5GMOBIX

5G for cooperative & connected automated MOBIlity on X-border corridors

D6.6

Final report on the business models for cross border 5G deployment enabling CAM

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Authors

Authors in alphabetical order		
Name	**Organisation**	**Author or Co-Author**
Aitor Fernandez	Asociacion Espanola Del Vehiculo Autonomo Conectado	Section 3.5 author
Edwin Bussem	KPN	Section 3.1 author
Jaime Ruiz Alonso	Nokia ES	Section 3.4 author
Joel Puga	Centro de Computação Gráfica	Section 4.3 author
Jorge Alfonso	Universidad Politécnica de Madrid	Section 4.2 author
Lidia Buenavida Peña	ERTICO	Section 3.6 author
Martin Speitel	Fraunhofer-Institut für Integrierte Schaltungen IIS	Section 3.3 co-author, Section 4.4 author
Olga Segou	Netcompany Intrasoft	Section 3.3 co-author, Section 4.1 author
Prune Gautier	Luxembourg Institute Of Science And Technology	Section 5 author
Tahir Sarı	Ford Otosan	Executive Summary, Section 1, 2, 6, 7, Annexes author, section 3.2 co-author
Thomas Donnelly	Satellite Applications Catapult	Section 3.2 co-author. Section 3.7 author

Control sheet

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ABBREVIATIONS

Abbreviation	Definition
5GAA	5G Automotive Association
AV	Autonomous Vehicle
AMQP	Advanced Message Queuing Protocol
ANPR	Automatic Number Plate Recognition
BMC	Business Model Canvas
CAV	Connected Autonomous Vehicle
CBA	Cost Benefit Analysis
CBC	Cross-border Corridor
CAM	Connected and Automated Mobility
CEDR	Conference of European Directors of Roads
C-ITS	Cooperative Intelligent Transport System
C-V2X	Cellular Vehicle to Everything
DoA	Description of Action
E2E	End to End
EC	European Commission
eMBB	Enhanced Mobile Broadband
ETPC	European Truck Platooning Challenge
EU	European Union
FAB	Semiconductor **Fab**rication plant
GA	General Assembly
ICT	Information Communication Technology
KPI	Key Performance Indicator
MEC	Mobile Edge Computing
mMTC	Massive Machine Type Communications

MNO	Mobile Network Operator
NEP	Network Equipment Provider
NRA	National Road Authorities
NSaaS	Network Slicing as a Service
OEM	Original Equipment Manufacturer
PESTLE	[P]olitical, [E]conomic, [S]ocial, [T]echnological, [L]egal, or [E]nvironmental
QoS	Quality of Service
RAN	Radio Access Network
RIO	Road Infrastructure Operators
SLA	Service Level Agreement
SME	Small and medium-sized enterprise
SOC	Silicon on Insulator
TRA	Transport and Road Authorities
TS	Trial Site
TSL	Trial Site Leader
UC	Use Case
UCC	Use Case Category
URLLC	Ultra-Reliable Low-Latency Communication
US	User Story
VNM	Value Network Model
WP	Work Package
WPL	Work Package Leader
X-border	Cross-border

EXECUTIVE SUMMARY

The development of business models for cross border 5G deployment enabling CAM requires a good understanding of the stakeholder ecosystem and of the dependencies created among the multitude of actors. 5G for CAM requires the cooperation and interaction of entities such as:

- Mobile Network Operators (MNOs),
- Automotive Original Equipment Manufacturers (OEMs),
- Software and Service providers,
- MNO vendors (suppliers),
- On-board Unit/Roadside unit (OBU/RSU) providers,
- Road operators,
- Cooperative Intelligent Transport System (C-ITS) centres,
- Research and Development (R&D) institutions,
- End users (individuals, drivers, commercial end users etc.)

In order to understand the needs of each type of stakeholder and the underlying value chains, 5G-MOBIX utilised well known analysis tools such as the Business Model Canvas to describe preliminary business plan concepts, Customer Exploration Maps to understand the customer needs for each stakeholder type, the Value Network Model to explore the connections and expectations among stakeholders in this ecosystem. Inputs were provided by experts within the consortium as well as external participants, on the basis of the 5G-MOBIX user stories which correspond to a wide range of CAM functionalities developed and tested over 5G networks in the project trials. More importantly, these functionalities were tested in cross-border scenarios, in order to assess the impact of roaming to the overall quality of service and are well-documented within the project. Inputs were provided directly from experts in the trial sites or through surveys developed within the project.

According to MNOs, the biggest challenge in large scale deployments is the amount of capital expenditures associated with the network rollout in order to support advanced functionalities. The biggest unknown for MNOs is the customer and their specific needs, as well as having a clear picture of where investments can be compensated. For Automotive OEMs, the main challenge is the standardization of a 5G-CAM applications. OEMs are familiar on how to implement standardized and regulated applications such as AEBS (Advanced Emergency Braking System), LDWS (Lane Departure Warning System), but it is unknown to them how to implement a safe, secure, and interoperable 5G-CAM application. A Common unknown reported by all stakeholders is the kind of services that might be preferred by customers and what will be the expected market penetration rate. These unknowns hinder private sector investments. Additionally, most of the stakeholders want to have a definition of liability borders of a 5G-CAM service, to have safer and accident-free operations.

Among the most important recommendations provided by the 5G for CAM stakeholders is the need for large scale validation in near operational conditions, an effort that was considered highly useful though costly. The variety of studies that target a good understanding of the business ecosystem and the driving forces behind the market was considered especially useful as well, at a much lower cost. In terms of human-centric recommendations, the wide adoption of 5G for CAM will bring about the upgrade of current skills in the workforce. In terms of deployment and investment related recommendations section, stakeholders indicated that the use of Software Architectures, SOC and AI Development, is highly desirable. Automation

is expected to require significant investment but can bring long-term benefits in terms of operational expenditures, as well as create the basis for data-driven developments in the sector.

In terms of key partnerships, the cooperation of government and road operators was always considered as significant for almost all stakeholder groups. Challenges in terms of connection loss, roaming, standardisation etc were frequently listed as important but not insurmountable based on 5G-MOBIX trial results. The work performed within the consortium corroborates the initial assessment that a proper network planning that takes into account the propagation characteristics of the border area (geography, placement of obstacles such as signs etc.) can bring observable benefits to the quality of service.
The significance of combating such challenges becomes very clear, especially since end users (such as drivers and passengers) found great value in the automation provided by advanced CAM. In a related survey, many end users responded that 5G for CAM would increase their feeling of safety and travel comfort, as well as decrease the stress level they experience while driving. Most end users were not intimidated by the new modality of travel and were willing to learn any new skill required to operate and maintain an automated vehicle. However, it is expected that 5G for CAM adoption will not immediately phase out other forms of transportation in their daily lives, since the pricing of such services remains a concern for private and commercial vehicle owners.

1. INTRODUCTION

1.1. 5G-MOBIX concept and approach

5G-MOBIX aims to showcase the added value of 5G technology for advanced Connected and Automated Mobility (CAM) use cases and validate the viability of the technology to bring automated driving to the next level of vehicle automation (SAE L4 and above). To do this, 5G-MOBIX has demonstrated the potential of different 5G features on real European roads and highways, creating and using sustainable business models to develop 5G corridors. 5G-MOBIX has also utilized and upgraded existing key assets (infrastructure, vehicles, components) allowing the smooth operation and co-existence of 5G within a heterogeneous environment comprised of multiple incumbent technologies such as ITS-G5 and C-V2X.

5G-MOBIX executed a series of CAM trials along cross-border (x-border) and trial sites using 5G technological innovations to qualify the 5G infrastructure and evaluated its benefits in the CAM context. The Project has also defined deployment scenarios and identified and responded to standardization and spectrum gaps.

Firstly, 5G-MOBIX has defined critical scenarios requiring advanced connectivity provided by 5G, and the associated features to enable selected advanced CAM use cases. The matching of these advanced CAM use cases and the expected benefits of 5G was tested during trials on 5G corridors in different EU countries as well as in Turkey, China, and Korea.

The trials also allowed 5G-MOBIX to conduct evaluations and impact assessments and to define business impacts and cost/benefit analysis. As a result of these evaluations and international consultations with the public and industry stakeholders, 5G-MOBIX identified new business opportunities for the 5G enabled CAM and proposed recommendations and options for its deployment. These have been documented in previous, preliminary deliverables of, specifically D6.1, D6.2, D6.3 and D6.4. These documents can be found in project website: (https://www.5G-MOBIX.com/).

1.2. Purpose of the deliverable

This deliverable aims to elaborate on possible new business opportunities that 5G-CAM will create. Other projects can take this deliverable as a reference in the future with its complete content. It contains customer exploration maps used to illustrate the needs of possible customers of each stakeholder, what are their customers likes and dislikes, jobs to be done, challenges, what we do not know about 5G for CAM, existing solutions and what would be game changing in the future.

In D6.2, preliminary concepts of business models for all 5G-MOBIX user stories were analysed by using the business model canvas tool. Business related gaps were identified, and recommendations were given to solve the defined gaps. Additionally, a set of questionnaires was prepared in D6.2 to use in this deliverable D6.6, to picture what the 5G for CAM business model might be, according to the understanding of major stakeholders.

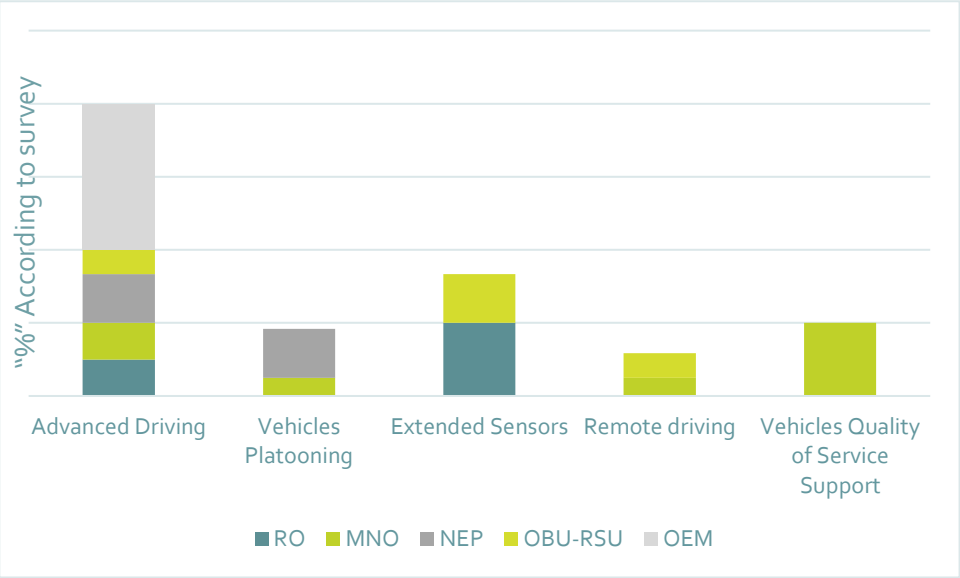
In section 3 of this deliverable, the customer exploration map tool is used to help 5G for CAM stakeholders to identify problems and challenges of their customer base and to explore possible solutions for identified problems. The consortium consulted expert opinions from 5G-MOBIX partners as well as external stakeholders. According to MNOs, the biggest challenge on 5G-CAM deployment is to try and find

justification for the capital expenditure associated with the network rollout to support all these 5G-CAM functionalities. The biggest unknown for MNOs when it comes to 5G-CAM to leverage their network infrastructure is the unknown customer. Where can the MNO compensate the cost of increasing coverage and capacity. For Automotive OEMs, the main challenge is the standardization of an 5G-CAM application. OEMs know how to implement standardized and regulative applications such as AEBS (Advanced Emergency Braking System), LDWS (Lane Departure Warning System), but it is unknown to them how to implement a safe, secure, and interoperable 5G-CAM application. Common unknowns for all stakeholders are what kind of services might be preferred by customers and what will be the related market penetration rate. These unknowns hinder the private sector investments. Additionally, most of the stakeholders want to have a definition of liability borders of a 5G-CAM service, to have safer and accident-free operations.

In section 4, a recommendation rating study is presented. In this study, 15 recommendations identified in D6.2 were classified by four different categories: Cross border corridor recommendations, human centric recommendations, deployment and investment recommendations and legal recommendations. Afterwards, these recommendations were asked to project partners from various stakeholder groups. We collected 10 answers from various stakeholder groups in our project. Then each recommendation rated from cost and utility perspective, according to the responses by the interviewed stakeholders. The most important recommendations according to 5G-MOBIX expert partners are listed in this section. According to answers to cross border corridor related recommendations, large-scale validations were consistently rated as the most important recommendation in terms of utility, as well as the most costly one in effort. The variety of studies that target a good understanding of the business ecosystem and the driving forces behind the market was considered especially useful as well, with a much lower cost. In human-centric recommendations section, "upgrade of current skills" recommendation is clearly considered the most important recommendation in terms of utility, its final score being the lowest of the four recommendations due to its being also the one considered the most costly. In deployment and investment related recommendations section, responses show that the most important recommendation regarding utility was Investment on Software Architectures, SOC and AI Development, though it was also the recommendation rated with the highest cost. On the other hand, the Cooperate for 5G Deployment was, by a significative margin, rated the lowest in cost. Though its utility was rated the lowest of the Deployment and Investment recommendations, it was only by a small margin, so it is also the recommendation with the best utility to cost ratio. According to answers to legislative recommendations, from the utility perspective the highest average value of the score is attributed to the "Creating a data economy" recommendation, with a very low deviation of both scores (utility and costs) between the partners. Furthermore, the highest ratio of utility score is marked by the data economy recommendation. From the cost perspective, the recommendation of "Determine the Best Use of Public Funds for 5G Infrastructure" has the lowest score, which makes it the most accessible recommendation from the economic point of view.

Questionnaires that were prepared in D6.2, were presented to various stakeholders and answers were analysed in section 5. In total, we collected 63 responses. Questionnaires were created from the business model canvas pillars. These pillars can be defined as "Value Proposition", "Key Resources", "Customer Relationship", "Key Partners", "Cost Structure" and "Revenue Streams". Firstly, enquires were made in terms of what the most valuable border crossing 5G-CAM service would be for each stakeholder organization. As it can be seen in Figure 1, advanced driving is the most valuable one.

Figure 1: Value of border crossing 5G-CAM Services



Furthermore, the consortium made enquiries in terms of the difficulty to integrate 5G for the CAM services in each stakeholders' operations, especially while border crossing. Advanced Driving seems to be difficult to be integrated in the operations for all stakeholders but road operators. MNOs indicate that all services will change their relationship with their customers, but network equipment providers consider that none of the proposed services will strongly change their relationship with customers. For MNOs, the main challenges identifiy were the Roaming handover, Cross-border operations, standardization, and low-coverage areas for 5G-CAM applications. For OEMs, the main challenges were Standardization, Accuracy of geo-positioning and low-coverage areas for 5G-CAM applications. For MNO vendors, the main challenge is MNO handover, but RAN optimisation and cross-border operations are also challenging. Considering OBU/RSU providers, the main challenges are MNO handover, connection loss while cross border operation, latency and Data and application-level protocol interoperability. Road operators have totally different concerns, and their main challenge is cybersecurity, and service providers consider that packet loss caused by congestion is their main challenge.

In addition, questionnaires were created to assess impact on end users such as drivers and passengers. In total we had 27 responses. As summary, the use of 5G-MOBIX service will mostly increase their feeling of safety in traffic and their travel comfort, as well as decrease their stress while driving. But when we ask them if the 5G-CAM services would affect their choice of travel mode, they all responded that they would use public transport, passenger car, walk or bicycle and taxi services as often as today, so the availability of 5G-MOBIX service will not affect their choice of travel mode. They are also somewhat concerned by the price of 5G-CAM services, but they are not afraid of their need to learn new skills or change their routine.

1.3. Intended audience

The dissemination level of D6.6 is public (PU) and is meant primarily for (a) all members of the 5G-MOBIX project consortium, and (b) the European Commission (EC) services. Intended audience is all 5G-CAM stakeholders that are at least, but not limited to the automotive industry, telecom industry, policy makers, research organisations, governmental bodies, standard developing organisations and insurance companies. Interested readers may also refer to:

- D6.5 - Final report on the deployment options for 5G technologies for CAM: Contains the technical lessons learned and recommendations stemming from the 5G-MOBIX trials. Issues of deployment planning and optimisation are reported in this document.
- D6.2 - Plan and Preliminary Report on the business models for cross border 5G deployment enabling CAM: The preliminary version of this document provides context and early assumption on the business models that can be foreseen and adopted per 5G-MOBIX user story.
- D6.7 - Final Report on the standardisation and spectrum allocation needs: Provides additional information on standardisation, as well as spectrum allocation issues in the cross-border areas.
- D6.8 - Final Report on EU Policies and regulations recommendations: Provides a description of the policy and regulation ecosystem as well as stakeholder recommendations to increase cooperation among the varied entities in the 5G for CAM value chain. Several expert interviews were performed to create an understanding of factors affecting stakeholder cooperation.
- D5.2 Report on technical evaluation: for technical information on the experimental evaluation of the technologies and deployment configurations used in the 5G-MOBIX trials.
- D5.3 – Report on Impact assessment and cost-benefit analysis: for more information stemming from the 5G-MOBIX trials on the overall impact of 5G for CAM and the cost-benefit analysis.

2. BUSINESS MODEL BASIS

2.1. Advantages & Challenges of Advanced Driving Use Cases

Four user stories from 5G-MOBIX project were selected by the consortium to provide the basis of the business model study. They were selected by the consortium on the basis of the overall technical challenge, the enhanced capabilities they provide and the increased CAM utility that makes them attractive to their users. These are:

1. **Frictionless Border Crossing:** Assisted Zero-Touch Border Crossing and Autonomous Truck Routing. These two user stories were combined to reduce the border crossing time and demonstrated in the Greece-Turkey border crossing area as part of the 5G-MOBIX project.
2. **Remote Driving Assisted Automated Shuttle/Teleoperation services:** The automated shuttle and remote driving user stories were combined as part of this use case. Though the shuttle is automated, it can request assistance from a remote operator in a complex situation. These user stories were demonstrated in the Spain – Portugal border crossing area as part of 5G-MOBIX project.

Further details for Frictionless Border Crossing use case and Remote Driving Assisted Automated Shuttle use cases can be found in the section 2.1.1 and 2.1.2, respectively.

2.1.1. Frictionless Border Crossing

This use case enables the automated transport of freight across the border between Turkey and Greece without human intervention. It requires certain pre-determined criteria to be satisfied, such as certain hardware being fitted to both the truck and the customs area, with supporting connectivity, software and potentially a dedicated crossing point where automated trucks may pass. It is possible, however, that the crossing point can be integrated for use by automated and manually driven vehicles.

The objectives of this use case are to:

- Maximize the efficiency of customs inspections by minimizing human intervention and mundane tasks leading to reduced waiting times.
- Carry out intelligent threat assessment of incoming trucks.
- Maximize the safety and security of border crossings in general.
- Enable hard border[1] crossing for autonomous trucks.

The hardware mounted on, or carried by, the truck includes:

- NFC tags attached to the goods being carried.
- CO_2 sensor – this will provide an indication of that people or animals are inside the load area.
- Proximity sensor to identify any potential obstructions or humans.
- GPS sensor to indicate the location of the truck.
- The licence plate as a truck identifier. This will be read by software associated with a camera at the customs checkpoint.
- Central Autonomous Driving Control Unit.

[1] Hard borders are areas that strictly controlled with checkpoints (e.g. Greece – Turkey and Bulgaria – Turkey). Meanwhile, borders in Schengen area are soft borders (e.g. Spain – Portugal, Belgium – Netherlands)

- Forward looking camera
- Forward looking radar

Current Turkish border gates have the following hardware in the vicinity of the customs checkpoint:

- A camera that includes licence plate recognition software.
- Thermal camera.
- X-Ray checkpoints.
- Intelligent border barrier.
- Intelligent border traffic lights.

For the use cases, additional hardware needs to be installed in the border areas:

- 3 LIDAR units to provide perception to autonomous trucks.

The combined assets and capabilities can deliver a threat assessment that automatically operates the intelligent border barrier and deliver automated driving instructions to the approaching truck. The following subsections explain the benefits at the border crossing of the capabilities that are created through the use case.

2.1.1.1. Mismatch of declared and registered information

Sensors onboard the truck read NFC tags associated with the truck's cargo and transmit the information to the customs infrastructure which compares the data with a truck manifest. Along with the license plate information, provided by the camera at the customs post, the data are checked for any mismatch. In the event of a mismatch, the intelligent traffic light will turn red, the barrier will close, and automated driving instructions will be issued causing the truck to halt at the barrier.

The advantage of this use case is that an assessment of the truck cargo can be made automatically while the truck is in motion and before it reaches the border crossing point (as indicated by the onboard GPS sensor). When evidence is provided that the cargo matches the manifest, the truck is permitted to cross and it does so without human intervention. One disadvantage is that there does not appear to be a means of determining whether additional cargo has been placed onboard the truck without any means of identification via NFC (or RFID).

2.1.1.2. Protection and safety of border personnel

The onboard proximity sensor can detect obstructions caused by people, animals, and objects. In such an event an automated driving instruction to stop the truck can be issued, thus avoiding an accident. This same feature is valuable for safety of road users in all locations and situations. This has the advantage of ensuring personal safety for those working around the customs area. Avoiding unnecessary collisions maintains uninterrupted traffic flow, since in the event of an accident, a disabled truck causes a major obstruction.

2.1.1.3. Preventing smuggling involving people and animals

Data from the onboard CO_2 sensors is used to detect the presence of people or animals in the load area of the truck. If such a detection occurs, an alert is sent to the border infrastructure which activates the thermal

camera at the customs checkpoint to confirm the presence of illegal persons or animals in the load area of the truck. If the algorithm detects that the probability of an illegal occupant or animal in the load area is above a pre-determined limit, an automated driving stop signal will be transmitted. The intelligent light will turn red and the intelligent barrier will be lowered to bring the truck to a halt for further investigation by border officials. This is an automated form of detecting people and animals where they should not be and preventing their illegal transport across the border. It is possible that the thermal camera could be bypassed by using an insulated space to prevent detection.

2.1.1.4. Legitimate operating scenario qualifying for zero-touch

In this scenario, the NFC sensor readings match the manifest, and the license plate read by the camera matches the manifest information. If the GPS sensor also indicates that the truck is approaching the border crossing point the traffic light remains green, the barrier remains open, and the truck is instructed to proceed across the border crossing point. The relevant authorization and measurements are displayed on the truck and customs information readouts.

In this scenario, the truck is enabled to pass through the customs post without by pre-qualifying as it approaches. This avoids the cost of unnecessary customs checks and the disruption it can cause to other road users. Cost savings are made by the customs operation as well as by the freight company which can minimize unnecessary stops thereby increasing efficiency and productivity and minimizing transit time.

Figure 2: Long waiting queues on GR-TR border

2.1.1.5. Challenges and benefits

Within 5G-MOBIX, the user story was trialled at the GR-TR cross-border corridor, which is situated at the south-eastern region of the European Union. The location constitutes a challenging geo-political environment due to the transport of goods essential for the European economy, while it is further characterized by rigorous border checks that worsen the already heavy and heterogeneous traffic, especially during the high-traffic touristic seasons. According to a recent study [1], a large portion of the time of international transport is wasted at European border crossing in south-east Europe, significantly raising the cost and delivery time of goods and contributing to the segmentation of international logistics. The study has shown that on average most border crossings take between 30 and 60 minutes but can easily surpass 90

minutes depending on traffic conditions and other factors (counting both waiting and procedural times). The largest portion of this delay is attributed to inefficient flow of information regarding the necessary documentation (33.4%), custom agents' inefficiency (21.9%) and lack of necessary infrastructure and equipment (21.3%). Since border control cannot be abolished due to security and smuggling concerns, improving the average control time by addressing the weak points of the process can significantly benefit the transport and logistics industry, and can greatly reduce both the time and cost of international transportation of goods.

In order to decrease the time spent at the borders and to avoid lines of trucks, which can extend up to a few kilometres, a new system is deployed at the borders of Turkey as confirmed by Trade Minister Ruhsar Pekcan [2]. The goal is to equip customs administrations with technological facilities, which will result in uninterrupted and quicker international trade operations at the customs. To serve this purpose, the "Transit Vehicle Tracking Program" is designed, which will allow the border gates and customs administration to get quick information on trucks and incoming vehicles beforehand, cutting the times spent at the gates.

Through an early effective risk analysis, it will be possible to intervene with respect to vehicles that are likely to be involved in smuggling or have already been involved in other illegal acts much more quickly. This will also ensure a more effective usage of the personnel. Despite the ongoing efforts to solve the issues observed at the border gates (as this example demonstrates), there are no measures yet to include automated and connected mobility in the system designs or cooperate with other countries, organisations, or authorities to share information about possible suspects that might require closer inspection at the borders by the customs personnel. However, the "Transit Vehicle Tracking Program" of Turkey supports the market need for a service such as the one envisioned in the "Assisted Zero-Touch Border-Crossing" and "Autonomous Truck Routing" user story.

The cost savings generated for logistics companies would need to be set against the additional cost of equipping their vehicles, operation of the system and any training required for drivers, administrators etc. Significant savings stand to be made and include faster transit times, reduced costs due to trucks sitting idle for shorter periods, reduced driver costs, reduced spoilage of fresh produce and lower fuel cost for both the truck and refrigeration unit.

It is also clear that without autonomous truck routing applications, autonomous vehicles cannot pass from border gates since autonomous systems cannot easily handle such manoeuvres in similar complex, crowded environment and 5G is the key element for autonomous truck routing because of the need for massive transfers of perception data between the infrastructure, the cloud, the customs and the trucks.

It is also possible for the customs authorities to enjoy significant financial savings, due to the better use of resources and improved scheduling. Safety for individuals in the border area and automated risk assessment of trucks are expected to improve as well. Further societal benefits should accrue, including reduced congestion and pollution as well as the benefits of freer trade between countries.

Besides all these benefits, this use case also has its own challenges:

- Other truck drivers might try to manipulate autonomous vehicles in customs area. The system must be designed for such misuses.

- Additional education for customs officers is needed (such as basic autonomous vehicle awareness trainings, system explanations, what to do if system fails etc.) to get the full benefits of autonomous truck routing and assisted zero touch user stories.
- If an autonomous vehicle breaks down in the area, a fast fix is needed. This must be guaranteed by the fleet owners or automotive OEMs.
- NFC tags, CO_2 sensors are open to manipulations. Certain companies provide more trustworthy equipment, but governmental bodies might need to define a new regulation for autonomous border crossing.

2.1.2. Remote Driving Assisted Automated Shuttle (Teleoperation Services)

In this scenario, the autonomous EV is driving along a defined route according to its map and suddenly an obstacle appears in its path blocking the original route. In this situation, the vehicle, after waiting a few seconds and observing that the obstacle does not move away, sends a warning signal to the fleet control centre located several kilometres away. At the control centre, an operator receives this alarm and makes the decision to take control of the autonomous EV remotely or to issue a set of new navigation commands to manage a new route. The operator is in a control centre, supervising one or several autonomous vehicles.

Interaction between cross-border cities is relevant from the point of view of the socio-economic development of the regions. Cross-border municipalities developed mobility solutions to improve mobility between international cross-border regions. In the case of the cross-border municipalities ES-PT, Valença and Tui, they have a combustion tourist train that runs through the historical centre of these two cities. The service is operated by a driver. The train runs between the two cities with a defined frequency (12 trips per day, 6 in the morning and 6 in the afternoon with one shuttle with maximum 40 passengers per trip). In the European context, tourism is the main reason for people to visit two cities in neighbouring countries. However, at this point of the border, the exchange of workers and trade is vital for the development of both cities, so the purchase of goods or services or work are other reasons for crossing a border.

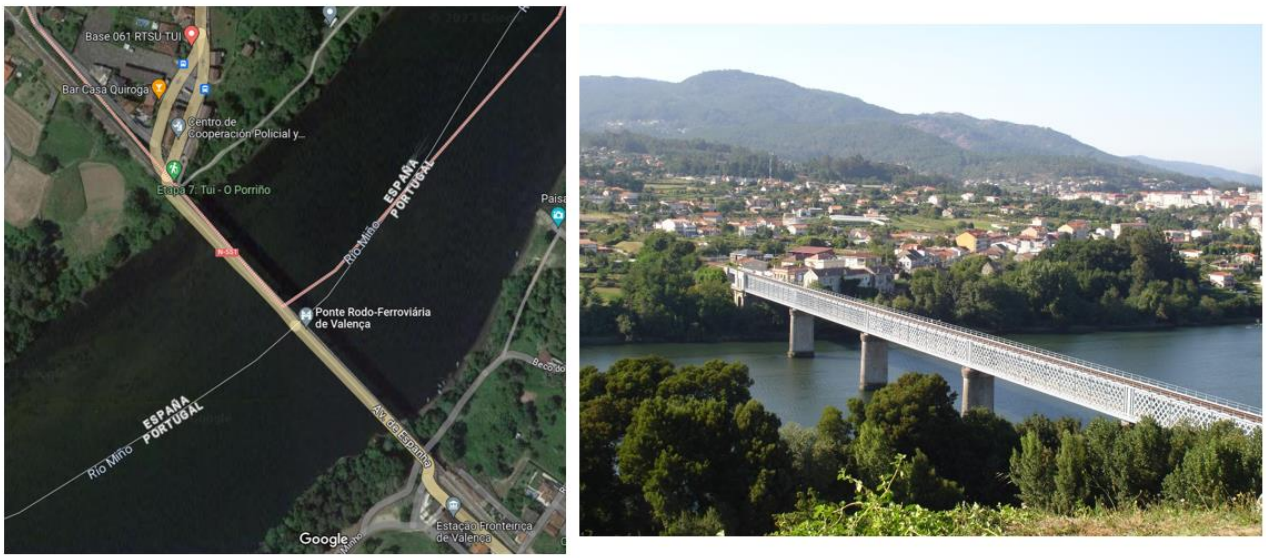


Figure 3: Remote Driving Assisted Automated Shuttle demonstration location on the Spain – Portugal border

Tui and Valença join the Galician axis A Coruña-Ferrol and Vigo-Tui with the Portuguese axis. The impact of this link is so significant that Tui-Valença is the largest point of communication in vehicle transit between Spain and Portugal, surpassing the Madrid-Lisbon link or traffic to Europe via the IP5. Only the links of Vilar Formoso and Fuentes de Oñoro or Badajoz-Caia are slightly ahead of Tui in terms of heavy vehicle traffic, as it is the gateway for Portuguese exports to Europe.

Figure 4: Current means of transport with combustion engine and need for a chauffeur

A few facts to give you an idea of the situation in both municipalities.

On the Spanish side (Tui):

- The area of influence of the city of Tui on the surrounding territory comprises a population that reaches 131,922 inhabitants with the statistical data of 2019.
- Tui has one of the most interesting historic centres in Galicia and the second largest in our Autonomous Community. The historic centre of the city of Tui has been declared, since 1967, as an asset of cultural interest, with the category of historical site.
- One of the main dynamics of development in tourism in recent years has been the presence of pilgrims on the Portuguese Way of St. James. Tui is the place of confluence of the Portuguese Jacobean routes in Galicia.
    - In 2019, according to data from the Pilgrim's Office of the Cathedral of Santiago, a total of 72,357 pilgrims made the Portuguese Way, representing 20.81% of all pilgrims who came to Compostela.
    - In 2022, according to the data provided by the Pilgrim's Office of the Cathedral of Santiago 93,184 pilgrims were registered in Tui, representing 21% of the pilgrims who arrived in Compostela in the Holy Year 2022 (438,323 pilgrims). These data consolidate the Portuguese route that enters Galicia through Tui as the second in number of pilgrims.
- The positive impact of the constant increase in the number of tourists and visitors together with the significant rise in the number of pilgrims has led to a significant increase in the number of tourist

accommodation establishments and, consequently, in the number of hotel beds in our municipality, with a total of 1,072 beds (source: REAT of the Galician Tourism Agency, October 2020).

- On 11 November 2020, the provisions of Article 9 of Law 13/2006, of 27 December, about business hours in Galicia, authorised the opening all year round, including Sundays and public holidays, from 10:00 a.m. to midnight. 00 to 24.00 hours.

On the side of Portugal (Valença):

- Valença is a major touristic spot in northwestern Portugal. It's main attraction is the historical Valença's stronghold, a fortified village classified as national monument since 1928. It attracts tourists and holiday makers from all northwestern Portugal and southwestern Galicia and beyond.
- Like Tui, Valença is an important point of passage for pilgrims in the Portuguese Way of St. James. The above mentioned 93,184 pilgrims registered in Tui in 2022 all passed through Valença and crossed the historical international bridge. It is estimated that 25% of pilgrims don't register as such, so the number of pilgrims passing through Valença may be as high as 120,000.
- The increased touristic interest has led to a rise of accomodations. According to Pordata, there were 248 beds in Valença in 2021. 25,2% of guests staying in Valença during the same period were foreigners, clearly showing the international impact of the town.

Figure 5: Remote Driving Assisted Automated Shuttle.

Regarding the impact on socio-economic aspects of a remote driving functionality for the autonomous EV, some factors should be taken into account because of the high importance and deep repercussion they have. These are detailed in the below sections.

2.1.2.1. *Increased Accessibility*

Remote driving allows for improved accessibility in transportation services between cross-border municipalities. It can provide a reliable and convenient option not only to take the control of the vehicle, but also to stablish a communication channel between passengers and the fleet management center in case of eventuality, incrementing the accessibility for those people who don't know what to do in those situations and enhancing the comfortability and sense of security for individuals.

2.1.2.2. *Enhanced Safety*

With a human operator remotely controlling the autonomous vehicle, the level of safety can be significantly increased. The operator can intervene and take control of the vehicle in complex or challenging situations where the EV ask for human input. This added layer of human oversight can help mitigate risks and ensure passenger safety.

2.1.2.3. *Job Creation*

The operation of remote driving services requires a skilled workforce to operate and monitor the fleet management center. This can lead to job creation in areas such as vehicle monitoring, remote driving operators, maintenance technicians, and customer support personnel. The establishment of the fleet management center can contribute to local employment opportunities and economic growth.

2.1.2.4. *Cross-Border Cooperation*

The use of remote driving technology for cross-border transportation services promotes cooperation and connectivity between different municipalities and countries. It can foster closer ties, economic integration, and encourage collaboration in areas such as regulation, infrastructure development, and standardization, which can have broader socio-economic benefits beyond the specific use case.

2.1.2.5. *Economic Efficiency*

Remote driving can potentially lead to improved economic efficiency in cross-border transportation services. The autonomous EV can be optimized for energy consumption and operational costs. Additionally, the remote driving functionality allows an efficient fleet management, optimizing routes and its supervision, which can result in cost savings and improved resource allocation.

2.1.2.6. *Technological Attraction*

Implementing remote driving in this context can contribute to technological advancements in autonomous vehicle technology, remote control systems, and connectivity infrastructure. These advancements could have an attractive component for industries or people in order to explore the region for touristic or business opportunities related to this field of knowledge or kind of experience.

2.1.2.7. *Challenges and benefits*

Overall, the remote driving use case for an autonomous EV providing a service between two cross-border municipalities offers various socio-economic benefits, including increased accessibility, enhanced safety,

job creation, cross-border cooperation, economic efficiency, and technological attraction. These benefits contribute to a more connected, sustainable, and efficient transportation system while stimulating economic growth and improving the quality of life for individuals in the region. Additionally, this solution could enable a Level 4 automated bus to be used on the route with remote human intervention being available where the robotic system is unable to provide full control. While not adopting full Level 5 automation, this helps to progress the technological solution while minimizing costs and providing a frequent scheduled service to support travel between Porto and Vigo for purposes such as tourism, employment, and commerce. While providing a 'fail safe' backup for a Level 4 vehicle, this system has the potential to be overwhelmed if obstructions are detected on several vehicles simultaneously, and there are not enough operators to address all of them at the same time. This could lead to delays while buses wait for an available remote driver.

For both use cases described above, it is essential that vehicles have uninterrupted connectivity as they pass through the border crossing, without any latency as a result of the potential changeover of supplier as the vehicle switches between telecom providers in each country. This may be easily resolved in the case of a multinational MNO, where the contract can cover more than one country however where a provider operates in a single country the process can be complex.

One potential solution to this issue is for a single MNO to provide a service for users in a defined area close to the border crossing. Generally, border crossings are sparsely populated and consequently have low-capacity networks so it would mean significant investment in infrastructure for the purposes of remote driving, automation, and customs processes. Regular users of the border could subscribe to that service, either directly or via their usual service provider which in turn has an agreement with the MNO investing in the infrastructure.

A service would be offered to those that wish to utilise the process, providing priority access to the network to ensure high capacity, reliability, and low latency. This is a premium service that would be offered to logistics providers and / or bus operators, who would have priority access to the network in the defined area. Capacity management will be key to ensure that the network does not become overwhelmed by other users in times of high demand however issues such as user location would need to be considered, as GDPR may prohibit companies from tracking the location of users.

Another option would be for users to use devices with two modems and two SIMs so that when they are in the area that is served by the overlapping networks of two operators (in adjacent countries) they can be connected simultaneously to both. Agreement would be needed between operators, to provide a similar level of service to a customer as they move from connection to one operator, into the 'overlapping' area, and finally to the second operator only.

2.2. Market Analysis

2.2.1. Frictionless Border Crossing

The market size for automated border control is expected to grow at an increasing rate till 2027 (Compound Annual Growth rate of 16.25%, multiple times EU's average growth[3]), according to a report by Mordor Intelligence [4]. MarketsAndMarkets estimates a CAGR of 13.3% reaching 3.9 billion USD until 2028 [5]. The Automated Border Control Market is segmented by Type (ABC E-gates, ABC Kiosks), Offerings (Hardware, Software, Services), Application (Airports, Land ports, Seaports), and Geography (North America, Europe,

Asia Pacific, Rest of the World). The market sizes and forecasts are provided in terms of value (USD million) for all the above segments. Mordor cites the following reasons for the projected growth:

- Rising country threats and terrorist attacks have diverted the government attempts in numerous regions toward improving the implementation of public-safety technology.
- Increased automation in ports, airports and other points of travel to address security concerns. An integrated border crossing can help reduce travel times, increase security and safety, and increase traveller comfort.
- Global rise of corporate travellers, means more traffic in border crossings.
- The COVID-19 pandemic has compelled infrastructure operators to utilize zero-touch technologies.

When seeking to find alternatives for frictionless border crossing it is apparent that there is little to compare directly with the 5G-MOBIX solution and use case outlined above however there are alternative proposals and systems in place that seek to facilitate zero-touch border crossing and could conceivably be integrated into a system to enable autonomous trucks to cross borders without stopping.

2.2.1.1. 'Smart Border' crossing between Sweden and Norway

Norway is a member of the European Economic Area (EEA) however it is not part of the European Customs Union which means that the Sweden-Norway border is also the EU's external customs border with requirements for customs controls.

There are more than 80 crossing points along the border with only 14 of them having customs offices (Policy Department for Citizens' Rights and Constitutional Affairs). It is considered by some to be the world's most advanced customs crossing as it uses all the basic modern components of the international standards from the World Customs Organization and is fully compatible with the World Trade Organization Trade Facilitation Agreement. The system has also been operationally tested for four years along the border.

The system allows for exports and imports by companies that are part of each country's Authorized Economic Operator (AEO) programmes that grant AEO status to companies that meet a set of defined criteria and is recognised in all EU member states. AEO status grants certain customs benefits to members such as fewer physical and document-based controls and prior notification for physical and customs controls. Sweden has 289 companies under AEO classifications and Norway has 27. There is a high cost associated with gaining AEO accreditation and for many companies the benefits are not sufficient justification. In addition to AEO, transport permits can be issued by both Swedish and Norwegian customs, which allow goods to be transported across borders, based on a few conditions, including the submission of electronic-only declarations.

Both countries require the provision of a summary declaration (i.e., pre-arrival information) at least one hour prior to arrival at the border. This means that most goods can be cleared on average within 3 – 9 minutes, although it is likely to be longer during peak periods. A risk-based approach is taken which means that most vehicles can clear customs without documentary or physical checks.

Heavy investment has been made in technology to enable the shared operations. Pre-arrival information and declarations are submitted electronically (without supporting documents) and are visible to both customs agencies to facilitate clearance at a particular border crossing.

Automatic Number Plate Recognition (ANPR) cameras are used at border crossings where no customs post is present, and they have been used to identify suspicious vehicles and detect violations. ANPR is linked to a national registry to enable checks and Norwegian customs plan to integrate ANPR into their systems to allow goods vehicles to cross the border without stopping if they have submitted a declaration and been cleared.

The system has benefited from intimate cooperation between the two countries, with agreement that each may carry out customs controls on the others' behalf. The declared goods must pass through a customs location and information is shared between each country's customs authority. This allows some border posts to be manned by only one country's customs authority.

2.2.1.2. Border between Canada and the United States

Although USA and Canada are members of the The United States-Mexico-Canada Agreement (USMCA), they are not part of a customs union so goods crossing the border are subject to customs procedures. The two countries have the world's largest bilateral trade relationship by value and their economies are highly integrated. The border is nearly 9,000km long and has 120 land ports of entry between them with an average of more than 570,000 two-way truck crossings each month, and the Ambassador Bridge between Ontario and Michigan carrying an average of 390,000 vehicles per month. (Policy Department for Citizens' Rights and Constitutional Affairs)

With such a high flow of people and goods across the border it is important that low-risk goods are cleared and allowed to pass quickly and that is achieved by the Free and Secure Trade program (FAST). To be eligible, manufacturers, importers, exporters and carriers must be accredited under the US Customs and Border Protection's (US CBP) Customs-Trade Partnership Against Terrorism (C-PAT) and the Canadian Border Service Agency's (CBSA) Partners in Protection programme. These are each country's respective trusted trader programmes, similar to the European AEO programme.

The dedicated FAST lanes are at four border locations and, based on pre-arrival information the carrier is sent a barcode which is scanned on arrival at the border. The benefit of participation is a reduction in time spent at the border of up to 81%, which means 15.6 minutes versus 81 minutes in the regular lane.

The Canada Customs Self-Assessment Programme is for low-risk goods and is available to both importers and carriers. Drivers must be approved under the FAST programme or Canada's Commercial Driver Registration Programme (CDRP) and can use the FAST lane at border crossings.

Both countries use eManifest programmes for compulsory pre-arrival information from carriers. Information must be submitted at least one hour in advance of arrival at a land border, or thirty minutes for FAST members. Again, a barcode is generated for use at the border. Commercial information can also be submitted in advance. In the USA the system is called US Pre-Arrival Processing System (PAPS), and in Canada the Pre-Arrival Review System (PARS). After information is submitted the customs broker, importer or carrier attaches a barcode to the commercial documents which is then scanned at the border.

ANPR technology is used at the border to identify the truck, driver, and information on the cargo. PARS/PAPS documentation and/or eManifest documentation is then also scanned and information on release or further inspection is provided to the border staff.

Both countries' authorities provide waiting time information at the major crossing points. In 2013 average waiting times at three major crossings for trucks into the USA were between 18.9 and 27.1 minutes, and for Canada between 16.8 and 17.6 minutes.

Clearly both systems above have reduced waiting times significantly at the borders however they fall short of automated truck routing and require a degree of human interaction. There is potential however to integrate them both into an automated system, similar to that demonstrated in 5G-MOBIX.

2.2.2. Remote Driving Services

Though remote diagnostics make up for a significant market size, there are no data for the projected size of the market for remote driving at the moment. Market studies for automated vehicles do not make a distinction between fully automated or remote operated vehicles. The teleoperations market was estimated as little over 400 million USD in 2022 and projected to increase to more than 4 billion by 2033, with a CAGR of 24.3% according to Persistence Market Research [6]. However, the report does not distinguish between robotics and electric vehicles. Known examples of vehicle teleoperation services follow below.

2.2.2.1. DriveU.auto

This service enables the teleoperation of vehicles via high-capacity connectivity and a software platform. It delivers ultra-low latency streams of high-definition video and audio to remote teleoperators and claims the best latency performance using proprietary dynamic video encoding and cellular bonding technologies (5G-Blueprint Consortium 2020 - 2023, 2022). The platform can be sold as a software-only solution or complete with all the computing and sensing hardware. The company cites fleet operators, OEMs and Tier 1s as target customers. The company's website describes their product being used for multiple applications including road vehicles, robots, off-road machinery and logistics yards and warehouses.

2.2.2.2. Designated Driver

The proposed product here is a system that can be integrated into any vehicle to enable teleoperation (5G-Blueprint Consortium 2020 - 2023, 2022). It can be obtained in several formats including a white label remote-vehicle control unit including driver and station and in-vehicle teleoperation software and hardware components. It can also be integrated into existing on-board sensing and computing hardware and can be integrated with fleet management software. The company also offers teleoperation as a service with certified remote drivers and can also help to integrate components into existing vehicles. In 2019 Texas A&M University announced that they would use Designated Driver's software to provide remote assistance and operation for its autonomous shuttles as a 'safety net' in situations such as challenging road conditions or sensor failure.

Visteon published a white paper describing how Designated Driver's software was integrated into their own open platform autonomous driving platform as part of the 'Highway Pilot' project in 2019 (Designated Driver and Visteon). In this demonstration the vehicle (an Audi A6) was being driven remotely from Portland Oregon USA, around a public road in Karlsruhe Germany, using a combination of Visteon's ADAS software and Designated Driver's teleoperations stack. The remote driving capability was relied upon to navigate the more complex sections of the route and was used to augment the autonomy system. It was found that it allowed fleet monitoring capability, including distributed live video and real-time diagnostics.

Both systems, and others that were researched, can be considered still to be in the development stages however they are finding real-world applications in off highway settings such as mines, and robotic delivery. Large scale commercial applications are still some way off.

2.3. Value Network Map of Advanced Driving Use Cases

2.3.1. Frictionless Border Crossing

The first value network represents the relationships involved in operating the Frictionless Border Crossing use case capability as described above. Figure 6 shows the key stakeholders, with groups aligned with industries and activities, as well as the customs operation and the necessary suppliers. This diagram focuses on the necessary stakeholders for zero-touch border crossing as far as possible.

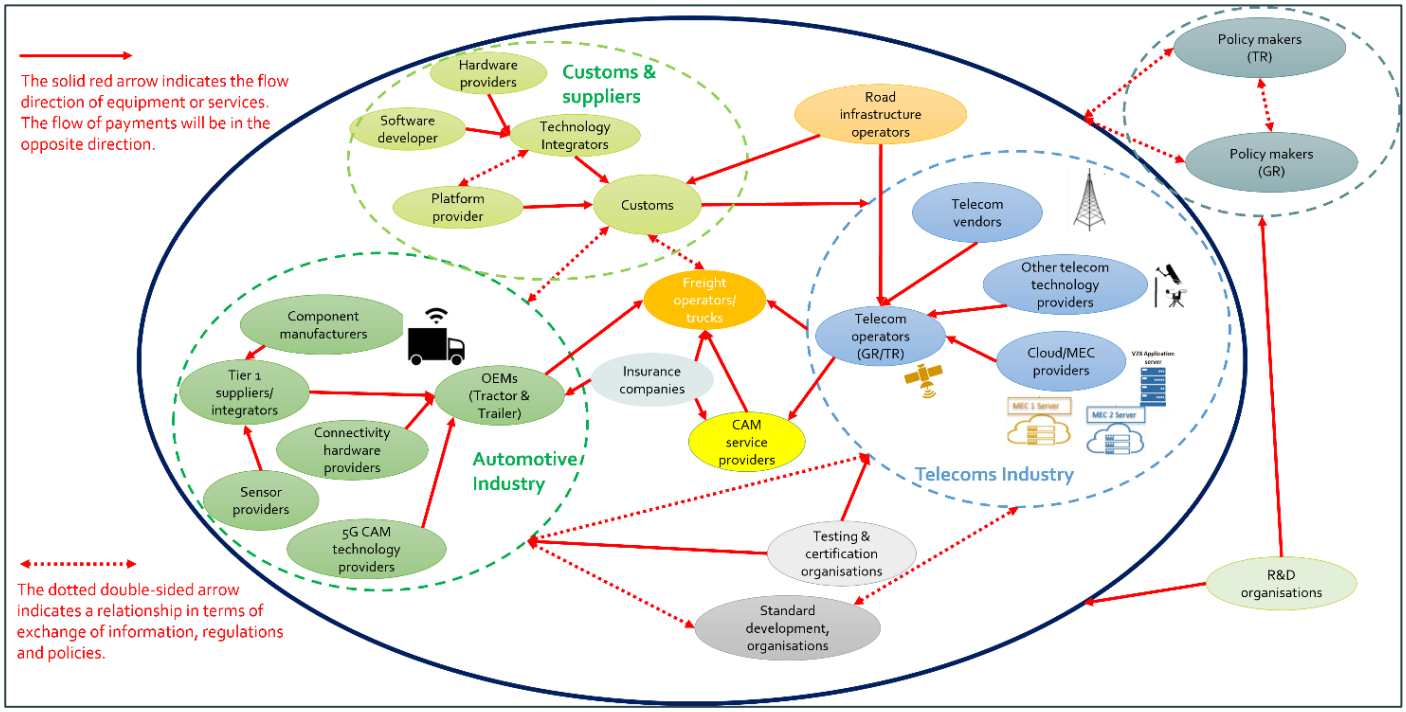


Figure 6: Value Network for Zero-Touch Border crossing and Autonomous Truck Routing

Automotive industry:

- In the traditional automotive industry component and sub-system manufacturers supply Tier 1 companies, which integrate them into higher-level systems and in turn supply the automotive OEMs, which in this case would be truck unit and trailer manufacturers.
- For CAM trucks the traditional supply chain is extended to include the providers of 5G-CAM related technology. Examples are the HD map providers and the providers of on-board sensors and telecom units. This includes all the hardware and software suppliers, together with all the relevant supply and logistics chains. In addition, for the process of automated border crossing, additional items such as dedicated sensors (NFC tags and readers, CO_2 sensor, proximity sensor, LIDARs etc.) will also be needed.
- Collaboration with the customs and telecoms industries will be necessary to develop effective capabilities in terms of automated border crossings.
- It is assumed that the vehicles (tractor units and trailers) will be provided directly to the freight operators, however, it could be via leasing or rental companies.

Customs & Suppliers:

- Hardware and systems are needed to transmit data from LIDARs and NFC tags, detect the presence of people, obstructions, and animals etc. in the vicinity of the border crossing.
- Individual component and subsystem providers will supply technology such as thermal cameras, intelligent signs etc. will supply a technology integrator who, working with a platform provider, will create the system that evaluates individual truck risks, detect position, and autonomously control vehicles in the customs area.
- The customs operation in each country will purchase internet connections via which the system operates for consignment booking (by freight operators) and real-time control of vehicles.

Telecoms Industry:

- The relationship with telecoms industries will be similar to that which is needed for CAM and will involve little additional involvement beyond provision of a secure, reliable connection between the network and automated vehicles, as well as access to the internet for the operation of the platform and consignment booking.

Table 1: Project stakeholders for roles within the Zero-Touch Border Crossing and Autonomous Truck Routing use case

		5G-MOBIX Project Partners	Role
Automotive Industry	OEMs	Ford Otosan	Providers of Connected and Instrumented Trucks for Autonomous Truck Routing and Assisted Zero Touch
	Onboard technology and IoT	WINGS, Ford Otosan	Provider of onboard IoT sensors, developer of software and AI
Customs & Suppliers	Hardware, software, and controls in the vicinity of the customs crossing area	WINGS, Tübitak	Provider of software, data fusion at the edge, Hardware, AI-enabled platform
		IMEC	5G modem provider
Telecoms industry	MNOs	Turkcell, Cosmote	Provision of spectrum and hardware used in the cross-border scenario
	Cloud	WINGS, Tübitak	Cloud that performs required calculations for automation functionality

2.3.2. Remote Driving Assisted Automated Shuttle

The second value network map represents the stakeholders and their relationships for the remote driving assisted automated shuttle use case. Figure 7shows the value network for autonomous driving however it also includes the addition of a control centre from which the remote driver(s) operate.

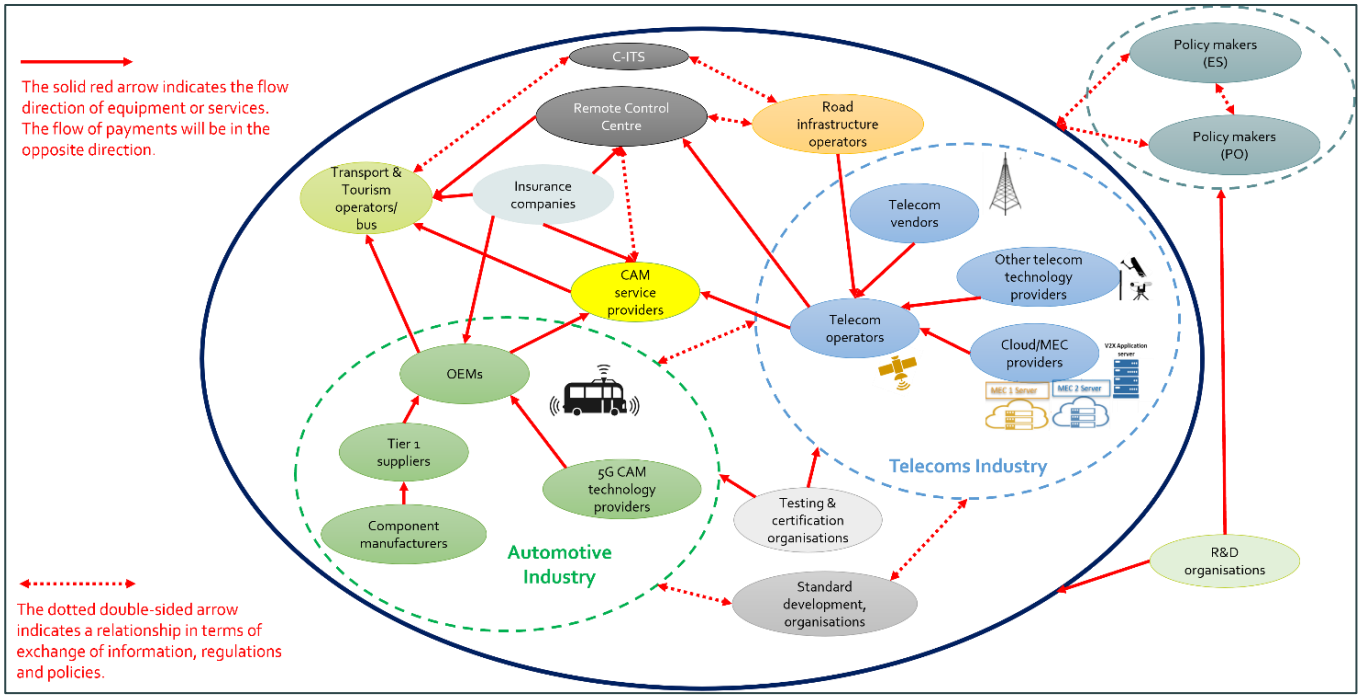


Figure 7: Value Network for Automated shuttle and remote driving

Remote Control Centre

- The remote-control centre could be a discreet service or owned by one of the other actors including the bus operator or tour company. It will operate a commercial arrangement with the bus operator, which will entail a remote driver taking control of the bus when it encounters a situation that the autonomous system is not equipped to deal with. As the remote driver will be in control of the bus they will need to be insured.
- Data exchange between the road infrastructure operator and the remote-control centre could contain information regarding current and foreseen issues (for example road works) enabling effective scheduling of resources.
- Interaction between the bus and transport operator and the C-ITS ensures that the latest map is always used. Roadworks or other obstructions can be reported ahead of time. Sensors on the bus can return data about the obstruction or delay as the bus is being remotely driven, ensuring maps are updated in real time.

Telecom operators:

- Similarly, to other user stories, the telecom operation supply chain remains relatively unchanged. Telecoms hinge on the supply of necessary equipment from vendors, to be rolled out as part of the telco operator's network.
- The telco operator's obligation is to provide adequate coverage as per their rules of their spectrum bids, as well as adequate QoS according to the SLA agreements established between the different entities in CAM and ITS. For fully automated cases or for remote driving, the QoS requirements can become more stringent.

Project stakeholders are listed on the table below:

Table 2: Project stakeholders for roles within the Automated Shuttle and Remote Driving use case

		5G-MOBIX Project Partners	Role
Automotive Industry	OEM	C-TAG, ALSA	Although not OEMs these partners prepared the test vehicle
	5G CAM Application Providers	A-t-Be, DEKRA, Catapult, TNO, VALEO, VEDECOM, VICOMTECH	Providers of On-Board Units, HD Maps, integration between 5G and other V2X technologies, software tools
Telecoms Industry	Infrastructure devices	C-TAG, Nokia Spain, Nokia Portugal	Provided the infrastructure devices used in the demonstration
	MNOs	Telefónica, NOS	Spanish and Portuguese MNOs
Road Infrastructure Operators	Road infrastructure management	DGT, Infraestruturas de Portugal, IMT, Norte Litoral	Road management, closures and securing authorizations

3. BUSINESS MODEL ANALYSIS

3.1. Finding Gaps from a Business Case Perspective

A successful business case for the 5G-enabled CCAM will only be achievable with the proper development and formalization of the horizontal working topics. Finding the gaps in the relationships between the various stakeholders and highlighting the components required to make the business cases feasible is crucial for realizing the anticipated new business prospects made possible by CCAM. The autonomous vehicle's safety and security assurance certification is one of the most critical issues because it necessitates the whole technical chain's homologation, including the vehicle, network, cloud, and application. The homologation of independent autonomous vehicles is already a significant issue, particularly for those driven by artificial intelligence. In order to ensure interoperability across MNOs and vendors for V2X functionalities, there will need to be a certain amount of standardization, especially when considering the vehicles' cross-border/frontier operation.

Another critical gap that needs to be filled is the liability issue. It will be required to determine each stakeholder's obligations in the safety of V2X systems in the event of an accident, and the most significant problem is how responsibility will be distributed between MNO and the vehicle OEM. With the development of high-level autonomous vehicles and remote driving, it is expected that defining accountability will become more and more challenging. Clear laws that govern the division of responsibilities and call for the

appropriate processes to evaluate the veracity of claims are necessary to support the development of the business model. In order to create a successful business model, new regulations are also required in the field of communication. Regulations will be necessary to ensure that infrastructures are being upgraded and compatibility is maintained since the V2X infrastructure must support vehicles roaming independently and guarantee the coexistence of V2X technologies and interoperability.

The other important issue is the entitlement to the data. The General Data Privacy Regulation (GDPR) must be adhered to when storing data because of the importance of the infrastructure, which requires regulators to develop protective regulations and enforce compliance. The EU Data Governance Act is a major step in this direction. The coordination between different MNOs is another important challenge that needs to be solved to create a business model for TO applications. In order to ensure high availability of the entire system end-to-end, network sharing has been recognized as a potential option; however, this presents several issues in terms of liability. Additionally, it will be necessary to divide the revenues according to each MNO's level of investment and the infrastructure's quality. In addition to these, problems arise from the non-standardization of the technology to be used in TO scenarios. Vehicle makers can enable inter-vehicle communication using alternative technologies such as C-V2X and IEEE802.11p. It is feasible that various vendors will utilize different technologies since regulations do not mandate adopting one of the technologies. This will lead to coexistence issues and hence market uncertainty.

3.2. Business Model Options for Connectivity

The logistics industry has the potential to reduce costs, which might increase demand for CCAM applications; however, the viability of the adopted business models is still up in the air. Thus, it is still challenging to make a business case. Although the current 4G/LTE mobile network standard may not meet the business model requirements for high network reliability, this is subject to change given the promise of the 5G mobile network standard, which would significantly reduce latency and improve reliability. The quality of service (QoS) of 5G-MOBIX solutions, which include cooperative overtaking, highway lane merging, truck platooning, valet parking, advanced driving in urban environments, road user detection, vehicle remote control, see-what-I-see, HD map update, media & entertainment, can enable seamless service along the route where the vehicle is connected. Adopting new business models for CCAM will aid in the identification of suitable finance plans, income distribution, and procurement models for 5G-enabled transportation systems.

3.2.1. Business Models for the Responsibilities of Governance and Connectivity

Cross-border 5G Continuity: In order to provide ongoing remote operation, MNO coordination in the form of roaming is necessary; yet, service continuity is a problematic issue, with handovers frequently leading to protracted service outages. TO service providers can ensure redundancy by entering into concurrent contracts with two telecom operators' providers to address this problem when a vehicle crosses the border. On the other hand, the dual SIM/modem is an unfavourable and subpar solution in the long run. Although there are templates for roaming contracts, seamless roaming necessitates expanding these business contracts.

Cross-border handover can be difficult for an operator that focuses on a single country because it necessitates technical and administrative coordination with numerous other operators. The fact that this effort takes the shape of a particular service justifies charging more to recoup the costs of the endeavour. Operators having a presence in multiple nations find it easier because they can essentially internalize this

work. For this reason, it is necessary to develop different business model alternatives, considering the operators' properties, such as the size of the service area.

Business model 1: Cross-border 5G Continuity within the Coverage Area of one MNO

In this scenario, legal processes are relatively easy compared to the latter scenario, as ensuring 5G continuity and handover is a problem that a single operator will solve internally. The traffic needed for TO scenarios typically calls for many users in a small region to have the reasonably high uplink capacity, high reliability, and low latency. For example, in the platooning scenario realized by 5G-MOBIX at the Turkey-Greece border, the uplink/downlink capacity difference may become a problem when the number of vehicles increases, as the information obtained from the sensors of the front vehicle is transmitted to the vehicles behind. On the contrary, the uplink capacity requirement of the extended sensor application is considerably higher than the required downlink capacity. Therefore, a flexible approach to the distribution of uplink/downlink timeslots for the TO service providers is needed to provide absolute data rates capable of supporting critical applications. Since the scenario includes a single MNO, the issue of how to negotiate infrastructure costs is not an issue. However, if infrastructure installation or improvement is required, especially for TO applications, how these costs will be reflected to which stakeholder is one of the important problems that need to be clarified.

Business model 2: Cross-border 5G Continuity within the Coverage Area of Multiple MNOs

In this scenario, different MNOs with different coverage areas only slightly overlap at the borders. This scenario is much more complex than the previous one. First of all, there should be a reciprocal roaming agreement between the two MNOs since both MNOs will be providers and customers to each other, which means that operators must exchange service characteristics among themselves and correlate the interpretation of the characteristics in the visited network. There is more than one solution to obtain continuity over the cross-border. The first is to use two networks simultaneously using multiple SIMs/modems. This scenario allows the connection to be maintained without needing a roaming agreement. However, there are more efficient methods considering the need for multiple SIMs and the scenario spread over a large area to cover more than two MNOs. The other solution is applying the handover between networks. Although handover is a more flexible technology that can work with a single model/SIM, it involves a more complex process in terms of agreements between MNOs. The configuration items on both sides of the border need to be brought into sync by both networks. Since these charges will increase the price of maintaining a roaming connection, a settlement method that pays for these efforts must be created.

5G Connectivity as a Service: 5G connectivity needs to provide some KPIs such as throughput, latency, connection density, reliability, positioning accuracy, coverage, and availability for successful implementation of TO scenarios. In order to obtain this infrastructure, MNOs need to do a lot of investment and infrastructure deployment or development. One crucial necessity to agree on will be who carries whose charges and where the money streams must be delivered in the case of border crossing vehicles. Infrastructure investment and service charging by MNOs is an unregulated issue for TO scenarios. It is still being determined who would pay the MNO for a SIM card or a subscription. The general trend has been to charge the automotive manufacturer for the cost of connectivity by adding these charges to the price of the initial vehicle and averaging connectivity costs across the entire fleet of vehicles. MNOs provide connectivity for automotive OEMs in a wholesale, B2B2C manner for automotive use cases. The expenses linked to the investment will need to be spread among many parties; consequently, the middlemen models are ideal for TO applications. Although the MNOs' direct clients are the OEMs, premium connectivity can be an option for people who buy vehicles with different subscription options in order to ensure the continuity of income.

Business models in which a connection subscription is acquired and paid directly by the final consumer are also viable to maintain the negotiating power of MNOs with end users. Although just a few OEMs currently offer monthly subscriptions to end users for connectivity services, it is anticipated that more OEMs will adopt this model in the future despite opposition from end users. In order to increase this rate, MNOs need to expand the service content, integrate performance parameters into service options, and take action to encourage users to subscribe to these services. Besides, MNOs can provide infrastructure as a service, including cutting-edge local/regional cloud computing services and related connectivity, for multi-MNO scenarios. Moreover, continuous mobile network coverage alongside roads would be necessary for such services to be delivered as efficiently as possible. By facilitating access to passive infrastructure, road operators can help to achieve this coverage.

3.3. Business Model Options for Automotive OEMs

Automotive OEMs (OEMs from now on) were known as only a vehicle manufacturer, but after common usage of 4G/LTE connectivity, OEMs started to provide basic connectivity features, such as remotely enabling of climate, locking/unlocking the doors, sounding the horn etc. Today, 5G is established as part of the 3GPP specifications, which will enable C-V2X communications to progress seamlessly into the 5G era. A key reason for these C-V2X developments is to meet demand within the automotive sector for automated driving technologies. Such technologies are evolving rapidly and are widely expected to transform driving experiences, provide safer vehicles and improve the efficiency of vehicle travel. In this context, the availability of advanced driver-assist systems (ADAS) (using technologies such as sensors, cameras, and radar) has increased in recent years, to improve vehicle safety. 5G communication is expected to complement and expand the capabilities of ADAS and provide additional benefits (such as reduced traffic congestion, improved energy efficiency and lower vehicle emissions)[7].

OEMs want to change their role with the opportunity that comes with 5G, for integration with smart-city and other connected-transportation initiatives that also use cellular technology. Also, OEMs planning to provide more advance features with the help of the 5G, such as automated driving (data sharing of dynamic objects, non-analyzed sensor signal sharing), automated valet parking, teleoperated driving, cooperative autonomous maneuvers [8][9].

Providing such more advanced features to customers means more complex system development. In addition to the challenges mentioned in the "Finding Gaps from a Business Case Perspective" section, OEMs must decide whether 5G-CAM application software development will be in-house or outsourcing or hybrid.

Since these new features are not usual for OEMs in their standard development cycles for serial production, go-to market strategies must be planned in detail and with the participation of MNOs and connectivity vendors such as cloud providers, modem providers etc.

We defined five alternative business models for automotive sector stakeholders in "Frictionless Border Crossing" and "Remote Driving Assisted Automated Shuttle" use cases. Each of them has bottlenecks and advantages.

Business Model 1 and 2 are business cases that are come from nature of traditional application development business models. However, Business Model 3, 4 and 5 are new business models that come with specifically 5G-CAM application deployments.

Business Model 1: Automotive OEM as full-service provider

In this business model, the automotive OEM is fully responsible of 5G-CAM applications, develops vehicle level autonomous software, agrees with a cloud provider, and uses this provided cloud to integrates related application. Settlement with MNOs for requirements and pricing and revenue sharing are strategies also under the OEM's responsibility.

Advantages of this business model are listed below:

- Faster software bugs fixing.
- OEM holds all intellectual property.
- Business manoeuvres can be done faster than business model 2, since OEMs closely monitor the effectiveness of business decisions.
- Software change cost is lower than business model 2.
- Limited revenue sharing with other stakeholders.
- Clear business and development liability borders.
- Lower pricing strategy dependability.
- Direct communication among the departments helps reducing ambiguity and miscommunication.

Bottlenecks of this business model are listed below:

- Correct team build up is challenging and takes long time,
- Failure on go-to market strategy due to potential lack of specific niche knowledge on 5G-CAM application development,
- Higher personal hiring and investment (operational maintenance, continuous trainings, system tool procurements etc.) costs than service provider

Business Model 2: A Service Provider that provides 5G-CAM application to Automotive OEM

While in business model 1 OEM is fully responsible of 5G-CAM application development, in this business model application development is shared between OEM and service provider(s). OEMs can agree with one or more than one service provider. As an example, for the "Frictionless Border Crossing" use case, one service provider provides autonomous vehicle software, one service provider provides related hardware and its installation to vehicle. Meanwhile the OEM leads integration of software and hardware. Requirements must be agreed among service providers, OEM and MNO.

Advantages of this business model are listed below:

- Since application development is shared among partners, know-how level can be higher than business model 1.
- Team build-up is easier since each developer partner has its own specialized area.
- Labour cost for OEMs is lower than business model 1 since service providers are paid only for a specific period unlike the full-time professionals.
- This business model offers better risk management, since service providers can help OEM with risk mitigation programs to enable OEM teams concentrate on other important tasks.
- OEMs do not need to give long-term commitment and so can scale up and down these resources as need be. As a result, OEMs can tend to outsource 5G-CAM application development to service providers.

Bottlenecks of this business model are listed below:

- Partners need to negotiate for each software change cost and revenue sharing models. This might exhaust the partners.
- Intellectual property rights are divided.
- Communication is not direct as it is in business model 1. This might cause wrong business decisions or developments.

Business Model 3: Infrastructure Based Perception

Perception of the environment is indeed a crucial task for autonomous vehicles. Normally, by facilitating the perception sensors, such as camera, lidar, and radar, a vehicle is able to localize itself inside an environment map. Additional to localization, autonomous vehicles make manoeuvres to avoid crashing to obstacles on their path. With the perception feature, autonomous vehicle detects the object and understand the location of it, classify the object (human, vehicle, animal etc.) and tracks the object which is useful for monitoring speed or velocity of the surrounding objects in relation to the vehicle itself. Hence, the perception part of autonomous vehicles is crucial and challenging.

In a confined area such as hard border crossing gates, perception can be outside of the vehicle. The area can be equipped with perception sensors such as lidars and cameras. With the 5G connectivity, this perception data can be transferred to a core that hold algorithms to classify, localize, track object for autonomous vehicle. After that, required data is transferred back to autonomous vehicles. Later, autonomous vehicle decides which autonomous manoeuvres to perform such as safest path to reach destination, emergency stop information etc.

Advantages of this business model are listed below:

- OEMs do not need to equip their vehicles with many expensive sensors (Lidar, camera, radars etc.).
- OEMs do not need to consider about perception developments. This will reduce the cost of holding a huge perception team.
- Perception provider purely focus on perception and become an expert on this area.
- OEMs can enhance their perception stack with this service.

Bottlenecks of this business model are listed below:

- Scalability can be limited with confined areas.
- Security of the area must be granted since used equipment is expensive.
- Standardization must be completed to common usage among different OEMs. Otherwise, solution will work for only one OEM.

Business Model 4: Cloud Based Routing

Path planning is like the brain of a self-driving car. It's how the vehicle makes decisions about how to move through the world. This is the part of the vehicle stack that makes decisions about how to move through the world. The process has three key sub-components: prediction and trajectory. Prediction in autonomous vehicle is all about how our autonomous vehicle is going to predict the trajectory or path of the other vehicle and take an action to avoid collision. After that, a trajectory for the autonomous vehicle is defined by the path planning function.

This business model is powered with infrastructure-based perception. All perception data that is gathered from infrastructure by the service provider transferred via 5G to a cloud that is owned by the routing service provider. Later, routing data is calculated in cloud algorithms to generate a path for subject autonomous vehicle. This path is sent back to vehicle via 5G, and the autonomous vehicle performs safe manoeuvres. In this business model, the path is not calculated by the autonomous vehicle and decisions made by cloud, unlike the infrastructure-based perception business model case.

This business model is also valid for confined areas such as hard border crossing gates, ports, construction areas and parking lots etc. Advantages and bottlenecks of this business model are similar to business model 3. Having another service provider that provides perception is an additional bottleneck since complexity is increased, but the security of the perception units that are deployed to the field is not a concern for the cloud-based routing service provider.

Business Model 5: Aftermarket Retrofitting

Aftermarket retrofitting for connected and autonomous vehicles refers to the installation of hardware and software components that enable vehicles to have connected and autonomous features after they have been manufactured. This can include adding sensors, cameras, and other equipment that allow the vehicle to sense its environment and communicate with other vehicles or infrastructure. It can also involve installing software that enables the vehicle to operate autonomously, such as self-driving capabilities. Retrofitting allows older vehicles to be upgraded with modern technology, enabling them to operate more safely and efficiently.

The Insurance Institute for Highway Safety (NHTSA) expects there to be 3.5 million self-driving vehicles on U.S. roads by 2025, and 4.5 million by 2030[10]. This numbers are quite few if we think about current vehicle market. Hence, there will be still so many non-connected and non-autonomous vehicles on the public roads for a long time.

Connected and autonomous driving is something that's not only for new cars, in this business model service provider develops retrofit kits that allow vehicles today on the road to drive autonomously. Such kits typically will come with a number of additional modems, sensors, graphic processors and the possibility to use existing vehicle components and sensors. This will be an intermediary solution or middleware that enables connected and autonomous driving for today's vehicles. Such retrofit kits can give lawmakers the required tool to bring autonomous and connected driving much quicker on the roads and reduce accidents and traffic fatalities. It will be crucial that those kits are available at an affordable price [11].

Advantages of this business model are listed below:

- Aftermarket retrofitting is a scalable since it can be applied to all brands.
- Provides customers with personalized and targeted services.
- Scalability increases the high revenue possibility.

Bottlenecks of this business model are listed below:

- Building brand awareness and promoting the service can be a major challenge.
- Retrofitting may require significant investment in technology and installation expertise.
- Pricing and packaging need to be carefully designed to appeal to the target market.

3.4. Pricing Strategies for 5G-CAM Applications

In this chapter, we want to list possible pricing strategies for a generic 5G-CAM application. These strategies can be applied also for "Frictionless border crossing" and "Remote Driving Assisted Automated Shuttle/Teleoperation" use cases. Pricing strategies are listed for the application development perspective. This application can be developed by OEM, MNO, or a service provider.

3.4.1. Freemium

The freemium model is a pricing strategy in which a basic version of a product or service is offered for free, while additional features or premium versions are offered at a cost. This can be used as a marketing technique to attract customers with the free version and then encourage them to upgrade to the paid version for more advanced features or functionality. As an example, basic 5G-CAM services such as ETSI Day-1 use cases [12] are offered for free, and customers can upgrade to premium features for a fee [13][14].

Advantages are:

- Freemium pricing can attract a large user base to the app, which can help promote adoption of 5G-CAM technology.
- Offering a free version of the app can increase brand awareness and exposure for the company developing the app.
- Gathering data from the free version of the app can help the developers improve their product and identify areas for monetization.
- Upselling premium features or services to existing users can increase revenue.

Challenges are:

- It may be difficult to balance between the free and premium versions of the app in providing enough value in the free version without giving away too much.
- The development and maintenance costs of 5G-CAM apps can be high, making it challenging to offer many features for free.
- Safety and security concerns may make it challenging to offer certain features only to paying customers.
- Regulations regarding privacy, data collection, and cybersecurity may restrict the use of freemium pricing models for 5G-CAM apps.

3.4.2. Subscription-Based Pricing

A subscription-based model is a pricing strategy where customers pay a recurring fee for access to a product or service over a specified period of time, such as monthly or annually. In the context of 5G-CAM applications, this would involve customers paying a regular fee to access features and services related to their connected vehicle, such as real-time traffic updates or remote monitoring capabilities.

Advantages are:

- Subscription-based pricing can provide a predictable, recurring revenue stream for the developers.
- Customers may be more willing to pay for access to premium features or services if they are offered on a subscription basis.
- Developers have a better idea of their future cash flows, which can help with planning and budgeting.

- Can encourage customer loyalty as users continue to renew their subscriptions.

Challenges:

- It may be difficult to convince users to pay for a subscription if they do not perceive significant value in the premium features or services.
- Customers may be hesitant to commit to a long-term subscription for a relatively new technology like 5G-CAM.
- Developers must continuously update and improve the app to justify the ongoing subscription fee.
- The subscription model may not work well for customers who only use the app occasionally or infrequently.

3.4.3. Pay-per-use Pricing

A pay-per-use pricing model is a strategy where customers only pay for the specific features or services they use, rather than paying a fixed subscription fee. In the context of 5G-CAM applications, this would involve customers being charged based on their usage of connected vehicle features and services, such as data usage or access to premium features.

Advantages are:

- Pay-per-use pricing can be attractive to customers who only need the app occasionally or infrequently, as they pay only for what they use.
- Can provide an alternative revenue stream for developers in addition to subscriptions or other pricing models.
- Developers can track usage data and adjust pricing based on actual usage patterns.
- May incentivize developers to improve and optimize the app for efficiency and reduced usage time.

Challenges are:

- It may be difficult to set an appropriate price point that both covers development costs and is attractive to customers.
- Customers may not be willing to pay for each use of the app, particularly if they perceive it as costly or inconvenient.
- The pay-per-use model may not work well for customers who use the app frequently or require continuous access to the app.
- It may be challenging to accurately track and measure usage, particularly if there are technical issues or connectivity problems.

3.4.4. Tiered Pricing

A tiered pricing model is a strategy where customers are offered different levels or tiers of a product or service, each with different features and corresponding prices. In the context 5G-CAM applications, this would involve offering different levels of connected vehicle services, such as basic, premium, and elite tiers, each with varying capabilities and associated costs.

Advantages are:

- Flexibility: A tiered pricing model allows for different pricing tiers, which can be adjusted based on the specific needs and preferences of the users.
- Increased revenue potential: By offering multiple pricing tiers, developers can potentially generate more revenue as users have the option to pay for additional features or functionality.
- Better user engagement: Users may feel more invested in an app if they have paid for it and are more likely to use it regularly.

Challenges are:

- Complexity: Designing and implementing a tiered pricing model can be complex and time-consuming for developers.
- User confusion: If not properly communicated, users may be confused by the different pricing tiers and what features are included in each tier.
- Competitive pressure: Tiered pricing models are already popular among mobile apps, and competing CAM apps may offer similar features at lower prices, leading to user churn.

3.4.5. Bundling Pricing

The bundling model is a pricing strategy in which multiple products or services are offered together as a package for a single price. This can be beneficial for both the seller and the customer, as the customer may receive a discounted price compared to purchasing each item individually, while the seller can increase sales and revenue by offering additional products or services. The success of this model depends on the relevance and perceived value of the bundled items to the customer.

Advantages are:

- Increased value proposition: Bundling different features or services together can provide a more compelling value proposition to users, especially if they would have to pay more for each feature individually.
- Increased revenue potential: By offering bundled packages at a slight discount, developers may be able to generate more revenue than if users were to buy each feature separately.
- Simplicity: For users, a bundled pricing model can make purchasing decisions simpler as they only need to consider one price for multiple features.

Challenges are:

- Difficulty in setting prices: Setting the right price for bundled packages can be challenging as it requires considering the costs and perceived value of multiple features.
- Risk of cannibalization: If users perceive that they don't need all the features in a bundled package, they may choose to purchase only certain features rather than the entire bundle, potentially leading to lower overall revenue numbers.
- Limited flexibility: Users may be hesitant to purchase a bundled package if it contains features they don't need or want and may prefer to buy only the features they need individually.

3.4.5.1. *Value Based Pricing*

Value based pricing is a pricing strategy for 5G-CAM applications that involves setting prices based on the perceived value of the app and its features to its users. This approach takes into account the unique needs and preferences of users and focuses on creating a pricing structure that maximizes the perceived value of the app to each user.

To use this strategy, developers need to conduct market research to understand what features are most important to their target audience and determine how much value users place on these features. They can then set price points for different features or packages of features based on this information.

For example, if users highly value a particular feature, such as high-quality video playback or advanced filters, developers may set a premium price point for that feature or package it with other highly valued features to create a more compelling value proposition. Alternatively, if certain features are not highly valued, developers may choose to offer them at a lower price or bundle them with other features to increase their perceived value.

Overall, value-based pricing aims to maximize revenue by matching prices to the perceived value of the app and its features to each user, rather than simply offering a one-size-fits-all pricing model.

Advantages are:

- Higher perceived value: Value-based pricing can help capture the true value that users perceive in an app, resulting in higher revenues. Users may be willing to pay more for an app if they believe it offers compelling value and meets their specific needs.
- Differentiation: By focusing on the unique value proposition of the app and its features, developers can differentiate themselves from competitors in the market.
- Flexibility: Value-based pricing can be adjusted based on changes in the market or as new features are added to the app.

Challenges are:

- Difficulty in determining value: Determining the true value that users place on an app can be difficult, and developers may need to conduct extensive market research and user testing to determine what price point is most appropriate.
- Limited appeal: Value-based pricing may not be attractive to all users, particularly those who prioritize cost savings over perceived value.
- User resistance to price increases: If prices are increased based on increases in perceived value, users may be resistant to paying more for an app they had previously been using at a lower price point.

3.5. Cost Benefit Analysis for the Advanced Driving Use Case

In this section a cost benefit analysis is presented for the *Advanced Driving* use case category and the for the user story *Complex manoeuvres in cross-border setting* demonstrated at the Spain-Portugal cross-border corridor. The user story includes three scenarios: 1) Lane merge for automated vehicles, 2) Automated overtaking, and 3) HD maps. The user stories are described in more detail in 5G-MOBIX Deliverable D2.1 (5G-MOBIX Consortium, 2019).

Advanced Driving enables semi-automated or fully automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or RSU shares data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or manoeuvres. In addition, each vehicle shares its driving intention with vehicles in proximity. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency.

The core of the business model is to provide services related to advanced driving for multiple stakeholders in the automated driving context. The service portfolio is assumed to include services for complex manoeuvres¸ assisted driving, collision avoidance and cloud-assisted driving. Each service has corresponding customer segments plus other relevant stakeholders (see Table 3). Next, we will explore specifics of a business model providing these services.

Table 3: Main customer segments for the services

Services	Main Customer segments
Complex maneuvers	Consumer, Emergency
Assisted driving	Consumer, Logistics
Collision Avoidance	Consumer, insurance company
Cloud-Assisted Driving	Logistics company, consumer

The data on the traffic forecasts, forecasted connectivity capacity requirements, and the necessary investments to deliver full coverage for the CAM use-cases at the border, presented in the 5G-MOBIX Deliverable D6.5 (5G-MOBIX Consortium, 2022), are used in the analysis. The analysis is conducted for the Spain-Portugal region. The costs are presented in Table 4. It is assumed that the costs for the connectivity infrastructure will be divided for several services, and not just one service package will need to cover the full costs. In this analysis it is assumed that the services of the Advanced driving use case category will need to cover 20% share of the connectivity costs. Furthermore, it is assumed that costs for the road-side units will not fall to the service provider.

Table 4: Costs at ES-PT CBC for the Advanced Driving UCC services

Costs: Spain-Portugal CBC			
	Cost Type (2025 est.)	Euros (total)	Share for the UCC
Connectivity (delta)			20 %
	CAPEX (one time)	962 100	192 420
	OPEX (12 months)	157 800	31 560
Automotive			100%
	CAPEX (one time)	7430	7430
	OPEX (12 months)	11 000	11 000

Several assumptions had to be made for the analysis:

- An automotive manufacturer is assumed to have a 5% market share both in Spain and Portugal. New passenger car registrations in 2022 [15]: 813 400 vehicles per year in Spain, 156 304 vehicles per year in Portugal. For an OEM with 5% market share this means: 40 700 vehicles in Spain , 7800 vehicles in Portugal, 48 500 in total for the market area covering the two countries.

- It is assumed that all sold new vehicles support connectivity and the service.
- 10% of customers buying a new vehicle are interested in buying the Advanced driving service → 4850 paying customers.
- The price of the Advanced Driving service package is assumed to be equal to Tesla's connectivity package, i.e. 9.90 euros per month.
- CAPEX for having level 4 autonomous is assumed to be equal to Mercedes Benz Level 3 Drive Pilot cost [16]
- For Automotive OPEX calculation, McKinsey's cost per passenger mile for robo-taxi in 2030 assumptions are used [17]. According to McKinsey, total cost for robo-taxi in 2030 is 1.35€ per mile. 82% of this cost belongs to OPEX and one vehicle travels 10 000km per year. Hence, we found the 11 000€ per year for OPEX.
- Inflation and interest rates have not been included in the calculations.

Table 5: Estimation of the income for the sales of the service in SP-PT market area

Income: Spain-Portugal CBC		
Advanced Driving	9.9 euros per month, 4850 customers, 12 months	576 180 €

Table 6: Benefit-to-cost ratio of the Advanced Driving UCC at SP-PT CBC

TCO	Benefits	Benefit-to-cost ratio
242 410€	576 180 €	2.38

Initial forecast seems favourable that the Advanced driving services and related infrastructure costs will be profitable. It can be argued that this business case may support the establishment of next generation connectivity infrastructure in cross-border contexts.

There are some potential alternatives that can be considered in later work:

- Pricing schemes could exist in which services are be sold individually to specific customers, not just as a bundle.
- There might be expansions of tailored services; for example to logistics companies and car rental companies. In those situations, an advanced driving service package will most likely be tailored according to market demographics.

3.6. Overall Business Model

In this section we analyse and describe the business opportunities and related potential business models for two use cases that were realised in the 5G MOBIX project. Both cases have been detailed in the previous sections. This section will apply a more pragmatic approach to define potential business models: calculate the cost-benefit of the actual situation and then identify a model for the 5G enabled case. We list the potential benefits for the involved stakeholders that the introduction of the 5G technologies offer. We consider the differences with the actual situation to determine the added value of the 5G technologies. In

next step we look at each stakeholders' contribution to realise this value and determine the win-win situation for all.

3.6.1. Deployment Cost Delta for Connectivity Investments

For our study, we need to consider the investment and operating costs of the 5G operator. Investments can be made by a regular MNO or by a dedicated 'private' operator installing a private 5G network.

On top of these investments, dependent on the already available infrastructure, additional equipment (e.g. LiDAR) might needs to be procured. Because of regulations "Economic Commission for Europe of the United Nations (UN/ECE) R130-R131-R152", the vehicles are already equipped with cameras and radars. The costs for a LiDAR camera are considered to be marginal when spread over all users.

The 5G-MOBIX Deployment Study, based on the user and use case demands, states that 700 MHz would be sufficient until 2025 for the GR-TR and ES-PT corridors. Hence, for frictionless border crossing and remote driving assisted automated shuttle use cases, one 5G base station using 700 MHz is sufficient.

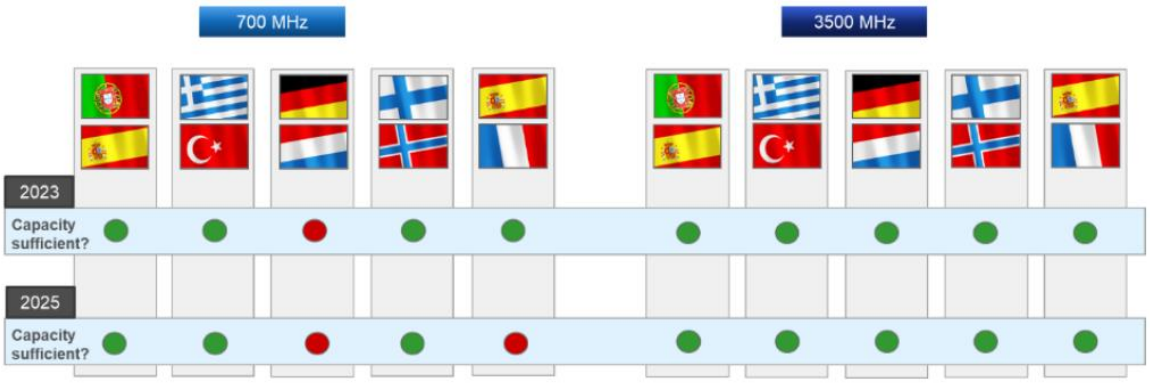


Figure 8: Overview of capacity sufficiency in 700MHz and 3500MHz

CAPEX and OPEX prices for 700MHz base stations per country are calculated in the 5G-MOBIX Deployment Study. Extensive industry research and interviews have provided the inputs for the cost catalogue (CAPEX & OPEX). Due to commercial sensitivity of these interviews, the cost results should be considered estimates. The calculated costs may vary by about +/- 20% within one country and from operator to operator. The highest cost estimates are in Norway, where the passive infrastructure per base station is around 103 kEUR. In addition, 24 kEUR can be expected for the active equipment (700 MHz). Up to almost 40% lower costs can be observed in Greece and Turkey. The ranking is similar for 3500 MHz active equipment, although prices in Portugal are relatively lower. The mid-band generally appears to be 5 – 10 kEUR more expensive per base station than the lower 5G band. The CAPEX for the selected European countries is visualised in Figure 9.

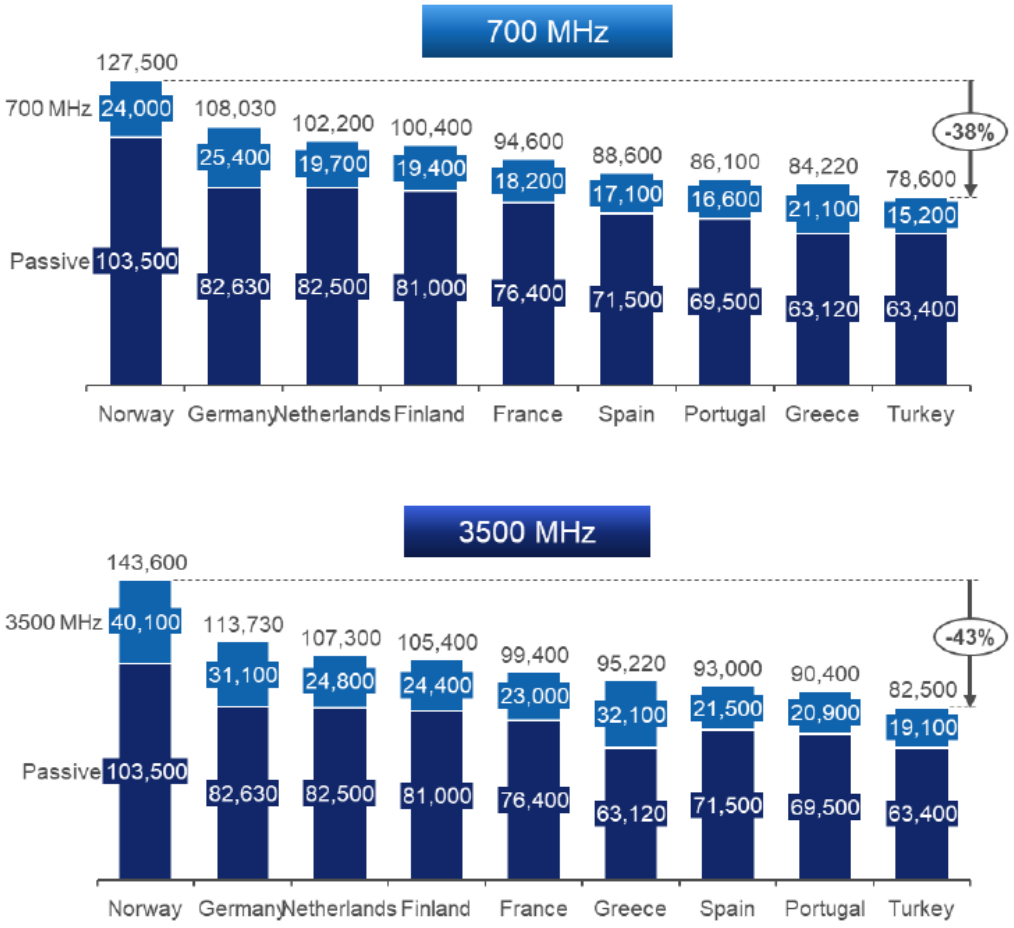


Figure 9: CAPEX per base station

The OPEX (annual operational expenses) from the 5G-MOBIX Deployment Study are presented in Table 7.

These CAPEX and OPEX numbers are used as the deployment cost delta for the investments in connectivity.

Table 7: OPEX per selected country according to Deployment Study

Country	DE	NL	PT	ES	FR	GR	TR	FI	NO
OPEX (€)	19.100	20.500	13.800	14.800	17.500	12.400	11.300	21.400	23.300

3.6.2. Business Model for Frictionless Border Crossing

In the current border crossing context, time is the biggest cost:

- Long waiting times in the traffic jams.
- Long administrative processing time at the border.

These costs are for the fleet owner. Potentially there are also costs for the owner of the cargo due to late delivery. However, these costs highly depend on the exact logistic case and are hard to calculate. Therefore, we will only take into account the costs for the fleet owner.

When a 5G network is enabled a number of services can be introduced to reduce these time costs:

- The largest portion of delay in traditional border crossing is attributed to inefficient flow of information regarding the necessary documentation (33.4%), custom agent's inefficiency (21.9%) and lack of necessary infrastructure and equipment (21.3%) [18]
- Using 5G-MOBIX services an estimated 80% reduction on process time with handling the documentation can be achieved, because all information is available in digital format, and an estimated 80% reduction in inefficiency because the trucks are automatically guided via the checkpoints minimizing interventions from customs officers.

Using these numbers and improvement, we can calculate the gains. These are provided in the below table.

Table 8: Gained Time on Border Crossing

Waiting Time Reason	Percentage	In Minutes	5G Influence	5G Gain (In Minutes)	Difference (In Minutes)
Documentation	33.40	30.06	-80%	6.012	
Custom Agent Inefficiency	21.90	19.71	-80%	3.942	
Lack Of Infrastructure	21.30	19.17		19.17	
Rest (Driver Mistakes, Vehicle Malfunctions Etc.)	23.40	21.06		21.06	
Total	**100**	**90**		**50.184**	**39.816**
Gain %					**44%**

According to our assumptions, by applying the 5G powered Frictionless Border Crossing use case, connected and autonomous trucks can earn 39.816 minutes to pass hard borders which means a gain in transfer speed of 44% with respect to traditional trucks.

The costs for the fleet owner, in this specific context, is considered to be mainly the costs of the truck driver, other costs within this context are considered negligible.

We took the ERI Economic Research Institute data [19] for truck drivers in several European countries related to our study (Table 9). The yearly average salary is 31.150€, or 2595,83€ in a month.

Table 9: Truck driver average yearly salaries for selected countries

COUNTRY	YEARLY AVERAGE SALARY (€)
France	38245
Belgium	49108
Norway	42000
Greece	24534
Germany	46202
Netherlands	48060
Austria	44561

Spain	33709
Sweden	36581
Bulgaria	10800
Total	**31150**

By combining the gains with the salaries, we can determine the cost improvement by applying 5G powered Frictionless Border Crossing use case (Table 10).

Table 10: Cost reduction by applying the 5G powered Frictionless Border Crossing use case

FLEET OWNER COSTS	ASSUMPTIONS
Total Monthly Salary Cost	2595.83 €
Average Amount of Crossings / Month	6* times
Working Hours / Month	224** hours
Gained Time / Month	3.98*** hours
Related Cost Reduction / Month	46.14 €

*: According to peer to peer interviews with truck drivers on GR-TR border crossing area
**: https://www.gov.uk/drivers-hours/eu-rules#:~:text=The%20main%20EU%20rules%20on,in%20any%202%20consecutive%20weeks
***: ((Average Amount of Crossings / Month) x 39.816 minutes gained time) / 60 minutes to find hour

With our assumptions, we see that fleet owner will earn 46.14€ per truck, per month, if truck moves autonomously only on the border crossing area. The rest of the driving in this assumption, must be handled by truck drivers.

This can be an early implementation of the use case. In the future, it can be coupled with level 4 automated trucks that travel fully autonomously on highways until reaching the hard border crossing point. In such a scenario, fleet owners will earn 46.14€ from Frictionless Border Crossing application and plus 2595.83 € that comes from removing the driver. Additional costs of operating a fully connected and autonomous truck must be subtracted from total gain to provide a full overview.

The monthly cost reduction can be taken as a reference to determine an acceptable market sales price for the 5G related service subscription.

This is not a net reduction in cost. In fact, the OBU (On-Board Unit) necessary to perform the service must be also taken into consideration. In our assumption, we select OBU cost as 200€, since it is the price of a 4G-LTE telemetry unit used in serial production by OEMs. We expect the cost of 5G telemetry units will be similar to 4G-LTE units in the next few years.

Table 11: OBU costs for the 5G powered Frictionless Border Crossing use case in vehicles

MODEM RELATED INFORMATION	ASSUMPTIONS
OBU Cost	200 €
Depreciation	5* years
OBU Monthly Cost	3.33** €

*: https://www.depreciationrates.net.au/modems
**: (OBU Cost / Depreciation Years) / 12

Based on these calculations, if we deduct the OBU cost from the earlier identified gains, we find net cost reduction for fleet owner of 42.81 € per truck, per month.

In the below business model, we propose a subscription-based pricing strategy, since the costs of having frictionless border crossing per truck are known. The following example proposes a monthly subscription of 15 €/month for the service. In this case, profit per truck per month will be 27.81 €.

As it stated in section 4.1.7, for frictionless border crossing use case, two 700MHz base station must be installed for the border area, one for Greek side and one for Turkish side. The infrastructure investment table for the Greek – Turkish border area then is:

Table 12: Turkish border area investments

NETWORK RELATED COSTS	ASSUMPTIONS
Initial Base Station Installation Cost	162 820 €
OPEX for Base Station	23 700 € / Year
Depreciation	10 Years
Total Monthly Cost	3331.83* €

*:(Initial Base Station Installation Cost / Depreciation / 12) + (OPEX / 12)

The 5G service provider needs to compensate 3331.83€ monthly cost by subscriptions from fleet owners or automotive OEMs get subscriptions from fleet owners and transfer the required amount to the 5G service providers.

Additional to the 5G service cost, for perception, 3 LIDARs must be installed to satisfy the use case requirements as they used in project demonstration. According to our business model, installation of the LIDARs and cloud costs belong to the infrastructure-based perception service providers.

We used Azure Virtual Machine and Google Cloud Pricing Calculators to calculate cloud cost. An example of our configuration can be seen on Figure 10:

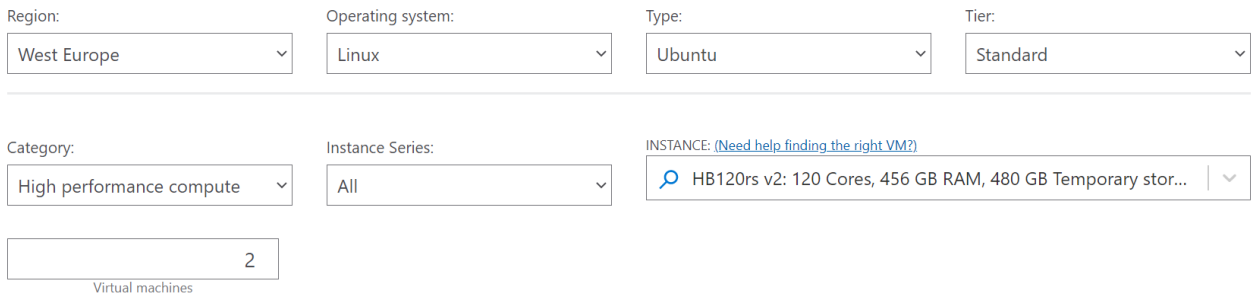


Figure 10: Azure Cloud Price Calculation Configuration

This setup is similar to the one used in 5G-MOBIX. The cloud costs are around 4000€. We used 5G-BLUEPRINT project as baseline for the LIDAR installation cost [20]. LIDAR OPEX costs comes from the OPEX / CAPEX rate of 700MHz base station, which is around 14% of the deployment. Consequently, LIDAR OPEX is 14% of installation cost, which is around 2000€ per year and 167€ per month.

Combining these numbers provides the below overview of the costs:

Table 13: LIDAR costs for perception at the Turkish border area

INFRASTRUCTURE RELATED COSTS	ASSUMPTIONS
Initial 3 LIDAR Installation Cost	14000€
LIDAR Depreciation	5 Years
LIDAR OPEX	167 € / Month
Cloud Cost	4000 € / Month
Total Monthly Cost	4400.33 €

As a result, the infrastructure-based perception service provider needs to compensate 4400.33€ monthly cost from OEMs or MNOs.

To reduce the complexity, we assume that automotive OEM compensates both the MNO and the infrastructure-based perception service provider costs, by selling the frictionless border crossing application to fleet owners. This means in total 7732.16 € per month must be gathered from subscriptions.

Therefore, break-even point based on needed subscriptions is **515**.

According to records, on average 280 vehicles pass daily from Turkey to Greece [21] and we assume half of them to be trucks. That means monthly 4200 trucks pass the border. Since we also assumed an average of 6 crossings per truck per month, the average obtained subscriptions maximizes at 700. Which is higher than the break-even point.

Given the subscription price (15€), the service provider profit can be calculated as follow (in our model, the OEM sells the application to fleet owners):

(Maximum Subscriptions – Break-even Point Subscriptions) x Subscription Fee in Euro

In this case, the profit for automotive OEM is **2768€** per month. The gross margin (the difference between revenue and cost of goods sold (COGS), divided by revenue) is **26%** which is quite acceptable for the automotive industry (the average of the industry is 8.5%)[22].

The business case largely depends on the 'service price' that can be obtained. The price sensitivity related to this assumption can be estimated. These are presented in Table 14 and Figure 11.

Table 14: Price sensitivity

SERVICE PRICE (€)	FLEET OWNER PROFIT/DRIVER PER MONTH (€)	OEM	
		PROFIT/MONTH(€)	GROSS MARGIN(%)
10	32.81	-732	-10
12	30.81	668	8
15	27.81	2768	26
20	22.81	6268	45

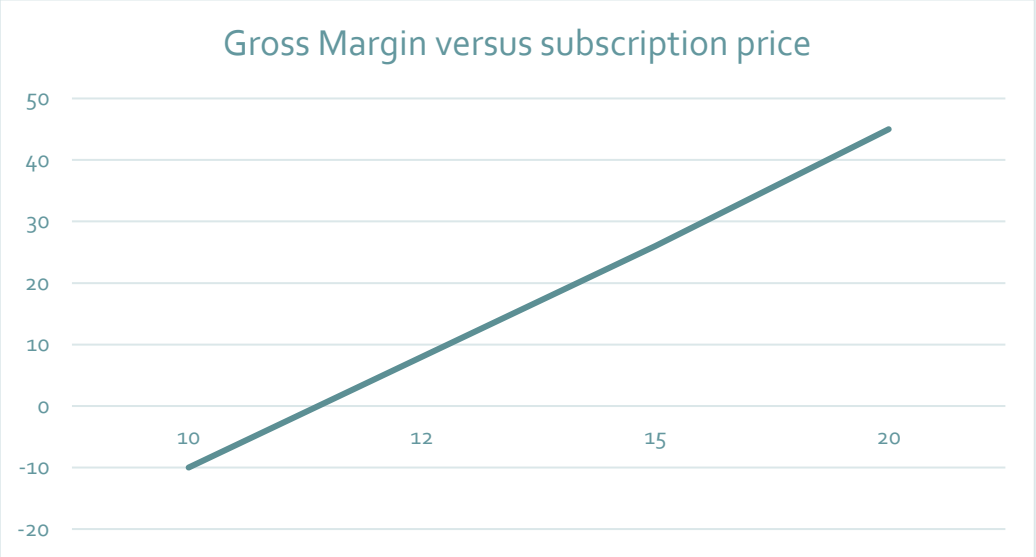


Figure 11: Gross margin versus subscription price

3.6.2.1. Further Considerations

The profit for the fleet owner is limited (27.81 EU/month per truck). This may not be attractive enough for considering the service. Additionally, the revenue of this business model can be improved by adding other borders like the Bulgaria – Turkey border, which has a five times higher number of border crossings per month.

Our study did not define the revenue-sharing model among the partners. Since the industry gross margin average for automotive OEMs is 8.5% and for their suppliers is 7.5%, it is possible to keep a balance between all stakeholders.

We deployed our frictionless border crossing application to the Turkish border area as we did in the 5G-MOBIX project demonstration. With this deployment, we assume Greek border controls can be easier than today.

There are a few other remarks to be made:

- Potentially the value of the service is higher when considering the cost of the cargo.
- The border control can impose the service to allow less working force for its operation. In this case, the subscription cost of the service can be lower, as operational cost for the border control diminishes.
- The installation of the 5G service is a must, when trucks are fully automated, and no driver is needed.
- In our study, we focused border crossing related business model, but beyond border crossing, business model on highways for automated and connected vehicles can be also calculated separately.

3.6.3. Business Model for Remote Driving Assisted Automated Shuttle Across Borders

3.6.3.1. Basic Business Model

In this case, the assumption is that today's service will remain the same and that all factors and parameters do not change, besides the fact the driver of the bus is replaced by automation.

The only cost component, therefore, is the driver's monthly salary, which is a cost for the fleet owner.

When the 5G network is enabled, several driver services are replaced by automation. However, the service provider must place the 5G equipment and underlying services.

These two considerations give the following overview:

Table 15: Remote driving assisted automated shuttle costs

FLEET OWNER COSTS	ASSUMPTIONS
Bus Driver Total Monthly Salary Cost	2187.33* €
OBU Cost	200 €
OBU Depreciation	5 Years
OBU Monthly Cost	3.33 €
Net Profit Per Month	2184 €

*: https://www.erieri.com/salary/job/bus-driver/spain

For this use case, one 700MHz base station must be installed on each side for ES-PT border area: one base station in Spain and one in Portugal. These 5G deployments can be performed by a regular MNO, or by a dedicated 'private' operator. This results in the below infrastructure costs.

Table 16: Infrastructure costs for the remote driving assisted automated shuttle

NETWORK RELATED COSTS	ASSUMPTIONS
Initial Base Station Installation Cost	174700 €
OPEX for Base Stations	2383.33 € / Month
Base Station Depreciation	10 Years
Total Monthly Cost	3839 €

Additional to the 5G network cost, a remote driving station with modem and cloud costs must be included, because it is vital to assist automated shuttles in complex situations. Our remote driving station costs assumption is in the table below.

Table 17: Remote driving station costs

REMOTE DRIVING STATION RELATED COSTS	ASSUMPTIONS
Initial Remote Driving Station Installation Cost	40000* €
OPEX for Remote Driving Station	466.67 € / Month
Remote Driving Station Depreciation	10 Years
Cloud Cost	4000 € / Month
Total Monthly Cost	4800 €

*: Cost information that comes from consortium partners.

We assume that shuttle owner (OEM) will compensate all the remote driving station and network costs as part of supplying the solutions. Within this setting, there seems to be no possible win-win model because the OEM pays in total 8639€ and can earn at most 2164€ from the fleet owner, leaving a gap of **6455€**.

3.6.3.2. Alternative Business Model

To improve this business case, the fleet owner could apply more buses and serve more passengers. This option increases the risk of the business case gets because the market viability for this assumption must be proven. Below, an alternative business model is investigated.

The service will foresee three automated shuttles to replace the combination of train and bus trips. One shuttle can carry 12 passengers, while the capacity of a train in combination with a bus is 40. Using three shuttles, the total number of passengers is almost the same, but this will largely reduce waiting time and give the tourists a transport medium with a higher frequency. The presence of 5G can also offer entertainment and more services and experiences in the shuttle while driving. It should be possible to increase the number of tourists that take the bus with this offer.

In this case, the cost components are:

- The monthly salary of the driver,
- The operational cost of the bus consists of the depreciation of the bus and the fuel consumption (we neglect all other parameters),
- An automated shuttle (100000€) will be half the price of the train bus combination (200000€).

These costs are for the bus company. The below table provides the full overview.

Table 18: Fleet owner bus costs

FLEET OWNER BUS COSTS	ASSUMPTIONS
Bus Driver Total Monthly Salary Cost	2187.33 €
30-day service/month requires 1,5 drivers/bus	3280.99 €
Actual Cost of a Bus	200000€
Depreciation Time of a Bus	10 Years
Monthly Cost of the Bus	1666.67€

Additional to cost of the bus, fuel costs must be added to cost of fleet owner.

Table 19: Fuel costs for bus operation

FLEET OWNER FUEL COSTS	ASSUMPTIONS
Distance of one crossing	20 km
Monthly driven km per bus	7200* km
Fuel Consumption per 100km	35 lt
Price for the one-liter fuel	1.581€
Fuel Cost per Bus per Month	3984.12€

*: As it stated in section 3.1.1 12 trips per day can be completed in a day with one bus. Hence, 12 x 20km x 30 days is use for calculation

In total, this provides operational costs per month of **8931.8€** for fleet owners.

There is also an actual income, based upon the ticket sales, resulting in a profit for the bus company:

Table 20: Fleet owner bus income

FLEET OWNER ACTUAL INCOME	ASSUMPTIONS
Amount Of People Transported Per Bus Drive	40
Number of Daily Trips	12
Number of Transported Tourists per Month	14400*
Actual Cost of One-way Ticket	2.20€
Monthly Ticket Income	31680€

*: 40 is the maximum capacity of a bus. If bus is fully booked for all trips, then it is 40 x 12trips x 30 days is used for monthly passenger calculation.

If we subtract operation cost from actual income, we see that the relative monthly profit for traditional train and bus company is **22748€**.

In the new business model, three automated shuttles offer the service. In this model, we increased the number of tourists by 70% to keep a 30% gross margin (divided over the three shuttles).

Unfortunately, to increase the service quality and improve the experience, the need for on-board entertainment possibilities, CO_2 reduction, and high-tech equipment might increase the price for a ticket for two reasons:

1. The transportation company has to invest in more buses and take the new entrepreneur's risk. To make it interesting, the envisioned profit should increase versus the basic business model situation. An estimate is that the goal is to increase the profit by about 30%.
2. Part of the ticket income will flow to the network/remote driving service providers to compensate for their costs and profit goals. We distribute ticket income equally to both providers. The proposal aims for a gross margin of 30% for the shuttle supplier (OEM).

These considerations lead to a proposed model for the bus company:

Table 21: Characteristics of the new business model for fleet owners

FLEET OWNER NEW BUSINESS MODEL	ASSUMPTIONS
3 shuttles (without driver) monthly cost	14452*€
Number of Transported Tourists per Month	24458
Proposed New Cost of One-way Ticket	2.60€
Part of Ticket Price for 5G Service	0.4€
Part Of Ticket Price for Remote Driving Service	0.4€
Part of Ticket Price for Bus Company	1.80€
Monthly Ticket Income	44024.4€
Relative Profit per Month	29572€

*: (One shuttle costs half of the monthly cost of a bus + electricity cost which is assumed as fuel cost)x 3 shuttles

The traditional train-bus company's profit is 22748€ and with this business model, the automated shuttle owner has a **29572**€ profit, which is **6824€** higher with a gross margin of **30%.**

For the network provider, the gross margin can be up to 61%, which is acceptable according to industry standards [23].

Table 22: Network provider business income

NETWORK PROVIDER BUSINESS INCOME	ASSUMPTIONS
Ticket Income	9783.2*€
Profit per Month	5944**€
Gross Margin	61%

*: 0.4€ from each ticket x Number of Transported Tourists per Month
**: Ticket Income – Network Related Costs

For the remote driving service provider gross margin is calculated as 51% which is 22% below the high performing start-ups [24]:

Table 23: Service provider business income

NETWORK PROVIDER BUSINESS INCOME	ASSUMPTIONS
Ticket Income	9783.2*€
Profit	4983,2**€
Gross Margin	51%

*: 0.4€ from each ticket x Number of Transported Tourists per Month
**: Ticket Income – Remote Driving Station Related Costs

The number of passengers that must be carried to reach the break-even point can be calculated as the total operation cost of the 3 shuttles (14452€), plus the total monthly cost of the network provider (3839€) and the total monthly cost of the remote driving service provider (4800€), resulting in a total 23091€ monthly costs. Recalculating gives **8882** tickets that must be sold to reach the break-even point, which is possible because the traditional train-bus passenger numbers are around 14400.

3.6.3.3. Further Considerations

The price of the ticket of 2,60 EUR is considerably higher than 2.20 EUR in the base business model assumptions. Also, the increase in number of passengers can be doubtful because it does not depend so much on the bus service itself, rather on the touristic attractiveness of the involved cities.

We omitted the costs for application development, including engineering costs. These might increase the cost of one ticket. The remote driving service provider might also request an additional share on tickets to increase its gross profit to catch-up with high performer startups.

4. CUSTOMER EXPLORATION MAP

The Customer Exploration Map tool helps stakeholders identify problems and challenges of their customers and to explore possible solutions for these problem (Example of Customer Exploration Map and its details, n.d.) in order to create business plans with a competitive edge. This document aims to identify what are the 5G-CAM customers, what they want, challenges and unknowns on the road to have successful 5G-CAM business model. To achieve this, a set of questions listed below has been asked to stakeholders in 5G-MOBIX work group and each stakeholder perspective is reported.

MNOs, automotive OEMs, application providers, network equipment providers, OBU/RSU providers, road operators and end users are the related stakeholders in 5G-CAM deployment.

- Who are your customers / users / stakeholders?
- What are their likes and dislikes?
- Jobs to be done and challenges to achieve solid 5G for CAM business model
- What we do not know, what are our assumptions, black spots and why/when is something a challenge / a good experience etc.
- What are the existing solutions that are used or could be used instead of 5G for CAM services?
- What would be game changing, perfect solution, and experience that 5G for CAM promised?

Figure 12: Customer Exploration Map example to fill by stakeholder

An example of the customer exploration map tool can be seen in Figure 12. Answers from the expert team in 5G-MOBIX project were collected according to this template.

Below we have presented the results for stakeholder groups MNOs, automotive OEMs, application providers, network equipment providers, OBU/RSU providers, road operators and end users.

4.1. MNO Perspective

4.1.1. Who are our customers / users / stakeholders?

Primarily, MNOs are looking at every person / legal entity or device as a (potential) customer. Translated into the context of 5G-CAM technology and use cases, the customers are individuals, automotive OEMs and infrastructure operators (government)

4.1.2. What are their likes and dislikes?

All customers are looking for efficient and safe travels. However, adding such features increases the cost of the vehicle as well as operation of the infrastructure. As such nobody is (currently) willing to take on the enhanced cost of 5G-CAM.

4.1.3. Jobs to be done and challenges

As 5G-CAM use cases are becoming more advanced and technology may be reaching maturity levels sufficient for broader roll-out, MNOs need to increase the coverage and capacity of their 5G networks. This includes the capabilities unlocked only through Stand-alone (SA) operation of the 5G network. As typically the existing customers for MNOs do not tend to accumulate in great numbers across the major road infrastructure networks, MNOs find themselves faced with discrepancies between past focus areas (urbanized areas with high concentration of personal / business users) for their network roll-out efforts and the now required focus on major roads (and border crossings).

The biggest challenge for MNOs is to try and find justification for the capital expenditure associated with the network rollout to support all these 5G-CAM functionalities. The business case is communal, and the value is in the absence of a transaction (accident). There is no business case today that can be monetized on the absence of a transaction.

4.1.4. What we don't know?

As indicated, the biggest unknown for MNOs when it comes to 5G-CAM to leverage their network infrastructure is the unknown customer. Where can the MNO compensate the cost of increasing coverage and capacity.

4.1.5. Existing Solutions

For CAM use-cases, a lot of time and effort has been allocated towards ITS-G5 technology in the past. For MNOs, this is not part of their connectivity offering and there is no business model associated with it for an MNO. But this technology suffers from the same challenges and unknowns; actually even more so as there are no opportunities to leverage these investments beyond their primary focus whereas for 5G connectivity it is merely a question of finding secondary uses to strengthen the business case. As most countries / member states have introduced coverage obligations towards MNOs as part of their spectrum auctions, a basic availability will always be achieved ahead of the existing ITS-G5 requirements.

4.1.6. This would be game changing!

For MNOs the biggest game changer will occur if some of the 5G-CAM technology would find its way into existing fleets under a governmental intervention requiring all vehicle and fleet owners to retrofit technology with connectivity, even if just for a single safety-related use. This would draw investments from MNOs to best serve this specific market.

4.2. Automotive OEM Perspective

4.2.1. Who are our customers / users / stakeholders?

Fleet owners, confined area (such as ports, mining, construction) operators, end users are the main customers of the automotive OEMs.

4.2.2. What are their likes and dislikes?

Low-cost operation is important for fleet owners and confined area operators. Low-cost operation could be achieved by decreasing number of employees, operation time, accidents that a human got hurt or an equipment damaged. Safety is also another important aspect for such customers.

End users (e.g.drivers, passengers) also look for comfortable, safe and fast travels.

Regardless of which group the end user falls into, 5G-CAM technology can contribute to addressing their concerns. Autonomous vehicles can be calibrated to optimise driving practices that can avoid aggressive or erratic driving that wears out tyres and brakes more quickly. Replacement of brakes and tyres are two of the major maintenance costs borne by fleets and drivers. Elimination of driving offences reduces costs and should help to reduce the driver risk element of insurance premiums.

Reduction or elimination of accidents and unexpected damage to the vehicle can result in significant savings, such as repair cost and provision of an alternative vehicle while out of service.

For fleet drivers in particular, automation can enable greater productivity as the 'driver' is free to carry out tasks that could otherwise be distracting such as making calls, reading messages or filling the necessary forms for crossing borders.

For the vehicle OEM it should be possible to ensure that Real Driving Emissions testing is more predictable, leading to closer alignment with WLTC results and giving the customer more confidence in stated fuel economy and CO_2 claims.

Where CAM is deployed in confined areas such as ports, greater productivity and predictability can result. In addition, removing some of the people from hazardous areas can contribute to health and safety and reduce costs incurred by protective measures.

4.2.3. Jobs to be done and challenges

Since customers desire low-cost, fast, comfortable, and safe operation/travel, an automotive OEM should focus on its 5G for CAM application developments to fulfil these requirements. For that purpose, related KPIs, such as reduced operation time, number of accidents prevented should be added to 5G-CAM application field tests.

Main challenge here is the standardization of an 5G-CAM application. Today, Automotive OEMs know how to implement safety applications such as AEBS (Advanced Emergency Braking System, a semi-automatic brake system designed to prevent collisions or limit their consequences) or LDWS (Lane Departure Warning System, that detects line marking on the road surface and warns the driver of unintentional lane departures), but these applications do not interact with any external infrastructure. Their operation is entirely contained within the vehicle. This is not the case for 5G-CAM applications. Network is another key pillar to achieve reliable, safe, and secure applications. And that is why regulatory bodies, standardization institutes should define related application requirements and test conditions, to have interoperability among all automotive OEMs and safe, secure applications.

The human element of the system cannot be underestimated, and OEMs will need to prepare and educate their customers for the arrival of automated vehicles. There might be some resistance to such radical

changes in the way a vehicle operates, and the benefits should be clearly communicated. If an accident does occur, there is a danger that the OEM will be blamed, and a strategy for managing this would be wise.

Automation can also bring challenges from an OEM branding perspective. With automation bringing ever more standardised modes of operation, OEMs will need to seek alternative ways to differentiate their product (e.g. what about automated sports cars). This will be a challenge.

OEMs will also need to develop new business models that incorporate the connectivity element of automation and the services delivered via the infrastructure. This should be seen as a benefit and an opportunity to generate repeating revenue throughout the vehicle's life. It will need interaction with a new group of stakeholders, which they previously may not have been in contact with, and familiarisation with a new industry.

4.2.4. What we don't know?

Which 5G-CAM application will be the first industry standard to deploy on vehicles, what will be the minimum requirements, who will be liable if an accident occurs during the 5G-CAM application active on a cruise, and how will the current business models evolve…?

4.2.5. Existing Solutions

It is possible to see 5G-CAM proof of concept application deployments on the market today, such as tele-operated (remote) driving, automated valet parking for AVs, Cooperative Manoeuvres etc. most of which were demonstrated in 5G-MOBIX and other H2020-ICT-18 projects (H2020 ICT-18-5GCroCo project home page, n.d.), (H2020 ICT-18 5GCarmen project home page, n.d.) ,but none of them deployable yet.

C-V2X PC5 and DSRC based CAM applications which are powered by ad-hoc and/or 4G-LTE communication, are early steps of 5G-CAM applications. 5GAA releases their findings about related fields in their website (5GAA studies about 5G and C-V2X, n.d.).

4.2.6. This would be game changing!

For confined area operators and fleet owners, removing drivers from the loop will be the main game changer since humans are one of the main expenditures of the operations and they are more error-prone than robotic systems. Whenever we see 5G-CAM applications common deployment on the market, it will be enable driverless operations.

4.3. Application Provider Perspective

4.3.1. Who are our customers / users / stakeholders?

Customers vary depending on the application, it could be targeted towards the vehicle owners/drivers, application providers or the telco/service providers. For example, cybersecurity services can be provided to all types of stakeholders, business/operational support services can be provided to the infrastructure providers (i.e. for billing, SLA assurance), etc.

4.3.2. What are their likes and dislikes?

According to the results of a recent public consultation (Open public Consultation on Connected and Automated Mobility, n.d.) on Connected, Automated Vehicles, the vehicle owners require a feeling of **security and cyber-resilience**. Another significant trend is that of **data sharing**. About one third of vehicle owners would accept data sharing with public authorities in order to support the development of public-interest services, while a third would prefer restricted/conditional data sharing, and one third would decline all data sharing. The vast majority of respondents (75%) considers it very important to be able to **choose among different service providers**, independent from the vehicle manufacturer. Industry actors also agree on cybersecurity being essential (87.7%), and report "security issues introduced by 3rd party actors" as the most crucial issue. Furthermore, almost all industry actors (98%) see business potential for the re-use of non-personal vehicle data.

4.3.3. Jobs to be done and challenges

Although most industry actors claim the process collected data in accordance with EU data protection rules (69.9%), they also report (64.2%) that they do not have experience with implementing Article 20 ("Right to portability"). More than half industry actors (69.8%) believe that specific guidance on how to implement existing data protection rules. When it comes to automated vehicles, the rules of operation must be the same in all countries. This is necessary for all stakeholders like road operators, fleet managers, car manufacturers and MNOs.

4.3.4. What we don't know?

The business case for advanced 5G-CAM services is not very clear in many EU regions. It is not clear what kind of services might be preferred by drivers in each region and the related market penetration rate. This can hinder investment in this sector. The business case for ITS companies may be different to the public and private transport by cars or buses.

4.3.5. Existing Solutions

According to the results of the public consultation and based on industry respondents, among the most preferred solutions for accessing in-vehicle data and resources at short/medium term are:

- Extended vehicle model via OEM back-end servers,
- Neutral server model,
- Other solutions listed are: Secured Vehicle Interface+ "Open OBAP", OBD2 port, Secure Vehicle Interface (SVI) concept.

Furthermore, UNECE WP.29 is working on the definition of storage of data from CAVs.

4.3.6. This would be game changing!

Solutions for virtualised cybersecurity could be game changing, as this approach could make remote management easier for all parties involved. Furthermore, the introduction of data sharing services from a trusted intermediary with anonymisation, encryption, authorisation, authentication on the fly, can simplify the collection of data and its sharing among "data consumer" organisations.

4.4. Network Equipment Provider

4.4.1. Who are our customers / users / stakeholders?

Network equipment providers mainly target three customer segments with their hardware, software and services portfolio: Communications service providers (CSP), enterprise verticals and hyperscalers. Additionally, they focus on licensees in selected industries that benefit from the value of their innovations, primarily in the mobile devices, automotive, consumer electronics and emerging IoT industries.

4.4.2. What are their likes and dislikes?

CSPs nurture a more diverse supplier ecosystem based on open architectures. Their aim is to broaden their supplier options and increase competition to strengthen their pricing power towards the network vendors. We have seen the first examples of CSPs relying on hyperscalers to lead the transition to a cloud-based operational and business model. This introduces new players and increases competition for established network vendors. Lastly, geopolitics and environmental, social and governance (ESG) criteria influence investment decisions. Security and sovereignty have become important factors in the vendor landscape. Government-funded broadband initiatives influence the investments of CSPs, for example in rural areas and support the emergence of neutral hosts.

Within the enterprise verticals segments, the digitalization and automation of operations across verticals accelerates demand for critical networks. In transportation, the transition to software-centric operations and the adoption of industrial clouds and operational technology (OT) edge will further increase efficiency. Private wireless networks and mission-critical transport edge applications are key enablers. In transportation, vehicle automation and the assistance to vehicle drivers are the main concern because these networks should be deployed.

Hyperscaler are companies like Alphabet (Google), Amazon (Amazon Web Services), Microsoft and Meta Platforms (Facebook) that provide cloud solutions at a global scale, leveraging massive, connected data centers. Hyperscalers need optical networks and IP routing. Within optical networks, we foresee that data center interconnect (DCI) technology will be a strong driver. Hyperscalers assume an increasingly important role in the telecommunication domain and will become ecosystem partners and potential competitors. Hyperscalers target edge computing as the next growth engine for industrial automation workloads and low-latency applications.

4.4.3. Jobs to be done and challenges

Critical networks combine carrier-grade resilience, reliability, and security with web scale flexibility and elasticity. As we move ahead in an era of digitalization, critical networks will gain much more importance and reliability requirements will increase significantly. Network vendors need to position their solutions in the automotive sector, giving their automotive customers enhanced capacity and connectivity while offering greater energy efficiency and ease of deployment. Vendors also need to improve also with new radio features the scalability of the radio handovers for automated vehicles and for transport applications.

Solutions that provided by vendors need to progress to new sectors like transportation. Vendors need to drive the market in fiber and 5G fixed wireless access, and in optical networks to give customers increased performance and cost efficiency. These networks must be deployed throughout the border of the countries to provide continuity on the sensors network and automotive virtualized applications.

Cloud and Network Services provided by vendors will provide a new solution category that will enable on-premises processing of a host of transportation and industry 4.0 applications and help customers accelerate their digitalization plans. Vendors must launch new Software-as-a-Service products for their communications service provider customers, giving them more flexibility and ways to capture revenue from transport sector.

4.4.4. What we don't know?

Risks related to vendor strategy and its execution:

- Vendor's ability to become and remain as a leading provider of technology, software and services in the industries and markets in which they operate.
- Trends, such as cloudification, open RAN/openness, virtualization and disaggregation with potential impact on vendor's portfolio of products and services, competitive landscape, business models and their margin profile.
- The degree vendor's investments, including venture funds, result in technologies, products or services that achieve or retain broad or timely market acceptance, answer to the expanding needs or preferences of our customers or consumers, or in breakthrough innovations, research assets, digitalization, and intellectual property that we could otherwise utilize for value creation.
- Vendor's ability and success in acquiring or divesting businesses and technologies, in integrating acquisitions, entering licensing arrangements, and in forming and managing joint ventures or partnerships.

Risk related to the surrounding economic, financial, and competitive environment:

- General economic and financial market conditions and other developments in the economies and industries where we, our customers and partners/suppliers operate.
- Duration of the COVID-19 outbreak, disruptiveness of the related measures to contain the virus and other prolonged impacts of the pandemic.
- The cyclical nature of the markets in which vendors operate, competitor behaviour, customer consolidation, customer purchase and spending behaviour, deployments and rollout timing.
- Accelerating inflation and our ability to pass increased costs to vendor's customers.
- Price erosion largely driven by competition challenging the connectivity business models of vendor customers.
- Vendor's dependency on a limited number of customers and large multi-year agreements.
- Competitiveness of or developments regarding pricing and agreement terms vendors offer, including developments with respect to customer financing or extended payment terms or credit lines that we provide their customers.
- Willingness of banks or other institutions to purchase vendors receivables.

4.4.5. Existing Solutions

There is a diversity of technology and enterprise with different approaches in the market.

The RAN market, including associated network management solutions and network services, is a highly consolidated market. All vendors offer similar solutions, such as 5G SA, NSA core and network infrastructure equipment. Deployment is currently limited.

Cloud and Network Services operates in a fast-moving marketplace characterized by numerous competitors that range from niche providers to global technology enterprises whose offerings span several technical capabilities. The competitive environment comprises networking companies, infrastructure and application software suppliers, services specialists, hyperscalers, cloud providers and a wide range of industry segment businesses.

4.4.6. This would be game changing!

Sensor's deployment in an efficient manner and interconnected between countries with low latency will create in Europe a global market size able to compete in the global market. So, roads must be covered with mobile connections.

The sensors network must be directly connected between the countries, not centralized in country/region isolated silos. So, fibre must be interconnected in the border of the countries.

This basic infrastructure along the roads will be the baseline for the full deployment of a pan-European automotive radio network.

On top of this network diversity of operators public or private could interconnect different radio layers with radio Slices supporting many different Use Cases.

4.5. OBU/RSU Provider Perspective

4.5.1. Who are our customers / users / stakeholders?

Car manufacturers, road operators, end users. OEM's, telecommunication companies, regulators, road authorities, insurance companies and end users.

4.5.2. What are their likes and dislikes?

Being able to enjoy comfortable and safe travel is one of the main challenges offered by autonomous mobility. Having technologies that minimize risks will facilitate their adoption by public entities and their exploitation by companies.

From the end user's point of view, being able to provide them with comfortable, entertaining and safe travel experiences will help increase interest in using these types of services.

Low cost and safety are the main concerns for both types of providers. The RSUs, in particular, imply several costs for road operators, from acquisition and installation to maintenance and end of life discarding. As such, it is important to install the least expensive and with minimum life-cycle costs that comply with the requirements. RSU capabilities, as well as installation procedures, must keep this in mind. Road operators and end users are also concerned with traffic efficiency, i.e., making vehicles travel from origin to destination in as less time and with as less expenditure of energy as possible.

The OBUs installed in the vehicles allow access to a multitude of information and data of each vehicle. This allows monitoring the correct behaviour of the system and the detection of vehicle faults, as well as the measurement of indicators such as driving speed, acceleration noise, number of lane changes, following

distance between vehicles... All this information allows an exhaustive analysis of the user's behaviour and the operation of the entire vehicle system.

Providing vehicles with OBUs capable of working at full capacity with the latest technologies, such as 5G, can lead to better overall driving performance at all levels. It should be added that all V2X communications are supported by the OBU, enabling more accurate information to be obtained from and for drivers. In combination with the RSUs integrated in the road infrastructure, a technology is available that will enhance the improvement and efficiency of driving and traffic management.

One of the main challenges is to achieve full acceptance by users and other stakeholders of this equipment and the benefits that OBUs can provide in their daily lives, which is an essential role for the application of new connected vehicle technologies.

Having devices capable of upgrading to the latest technologies and evolving along with "communication technologies like 5G developments is one of the long-term goals. The overall implementation and upgrade costs and the current shortage of hardware elements such as chips is one of the current "brakes" to the implementation of OBUs in vehicles.

To promote the progress of OBUs and implement improvements in line with mobility needs, it is still necessary to coordinate driving simulation systems with field tests in both controlled and real-world environments.

4.5.3. Jobs to be done and challenges

In the interest of safety, both OBUs and RSUs should be able to acquire and transmit data in as close to real time as possible. While 5G, with its associated very low latency, allow 5G enabled devices to communicate at the necessary velocity, this would be for naught if OBU and RSU sensors/associated sensors are incapable of obtaining data at a similar velocity. It is important to take into account the costs associated with the development of the system, so boosting its scalability in production as soon as possible will be key to achieving its success.

It will also be necessary to study the needs in terms of computing resources, so it will be necessary to take into account the power requirements of the chips, as well as the artificial intelligence that will be used, achieving a good exploitation of data and joint decision making.

When defining the user experience, it is critical to take into account user training, as its misuse could trigger serious problems that would delay the adoption of these technologies, such as the distractions they generate in level 3 automated driving scenarios.

It will also be key to include different user experiences for all users, including groups such as the elderly, people with some kind of disability, etc.. CTAG for example has developed its own OBU (HMCU) integrating elements and the latest upgrades for 5G (using for example Qualcomm chips for its modems integrated in the HMCU). These in-house developments within the research field are helping to drive down costs in the future and bring more OBU options to the market.

4.5.4. What we don't know?

Current investment in device integrations and developments for OBUs and OBUs themselves is still a highly variable factor as they are in many aspects, such as 5G adaptations, research, and experimental

deployments. It is also still somewhat uncertain which direction will be taken by the elements to be integrated in OBUs such as 5G modems and chips suitable for full use with 5G technologies and the 5G infrastructure.

How much interest will road operators have in installing RSUs? So far, the interest and acceptance of different operators in devices such as RSUs and OBUs is very positive. In the SISCOGA corridor, for example, numerous devices of this type have been deployed and encouraged development in various projects (5G-MOBIX, AUTOPILOT, CROADS, CMOBILE, CRUSOE ...).

Who is liable for incorrect readings from the RSUs sensors? This question cannot be simplified to a short answer even if we can answer it even without standardisation or supporting regulations. There are several actors involved and the failure to receive or transmit an RSU can be due to a multitude of factors (from purely mechanical failure to failure to send messaging by a sender outside the RSU, sensor failure, network failure, GPS failure....).

As the RSUs are wired together, it is possible to detect problems remotely. If the messages have been sent in a correct way, in this case it can be considered that the vendor of the RSUs or OBUs should be responsible for solving problems in reading the messages and providing the necessary support and maintenance of this equipment in case of failure or error.

How many RSUs will be needed per road segment? It depends on what is considered as a road segment reference as we understand it to be the specific representation of a portion of road with uniform characteristics. If there are no obstacles, an RSU can provide coverage of up to 1km. It does not usually provide coverage over the entire motorway, but it is necessary to have a strategy for its placement, for example to place them at all the entrances to the motorway and if there is no entrance in between, every 10km. This way the events are registered when entering the motorway and if an event update arrived it would receive it every 10km. Anyway, it depends on the characteristics of the use-case you assess. Accidents could result in a short distance message by direct communication (C-V2X, DSRC) and a longer distance message to the downstream flow using a cellular solutions, and to the ITS center for traffic management guidance. It is not a one fit solution. Gantries over the road are a means of communication towards non-connected traffic participants. For some of these items a RSU may be necessary.

What will be the interoperability requirements for easy and cost effective deployment of RSUs and OBUs? The basic requirement to be considered is compliance with the defined standards. For this purpose, for example, regular Plug Test sessions are held, which CTAG also attends with its teams and which ensure interoperability. Also, different levels of interoperability could be considered in order to define the requirements to be considered, also taking into account non-technical aspects of interoperability (Source: EC New European Interoperability Framework 2017):

- Legal Interoperability
- Organisational Interoperability
- Semantic Interoperability
- Technical Interoperability

Within the main technical aspects should be considered as main requirements to be fulfilled to ensure Interoperability:

- Data Security

- Data Integrity
- Data Accessibility
- Transport Protocols
- Services & Messages

Understanding the different interfaces at all levels (physical layer, data link layer, network layer, access layer, application layer, presentation layer, session layer) must be achieved. Interactions between entities such as messaging servers and end-user applications must also be standardised to ensure interoperability and increase market choice for different vendors and purposes.

4.5.5. Existing Solutions

There are already a range of commercially available OBUs and RSUs with 4G LTE, DSRC and C-V2X PC5 capabilities, though prices are still high and real world, everyday use is still low and mostly untested.

In line with the above, it is important to take into account the costs associated with the development of the system, so boosting its scalability in production as soon as possible will be key to achieving its success.

This would be game changing!

OBUs will allow vehicles to send/receive position and sensor readings to/from other vehicles (V2V), infrastructure (V2I), network connected software (V2N) and pedestrians (V2P). RSUs on the other hand, allow the capture and sending of data related to road conditions and traffic operation. Both technologies would be instrumental in increasing road safety and decreasing accidents and mortality, not to mention reducing traffic congestion and all associated problems. Moreover, OBUs can be installed in legacy vehicles, so we can gain these benefits more immediately, without having to wait for further development of other technologies, like self-driving vehicles. OEMs, road operators and end-users would value efficient, cost effective and interoperable OBUs and RSUs that could be easily deployed and interfaced within an existing communication infrastructure, with minimum configuration effort.

4.6. Road Operators Perspective

4.6.1. Who are our customers / users / stakeholders?

Vehicle drivers (private), freight vehicle drivers, bus and coach drivers, Transport and Logistics companies, Emergency Services, Local and national governments (officers and elected officials). Shortly, everyone using the road.

4.6.2. What are their likes and dislikes?

Road Operators want to provide a high-quality service to their customers. They like systems and technologies that reduce congestion and accidents. A particular dislike is the costs of deploying, operating and maintaining technology solutions.

4.6.3. Jobs to be done and challenges

Road Operators are unsure whether to invest in 5G or ITS G-5 based technologies as they are unclear what technology will become dominant and what will be supported by vehicle manufacturers. Road operators are unsure whether third parties such as mobile operators will roll out the necessary infrastructure or whether they need to deploy it. Road Operators are aware of automated vehicles but unclear on when they will become common on their networks.

4.6.4. Existing solutions

There are some roads equipped with road-side units, 5G and ITS-G5 but these are generally limited to test-bed / technology pilot sites. Older technologies such as variable message signs are used to provide information to drivers such as roadworks or congestion and to provide safety messages such as temporary speed limits.

4.6.5. What we don't know

What will be the uptake of connected and automated vehicle services over the short to medium term (next 10 years). This influences investment decisions and choices on which technologies to deploy on road networks.

4.6.6. This would be game changing!

Provision of affordable 5G services through on-board units and infrastructure that has real impacts on driver behaviour and traffic conditions. If accidents and delays can be reduced, this will significantly improve the experience for road operator's customers. For toll-roads this might lead to increased income as more drivers use the road due to the higher quality experience.

Provision of information directly in-vehicle could lead to reduced need for physical infrastructure such as variable message signs and ultimately, reduce operational costs. However, this would mean that the majority or all vehicles capable of receiving in-vehicle information.

4.7. End User Perspective

4.7.1. Who are our customers / users / stakeholders?

End users will comprise drivers of cars, commercial vehicles such as trucks and vans, passenger service vehicles for example buses and taxis, emergency service vehicles including breakdown services, and vehicles with trailers such as caravans. It could be argued that other users might include non-vehicular actors such as pedestrians and cyclists, as well as motorcyclists, who have an interest in the behaviour and safety of motorised traffic. These are the direct end users although some of those described in the immediately preceding sections above. The 'drivers' includes those using fully automated vehicles as well as those that are manually controlled and everything in between.

4.7.2. What are their likes and dislikes?

For those that will continue to use manually operated vehicles for some time, as well as for pedestrians, cyclists/motorcyclists etc., it will be important that automated vehicles behave in a predictable and consistent manner to prevent potentially dangerous evasive action. Maintaining that predictability regardless of the nature of the road (e.g., urban, rural, border corridor etc.) will be important, as those road users should not be expected to modify their behaviour, depending on whether the road has effective connectivity. This will be particularly important during the transition from driven to automated vehicles, where different levels of autonomy will be using the road along with manually driven vehicles. Where safety is improved it benefits the occupants of all vehicles and potentially other road users such as pedestrians.

Drivers of automated vehicles at different levels will benefit from the ability to remain in 'autonomous' mode in as many locations as possible. In SAE level 1 – 3/4 cars there may be a need for the driver to take control of the vehicle under certain circumstances, and one of those might be in areas where there is insufficient connectivity for the vehicle to operate safely in a collaborative or autonomous condition. Provision of ubiquitous connectivity and access to automation infrastructure in as many locations as possible will minimize the probability of driver intervention being needed, and increase driver satisfaction and confidence in the systems. This in turn is likely to increase the adoption of automated vehicles leading to greater economy of scale leading to reduction in vehicle prices. Where autonomy is intermittent it will be difficult to achieve widespread adoption of vehicles with the technology.

There are possibilities for commercial users. Automated trucks can provide savings in terms of driver cost, but also from potential fuel savings gained by platooning, which has the added benefit of increasing road capacity safely. Buses can gain from the ability to remove the driver, potentially creating space for more passengers. Removal of the driver can only happen if journeys can be completed in their entirety without the need for manual intervention and that will depend on ubiquitous connectivity and access to infrastructure before those benefits can be realised. Platooning still has benefits when a driver is in place however it is mor valuable if it can be achieved in unbroken sections of road.

Ensuring that the connectivity and infrastructure is present throughout the road network will benefit the end user in terms of safety and commercial returns, as well as driving the adoption of vehicles with higher levels of autonomy, bringing multiple benefits such as access to efficient cost-effective transport to a greater number of people and enabling the transition from legacy transport modes.

4.7.3. Jobs to be done and challenges

The infrastructure and technical jobs to be done are discussed in other sections of this report. The need to gain long-term user acceptance and 'buy-in' will be needed for adoption of automation. End users must be informed and educated so that they understand why this is taking place and what the benefits will be to each user group. There will be implementation costs and many of those will be borne by users both through the vehicles they use and also via taxation for some of the infrastructure.

The process will need to start before implementation of infrastructure, to encourage acceptance and to prepare users to invest in vehicles with the necessary technology. There will be challenges to persuade users who do not appreciate the proposed benefits, and will wish to continue using manually driven vehicles for longer periods. Interaction between automated and manual vehicles will be important.

4.7.4. What we don't know?

The biggest unknown is how user groups will react to automation and therefore the rate of penetration into the market. The 5G infrastructure must be able to deal with the highest rate of adoption that can be foreseen to maintain confidence in user groups from the outset.

It may be assumed (but needs to be tested) that commercial road users will see the biggest benefits first, and therefore are likely to adopt technology earlier than the general population. Early adopters will be important to demonstrate the benefits to ither use groups.

It is not yet known how incidents will be viewed among user groups and those that will have to fund the technology and infrastructure. Any incident that can be interpreted as being related to automation and 5G, could be reported unfavourably by press and other actors that are external to this endeavour. This could affect confidence and adoption of the technologies.

4.7.5. Existing Solutions

This is a wide-ranging and open question. From a user perspective the technology should be transparent, requiring no prior knowledge or ability to interact. As a newly emerging technology the only alternatives from this perspective are the current situation of manually controlled vehicles, some with ADAS capability and earlier-stage autonomous capability, and other modes of transport.

4.7.6. What would be game changing?

The main influences here are likely to be cost, confidence and legislation.

The cost equation must work for commercial adopters of automation. For freight forwarders, for example, the benefits must at least match the cost of implementation. Adoption among one set of end users provides confidence to others to consider automated vehicles and use of the infrastructure.

Legislation that encourages implementation would be beneficial. It may relate to road operators' responsibilities, or to determination of liability in the event of an accident, or to a number of other areas that will either drive or hinder this programme. It is important that there is an alignment between states to ensure consistency across border corridors in terms of both cost and legislation.

These are areas that address the needs of potential end users.

5. RECOMMENDATION EVALUATION

In this chapter, recommendations are taken from "D6.2 preliminary report on the business models for cross-border 5G deployment enabling CAM" [25]. The recommendation rating methodology is taken from "D6.1 plan and preliminary report on the deployment options for 5G technologies for CAM" [26].

The recommendations are categorised into four different groups:

- XBR – Cross-border corridor recommendations,
- HCR – Human-centric recommendations,
- D&I – Deployment and investment recommendations,
- L – Legal recommendations.

The prioritisation of the measures is shown next to the recommendations under the following terms:

U:	Utility Score
C:	Lifecycle Cost Score
F:	Final Score = (Utility Score/Lifecycle Cost Score)

High priority
Medium priority
Low priority

The scores listed in the subsections were provided by a questionnaire used to interview the 5G-MOBIX stakeholders.

5.1. Cross-Border Corridor Recommendations

Table 24 presents the Cross-border recommendations provided by the 5G-MOBIX project partners about 5G technology for CAM applications. According to the responses, large-scale validations were consistently rated as the most important recommendation in terms of utility, as well as the most costly one in effort. The variety of studies that target a good understanding of the business ecosystem and the driving forces behind the market were considered especially useful as well, with a much lower cost. Therefore, in the case of the utility-to-cost ratio, they were ranked higher than large-scale validation. The recommendation that offered the best utility-to-cost ratio is the requirement for a cost-benefit analysis in the critical corridors, that is contingent on the definition of critical parameters for policy and business requirements.

Table 24: Cross-border Recommendations

ID	Recommendation	Description	U	C	F
XBR1	**Create a Cost Benefit Analysis for the critical corridors**	In order to execute on the existing plans regarding the critical corridors where 5G CAM services can be used, some public investment is necessary for those locations where private investment alone is not sufficient (or not soon enough). In order to create a CBA for such public investment, policy makers need to define inputs. For this to happen, ecosystem participants must provide policy makers with guidance on how certain parameters of policy requirements affect the necessary investment. This is an iterative process which requires investment of time and resources from all participants.	3.101	2.04	1.52

XBR2	**Perform a VRIO analysis for potential products and offerings**	Perform a VRIO analysis for potential products and offerings, targeting the Cross Border Corridor environment and its specificities: Technical improvements are not sufficient to ensure the high innovation potential coming from the 5G-MOBIX CBC trials or the viability of future products and offerings coming from the CBCs. VRIO analysis assesses the (V)alue, (R)arity, (I)mitability, (O)rganisational support associated with a capability, in order to estimate its effect on the creation of competitive advantage. VRIO poses four important questions: (a) Is the offering Valuable? (b) Is it Rare? (c) Is it hard to Imitate? (d) Is there Organisational support to ensure its exploitation? When all requirements are met, long-term competitive advantages are created.	3.1	2.1	1.48
XBR3	**Perform large-scale validation to increase trust in the research results**	Perform large-scale validation to increase trust in the research results: Large scale data pilots are necessary to address the technology's readiness in near operational environments. Liaison with similar projects such as 5G CroCo and 5G CARMEN and exchange of information can strengthen our understanding of the effects of a growing number of connected vehicle when it comes to data volume, latency, reliability, availability etc. The availability of rigorous research results proving the viability of 5G for CAM (and their wide dissemination) can go a long way towards increasing trust in the technology, both for investors and for the buyers of 5G CAM services.	3.799	3.02	1.26
XBR4	**Regional market analysis**	Regional market analysis should be performed to assess the potential for growth of 5G for CAM in the specific countries (e.g. Compound Annual Growth Rate). Additional analysis should be made to assess what is the buying power for 5G CAM in the area. Furthermore, there needs to be an assessment of the most sought-out services by the drivers in the region, as such selections might not be universal across the EU. Deployment plans can then be finetuned to the connectivity and latency requirements for the required services, optimising the potential for adoption of 5G CAM as well as the placement of investment in the Cross-Border Corridors.	3.1	2.08	1.49

5.2. Human Centric Recommendations

These recommendations are part of what D6.2 identified as 'Cooperation enablers': the group of technologies, policies, cooperation strategies, etc. that can be considered to help alleviate the negative impacts of the barriers and act as business catalysts boosting the adoption and deployment of 5G and CAM. These recommendations aim to increase awareness, research and innovation human capital within the EU. According to the responses by the interviewed stakeholders, recommendation HCR1 'Upgrade of current

skills' is clearly considered the most important recommendation in terms of utility, its final score being the lowest of the four recommendations due to its being also the one considered the most costly. It should be noted, that even if the overall utility score of HCR1 is the highest of the group, when looking at the business impact alone, this recommendation is only third of the four, so it seems that there is agreement between the responders that this is a complex recommendation to assess. The highest ratio of the four measures corresponds to the HCR4 'Guaranteeing consumer choice', which also places second in overall utility, and second best in terms of costs, and second best again in business impact on its own, making it an agreed recommendation to focus on.

It should be noted, however, that absolute differences in the final scores of the 4 HCR recommendations are quite small. Utility in all 4 cases was considered between 3 and 3.5, Cost between 2.5 and 3, with overall ratios with even smaller differences. This seems to suggest that none of the recommendations in this category can be considered to be a clear priority over the others. The fact that they were all more or less equally rated as something that can be addressed in the next decade in terms of time criticality also suggests that the way these are described, they could be seen as a sort of a 'set', and somehow related with each other, but without an urgency to push for any of them significantly.

Table 25: Human-centric Recommendations

ID	Recommendation	Description	U	C	F
HCR1	**Upgrade of current skills**	Although there is a large number of professionals active in the 5G, CAM, big data, cloud computing, computer vision, embedded devices, artificial intelligence and automotive markets, and EU academic and research institutes heavily invest in their education, the realization of the 5G-enabled CAM vision requires continuous education of young professionals with additional focus on the specificities of 5G and CAM. In order to alleviate the impact of the technical disparities among member states, there needs to be invested effort to improve education.	3,433	3,04	1,13

HCR2	**Improve 5G and CAM related education in universities**	Another important aspect is the upgrade of current skills in the existing workforce. For example, the increased automation in ITS centers requires personnel re-training. It is important to note that at the level of publicly funded projects, dissemination and communication activities are instrumental and should be intensified. The inclusion of academic and research partners in 5G CAM projects ensures that these activities will reach a large audience, with additional focus on students, early stage researchers and young professionals in the beginning of their careers. Commercial partners need to ensure that their knowledge reaches their employees and clients. The road-mapping activities, research papers, evidence-based best practices and recommendations to be published by many projects, can be considered a further step towards the effective dissemination of specialized knowledge.	3,168	2,72	1,16
HCR3	**Fostering Job Creation and Entrepreneurship**	At the Member State level, a strong connection among high-tier research and academic establishments and the workforce should be established. Legislation could foster the creation of start-ups by ensuring tax breaks and protecting licensed or patented intellectual property. The Digital Single Market policies of the EU are a stepping stone for the creation of a viable ecosystem of highly innovative start-ups, however there are blocking factors when it comes to 5G/CAM. The creation of a data-driven economy where third parties can create added-value services on big data in the area of transport can greatly benefit from 5G CAM assuming that a level of protection personal data can always be enforced.	3,067	2,56	1,20
HCR4	**Guaranteeing consumer choice**	It is one thing when a consumer buys a particular vehicle which uses a cellular service from a particular MNO in order to provide services that are integral to the usage of the vehicle. It is another thing when the cellular service from this particular MNO limits the choice of which additional services can be used in the vehicle. Consumers should be free to choose which MNO/MVNO they want to use for such services (e.g. Infotainment)	3,218	2,68	1,20

5.3. Deployment and Investment Recommendations

Table 26 presents the Deployment and Investment recommendations provided by the 5G-MOBIX project partners in relation to 5G technology for CAM applications. The responses show that the most important recommendation regarding utility was Investment on Software Architectures, SOC and AI Development, though it was also the recommendation rated with the highest cost. On the other hand, the Cooperate for 5G Deployment was, by a significative margin, rated the lowest in cost. Though its utility was rated the lower of the Deployment and Investment recommendations, it was only by a small margin, so it is also the recommendation with the best utility to cost ratio.

Analysing the responses, we also found out that the 5G-MOBIX project partners see the most business value on the Investment on Better Infrastructure and Investment on Software Architectures, SOC and AI Development recommendations, while the Investment on Software Architectures, SOC and AI Development recommendation is seen as the most time critical.

Table 26: Deployment and Investment Recommendations

ID	Recommendation	Description	U	C	F
D&I1	**Investment On Better Infrastructure**	Road infrastructure needs to be upgraded to meet the demands of the future, to ensure efficient and sustainable mobility and logistics, to enable digital services and to remain resilient to the effects of climate change and resource scarcity. Increasing EU Competitiveness needs to include investment, cost, price, and innovation in road infrastructure and traffic management and must satisfy industry and public authorities, as well as consumers/drivers in order to be sustainable. On regional level, investments in transport infrastructure have been shown to correlate with competitiveness, through enhanced accessibility of services and transport endowment, lower office rental prices, reduction in emissions and noise level, increased labour supply and productivity, increased new business density, increased number of enterprises in certain sectors, growth of FDI inflows, increased export of goods and services, etc. Many CAM-related services are also at the core of smart cities operational concepts which also correlate with regional competitiveness. Better infrastructure is especially needed both in remote regions, to help closing the economic, social and productivity gaps, and cross-border regions, to ensure the swift and safe deployment of 5G for/and CAM autonomous features of CAVs.	3,67	3,23	1,14
D&I2	**Investment on Software Architectures, SOC and AI Development**	These areas are the major investment that the leading countries have made to win the race of 5G and autonomy. The EU must invest heavily in the development and promotion of more FAB	3,74	3,34	1,12

		development, AI and software otherwise the Chinese and American companies would dominate these areas and the stakeholders in Europe would be fully dependent on them to develop any autonomous vehicle and 5G hardware products. That would put Europe and the industrial ecosystems in a difficult position as all the IP and the owner of the value add business for the European economy would be outside of the EU.			
D&I3	**Cooperate for 5G Deployment**	When a cross-border infrastructure is planned, it must be decided how the costs, benefits and responsibilities will be divided between the respective parties. Road operators, road authorities and mobile network operators should collaborate to create synergies for connectivity deployment along CAM corridors and cross borders, working together to develop end-to-end solutions for future mobility and transportation services.	3,59	2,76	1,30

5.4. Legislative Recommendations

Table 27 presents the legislative recommendations regarding the cross-border issues. From the utility perspective the highest average value of the score is attributed to the "Creating a data economy" recommendation, with a very low deviation of both scores (utility and costs) between the partners. Furthermore, the highest ratio of utility over score is marked by the data economy recommendation. From the cost perspective, the recommendation of "Determine the Best Use of Public Funds for 5G Infrastructure" has the lowest score, which makes it the most accessible recommendation from the economic point of view.

Overall, the legislative recommendations are commonly agreed by the partners and the scoring is constant with the lowest deviations in "Creating a Data Economy" and "Having Open Discussions About Machine Ethics".

Another significant finding is that all recommendations are equivalent in value, have low deviations between the partners and low costs of implementations. A crucial aspect of the costs in the legal sections is that it cannot be compared with the required costs in recommendations targeting infrastructure aspects.

Table 27: Legal Recommendations

ID	Recommendation	Description	U	C	F
L1	**Creating a Data Economy**	5G-enabled CAM in conjunction with smart infrastructures has the capacity to transform the economy by enabling third parties to create new data-driven services. The main challenge is to create ethical data proxies that can provide sanitized data to any interested third-party, in order to minimize risks to citizens' digital rights and ensure GDPR	3.516	2.81	1.25

		compliance. This would be a key step to enable a data economy. The creation of industry-standard data formats is necessary as it would contribute to data interoperability as well as the creation of anonymization and sanitization services that would facilitate multimodal transportation, providing a complete travel experience for passengers.			
L2	**Legislating for the Future and Creating Clear Liability Borders**	5G for CAM creates a complex ecosystem of actors, creating a web of B2B and B2C relations. There need to be clear definition of fair use policies, penalisation procedures, liability borders, consumer rights protections, as well as a clear understanding on the effects of such policies to billing, fees and taxation. Special attention should be paid to cross-border harmonisation of legislation linked to 5G for/and CAM solutions, to ensure a homogenous deployment throughout the EU and the maximum protection of EU citizens' rights. Currently the vehicle owner is responsible for any kind of damage caused by the vehicle. The risk is typically covered by insurances. With automatic driving vehicles this may have to be changed, because the OEM or car operator (in case of remote driving or fleet management) gets a higher responsibility for failures. This will have to be aligned within Europe.	3.334	2.42	1.38
L3	**Determine the Best Use of Public Funds for 5G Infrastructure**	the EU has already signalled its intention to stimulate the development of 5G infrastructure covering some roads / corridors. Arguably, this was the most important step, but in order to implement such a plan a CBA should be made in order to decide where the benefits for the public good justify the usage of public funds to stimulate additional investment in 5G infrastructure	3.183	2.21	1.44
L4	**Having Open Discussions About Machine Ethics**	Certain application follows the state of the user, and once a HO is performed the application instance running on the other side of the border needs There are cases where a driver is required to make a moral choice, e.g. swerve and risk damage to the vehicle instead of injuring a pedestrian. A recent survey from MIT showed that moral choices when driving are not universal. Although the EU has provided guidelines for Trustworthy and	3.234	2.37	1.36

		Ethical AI, there needs to be a comprehensive framework for the ethical programming of automated vehicles, and a close inspection of the moral choices involved in driving. Having moral safeguards can increase the public's trust in connected, cooperative and automated mobility and may influence the uptake of a novel and disruptive technology. have the previous user information/data from the instance running in the originating country border.			

6. ANALYSIS OF QUESTIONNAIRE ANSWERS

6.1. Introduction

5G-MOBIX plans to demonstrate the potential of different 5G features to bring automated driving to the next level of vehicle automation, through trials on real European roads, along cross-border and local corridors. 5G core technological innovations are used to qualify the 5G infrastructure, evaluate its benefits in the Connected and Automated Mobility (CAM) context, and create sustainable business models to develop 5G corridors.

The emergence and rise of connected automated vehicle refer to both technological and industrial developments; in progressive yet rapid stages, it will become possible to safely confer more and more driving responsibilities to automated systems in road transport. These innovations involve personal vehicles, but also public transport and logistics/freight vehicles.

The objective is to take full advantage of technology's potential to deliver a renewed transport and mobility system with the following 5G-CAM service use case categories:

- **Advanced Driving** enables semi-automated or fully automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or RSU shares data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or manoeuvres. In addition, each vehicle shares its driving intention with vehicles in proximity. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency.
- **Vehicles Platooning** enables the vehicles to dynamically form a group travelling together. All the vehicles in the platoon receive periodic data from the leading vehicle, in order to carry on platoon operations. This information allows the distance between vehicles to become extremely small, i.e., the gap distance translated to time can be very low (sub second). Platooning applications may allow the vehicles following to be autonomously driven.
- **Extended Sensors** enable the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation.
- **Remote Driving** enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. In addition, access to cloud-based back-end service platform can be considered for this use case group.
- **Vehicle Quality of Service Support** enables a V2X application to be timely notified of expected or estimated change of quality of service before actual change occurs and to enable the 3GPP System to modify the quality of service in line with V2X application's quality of service needs. Based on the quality of service information, the V2X application can adapt behaviour to 3GPP System's conditions or notify the driver that a manual takeover is necessary. The benefits of this use case group are offerings of smoother user experience of service.

The entire mobility and transport ecosystem will need to adapt to these upcoming changes, therefore, we are interested in how each member of the potential 5G-CAM ecosystem operates.

In this survey, 5G-MOBIX tries to elaborate business perspectives of various stakeholder, how they see value proposition, who are the key partners for them, what the challenges are on a business level, what are their key resources to achieve 5G-CAM application, network, equipment etc.
The survey is targeted at 5G or CAM ecosystem stakeholders and differentiates between different categories with a tailored questionnaire for each.

The current questionnaire has been running for more than one month, from May 17th to June 27th 2022. We had huge difficulties to collect enough responses for each stakeholders' groups. Indeed, the final number of responses for each group is:

Table 28: Survey Respondents

Stakeholders' Group	Number Of Respondents
Software / Service Providers	11
Road Operators	4
OBU/RSU Providers	6
Network Equipment Providers	3
Cloud/MEC Providers	1
OEM	3
MNO	8
End Customers	27

We decided to exclude from the analysis the stakeholder group categories with less than 3 respondents in order to have representative results. Since, Cloud/MEC Providers stakeholder group has less than 3 respondents, it has been excluded and marked as red in the Table 28.

Nevertheless, even within the categories with more tant 3 respondents, the number of no answer and/or a big standard deviation between the responses did not allow us to capitalize all the questions.

Therefore, the following results are not as wide as we expected, but all insights possible have been extracted.

The analysis of the results will be presenting following the cases of the Business Model Canvas (Pigneur, 2010), for all stakeholders but the End-Customers. For these last one, a dedicated paragraph is available at the end of this section.

6.2. Value Proposition

This section aims to highlight the value propositions underlining the 5G services.

In the first question, we asked the stakeholders what the most valuable border crossing 5G-CAM service for their organization is.

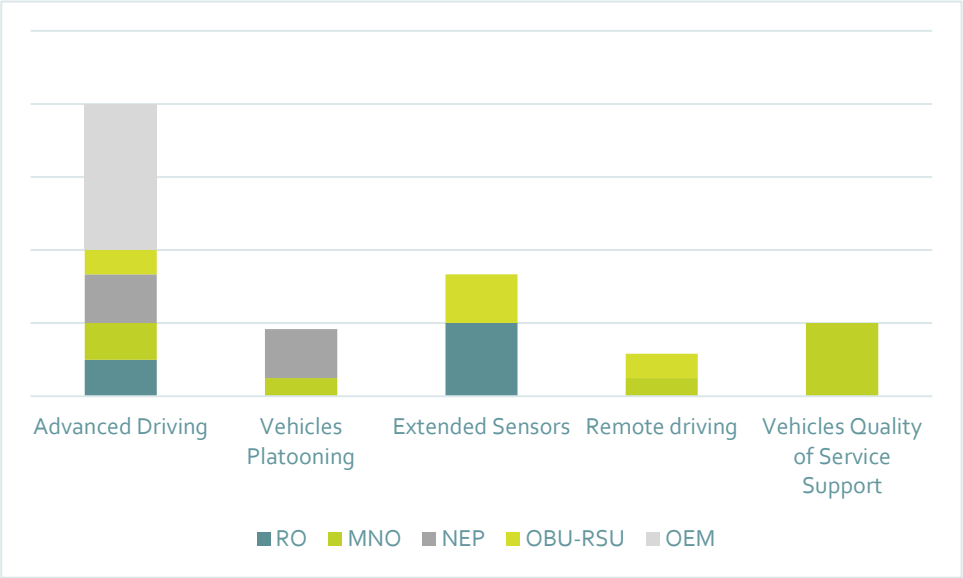


Figure 13: Value of border crossing 5G-CAM Services

From this figure we observe:

- For road operators, extended sensors (50% - commenting with the reduction of accidents) are the most valuable services, followed by advanced driving (25%).
- For MNO, the most valuable services are vehicle quality of service (50%), advanced driving (25%), and vehicle platooning (12,5%). However, MNOs do not choose the use cases, and the technology is not perceived to be mature enough to determine the value of the services accurately.
- From the network equipment provider perspective, there is no value difference, but selecting the firsts in time, they have chosen advanced driving (33.3%) and vehicle platooning (33.3%).
- OBU/RSU have chosen extended sensors (33.3%) to develop traffic data sensing and management further, but also advanced driving (16.67%) and remote driving (16.67%).
- Advanced driving is the most valuable border crossing 5G-CAM service for OEM (100%) even if they comment that extended sensors and remote driving are also valuable.

The second question aimed at rating the value propositions for each 5G-CAM service category regarding their relevance for their organisation. Observations are:

- Road operators, MNO have very divided opinions, with no consensus on the value proposition, and they split their preferences between all responses, without allowing us to reveal clear trends.
- Road operators emphasized for Extended sensors on improved maintenance and cost reduction and they added Improve Highway safety in this new environment, New business models based on network services and edge computing services to reduce CAPEX and OPEX costs of Road Operators and Automation of Road Operator' services related to traffic management as possible value propositions.
- For MNOs, the value proposition "Reduce Investment costs" is important for Advanced driving, Vehicle Platooning and Vehicles QoS. They also consider that Vehicle Platooning will improve quality of customer experience and that Vehicle QoS will create New Data based services and New customers.
- Network Equipment Providers gave us a more united point of view. They consider the value propositions: Improved market share, improved quality of service, new customers, energy efficiency, innovative image and security adequate for Advanced Driving, Vehicle Platooning, Remote Driving and Vehicle QoS.

- More than half of the on-board unit providers' respondents did not answer the question, but they suggested the value proposition "Emissions reduction".
- Concerning OEM, they consider that the value (for them) for:
  - Advanced Driving is: Increased market share, improved safety of vehicles and new revenue opportunities.
  - Extended Sensors is: Improved safety of the vehicle, an innovative image, and new revenue opportunities.
  - Remote Driving is: an innovative image, closer customer relationships, and new revenue opportunities.
  - Vehicle QoS is: improved safety of vehicles.
- OEMs also commented that increased customer happiness and decreased cost of ownership for the vehicle is their number one priority. They added as additional value propositions: higher multi-Gbps peak data speeds, production improvements and new investments, higher reliability and massive networking capacity that increased the availability and consequently higher vehicle capacity on the road, and a more uniform user experience for more users.
- Software Service Providers gave very heterogeneous responses that do not allow us to form conclusions. Most of them did answer the questions, but no real trend can be determined.

Concerning the impact of the 5G-CAM services on the goals of city and transport planners, questions were targeted only to Road operators. The following table represents their responses concerning the consequences they foresee.

Table 29: Impact on the goals of city and transport planners

Support and Improvement	Neutral
Reduction of (individual) motorized traffic.	Promotion and supplement of public transport.
Reduction of vehicle ownership.	Enhancing cross-border labour mobility
Promotion of active modes of transport (walking, cycling).	Promoting cross-border trade
Improvement of traffic flow and infrastructure capacity.	Less conflicts between different road users.
Improvement of traffic flow and infrastructure capacity while border crossing.	Increase of equity/ improving mobility of mobility constrained users.
Improvement of traffic safety.	Improvement of land use/ less space required for road transport (parking space, cross-border site etc.)
Lowering emissions caused by road traffic (air pollution and greenhouse gas emissions).	
Integration of land use and mobility needs.	
Less noise emissions.	
Efficient/ less investment in (road) infrastructure.	

6.3. Key Resources

This section is dedicated to key resources and aims to fine-tune the focus of the stakeholder's portfolios.

The following table presents the results:

Table 30: Stakeholders' portfolio focus

Stakeholders Group	Focus
Road Operators	Traffic management and safety Tolling payment. Efficiency of the road infrastructure. Users Security, Traffic reduction
MNO	Connectivity New services, including connectivity Mobile network, Data network, Application platforms, Service management Communication
MNO Vendors	Radio and Core HW and SW MEC Network Management solutions (inc. network orchestrations and slicing) 5G RAN and core provider
OBU/SRU	Software developer Artificial intelligence Design and development of multi-sensor perception systems for the automotive industry. Backoffice tools (video big data). Tools for integrated mobility management Simulation and planning of new mobility strategies. RSU manufacture Roadside extended sensors to support automated vehicles comprehensive solutions for traffic management Focused on the infrastructure side
Service Providers	Autonomous Driving software Remote operation and highly automated driving Privacy and data protection, ethics-by-design, security, social acceptance of technology Big Data MLOps Integration Software Development Data ingestion from the car AI/ML based post processing ad intelligence generation at the cloud/edge

	feedback to the car / autonomous driving commands to improve efficiency and safety ITS Solutions for Infrastructure Operators Testing and certification, and test tool development

OEMs considered the following key resource factors needed to enable 5G for CAM:

- Mobile Network Operator (MNO), 5G devices and proper infrastructure
- Labour. Finding a qualified person in the job market who fits demands is very tough.
- Vehicles. They will have extra equipment to enable 5G-CAM, which will introduce costs.
- Labour, hard to find well-trained employees. Network prices are unknown.

The following question considered the difficulty of integrating 5G for the CAM services in each stakeholders' operations, in a cross-border context.

Advanced Driving seems to be difficult to integrate in the operations for all stakeholders except Road Operators (Figure 14).

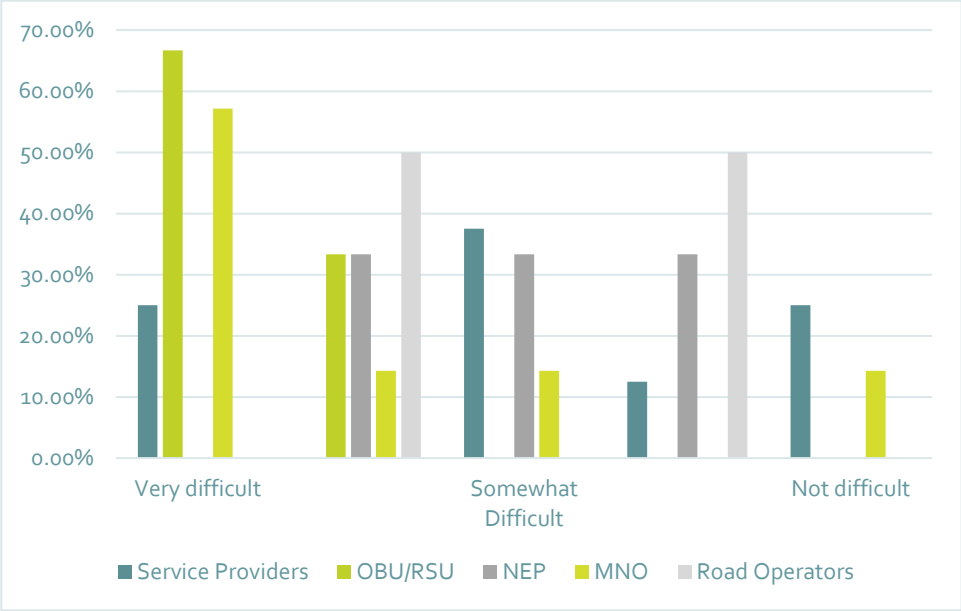


Figure 14: Difficulty for Advanced Driving

For Vehicle Platooning, the integration in the stakeholder's operation is less difficult, even though OBU/RSU providers and MNOs have some doubts (Figure 15).

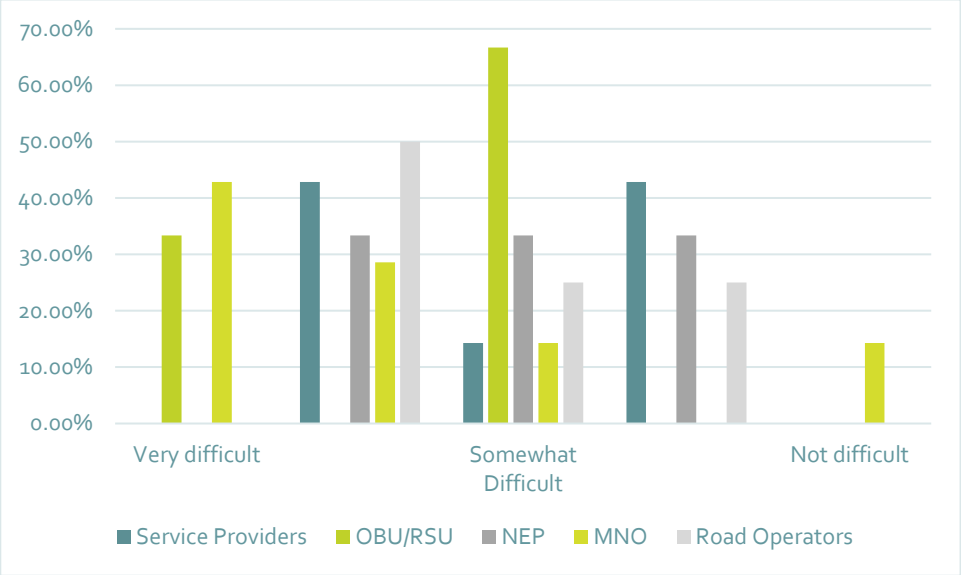


Figure 15: Difficulty for Vehicles Platooning

For Extended Sensors, there is no clear trend concerning the implementation in the operations (Figure 16).

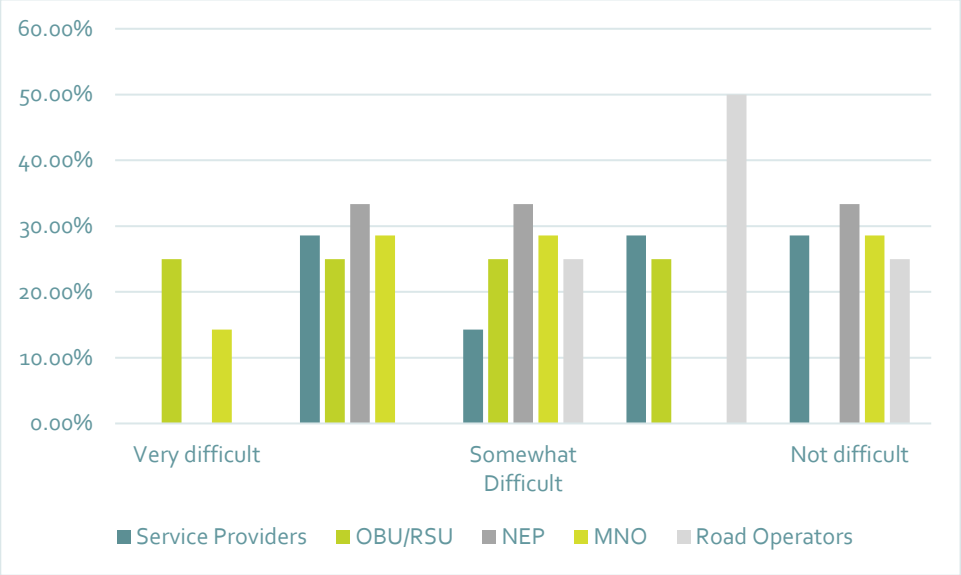


Figure 16: Difficulty for Extended Sensors

Remote Driving, like Advanced Driving, will be difficult to integrate for all stakeholders (Figure 17).

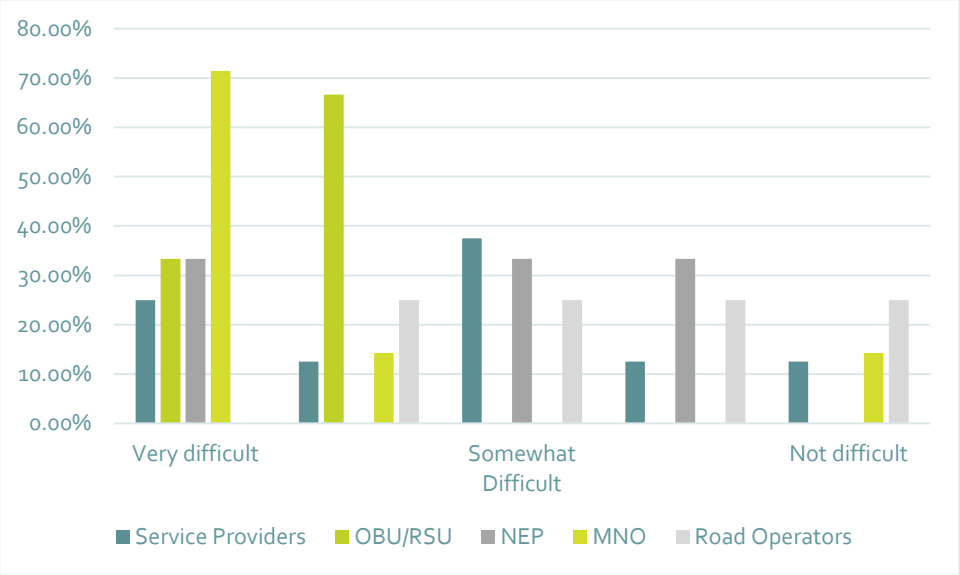


Figure 17: Difficulty for Remote Driving

And finally, for Vehicles quality of service support, no clear trend can be extracted (Figure 18).

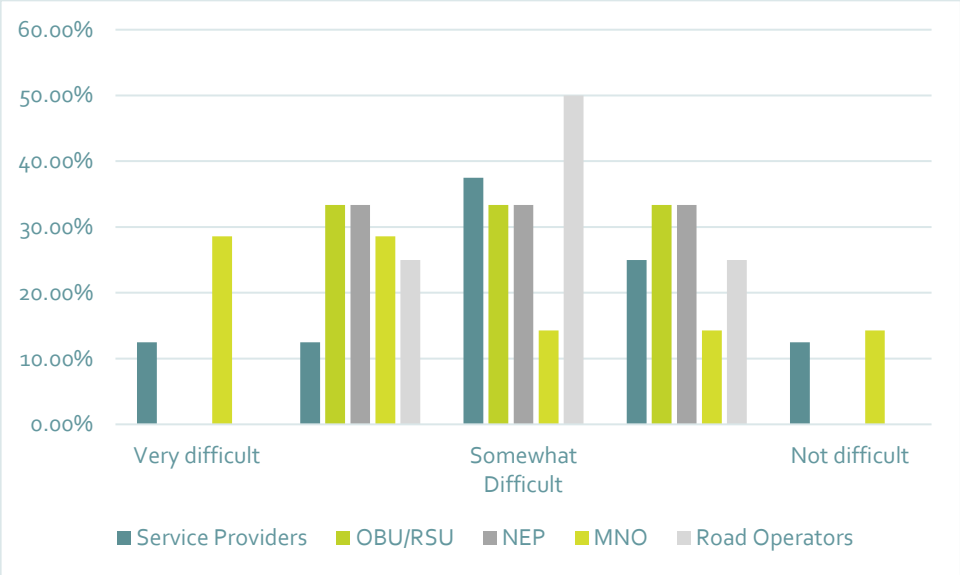


Figure 18: Difficulty for Vehicles QoS Support

The next step was to determine whether OEMs are currently developing or offering the following 5G-CAM services for their customers and how, in the context of border crossings, they would prioritize the implementation of 5G for the following CAM services in their production.

They declared having extended Sensors and Remote Driving services in development but did not respond or give clear trends for the other services.

Moreover, they considered that Advanced Driving and remote Driving would demand very high efforts, Extended Sensors high efforts, and Vehicles Platooning low efforts, while there is no clear trend for Vehicle QoS Support.

The next question explored in what areas further expertise and/or substantial is necessary to enable deployment of the 5G-CAM services.

In general, all stakeholders did not respond to this question.

One participant (MNO) declared needing digital road information and regulation, and one Service Provider highlighted Certification Processes.

Considering the importance of enabling 5G for CAM services for border crossings, most of the participants responded between somewhat important and very important.

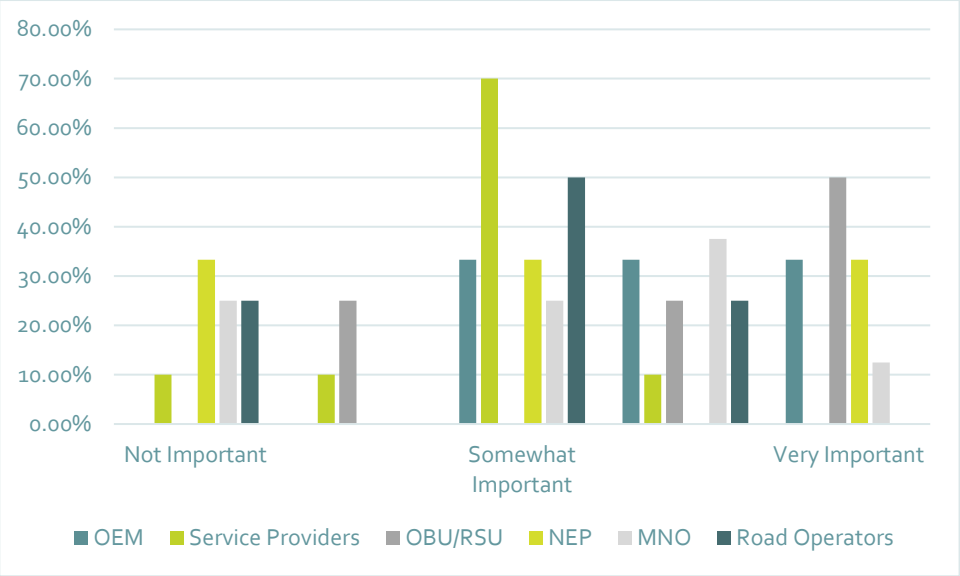


Figure 19: The importance of the enabling border crossing 5G-CAM Services

Finally, the last two questions assessed the expectations of OEMs about "5G" connected autonomous vehicles on the EU public roads and the estimated percentage of the vehicles they produced with "5G" connectivity in 2030. One-third expects 5G connected Autonomous vehicles on the roads between 2026 and 2029, and the other two-thirds between 2030 and 2035. Two-thirds expect more than 20% of their production to be equipped with 5G connectivity in 2030.

6.4. Customer Relationship

The questions about the stakeholders' customer relationships and the changes brought by 5G provided the following insights:

- MNOs indicate that all services will change their relationship with their customers.

- OEMs consider that Advanced Driving, extended Sensors and Remote Driving services will change their relationship with customer, but Vehicles platooning and Vehicles quality of Service Support will not.
- Network Equipment providers consider that none of the proposed services will strongly change their customer relationship.
- OBU/RSU indicate that only Extended Sensors Service will change their relationship with customers.
- For Road Operators, Remote Driving and Vehicles Quality of Service Support will impact their relationship with customers.
- Software Service providers mostly did not respond to this question.

6.5. Key Partners

In this section, we asked the participants what partnerships are essential for them to support deployment of border crossing 5G-CAM services.

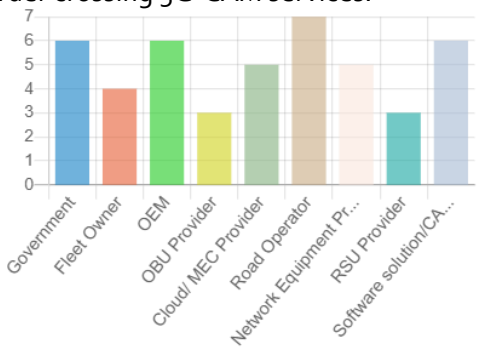


Figure 20: MNO partnerships

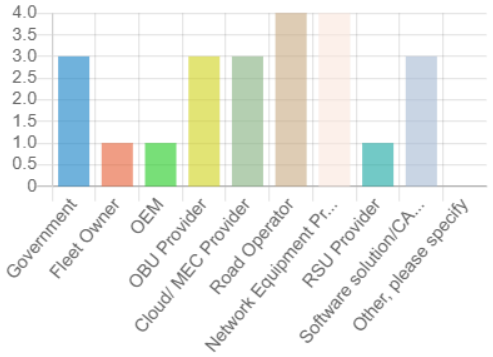


Figure 22: OBU/RSU partnerships

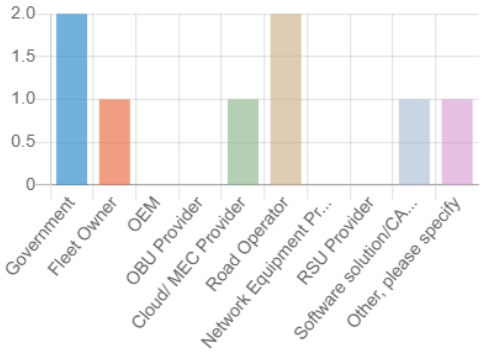


Figure 21: Network equipment provider partnerships

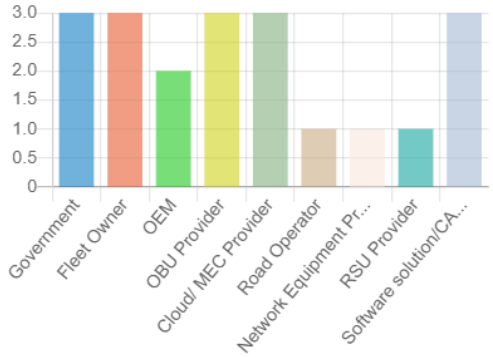


Figure 23: OEM partnerships

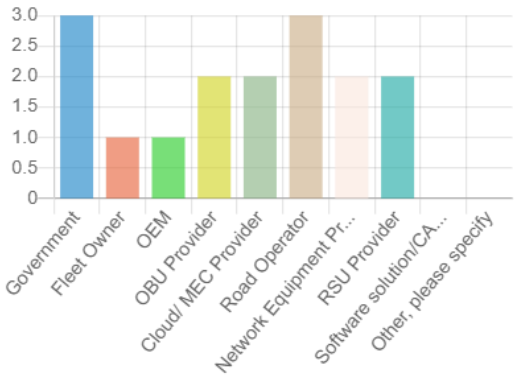


Figure 24: Road Operators partnerships

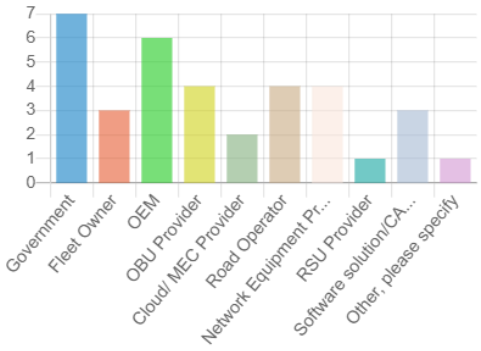


Figure 25: Service Providers partnerships

Governments are always a key partnership for almost all stakeholders' groups, and Road Operators also play a huge role. They mainly cited that standardized services are needed, and governments are driving a lot of the standards. Road operators are required to take ownership and work together to digitize the roads.

MNOs and OEMs are covering the largest ecosystems. Logically, as OEMs are driving the technology and future demand, while connectivity is required because there will be no utilisation of 5G without working and reliable networks.

The survey tried to understand what steps are needed to form the cooperation between the above-mentioned partners, but participants declined to respond to this question.

6.6. Obstacles and Challenges

The first question related to obstacles and challenges investigated the concerns of some of the stakeholders on dedicated subjects. These questions provided the following insights:

- 66.7% of OEMs have concerns related to accepting maneuvers coordination messages from a road infrastructure, mostly in regard to safety and responsibilities. They consider that liabilities must be defined strictly.
- 75% of Road operators considers having concerns related to accepting data from vehicles, from a data protection / GDPR point of view, but also considering the quality of data (real data, with no errors or delays) whereas 66% of OBU/RSU have no concerns on this issue.
- The second question addresses the most topical challenges for each stakeholder in its operation. The following tables illustrate the stakeholders' responses. To summarize, we can say that:
- For MNO, the main challenges are Roaming handover, Cross-border operations, Standardization and low-coverage areas for 5G-CAM applications.
- For OEM, the main challenges are Standardization, Accuracy of geo-positioning and low-coverage areas for 5G-CAM applications.
- For MNO vendors, the main challenge is MNO handover, but RAN optimisation and cross-border operations are also challenging.
- Considering OBU/RSU, the main challenges are MNO handover, connection loss while cross border operation, latency and Data and application-level protocol interoperability, but 6 more categories are also challenging.
- Road operators have totally different concerns, and their main challenge is Cybersecurity, and Service providers consider that packet loss caused by congestion is their main challenge.

These below figures provide the detailed results:

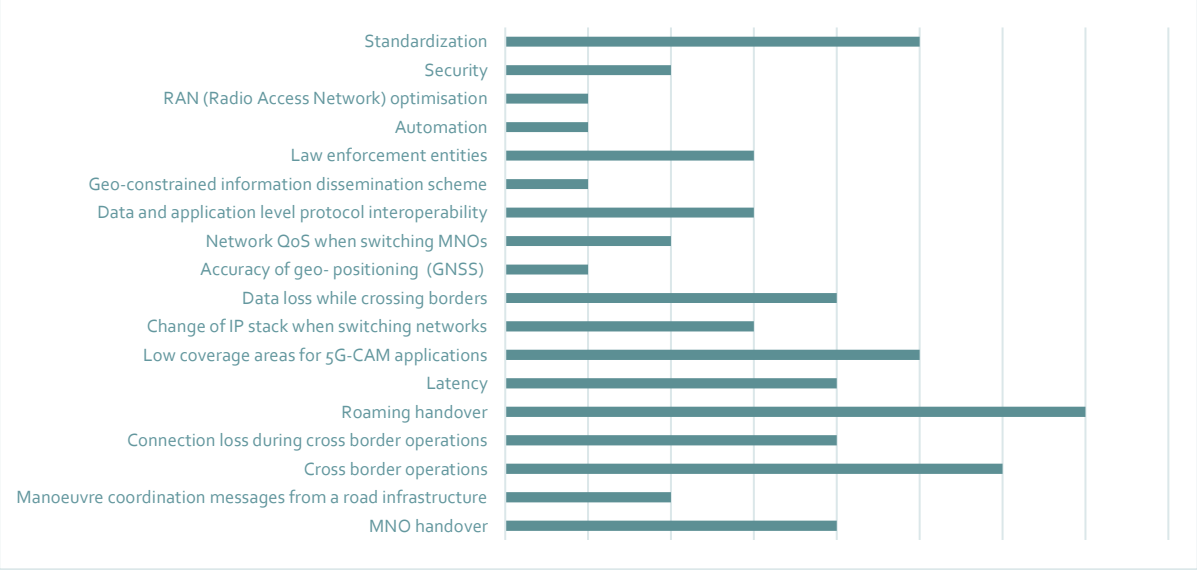


Figure 26: MNOs challenges

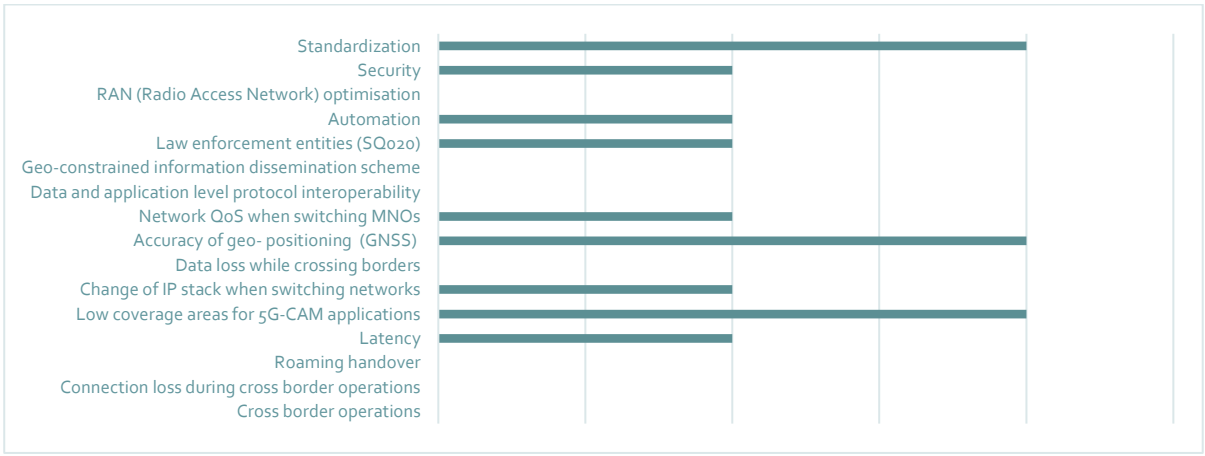


Figure 27: OEM challenges

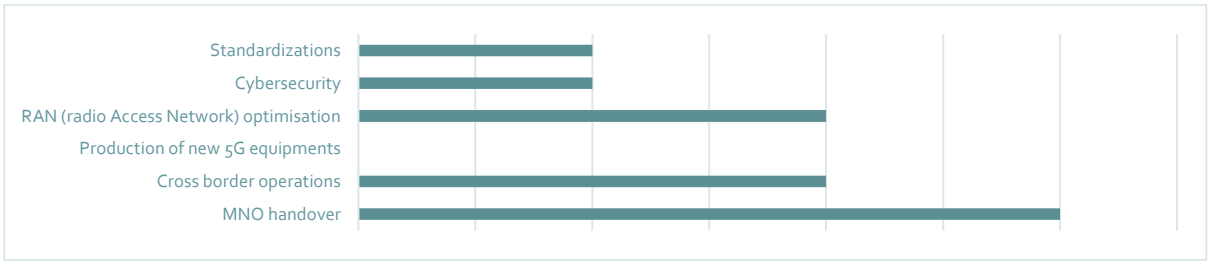


Figure 28: MNO Vendor challenges

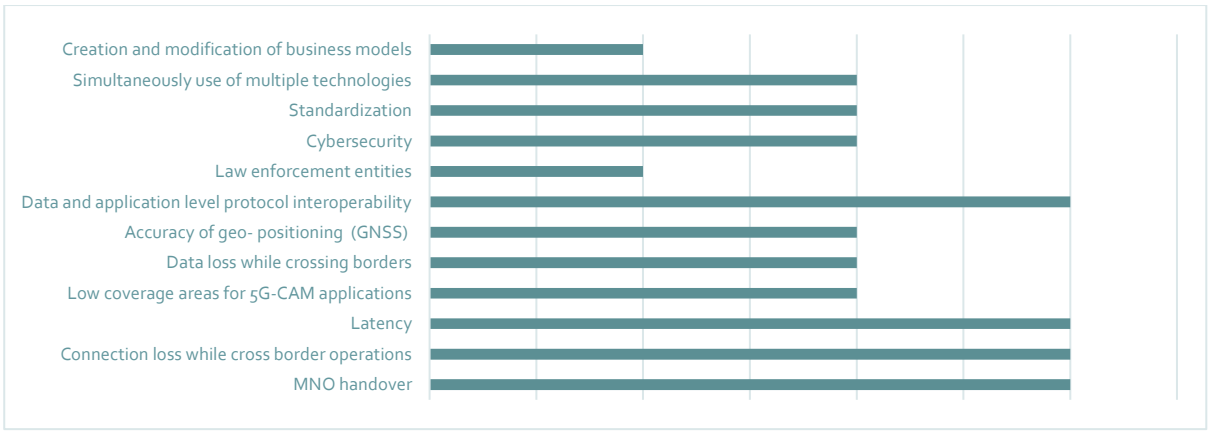


Figure 29: OBU/RSU Challenges

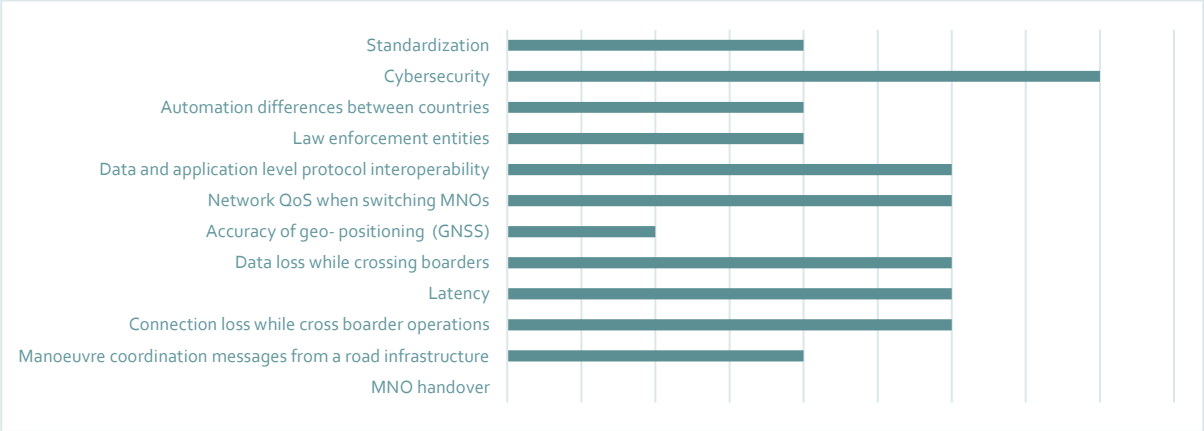


Figure 30: Road Operators challenges

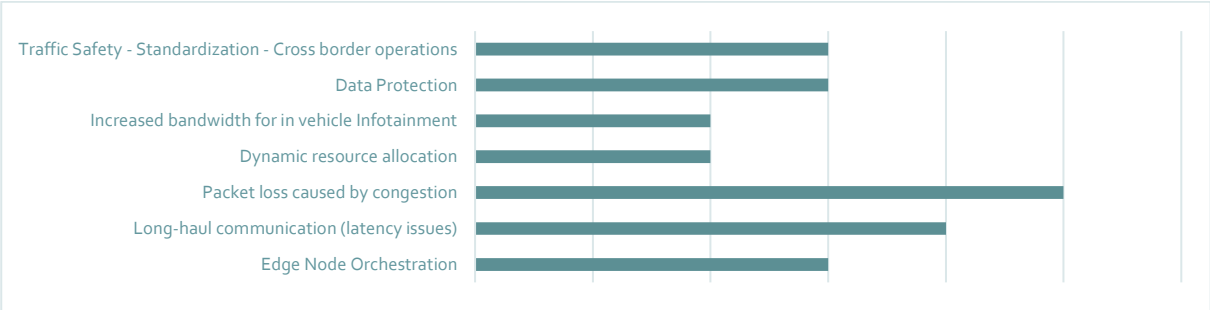


Figure 31: Service Providers challenges

The second question focussed on challenges related to the implementation of 5G-MOBIX border-crossing services. The answers provided the following insights:

- **OEMs** expect to have around 10% of their vehicles production equipped with a sim card from the factory to enable advanced driving functions in 2024. They think that the main challenges related to the implementation of the 5G-MOBIX services are the lack of standardization, the fact that the technology, as well as the equipment is not ready, and costs. Concerning the liability challenges of 5G-CAM services in case of safety-critical issue occurred, they consider that liability must be defined strictly in regulations, and that strict agreements between parties to understand liabilities are mandatory. They also consider the level of costs required for data protection as moderate. They highlight the fact that regulations must be completed in order to see 5G-CAM enabled vehicles on the road before 2026, and that standardization of 5G-CAM application is needed, as well as minimum required KPI's definition.
- **MNOs** consider that there is no clear demand for border crossing 5G for CAM services, and this thus has no priority. Nevertheless, they cited standardized network slice instances, interoperability and contracts as challenges. They also consider that a network service provider can never take responsibility for safety-critical issues regarding mobility. From a legal point of view, they highlight some issues currently known, like data breakout at other country will conflict with current data interception legislation and data exchange during handover that might cause issues with privacy legislation, as well as new challenges around responsibilities, governance, sanction regime, agreements for TDD interference avoidance, RAN optimization to achieve coverage and avoid ping pongs, and resources sharing.
- While considering regular congestion and traffic safety as the most topical challenges on their road networks, **Road operators** did not give a clear answer to the question related to the implementation of

5G-MOBIX border-crossing services. Nevertheless, they highlight the challenge of a common traffic regulation between road operators in European corridors and the need for high performance to automate traffic management services and continuous control of traffic management services when switching from one MNO to another. To enable 5G-CAM services, they added the need for common traffic policies between different countries and common regularisation and standardisation of CAM road infrastructure technologies.

- For **Network Equipment Providers**, the main challenges related to the implementation of border-crossing 5G-CAM services are Radio optimisation and KPIs generation for service monitoring, cross-border MNO seamless handovers; networks synchronisation; solution scalability, and the coordination of large group partners, arranging permissions and working conditions at the border area. They consider that a connectivity and roaming framework for CAM services is needed to enable 5G-CAM services.
- For **OBU/RSU**, the main challenges are achieving homogeneity of processes and legislations, obtaining network values that are truly adequate for the implementation of the proposed CAM services, minimising costs, as well as the connection between MNO and legal aspects, together with procurement processes that are considered as the key blockers for any actual deployment. Moreover, the harmonisation of data privacy-related aspects (namely in the scope of video technology), together with responsibility related aspects on automated/remote driving need to be address by legislation.
- **Service providers** consider that the main challenges from their perspective are the absolute certainty in handover from network to others, data protection and data sharing issues among third parties through ethical data proxies/trusted intermediaries, as discussed in the upcoming EU Data Governance Act, as well as regulation, interoperability, issues related with bad network coverage and long interruption times and MNOs agreements. For the challenges related to liability for safety-related issues, they consider that liability borders are not well-defined, and it could complicate insurance claims and corporate liability policies, and that a clear framework is needed. Moreover, in their opinion, applications must handle latency and data loss-related issues, and a clear regulation should decide who is responsible and to what extent.

6.7. Cost Structure

The questions about cost structure, due to the commercially sensitive nature of the questions, were not answered by the participants. However, some of them provided indicative figures that are summarised in this paragraph and tables.

For the expected increase in some cost categories for supporting the deployment of 5G for CAM services for the next 10 years, we can find some insights for Service Providers, MNO and OEM.

Table 31: Expected impacts on costs

	Service Providers	MNO	OEM
Staff costs	Negligible to Minor	Minor to Moderate	Moderate
Equipment and materials, including maintenance costs	Moderate to Significant	Significant	No data
Consulting / External services	Minor to Moderate	Moderate	Minor to Moderate
Network / Cloud / Hosting	Moderate	Significant to Major	Moderate to Significant

Patent / Sublicense	Moderate	Moderate to Significant	Moderate

6.8. Willingness to Pay

In this section, we wanted to estimate how likely the stakeholders' groups are to invest in supporting 5G-CAM services during the next ten years, considering the different 5G-MOBIX services. In some cases, the responses were too eclectic to be usable, but some trends can be identified:

- To start, all stakeholder groups are likely to invest in Extended Sensors.
- Network Equipment Providers are likely to invest in all the described services.
- Vehicle Platooning and Vehicle Quality of Service Support seem to be good investment opportunities for Service Providers and Network Equipment Providers but not for Road Operators.
- Service providers and Road Operators are not interested in Remote Driving.

6.9. Revenue Streams

The final part of the Business Model Canvas survey investigated the revenue streams.

Considering the mode of payment, OEMs prefer One-time Payment for Equipment and materials; they also consider One-time payment or Pay per vehicle as a possibility for Consulting / External Services. For Network / Cloud / Hosting, they prefer Pay-per-use or Monthly / Quarterly / Yearly fees; for patents, they expect a Pay-per-use. They consider that customers could receive discounts if they provide road data.

The last question investigated the expected impact in revenue as a result of deployment of 5G for the CAM services for the next ten years. The below figure presents the results.

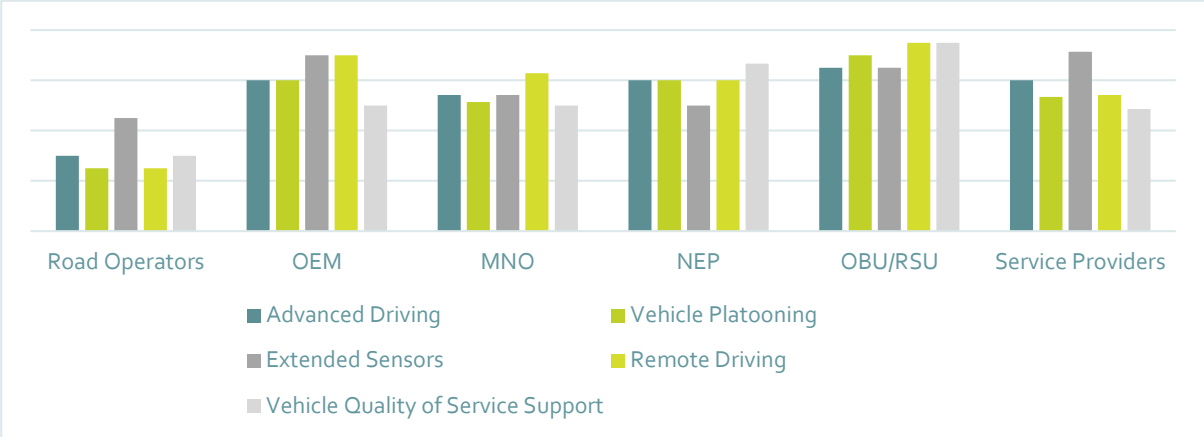


Figure 32: Expected Impact on revenue per stakeholders' group

Road operators are the most pessimists considering possible incomes. They quoted "they have nothing that comes to generate extra incomes".

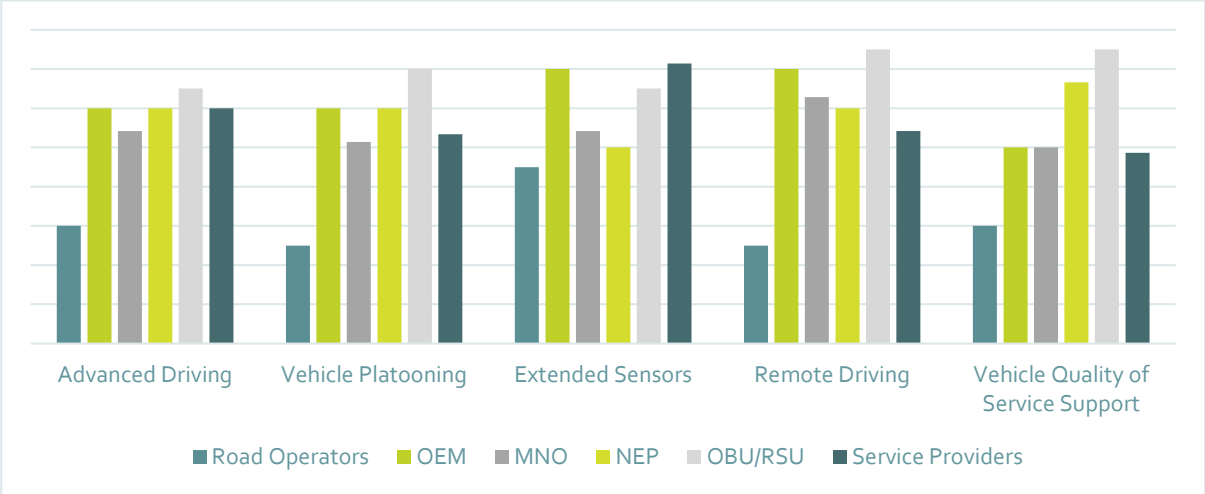


Figure 33: Expected Impact on revenue per service

Considering the services, they are quite balanced in terms of revenue generation, even if Vehicle Quality of Service Support is less prolific.

6.10. End Customers Questionnaire

To complement the survey among the stakeholder groups, end users have been questioned using a dedicated questionnaire, very different from the other stakeholders and then not comparable.

In a nutshell:

- There were 27 respondents
- 50% is in age group 36-47 years
- 81% is living in urban area
- 89% currently has paid work
- 90% has a car available for their use (all the time or quite often)

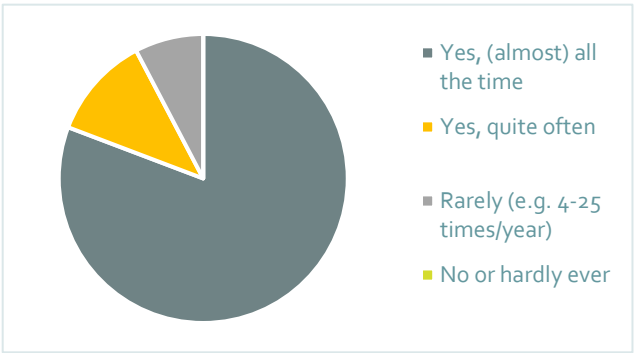


Figure 34: Car availability

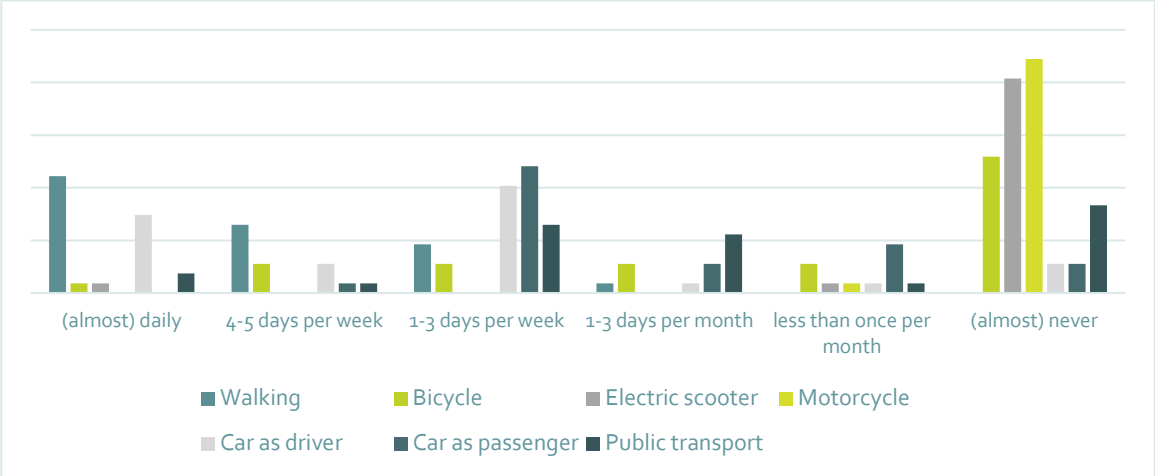


Figure 35: Means of transportation

Concerning their mobility habits, they use their car almost daily as driver, and they walk. They add bicycle, public transport, and car as passenger in their weekly routine.

Only a very small part of them is crosses borders in their normal life.

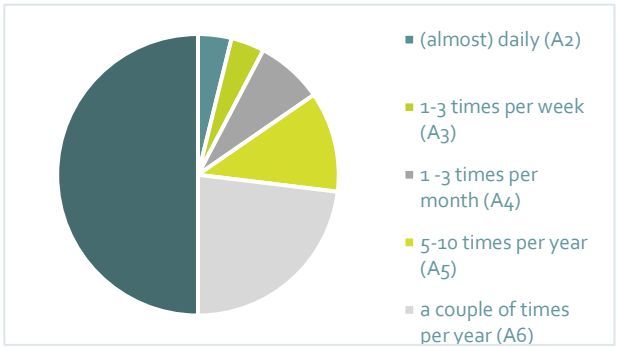


Figure 36: Border-crossing habits

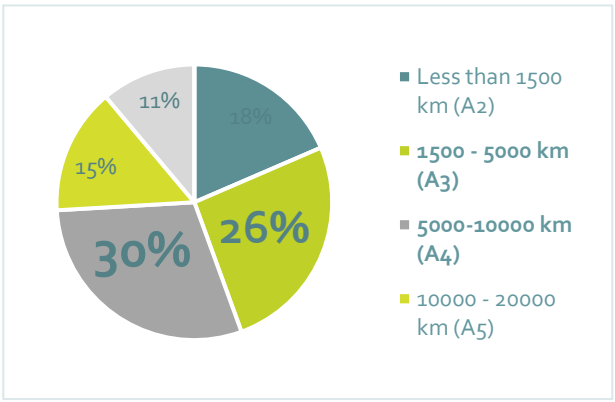


Figure 37: Driving distance habits

56% of the respondents did drive between 1500 and 10000 km during the last 12 months as a driver, and none of them drive more than 50000 km.

More than 50% on our audience declared purchasing or changing their car once in more than 10 years, and when ¼ of them wants to pay less than 15000€, half of them is willing to spend between 15000€ and 35000€. Only one respondent plans not to purchase a car anymore.

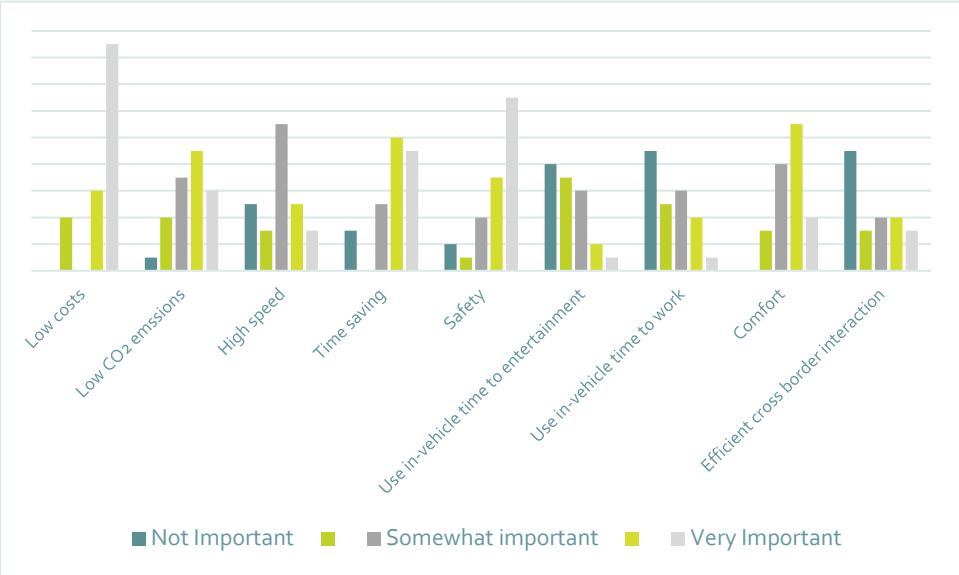


Figure 38: Important factors in mobility choices

The previous figures give us the priority factors of end users for the choice of mobility alternatives.

Cost is definitively one of the main factors, safety follows closely, and then comfort, time saving and low CO_2 emissions. Efficient cross border interactions, possibilities to use in-vehicle time to entertainment and to work are the less important factors.

Participants added some other factors too:

- Convenience when travelling with kids, pets, goods…
- Freedom / Flexibility (for instance while picking up a child to day care on the way to work or back home)
- Health related issues (like Covid).

Moreover, they experience the following issues regarding their mobility, number one being unpredictability of travel time, then lack of time.

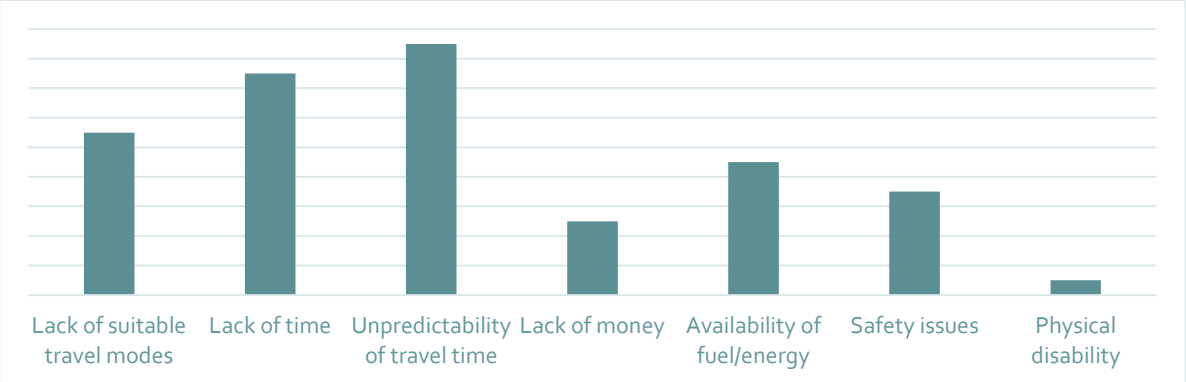


Figure 39: Mobility issues

Specifically related to cross-border travels, the preferred means of transportation are first aviation followed by passenger cars. These choices fully align with cross-check the previous answers. Indeed, plane is the fastest way to travel, with a level of freedom during the trip and very high safety. Then, passenger cars are the mobility choice that allows the most flexibility, freedom, and spontaneity.

Considering cross-border travel, it may be important to distinguish EU-wide and World-wide. Indeed, intra-Europe cross-border processes are mainly considered as not complicated and fast for 88% of the respondents, while 67% consider worldwide processes very complicated and time-consuming.

The last section of the survey assesses the 5G-MOBIX services, their value and their advantages for the end users.

Considering the possible use of 5G-MOBIX Services, if available in their cars, respondents in general agree to regularly use them, even if Remote Driving is less accepted than the majority.

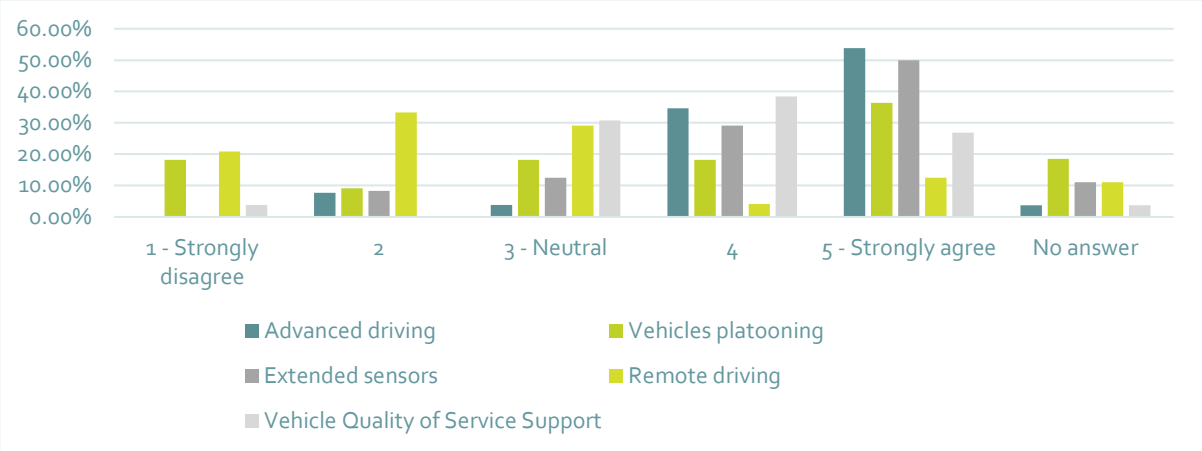


Figure 40: Willingness to use the services

Then, participants were asked about the changes 5G-MOBIX services will imply compared to their usual travels. Their responses are presented in the below table and discussed afterwards.

Table 32: Changes implied by 5G-MOBIX Services

Advanced Driving would affect…	Increase (%)	Same (%)	Decrease (%)	No answer (%)
…. the number of trips I make	18,52	**77,78**	0,00	3,70
… the length of trips I make	25,93	**59,26**	11,11	3,70
… my passenger car use	22,22	**66,67**	3,70	7,41
… my passenger car use during peak hours	18,52	**74,07**	3,70	3,70
… my feeling of safety in traffic	**74,07**	11,11	11,11	3,70
… my travel comfort	**81,48**	14,81	0,00	3,70
… my stress while driving	22,22	14,81	**59,26**	3,70
Vehicles platooning would affect…	**Increase (%)**	**Same (%)**	**Decrease (%)**	**No answer (%)**

…. the number of trips I make	7,41	**62,96**	3,70	**25,93**
… the length of trips I make	14,81	**55,56**	3,70	**25,93**
… my passenger car use	25,93	**44,44**	3,70	**25,93**
… my passenger car use during peak hours	18,52	**55,56**	0,00	**25,93**
… my feeling of safety in traffic	**59,26**	7,41	11,11	**22,22**
… my travel comfort	**59,26**	14,81	0,00	**25,93**
… my stress while driving	18,52	7,41	**51,85**	**22,22**
Extended sensors would affect…	**Increase (%)**	**Same (%)**	**Decrease (%)**	**No answer (%)**
…. the number of trips I make	7,41	**77,78**	0,00	14,81
… the length of trips I make	7,41	**74,07**	3,70	14,81
… my passenger car use	18,52	**66,67**	0,00	14,81
… my passenger car use during peak hours	14,81	**70,37**	0,00	14,81
… my feeling of safety in traffic	**70,37**	11,11	3,70	14,81
… my travel comfort	**66,67**	18,52	0,00	14,81
… my stress while driving	11,11	7,41	**66,67**	14,81
Remote Driving would affect…	**Increase (%)**	**Same (%)**	**Decrease (%)**	**No answer (%)**
…. the number of trips I make	7,41	**55,56**	3,70	**33,33**
… the length of trips I make	7,41	**59,26**	0,00	**33,33**
… my passenger car use	11,11	**59,26**	0,00	**29,63**
… my passenger car use during peak hours	11,11	**55,56**	0,00	**33,33**
… my feeling of safety in traffic	**25,93**	22,22	18,52	**33,33**
… my travel comfort	**40,74**	18,52	7,41	**33,33**
… my stress while driving	25,93	**29,63**	14,81	**29,63**
Vehicle Quality of Service Supoort would affect…	**Increase (%)**	**Same (%)**	**Decrease (%)**	**No answer (%)**
…. the number of trips I make	3,70	**81,48**	0,00	14,81
… the length of trips I make	3,70	**77,78**	3,70	14,81
… my passenger car use	14,81	**70,37**	0,00	14,81
… my passenger car use during peak hours	11,11	**70,37**	3,70	14,81
… my feeling of safety in traffic	**51,85**	33,33	0,00	14,81
… my travel comfort	**48,15**	37,04	0,00	14,81
… my stress while driving	3,70	37,04	**44,44**	14,81

To summarize, the use of 5G-MOBIX service will mostly increase their feeling of safety in traffic and their travel comfort, as well as decrease their stress while driving.

But when we asked them if the 5G-CAM services would affect their choice of travel mode, they all responded that they will use public transport, passenger car, walking or bicycle and taxi services as often as today, so the availability of 5G-MOBIX service will not affect their choice of travel mode.

The figure below complements these views by adding the concerns. It shows that end customers are very concerned about data security, privacy, and safety for themselves and other road users. They are also somewhat concerned by the price of 5G-CAM services and technical aspects (reliable function of the services, insufficient coverage and liability in case of an accident or malfunction). Conversely, they are not afraid of their need to learn new skills or change their routine.

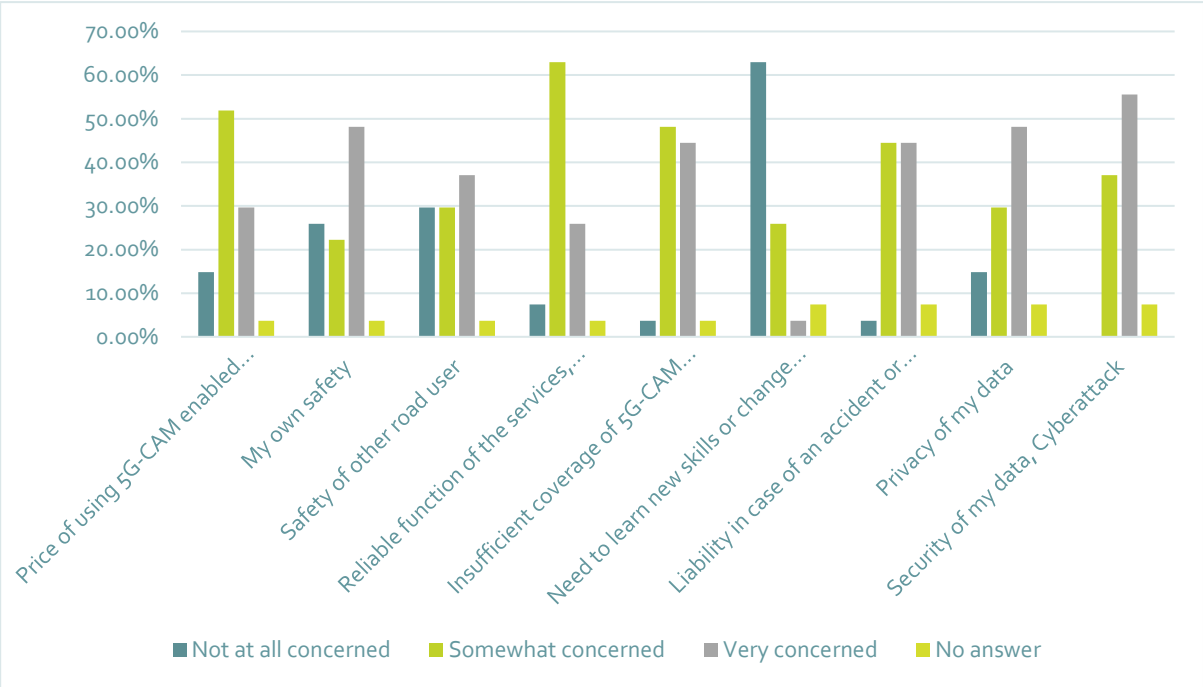


Figure 41: Concerns regarding the future use of 5G-CAM services

Taking the expected behavioural change and concerns into account, the willingness to pay becomes interesting:

- The first two services they are willing to pay are Advanced Driving and Extended Sensors.
- The one they are the least willing to pay for are Vehicles of Service Support and Remote Driving.
- For Advanced Driving, they consider paying one-time fee when buying a new car.
- For Extended Sensors the same or by a yearly subscription.
- Moreover, they have no clear expectations about savings through using 5G-CAM services (more than 33,3% of no answer for each category).

7. CONCLUSIONS

This document describes in detail customer focused approach of 5G-CAM services with customer exploration map tool. This tool helps stakeholders to focus on the most important insights about their customer and additionally to explore existing solutions for existing problems. Moreover, thinking about aspects stakeholders do not know yet about their customer challenges the identified problems and jobs to be done. Expert 5G-MOBIX partners that operate in different stakeholder category provided their insights according to asked questions in the tool. It is shown that each stakeholder has various customers, and these customers have different likes and dislikes. What needs to be done and challenges are also identified per stakeholder. Experts also answered what they do not know yet to have 5G for CAM services on the road and what are the existing solutions on the field. Additionally, they described what would be game changing with commonly seen 5G-CAM services on the public roads. Common unknown is which 5G-CAM services will be the first industry standard to deploy on the public roads.

After customer exploration map study, we exploit recommendation rating methodology that "D6.1 – Plan and preliminary report on the deployment options for 5G technologies for CAM" deliverable used to show utilization cost impact and lifecycle cost impact per recommendation that is described previously in "D6.2 - Plan and Preliminary Report on the business models for cross border 5G deployment enabling CAM" deliverable. Recommendations classified in four different categories and each category evaluated by cost and utility perspective. We showed which recommendation more costly, and which one has more utilization impact. According to answers, in cross border deployment related recommendations, large-scale validations were consistently rated as the most important recommendation in terms of utility, as well as the most costly one in effort. In the human-centred recommendations section, the recommendation "upgrading current skills" is clearly seen as the most important recommendation. In the section of recommendations related to deployment and investment, the responses show that the most important recommendation about utility was Investment on Software Architectures, SOC and AI Development, though it was also the recommendation rated with the highest cost. Based on the responses to the legislative recommendations, from the utility point of view, the highest average score is attributed to the "Creating a Data Economy" recommendation.

According to prepared questionnaires in D6.2, we gathered answers from various stakeholders in and out of our consortia. After that, we analysed these answers per stakeholder category and per business model canvas tool elements that are also explained in detail per user story in our initial study in D6.2. It is shown that, advanced driving use case category is the most valuable 5G-CAM service, but it also seems to be difficult to be integrated in the operations for all stakeholders, except road operators. Government is the main key partner for all stakeholders, since standardization is the main request according to respondents.

Since the advanced driving use case category is determined to be the most valuable 5G-CAM service, we shaped our business model basis and analysis sections accordingly. We chose the four user stories from the advanced driving use case category that demonstrated also on 5G-MOBIX cross border areas. These are "Assisted Zero-Touch Border Crossing" and "Autonomous Truck Routing" that were demonstrated in the Greece-Turkey border crossing area to show the border crossing time reduction, and "Automated Shuttle" and "Remote Driving" user stories that were demonstrated in the Spain – Portugal border crossing area to show more efficient transportation solutions. We combined all user stories under two use cases; Frictionless Border Crossing and Remote Driving Assisted Automated Shuttle. After that, we perform TCO and cost benefit calculations for MNOs, OEMs, and fleet owners. We found that both use cases have a good business case. On Frictionless Border Crossing business model, the profit for automotive OEMs is 2768€ per month,

and the gross margin (the difference between revenue and cost of goods sold (COGS), divided by revenue) is 26%, which is quite acceptable for the automotive industry. On the Remote Driving Assisted Automated Shuttle business model, the automated shuttle owner has a 29 572€ profit, which is 6824€ higher with a gross margin of 30%.

In additional to the use case-based business model analysis above, we also did a cost benefit analysis for the advanced driving use case category and showed that TCO is **242 410**€ and created income is **576 180** €. Hence, benefit-to-cost ratio is **2.38**.

In summary, our findings show that 5G-CAM applications have promising business models and it is worth investing their deployments.

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ANNEXES

Annex 1 – Questionnaires

Questionnaires cover page and MNO related questionnaire are listed in sections below. We created questionnaires for also vehicle OEMs, end customers, road operators, cloud and MEC providers, network equipment providers and RSU providers. However, since other questionnaires of stakeholders are similar to MNO questionnaires, we placed only MNO questionnaire below.

Cover Page of Questionnaires:

About 5G-MOBIX

5G-MOBIX aims to showcase the added value of 5G technology for advanced Connected and Automated Mobility (CAM) use case categories and validate the viability of the technology to bring automated driving to the next level of vehicle automation (defined by the Society of Automotive Engineers (SAE) as Level 4 and above). To do this, 5G-MOBIX plans to demonstrate the potential of different 5G features on real European roads and highways and create and use sustainable business models to develop 5G corridors. 5G-MOBIX also utilizes and upgrades existing key assets (infrastructure, vehicles, components), and ensures the smooth operation of 5G within a heterogeneous environment comprised of multiple incumbent technologies such as ITS-G5 and C-V2X. 5G-MOBIX executes CAM trials along cross-border (x-border) and local corridors using 5G core technological innovations to qualify the 5G infrastructure and evaluate its benefits in the CAM context. The project also defines deployment scenarios and serves to identify and respond to standardisation and spectrum gaps. 5G-MOBIX consists of 55 partners from 10 countries from the EU and Turkey representing European ICT industry and cooperates closely with South Korea and China to bring forward advances in 5G for CAM. It is coordinated by ERTICO-ITS Europe.

Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 825496.

Scope and intended audience

Task 6.2 is about the analysis business model analysis of current market and future new business opportunities. We are defining business models for a significant group of 5G-CAM services use cases, to develop and evaluate new business opportunities for CAM and 5G, financing schemes, revenue allocation and procurement models. The following questionnaire is a research instrument and it will help to know what current stakeholders think about those services. The questionnaire explores the different areas and elements defining the use cases' business models. The results will provide feedback to refine the business models already outlined by 5G-MOBIX project partners. The potential stakeholders have been grouped in several categories including road operators, OEMs, MNOs, network equipment providers, RSU providers, cloud/MEC providers and end users/customers.

The results will be used internally in the elaboration of the deliverable D6.2 of 5G-MOBIX which will be made publicly available in the project website, www.5G-MOBIX.com.

Benefits for participation

The results of this questionnaire will be provided to you via email if you leave your e-mail address at the end of the survey. In this case your address will be stored and used separated from your answers. The results will also be published in on the 5G-MOBIX website.
Your name or your organization name will not be shared in deliverable or in any other public area.

Contact

For more information about the project, you may contact the Project Coordinator Coen Bresser via email: c.bresser@mail.ertico.com
For more information on the questionnaire and your rights as a data subject, you may contact via email: Tahir Sari (Task Leader) tsari1@ford.com.tr, Luxshiya Ariyanayagam luxshiya.ariyanayagam@iis.fraunhofer.de or Maija Federley maija.federley@vtt.fi

1. MNO Questionnaire:

The emergence and rise of connected automated vehicle refers to both technological and industrial developments; in progressive yet rapid stages, it will become possible to safely confer more and more driving responsibilities to automated systems in road transport. These innovations involve personal vehicles, but also public transport and logistics/freight vehicles.
The objective is to take full advantage of technology's potential to deliver a renewed transport and mobility system with the following 5G-CAM service use case categories:

- Advanced Driving

  Advanced Driving enables semi-automated or fully-automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or RSU shares data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or maneuvers. In addition, each vehicle shares its driving intention with vehicles in proximity. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency.

- Vehicles Platooning
  Vehicles Platooning enables the vehicles to dynamically form a group travelling together. All the vehicles in the platoon receive periodic data from the leading vehicle, in order to carry on platoon operations. This information allows the distance between vehicles to become extremely small, i.e., the gap distance translated to time can be very low (sub second). Platooning applications may allow the vehicles following to be autonomously driven.

- Extended Sensors

Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation.

- Remote Driving

  Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. In addition, access to cloud-based back-end service platform can be considered for this use case group.

- Vehicle Quality of Service Support

  Vehicle quality of service support enables a V2X application to be timely notified of expected or estimated change of quality of service before actual change occurs and to enable the 3GPP System to modify the quality of service in line with V2X application's quality of service needs. Based on the quality of service information, the V2X application can adapt behaviour to 3GPP System's conditions. The benefits of this use case group are offerings of smoother user experience of service.

The entire mobility and transport ecosystem will need to adapt to these upcoming changes, therefore we are interested in how each member of the potential 5G-CAM ecosystem operates.

PROPOSED QUESTIONS

1. Value Proposition

In regard to the development and deployment of connected automated vehicles, we see the following value propositions and business opportunities that may be relevant for MNOs:

- Aftermarket and tethered services models:
  The aftermarket and tethered services models, via data services subscriptions, feature smart car devices and applications either embedded in a vehicle at the time of its manufacture or installed as an aftermarket product, creating opportunities for MNOs at different levels of the value chain. All three models represent opportunities for mobile network operators (MNOs), but ultimately each MNO must adopt a business model meeting the needs and requirements of its customer base.

- Vehicle diagnostics:
  MNOs could provide with insurance providers and offer individualized insurance policies, where the connected car system offers features such as a safety score based on driving behaviour, vehicle diagnostics, emergency assistance. By offering these services, MNOs are able to develop data monetization solutions for fleets and insurance carriers in a wider ecosystem.

- Improved Road Safety & Efficient Traffic Management:
  By cooperating with Road Operators, MNOs are able to approach the role of consultant or data provider for Efficient Traffic Management and Improved Road Safety. From a data point of view, vehicles' continuous broadcast of their location, speed, and other data would give cities' traffic management system real time data on traffic conditions that are more detailed and accurate than data available today. It will also enable the establishment of more efficient plans for road maintenance and traffic management.

- What is the most valuable border crossing 5G-CAM service for your organization? (Please select one)

Advanced Driving ☐

Vehicles Platooning ☐

Extended Sensors ☐

Remote driving ☐

Vehicles Quality of Service Support ☐

- Please explain, why:

Please rate the value propositions for each 5G-CAM service category in regard to their relevance for your organisation, giving the most important value proposition grade 1, for the second grade 2, for the third grade 3 etc. (grades "1…7", or "0" if not relevant at all, can be used to as many as necessary)

- Advanced Driving

Improve market share _____ Improve quality of service _____

New customers _____ Reduce investment costs _____

New (data-based) services _____ Security _____

Reliability _____ Energy efficiency _____

- Vehicles Platooning

Improve market share _____ Improve quality of service _____

New customers _____ Reduce investment costs _____

New (data-based) services _____ Security _____

Reliability _____ Energy efficiency _____

- Extended Sensors

Improve market share _____ Improve quality of service _____

New customers _____ Reduce investment costs _____

New (data-based) services _____ Security _____

Reliability _____ Energy efficiency _____

- Remote driving

Improve market share _____ Improve quality of service _____

New customers _____ Reduce investment costs _____

New (data-based) services _____ Security _____

Reliability _____ Energy efficiency _____

- Vehicles Quality of Service Support

Improve market share _____ Improve quality of service _____

New customers _____ Reduce investment costs _____

New (data-based) services _____ Security _____

Reliability _____ Energy efficiency _____

- Please list further values that you expect through deployment of 5G-CAM services and rate them

Other kind of values:

	Neutral		Somewhat important		Very important
_____	☐	☐	☐	☐	☐
_____	☐	☐	☐	☐	☐
_____	☐	☐	☐	☐	☐
_____	☐	☐	☐	☐	☐

2. Key Resources

- Where is the focus of your portfolio? Please describe your core operations:

- Please estimate how difficult the integration of 5G for the following CAM services is in your operations, especially while border crossing?

	Very difficult		Somewhat difficult		Not difficult at all
Advanced Driving	☐	☐	☐	☐	☐
Vehicles Platooning	☐	☐	☐	☐	☐
Extended Sensors	☐	☐	☐	☐	☐
Remote driving	☐	☐	☐	☐	☐
Vehicles Quality of Service Support	☐	☐	☐	☐	☐

- In what areas is further expertise and/or substantial progress necessary for your organization to enable deployment of the following 5G-CAM services? (Please tick the crucial areas)

	Technology	Legislation	Procurement	Revenue share	Data sharing solutions	Other, please specify
Advanced Driving	☐	☐	☐	☐	☐	_____
Vehicles Platooning	☐	☐	☐	☐	☐	_____
Extended Sensors	☐	☐	☐	☐	☐	_____
Remote driving	☐	☐	☐	☐	☐	_____
Vehicles Quality of Service Support	☐	☐	☐	☐	☐	_____

- How important is the enablement of border crossing 5G-CAM services to your organisation?

Not at all important		Somewhat important		Very important
☐	☐	☐	☐	☐

3. Customer Segments

- Please specify the respective target groups in reference to the use cases

	Authority	Vehicle drivers	Fleet owners	Vehicle OEMs	Road operators	Other, please specify
Advanced Driving	☐	☐	☐	☐	☐	_____
Vehicles Platooning	☐	☐	☐	☐	☐	_____
Extended Sensors	☐	☐	☐	☐	☐	_____
Remote driving	☐	☐	☐	☐	☐	_____
Vehicles Quality of Service Support	☐	☐	☐	☐	☐	_____

4. Customer Relationships

Please rate the changes that the mentioned 5G-CAM services will bring to your relationship with your customers:

	Completely				No changes
Advanced Driving	☐	☐	☐	☐	☐
Vehicles Platooning	☐	☐	☐	☐	☐
Extended Sensors	☐	☐	☐	☐	☐
Remote driving	☐	☐	☐	☐	☐
Vehicles Quality of Service Support	☐	☐	☐	☐	☐

5. Key Partners

- What partnerships are essential for you as a MNO to support deployment of border crossing 5G-CAM services?
  Please tick the required partners and **give an order of priority** from 1 (the most important partner) to the number of your total needed partners (the least important partner).

Partnerships	This partner is needed	Ranking (1 to x)

Government		
Fleet Owner		
OEM		
OBU Provider		
Cloud/ MEC Provider		
Road Operator		
Network Equipment Provider		
RSU Provider		
Software solution/CAM service provider		
Other, please specify:		

5.1 What steps are needed to form the cooperation between the above-mentioned partners?

	Technology	Legislation	Procurement	Revenue share	Other, please specify
Government	☐	☐	☐	☐	
Fleet Owner	☐	☐	☐	☐	_____
OEM	☐	☐	☐	☐	_____
OBU provider	☐	☐	☐	☐	_____
Cloud/ MEC Provider	☐	☐	☐	☐	_____
Road Operator	☐	☐	☐	☐	_____
Network Equipment Provider	☐	☐	☐	☐	_____
RSU Provider	☐	☐	☐	☐	_____
Software solution/ CAM service provider	☐	☐	☐	☐	_____
(Other, please specify _____)	☐	☐	☐	☐	_____

6. Obstacles and Changes

6.1 What are the most topical challenges in your operations as MNO?

☐ MNO handover
☐ manoeuvre coordination messages from a road infrastructure

- ☐ Cross border operations
- ☐ Connection loss while cross boarder operations
- ☐ Roaming handover
- ☐ Latency
- ☐ Low coverage areas for 5G-CAM applications
- ☐ Change of IP stack when switching networks
- ☐ Data loss while crossing boarders
- ☐ Accuracy of geo- positioning (GNSS)
- ☐ Network QoS when switching MNOs
- ☐ Data and application level protocol interoperability
- ☐ Geo-constrained information dissemination scheme
- ☐ Law enforcement entities
- ☐ Automation
- ☐ RAN (Radio Access Network) optimisation
- ☐ Security
- ☐ Standardization
- ☐ Other, please specify? _____

- Which are from your perspective as an expert the main challenges related to the implementation of the introduced border crossing services?

- What kinds of challenges do you see related to liability for the safety-related issues?

- Please describe legal terms and other conditions that have to be established, so that you can enable 5G-CAM services, especially while border crossing:

The following questions in the section below, aim to obtain financial information. Due to the sensitive nature of the questions, they are not mandatory to answer and we fully understand if you hesitate to give any statements. However, by providing even some indicative information you would help us to precise our research results.

Cost Structure

Please estimate the expected increase in the following cost categories for supporting deployment of 5G-CAM services for the next 10 years:

	Negligible	Minor	Moderate	Significant	Major
Staff	[ ]	[ ]	[ ]	[ ]	[ ]
Equipment and materials, including maintenance costs	[ ]	[ ]	[ ]	[ ]	[ ]
Consulting/External Services	[ ]	[ ]	[ ]	[ ]	[ ]
Network/Cloud/Hosting	[ ]	[ ]	[ ]	[ ]	[ ]
Patent/Sublicense	[ ]	[ ]	[ ]	[ ]	[ ]
Others (please specify)	[ ]	[ ]	[ ]	[ ]	[ ]

7. Willingness to pay

How likely is your organisation to invest in supporting 5G-CAM services during the next 10 years?

	Not at all likely		Somewhat likely		Already under preparation
Advanced Driving	☐	☐	☐	☐	☐
Vehicles Platooning	☐	☐	☐	☐	☐
Extended Sensors	☐	☐	☐	☐	☐

Remote driving

Vehicles Quality of Service Support

8. Revenue Streams

- Please describe your each current revenue stream in the context of vehicles, infrastructure, logistics and cross-border operations:

- Please evaluate expected impact in revenue for your organisation as a result of deployment of 5G for the following CAM services for the next 10 years:

	Impact Level:				
	Negligible	Minor	Moderate	Significant	Severe
Advanced Driving					
Vehicles Platooning					
Extended Sensors					
Remote driving					
Vehicles Quality of Service Support					

- Please describe further opportunities to generate extra income or cost savings with 5G-CAM services which you can identify for the operations of your organisation or in the partner network:

- Please write here if you have any other comments or suggestions with regard to business perspectives on border crossing 5G-CAM services:

THANK YOU FOR YOUR VALUABLE INPUTS FOR OUR RESEARCH!

Annex 2 – Scoring methodology for prioritisation (from chapter 2)

Recommendations that are used in this evaluation were listed before in D6.2. For the evaluation methodology, the approach of D6.1 was followed. We collected 10 answers from project partners. They rated 15 recommendations based on their utility and cost perspective.

The evaluation criteria objective is to understand the impact that recommendations have and provide a prioritization level base in colours (red, yellow, green as presented in chapter 4). The recommendation evaluation study assesses each recommendation based on two factors:

Utilization:

The utilization value measures the level of how critical each criterion is, ranging from 1 to 5. With 1 having a minimal impact and 5 a critical impact. These recommendations are assessed based on the

Table 33: Utilization Cost Impact Matrix

			UTILITY SCORE(Higher is better)							
			Minimal	Low	Average	High	Critical			
		Scoring System	1	2	3	4	5	WEIGHTS	SCORE	WEIGHTED SCORE CALCULATION
1	Impact	Has user value	Has no user value	Has little value, brings awareness to a specific gap	Has average value somewhat limits an existing gap	It has the potential to simplify 5G for CAM adoption	Has great user value - will greatly help adoption of 5G for CAM	0,17		0,00
2	Impact	Has business value (for Europe?)	Has no business value	Has little value, brings awareness to a specific gap	Has average value somewhat limits an existing gap	It has the potential to increase investment or the creation of new products and services, or mitigate known gaps	Has great business value - this recommendation can improve investment in 5G for CCAM and will help create new products/services/business models, or solve known gaps	0,17		0,00
3	Impact	Has technical value	Has no technical value	Has little value, brings awareness to a specific gap	Has average value somewhat limits an existing gap	It has the potential to mitigate or circumvent a technical gap	Has great technical value - this recommendation bridges a significant technical gap	0,17		0,00
4	Impact	Has operational value	Has no operational value	Has little value, brings awareness to a specific gap	Has average value somewhat limits an existing gap	It has the potential to improve operational procedures	Has great value in terms of improving operational procedures - it can bring multiple operational benefits	0,17		0,00
5	Impact	Has standardisation value	Has no standardisation value, does not utilise or validate an existing standard	Has little value, brings awareness to a specific gap	Has average value somewhat limits an existing gap	it has the potential to drive standardisation efforts or support an existing standard	Solves a significant standardisation gap or is based on existing well known, industry accepted standard	0,17		0,00
6	Criticality	This recommendation is time critical	not time critical	2021-2035	2021-2030	2021-2025	Recommendation is time critical and should be applied within 2021-2023	0,17		0,00
							SUM SHOULD BE EQUAL TO 1	1	TOTAL SCORE	0,00

Lifecycle cost:

The lifecycle cost analyses the cost of acquisition and the recommendation's utilization by defining the acquisition cost of the research, development, deployment and integration of the solutions. The cost of utilization is defined as the cost to operate, train, maintain and deploy these solutions.

Table 34: Lifecycle Cost Impact Matrix

		Just put an "x", ONLY one 'x' per row							
		Very Low	Low	Medium	High	Very High			
	Lifecycle Cost factor	1	2	3	4	5	ANSWERS	WEIGHTS	WEIGHT* SCORE
Acquisition	Cost to research		x				2	0,1	0,2
	Cost to develop	x					1	0,2	0,2
	Cost to deploy		x				2	0,1	0,2
	Cost to integrate			x			3	0,1	0,3
Utilisation	Cost to operate				x		4	0,1	0,4
	Cost to train			x			3	0,2	0,6
	Cost to maintain			x			3	0,1	0,3
	Cost to dispose		x				2	0,1	0,2
							SUM OF WEIGHTS is 1	1	2,4	Cost Score

The average between the utilization and the lifecycle cost will provide us with the level of prioritization of the recommendations. The prioritization is weighted from 1 to 5, with 1 recommendation having a very low importance and with 5 a very high criticality.