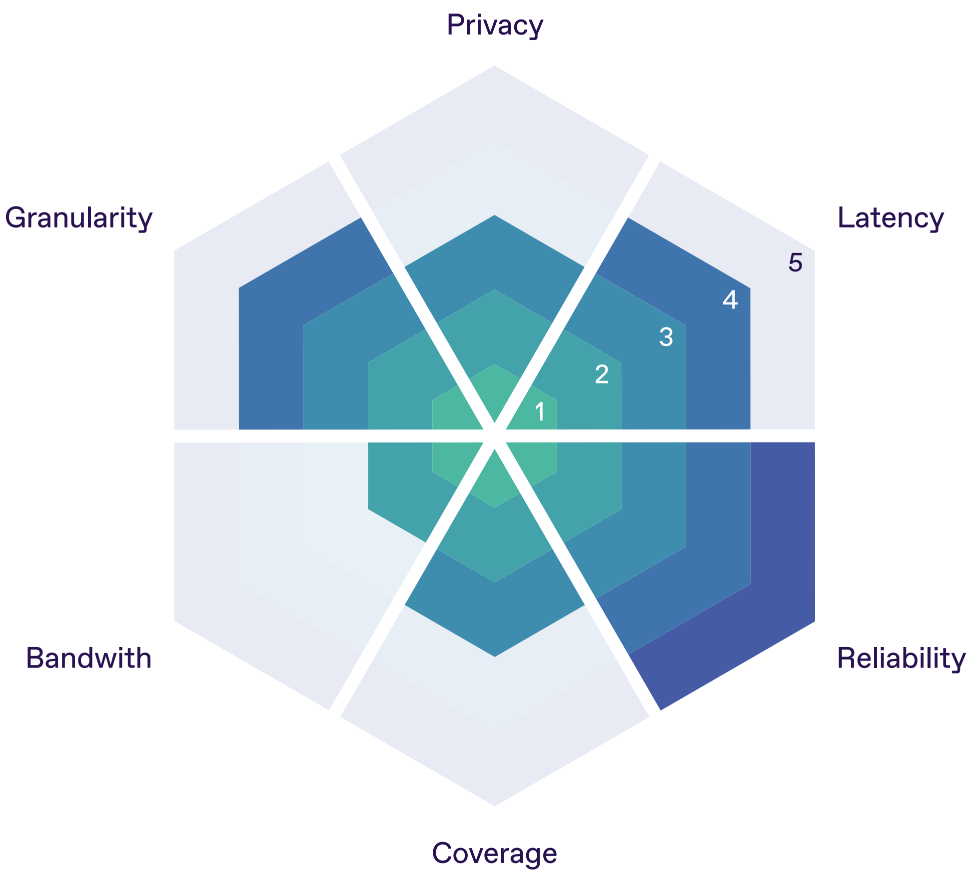
Current market leaders Google Maps and Waze use mobile network connections and smart phone interfaces to inform drivers about downstream events and conditions on their route.



Performance Requirements

Reliability is the most important performance factor in this market, followed by granularity and latency.

Connected navigation systems are popular and smart phone apps are currently leading the market. Network operators are aware that this is a competitive market and that a loss of dominance in this is affecting their ability to effectively inform drivers. For any provider to be a primary source of information for drivers, the messages must be reliable, accurate and timely.



Informed Journeys

MARKET 2

Services

1. Event information

These services supply CAVs with information about planned or unplanned 'events' which could relate to their onward journey, where an event is a real-world occurrence external to the normal operation of a road network but potentially having a noticeable effect on that network. Realtime information on events can be used to plan journeys both in advance and once they are underway.

2. Traffic management information

These services supply CAVs with information about any temporary layout changes or location specific restrictions and regulations that are in place. These services may often relate to events (see above) but are about how the traffic manager is responding to the event rather than about the event itself.

3. Traffic conditions

These services supply CAVs with information about traffic conditions further on their journey or the surrounding road network. These could relate to events and traffic management or be the result of more subtle and emergent properties of traffic on a road network.

This information could be derived either from fixed location sensors or crowdsourced from other connected vehicles – or a combination of both. These data types are already extensively used to provide in-vehicle information services and are used to calculate traffic flow, speed and density as well as more granular information such as lane utilisation or turning counts.

4. Availability of supporting service infrastructure

To complete informed journeys, drivers should be made aware of the location, availability and status of supporting infrastructure that they will require, including but not limited to:

- Parking spaces
- Charge points and petrol stations
- Connectivity facilities

CASE STUDY

Electronic Horizon Support

The information provided by the services in Market 2 can be amalgamated into a data set which supports a fully informed driving experience for either the driver or the autonomous control system.

Reacting to changes in driving conditions, whether that be the shape of the road, the sensors and infrastructure available, the connectivity conditions, or any unforeseen events or circumstances, can be done within a larger timeframe with an Electronic Horizon. This service plays a key role in enabling more comfortable, efficient and safe driving experience in the Advanced Driver-Assistance Systems (ADAS) and CAV spaces.

Electronic horizon can be supplied as an integrated solution that uses the anticipatory data and vehicle sensors to control a range of driving support processes, from dynamic headlight alignment to improved fuel efficiency, and routing and rerouting.

Messaging standards from the European Telecommunications Standards Institute (ETSI)

CAM

A Cooperative Awareness Message is the syntax and semantics that will be used to handle awareness messages from road users. Via vehicle to vehicle (V2V) and V2I signals, vehicles will distribute information on their position, dynamics and attributes.

DENM

A Decentralised Environmental Notification Message is a signal that is used to issue road hazard warnings to road users. Information on hazards or abnormal traffic conditions, including their type and position, are broadcast.

Intelligent Management

Network and fleet operators can make data-driven decisions on the operation of their network or fleet.

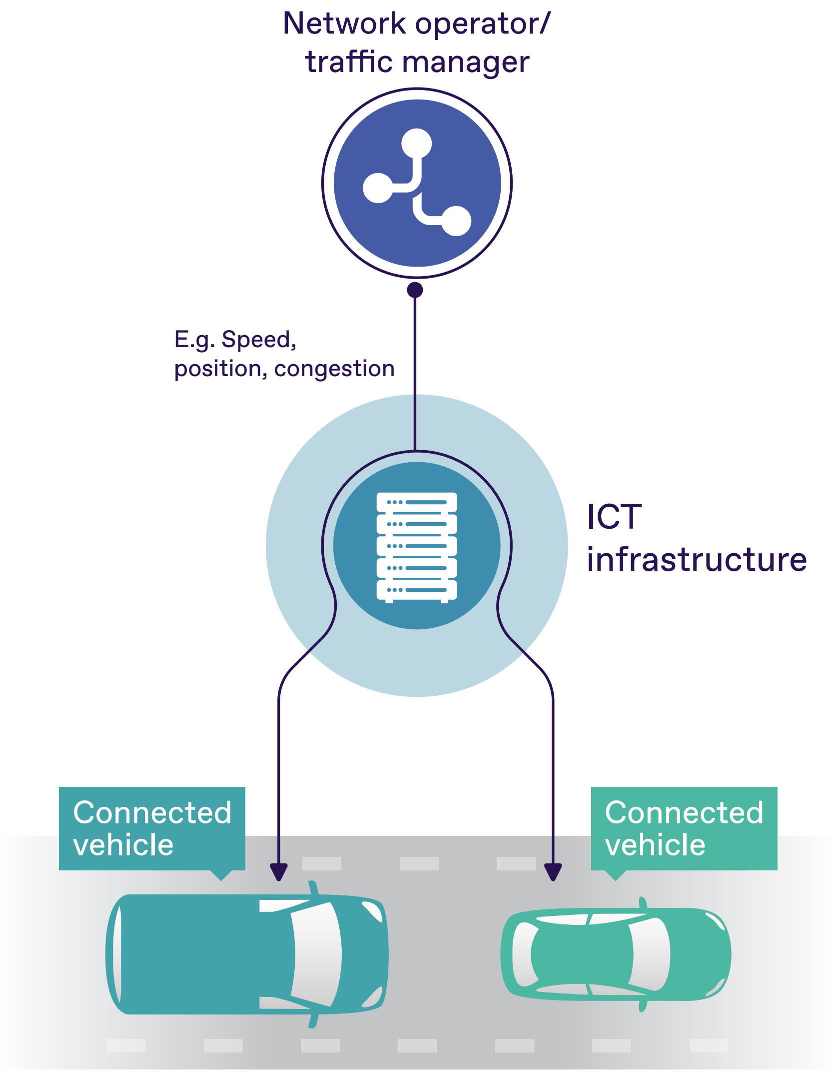
MARKET 3

Network or traffic information can be directly communicated to connected vehicles, rather than using variable messaging signs (VMS).

Connectivity enables valuable information services to various parties responsible for, or interested in, the behaviour and performance of some or all of the vehicles on road network.

In this market, information transmitted by connected vehicles is input into the management processes of road network operators and the like. This awareness of what is happening on the road network is supplementing and perhaps ultimately replacing existing data sources.

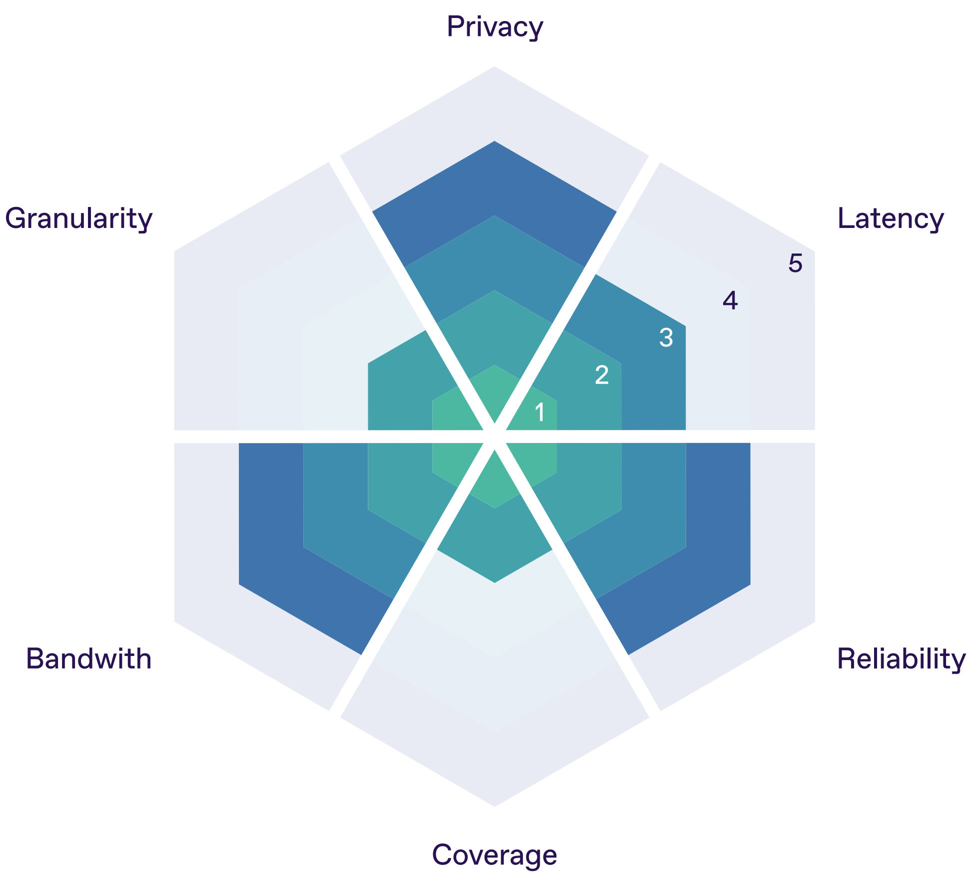
In the daily operation of road networks, information about the road fleets from CAM data sets can be used to manage variables like diversions, toll rates, emission restriction zones and other flexible factors.



Performance Requirements

Privacy and bandwidth are the most important requirements for this market. Large quantities of data relating to individual vehicles is to be exchanged.

Coverage is of low priority for these services, many of which are already operating based on other data inputs. This connectivity layer will add additional information and will only be of significant cost benefit to high-volume road networks or large fleets at first.



Intelligent Management

MARKET 3

Services

1. Basic vehicle information

Current network management services use cameras and in-road capacitance sensors to monitor congestion levels and input into decisions. These decisions result in actions such as variable speed limits and lane closures or other diversions.

With a greater volume of detailed information on the vehicles using a network, the real-time management of the network use can become more intelligent. CAM data sets can provide a view of the status of each vehicle on the network, including their AV capabilities and fuel/emission type.

2. User-specific journey information

These information services enable fleet operators – passenger or logistics – to manage and optimise the movements of the vehicles under their control. The key distinction between these and the basic vehicle information services described above is that these services largely depend on vehicle-specific information rather than aggregated data about a number of unidentifiable vehicles.

3. Infrastructure and environmental information

These information services relate to the condition of the road network and the environment in which is situated. Through their on-board sensors, CAVs will be collecting and processing information about their environment which could be useful beyond the immediate needs of the particular vehicle.

Network operators are concerned about both the condition of the infrastructure under their management and factors which could have an impact on the operation of their network. For example, CAVs could collect detailed information about the condition of road surfaces which can be communicated to network operators to inform maintenance schedules and the like.

CASE STUDY

Flexible Management of Road Networks

The basic vehicle information provision services in the Intelligent Management market opens the opportunity to manage the restrictions and regulations imposed on individual vehicles or types of vehicles at different time periods or in certain circumstances. Flexible management is mostly motivated by policy stances and journey efficiency.

Examples of services raised by network operators in this research include:

Smart Motorways

Many ITS services deployed on motorway networks are dependent on real-time traffic information. For example, variable speed limits set in response to slow moving vehicles or dynamic hard shoulders initiated in response to high traffic density. This information is currently collected through fixed location sensors such as inductive loops, which could be complimented by or eventually replaced by, the basic traffic information collected through connectivity infrastructure.

Emissions Management

With a real-time understanding of the mix of fuel types in a network fleet, variable restrictions on speed and the location/size of emissions restricted zones can be altered accordingly.

Flexible Tolls

Demand for routes across the network will be visible to the operator. They can manage the balancing of network use by altering tolls in real-time. Coupled with the informed journeys market services, drivers can make decisions on how these tolls affect their routes and may alter them according to the intention of the network operator.

Flexible Road Side Uses

A potential benefit of CAVs identified by the Arup in the UK is the flexible use of road side kerbs. As urban network operators have a more detailed insight into the type and volume of road traffic at different times, they are able to model the most efficient use of kerbsides. For example, allowing wider pavements for more pedestrian traffic at times of low road transport demand, or allocating a lane to public transport during certain timeframes.

Coordination of vehicles

MARKET 4

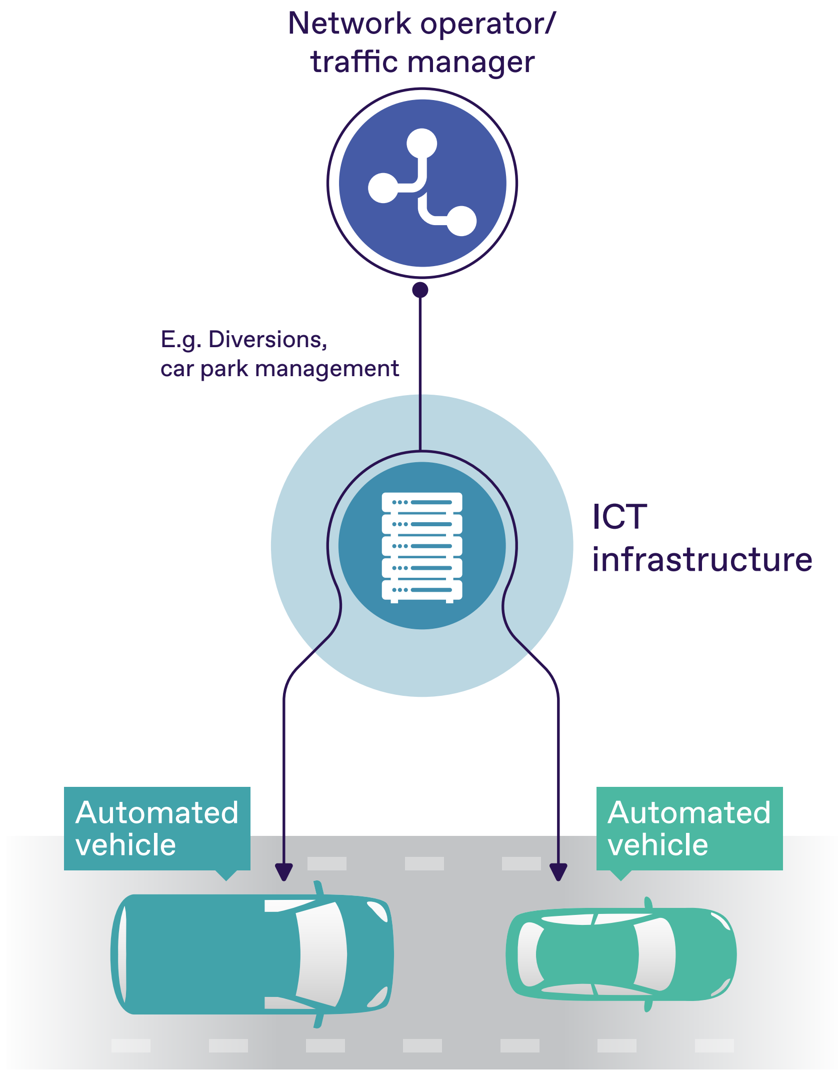
Network and fleet operators can instruct the route choice and driving behaviour of vehicles for the best overall outcomes for the users of the network or space.

An external system or operator has some degree of control over the actions of the CAV in particular scenarios.

All the other markets presented here relate to transmitting information to connected vehicles; whereas in these circumstances instruction is transmitted to automated vehicles.

Current applications pertain to specific scenarios and fleets. For example, Waymo's trial fleet of unmanned CAVs are in contact with a remote team that intervene and direct the vehicle's driving decisions when it is unable to process the surrounding environment. Another example would be the coordination of unmanned buses in a depot for the most efficient use of space.

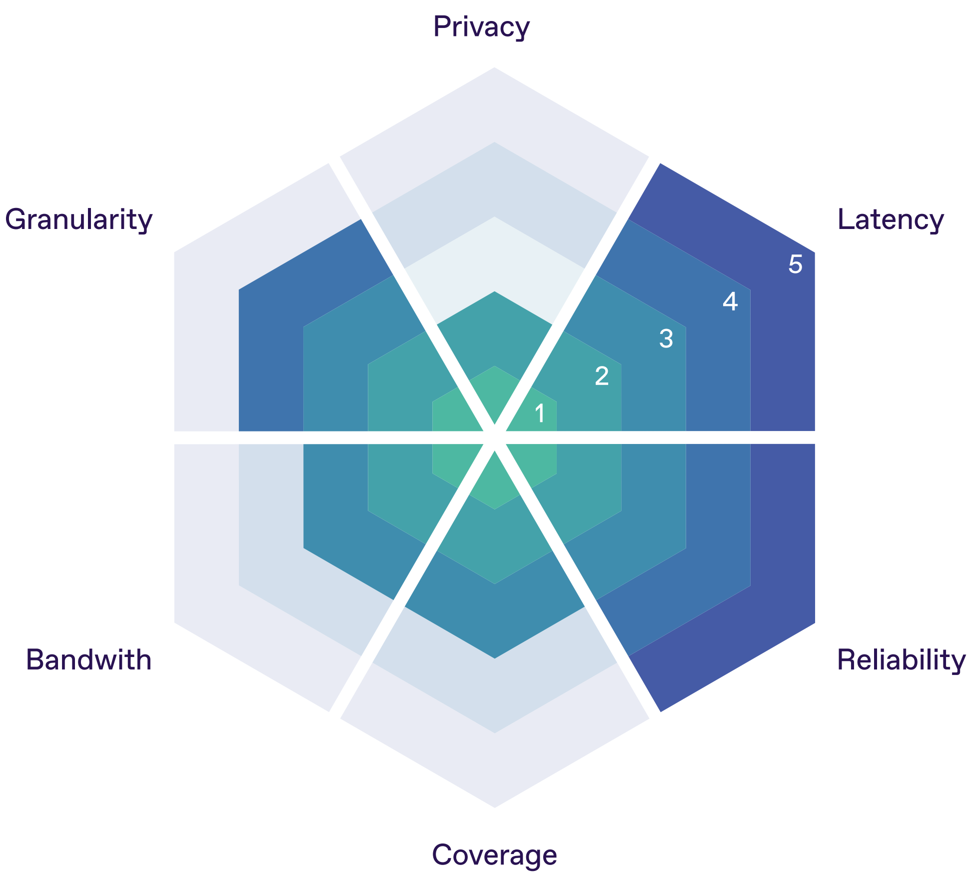
This market is the least developed of all the markets analysed and is highly dependent on the environment in which the information services are applied.



Performance Requirements

Performance requirements are high in this market as the simultaneous coordination of multiple connected vehicles is a high risk activity.

It is highly unlikely that CAVs will follow external instructions 'blindly' even in highly controlled private sites, but they will still make use of their on-board sensors and autonomous control system to ensure safety and prevent any collisions unforeseen by the optimising system.



Coordination of Vehicles

MARKET 4

Services

1. Space management services

These services would supply a group of co-located CAVs with detailed, coordinated instructions on paths to take, manoeuvres to make and driving behaviours at specific times and under specific circumstances.

The assumption behind this category of services is that, in some scenarios, optimised movement of CAVs to achieve the most efficient use of space and aggregate movement of vehicles within that space is best achieved by an external arbitrator determining the movements of all vehicles in the scenario rather than letting the vehicles make their own decisions.

2. Incident management

These services would instruct CAVs in the vicinity of a traffic incident of a particular diversionary route to take. These services are in many ways similar to some of those described in Market 2 but, importantly, differ in two ways:

1. Where Market 2 services provide information on diversionary routes to take in the event of an incident or unexpected traffic congestion, the decision on whether or not to follow that advice is left entirely to the discretion of individual drivers/vehicles. Here we are referring to diversions that are to some degree mandated.

2. In the event on an incident, equivalent Market 2 services are likely to provide the same information to all vehicles in a particular vicinity. With the incident management services discussed here, it may be that different sub-sets of vehicles are given different routes to spread the impact of the incident on the surrounding network rather than putting pressure on a single route. The differing instruction may be derived based on, for example, the vehicle's intended destination or the vehicle type, e.g. a different route offered for HGVs

3. Fleet optimisation

These services would instruct CAVs that are part of a fleet (e.g. logistics, public transport, taxis) on which route to take in real-time in response to changing traffic conditions and demand for their services. This is an established approach in a fleet management context, particularly where it concerns last mile logistics operations in urban environments. Equivalent information services are increasingly used for passenger transport as public transport and shared mobility options become more demand responsive and coordinated.

The driving environment will dictate the level and granularity of coordination imposed on individual vehicles.

4. Coordinated corridors

One of the Market 1 subsectors relates to enabling information services for the operation of platooning where CAVs communicate between each other to coordinate a platooning group.

In the future, this type of service could be extended to all vehicles on a stretch of road to efficiently move them without any driving decisions being made by the vehicle's driver. After transmitting the routing intention, control of the vehicle is complete rescinded to a central controller. This infrastructure coordinates all connected vehicles on the road segment, using algorithms and risk profiles to move them efficiently and safely.

5. Smart city management

These services would instruct CAVs in relation to variable restrictions applied in an urban context, e.g. to create pedestrian zones or dynamically manage on-street parking. These restrictions can be more stringently applied when a subset of road traffic is coordinated and following road regulations mostly without fail. Law enforcement and other emergency scenarios that require access via roads will be more efficient and effective as road transport is coordinated and – if regulation extends to it – cooperative.

Connected Travellers

Travellers can be productive and/ or entertained whilst travelling in an automated vehicle.

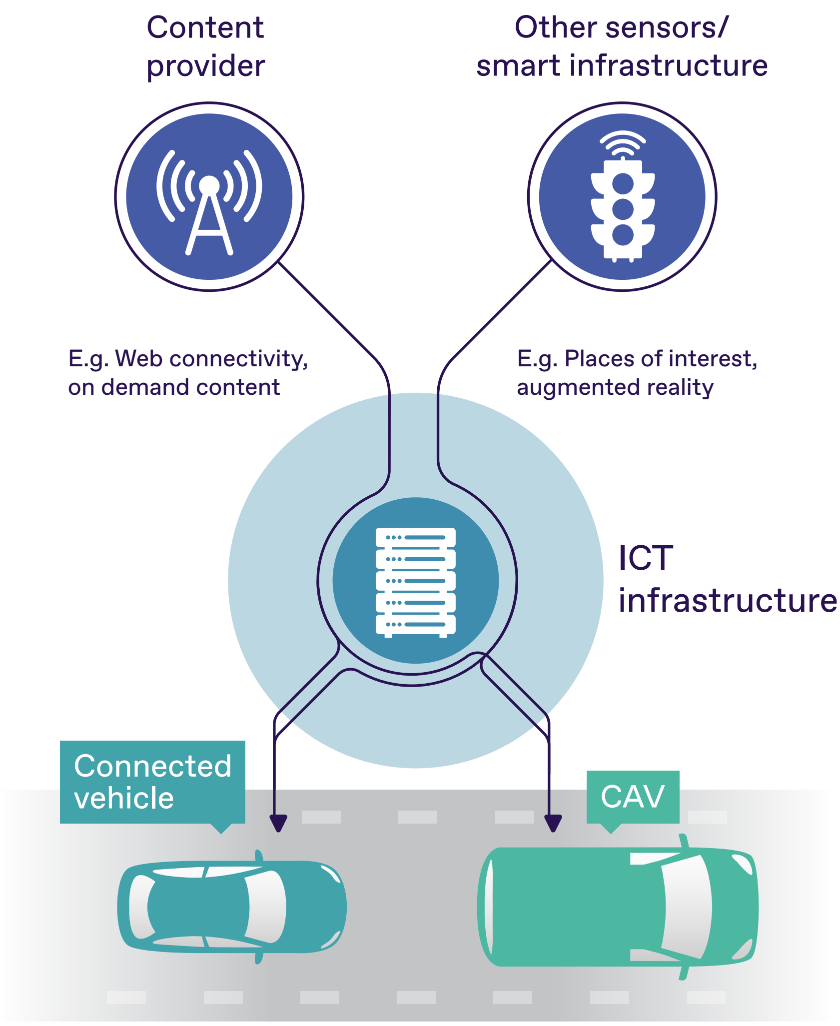
MARKET 5

Consumers have an ever increasing expectation and requirement to be able to access internet enabled services at all times and in all circumstances.

The provision of connectivity for those using public transport is increasing and improving all the time. Passengers are able to browse the web, consume media and communicate with others whilst travelling. Much of the expected benefits of automated vehicles relates the fact that individuals who otherwise would have been drivers all become passengers to some extent.

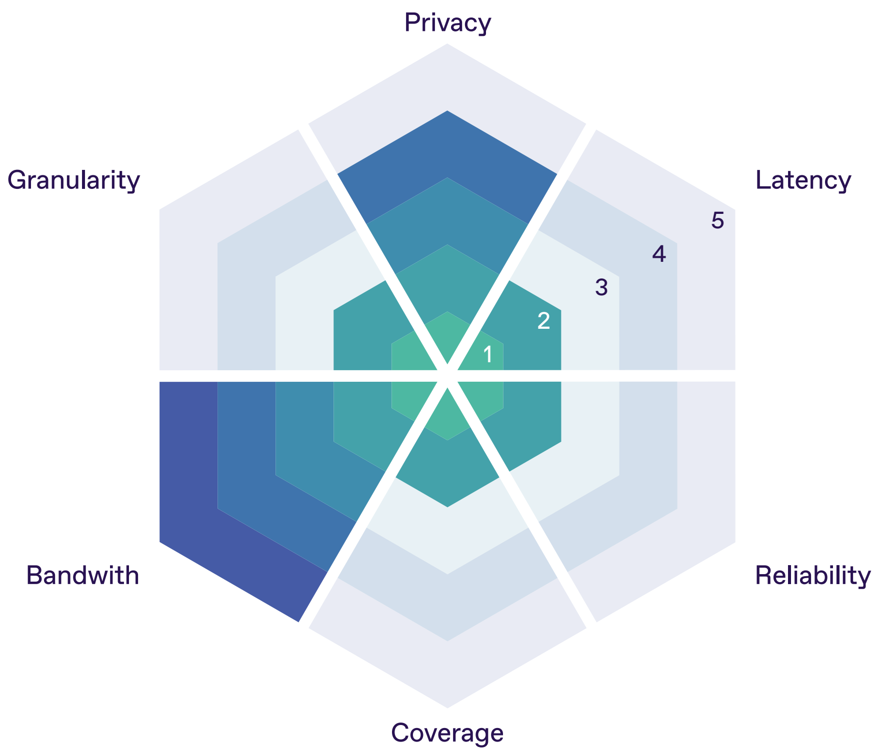
Whereas the previous four markets discussed here relate to specific information services which enable or improve the capabilities and impact of CAVs, Market 5 relates to the whole breadth of internet-enabled services which will become increasingly desirable to CAV users as their role in controlling the vehicle decreases – or is ultimately removed completely.

Once they are not actively driving, passengers can browse the web, consume media and communicate with others whilst travelling.



Performance Requirements

These services are not critical to CAV operations, but the perceived value of them is high. Their performance must be sufficient to positively impact the passenger experience.



Services

1. Internet-enabled consumer services

This market has a much wider scope that information services for CAVs. The entire range of internet-enabled services are effectively in scope and it is not necessary within the scope of this report to describe and sub-categorise those.

2. Enhance journey information

Passengers are supplied with information that is relevant to their journey including:

- Vehicle and journey performance information, including arrival time estimates and refuelling or charging requirements.
- Predictive quality of connectivity for the rest of the route.
- Alerts on any changes to the route or other driving decisions that the CAV operating system or central coordinating system has made.
- Commercial partner content that is location and route specific. For example, advertising upcoming services like rest stops and points of interest.

Underpinning Communication Services

MARKET 6

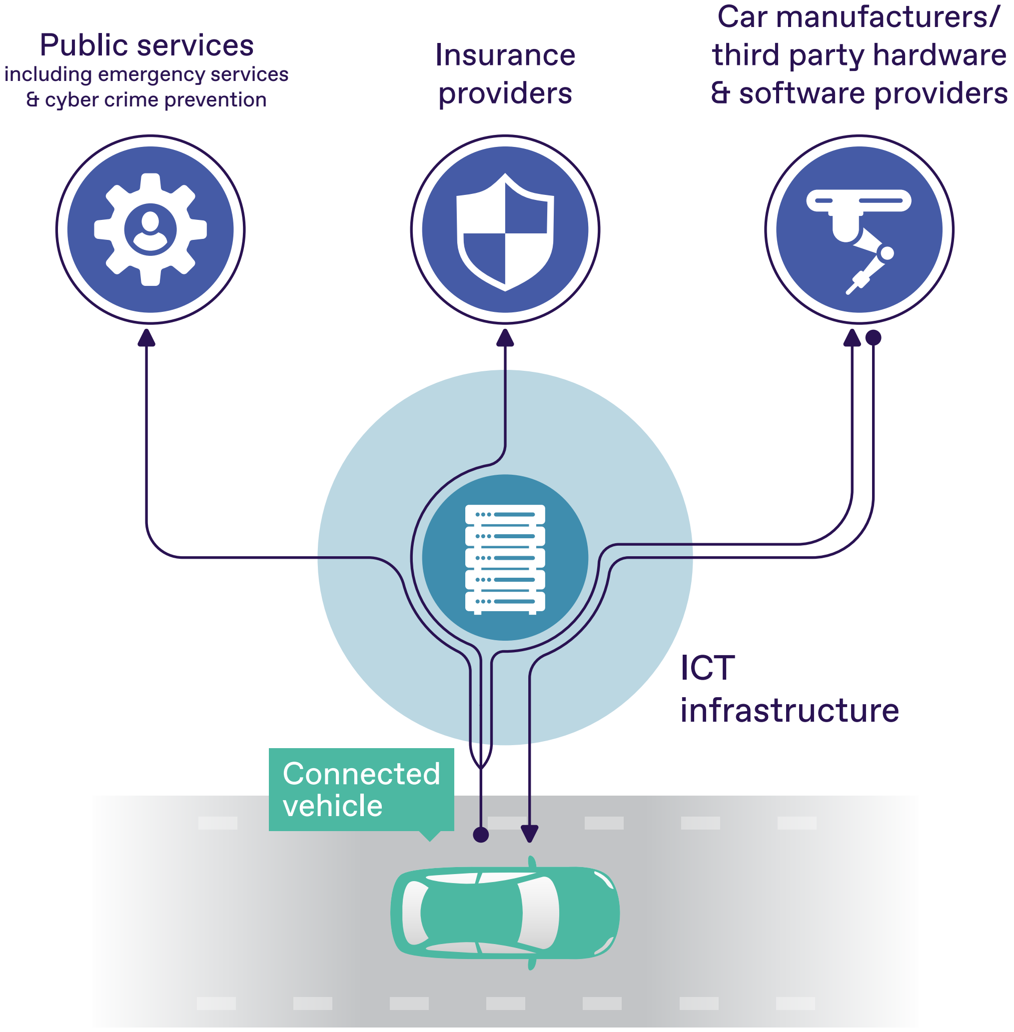
Safe and effective communication networks with no interoperability or legacy equipment issues.

In operating connected vehicles on public road networks, there is significant opportunity to commercialise the enabling and accompanying data-driven services.

The complexity of effectively and securely communicating with networked devices (including in-situ, cloud computers, mobile edge computing (MEC) and the vehicles themselves) will be addressed by computing services that are either translated from other IT-enabled industries or developed for this sole purpose.

Road transport and the processes of ownership, maintenance and use interface with an array of service and industries that will gain value from the increased quantity and quality of data on vehicles and their use that is a direct result of connected vehicle diffusion.

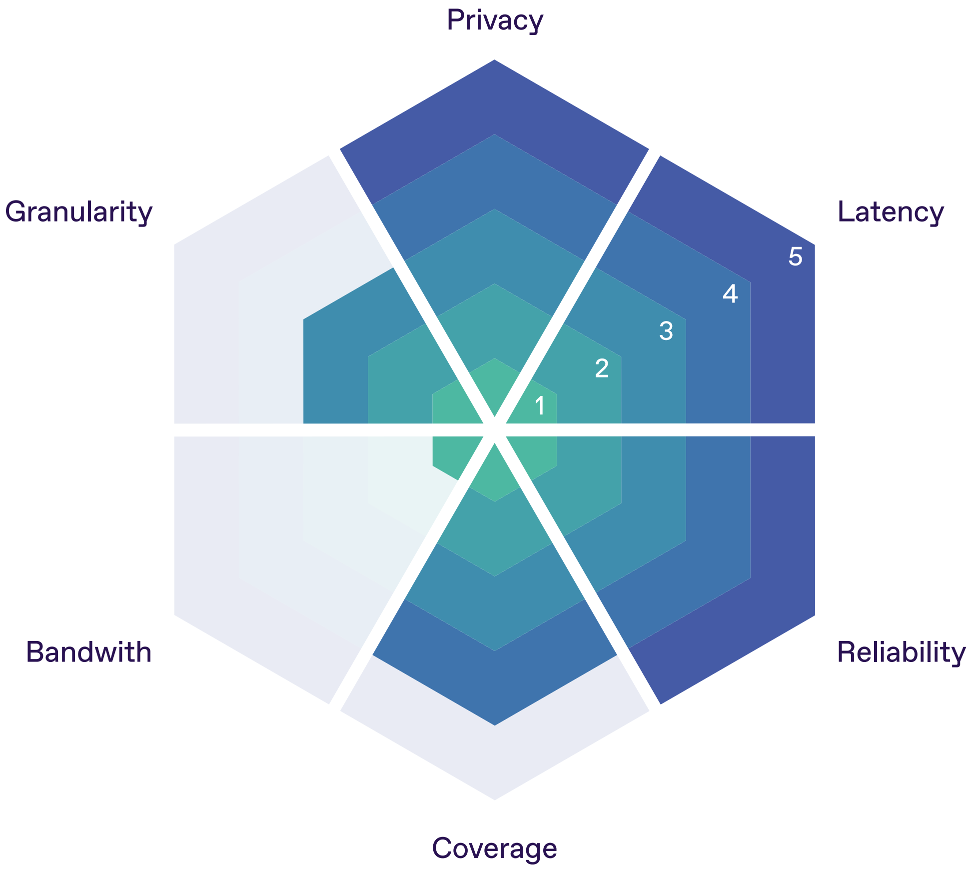
Supporting systems will be used to enable safety-critical and other real-time communication operations. Information from connected vehicles will inform interfacing services and operations.



Performance Requirements

Privacy is rated high in this sub-sector. These services are responsible for the anonymisation of personal information and support all services, including those that transfer sensitive information, so are at a significant risk from attempts to breach security.

In terms of performance, latency must be as high as possible and bandwidth as low as possible. The current technology state-of-the-art assumes that supporting services such as IAM will be sharing bandwidth with the communications that they are enabling. As such, they will need to be as quick as any safety-critical process that they are supporting, and as small as possible, so as to not impact on the size of the operating signals being sent on the same channel.



Underpinning communication services

MARKET 6

Cybersecurity technology providers are working to translate services applied in other industries that require private and secure communication networks to the CAV technology space.

Services

1. Secure communication services

Cybersecurity technology services that enable private and secure communication networks, such as:

- Identity and access management (IAM) services: Encryption and device identification services for the protection of connected systems and protection of service infrastructures.
- Security operation centre (SOC) services: A supervision and incident management platform for car manufacturers and other service providers (such as third party software or hardware providers) to use in the monitoring and update of communication security and risk management.

2. Over the air software updates

Vehicles with automation capabilities will have a significant amount of on-board software to support this processing. Updates to enable new functionality or fix bugs will be desirable for OEMs to ensure that their products are working safely and effectively.

3. Cybercrime prevention services

Crime prevention services will see commercial value both in the provision of event monitoring data (from SOCs) for their reactive processes and in any other threat or vulnerability intelligence services that can facilitate their proactive processes. Arrangements like this have already been operating in communications-enabled industries such as banking and utilities and are expected to translate across to connected road transport.

4. Other road fleet management services

As the concentration of connected vehicles increases, various existing services that support the safety and organisation of road fleets – such as insurance market services and emergency services – will develop or translate across industries to utilise the new wealth of data resources available to them. The provision of this data is a commercial opportunity for entities that have ownership over it.

MARKET STRUCTURES

How will the markets develop?

FUNDING SOURCES

Most likely to develop ↑ / Least likely to develop ↓	Infrastructure	Services
Scenario 5	Mixture funding from Public & Private sectors, & Users	Mixture funding from Public & Private sectors, & Users
Scenario 1	Public investment	Public provision
Scenario 2	Public investment	Users & Private sector
Scenario 4	Private investment	Users & Private sector
Scenario 3	Private investment	Public provision

We explored which of the 5 market structure scenarios would be the most likely to apply across CAV information services.

Scenario 5 was judged to be the most likely, as this is the structure that is representative of today's research programmes; R&D is undertaken by private industries with funding from the European Commission and taxes.

The application of these scenarios is largely dependent on four factors:

1. Existing markets from which these services have emerged (or are emerging);
2. The ownership and operational responsibility of the environment within which the services are deployed, as well as the geographic scale of the environment;
3. The type of value generated by the services;
4. The performance demands of the services.

These factors are reflected in an example description of Scenario 5, devised in the workshop:

The publicly owned road networks will invest in sensors and other connected, proximity devices, whilst the telecommunications infrastructure will be funded by private bodies.

Services will be paid for by whoever realises the value of them. Individual safety or efficiency improvements will be paid for by end-users, whilst aggregate traffic and environmental management benefits will be provided by public services. Private companies and OEMs will pay for fleet management, private advertising and other revenue-generating services.

Further research is required to develop an actionable understanding of the communications market for CAVs for all players.

Future Action

Action 1

Use this Research Framework as a Platform for Industry Coalescence

Establishing a user-led, value-focussed approach to analysing the CAV ICT market has been a key deliverable of this research.

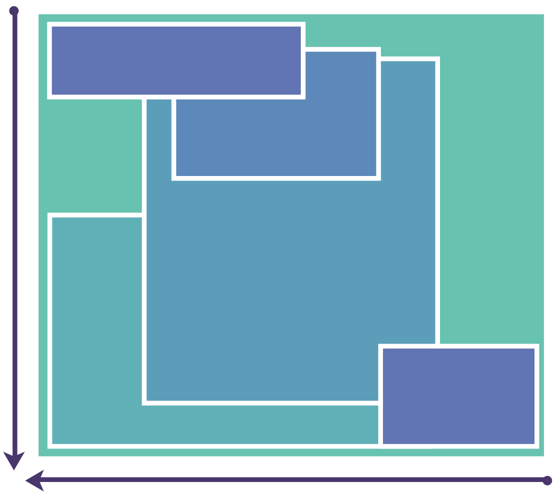
Alongside the frameworks for analysis and the presented findings, this approach could be adopted by the wider CAV and ICT industries to ensure that their realised services are viable, sustainable and complementary.

Work to date to understand the emerging CAV infrastructure market has been undertaken has been relatively narrow in its focus, too high-level or tied to a particular set of ICT technologies. This research offers at least the outline of a holistic, value-based, technology-agnostic assessment of the potential demand for information services for CAVs.

The three core frameworks that we delivered in completing this research should be used in further research, analysis and development to ensure that a common understanding of the users and their value perceptions is integrated into the CAV technology space.

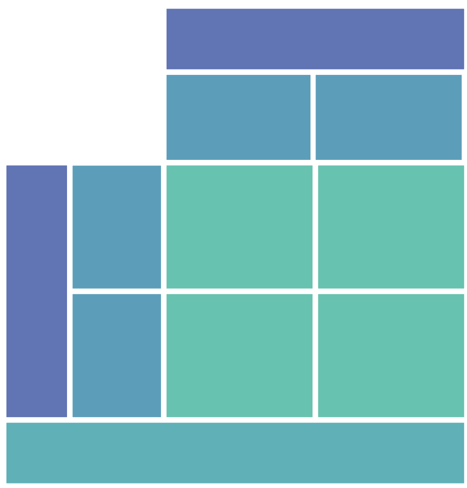
The three models that can be used elsewhere to shape future thinking are:

1. Categorising information services



2. Rating performance requirements

3. Structuring the markets



These frameworks will support and enable further developments and collaboration in CAV communication markets to stimulate a baseline focus on what generates value for the users, and society at large.

Action 2

Stimulate Investment by Sizing the Market

In order to make decisions about developing or deploying ICT solutions, the financial implications must be known.

A cost-analysis for the deployment of ICT infrastructure solutions for CAVs in robust business models requires a market sizing analysis. With this, decisions on the distribution of investment and resources can be made to ensure that financially viable solutions are released. Without this awareness, the sustainability of emerging solutions will remain unknown.

The market sizing analysis should continue with the bottom-up, value-based approach that this phase of research has taken. This way, the end-users and their needs are accounted for by design in R&D and investment decisions on the potential for different solutions.

Action 3

Support User-Led Innovation

These markets are still emerging. Where are the opportunities to develop new methods of value generation?

Many of these market services have been identified and highlighted in this research as translational services. That is, services and their enabling technologies are already in use in other communication and ITS applications, and their providers will enter the CAV services market by translating their business models across.

Though this research is in the early stages, it identified in various locations relatively immature and otherwise unique services, that could hold significant opportunity if developed upon.