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

Report on the international cooperation and results

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ABBREVIATIONS

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
5GAA	5G Automotive Association
5GIA	5G Industry Association
5GMF	Fifth Generation Mobile Communication Promotion Forum
CBC	Cross Border Corridor
CAM	Connected and Automated Mobility
CAPEX	Capital Expenditure
CATT	China Academy of Telecommunications Technology
CAV	Connected and Automated Vehicle
CU	Central Unit
DoA	Description of Action
DU	Distribution Unit
EC	European Commission
ETSI	European Telecommunications Standards Institute
FIRE	Future Internet Research and Experimentation
GA	General Assembly
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Communication Union
JCT	Yeoju Junction
Jinan-1-SDAS	Shandong Academy of Sciences
Jinan-2-SDHS	Shandong Binlai Expressway
KATECH	Korean Automotive Technology Institute
KPI	Key Performance Indicator

MNO	Mobile Network Operator
MoU	Memorandum of Understanding
NR	New Radio
OBU	On-Board Unit
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
QoS	Quality of Service
RSU	Roadside Unit
SDO	Standards-Developing Organization
StVZO	Road Traffic Licensing Regulations
TS	Trial Site
TSDSI	Telecommunications Standards Development Society, India
TSL	Trial Site Leader
WP	Work Package
WPL	Work Package Leader
X-border	Cross-border
V2X	Vehicle-to-Everything

EXECUTIVE SUMMARY

Funded under the European Union's Horizon 2020 Framework Programme, the 5G-MOBIX project aims at executing Connected and Automated Mobility (CAM) trials along countries-border and urban corridors using 5G core technological innovations.

The 5G-MOBIX project establishes the technological foundation that can pave the way for the commercialization of 5G for CAM use cases. These types of business cases involve a diverse group of stakeholders and compose the 5G-MOBIX marketplace. This market is made up of various main industries, including telecoms providers, infrastructure, logistics and transit, automotive, consumer and society, and public administration. 5G-MOBIX members have identified the cooperation among all these entities as a fundamental resource for the successful and rapid development of CAM.

Nowadays, there are only a small number of business cases that fully utilize and require 5G technology in CAM contexts, as the CAM market is not fully developed yet. However, since the 5G-MOBIX consortium incorporates the essential ecosystem to deploy CAM, it can be considered as a realistic emulation of the future CAM marketplace. In this scope, 5G-MOBIX has identified the development of a business case that is beneficial for all of the various players involved as an essential precondition for the commercialization of the 5G marketplace. The ultimate goal is to qualify the 5G infrastructure and evaluate its benefits in the CAM context, as well as defining deployment scenarios and identifying standardisation and spectrum gaps.

Given the nature of its mission, 5G-MOBIX sees international cooperation as a key asset for the promotion of the rapid development of the automotive and telecommunications industries. Cooperation is a strategy that allows different sets of knowledge or complementary capabilities to flow among different manufacturers, operators and public agencies to increase the speed of testing, development, standardization and deployment.

In particular, 5G-MOBIX acknowledges the necessity of strengthening cooperation in key fields such as automation, interconnection, transportation information services, intelligent city transportation, freight transport and logistics and fosters exchange activities in the intelligent transportation industry by co-organizing conferences, demonstrations, seminars and technical visits, etc.

In *D7.6 - Report on the international cooperation and results*, we describe the actions that have been undertaken to bring high-visibility to 5G-MOBIX activities and outcomes by ensuring a presence at relevant events and through other channels.

In Section 1, we introduce 5G-MOBIX, its mission and vision, as well as defining the content and goals of this deliverable. In Section 2, we list the dissemination activities carried on by 5G-MOBIX, with a focus on the publication of scientific papers. In this scope, we discuss the effort made to exploit the 5G-MOBIX results by

involving relevant research organisations as well as business stakeholders and public authority representatives in fora and consultation workshops to ensure the widest diffusion of 5G-MOBIX outcomes.

All public and private stakeholders involved in the research and deployment of 5G for CAM that have contributed to the success of 5G-MOBIX are presented in Section 3.

In Section 4, we discuss the impact that the liaison agreements between the members of 5G-MOBIX and international organization had on the project.

Section 5 addresses the global vision for 5G CAM deployments. We discuss other EU-funded projects for cross-border trials which are of interest for the goals and vision of 5G-MOBIX. Furthermore, we describe the contributions of the Chinese and Korean trials to the 5G-MOBIX project, with the aim of highlighting the positive impact that international cooperation has in the implementation of cross-border scenarios. Finally, we analyse the current policies involving CAM in EU and extra-EU countries with the purpose of drawing the attention on the challenges and opportunities of homogenizing and standardizing the regulations at an international level.

Section 6 is the conclusive chapter of this report, in which recap the contributions of D7.6, as well as suggesting directions for future work.

1. INTRODUCTION

This section introduces the 5G-MOBIX project by describing in brief its aims and objectives. It also specifically presents the objectives of this deliverable, D7.6 - Report on the international cooperation and results.

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 demonstrates the potential of different 5G features on real European roads and highways, while creating and using sustainable business models to develop 5G corridors. 5G-MOBIX also utilizes and upgrades existing key assets (infrastructure, vehicles, components) and 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 CAM trials along cross-border (x-border) and urban corridors using 5G core technological innovations to qualify the 5G infrastructure and evaluate their benefits in the CAM context. The Project also defined deployment scenarios and identified and responded to standardisation and spectrum gaps.

5G-MOBIX defined critical scenarios needing advanced connectivity provided by 5G, and the required features needed to enable some advanced CAM use cases, including tethering via vehicle, CAVs cooperative collision avoidance, emergency trajectory alignment etc.

Through the joint effort of 58 partners from 13 countries, 5G-MOBIX developed and evaluated automated vehicle functionalities using 5G core technological innovations along two cross-border corridors (Spain-Portugal and Greece-Turkey) and 6 pre-deployment urban trials (France, Germany, Netherlands, Finland, China and South Korea).

The trials also allowed 5G-MOBIX to conduct evaluations and impact assessments and define business impacts and carry out cost/benefit analysis. Based on 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.

Through its findings on technical requirements and operational conditions, 5G-MOBIX actively contributed to standardisation and spectrum allocation activities. The details regarding these activities are contained in D6.7.

1.2. Purpose of the deliverable

This deliverable outlines the activities undertaken to support the project consortium cooperation and collaboration with the international 5G organisations and other 5G for CAM projects in order to compare results and achieve interoperability and harmonisation of the work and end results among these partners. We have used the IEEE 5G World Forum platform to get all 5G Fora and 5G for CAM active stakeholders and projects on a yearly basis in-person and later online to announce openly their national strategies and concepts. As a matter of fact, it took three years for all organisations to clearly open up to each other and announce their results and plans in full confidence. This has allowed the 5G-MOBIX project to capture active and apparent and non-active and hidden stakeholders in the sector in an effective way, as well as creating a core community around 5G for CAM.

1.3. Intended audience

The audience targeted with this Report are international 5G Fora, 5G for CAM projects, Standardisation bodies and institutes such as ETSI, ITU and IEEE.

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2. DISSEMINATION ACTIVITIES

One of the objectives of 5G-MOBIX is to disseminate systematically its activities and results, to increase its impact and visibility across the EU and worldwide.

In this section, we present the actions that have been undertaken by 5G-MOBIX and its members to promote the outcomes of its activities among communities of experts and relevant stakeholders, as well as its initiatives to foster collaboration amongst European and global partners in this field.

In Table 1, we summarize the three stages that were carried out according to the 5G-MOBIX dissemination strategy.

Table 1: the three stages of 5G-MOBIX dissemination plan

Stage	Description
First stage *(M1-M12)*	During the first stages of the project, a greater focus was placed on the activities that involved communication. When the results of the initial project became known, the dissemination operations reached their peak intensity and continued until the phase was complete. The primary goals of the actions that were classified as dissemination were to increase awareness and provide information to important stakeholders about the concept of the project, as well as its anticipated impact and the results of the initial initiative.
Second stage *(M13-M24)*	During this phase, the actions that are targeted at making the outcomes and developments of the initial project available took place.
Third stage *(M25-M45)*	In the last stage of the project, a significant amount of work was put into properly communicating the project's findings to the various target audiences in order to assure the project's continued viability in the long run.

Following the strategy described in Table 1, the members 5G-MOBIX carried out a total of 216 dissemination activities, which are subdivided into 5 categories, shown in Figure 1.

Of those, a total number of 68 papers that have resulted by the work undertaken in this project have been published in scientific journals, conferences and thesis, including top-tier journals such as IEEE Transactions on Vehicular Technologies, which testifies the involvement of 5G-MOBIX members into the production and dissemination of scientific documentation. The topics addressed in the publications span from 5G-based

vehicle platooning to software-defined location privacy. The full list of published papers is presented in D7.3, published on 4th of May 2022 [1].

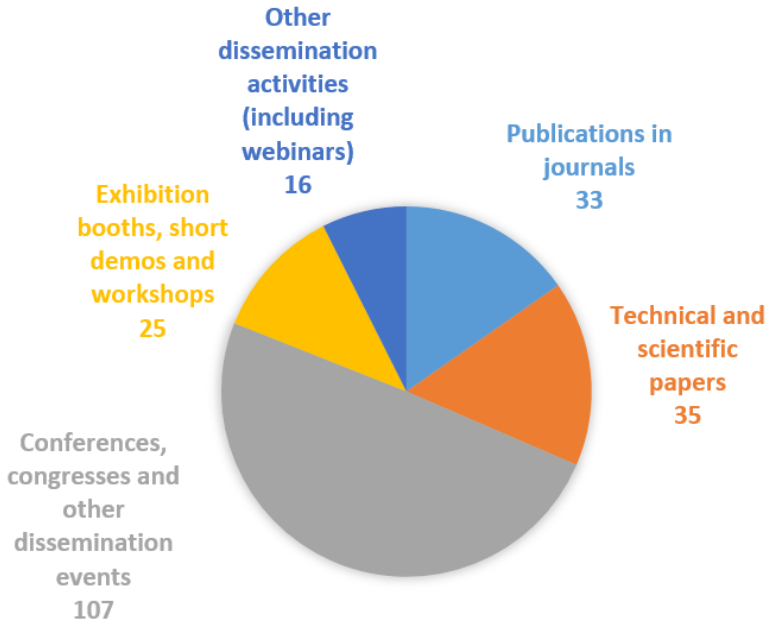

Figure 1: 5G-MOBIX dissemination activities by category

2.1. Conferences and Events

As shown in Figure 1, partners of 5G-MOBIX presented, hosted a booth and organized workshops related to the project in a total of 132 national and international events.

In the following section, we present the main events (in terms of attendance and international presence) organized by the members of 5G-MOBIX.

The full list of conferences and event is presented in D7.3.

2.1.1. Worldwide 5G Industry Fora Sessions

The Worldwide 5G Fora sessions [2] are an event that have been organized and co-chaired yearly by Latif Ladid, 5G-MOBIX UNI.LU representative and 5G Initiative Co-Chair, since 2018. The goal of these fora is to promote the sharing of information and ideas among various industry associations that are primarily focused on 5G. The attendees were asked to describe their endeavors, visions, roadmaps, trials, and pilot projects related to the deployment of Full 5G and the evaluation of its potential in the real world.

In particular, session discussions during the Worldwide 5G Industry Fora focus on the following three primary subjects:

- **Regional visions:** The 5G standards process should assure interoperability and ubiquity by including regional perspectives and the participation of vertical industries. However, because of the many ecosystems and approaches that exist across the world, various concepts of 5G may emerge. As a matter of fact, operators analyze their spectrum portfolios and build 5G experiments, pilots, and use cases with verticals taking into consideration the particularities of their position in the respective region.
- **Roadmap for Full 5G vision, including spectrum, standards, and deployments:** the discussions enabled in the forum aimed at answering to four fundamental questions: i) what are the available target spectrum and candidate bands and when and how would the allocation happen, ii) what does the current image of 5G deployments look like (dense urban, rural etc.), iii) what is the roadmap of 5G for automotive, and what can be done to ensure its success, iv) how are different industries, or verticals, contributing to the standardization and development of 5G.
- **Industry international cooperation**: the sessions that focus on this topic aimed to investigate the ground for joint inter-regional projects and cross-continental collaborations towards the success of 5G. Specifically, the goal of these sessions was to investigate how 5G can be used in developing countries.

Notable guests of the last edition (2021) were Wang Zhiqin, Chair IMT-2020 Promotion Group (China); Yoshinori Ohmura, Secretary General 5GMF (Japan); Pamela Kumar, Director General TSDSI (India); Dong Ku Kim, Chair Executive Committee 5G Forum (South Korea); Colin Willcock, chairman 5G-IA (Europe); José Marcos Brito, Secretary General 5G (Brazil); Chris Pearson, President 5G Americas (Americas); Dr. Mitch Tseng, Senior consultant "Next Generation Communication Technology Office" (European Commission); Bernard Barani, Deputy Head of Unit DG CNECT, IEEE; Ashutosh Dutta, Chair IEEE Future Networks Initiative; Tao, Project Manager, EU-China 5G-DRIVEChen; Andreas Mueller, Chairman, 5G-ACIA; Maxime Flament, CTO 5GAA; BCG: Heinz Bernold, Partner & Director, BCG; Wanshi Chen, Chairman TSG RAN, 3GPP.

2.1.2. 5G for CAM Summit 2021

The 5G for CAM Summit 2021 [3] served as a forum for participants from a wide range of EU-funded projects related to CAM. Sharing experiences, reporting findings, and talking about the next steps towards deployment were the goals of this event. It was co-chaired by Latif Ladid, 5G-MOBIX UNI.LU representative and 5G Initiative Co-Chair, and Jorge Pereira, Principal Scientific Officer of the European Commission.

The 5G for CAM program initiative quickly evolved into a gathering spot for all European teams conducting research in the cross-corridors mobility scenarios, in addition to bringing stakeholders from the United States and Canada to the 2021 IEEE 5G World conference event. This dual strategy has tremendously eased the communication between them, and it has created synergies in their collective efforts to work together under the neutral umbrella of the IEEE 5G Initiative. This activity, initiated and developed under the 5G

MOBIX project has greatly contribute towards building an international community that needs to meet and exchange best practices, ideas and innovation in the field of 5G.

The topics that were discussed at the conference were related to all of the mobility verticals that were targeted by the European 5G Action Plan within the scope of the European Single Digital Market. These mobility verticals included roads, rails, water ways, and coastal maritime, along with a multi-modality component of the discussion. In addition to discussing a wide variety of infotainment-related themes, the conference's primary emphasis was on the primary societal goals of CAM.

The participants had a common objective: to lay the groundwork for a complete ecosystem focusing on infrastructure, equipment, and services that were built on top of 5G advanced connectivity, while also defining the responsibilities and resources (in terms of technology and investments) that were necessary for the development of mobile and fixed broadband. In this context, the work and financing from EU Horizon 2020 of 5G in cross-border stretches of Trans-European Transport Network (TEN-T) was regarded as the beginning point for the large-scale deployment of 5G in Europe. Even though the EU-funded initiatives were the primary topic of discussion at the 5G for CAM 2021 conference, participants from other regions of the world were welcome to attend in an effort to foster transcontinental collaboration.

Notable guests of the last edition (2021) were Maxime Flament, CTO, 5G-AA; Magnus Frodigh, Vice President and Head of Ericsson Research; Peiying Zhu, Senior Vice President of Wireless Research, Huawei; Chih-Lin I, Chief Scientist, Wireless Technologies China Mobile Research Institute; Riccardo Calabro, Director Product Marketing Qualcomm CDMA Technologies GmbH; Coen Bresser, Senior Manager I&D at ERTICO – ITS Europe, 5G-MOBIX Project Coordinator; Uwe Herzog, Programme Manager at Eurescom GmbH and 5G-DRIVE Project Coordinator; Eusebiu Catana, Senior Manager, ERTICO.

3. COOPERATION WITH THE INTERNATIONAL COMMUNITY

To incentivize knowledge transfer and disseminate the activities of 5G-MOBIX worldwide, the members of the consortium have been in direct contact with international stakeholders and jointly attended global events in the fields of telecommunications, information and communications technology (ICT) and automotive.

3.1. 5G-MOBIX International Partners

Several organizations have been officially involved in 5G-MOBIX activities. In Table 2, we describe the main partners of the project.

Table 2: Partner organizations of 5G-MOBIX

Organization	Description
5GAA	The 5G Automotive Association (5GAA) is a global organization that was established in 2016 in Munich, Germany, by eight founding members - AUDI AG, BMW Group, Daimler AG, Ericsson, Huawei, Intel, Nokia, and Qualcomm Incorporated [4]. The 5GAA's primary objective is to allow businesses in the automotive, information technology, and telecommunications industries to collaborate with one another. Since its inception, 5GAA has experienced rapid expansion, extending its membership to include 130 companies in a variety of industries, including but not limited to Tier-1 suppliers, automotive manufacturers, mobile operators, infrastructure vendors, and chipset/communication system providers. The ultimate objective is to make use of the various areas of knowledge held by its members in order to design and create the next generation of connected mobility and automated vehicle solutions. In this context, the 5GAA endorses the use of 5G as the best possible platform to carry mission-critical communications for safer driving, as well as to assist the development of Vehicle-to-Everything (V2X) and, consequently, connected mobility solutions. The contributions made by 5GAA focus on the following topics: i) defining use cases and deriving technical requirements and Key Performance Indicators (KPIs), ii) defining, developing, and recommending system architectures and interoperable solutions for the use cases, iii) evaluating and validating the solutions through the testbeds, iv)

	standardizing the solutions that have been presented, v) defining business models and go-to-market strategies for industrial adoption.
	Involvement with 5G-MOBIX 5GAA is an Advisory member of 5G-MOBIX.
5G-IA	The 5G Infrastructure Association, also known as 5G-IA, is the private counterpart to the 5GPP (being the European Commission its public side) [5]. The 5G-IA is dedicated to the continued development of 5G in Europe as well as the formation of a global consensus around 5G. In order to accomplish this objective, 5G-IA brings together a global industry community of telecoms and digital actors. These actors include MNOs, manufacturers, universities, research centers, and small and medium-sized enterprises. 5G-IA engages in a wide variety of activities in strategic areas such as standardization, frequency spectrum, research and development projects, technology skills, international cooperation, and collaboration with industry sectors, especially for the development of trials. Through a partnership Board, the 5G-IA formally engages in conversation with the European Commission. Additionally, the 5G-IA closely coordinates the activities of its Policy Work Groups with those of the 5G Initiative Projects and Technical Work Groups. The 5G-IA emphasizes its goals and action plan, which are as follows: • Communicating with vertical industry sectors and ensuring that the EU will support and enforce the necessary policies and regulations in order for 5G to be adopted in the many different vertical industries throughout Europe. • Steering the implementation of the 5G PPP program through cross-project cooperation in Europe and targeting the utilization of the achievements of the 5G PPP in a consistent manner. • Increasing the amount of radio spectrum that is available for use while also developing an all-encompassing standardization roadmap with the end goal of creating a 5G communications standard that is internationally interoperable.

	• Defining its "5G trials roadmap strategy" for the implementation of advanced pre-commercial and pan-European trials to be launched in key sectors, with the goal of ensuring a clear European voice on 5G around the world.
	Involvement with 5G-MOBIX Other than being the private counterpart of 5G PPP, many members of 5G-MOBIX (e.g. ERTICO) are part of the consortium and of its follow up, 6G-IA.
3GPP	Founded in 1998 in Sophia Antipolis, France, the 3rd Generation Partnership Project (3GPP) provides a stable environment for the production of specifications that concerning mobile telecommunications technologies, namely radio access, core network, and service capabilities [6]. This project brings together seven international standards-developing organizations (SDOs) in the field of telecommunications: ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, and TTC. It is currently focusing on LTE and 5G. Making these systems both backward- and forward-compatible is one of the primary priorities of the 3GPP, as this helps to ensure that the usability of user equipment is not disrupted in any way. 3GPP is working on "forward compatibility" into Non-Standalone NR equipment in this scope since several operators are working on dual connection between LTE and 5G NR equipment employment the Non-Standalone NR equipment. In addition, the 3GPP specifications take into account interoperability with networks that do not use the 3GPP standard as well as non-radio access to the core network.
	Involvement with 5G-MOBIX All operators involved in 5G-MOBIX fed results to 3GPP as part of their standardization process.
CATT	The China Academy of Telecommunications Technologies (CATT) is a research institute affiliated to the Ministry of Industry and Information Technology (MIIT) of China. It is considered a "think-tank for the government and an innovation and development platform for the industry". Since its foundation in 1957, CATT has provided strong support for major strategies, plans, policies, standards, tests, and certification for the

	development of the national ICT sector and IT application. For this reason, CATT is an essential player in the development and innovation of the Chinese ICT sector. In recent years, CATT has expanded its innovation efforts to reach a broader research landscape. It has conducted in-depth research and foresighted planning in 4G/5G, smart manufacturing, Internet of Things (IoT), V2X, cloud computing, blockchain, etc. national activities.
	Involvement with 5G-MOBIX CATT conducted the 5G-MOBIX pre-deployment China trial which is described in Section 5.2.2.
KATECH	The Korean Automotive Technology Institute (KATECH) is Korean a government-funded research institute that operates on a not-for-profit basis. In addition to providing support for the automotive R&D policy of both the central and local governments, KATECH is also responsible for the planning of large-scale projects for the national government and assumes the responsibility of evaluating and certifying automotive parts. It is involved in the Korean automotive industry in a number of different fields, such as CAM, EVs, advanced materials, reliability, and hydrogen mobility [7]. KATECH, in its role as leader of the Korean TS, provided the most important findings of the remote-controlled vehicle under SAE L4.
	Involvement with 5G-MOBIX KATECH coordinate the 5G-MOBIX pre-deployment Korean trial site, which is described in Section 5.2.1.

3.2. Organizations of interest for 5G-MOBIX

In Table 3, the associations, coalitions and consortia that are of interest for the vision and the activities of 5G-MOBIX are listed. Similarly to 5G-MOBIX, most of these entities aim at investigating the potential of 5G and/or other technologies for the automotive sector, as well as standardization and promotion individual or joint activities of the members to external stakeholders.

These associations have been often invited to events organized by 5G-MOBIX members (such as the Worldwide 5G Industry Fora Sessions described in Section 2), thus allowing a continuous interaction, and sharing of information and ideas with 5G-MOBIX.

Table 3: Organizations of interest for 5G-MOBIX

Organization	Description
5G-ACIA	5G-ACIA is a working group of the Electro and Digital Industry Association, a global forum to allow diverse sets of stakeholders from a diverse set of industries to cooperate for the creation of a new ICT ecosystem and define frameworks for the CAM market [8]. 5G-ACIA has its headquarters in Frankfurt-Am-Main, Germany. Stakeholders in 5G-ACIA include academic institutions, research institutes, government bodies, industrial automation enterprises, Mobile Network Operators (MNOs) and chips manufacturers. The ultimate objective of 5G-ACIA is "to maximize the use of 5G in industrial applications." Furthermore, 5G-ACIA determines the spectrum requirements for 5G networks used in industry.
5G Americas	5G Americas is a trade group for the telecommunications industry that has its headquarters in Bellevue, Washington. Its membership includes prominent telecoms service providers and manufacturers, including AT&T, CISCO, Ericsson, Intel, Nokia, and Samsung [9]. The mission of the organization is to foster the advancement of LTE wireless technologies and their transition to 5G throughout the ecosystem's networks, services, applications, and connected devices in the Americas and overseas. In particular, 5G Americas investigates i) communications based on satellites, ii) communications via cellular networks, and iii) data protection.
IMT-2020 (5G)	On the basis of the original IMT-Advanced Promotion Group, the IMT-2020 (5G) Promotion Group was established in China 2015 [10], with the support of three ministries. It is the most important venue in China for advancing research and development of 5G technology. The most influential MNOs, vendors, academic institutions, and research organizations in the field of mobile communications are among its members.

5GMF	Founded in 2014 by a consortium of public and private players in Japan, the Fifth Generation Mobile Communication Promotion Forum's (5GMF) aims at conducting research and development concerning 5G to achieve early realization of those systems, with the intention of contributing to the healthy growth of the use of telecommunications in the process [11]. The goals of 5GMF can be summarized as it follows: • Engaging in research and development of 5G systems, as well as in studies pertaining their standardization. • Collecting information on 5G and exchanging it with other organizations.
TSDSI	The standardization of telecom and ICT goods and services in India is the mission of the Telecommunications Standards Development Society of India (TSDSI) [12]. TSDSI is a nonprofit organization, whose declared goals are i) the development and standardization of telecom and ICT requirements and solutions that address the Indian ecosystem, ii) The dissemination of Indian requirements and initiatives to the rest of the globe, iii) The contribution to the development of manufacturing skills in India In recent years, TSDSI has been actively promoting the adoption of 5Gi, which is an extension of 3GPP 5G standards. This has been done in order to meet the critical rural coverage requirements that are necessary in India. This particular set of guidelines has resulted in the collaborative creation of intellectual property with enterprises based in both Europe and China.
5G Brasil	Telebrasil is a private organisation with 65 institutions as members. Its primary mission is to support the growth of the telecommunications sector in Brazil [13]. 5G Brasil is a private autonomous project of Telebrasil. Its primary objective is to foster the growth of a 5G ecosystem in Brazil by facilitating and creating contacts between the country's ICT industry, the Brazilian government, and the regulatory body in the country. 5G Brasil promotes national and international cooperation agreements for the development and adoption of 5G technology, represents the members' common interests in national and international forums related to 5G, and fosters 5G technology development and adoption.

4. LIAISON AGREEMENTS WITH SIMILAR PROJECTS

In this section we present the liaison agreements stipulated between the 5G MOBIX coordinator, ERTICO – ITS Europe, and entities conducting similar tests in the field of 5G for CAM.

4.1. China: Memorandum of Understanding between ITS China and ERTICO – ITS Europe

ERTICO organized the Europe-China ITS Summit in September 2018 with the goal of boosting ERTICO's international cooperation. The summit was held in Shanghai, China. During the course of the Summit, the two organizations came together to inaugurate a new Joint Innovation Centre as well as sign a Memorandum of Understanding (MoU) [14]. Figure 2 shows the celebration of the MoU signature.

The exchange of information on ITS and mobility among ITS partners from the two continents is essential to the development of technology in the transportation sector. In this regard, Jacob Bangsgaard, who was serving as the CEO of ERTICO at the time, stated: "We have been working with China for 20 years and seen the relationship change, the integration of our organisations is more complex and deeper than ever before, and it will increase. This new centre will facilitate these efforts".

Figure 2: Celebration of the Memorandum of Understanding between ERTICO ITS and CHINA ITS

This collaboration and the Joint Innovation Centre served to speeded up the cooperation between enterprises, authorities, and research institutes in both Europe and China. This promoted a series of cooperation activities between the companies which are part of ITS China and ERTICO. Some of these activities include the promotion of ITS standards, the creation of cooperation projects, the exchange of knowhow, and the organization of networking events and site visits in Europe and China.

The expansion of China's and ERTICO ITS-collaborative Europe's efforts in the development of ITS and services is a goal that both organizations have in common. Both Europe and China are experiencing similar difficulties in the field of ITS, and as a result, both regions are working to increase their level of collaboration in ITS research and development, as well as their efforts to promote the flow of knowledge.

Additionally, both parties acknowledge the benefits of advancing global ITS standards that are consistent with one another. In this regard, both ITS China and ERTICO ITS-Europe are aware of the significance of consolidating their connection and the establishment of more intimate kinds of collaborative working relationships. The collaboration focuses on the following three primary points:

- Regularly share and exchange information of mutual relevance and provide information services for the industries and members of both Europe and China.
- Encourage the development of policies and technologies within the intelligent transportation industry, cooperate in the creation of intelligent transportation standards, technological research and development, and hold cooperation meetings within the framework of the ITS World Congress.
- Strengthen cooperation in important areas such as automation, interconnection, transportation information service, intelligent city transportation, freight transport and logistics, and organize exchange activities in the intelligent transportation industry. These activities include establishing together the China-Europe ITS Joint Innovation Centre, co-organizing conferences, demonstrations, seminars, and technical visits, etc., as well as building a platform for cooperation of the members of both sides and fostering a more rapid expansion of the industry.

The MoU was signed to formalize existing collaboration between the ERTICO Partnership and the European ITS Community and that of China. Taking advantage of the collaboration, 5G-MOBIX has benefitted from this collaboration by having access and a direct link to Chinese partners in the project who were interested and able to work on the same objectives of the project.

The outcome of this collaboration resulted in the opportunity to be able to cross-check ideas and operational practices in testing 5G applications cross-border and thus ensure alignment with the approach and technologies that our counterparts in Asia are using. Cross-checking with the pilots in Asia, on the performance of the relevant 5G systems and services, and the ability to enhance the exposure of EU projects, partners and knowledge in Asia has greatly contributed towards building a truly international community that cooperates on the topic of 5G benefits on transport.

Thanks the MoU, ERTICO had the possibility to involve the China Academy of Telecommunications Technology (CATT) in 5G-MOBIX (see Section 5.2.2). In particular:

- In June 2019, ERTICO co-organised the EU-China ITS Forum at the World Transportation Convention in Beijing.

- In June 2020, ERTICO participated in the Belt and Road International Transport Alliance Board Meeting, at which the 5G MOBIX project was presented as open for collaboration.
- In September 2020, ERTICO had planned a business delegation to China which was to include a 5G Workshop at the Huawei headquarters, to include 5G MOBIX Chinese partners, as well as visits to multiple 5G V2X demonstration sites, however due to the COVID-19 crisis this was delayed to 2021.

4.2. Other Liaison Agreements

The partnership between initiatives with a similar aim that are part of the European Union have been made official in the form of a collaboration with 5G-PPP. Because of the structure of the grant agreement and the 5G-PPP partnership, no supplementary MOUs between projects were required to be implemented.

The participants of 5G-MOBIX were given the opportunity to discuss their vision, approach, and outcomes as a result of the cooperation that took place inside the task forces of the 5G-PPP, which also made it possible to coordinate these aspects with the other projects in HORIZON 2020 cross-ICT-18 [15] and the ICT-42 5G-Blueprint [16]. The collaboration between EU cross-border projects is further discussed in Section 5.1.

5. COMMON INTERNATIONAL AND GLOBAL VISION FOR 5G CAM DEPLOYMENTS

Although Europe was a driving force and a leader in the creation of 4G, the continent's rollout of the 5G technology was beset with problems, including significant delays. This ultimately resulted in Europe being put at a disadvantage in comparison to global competing powers.

During his State of the Union (SoU) speech in 2016, the European Commission President Jean-Claude Juncker (2014-19) set as an European Union objective "to completely deploy 5G, the fifth generation of mobile communication networks, across the European Union by 2025" [17].

In a socioeconomic study, it was determined that the rollout of 5G would result in the creation of millions of jobs and billions of euros in economic benefits [18]. To put this into perspective, investments totaling approximately 57 billion euros are expected to result in the creation of 2.3 million jobs in Europe, and the benefits derived from the introduction of 5G could generate 113 billion euros annually in just four key industries (automotive, healthcare, transport, and utilities).

However, in order for 5G for CAM technologies to be advanced and implemented on a broad scale, not only a standardized strategy to research and development, testing, deployment, and market penetration is required on a global level but also international cooperation. This is especially relevant for corridors that transcend international borders [19]. The 5G MOBIX project aim to advance international cooperation is an action supporting the European Union objectives, as these were set in the SoU referred to above, thus contributing to the creation of jobs and economic benefits for both Europe and globally.

This section analyzes the most relevant trials for cross-border CAM in the EU, South Korea, and China, that were used as pilots within 5G MOBIX in its international cooperation tasks of working on 5G for CAM technologies standardized strategy for research, testing, deployment and market penetration at a European and global level.

5.1. Cross-border trials within EU

Within the context of Horizon 2020, the European Commission launched a 5G Public-Private Partnership (5G PPP), with EU funding of 700 million euros, in collaboration with 5G-IA [20].

5G PPP brings together a diverse collection of stakeholders from the field of communications technology and from its extended value chain. These stakeholders include user industries as well as players from the fields of microelectronics and information technology.

The 5G PPP welcomes participants from all over the world and it was designed to be carried out in three stages, beginning with the demonstration of basic technologies and progressing on to proof-of-concept

tests and trials involving vertical industries (in this case, CAM). It also encompasses investigations into longer-term developments beyond 5G.

A long-standing legacy of experimentation for the purpose of testing and validating new technologies, services, and applications can be found in Europe. However, the realization that end-to-end systems are now too complex and too heterogeneous to be analyzed or even simulated, highlights the need for extensive testing and validation on prototypes. In particular, end-to-end systems, as well as individual (sub-) systems, need to be tested in the real world, in actual situations, with real traffic/loads, and with real users. In addition, it is impossible for anyone, even for the wealthiest organizations, to have the financial means to assemble and run an entire proprietary system.

Based on this concept, 5G PPP provides first trial platforms and, subsequently, conducts the trials themselves. For CAM, the approach was slightly different because the platform is actual infrastructure in a specific section of each considered corridor, which has its unique characteristics. In the case of 5G-MOBIX, for instance, the trial between Greece and Turkey had to take into account aspects such as rigorous border checks, customs etc., which were, instead, absent in the Spain-Portugal corridor trial.

In support of the 5G for CAM strategic priorities as they were stated in the SoU referred above, the European Commission launched two Calls targeting cross-border corridors, with 105M€ EU-funding. The aim was concretely to engage the constituency, identify gaps, create consensus, propose solutions, and, most importantly, test and validate in the field.

A first 5G for CAM Call was launched at the end of 2017. The objective was to "identify the problems and barriers and provide a blueprint towards accelerating the deployment of 5G for CAM in cross-border scenarios, and in general in areas where there would be no business case and therefore deployment would not happen, or where there are identified mild market failures and therefore deployments risk being substantially delayed."

Three cross-border corridor projects with 63M€ EU-funding were selected and launched in Nov 2018:

- **5G-MOBIX**: Kipoi (GR) - Ipsala (TR) and Vigo (ES) – Porto (PT)
- **5GCroCo**: Metz (FR) - Luxembourg (LU) - Saarbrücken (DE) triangle [21]
- **5G-CARMEN**: Münich (DE) – Innsbruck (AT) - Bologna (IT) [22]

The members of these project have collaborated on the planning and execution of events and activities, including a series of workshops and webinars.

The collaboration of the three projects aimed at achieving the following objectives: i) to have a comprehensive overview of the most prominent requirements and applications expected for 5G in cross-border environments; ii) to analyze the key challenges that need to be addressed for CAM support in cross-border environments, based on the work of the three projects; and iii) to provide a list of candidate

technological enablers and solutions to be investigated within the projects, which may potentially mitigate or resolve the key challenges.

In particular, it is worth mentioning the webinar "5G Trials for Cooperative, Connected, and Automated Mobility (CCAM)", held on the 6th of November, in which the coordinators of the three projects presented the joint white paper "5G Trials for Cooperative, Connected, and Automated Mobility (CCAM) along European Cross-Border Corridors."

Another relevant co-hosted event was the webinar "5G for CAM deployment: challenges and lessons learned" on the 3rd December 2021, where 5G-MOBIX, 5G-CroCo, and 5G-CARMEN shared their knowledge and experiences regarding the difficulties encountered and the valuable lessons learned during the deployment and integration of 5G for CAM use cases in cross-border scenarios.

A second 5G for CAM call was launched in 2020, aiming both at automotive and rail cross-border corridors. Three projects, mainly with road transport focus, were selected and launched Sep 2020:

- **5G-Blueprint** - North Sea corridor (BE-NL) [16]
- **5G-ROUTES** - Baltic corridor (FI-EE-LV-LT) [23]
- **5GMED** - Mediterranean corridor (ES-FR) [24]

A fourth one, focusing on rail, was launched Nov 2020: **5Grail** [25]. The total EU-funding was 42M€.

5G-MOBIX and 5G-Blueprint have been involved in each other activities since the launch of 5G-Blueprint. In particular, it is important to highlight the fact that 5G-MOBIX hosted a number of workshops at the 5G-Blueprint event. "The role of 5G in autonomous driving and intelligent transport systems in Helmond" on the 5th of April 2022.

The trials conducted by the seven projects did not only provide insights from a technological perspective, but also served to investigate the economic challenges and opportunities of adopting 5G tools in cross–border transport and logistics, as well as in passenger transport: bringing capital expenditure (CAPEX) and operational expenditure (OPEX) into view, both on the supply (telecom) side and the demand (transport and logistics) side, leading to the transformation of current business practices as well as new value propositions [19].

5.2. International cross-border trials of 5G-MoBiX extra-EU partners

Within the 5G-MOBIX project, two trials were conducted by KATECH and CATT, the extra-EU partners of 5G-MOBIX, in controlled environments to emulate the cross-border scenarios in, respectively, South Korea and China.

In this section, we describe the trials and discuss the reached achievements, as well as discussing possible future collaboration between the Asian partners and the EU.

5.2.1. The Korean trial

The South Korea trial conducted by KATECH addressed two of the five use cases identified by the 5G-MOBIX project, namely Remote Driving and Vehicle QoS (Quality of Service) Support, by using mmWave communication.

KATECH was in charge of the 5G-MOBIX Korean Trial Site (TS) and collaborated closely with a variety of technical partners like ETRI, SNETICT, and Renault Samsung Motors. The two use cases chosen for the trials served as investigation ground for remote controlling a vehicle through the use of mmWAVE communication. The collaboration of KATECH to 5G-MOBIX precisely matched its own objectives, which are to foster the innovation of CAM technology and to harmonize all of the stakeholders' strategic technologies related to 5G.

The Korean TS utilized two separate testing locations, primarily the testing grounds at KATECH and the testing site along Yeoju Highway.

KATECH's own testing ground was used to test the use case of remote-controlled vehicles, and it offered two different types of closed test roads: a 1 kilometer patch of different types of test roads (such as a pavé road, straight lane, and braking track), and a road emulating an urban environment composed of multiple intersections and a roundabout.

The Yeoju Highway test was constructed in parallel to the main highway and is located between the Yeoju junction (JCT) (shown in Figure 3) and the Gamgok interchange (IC).

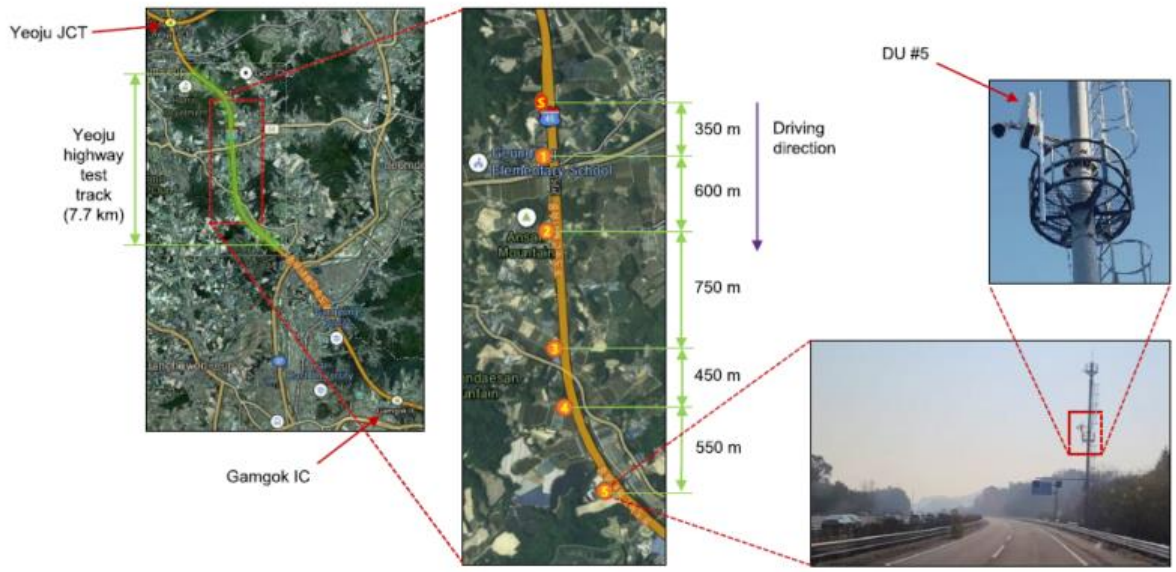

Figure 3: Figure 2: Celebration of the Memorandum of Understanding between ERTICO ITS and CHINA ITS**, DU deployment [26]**

At the Korean TS, ETRI and SNETICT were in charge of the mmWAVE (SA) network (base station and 5G Core network), whereas KATECH is in charge of the remotely-controlled vehicle, a Renault Arkana, that is based on mmWAVE, and Renault Samsung Motors was responsible for providing the necessary technical support. The mmWAVE OBU was installed in a L4 autonomous vehicle. Inside of the test car, there were a total of eight cameras ready to transmit real-time footage to a distant server using mmWAVE communication. The mmWAVE base station as well as the core network were both mounted in the moving base station vehicle, which was a Renault Master van equipped with a remote control station.

The primary features, including real-time video streaming and control RCV through mmWAVE communication, were put through their paces during the field trial in order to be tested and validated. Figure 4 illustrates the field trial conducted on the target vehicle with the base station being located in the Renault Master van in the front of it.

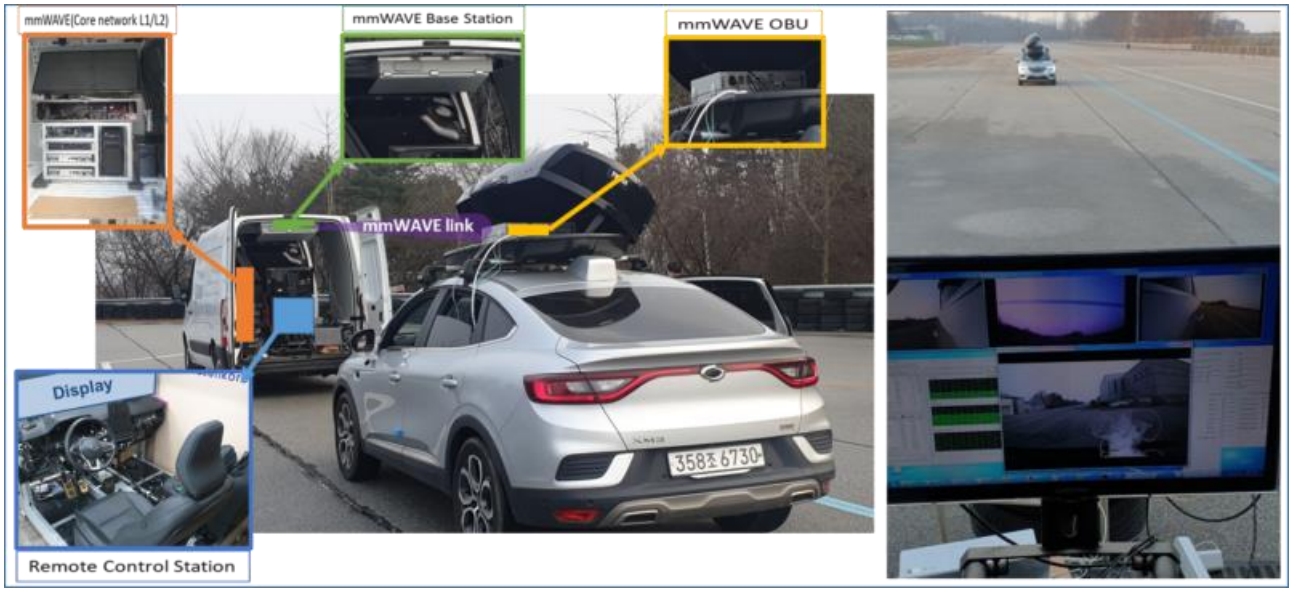

Figure 4: Field trial of the remote controlled via mmWAVE communication.

After successfully developing, testing, and validating the mmWAVE network system and integrating it into the remote control vehicle, KATECH also tested it in the closed ground with predefined scenarios such as high-speed maneuvering with the remote-controlled vehicle and various other maneuvers such as lane changing and avoiding a sudden obstacle. KATECH's testing ground was equipped with predefined scenarios such as high-speed maneuvering with the remote-controlled vehicle.

Additionally, KATECH contributed to 5G-MOBIX by dealing with one technical problems specific to the cross-border sites; mmWave applicability, and have analysed the cross-border issues related to Korean user stories.

Overall, with its activities and findings, KATECH has contributed to the deliverables from WP2 to WP6, in particular D2.2, D2.3, D2.4, D3.2, D3.3, D3.4, D3.5, D4.1, D4.2, D5.1, D6.3, which cover 5G-enabled CAM use

cases, 5G architecture and technologies, vehicle adaptation, corridor infrastructure, and the KR site's roll out plans.

5.2.2. The China Trial

In accordance with the goal of the 5G-MOBIX project, the China trial conducted by CATT contributed to dealing with two technical problems specific to the cross-border sites: Low coverage Areas and Session & Service Continuity by emulating a 5G cross-border scenario at the Jinan location [27].

Collaboration with 5G-MOBIX benefits the requirement to accelerate the Chinese pace of 5G application and strengthen the construction of new infrastructure, industrial Internet and Internet of Things. To match the main objective of 5G-MOBIX, the Dalian University of Technology (DUT) 's and the related stakeholders, researchers made a series of trials on the quality of autonomous driving and 5G communication services for cross-border scenarios. Doing so, they tried to explore the potential and commercial value of Cross-Border 5G technology for advanced CAM. These collaborations focused on the technical issues involved in 5G-MOBIX for achieving roaming and inter-working between various MNOs, and other service providers, which is helpful to improve the performance in 5G deployment under Chinese MNOs.

In order to replicate the relevant scenarios, it was proposed to make use of a number of different 5G MNOs, e.g. China Unicom and China Mobile. As a result, they set up the multiple 5G SA network within the enclosed portion of the Shandong Academy of Sciences (Jinan-1-SDAS, urban road), in addition to selecting the Shandong Binlai Expressway as their preferred location (Jinan-2-SDHS, highways), which is shown in Figure 5.

The purpose of this simulation was to validate essential technical performance of 5G, including cloud-assisted advanced driving, cloud-assisted platooning, and remote driving. Three user stories were devised to accomplish this.

Figure 5: Jinan-2-SDHS field trial

Also, taking into consideration the needs of the 5G-MOBIX project, the partner built a 5G shared MEC framework in Jinan-1-SDAS in collaboration with China Mobile and a 5G SA framework in Jinan-2-SDHS in collaboration with China Unicom.

In addition, by adhering to the XBI-CS list of the 5G-MOBIX, they constructed the MEC cloud, produced the 5G V2X apps with the Roadside Unit (RSU) and On-Board Unit (OBU) equipment from ZTE, DATANG, and other manufacturers in order to evaluate the 5G performance indexes, and developed the CAM application on this server. Figure 6 shows the equipment mounted on the target vehicle in both trials.

Figure 6: In-vehicle equipment in the two trials

The China partners shared the results of the tests from CN user stories and built three use cases for each US to validate 5G performance in China in accordance with the need of the 5G-MOBIX project.

Additionally, the findings demonstrated that a complete 5G SA wrapped in SDIA improved the Quality of Service (QoS) of the transmission sent from the car to the cloud server.

These China trial contributed to 5G-MOBIX deliverables D2.2, D2.3, D2.4, D3.2, D3.3, D3.4, and D3.5, as well as D4.1, D4.2, D5.1, and D6.3.

To express the impact that this 5G-MOBIX trial had on the Chinese 5G ecosystem, we report the words of Dr. Yanjun Shin from Dalian University of Technology: "During the COVID-19 pandemic, major emergencies require advanced mobile communication technology represented by 5G, furtherly 5.5G and 6G, to achieve close coordination and flexible scheduling of social resources in a more inclusive, intelligent and efficient cross-regional coordination. We expect to make further cooperation among the Chinese partners and the

EU partners. Also, we thank the 5G-MOBIX project for providing the DUT the chance to build solid research relationships with the EU partners and share our experiences in developing and testing the 5G CAM. Furthermore, we are glad to share more innovative findings concerning the CAM use cases on 5G and future 5G enhance technology among China and Europe partners".

5.3. Analysis of government policies

In the prior sections, we discussed the technological and operational efforts that have been carried out by 5G-MOBIX in regard to CAM cross-border scenarios both inside and outside of Europe. We also highlighted the favorable results that have been gained by the other HORIZON 2020 EU projects for CAM cross-border corridors.

However, the widespread implementation of CAM in public road networks provides national regulators and road operators with a new dilemma regarding the relationship between infrastructure and road users. Even though it is anticipated that the norms and context of vehicle operation will remain the same, the automation of driving tasks shall contain all of the safety and compliance demands that a human driver ought to adhere to. Some laws are amenable to being modeled using computation, while others belong more squarely within the realm of behavior and culture.

The road network has become more complicated as a shared space resulting in the higher multiplicity of the stakeholders active within the road network ecosystem of products and services and users. Road Operators are dedicated to the implementation of high-level automation in cars as well as in the infrastructure, but they pay top attention and concern to any issues that have an impact on road safety.

In light of the regulatory concerns that could have a significant impact on supporting CAVs crossing international borders that could be implemented to support them, the existing national policies and regulations need to be taken into consideration and harmonized.

In this section, we present the regulations and policies adopted by European and extra-European countries actively involved in the CAM trials and deployments. The 5G MOBIX project consortium aims, with this listing to raise awareness of the diversity of regulations and the need for a more harmonised approach in testing CAM on public roads so that interoperability can be promoted and a more seamless cross-border transport achieved. The Discussion part that follows the listing of regulations and policies of the countries participating in 5G MOBIX aims to recommend EU regulatory bodies to accelerate the adoption of common policies regarding CAM.

5.3.1. EU

In Table 4, we report the policies of the EU countries mostly involved in CAM testing, deployment and regulation. For each country we describe the requirements for conducting tests on public roads and/or the current status of regulations for the commercialization of CAVS.

Table 4: Regulations and Policies in EU countries actively involved in CAM testing and deployment

Country	Policy
Belgium	According to Belgian authorities, the steps to be followed to test CAM on public roads are the following [28]: • Discussion with the relevant organizations; • Completion of the application form, including all required papers; • Agreement on how to communicate with the other drivers on the road; • Notification to the police; • Allow the authorities, such as the administrations and the police, to assist with the testing; • After the testing is complete, a test report should be given to the authorities so that it can be discussed. Documentation needed: • Auditing record maintained by the test's organizer that demonstrates that the internal tests have yielded adequate data to enable testing to be carried out on the public road network without putting road users in any additional danger as a result of the testing; • Risk assessment; • Training plan for test drivers; • Copy of an insurance policy for the tested vehicle; • Copy of the roadworthiness test certificate; • Copy of the appropriate driver's license for every test driver; • A picture of the vehicle
	Main organizations in charge: The organizations involved in the process depend on the region where the testing takes place. They are: • Federal Public Service Mobility and Transport • Flemish Ministry of Mobility and Public Works • Brussels Regional Public Service Mobility • Walloon Regional Public Service

Estonia	Testing of CAM are permitted on Estonia's public highways and streets beginning in March of 2017.These vehicle can undergo testing in either public or off-road environments [29]. In order to successfully complete those tests, it is necessary for it to conform to the following requirements: • Not exceed SAE L3; • Have a driver who is either physically present in the vehicle or is able to take charge of it remotely in the event that this becomes necessary. Because the driver is the one who is legally accountable for the vehicle, he or she needs to have a license that lets them drive that particular kind of vehicle; • The vehicle needs to comply with the most relevant portions of EU Directive 2007/46. Furthermore, it is asked to realize a trial plan, which shall include the following points: • General description of the trials; • Technical specifications of the vehicle; • Information of the road area where the trials will be conducted; • Proof of insurance cover for third-party liability; • Description of measures to ensures road safety; • Require a test plate certificate. For its application, manufacturer shall describe how has trained or will train its stewards/safety drivers; • In the event of an accident, the only person who may be held criminally liable is the driver; the liability does not extend to the manufacturer or to any other legal body. In October 2019, the conclusion that was reached during discussion at the E-Estonia Council was that, despite the presence of a working legal framework for testing CAM vehicles on public roads, an algorithmic-liability law should first come into effect.
	Main organizations in charge: Estonian Road Administration.
France	The standards that shall be met for CAVs to be used on French roads were established by Decree n° 2021-873 on June 29, 2021. This Decree encompasses all levels of automation up to and including completely automated systems, under the condition that those

	systems are deployed in pre-defined courses or zones and are supervised by a remote operator [30].
	
	The provisions and requirements, among other things, specify responsibility principles that were established in ordinance 2021-443 dated 14 April 2021 and will go into effect on 1 September 2022. This will allow to deploy automated passenger transport services beyond a framework that is considered experimental.
	
	The following are the files that shall be submitted in order to obtain the certificate WW DPTC in order to carry out the test:
	
	• Design file – Technical system
	  ◦ Declaration of functionality and safety, which summarises the characteristics and conditions of use of the vehicles;
	  ◦ Capabilities of the technical system: manoeuvring, perception;
	  ◦ and localisation capabilities, remote intervention capabilities;
	  ◦ Types of routes or areas covered by the technical system;
	  ◦ System requirements for testing and facilities outside the vehicle.
	
	• Preliminary safety file – In project phase
	  ◦ Routes or areas identified for the circulation of the system;
	  ◦ Characteristics of the service;
	  ◦ Proposed operational safety management system;
	  ◦ Proposed layout of the technical and safety installations located outside the vehicles;
	  ◦ Responses to the technical system requirements for technical and safety facilities;
	  ◦ Characteristics and level of service of the road, its facilities and the technical and safety installations necessary to achieve the safety level;
	  ◦ Test and trial programme.
	
	• Safety file – Commissioning decision
	  ◦ Verification that the technical and safety facilities and installations outlined in the preliminary safety file have been effectively implemented;
	  ◦ Final version of the safety management system that is now in use;
	  ◦ Presentation of the Agreements Reached Between the Road Managers and the Service Organizer;

	• Give a report on the experiments and testing that were carried out.
	Main organizations in charge: • Ministry of Ecological Transition and Solidarity (in charge of Transport) • Ministry of domestic affairs (in charge of Traffic Safety) • Ministry of Economy and Finance • Ministry of Energy and Climate
Germany	The Road Traffic Licensing Regulations (StVZO in German) is the document that contains the pertinent regulations [31]. The vehicle that is required to pass the dynamic driving tests may be eligible for an individual operating permit under section 19.6 of the StVZO. In the event that the vehicle will be testing functions that are not permitted by the law as it stands, there is a requirement for an exemption approval (70 StVZO): In addition, the law may demand that a particular permit be obtained in order to comply with the regulations of the road. The EU regulation UN-ECE-R79 on steering systems places a significant restriction on the range of automation functions that can be utilized. According to this regulation, a long-term automated steering intervention is only permitted for speeds of less than 10 kilometers per hour. By June of 2018, the regulation was in the process of being revised. The following steps are recommended for the owner of the vehicle in order to receive the admission: • Describe the modifications that have been made to the vehicle's technical components (the differences from the serial type). To the greatest extent possible, make use of references to preexisting standards and laws; • Create a Failure Modes and Effects Analysis FMEA and/or other failure analysis models that are comparable for either individual system modules or the entire system itself; • Explain what technical countermeasures are and the best approach to keep them under control; • Define organizational guidelines for the research and development staff as well as the technical personnel. These guidelines should address questions such as how to obtain the keys, who among the employees has the internal

	permission to develop and download code on the system, how you will (long-term) educate your employees, how you will prevent misuse, and so on; • After the previous documentation is completed, choose an independent testing institution and enter into a contract with it and prepare an assessment report concerning the technical modifications made to the vehicle, its level of safety, and any organizational issues or countermeasures. This evaluation report can include some new requirements that you have to fulfill in order to move forward; • Supply the independent testing organization with the documentation that you have developed in advance of the procedure, and organize a demonstration with the vehicle in which you exhibit the driving features in a variety of scenarios.
	Main organizations in charge: Federal Motor Transport Authority
Greece	The following is an outline of the most important aspects for testing that shall be adhered to in Greece [32]: • Operation is only allowed in a dedicated bus lane; • The lane of use should be adequately marked while signs identifying the operation of the autonomous cars should be put in place; • The vehicle should have labels inside and outside indicating the absence of a driver; • The remote operator shall have the ability to stop the vehicle in the event of an emergency, in the event that they lose visual communication with the vehicle, or in the event that the maximum number of passengers allowed is exceeded; • The maximum operating speed is set to 25km/h. The procedure for granting the licence to operate is broken up into two discrete sub-periods, which are as follows: • the testing phase, during which there shall always be an operator on board who is able to perform emergency braking; • the operating time, during which, under certain circumstances, the operator may be moved to a remote control center.

	Main organizations in charge: Greek Ministry of Transport, Infrastructure and Networks
Italy	According to the Decree 28/2/2018 issued by the Ministry of Infrastructures and Transport, a Ministry authorization is required in order to test autonomous vehicles on public roads [33]. The authorization is only valid while the test is being conducted inside of the stated testing region. In order for vehicles to pass inspection, they need to be able to record comprehensive technical data at a frequency of at least 10 hertz. Testing is permitted so long as the vehicle supervisor satisfies a list of prerequisites, stays in the test vehicle at all times, and maintains a state of readiness to respond to any potential hazards. The certification of a new transportation system is something that a local authority, such as a municipality or the authority responsible for the infrastructure, shall request from the fifth division of the Italian Ministry of Transport. For the purpose of conducting a risk assessment research, it is necessary to compile a dossier in accordance with the EN 50126 technical standard. The technicians of the Ministry will add their views and suggestions to the project, which will then need to be adjusted properly.When they are satisfied, a commission of national specialists reviews the dossier and gives a temporary certification to operate in dry run mode. This commission is generally chaired by a high ranking official of the Ministry, such as a vice minister or someone along those lines. The results of the dry runs are reported, and if they are successful, the certification to open to the public is granted.
	Main organizations in charge: Ministry of Infrastructures and Transport
Luxembourg	To conduct a CAM trial on public roads it is necessary to Make a formal application to the Ministry of Sustainable Development and Infrastructure in Luxembourg, including the following information [34]:

	• A report of a technical service for non-type approved vehicles and the original certificate of conformity for type approved vehicles with any modifications made to the vehicle; • A description of any error prevention procedures that have been implemented; • An explanation of the technique for entering the safe state in the event of any errors; • The route that was intended to be taken for the trip; • The anticipated duration of the trip in hours; • Documentation regarding the training that the driver of the vehicle received; • A technical assessment of the vehicle will be carried out by the Société Nationale de Circulation Automobile in order to confirm that none of the alterations pose any potential threats to safety, and a report on the inspection's findings will be sent to the Ministry; • In the event that the Société Nationale de Circulation Automobile does not identify any technical problems and that all other provisions are satisfied, the Ministry will provide a permission for the period of time that has been specified; • Throughout the entirety of the trip, the car is required to have a label that reads "Essai scientifique" affixed to either the front or the back of the vehicle.
	Main organizations in charge: • Ministry of sustainable development and infrastructure Luxembourg • Société Nationale de Circulation Automobile
Poland	The procedure for testing automated vehicles was included in the Act on Electromobility and Alternative Fuels (Dz. U. 2018 poz. 317), which provides an update to the Traffic Law Act. This law was passed in Poland in 2018. According to the documentation available, the testing can take place if and only if certain safety constraints are met, as well as if the relevant testing authorization is obtained [35]. The permission can be obtained from the authority responsible for road control. It is granted on the basis of the formal application, which needs to include the following information in order to be considered valid: • The applicant's name, including their surname, as well as the name of their company and their address;

	• Information on the location of the test, including the beginning and ending dates; • The planned testing route; • A list of the people responsible for securing the testing route; • The signature of the person in charge of organizing the test. A copy of a professional vehicle registration should also be attached to the permit in addition to the following: • A confirmation of signing a compulsory liability insurance policy on the possible damages incurred during the test; • A confirmation of paying the insurance fee; • A copy of the insurance policy By posting the application on its website for a predetermined amount of time, the organization responsible for road supervision facilitates public conversations with the surrounding community (not shorter than 7 days). An objection can be lodged by the owner of a structure or plot of land that is situated along the proposed testing path. After receiving the positive decision of the relevant road supervisory entity and the opinion of the Voivodeship police commander about the potential testing disruptions on traffic flow and safety, the final permit is given. During the testing, the organizer of the tests is obliged to: • Provide the Police with the possibilities to ensure the traffic safety, life and health protection of people and property; • The person in charge of organizing the tests has a responsibility to submit an official report to the organization in charge of transportation technical supervision no later than three months following the conclusion of the tests; • The report is required to be formatted in accordance with the template that was presented in an applicable Ordinance issued by the Minister of Infrastructure.
	Main organizations in charge: • Voivodeship police commander

Spain	The purpose of Instruction 15/V-113 is to create a framework for the regulation of the granting of special authorizations for testing and research tests that are carried out on roads open to general traffic using automated vehicles with an SAE L3 rating or above. Before granting an exemption, the instruction stipulates a number of standards that shall be met about the vehicle, the driver, and the application [36]. These requirements are as listed in the following. • A current insurance policy; • A proof that they have satisfied basic standards of both safety and performance, including an examination on a test track; • An independent and accredited laboratory is required to carry out the tests in order to determine whether or not the vehicle satisfies the safety criteria; • Driver qualifications should include a current and valid driver's license for each individual driver. Even if they are not physically present in the cabin at the time of the request, they will be liable for driving and controlling the vehicle in accordance with the request; • The applicant is required to provide proof in the form of a statement of responsibility that the driver is familiar with or has been trained in the operation of the automated vehicle; • It is essential to have at least one person behind the wheel of the car at all times; • The applicants need to meet the eligibility requirements (be they OEMs, Tier1s, researchers, or something else) and supply the documentation that is needed in the instructions. This paperwork, among other things, has to describe the cars that are being tested as well as the description, location, and schedule of the tests that are desired; This license is good for a period of two years after it has been issued, and it can be used anywhere within the DGT's jurisdiction. Any driving that takes place outside of the specified testing zones should be completed in manual mode.
	Main organizations in charge: • General Directorate of Traffic

5.3.2. Extra-EU

In Table 5 we summarize the policies and regulations of few extra-EU countries which are at an advanced stage of CAM testing, deployment and commercialization. By providing a global perspective of the differences, challenges and opportunities concerning CAM policies in other countries, 5G-MOBIX aims at fostering discussions on the topic between national and EU regulatory bodies.

Table 5: Regulations and policies in extra-EU countries actively involved in CAM trials and development.

Country	Policy
China	In accordance with the law of the People's Republic of China that currently in effect, the testing of CAVs is permitted on public roads in China. However, the road testing for CAVs is restricted to specific areas of regular public highways that are chosen by the competent departments and notified to the public [37]. In addition, road tests for CAVs should comply with numerous stringent regulations, including (but not limited to) the following: • The test applicant shall be an independent legal person registered in the PRC that is capable of manufacturing, research and development, and testing of CAM-related vehicles and components • The test applicant should also have sufficient financial capability to make civil compensation for likely personal or property damages caused by CAM tests; • The test applicant shall be capable of conducting distance-monitoring, recording, analysis, and reproduction of the tested CAVs • There shall be personal qualification requirements placed on the test driver; • There should be technical requirements placed on the tested • A formal application for road testing, which needs to be accompanied by extensive documentation including proof that the CAV being tested is covered by insurance for more than RMB 5 million.
	Organization in charge: • Ministry of Industry and Information Technology • Ministry of Public Security • Ministry of Transport
Japan	On public roads, testing of automated driving systems may take place in accordance with the Guidelines for Public Road Testing of Automated Driving Systems, another procedure

	that does not comply with the Guidelines, always with the preliminary advice of the police or a combination of both of these [38]. The following are the fundamental requirements for carrying out these tests: • The driver should always be able to operate the vehicle; • The driving session should meet the rules of the Road Traffic Act; • The Safety Regulations for Road Vehicles (Ministry of Transport Ordinance nr 67 of 1951) are met by the test vehicle. A substantial amount of driving testing should first be carried out in test facilities before it may be undertaken on public roads. • Testing on public roads should begin in an environment where there are relatively few elements that cannot be anticipated; • Implementing Entities are obligated to conduct a pre-trip inspection of the traffic conditions on any public roads they intend to use; • In order to properly supervise the autonomous driving systems, there needs to be a second person present in the test vehicle; • The test driver is required to possess the valid driver's license that corresponds to the used car being evaluated; • The test driver is solely responsible for all aspects of legal driving; • The individual is not required to handle the steer but is expected to monitor the traffic in the surrounding area; • The individuals or organizations that are responsible for the planning and execution of public road testing are referred to as "implementing entities"; • They need to establish a plan for testing public roads and take appropriate precautions to protect everyone's safety. In addition, the entities in charge of implementation are responsible for the following: • The required qualities of the test driver; • An appropriate level of cybersecurity when testing on public roads; • The recording of various data regarding driving and the condition of the vehicle; and the required qualities of the test driver. Public highways, as specified in article 2(1)-1 of the Road Traffic Act (= statute nr 105 of 1960), and private testing facilities are both acceptable options when it comes to testing infrastructure.

	Organizations in charge: • National Police Agency • Ministry of Land, Infrastructure, Transport and Tourism
South Korea	The Ministry of Land, Infrastructure, and Transport of the Republic of Korea, which is the government agency in charge of the regulation of motor vehicles, has the authority to designate testing zones after examining proposals submitted by local governments [39]. Within these testing zones, a variety of restrictions that normally need to be followed in order to operate an autonomous car in Korea will not be enforced. This is because the Act on Motor Vehicle Management is the law that regulates the safety of motor vehicles in Korea. In addition, the Ministry of Land, Infrastructure, and Transport of the Republic of Korea has the authority to designate some public roads as "safety zones" for CAVs. Continued investment in infrastructure such as road facilities and ITS which support CAM, is intended to make such safety zones more reliable in the future. If market participants in the autonomous vehicle industry first anonymize and process any personally identifiable information collected into non-personally identifiable information, then the collection and use of big data would be exempted from the laws aiming at protecting privacy, such as the Act on Personal Information Protection. The Ministry of Land, Infrastructure, and Transport amended the Rules on the Performance and Standards of Automobiles and Automobile Parts (the "Safety Standards") in order to implement new safety standards for autonomous vehicles on the 31st of December, 2019, prior to the enactment of the Automated Vehicles Act. On January 1, 2020, the amended laws that are relevant to SAE L2 went into effect. Although the Act on Motor Vehicle Management, which is a statute that governs the Safety Standards, already contains a provision that conceptually defines a 'autonomous vehicle,' the amended Safety Standards introduces the definition of 'autonomous driving system,' which encompasses all equipment, software, and other devices that are directly related to autonomous driving. In addition, the Safety Standards adopt the concept of an operable area (similar to the Operational Design Domain outlined in SAE J3018). According to this concept, the OEM is required to designate a particular area in which the CAV system can be operated normally

	and safely. The Safety Standards do not, however, impose a requirement on such a producer to advice customers of the area in which the product can be operated.
	Organization in charge: • Ministry of Land, Infrastructure and Transport
US	The regulatory framework for testing CAM on public roads in the United States does not follow a uniform standard throughout all of the states [40]. There are certain states in which the governor has issued executive directives concerning autonomous vehicles. In the following, we list the main • **California**: the first protocols for testing autonomous vehicles were developed after the Bill 1298 in the year 2012. Other laws detail the authority of law enforcement agencies to confiscate autonomous vehicles that have been wrongly licensed, the authority of local municipalities to levy special fees on driverless taxi services, and a variety of other aspects that are associated with autonomous vehicles. • **Colorado:** The state of Colorado has passed legislation that lays out the legal standards for automated driving systems and specifically enables citizens to drive self-driving cars, providing that such vehicles conform to the laws of both the state and the federal government. • **Florida:** in 2012, it became the first state to enact legislation that would allow for the safe testing of technologies related to self-driving cars. Additionally, the legislation made it clear that the state of Florida does not prohibit the testing or operation of autonomous vehicles in any capacity. Later legislation that was passed in 2016 expanded on this overarching concept and even prepared the path for the testing of fully automated vehicles that did not require the presence of a human driver. • **Kentucky:** Although Kentucky has a law that regulates autonomous platoons of commercial vehicles, the state does not have any legislation on the books that pertain to self-driving cars that are not used for business purposes. Because of this, there is currently no law that expressly prohibits self-driving cars. • **Nevada:** In certain situations, it should be illegal for a person to use a portable wireless communications device or a cellular phone while they are behind the wheel of a motor vehicle. The bill should also include provisions for sanctions and any other issues that are pertinently related to the issue.

	• **Pennsylvania:** The state of Pennsylvania does not have any rules that apply to autonomous vehicles used for non-commercial purposes. There have been two laws issued that are related to autonomous vehicles. One of these laws allots funds for the development of autonomous vehicle technology, while the other law defines the parameters for platoons of commercial vehicles that operate autonomously. • **Texas:** has passed legislation that not only specifies a range of terminology related to autonomous vehicles but also makes it clear that the operation of self-driving vehicles is not illegal in the state. The legislation also prohibits local governments from passing laws against self-driving vehicles and allows for the use of completely autonomous vehicles—vehicles that have no human operator at all—under certain conditions. However, these provisions are only applicable in certain settings.
	Organizations in charge: • Department of Transportation • National Highway Traffic Safety Administration • Each respective Federal State

5.3.3. Discussion

As highlighted by Table 4 and Table 5 in the previous parts in this section, the situation concerning regulations and policies adopted by governments with regards to testing and trialing appears extremely fragmented and heterogeneous not only around the world, but also within the EU, in particular for what concerns high level of automation for CAVs.

Since 2019 the European Commission has passed a number of relevant implementing regulations that address the various driver assistance measures that were included in the Regulation.

Along with the publication of the EU's strategy on automated mobility, the Commission's proposal for the revised General Safety Regulation was also released at the same time. This strategy outlines a comprehensive set of actions that the EU is planning to take in order to facilitate the deployment of CAM systems. These envisioned steps including the deployment of important technology and infrastructure, putting in place the appropriate legal framework for the EU internal market, and ensuring that automated mobility offer considerable benefits to the population of Europe, such as road safety, better access to mobility, lower greenhouse gas emissions etc.

The European Commission plans to adopt technical rules for automated and connected vehicle based on the General Safety Regulation. These rules will focus specifically on automated vehicles that replace the driver on highways (SAE L3), as well as on fully driverless vehicles such as urban shuttles or robotaxis (SAE L4).

Before fully CAVs may be sold in the EU, they will need to first be evaluated thoroughly for their level of maturity and safety in accordance with the technical rules that will be established by a Delegated Act and an Implementing Act. These will encompass testing processes, regulations for cybersecurity, rules for data recording, as well as requirements for monitoring the safety performance of completely driverless vehicles and reporting incidents by manufacturers.

6. CONCLUSION

International cooperation has been a key asset for the smooth and impactful completion of the 5G-MOBIX project. Since its launch in 2018, 5G-MOBIX has been active in promoting international cooperation with the members in the public and private sector and in promoting the rapid development of the automotive and telecommunications industries. In this scope, it acknowledged the necessity of strengthening cooperation in key fields such as automation, interconnection, transportation information service, intelligent city transportation etc.

To stimulate long-term EU and global cooperation and innovation initiatives, 5G-MOBIX has been facilitating the exchange of knowledge and experience between 5G industry and V2X industry researchers in the EU and beyond via dedicated events and dissemination of results both online and offline.

In D7.6, we described and discussed the goals, challenges and opportunities that the 5G-MOBIX addressed to foster international cooperation. We also listed and discussed the activities that made this project a strong linking activity among EU member states and this community with non EU countries in the field of cross-border 5G testing in CAM.

In this scope, the Deliverable first described the dissemination activities undertaken by 5G-MOBIX members, including scientific publications, seminars, booths, workshops and conferences. Subsequently, it presented international organizations of interest for the activities and vision of 5G-MOBIX, with which a contact was established during one or multiple international events. Similarly to 5G-MOBIX, these organizations also aim at the development of 5G locally and worldwide and contribute to the dissemination of information and results.

In this report, the cross-borders trials conducted by China and South Korea 5G-MOBIX partners were evaluated to highlight the strategic benefits of cooperating internationally with countries with an advanced know-how in 5G networks. Other cross-border trials within the EU were discussed as well.

Finally, we proceeded with a survey of the regulations and policies in the EU and abroad regarding CAM trials and commercial adoption. The survey highlighted that, despite being a mature technology, different sovereign countries have highly diverging views on 5G for CAM, on the subject of both trials and commercial deployment. Given the complexity of harmonizing the communication between different national bodies, MNOs and vendors, the lack of a harmonized regulatory framework at an international level is especially affecting cross-border scenarios.

Having shown the clear benefits of international cooperation, we recommend European countries to keeping working closely on both technological/operational aspects of 5G for CAM, as well as jointly converging on regulations and policies to speed up the adoption of this technology which is essential for the future of a seamless mobility that takes full advantage of what 5G technologies have to offer.

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