ITS UK Position Paper

Connected Digital Transport Infrastructure

Enabling Safe and Efficient Deployment of Connected, Cooperative, and Automated Mobility: Key Challenges and Potential Benefits

Intelligent Transport Systems UK
Empowering Transport Technology

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Contents

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About Intelligent Transport Systems UK

ITS UK is the national association representing the transport technology industry. ITS UK provides a national platform to support the roll out of technology for a cleaner, safer and more effective transport network, both at home and abroad. We support our 190+ members - from both the private and public sector, and covering all sizes and disciplines - through advocacy to policy makers, connecting people and organisations, promoting the industry overseas and supporting innovation across the intelligent transport ecosystem.

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Executive summary

This report highlights the key challenges in ensuring the safe and efficient deployment of Connected and Automated Mobility (CAM) and Cooperative CAM (CCAM) services in the UK from a connectivity perspective and presents recommendations for the UK Government to address these challenges.

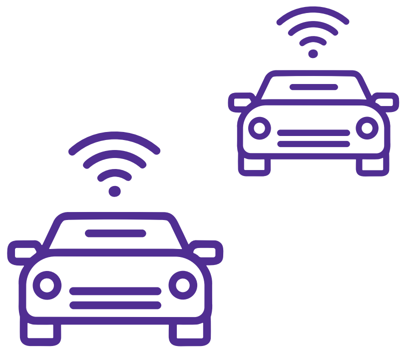
The focus is to examine the barriers to the adoption and rapid expansion of CAM and CCAM services in the UK, particularly regarding transport connectivity. This study will investigate existing transport connectivity technologies and the technical challenges they face in meeting the stringent requirements of CAM and CCAM services, including bandwidth availability, communication latency, and reliability constraints. If these challenges are not addressed promptly and effectively, they could impede the successful deployment of CAM and CCAM services. Therefore, this report advocates for the use of cellular-based 5G logical network slicing as a viable and cost-effective solution that could unlock significant benefits across various sectors, including automotive, rail, micromobility, and unmanned aerial systems.

01 Connectivity Technologies for Transport

Connected and Automated Mobility (CAM) is built upon multiple connectivity technologies that support the interaction and cooperation between Connected and Autonomous Vehicles (CAVs) and their surrounding environment including the road infrastructure.

Multiple wireless communication standards[1] have been developed by the automotive industry in collaboration with standardisation bodies, such as the Third Generation Partnership project (3GPP), the European Telecommunications Standards Institute (ETSI) and the Institute of Electrical and Electronics Engineers (IEEE), along with the academic community to support the requirements of future Intelligent Transportation Systems (ITS) applications. Dedicated Short Range Communication (DSRC) and Cellular vehicle-to-everything (C-V2X) are the two key existing wireless technologies for vehicular communications and CAM. DSRC uses WiFi-based physical and medium access control layer protocols through its de facto IEEE 802.11p standard (and its enhanced version IEEE 802.11bd[2]) which is also used by ITS-G5 technology. C-V2X can support long range and high data rates, which makes it suitable for many CAM applications. The C-V2X was developed by 3GPP to support vehicular applications by introducing two communication modes: (i) network communications where data are relayed between vehicles through the evolved Node B (eNodeB) of the deployed 4G/5G networks; (ii) In contrast, direct communication among vehicles occurs using the sidelink channel over the PC5 interface, allowing vehicles to exchange data directly without passing through the eNodeB. The latter can support **low latency** vehicular applications; however, it falls short for meeting the stringent requirements of advanced autonomous driving features required for the deployment of CAVs and CAM, which is a common limitation for IEEE 802.11p as well. To that end, **5G NR V2X** standard[3] was developed to guarantee **ultra-reliable and ultra-low latency communications.** This latest standard is expected to co-exist with C-V2X to support CAVs advanced features.

The technology neutral nature of spectrum regulations in the UK means that both C-V2X, and ITS-G5/DSRC have equal rights to operate in the 5.9 GHz frequency band, subject to compliance with the relevant regulatory technical conditions. ITS-G5, which operates in the DSRC network, has been already deployed and tested on UK roads as part of projects like UK CITE[4] which has deployed ITS-G5 roadside units in Coventry and on the M40, M42, A45 and the A46 road network to communicate emergency and warning messages with vehicles. Compared to C-V2X, which is gaining traction due to the widespread deployment of cellular network infrastructure, ITS-G5 may perform better in low traffic density scenarios due to its lower latency, although it is equivalent to that achieved by C-V2X LTE-PC5 communication mode. However, C-V2X has proven its supremacy in high traffic density scenarios in urban areas as it can handle network congestion in a better way, especially with the latest 5G NR V2X standard. Moreover, C-V2X direct communication mode has been deployed commercially in China[5], which further proves the maturity of this technology.



02 Challenges Facing CAM and CCAM Successful Deployment

Existing road infrastructure in the UK requires enhancement in terms of connectivity (as the limited existing deployment of connectivity technologies are either underutilised or superseded) to ensure efficient exploitation of the full potential of CAM and Cooperative CAM (CCAM).

CCAM is built upon cooperation among CAVs and other road users including connected smart road infrastructure. Therefore, achieving ultra-reliable and ultra-low latency communications among the above actors is a fundamental requirement for achieving efficient, safe and secure deployment of CAM and CCAM services. These services not only support traffic authorities and the DfT's ambition of reducing traffic congestion, cutting the carbon footprint, and optimising the use of the road network capacity but also enable achieving **Vision Zero** (i.e., a road safety strategy that aims to eliminate all traffic fatalities and serious injuries). Ensuring the availability (i.e. adequate coverage), resilience and security of any deployed connectivity technology (e.g. 5G or future 6G) would significantly support the above vision. The choice of the connectivity technology to deploy on roads is crucial due to its impact on fulfilling the strict requirements of CCAM applications, especially the safety-critical ones, as well as on determining the level of investment required. Even though some vehicle OEMs still publicly support DSRC/ITS-G5, the consensus view amongst the vehicle OEMs tends to converge towards supporting 5G-based technologies as they are deemed to be a better option for future deployments. This viewpoint renders some previously deployed physical infrastructure for DSRC/ITS-G5 communications obsolete.

To successfully deploy cellular based connectivity technologies (i.e. 5G and future 6G), **ensuring efficient and secure access** to the required bandwidth is compulsory. However, the emergence of advanced mobile user applications, such as augmented reality (AR gaming and AR-enabled navigation and wayfinding etc.), and the anticipated rapid increase of Drones usage for civilian applications in the UK (the UK is set to become home to the world's largest automated drone superhighway developed within the Skyway project[6]), along with the anticipated rapid and expanding deployment of CCAM and CAVs, with excessive demand on bandwidth, will lead to several challenges in ensuring the availability of the required bandwidth to support CCAM and CAVs service requirements, especially in congested communication scenarios. Therefore, Mobile Network Operators (MNOs) are seeking effective bandwidth allocation strategies, such as logical or physical network slicing, to support safe and efficient CCAM deployment. Such strategies must ensure that **sufficient bandwidth is readily available** for CCAM applications through effective innovative resource allocation solutions. 5G standalone (SA) architecture with its cloud-native 5G Core networks and edge computing capabilities is an enabler of this.

The requirement of high bandwidth and ultra-low latency communications to achieve safe and efficient integration of CCAM on the roads has been demonstrated recently during the 5G Automotive Association (5GAA) C-V2X Tech Demos event held in Berlin in October 2024[7]. It was demonstrated for the very first time 5G-V2X Direct technology integration in Audi and BMW vehicles to alert drivers about pedestrians and cyclists even before they can see them, leveraging sensors and a camera feed from other vehicles. The demonstrations showed the high bandwidth and low latency performance characteristics of 5G-V2X Direct using ETSI Release 2 messages[8]. During this event a demo run by Vodafone has achieved < 20 ms round trip time over cellular network for 5G user -> MEC -> 5G user, further highlighting the potential of this technology in supporting CCAM applications.

The main questions that require investigation are:

- What is the most appropriate connectivity technology to deploy on the road infrastructure to support the efficient, safe and secure integration of CAVs and CCAM services?
- If 5G-based cellular technology is adopted, then how to ensure the availability of the required network resources to meet the strict requirements of safety-critical applications of CCAM such as ultra reliable and ultra-low latency with robust security safeguards?
- Given the fact that other connectivity technologies are already deployed, such as ITS-G5, how to ensure *interoperability* and *coexistence* of these technologies with the 5G-based cellular technology?

03

5G-based Network Slicing as a Solution

The rapid deployment and coverage expansion of 5G technology is envisioned to efficiently support diverse new business-driven use cases from vertical industries such as autonomous driving, digital twins and enhanced cyber resilience.

However, these use cases bring unique divergent and challenging requirements, including a broader range of strict performance, cost, security safeguards, and mobility management. Therefore, to deal with such challenges the network slicing concept has emerged as a potential promising approach for resource allocation and management. In this approach, a single physical network can be divided (sliced) into several logically isolated and self-contained networks, each of them can provide customised services for a specific application, thus fulfilling its distinct requirements in a sustainable way[9]. A single network slice can support one or many services (e.g. CCAM and CAVs, safety and traffic efficiency applications), and it may include components belonging to access, transport, core, and edge networks in the form of capacity, computing, storage, and Virtual Network Functions (VNFs)[10]. Slices should have specialised features (slice types) to accommodate the diverse requirements of the applications they support, e.g. an enhanced mobile broadband (eMBB) slice requires large bandwidth to support high-data-rate services; while ultra-reliable and low-latency communications (uRLLC) slice, serving mission-critical services (e.g. safety messages dissemination in CAVs network, manoeuvres coordination among CAVs etc.) requires high reliability, ultra-low latency, and very robust security. In addition, a network slice that supports remote control and monitoring of CAVs or a fleet of passenger carrying autonomous shuttles, such as the real-world testing performed within the Solihull and Coventry Automated Links Evolution (SCALE) project[11], may combine both above requirements.

a. Logical slicing vs dedicated physical slicing?

To provide the required connectivity for the digital transport infrastructure MNOs could opt for either (i) logical network slicing-based deployment technology or (ii) deploy a physical infrastructure for exclusive use by CCAM and CAM applications (i.e. a dedicated physical network slice). As MNOs are looking to generate new revenue growth and create new value through partnership with vertical industries (i.e. the users of network slices), the increased capabilities of 5G technology, including bandwidth, data rates, security and latency, offer a value that MNOs can bring to these markets. The automated operation of network slicing allows MNOs to package these valuable network capabilities into differentiated services that can drive profitable growth. CCAM and CAM applications are anticipated to be among the most profitable markets for MNOs, this is backed up by the forecasts published in 2019 by The Society of Motor Manufacturers and Traders (SMMT) in a report titled “Connected and Autonomous Vehicles: Winning the Global Race to Market”[12]. This report highlights the leading position of the UK in the global race to market for CAV technology, with an anticipated £62 billion boost to the UK economy by 2030 and analyses the wide-ranging societal and economic benefits to be achieved by gradually increasing CAVs on our roads.

Regardless of which deployment option will be chosen by MNOs, each of them has its own merits and limitations as discussed below.

b. Logical slicing - Pros and Cons

Due to the strict operational security requirement for CCAM services and the increasing cybersecurity risks targeting this technology in addition to the often-limited capital or operating funding for deploying new installations and maintenance, it is necessary to ensure that robust security measures are in place to protect the logical slices used by CCAM critical applications. MNOs can provide various logical network slices each dedicated to a different CCAM service. For example, a high-priority logical network slice for low data rate transport messaging, and a high data rate logical network slice for video streaming/remote vehicle control.

A logical network slice is a virtualised network created on top of a physical network infrastructure, and it usually uses software-defined networking (SDN) and network function virtualisation (NFV) technologies to create flexible and scalable network slices for serving specific applications. Such flexibility is beneficial to MNOs as it enables them to create network slices tailored to specific users' needs, which can improve service quality and reduce their operational costs. However, such a logical split of the physical infrastructure resources may necessitate additional protection measures to defend against a myriad of attacks. This logical slicing technology enables 5G network users to simultaneously connect or switch between different slices to get access to multiple services with guaranteed quality of service. Nonetheless, switching between network slices, aka **Inter-Slice-Switching**, can be maliciously exploited by attackers to cause a **Distributed Slice Mobility (DSM) attack**[13]. DSM attack is a distributed denial of service (DDoS) attack that can disrupt the operation of the target network slice, and its users. Therefore, if logical slicing is chosen for deployment, then robust security solutions should be put in place to mitigate the increasing security attacks.

	Implementation	Security	Efficiency	Scalability	Operational costs
Logical slicing	Software-based (Shared physical infrastructure)	Strong security through logical isolation of slice	Higher efficiency and flexibility	High and more cost-effective	Moderate
Physical slicing	Hardware-based (dedicated physical infrastructure)	Higher level of security through physical slices isolation	Less efficient due to its static nature	Costly	High

Table 1. Logical Slicing vs Physical Slicing

c. Dedicated physical slicing - Pros and Cons

A physical network slice creation is a costly process as it involves physically dividing network components like antennas or base stations to create a separate physical network infrastructure with its own exclusive resources. This may also require additional investment to provide the necessary hardware components. This makes it less flexible and less adaptable to the frequent dynamic changes of CCAM users' resource requirements. Compared to logical slicing where **software-based** security policies and access controls are used to prevent unauthorised access between slices within the shared physical infrastructure, physical slicing can guarantee a higher level of security by **physically isolating** network slices, minimising the risk of cross-contamination between different slices.

04 Benefits and Application of Digital Connectivity in Transport

Bringing digital connectivity to transport, with adequate security and resilience measures, through the deployment of the above discussed network slicing solution would enable the following benefits:

- Significantly enhance road safety for drivers and vulnerable road users (e.g. pedestrians, cyclists etc.), especially in urban areas.
- Improving traffic flow management and congestion mitigation through enhanced real-time coordination among smart road infrastructure and CAVs as well as other CCAM vehicles.
- Achieving substantial improvement in fuel economy and emissions reduction, thanks to the advanced CAVs coordination applications enabled through digital connectivity of the transport infrastructure.
- Efficiently support advanced multi-modal mobility services such as Mobility as a Service (MaaS).
- Supporting rapid market expansion and wider adoption of autonomous vehicles (AVs) by providing external data streams into AVs, leading to better AV's decision making, and earlier public acceptance. In addition, tele-operated driving (using 5G and beyond) will enable support for L5 vehicles that are not qualified on certain roads or conditions.

Enabling robust and secure connected transport infrastructure will pave the way for improved efficiency in several existing applications while enabling the deployment of new applications in several sectors as discussed here.

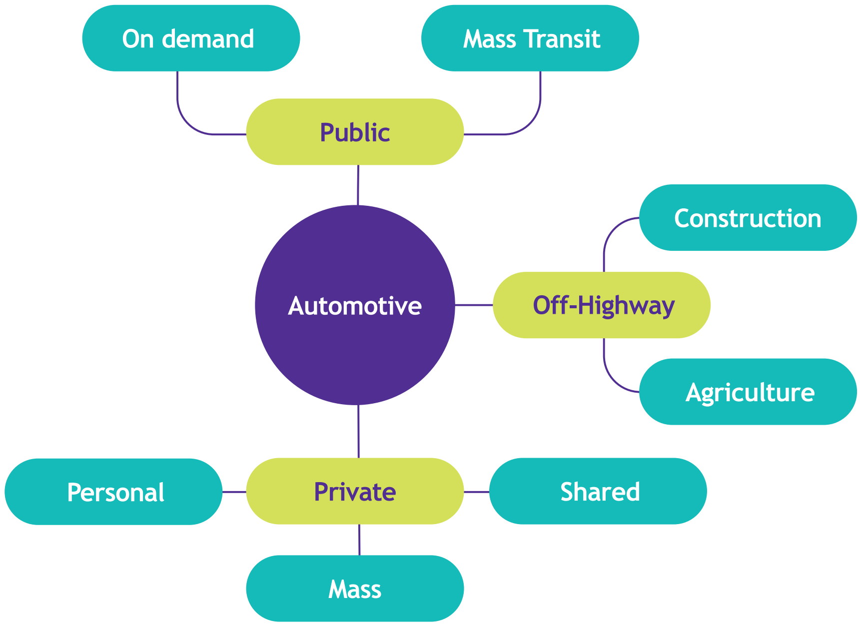


Figure 1. Overview of the potential applications in the automotive sector

a. Automotive sector

As shown in Figure 1, improved transport connectivity will increase the attractiveness of CAVs market which leads to a rapid expansion of their adoption in different automotive services including public transport which will benefit from the introduction of advanced mass transit solutions such as connected autonomous shuttles, like the ones being demonstrated by the SCALE project. In addition, CAV-based on demand mobility is anticipated to emerge and provide an efficient mobility solution to suburban population with limited access to mass transit. The benefits of CAVs and CCAM will extend to the private automotive sector as well by providing drivers and passengers with enhanced safety on roads and significantly improved travel experiences through advanced route planning, re-planning, and recharge scheduling solutions for electric vehicles, etc., thanks to the enhanced transport connectivity. Other sectors which rely strongly on the automotive services for their operation, such as construction and agriculture, will also see improved efficiency in their operation as platooning applications for trucks, for example, will enable faster and more cost-effective delivery of materials and goods, significantly reducing their operational cost.

b. Micromobility sector

Faster, more economic and safer journeys are expected for the different micromobility means. This is because E-Scooters or E-bikes for examples will be able to receive safety alerts from CAVs/CCAM vehicles as well as other important traffic information from the road infrastructure, so that they adapt in real-time their journeys based on the rapidly evolving road and traffic conditions to optimise their safety level and the cost of their journey. Moreover, they will also be able to highlight their presence to other vehicles, both human-driven and CAVs, augmenting on-board sensor information (if the latter is available) to further enhance safety and efficiency on roads.[7]

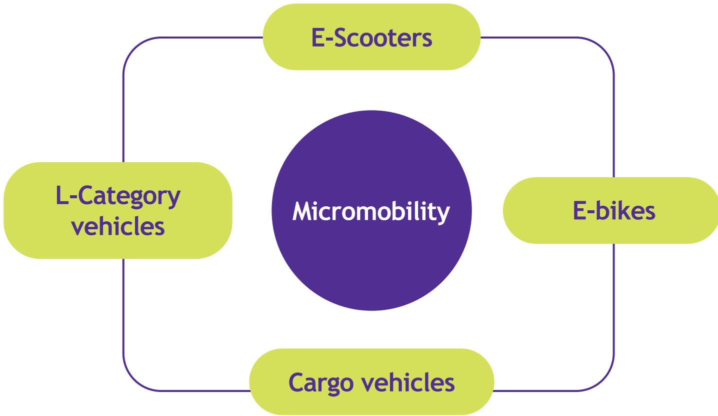


Figure 2. Overview of the potential applications in the micromobility sector

c. Rail sector

The rail sector with its different service categories, especially for passenger transport using trams, will operate with higher safety levels alongside other road actors such as micromobility vehicles, e-scooters and CAVs. Enhanced connectivity will enable improved coordination and timely speed adaptation, significantly lowering the risk of incidents.

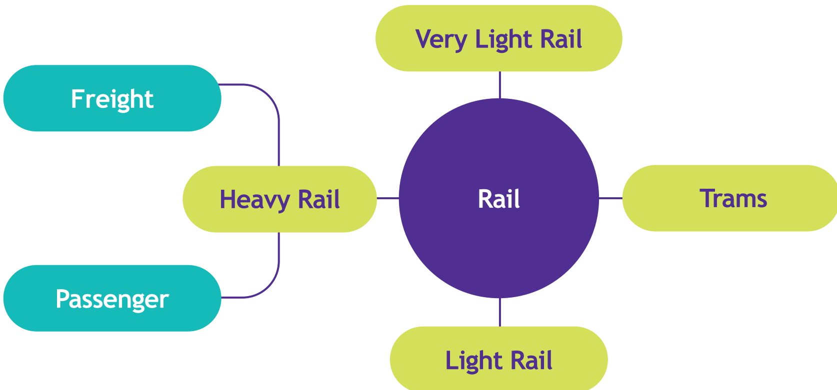


Figure 3. Overview of the potential applications in the rail sector

d. Future Air Mobility sector and Aerial Systems enabled services

Unmanned Aerial Systems (UAS) will play a key role in supporting connected transport infrastructure to achieve enhanced safety, more efficient traffic flow management and reduced emissions by offering complementary services to CAVs and CCAM. These services include rapid intervention in emergency situations, such as car incidents in cities and highways, by ensuring real-time aerial view of traffic conditions. UAS can also ensure last mile delivery of goods in urban and suburban areas as well as transporting passengers through their eVTOL services. Such services benefit significantly from the enhanced transport infrastructure connectivity as UAS require robust and secure connectivity to operate safely and coordinate with the ground infrastructure.

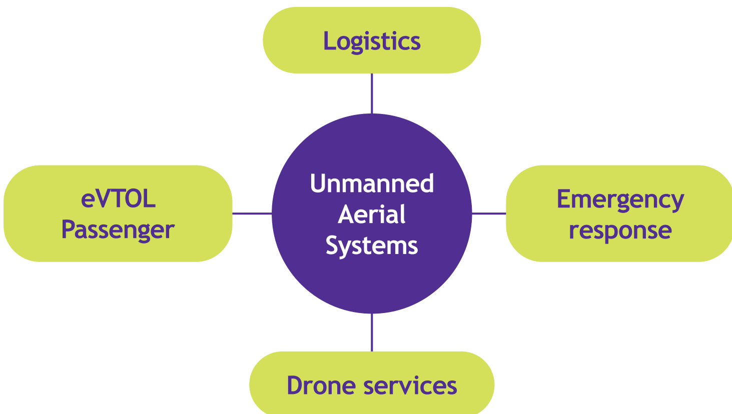


Figure 4. Overview of the potential applications in future air mobility and aerial systems enabled services

e. Authorities, regulations and standards

To take full advantage of digital transport connectivity the above discussed applications need to be compliant with the policies in place and their underlying communication and coordination technologies need to be standardised to ensure wider adoption and easier interoperability with other services/technologies. Local authorities and the DfT would benefit from pilot projects that provide evidence of the above discussed benefits and allow them to define a successful deployment and adoption strategy of connected transport infrastructure.

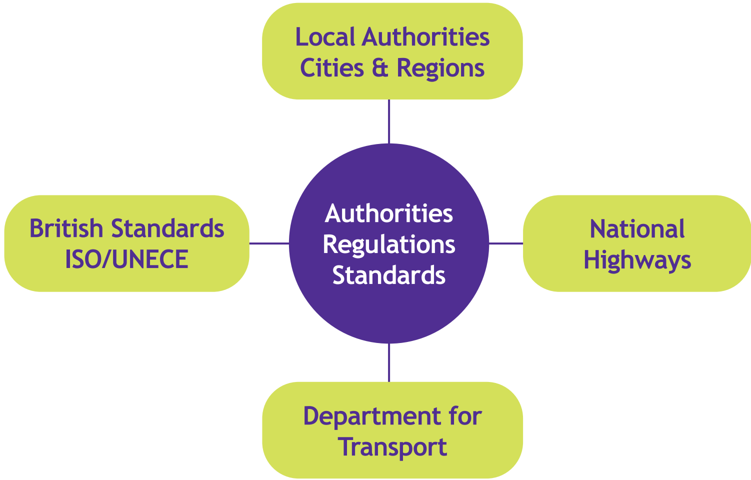


Figure 5. Key Authorities, regulation and standardisation bodies for digital transport connectivity

05 Future Requirements

Based on what has been discussed in this report, we would recommend the following actions:

- Government should incentivise MNOs to invest in the deployment of 5G logical slicing solutions in their existing access points as well as for their future planned deployments. Indeed, in logical slicing, when the MNOs install an access point to serve CCAM applications in both urban and suburban areas, they will automatically expand the coverage of their services and thus be able to increase revenue. The extended coverage of 5G service will unlock future applications and business cases for the MNOs beyond CAVs and CCAM applications.
- Government funding should be targeted towards initiatives that have a viable rollout/scale-up strategy of the developed technologies through R&D projects. Thus, digitised solutions will be more suitable as they are more cost-effective. We recommend funding for connected digital transport through the 5G logical slicing solution discussed in this report.
- Government should strike a balance between funding far-sighted initiatives, which may deliver benefits many years from now, and other initiatives, which could rollout/scale-up and deliver benefits in a much shorter timescale such as those targeted at enhancing connectivity for CAM and CCAM services.
- All future transport means in the ground, sky and water require secure connectivity solutions to operate safely and efficiently. Therefore, the Government is invited to promote or fund the research into, and deployment of, network slicing for critical transport communications. Indeed, the 5G logical slicing solution that is recommended to be tested on ground road infrastructure could be further expanded to UAS, such as eVTOL services, and autonomous ships at a lower deployment cost by leveraging the lessons learned from the ground transport infrastructure deployment.
- Future capital investment in R&D projects investigating the technical challenges facing the successful deployment of connected transport infrastructure solutions that will power CAVs and CCAM services is required. In addition, the new generation of telecom and cyber security engineers are required to undergo upskilling to master the advanced connectivity technology used by CAVs and CCAM services.

06
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