Fifth Generation Cross-Border Control

Deliverable D5.2
Cost/Benefit Validation of Relevant 5GCroCo Business Potentials

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Editor(s):	Xavier Vilajosana (WSE), Outmane Laaroussi (DTAG), Edwin Fischer (DTAG)
Authors:	Selva Via (CTTC), Edwin Fischer (DTAG), Dirk Hetzer (DTAG), Marc Bouillon (Orange), Fabien Coulet (HTW), Cliff Everingham (Volvo), Andreas Schimpe (TUM), Didier Rouma (Post Lux), Antonio Eduardo Fernandez (Stellantis), Israel Gonzalez Vazquez (Volkswagen AG)
Reviewers:	Uwe Puetzschler (Nokia), Johannes Springer (DTAG), Olivier Sancier (Stellantis), Bernhard Blieninger (Fortiss), Israel Gonzalez Vazquez (Volkswagen AG)
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V3.0	31-08-2022	• Revised version based on feedback from previous interim review and latest insights prior to the end of the project	Edwin Fischer

Executive Summary

In this document, the use cases and the Key Performance Indicators (KPIs) defined in WP2; the Vehicular-to-Anything (V2X) technologies and standards described in WP3; together with the existing business studies derived within other relevant 5G consortia and projects (e.g., 5GAA, GSMA, 5G NetMobil, and 5GCAR), will serve as starting point to develop the cost benefit analysis of the 5GCroCo application scenarios and technological ecosystem (Multi-vendor for telco equipment, multi-OEM (Original Equipment Manufacturer) for automotive, Multi-Mobile Network Operator (MNO), cross-border, and multiple content providers).

The document is structured in three main chapters, first identifying the stakeholders, recovering the knowledge gained in D5.1. Then, an important effort is put on the identification of the assumptions that the different stakeholders in the Cooperative, Connected and Automated Mobility (CCAM) ecosystem need to make in order to devise the market development directions. These assumptions are wide and may cover complementary future developments due to the still unknow directions that regulations, market development and technologies will take.

In addition, the document identifies the costs sources for the deployment of the 5GCroCo scenarios and beyond. The cost analysis is performed from a sector/role perspective, identifying what are the main costs due to the materialization of CCAM for each of the involved stakeholders.

This cost analysis is used to discuss the potentials and barriers of the different applications considered in the project. The document goes further and presents a Cost/Benefit analysis identifying key directions in which the technology for sure will have an impact. The connected vehicle market, safe mobility, and the efforts done towards clean mobility are carefully analysed to derive estimated benefits of the full deployment of CCAM ecosystems.

Contents

List of Abbreviations and Acronyms

3GPP	Third Generation Partnership Project
5GAA	5G Automotive Association
5G-PPP	5G Private Public Partnership
ACCA	Anticipated Cooperative Collision Avoidance
AD	Automated Driving
ATB	Automobile Transmission Board
AV	Automated Vehicle
B2B	Business to Business
B2C	Business to Customer
BMC	Business Model Canvas
C-V2X	General term for V2X based on cellular technology
CAD	Connected and Automated Driving
CAPEX	Capital expenses
CBA	Cost Benefit Analysis
CCAM	Cooperative, Connected and Automated Mobility
CEA	Cost – Effectiveness Analysis
CPE	Customer Premises Equipment
DL	Down Link
eCall	Emergency Call System
eMBB	Enhanced Mobile Broad Band
ETSI	European Telecommunications Standards Institute
Euro NCAP	European New Car Assessment Programme
GDPR	General Data Protection Regulation
GHG	Green House Gas
HAD	Highly Automated Driving
HD	High Definition
HGV	Heavy Good Vehicles
ICT	Information and Communications Technology
IaaS	Infrastructure as a Service
IEEE	Institute of Electrical and Electronics Engineer
IETF	Internet Engineering Task Force
IR	Internal Report
ITS	Intelligent Transportation Systems
k	Thousand (financial)
KPI	Key Performance Indicator
LTE	Long Term Evolution
MAMCA	Multi Actor Multi Criteria Analysis
MEC	Mobile Edge Computing
MNO	Mobile Network Operator
MSL	Minimum Service Levels
MWC	Mobile World Congress
NHTSA	National Highway Traffic Safety Administration
OBU	On-Board Unit
OEM	Original Equipment Manufacturers
OPEX	Operational expenses
PC5	Sidelink interface for direct V2V/V2I communication
QoS	Quality of Service
RSU	Roads-Side Unit
RTA	Road Traffic Authorities
SA	Stand Alone
SaaS	Software as a Service
SLA	Service Level Agreement
SME	Small and Medium-sized Enterprises

SRTI	Safety Related Traffic Information
TCO	Total Cost of Ownership
TCU	Telematic Control Unit
TMS	Traffic Management System
ToD	Tele-operated Driving
UC	Use Case
UE	User Equipment
UP	Up Link
URLCC	Ultra-Reliable and Low-Latency Communications
Uu	Air interface between UE and 3GPP network
V2I	Vehicle-to-Infrastructure (communication)
V2N	Vehicle-to-Network (communication)
V2V	Vehicle-to-Vehicle (communication)
V2X	Vehicle-to-Anything (communication)
VCoC	Vehicle Control Centre
VoD	Video-on-Demand
WG	Working Group
WP	Work Package
XaaS	Anything as a Service

1 Introduction

The validation of relevant 5GCroCo business potentials is an important part of the project activities. The combination of technical innovation with new ideas for the ecosystem will support a wide range of new stable use cases for CCAM.

The selected use cases from 5GCroCo (Tele-operated Driving, High Definition (HD) Mapping and Anticipated Cooperative Collision Avoidance) are perfect examples to demonstrate the power of the different partners in the project (OEM, supplier, MNO, road authorities, academia) for developing the CCAM ecosystem.

1.1 Objective of the Document

This report analyses the cost drivers to support the 5GCroCo use case applications, namely the capability to tele-operate vehicles, the delivery of HD map content in real time to CCAM vehicles and the full integration of ACCA services in vehicles and road infrastructures.

The document sets forth assumptions related to the 5G and CCAM technology and ecosystem adoption and categorizes the costs to deploy, integrate and maintain the 5G infrastructure to address the aforementioned applications. Special emphasis is put in identifying the cross-border requirements and assumptions that need to be materialized in order to accelerate the market development in this context. The goal of such analysis is to identify the cost sources, that may be used to guess possible benefits if the 5GCroCo applications are finally to be implemented. The document takes a careful approach, given the complexity and number of parties involved in the CCAM chain, and aiming to avoid any possible overselling or over dimensioning of the possible benefits that such ecosystem may provide.

According to D5.1 [1], the stakeholders' assumptions are used to identify and target the investment and development of the 5GCroCo use cases. The identified assumptions, which may be sometimes considering different origin perspectives, lead to the cost analysis for each of the involved stakeholders, including vehicle and OEM manufacturers, telecommunication operators, road operators and technology providers.

Along with the document certain emphasis is put in transversal aspects of the technology and business model including mentions to competing technologies and businesses, IP protection considerations and constraints coming from ethical and data protection.

The findings of this document can be summarized as:

- A list of the main assumptions, categorized by stakeholder role that are needed in order for the CCAM in the 5GCroCo applications to be materialized.
- A detailed cost analysis for each of the roles in the CCAM ecosystem, helping to assess the benefit boundaries of the envisioned applications.

- A benefit analysis beyond pure economic aspects, including aspects such as safety and sustainability.

1.2 Structure of the Document

Section 2 presents an overview picture of roles, stakeholders and entities involved in the CCAM ecosystem. Section 3 is central to the document and provides a deep study of the assumptions made by the involved entities and the cost drivers to include CCAM in the envisioned applications. These assumptions set the stage for the analysis, as well as identifying what should be enabled before the market is fully developed. Complementarily, in this section, cost drivers are detailed for each of the involved sectors which should be seen as the barriers to overcome in order for the business to be materialized. Section 4 details the value potentials of the 5GCroCo CCAM envisioned applications. Value potentials go beyond direct economic benefits and consider aspects such as sustainability, safety, and comfort of the end users. Section 5 summarizes the main outcomes of the analysis.

2 Key Entities, Roles and Stakeholders

5GCroCo has identified the key stakeholders in Deliverable D5.1 [1], this content is duplicated in this D5.2 report in order to provide a self-contained document.

Stakeholders need to define and drive the development of the market, first and foremost through generating value from the potential applications defined in the proposed use cases, secondly by applying the technologies developed and evaluated within the project in other existing but relevant applications, and finally by empowering new applications based on the experience and outcomes gained.

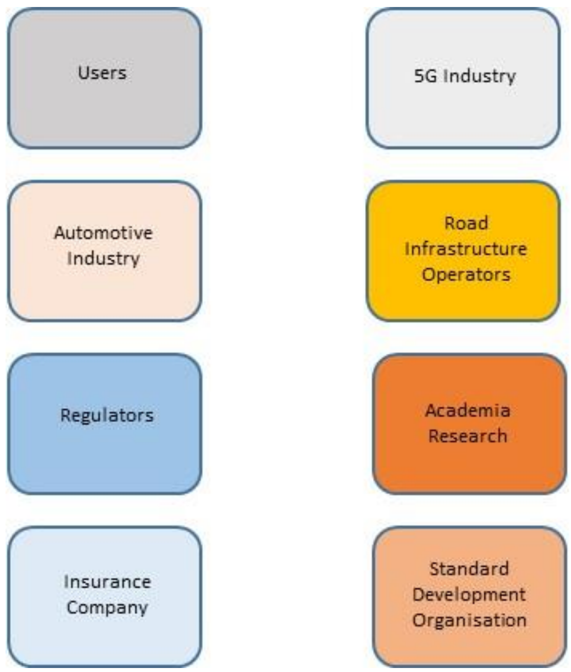

Figure 2-1: Main Stakeholders Categories

In the envisioned 5GCroCo ecosystem, the following stakeholders will take a structural role:

Users: are the consumer of dedicated services, in different relation B2C, B2B or B2B2C. This includes "Mobility Service Providers and logistics" (MSP) fleet operators, freight transport services, etc.

The Automotive industry, covered by vehicle manufacturers and Tier 1/OEM providers will be in charge, along with other partners in the ecosystem, of embedding both: intelligence and communication components, in vehicles and its dedicated infrastructures (e.g., Mobile Edge Cloud). Vehicles that are smoothly collaborating with other vehicles or devices, will enhance awareness and problem-solving functions for safety, automation, and traffic efficiency under very strict time/space performance requirements. In the early days they will be the drivers of novel 5G empowered applications, especially related to the safety of the vehicles. The existence and growth of the 5G infrastructure (through eMBB for example) will motivate development in the application market and favour the development of additional services.

5G Industry: telecom infrastructure providers and manufacturers will develop the infrastructure to meet the 5G requirements, as defined by the regulation bodies. Telecom industries including operators, vendors and telecom manufacturers will need to collaborate and align their developments to the automotive industry and other sector demands. In this context, the manufacturers need to have an influence on early harmonization and system specifications, in order to create the corresponding markets and address them with competitive products at the appropriate time. This is achieved today thanks to their presence in regulation bodies.

Industrial and Telco equipment vendors recognize the need to disassemble vertically integrated technologies and to support success stories to validate the KPIs that stand their technological assumptions. The generation and ownership of intellectual property is essential to ensure profitability of the manufacturer's business, and at the same time, to provide incentives for competition through open platforms or cross-license agreements on fair and reasonable terms.

Mobile Network Operators recognize the potential that the automotive sector offers to expand their total service offering, thereby increasing their market size and growth rate. The need to enhance existing infrastructure or functions has also been identified in order to achieve V2X Services' QoS metrics. Yet, the risk of a single infrastructure technology will polarize the stakeholder's opinion, enabling alternative ecosystems to further develop (e.g., IEEE802.11p vs C-V2X). In Figure 2-1 MNO is included in the 5G industry.

Small to medium sized enterprises (SME) in the sector will create strong R&D links with both academia and leading industrial entities, which helps them within the value chain. The SMEs, at the same time provide, an innovative character with necessary edge competence, services and products.

Road Infrastructure Operators: Road Traffic Authorities (RTA) are mainly responsible for operating road infrastructure; they can be public or private entities and usually manage a large infrastructure for long periods of time. RTA's take into consideration the necessary requirements to address the most challenging scenarios such as the cross-border corridor. RTA will need to be convinced by Telecom industries to adopt 5G technologies with the automotive industry playing a fundamental role. Without a clear alignment in the ecosystem of Regulator-RTA-Vehicle Manufacturer-Telecom industry, the expected growth of the vehicular connectivity will not develop.

Standardization bodies: V2X standards are being developed at different bodies; e.g., the ETSI, 3GPP, IEEE, and others are developing core specifications to regulate the communication of vehicles at different layers and sometimes proposing competing technologies. The role of standardization bodies is crucial to ensure that the investment of large companies is taking the right directions while also allowing for interoperability among different vendors. Standardization bodies must, therefore, define clear pictures of the technologies and align, when possible, to avoid non-coexisting, non-compatible and fragmented markets.

Academia and Research are interested in building on and further developing existing software skills and research strength in V2X systems. The gained expertise will permeate into the daily university life and will be disseminated within academic education as preparation for future European ITS and 5G experts.

Insurance Companies: among other sectorial institutions related to risk assessment, updates in the vehicular/transport infrastructure and the early focus of 5G technologies to provide extended security services in vehicles are of utmost relevance to insurance companies' business models. To this end, it is expected that 5G enabling extended services and tailored audits will improve risk assessment in such companies.

The following table lists the stakeholders per category and type and provides a short description or examples:

Table 2-1: Key Entities, Roles and Stakeholders

Stakeholder category	Subtype	Description	Symbol
Users	Drivers	Person managing the vehicle.	D
	Passengers	E.g., passengers of public transportation or taxis.	P
	Vehicle Owners	E.g., Rental Car SME (Small and Medium Enterprise).	VO
	Mobility Service Provider	Logistic & Mobility Service Provider	MSP
Automotive Industry	Car OEMs	Car manufacturers.	OEM
	Tier 1 Supplier	On-Board Unit (OBU) manufacturer.	1TS
	HD Map provider	Provides HD maps in streaming.	MP
	Map provider	Provides updated maps in real time; e.g., Open Street maps.	MP

Stakeholder category	Subtype	Description	Symbol
	Tele-operated service providers	Enables automated vehicles to be tele-operated in critical situations.	TO
	Vehicle Control Center	New business opportunity. For safety and security purposes, in private or rental fleets. For example, it could be an SME providing this service.	VCoC
5G Industry	MEC providers	Provide the virtualization of edge computing facilities close to the Telecom operator infrastructure.	MEC
	Mobile Network Operators & Infrastructure Provider	The provider of the ICT infrastructure or network services. Can be cellular but also other technologies can be considered. There can be neutral operators leasing the infrastructure.	MNO
	Cloud provider, backend system host	Provide computing infrastructure. Coordination with MNOs will be required in order to guarantee QoS.	CL
Regulators & Law-makers	Transport and road authorities	Authorities should regulate the use of 5G in the vehicular space.	TRA
	Telecom and spectrum regulators	Need to drive the technology growth by providing the needed regulations to support the requirements of the technology.	TSR
Road Infrastructure Operators	Road operators	Owners/managers of the infrastructure. Play a critical role as they must deploy and operate the technology in the infrastructure.	RIO
Standard Developing Organizations	-	Should drive the technology to be more secure, more efficient and enable market defragmentation.	SDO

Stakeholder category	Subtype	Description	Symbol
Academia and Research	-	Should research novel approaches and techniques to improve the technology. Should also be the tool to disseminate and train new professionals in the sector. Can also act as neutral players when decisions must be taken based on technical and societal criteria, and not only commercial interest.	AR
Insurance companies	-	Should be in touch with regulation authorities and the manufacturing sectors. Should be vigilant to the regulations and technical possibilities.	IC

In this deliverable, the assumptions and cost drivers will be related to the different stakeholders, identifying their scope and sector they influence.

3 Value and Cost Deployment Study

The value and cost analysis in the following section will be focused on a detailed evaluation of the main cost driving elements, the necessary assumption for special cross-border scenarios and the impacts for the business partners in the ecosystem. This cost analysis study is aligned with the architecture defined in D3.2 [2] in which the building blocks to enable the CCAM are detailed.

3.1 Methodology

While the methodology for cost deployment is focused on the selected CCAM use cases of 5GCroCo (ToD, HD Mapping, ACCA) it is not limited to only these use cases. In the first Description of 5GCroCo Business Potentials deliverable [1] the main relations between the main players are displayed and described. Figure 3-1 gives an example for Tele-operated Driving (ToD).

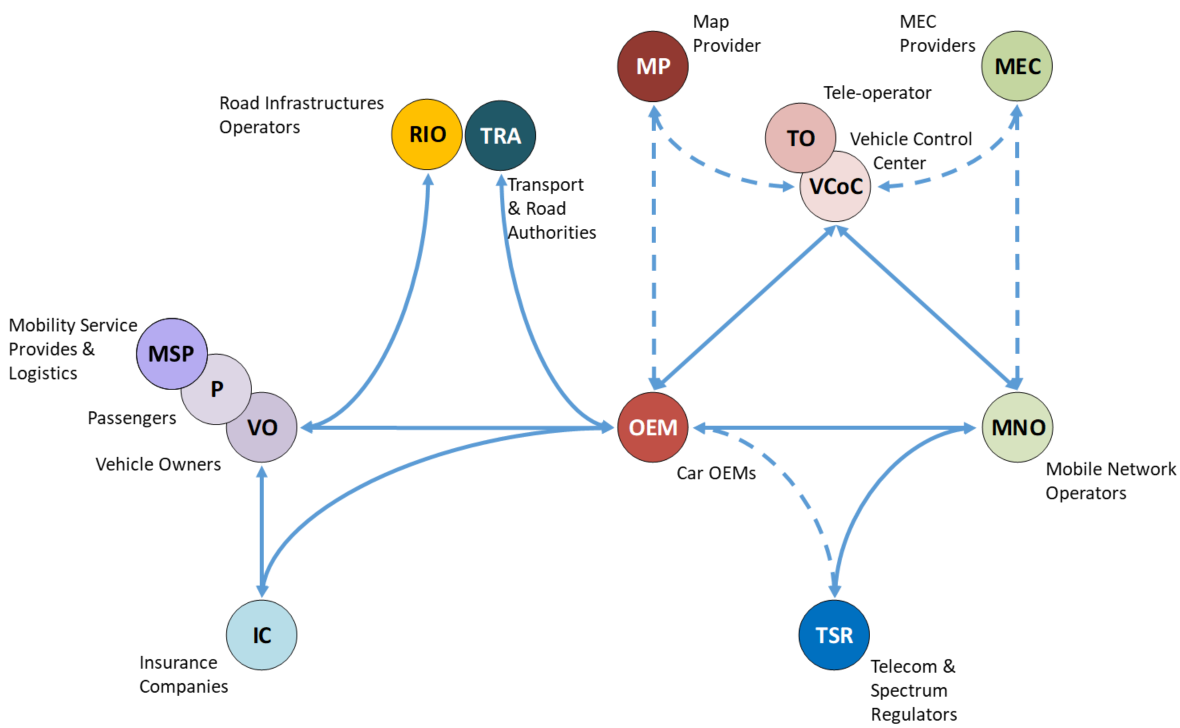

Figure 3-1: Relations Between Main Players in ToD Use Cases

The selected approach in the cost deployment will be based on full cost methods with Activity-Based Costing and Activity-Based Management / Operation. This will include an examination about variable and fixed costs, understanding of related external cost influences, investment and re-investment strategies and related benefit analysis.

The approach includes the following elements:

- Identification of the different roles in the CCAM ecosystem with respect to the current 5GCroCo use cases (las described in Section 2)
- Collection of assumptions from the different verticals and CCAM use cases (Section 3.2, and 3.3)
- Examination of possible revenue streams to pay back the services/infrastructure, basis for this task is the given assumptions with related weight and probability (Section 3.4)
- Analysis of cost drivers (Section 3.5)
- Identification of the base cost for a service to maintain the entire CCAM ecosystem given the defined applications (Section 3.6)

3.2 Assumptions

A full materialization of the CCAM ecosystem involves the investment from multiple stakeholders who will drive their levels of investment based on strategic and market perspectives of the CCAM ecosystem. It is obvious that technology demand is a prime driver, but it is also clear that demand will not be materialized in the same manner for all the involved stakeholders. This section presents and analyses the key premises and assumptions that motivate the different stakeholders to invest in the development of CCAM applications. All cost analysis and value generation perspectives are based on the fact that some of the presented assumptions materialize. It is only possible to derive such a complex analysis if the involved entities in this work make certain assumptions related to regulation, demand for services and willingness of the entities in the value chain to adopt the technology.

It may also be problematic that the assumptions made by certain stakeholders depend on the assumptions made by others, however doing so helps in describing a dependency chain between involved stakeholders while identifying any possible challenges in these relationships that may become real barriers for the realization of the technology.

The assumptions introduced in this section are organized first by application, understanding however that some overlapping may exist between them motivated by the use of a similar core architecture. A second classification splits them by industry, the main categories being the OEM manufacturers, the telecommunication system development companies, the telecommunication network operators, the road and infrastructure operators and third-party companies providing software services. As a final remark, certain assumptions may overlap or be in contradiction with others because market perspectives are still not clear, and a further refined market analysis might need to consider different scenarios.

3.2.1 Telco and ICT Equipment Manufacturers

#	Assumption	Description	Stakeholders
1	Increasing demand for new 5G CCAM oriented technologies.	There is a demand for 5G computing and network equipment to be deployed in infrastructures related to mobility. This demand increases.	Equipment manufacturers

3.2.2 Automotive

#	Assumption	Description	Stakeholders
1	Coverage available in all roads	The basis to use connectivity for any CAM service is to have coverage available everywhere, including cross-borders. This is not the case today, but the initiatives from the EU, i.e., CEF2 Digital (Connecting Europe Facility 2021-2027) and RRF (Recovery and Resilience Facility) are to promote the engagement and co-financing of 5G deployment to guarantee full coverage of roads and railways.	MNOs, Equipment manufacturers
2	The connectivity business model has to evolve from the current definition based on data volume	For use cases in 5GCroCo like Tele-operated Driving and HD Mapping, the volumes exchanged can be very large. It is difficult to promote these services or to make them economically viable with the current business models where the OEM pays based on the volume exchanged.	MNOs
3	The connectivity costs have to be coherent with the automotive industry cost structure and business model	There are two axes in this problem: one is that in most cases the car in a CAPEX operation for the final customer while connectivity is an OPEX cost, making it difficult to transform one into the other. Today only a small number of OEMs have an end-customer monthly subscription for connectivity services, though it is likely this model will be adopted by an increasing number of OEMs despite resistance from end customers. The second issue is the cost sensitivity of the automotive industry. As a car is deemed expensive, in order to reduce costs all different	MNOs, Automotive

		cost drivers will need to be carefully controlled. Today with a cost model based on the data volume, operations like OTA can be difficult to justify. As a result, while there have been industry trends towards including connectivity as part of the purchase price of the vehicle, it now appears increasingly likely many OEMs will consider adoption of end-customer subscription payment models.	
4	The end user is not paying for the connectivity.	The overall trend has been to assign the cost of the connectivity to the automotive manufacturer by applying these costs to the initial vehicle purchase and so averaging connectivity costs across the full fleet of vehicles. However, this payment model is increasingly being reviewed as described above.	MNOs, Automotive
5	Drivers will accept to pay for these services (based on the level of automation) as an extra cost on top of the car.	This charge could be included in advanced driving functionality charges or as an extended service offered by a third party, depending on the future level of adoption of CAM services by users	MNOs, Automotive, Service providers, Entertainment companies
6	Regulations may impose CCAM services so as to reach “5 star” Euro NCAP rating	Regulations may mandate certain levels of automation in the years to come. This may be a strong incentive for the development of the market similar to what happened from April 2018 in Europe with the introduction of eCall.	All
7	5G V2X connectivity massive adoption	For some use cases like HD map or ACCA, it is crucial to have a critical mass of cars adopting the V2X connectivity in order to contribute with their sensors in a CPM (Cooperative perception message) approach. In order to achieve such critical mass, all the previous factors are essential.	Automotive, OEMs

8	Automation will be a more secure solution	Higher levels of automation with CCAM are considered essential to achieve the objectives defined by the EC for 2030 in term of traffic casualties and injuries. The customer perception is also important for the success of the service adoption. Onboard sensors can avoid accidents, but connectivity brings anticipation, and this provides a more reliable and more secure automated driving experience.	Automotive, OEMs, MNOs, Service providers, Road operators
9	The option will be attractive to customers	This will possibly augment the demand for this service. Idea of office in the car such as the case of logistics and last mile delivery,will raise demand, and connectivity services are being increasingly viewed by OEM's and customers alike as core features of vehicles	Automotive, MNOs, Service/application providers

3.2.3 Infrastructure Operation

#	Assumption	Description	Stakeholders
1	Reliability of CCAM services	CCAM services shall be reliable and provided in any circumstances, i.e., no interruption of service in case of network failure. CCAM service, which is safety related, shall have priority over any entertainment service.	Telecom Operators, OEMs
2	Direct communications	Direct V2V and V2I communications should be implemented to ensure continuity of service anywhere, at any time.	Road Operators, OEMs, Telecom operators (V2I)
3	Management of traffic and event data	Traffic and event management is the sole responsibility of Road Operators; therefore, the Traffic Management System (TMS) in the MEC of Telecom Operators shall be under the responsibility of the closest Road Operators or a dedicated TMS operator.	Telecom Operators, IT and software suppliers
4	Drivers may decide to accept a charge to use CCAM enabled roads	Enabling CCAM services requires a huge investment. One possible ROI model is to charge end users for the services. The model is not clear today, but a possible option involves drivers paying a fee for it.	Road Operators, MNOs, other.

5	Authorities will take care of the extra costs from the road operators to extend their infrastructures with CCAM features.	Such a large-scale infrastructure deployment and maintenance needs to involve governments and authorities. To enable the CCAM transition these authorities need to develop adoption programs and support infrastructure providers in the transformation.	Road Operators, MNOs, Automotive
6	CCAM provides social benefits in terms of security in the road and less causalities.	CCAM offers the possibility to reduce accidents and improve the safety of vehicles and roads.	All
7	A dataspace has to be settled by a "operational ITS message handler (OIMH)"	It is complex to define the responsibilities, liabilities between the players in the CCAM, involving many different players in the CCAM ecosystem. Dataspace [3], will be a useful tool in that context.	OEMs, Road Operators, Telecom operators

3.2.4 Infrastructure Services

#	Assumption	Description	Stakeholders
1	Growth of CCAM Vehicle market	Infrastructure service providers expect a progressive growth of the number of vehicles including CCAM services. This can be a trigger for the adoption and full deployment of the technology.	Automotive partners, Road Operators, Software and Service providers, …
2	Infrastructure operators demand	Infrastructure operators demand for software/cyber-physical systems to interact to CCAM enabled vehicles will increase. Maybe as a response to governmental regulations or due to market potential increase or OPEX reduction.	Road Operators, Infrastructure and Software providers
3	Revenue stream from CCAM services	There will be a money flow that will ensure the demand for CCAM services in national and cross-national infrastructures. Either governments or drivers will pay for the services to the road operators or other service providers, and these will acquire/pay services to software providers and telco operators. The entire economic chain needs to be defined.	Road Operators, Infrastructure and Software providers, MNOs.

4	There will be a need for integrator players that take the responsibility for the final solution	This integrator will not be mandatory if different CCAM services could co-exist, if decision making will be completely devoted to CAR (driver or autopilot). Operational role to deal with the software issues, maintenance and liabilities. Cross border responsibility needs to be developed through agreements. This integrator could be held by the actor offering XaaS to CCAM service providers. In that case, it does not care about service logic of CCAM. It deals with software infrastructure support issues.	Road Operators, Infrastructure and Software providers, MNOs.

3.2.5 Telco Operators

#	Assumption	Description	Stakeholders
1	Additional Infrastructure required for CCAM	CCAM will require additional infrastructure deployment compared to what should be deployed only for mass market Internet connectivity on the road. Actors involved in deployment must find ways to fund and/or to have return on investment for this incremental infrastructure.	MNOs
2	Multi business model support	Today it is unclear how the CCAM will be priced and valued. If the MNO is responsible of infrastructure deployment, customer's MNO for CCAM should be the end-user/driver (B2C), the car maker (B2B), the road operator (B2B), an independent CCAM service provider (B2B) or a car maker consortium (B2B), etc. It could depend on the CCAM service itself. Basic assumptions: -Features outside the operation of the car, services that may be of interest for the end customer. Some CCAM services are focusing in that direction. - The vehicle is an enabling tool. But there are features that are built on top of it.	All

		- Car manufacturers have an agreement with MNOs. - Services built on top may be offered to user/interested parties for further monetization.	
3	Multi CCAM services beyond use-cases of 5GCroCo	The service/use cases to taken into account in order to find right economic model should be broader than those which are seen in the 5GCroCo project. For instance, truck platooning should be taken into account in the economical equation, as well as service for mass market. Telco operators are not fully managing end-user provided services and are more generic in term of delivering services in 5G (user services are agnostic except for quality of services). Telco Operators' business model is linked to the global 5G service eco-system in which 5GCroCo is a part.	Road Operators, Infrastructure and Software providers, MNOs.
4	Agreements	All partners should align and agree on the future demand to be handled through the infrastructure. Depending on the use cases, users and Telco operators will define the required resources to be invested	MNOs
5	Infrastructure as a service for CCAM services	MNO's will offer infrastructure as a service including advanced regional/local cloud computing service and associated connectivity	MNOs
6	Offering additional infotainment service support (slice, …)	The car OEM could offer new advanced services (Video-on-Demand (VoD), Radio on demand, streaming) to car occupants (including regular drivers when the car is in autonomous mode). Car OEMs could thus valuate connectivity by advanced entertainment services and infotainment. This connectivity will be settled using 5G antenna and specialized modules. One slice could be dedicated to infotainment when 5G SA becomes available.	MNOs, Automotive, Entertainment Service Providers

3.2.6 Software Providers

#	Assumption	Description	Stakeholders
1	Road operators and MNO will require specialized CCAM software to be deployed in their infrastructures or as a service from the cloud	The MNO will offer edge computing capabilities in which dedicated CCAM software will run. This software can be delivered/owned by third parties that will be paid for their solution. Road operators and MNOs will define service agreements for the use of edge services, and they will pay for the dedicated CCAM application from a software provider.	Software integrators, Infrastructure providers
2	There is a need of a middleware layer performing message treatment	The operational ITS message handler (OIMH) performing real-time value-added treatment: receiving specialized message from cars, trucks, RSU, camera (MB). It will feed the ITS dataspace with refined data accessible by all actors involved in the ITS (Car OEM, road OP, CCAM service providers, etc.) as well as external stakeholders such as insurance company, law, …). This middleware will be a common enabler for CCAM services developers, providers.	MNOs, Road Operators, Software providers

3.2.7 CCAM Service Operator

#	Assumption	Description	Stakeholders
1	OEMs or dedicated operators (e.g., ToD operator) will require specialized CCAM service operation to	The operator will offer capabilities in which dedicated CCAM software will run. This operation can be delivered/owned by third parties that will be paid for their solution. OEM's or public regulators will define service agreements for the services and any of them will pay for the dedicated CCAM operators. The operation will be based on different network basis (MNO, road infrastructure)	Software integrators, Infrastructure providers, OEMs, insurance

	be deployed for dedicated markets		
2	There is a need of interworking between different CCAM operators	The operation of CCAM services performing real-time value-added interaction: receiving specialized messages from and to cars, trucks, RSU, camera (MB). This has to work cross-border with the required KPIs. It will lead to an application interworking by the involved actors (Car OEM, road OP, CCAM service provider etc.)	Software integrator, MNOs, Road Operators, OEMs

3.3 Specific Assumptions for 5GCroCo Cross Border Use Cases

The materialization of the CCAM ecosystem involves multiple stakeholders, see e.g., Section 2 and Section 3.2. These come together to enable infotainment and software update services as well as driving assistance, automated driving and traffic safety to benefit the end user and society. Various types of requirements must be fulfilled to enable these types of features. In turn, different decisions can be made with the goal to meet these requirements, by different stakeholders affecting the overall system. It is therefore important that stakeholders work together to address these challenges. In cross border situations, the different country settings are another dimension that needs to be taken into consideration. While some aspects can be addressed using the corresponding solutions within a country, other aspects can be even more of a challenge when crossing a border.

Already within a country, the CCAM ecosystem needs feasible technical solutions to work and feasible payment solutions to maintain the system. In cross border situations, the technical solutions need to adapt according to differences between the countries, such as updating which rules to follow, the available spectrum and relevant stakeholders, all while maintaining a secure ecosystem that can be trusted. At the same time, payment solutions may consider that some vehicles cross borders frequently while others tend to stay within the same country most of the time. One important requirement to agree on will be who carries which costs and where the payment streams shall be sent in the case of border crossing vehicles.

In future the deployment of CCAM services will also be based on new steering functions for the network usage. So called network exposer functions (e.g., dedicated API's to set QoS from user side, usage of network slices, integration of MEC services etc) will support a new level of network offer from MNO to the users. The key parameter for the success of such service approaches is the interoperability with different MNOs in different countries adapted in different use cases.

In 5GCroCo, three different use cases are investigated in terms of cross border challenges and solutions, refer to 5GCroCo D2.1 [4] and D2.2 [5] for more details. These use cases are not limited to the specific service that they represent, but stand for a representative set of services relevant for a CCAM ecosystem in general.

The assumptions for the different specific 5GCroCo use cases respectively applications are further analysed in the following sub-sections:

3.3.1 Tele-operated Driving (ToD)

ToD is beginning to emerge as a basic building block for Highly Automated Driving (HAD), where cross-border support will be essential for many autonomous driving use cases. Regulations for autonomous driving vehicles, with level of autonomy SAE 4 and above, are now in constant development and with a high probability for the release of specific legal requirements in those markets, on which a ToD solution is used as backup, to maintain autonomous driving over deadlock situations. Safety is a priority in the automotive sector and positively perceived by the end customers and, for this reason, ToD is included in cross-border situations. On public roads (e.g., in Germany) it is expected that tele-operation in an indirect driving mode will become a ‘must-have’ for HAD.

For the cross-border areas, beyond the technical requirements to support the low latency “roaming”, there appear many other challenges. These are in the form of institutional demands or of technical needs which will require a new series of agreements across the different players involved to ensure service continuity for the end user. All this is reflected with large investments in development of the needed tools, deployment of new technology in the vehicles, as well as new infrastructure in the roads, the MNOs, software providers, Vehicle Control Center (VCoC) and others.

The assumptions drawn in this document, clearly point out the need for the definition of an economical chain, regulations and involvement of authorities. This is aligned with other institutes and key players working on tele-operation across the world which are now also looking on the creation of standards and new technological enablers to be used for the delivery of a tele-operation system that will be safe and suitable for the end customer[1].

The interworking between many existing and new market players will help to materialize an ecosystem of services and applications not existing today.

3.3.2 High Definition (HD) Map Generation and Distribution for Autonomous Driving

CCAM services such as Automated Driving, risk having severely limited functionality without highly accurate and dynamically updated HD map data. Hence, maintaining accurate HD map data for traffic, location and positioning is highly important

[1] NIST – National Institute of Standards and Technology (USA) - https://www.nist.gov/news-events/events/2020/11/nist-vehicle-teleoperation-forum Andromeda Consortium (Israeli group) https://israellivinglab.opendatasoft.com/pages/home/

In order to realize the business case for producing, updating and maintaining HD map data, there is a need for defining a sustainable value chain including stakeholders from Automotive, MNO's, road infrastructure operators, mapping companies and vehicle owners. In particular, as many CCAM services require high quality coverage along highways and through national borders there will be a strong demand on collaboration between MNO's networks in maintaining services provided at the cross-borders. This in turn will require considerable investment by MNO's for extended road coverage, network capacity and service availability while providing the necessary higher bandwidth and lower latency required and delivered through 5G.

The costs for carrying large volumes of HD map data, traditionally paid by OEMs through providing safety services to their end customers, will also need to be justified. As it is essential that accurate HD Maps are maintained especially for frequently changing data such as road conditions, this opens possibilities for OEMs to monetize providing updated road traffic data from vehicle sensors to mapping companies and road infrastructure operators as a way of offsetting traffic costs.

3.3.3 Anticipated Collaborative Collision Avoidance (ACCA)

The ACCA application, including the cross-border support developed in the project can become one of the first promoters of CCAM services at large scale. Safety is a priority in the automotive sector and positively perceived by the end customers. The materialization of ACCA requires the entire development of a value chain, involving stakeholders from end users, CCAM service providers, road operators, MNOs, the automotive sector, and regulation authorities.

In the cross-border areas beyond the technical requirements to support the low latency "roaming", there are institutional and technical agreements required between operators (telco, road, ToD operator) in order to ensure service continuity for the end user. This comes with large investments and the development tools and services, including different stakeholders, and building up an ecosystem not existing today. The cost drivers presented in the document show that the building blocks are clear and the materialization of this business and commercial chain depend on the demand and a clear regulations framework.

3.4 Value Chain Discussion

The value chain discussion in this section is based on the 5GCroCo use cases. These use cases serve as examples for which the business and financial relations in CCAM ecosystems are illustrated and explained. The different business roles are outlined below. Not all roles listed are applicable to all use cases respectively services.

- **Middleware/Message Provider.** This role is in charge of collecting messages (like DENM, CAM, etc.) from cars and road operator RSUs, processing them and sending elaborated data to CCAM services providers in a smarter way (filtering, correlating, fusing…). This could be associated to e.g., the MNO. The corresponding software which is performing the process is running on MEC servers.
- **MNO.** This role is in charge of offering 5G connectivity plus MEC capabilities, offering IaaS, PaaS, SaaS, to Software operator. This role is obviously played by the

corresponding well-known stakeholder. Several MNOs could be present in a given area/country (N in a given country) in the country touching the country border.

- **Software Operator.** This role is in charge of deploying software on the MEC servers, troubleshooting, scaling using tools offered by MNO relying on XaaS for deployment.
- **Software Provider.** This role is in charge of development in a DevOps way to ensure adaptation to operational condition. This role could be played by a stakeholder also playing the role of software operator.
- **CCAM Provider:** This role is responsible for CCAM service. It could be associated with the software operator/provider.
- **Dataspace (industrial) Provider:** This role is responsible for dataspace maintenance, building, management, security, policies, and the relationship with different entities clients of the dataspace. A dataspace in a data integration system, offering flexibly, as depicted in the Fraunhofer paper [3], "The Industrial Data Space is a virtual data space leveraging existing standards and technologies, as well as accepted governance models, to facilitate the secure exchange and easy linkage of data in a trusted business ecosystem."

3.4.1 Tele-Operated Driving

The ultimate goal of ToD is to add value, i.e., comfort, practicality or similar advantages for the vehicle owner (VO) or passengers (P) of the tele-operated vehicles, or other mobility service providers (MSP) and logistic companies. The vehicles and passengers would be insured by an insurance company (IC), potentially through the original equipment manufacturer (OEM) as well. If the OEM is not generating the HD maps for AD and ToD itself, this would instead be supported through a map provider (MP). To run the ToD technology, the vehicle needs to be connected to the vehicle control centre (VCoC) via a mobile network enabled through the mobile network operator (MNO). Similar to the provision of maps, the tele-operation, carried out by the tele-operator (TO) in the VCoC, is a service that could be run by the OEM. It is also conceivable that the VCoC service is offered by new partners, i.e., Small and Medium-sized Enterprises (SMEs), which focus on the provision of tele-operation services. For privately owned, tele-operated vehicles, it may also be the vehicle owners that are paying for subscriptions of the VCoC services. The VCoC may also benefit from using HD maps, i.e., maybe supported by an MP. Finally, Mobile Edge Computing (MEC) providers may also support the VCoC or the OEM (through the MNO) by offering functionality in the cloud.

The dataspace would be an interesting component for ToD even if not depicted in Figure 3-2. The VCoC will have to log some events of tele-operation such as the beginning of a remote-control session as well as the context around why the service was required. This information could be used by other cars in the vicinity; for instance, in case an accident occurs. Furthermore, in case that some processing could be performed in a distributed way over a piece of software in the MEC, to relieve the VCoC from performing real time adjustments, an interface between MEC and dataspace is to be set in order to follow the same approach explained before and log key events that are now performed by the AI embed system in the MEC.

For the deployment of the ToD use case, other parties, e.g., the road infrastructure operators (RIO), transport and road authorities (TRA), and telecom and spectrum regulators (TSR) were identified to be involved.

The value chain of the ToD use case illustrated in the below Figure 3-1 shows the flow of exchanges (in terms of resources and money) between different stakeholders:

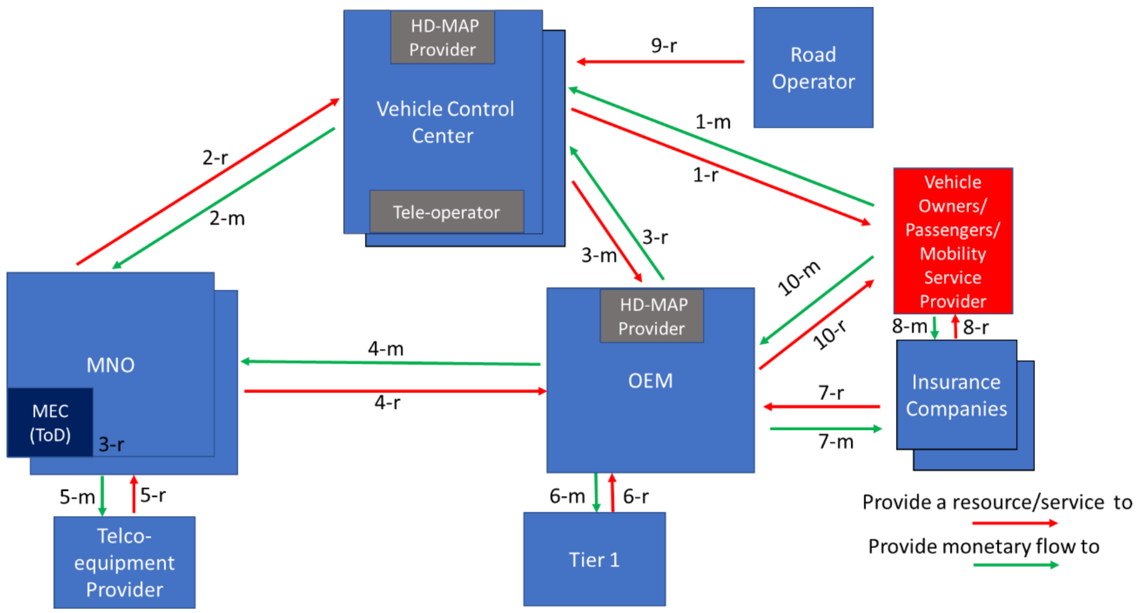

Figure 3-2: Value Chain of ToD Use Case

Further details related to the monetary and resources flow exchanges are also described in the below table:

Table 3-1: Resources and Monetary Flows

	Domain	Reference in the figure	Description
Resources	Service	1-r	Value-added Service delivered to car driver, passengers or mobility service provider
	Connectivity & IT	2-r	MEC support + Connectivity to connect ToD service provider facilities
	Software	3-r	Application Programming Interface (API) to enable the ToD service
	Connectivity	4-r	Connectivity for cars (5G, 4G RAN)
	Equipment	5-r	Equipment for MNOs (Hardware & Software): Antennas systems, radio units, …

	Equipment	6-r	Tier 1 will provide equipment/components to OEMs for integration into the cars
	Service	7-r	Provide insurance to cover the ToD service
	Service	8-r	Insurance contract to car driver, passengers or mobility service provider
	Permission	9-r	Provide the regulation & authorization for ToD usage
	Equipment	10-r	Provide car and embedded ToD feature (ready for Activation)
Monetary flows	B2C/B2B	1-m	Car driver / mobility service provider pays for ToD service
	B2B	2-m	Vehicle Control Centre (ToD service provider) pay MNO for the MEC support and connectivity to the VCoC
	B2B	3-m	The ToD service provider pays OEM to have access to the API and all related data needed to enable the ToD service
	B2B	4-m	OEM pays MNO for the connectivity of cars through 5G/4G sites
	B2B	5-m	MNO pays Telco Equipment Vendor to have all the equipment needed to have an operating 5G/4G connectivity
	B2B	6-m	OEM pays Tier 1 for the vehicle components
	B2B	7-m	OEM pays insurance companies to have access have ToD insurance coverage
	B2C/B2B	8-m	Car driver / mobility service provider pays the insurance company to get insured
	B2C/B2B	10-m	Car driver / mobility service provider pays the OEM for the car with ToD embedded feature

3.4.2 HD Mapping, ACCA & Associated CCAM Services

The value chain of the two 5GCroCo use cases HD Mapping and ACCA are presented in this subsection and illustrated in Figure 3-3.

It has been chosen to gather HD Mapping and ACCA because these two use-cases are complementary considering the following points:

- HD Mapping and ACCA are collaborative uses-cases, in a sense that several sources of data carried by messages are delivered by cars and possibly also by road infrastructure (RSU),
- ACCA use case could be implemented by the service logic of the car using real time information provided by HD Map provider. ACCA and HD Map providers need to work in a collaborative way at the car level.
- HD Mapping and ACCA will participate to the same data ecosystem and will use the same message layer elaborated by the message provider.

Business roles

The roles involved in the proposed value chain framework are presented in Figure 3-3. A role could be played by an individual actor/stakeholder or grouped with another stakeholder with a larger scope and footprint.

Strong assumption on how the proposed roles would be played by different stakeholders is taken. It is assumed that every role could be viable in a business sense as each provides resources to one or several other roles and in turn receives payment from them.

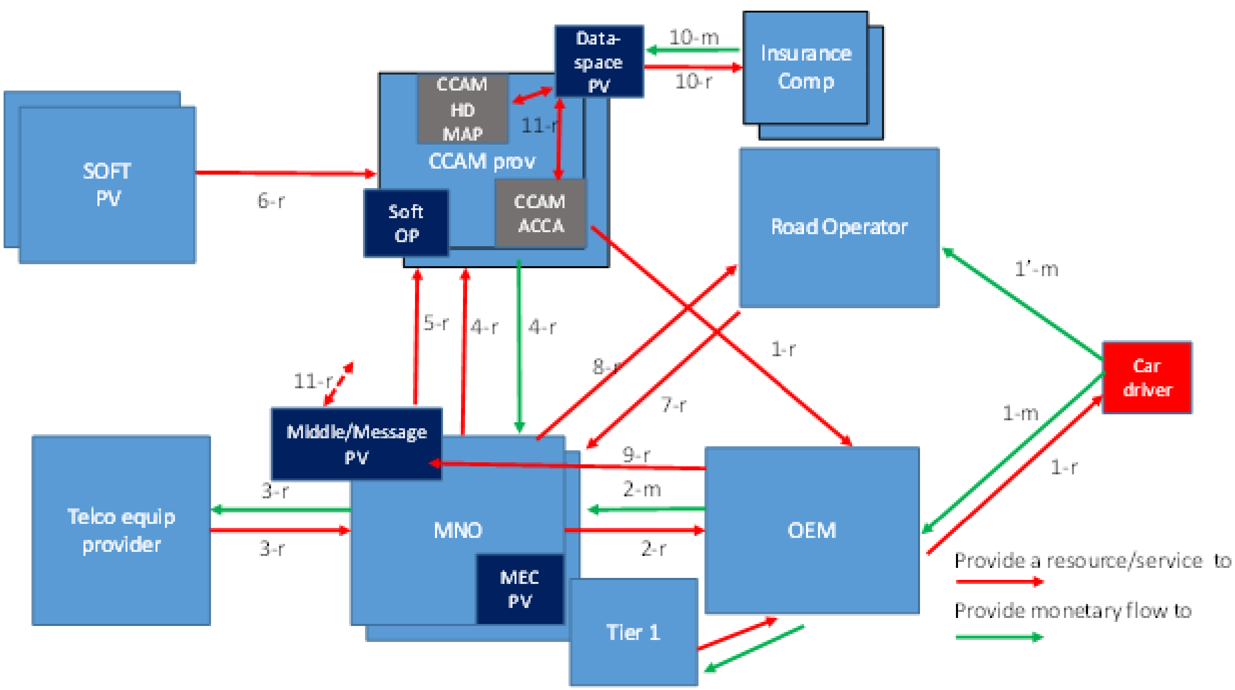

Figure 3-3: Value Chain: HD Mapping, ACCA and Associated CCAM Services

Ecosystem organization

The ecosystem appears too complex to define precise scenarios, and well-organized traditional value chains starting from primary resources to final product. A possible organization of the ecosystem is presented by identifying resources and monetary flows. The resource flows and monetary flows corresponding to Figure 3-3 are described in the table below.

Table 3-2: Resources and Monetary Flows

	Domain	Reference in the figure	Description
Resources	Data	1-r	Value-added data delivered to car driver or autonomous car system (ACCA, HD MAP update, etc.)
	Connectivity	2-r	Connectivity for cars (5G, 4G RAN)
	Equipment	3-r	Equipment for MNO (Antenna system, …)
	IT	4-r	MEC support + Connectivity to connect CCAM service provider facilities
	Data	5-r	Refined Data/messages from road infrastructure and vehicle
	Software	6-r	Software for empowering CCAM service logic
	Data	7-r, 9-r	Raw data/message from (road, car)
	Connectivity	8-r	Connectivity for RSU (V2I) based on 5G, 4G RAN)
	Data	10-r	Data interesting insurance company (case of accident, injury, pay as you drive …)
	Data	11-r	Feeding the dataspace and possibly consuming stored data
Monetary flows	B2C	1-m	Car driver pays for CCAM service (ACCA, CCAM package …) (option 1)
	B2C	1’-m	Car driver pays a fee for CCAM service for the road under the responsibility of road operator (Toll) (option 2)
	B2B	2-m	OEM pays for connectivity to a given MNO in charge of relationship with other MNOs

			(inside country for national roaming or cross border for international roaming).
	B2B	4-m	The CCAM provider pays to the MNO the MEC usage in the context of IaaS offer, and possibly an additional fee for connectivity to connect premises of CCAM provider

Principle of a dataspace

The business configuration proposed in Section 3.4.2 allows actors participating in CCAM ecosystems to receive income from a dataspace in which they are involved. This dataspace will be fed by refined data provided by the message/middleware provider or by the different CCAM providers. This external source of income is valuable for the ecosystem though the drawback is that the actors of the ecosystem must also invest. However, it appears that building a dataspace is a must due to regulatory constraints, or operational requirements (traffic control). Concerning dataspace, several actors could find the dataspace through a collaboration with the dataspace physically distributed between several entities/actors. Actors participating in the provision of dataspace could earn income when data they own is valorised for 3rd party usage (insurance, road authority, developers, HD Map provider).

Connectivity offer

The end user or the OEM will need to pay for connectivity that an operator is providing, and for managing the relationship with other MNOs in order to ensure roaming at country or national level. In some cases, the end user (driver, car occupant) could purchase connectivity in B2C mode even if not used on a personal smartphone. This could be the case if a multi-SIM on-board unit is installed in the car. It should be assumed that one SIM will be used by OEMs for operational service (OTA, CCAM,…). It seems unlikely that end-user connectivity will be supporting CCAM services such as ACCA, or HD Mapping.

Some use cases, such as ACCA, require low bandwidth and the corresponding produced data will not be large but nevertheless significant over a longer duration. There is a requirement on the MNO to improve coverage in order to achieve full spatial coverage for the transport corridors in order for CCAM services to be fully supported, however it is not clear today how the operator will receive payment for this. Possibilities include the OEM using additional revenues from entertainment services (like video-on-demand, the road operator by connecting their RSU (V2I) or the CCAM service provider by the use of IaaS offer of the MNO including MEC and specific connectivity for CCAM services. This specific connectivity could rely, for instance, on a specific slice with enhanced QoS compared to eMBB. This raises some issues to be tackled because in this case the slice ends at the UE side attached to the car which remains the responsibility of the OEM.

A second option could be a separation between a MEC offer (XaaS) and a connectivity offer. But this brings some drawbacks in terms of possible synergies between the MEC offer (distributed cloud), and the connectivity offer in terms of optimization and service features such as real time MEC switching during handover.

Note that for VoD service, the corresponding contents could be cached in the MEC server.

Such services allow the OEM to monetise the subscriptions paid to the MNO for general purpose (OTA, CCAM) with VoD, or specific entertainment services. This source of revenue could compensate expenditures for connectivity when this is not directly monetized with CCAM services sold directly to car drivers in order to ensure advanced features such as autonomous driving. These different services will rely on different slices.

From events to data and logic of service

The CCAM providers will rely on the middleware/message provider to build the service logic they are responsible for which is, for instance, the case with the ACCA service. But the use-case imagined based upon the messages delivered by the event are numerous. At the end, if several different CCAM providers co-exist with several service providers, there could be a need of an orchestrator/integrator for the different service logic in order to harmonize the car behaviour. Consider the interaction between “Lane Merge” and “ACCA” and the case where a collision could be prevented by changing the car lane. Furthermore, autonomous cars could also take decisions on the basis of the HD map when this is available at the car during a relevant event. It could be assumed that ACCA events will probably arrive before the HD map specific element of interest is updated. One of the CCAM providers could be the HD map provider relying on the event to enrich the HD map in real time.

All these events sent by the middleware/message provider will be treated by the CCAM provider which define events on the basis of these messages and derive service logic. These events will be stored on the dataspace in a compatible format.

3.5 Cost Drivers

The evaluation of the main cost drivers in the CCAM ecosystem is essential to optimize the business effects for future deployment and operation. CCAM solutions are complex and will need to be supported by multiple partners in the system (e.g., OEM, road authorities and MNO’s). This interworking should be supported by stable business cases for all players.

To be able to understand further the business requirements and implications, it is necessary to break down the cost of each player into subcategories as described in the subsections below.

3.5.1 Telco and ICT Equipment Manufacturers

#	Cost Category	Description	Stakeholders
1	Development of specific features for autonomous driving	In car embedded equipment (such as modem) and network equipment may require dedicated features supporting autonomous driving such as security and reliability.	Equipment manufacturers, MNOs, OEMs
2	Parts embedded in the vehicle may have extra costs due to specific needs of the industrial sector.	In car embedded equipment (such as modem) could have to follow strict hardware requirements (redundancy, security, reliability, size, powering,). Costs will be linked to research, design, production, testing, industrialization, sales and support.	Equipment manufacturers, MNOs, OEMs
3	Integration costs	Integration costs linked to validation with car manufacturers and Mobile Network Operators.	Equipment manufacturers, MNOs, OEMs
4	Homologation/Certification costs	Homologation/Certification costs related to network equipment/car embedded equipment parts dedicated to automotive driving/health/security	Equipment manufacturers, MNOs, OEMs

3.5.2 Automotive

#	Cost Category	Description	Stakeholders
1	Chipset cost	This is the cost of the chipset compatible with 5G to be equipped in the Automobile Transmission Board (ATB) of the car	All OEMs
2	Technology license	This is the license cost normally included in the ATB by the Tier1 but there is controversy about a price based on a %	Tier1 and OEMs
3	Antennas integration for new bands	5G comes with new bands and technologies (Uu and PC5) each of them with one or more different antennas. The cost and more important the design impacts have to be taken into account	All OEMs

4	Innovation costs	Before entering into the development, an innovation phase has to be launched demonstrating a Technology Readiness Level 6 (technology demonstration) to be engaged	Tier1, OEMs, Researchers
5	OEM development costs	This takes into account all costs needed during the development phase: specification preparation, provider choice, convergence, module validation and car integration	Tier1, OEMs
6	Security & Data integrity	Platform development cost to handle additional data with stringent security requirements.	OEMs
7	Tier1 development costs	Similar costs are applied in the Tier1 side to provide an ATB with the 5G module ready. This shall be exploited between software and hardware costs	Tier1
8	OEM validation costs	A very important phase in the development with strong requirements in the case of any function linked to safety. This includes validation on all the phases and also on a end2end perspective. Starting from the module, then in the car with track tests and final on-road tests	OEMs, Tier 1, Road Operators
9	Homologation costs	The homologation costs could be split between the telecom homologation costs and the functional homologation costs. In the second category falls anything related to regulation, in the case of any use case that for instance shall be included in the EuroNCAP.	OEMs
10	Industrial tools	The new module will be integrated in the factory and tools must be developed and deployed in the factories to validate the proper function of the module before been given to the customer	OEMs
11	Production Costs	With new telematics control units modules come additional production costs and additionally supply logistics including faulty unit management and skills training for production staff.	OEMs

12	Aftersales costs	This includes all the costs needed to train the dealers and the repair shops, as well as the warranty costs. Specific tools shall be developed for diagnosis, calibration, etc.	OEMs
13	Telecommunication costs	There are costs linked to the communications exchanged between the car and the cloud. Different types of communications shall be identified: vehicle-OEM cloud, vehicle-Tier1 cloud, vehicle-3rd party cloud and they should be billed differently. Additionally, architecture design changes and additional costs for capacity management and monitoring.	OEMs, Tier 1s
14	IT costs	IT infrastructure costs, including upgrade of platform capacities and data management	OEMs
15	System security	Periodic security system audits to meet security requirements and ensure integrity of the data systems	OEMs
16	Operational Costs	More advanced monitoring, troubleshooting and diagnostics tools required to ensure performance SLAs are met.	OEMs, Tier 1s

3.5.3 Infrastructure

#	Cost Category	Description	Stakeholders
1	Cloud Computing resources	The cost of the infrastructure to host the required databases, brokerage systems and analytics regarding the operation of CCAM services	Software Providers
2	Roadside infrastructure	Cost of deployment and maintenance of roadside infrastructure to allow direct V2I communications	Road Operators
3	Ground infrastructure deployed to host the 5G infrastructure	Infrastructures controlled by road operators to provide the support or access to the V2x supporting infrastructure. Fibre, electricity, etc. may depend on the agreement between road operators and MNOs	Road operators, telco operators, other service providers
4	Paying for MEC infrastructure or third-party	Costs due to the use of MEC services to deploy and feed the traffic management systems of the road operators. Paying for third party information	Road Operators

	service providing CCAM information	(map providers, other traffic analytics based on cellular network information, etc…)	
5	Cost of the data traffic to provide CCAM services	This can be a cost per vehicle, can be a cost for the CCAM service providers or even for the road operator. Depends on the model preferred.	End user, Road operator, MEC application provider…
6	Cost of Sharing	Cost of infrastructure and data sharing derived from cross border multiple road operators management	Road Operators

3.5.4 Telco Operators

#	Cost Category	Description	Stakeholders
1	Spectrum ownership	The cost corresponding to spectrum licensing. It consists mainly of a fixed cost for a given spectral amount for a given period (several years, for instance 15 years). The computation of spectrum usage cost for Automotive could be complex. Licensing could be local in some cases, or national for a whole country in most cases. It could be imagined that dedicated spectrum for automotive services is allocated to guarantee QoS. Other possibilities would be to mix Automotive with Mass Market traffic using QoS mechanisms triggered in case of congestion. Ultimately, the most efficient mechanism will come with 5G Standalone, where slicing and QoS within slices will allow for flexible and dynamic allocation of network resources to any service category, from CAM to infotainment, telemetry, passenger communication etc.	MNOs
2	Spectrum sharing usage	This cost corresponds to renting of a given amount of spectrum from another MNO who is the owner of this spectrum. This could be in addition to renting of shared base station	MNOs

		capacity of another MNO who own and operates the RAN infrastructure, while supporting/operating the spectrum of the first MNO	
3	Roaming	This cost corresponds to the complete support of homed UEs by a visited network. This cost could be zero or reduced in the case of faire reciprocity usage (symmetrical MNO), or when several MNOs collaborated in a transparent way to ensure real time service continuity. Roaming transparent continuity could also lead to Billing System modifications to handle seamless handover charging between different country MNOs (end-user charging or inter-connect).	MNOs
4	5G equipment's purchase	Hardware Cost: This cost is traditionally integrated in CAPEX. It includes 5G systems (antenna, RRU, BBU, IT servers to support 5G core). When using virtualization, 5G core function could run on shared servers. This sharing could be set in several ways: sharing with other services (mass market) or relaying on slicing technology. This will reduce the usage cost of servers for automotive services. Some servers could be dedicated for automotive ensuring QoS, resiliency, robustness.	MNOs
5	5G equipment licensing	Software License Cost: Cost during usage process of infrastructure could depend on variable parameters such as spectrum used on antennas, number of connected users, … It depends on the cost model of the provider. In the case of heavy loads, operators could also pay for the extra cost.	MNOs
6	Physical site renting	Site rental: This cost corresponds to the renting of locations used to install antennas systems on tower, masts, or possible other	MNOs

		sites such as Roadside Units (depending of the size of antennas)	
7	Cloud computing/Edge computing	This cost corresponds to the IT infrastructure supporting the automotive software. This could be centralised (regular datacentre) or decentralized (MEC). For the sake of automotive service continuity specific connectivity should be provided from third part access MNO towards nominal IT infrastructure	MNOs
8	Operation costs	These costs embed management of global infrastructure (supervision, maintenance), deployment… (strong SLAs possibly required)	MNOs
9	Professional Services	These are costs paid to third party (or internally) to perform civil works, HW installation, sites integration, …	MNOs
10	Running business operational costs	These costs embed business operation supports such as partners charging, invoicing, collection or back-office support or global administrative tasks.	MNOs
11	Backhauling/Backbone usage (VPN, …)	Infrastructure (Fibre, active equipment's), and connectivity towards service elements such as ToD control centre	MNOs
12	Redundancy costs/high availability cost	High availability will require redundancy of systems (to which extend is yet to be defined) To ensure higher grades of service availability. This may require replication/more equipment to reduce failure risk. Maybe bound to autonomous driving levels. Depends as well to the service it is required.	MNOs
13	Integration costs to other country operators. Considering as well MEC applications and APIs	Cost between different MNOs, due to interconnecting Roaming/MEC/Edge computing infrastructures/networks.	MNOs

	that may be different -> MEC roaming agreements.		
14	Training/ commercialization efforts	Related to standard commercial costs, it is an incremental cost but not very significant.	MNOs
15	Cost of Data Exchange	Cost of setting up and maintaining a platform that allows cross border MNOs sharing network data and planning the network accordingly	MNOs

3.5.5 Software, Service Providers & CCAM Service Operation

#	Cost Category	Description	Stakeholders
1	ToD service operation	To offer the service of remote operation from the operator perspective, a novel setup of control room, i.e., VCoC needs to be developed with hardware and software for which safety eventually needs to be certified. This will become a new business for which the specific costs and requirements are partly uncertain. For instance, it is assumed that a training for remote operators will need to be established.	SMEs, Road Operators, OEMs
2	Support service for ACCA, ToD, etc.	Safety Related Traffic Information (SRTI) service provider (for ToD on/off decisions) SRTI includes subservice providers based on Data Task Force report (10/2020)	Road Operator
3	Evolution leap of the CCAM market today	The market needs to evolve further. For each of the 5GCroCo applications the market value chain needs to be defined. This requires a large investment in terms of marketing, product positioning, sales investment and influence on regulators	SMEs, Road operators, governments, regulations, MNOs
4	Development cost of the CCAM software	The software needs to be developed and accommodated to the edge/cloud infrastructure. The information flow and use cases need to be defined so as to match the different customers (road operators, telco operators, OEM)	SMEs, Road operators, MNOs

5	Certification cost	Dealing with critical operation applications which may need to be certified and validated by a third party. The process may be long and costly.	SMEs, Road operators, MNOs
6	Heterogeneous infrastructures	Each road operator and each MNO may have different infrastructures and APIs. The integration of application services such as ACCA into TMS/SCADA systems may require certain levels of customization and/or ad-hoc solutions. This makes it difficult to develop general cost-efficient solutions	SMEs, Road operators, MNOs
7	Operational costs and customer support	Critical applications require 24/7 assistance. Assuming DevOps models for software generation this will lead to CCAM operational costs.	SMEs, Road operators, MNOs
8	Licensing fees	Some of the software may integrate different elements subject to licensing requirements	SMEs, Road operators, MNOs
9	Data protection and privacy	The CCAM systems rely on critical information which needs to be safely preserved. This may add significant costs to ensure its security, privacy and protection	OEMs, Road operators, MNOs

3.6 Cost Analysis Discussion in the 5CroCo Specific Cross Border Use Cases

CCAM use cases (including 5GCroCo examples) are quite complex already under the condition of national market regulations which will only increase in cross-border constellations. Starting with technical challenges in the areas of service handover between different providers, the national regulation could be different in the given markets which will affect the profitability and complexity for CCAM solutions in multinational deployments (as already described in Section 3.3 and 3.4).

Cross border specific costs may derive from the effort in coordination among MNOs in order to align network configurations and services setups, to ensure seamless service continuity.

3.6.1 Tele-operated Driving (ToD)

There are many big cost drivers for HAD and in general with ToD. These costs come from, amongst others, the procurement of chipsets, OEM development and validation costs, industrialization of tools and equipment needed in the vehicles as well as on the tele-operation centres. In order to deploy the ToD solution in a specific country there will be adaptations in the car, the need for 5G network coverage on roads with ToD permission and VCoC backend service, etc. The cross-border solution will lead to additional costs driven by the need of interworking between different components or partners having their position in other markets and countries. These include MNOs, road operators, ToD centres, insurance companies, etc.

This interworking has to be designed on stable standards with clear and efficient interfaces (API`s). To go from a dedicated solution in a restricted technical and economic area, to an approach with complex international constellations (multi-MNO / OEM / Road Infrastructure Provider / ToD service) will increase the cost for the system solution estimated to be double. A clear example of this may be cost increases due to the impact where border regions not currently covered with standard 5G solutions, will force the MNOs to invest massively in infrastructure upgrades. This is of course neither limited to ToD, nor can the efforts and costs associated exclusively be attributed to ToD.

3.6.2 High Definition (HD) Map Generation and Distribution for Autonomous Driving (HD Mapping)

For HD Mapping, there will be new cost drivers in addition to the obvious being increased data transmission costs. Data download has traditionally been paid for by the end customer through the OEM either included with vehicle cost, or by way of pay-as-you-go or subscription payment model. In HD Mapping and cross border applications there will be the additional sensor and infrastructure costs, data hosting along with substantially increased complexity required for interworking between bordering network operators. The later the required HD map content is downloaded, the more precisely is known the specific content needed so preventing the download of unnecessary map tiles, should the vehicle or driver decide to change route[2]. QoS prediction can assure map downloads are not initiated too late due to network congestion delaying the download of map data before reaching the corresponding tile. Such systems come at additional cost and depend on the actual realization of the prediction.

The implementation of a cross border solution alone will be a significant cost driver where HD Mapping data is transmitted and made available through MEC hosted applications, seamlessly supporting vehicles located in different networks. The interworking between Road Traffic Operators, OEMs, and HD map content providers will likely support standardized solutions, and this along with the inter-operational support between multiple MNOs will drive increased costs and additional investment to ensure seamless operation and service

3.6.3 Anticipated Collaborative Collision Avoidance (ACCA)

The ACCA service may become one of the first 5G use cases to materialize, also in the cross-border area. Yet the creation of the entire value and service chain and how this is operated in the cross border is still uncertain. The costs to deploy the 5G infrastructure in the cross-border areas are very large. Also, road operators or ACCA service providers need to invest in the development

[2] HD maps can also support assisted driving systems and often the navigation system (destination and route) is not used while these systems are active. The HD map client can therefore only estimate the route the vehicle takes.

of the market, assuming all vehicles come with the C-V2X modem and that users are willing to pay for that service. One option is that OEM and car manufacturers include the service as a cost element of the vehicle or obtain a recurrent payment complementing the leasing/renting model. In the cross-border area, ACCA service providers will need to coordinate in case their services are subject to national borders or bind to specific roads/highways. Coordination and compatibility may introduce operational and service costs. Other aspects related to data privacy and information security of the users of the service may be taken into consideration and do not neglect the costs to protect this critical service.

3.7 Planning Deployment Methodology

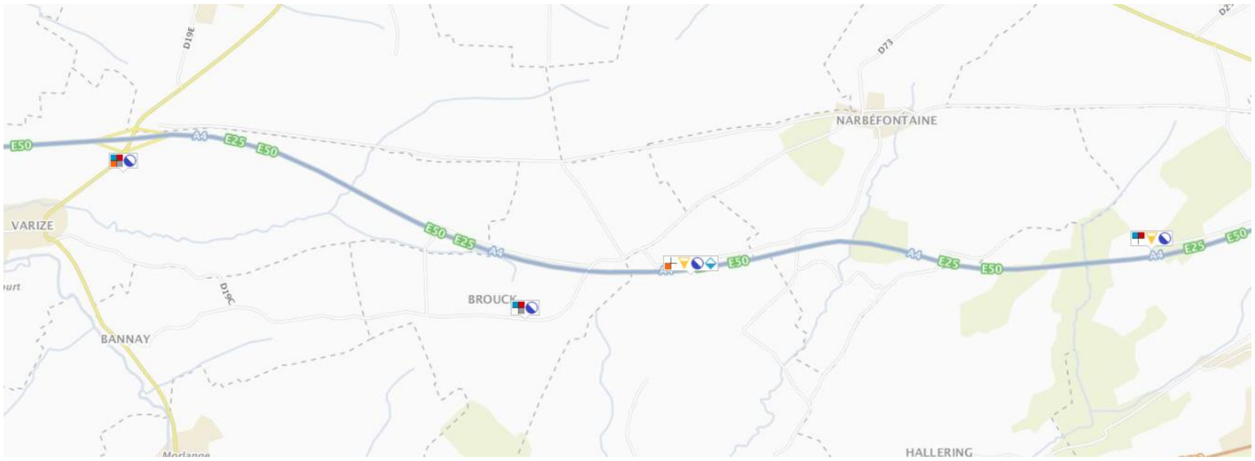

Figure 3-4: Corridor track from Forbach to Metz[3]. All sites are shared between 2 or more MNOs, only one site is used by a single MNO.

The infrastructure for CCAM may be deployed by several MNO inside each country. Indeed, these MNOs are competitors on the general public broadband market. How these different MNOs will be involved on the deployment on the infrastructure for CCAM is an open question. Several options are possible depending on the way the infrastructure deployment will be initiated. This could be done by pure commercial perspective, or following a call issued from an institutional stakeholder (Europe, State), or finally by regulation obliging to develop new road security features enabled by 5G.

In all cases, network sharing between MNOs could be considered for some reasons: in order to reduce cost for deployment or/and in order to ensure resiliency and particularly resilience against failure or outage of one MNO network. This goal could be achieved in a highly cost-efficient way by network sharing.

For that purpose, commercial agreements should exist between NMOs allowing network sharing between them.

[3] Cartoradio, https://www.cartoradio.fr/index.html#/ , ANFR : French National frequencies agencies

In that perspective, sharing towers is seen as a first step in order to establish concrete passive network sharing between MNOs.

To be conservative, and because we don't know today what will be the real deployment conditions, in the study we have performed inside 5GCroCo, we take into account only passive infrastructure shared between MNOs (mast, fiber, etc.). This way of sharing is already developed in many countries in Europe such as France, for instance.

Furthermore, we take the assumption that national roaming, as well as cross border roaming will be possible. This roaming will be particular because it is performed at real time in coherence with URLLC and CCAM services. This should allow to reduce cost of infrastructure deployment (densification effort will be shared between MNOs) and will allow to provide in a natural way resilience against failure of one MNO network. In that perspective, active network sharing should not be systematically an option in order to keep several networks in parallel: several antennas, at least 2 of the same band over the same mast, for instance.

We have to quote that CCAM deployment will rely on EMBB as well as URLCC, and that URLCC brings completely new perspectives with potentially new regulatory rules which will depend on the type of the B2B market.

Two options exist for 5G deployment for CCAM: using low/middle band with or without refarming or using 3.5 GHz band. Standalone (SA) deployment should be preferred in order to provide advanced features (slicing, URLLC).

Considering France, and especially corridors involved in 5GCroCo Project, three corridor components have been taken into account for a preliminary/internally deployment study. The assumption has been made that several types of antennas (bands) will be used for CCAM services. All existing sites will be used for CCAM. In every existing site the assumption has been that 3.5 GHz antennas as well as 700 GHz sites (or low and medium bands with refarming) will be installed. These existing sites could be sites operated by the historical MNO (Orange) or operated by competitive MNOs. In the majority of the cases, even today, it exists passive network sharing between MNOs in France and especially for the 5GCroCo corridors where approximatively 66% of sites are shared sites. For this reason, it is consistent in our deployment study to make the assumption that all existing sites will contribute to CCAM infrastructure along corridors. As a consequence, all sites of the different MNOs are merged for the study.

For a first phase, we have defined a scenario called low band coverage scenario. In that scenario, deployment relies only on existing sites (4G sites) as described before. 3.5 GHz antennas will be deployed in every site as it could be planned for 5G mass market. In that scenario 5G coverage layer will be provided by low band. 3.5 GHz band will provide additional throughput but with no continuity along the road. How this component will be used in an efficient manner is an open question. In the case of this low band 5G coverage scenario, the use of 4G sites should be sufficient to ensure basic connectivity along the road. Indeed, the maximum inter site distance off existing 4G sites is approximatively 6-7 km in a rural environment (see Figure 3-4) ensuring relatively good coverage, approximatively 15 Mbps downlink (D)L, 10 Mbps uplink (UL) at the cell edge with low traffic load. The corresponding simulations have been performed on the basis of omni antennas installed on the roof of a car in order to improve radio link budgets.

For a second phase, we have defined a scenario called 3.5 GHz high coverage scenario. In that scenario, new sites are deployment only for 3.5 GHz in order to achieve full 3.5 GHz coverage with acceptable uplink UL / DL throughput at the cell edge. 1 site per 3 km should be sufficient in that scenario (to be confirmed by real measurements in situ). Then, throughput for UL in the 3.5 GHz high coverage scenario should be 8 Mbps at the edge. That should be enough for ToD service with degraded/adapted features (reducing speed of vehicles, reducing quality of video, compression of complementary sensor information, etc.)

For a third phase, we have defined a scenario called 3.5 GHz high throughput for which we have taken the same assumption than in the 5GCroCo WP6 Deliverable [6], 1 site per km. Some radio budget simulation shows that throughput for UL with high throughput 3.5 scenario should be between 70-90 Mbps at the edge of the cells if the cells are not loaded.

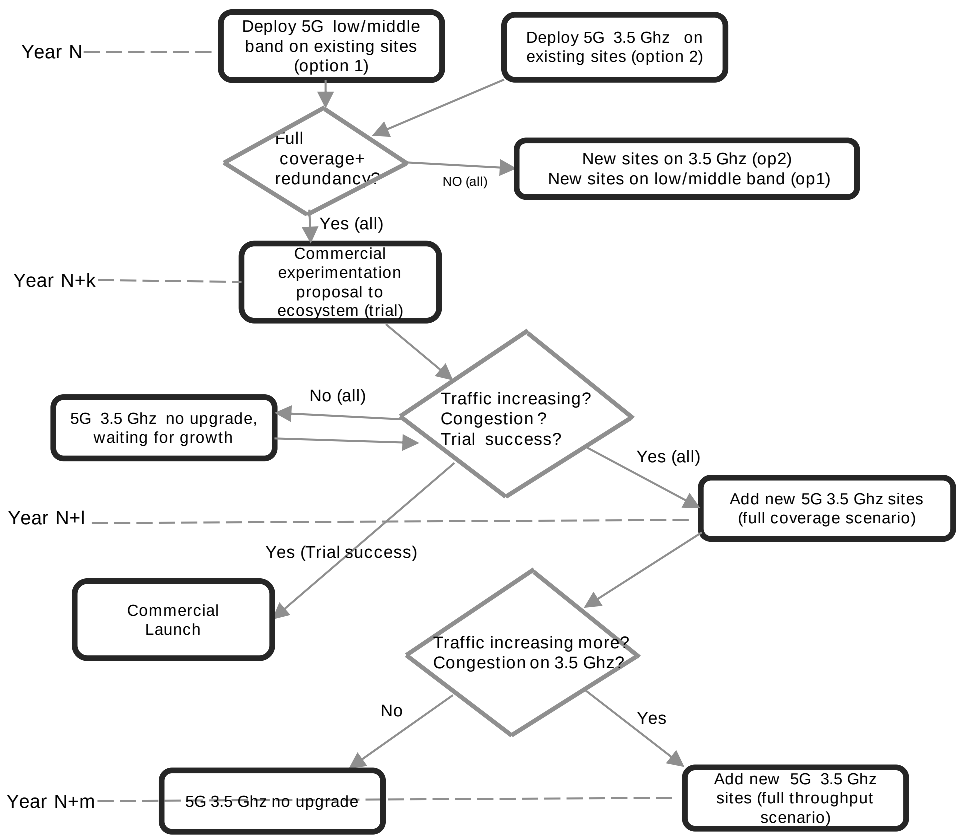

Figure 3-5: Example of Planning Process

Figure 3-5 gives an example of possible planning process for 5G deployment for CCAM along corridors. We make the assumption that the deployment will begin on the basis of the existing 5G infrastructure at year N.

Year N will be the beginning of 5G deployment for CCAM in order to achieve low band coverage scenario in order to fulfil the strong requirement to obtain full coverage along corridors, and mechanism ensuring redundancy and resiliency. The effort will depend on the existing 5G deployment for mass market for entertainment services, infotainments services, etc… in B2B2C, or in B2C mode. For the French corridor section, a study performed in the scope of 5GCroCo shows that a few supplementary sites should be required comparing to today's deployment for 4G with the assumption of an equivalent of national roaming ensuring resilience.

When full coverage and redundancy is obtained (low band coverage scenario), trials could begin. For that purpose, the assumption was made that an European cross-border consortium involved in the different corridors will propose to external partners to launch trials, or pre-commercial launch on the basis of the low band coverage scenario. As there is a risk that this phase will not be a success, the effort for first deployment in terms of deployment should be limited. If the trials are a success at year N+L, traffic will probably increase, densification at 3.5 GHz for instance (depending on the type of service involved) will be required. This will lead to the 3.5 GHz high coverage scenario, which could be achieved after or before official commercial launch of some CCAM services of the previous trials. After that, as explained before, deployment could rely on low/middle band ensuring full coverage more easily.

The internal study shows that an increase of approximatively 36% of sites will be needed to achieve the 3.5 GHz high coverage scenario compared to low band coverage scenario. Investments will be important, and even more important if full redundancy for resilience purpose will be mandatory (at least several 3.5 GHz system in every site, or/and supplementary sites). The increase of new sites when considering sharing is similar (42%) because the existing sites are already shared.

At the end of the day, at year N+M 3.5 GHz high throughput scenario will be realized by increasing more 3.5 GHz sites densification until 1 site per kilometre in order to support important ToD deployment, and/or cooperative/perception with high-definition video.

The internal study shows that an increase of 200% of sites is needed compared to low band coverage scenario. Investments will be important, and even more important if full redundancy for resilience purpose will be mandatory (at least several 3.5 GHz systems in every site, or/and supplementary sites).

3.8 Total Cost Summary

The CCAM ecosystem can be developed in different ways. This summary presents an indication of the total cost per aggregated building block for the infrastructure enabling CCAM and for the CCAM-specific services. While there are multiple options and almost infinite combinations of how such ecosystems could materialize in the European market(s), there are likely still variations from country to country despite a Common Single European Market. 5GCroCo will not discuss the various deployment and operating models possible, such as e.g., a multitude of network sharing models from passive to active infrastructure sharing, CCAM services and service platforms per vehicle OEM or shared between vehicle OEMs, independent 3rd party CCAM service providers or road operators etc. Instead, a principal indication of costs not reflecting network sharing with its numerous possible combinations is considered.

The identified main cost components by domain (from section 3.5) include: Telco Equipment Manufacturers, Automotive, Infrastructure, Telco and Software/service providers. An approach per use-case has been developed (ToD, HD Mapping, ACCA), consisting in identifying on one hand the specific cost components devoted to each use-case and on the other, the global/ nonspecific cost components which are expected to be present in every use-case, and then which could be mutualized.

Common infrastructure cost baseline:

1) Spectrum

   In an evolved CCAM service ecosystem, up to 50% of the available and deployed spectrum could be required for CCAM, while the other 50% will be used for passenger infotainment, personal communication services and legacy M2M and IoT services.

   During the initial period of a 5G network infrastructure deployment between 2020 and 2025, only a small, but growing fraction of the deployed spectrum will be utilised for CCAM, given the announced introduction of first 5G-enabled vehicles towards the end of 2021 in Europe, followed by a growing number of vehicle models being introduced in the years ahead.

   The initial network rollout of 5G will be primarily driven on legacy spectrum (800-2600 MHz) on the basis of refarmed spectrum, augmented by designated low band “5G” spectrum, i.e., 700 MHz. The assignment of the 700 MHz bands is ongoing across Europe, with strongly varying prices in the auction/allocation procedures carried out per country (as applicable to most spectrum bands for cellular mobile networks). Without refarming of legacy spectrum, any basic, coverage-driven 5G deployment (regardless of 5G NSA or SA) will fall short of capacity compared to e.g., 4G deployments in the same legacy bands.

   For simplicity reasons, the spectrum costs for 5G for CCAM in sub-3 GHz bands will not be considered here, as their usage specifically for CCAM is negligible in comparison to eMBB type usage.

   Considering a cost factor of spectrum for 5G for CCAM, 5GCroCo assumes that only the 3.x GHz spectrum assignment should be considered regarding proportionate costs attributable to CAM services. A large-scale rollout of 3.x GHz RAN infrastructure along major transportation corridors can be envisaged for around 2025, which is 5 years after the first assignments of “5G” spectrum in Europe and given the typical spectrum assignment period of 15 years across Europe, only two thirds of the total 3.x GHz spectrum costs can be considered accordingly. Again, the assignment of the 3.x GHz bands is ongoing across Europe, with strongly varying prices in the auction/allocation procedures carried out per country so far.

For simplicity reasons, we assume that any square kilometre of a country contains an average of 2 km of roads (based on geodata and transportation infrastructure data for France and Germany, for Luxembourg the ratio is 1:1.2, while it might be different again for other European countries)

The spectrum assignments per MNO are in the range of around 100 MHz TDD in the 3.x GHz band, with an average price of x € per 100 MHz

Example Germany:

The cost of 5G spectrum in 3.x GHz was 1,500 million € per 100 MHz nationwide, with only the last 2/3 of the assignment period being relevant for CAM (1,000 million €), of which 50% of the spectrum available being attributable to CAM (500 million €), so for a road network with a total length of 620,000 km (all road types) the 10 year TCO spectrum cost for CAM is approx. 80,000 € per 100 km and thus negligible compared to the 5G network deployment costs below.

2) RAN

The rollout of 5G in sub 3 GHz legacy bands including the 700 MHz band is primarily being done by upgrades of existing sites (base station sites supporting 800-2600 MHz), often in combination with periodic network modernisation. 80% of the sites should be upgradable at a minimum effort, while 20% of the sites will require some civil work primarily related to antenna carrier / pole upgrades

The average upgrade costs are calculated with 60,000€ per site, of which less than 10% could be attributed to CAM, i.e., 6,000 €

The rollout of 5G in 3.x GHz sites along the road network will require a dense deployment in the range of approx. 1 km inter-sited distance (ISD), so approximately 80% of the required sites will need to be created from scratch, while only 20% will be deployable with upgrades on existing sites with extra antenna costs for massive MIMO. This upgrade is estimated to come at 70,000 € per site, with 50% attributable to CAM, i.e., 35,000 €

The deployment of a new site including backhaul is calculated with 150,000 € per site, of which 50% could be attributed to CAM, i.e., 75,000 €

With 80% new sites and 20% upgrade sites, a stretch of 100 km of road with an ISD of 1 km will require 80 new sites and an upgrade of 20 existing sites, hence 80 x 150,000 € + 20 x 70,000 €, in total 12 million € + 1.4 million € = 13.4 million €, of which 50% are attributable to CAM, i.e., 6.7 million € per 100 km.

To include recurring OPEX for a TCO view, approximately the equivalent of the CAPEX over a period of typically 8 years needs to be added, so the RAN TCO attributable to CCAM is 13.4 million € per 100 km.

3) Core network

No extra provisions are being assumed related to CCAM, with the exception of implementation and continuous configuration of interfaces and data elements required for seamless cross-border service continuity and local breakout to MEC instances.

The cross-border service continuity element is estimated to require the setup of a system for network configuration data and integration into the OSS systems and extension of the international roaming interfaces and exchange platform IPX per MNO with a CAPEX of 500.000 € and an annual OPEX of 20% of the CAPEX, so a 5-year TCO of 1 million €, again 50% attributable to CCAM, i.e., 500,000 €.

The local breakout to MEC systems is calculated with a 5-year TCO of 100,000 € per MEC location. 50% of this will be attributable to CCAM, hence the costs are 50,000 € per MEC location.

4) Multi-access edge cloud MEC

It is assumed to have one MEC location for covering an area of 10,000 km^2 (100 km x 100 km), which, according to the calculations applied in the spectrum section above, hosts 20,000 km of roads (all road types). Given the level of criticality for some MEC-based CCAM services, redundancy and fail-safe provisions need to be applied. This results in a 5-year TCO of 200,000 € for the MEC systems per location. Each location serves a region representing the respective part of the 5GCroCo corridor in France, Germany and Luxembourg

5) Vehicle CAM infrastructure

The 5G communication module, the onboard unit for CCAM and the related sensors and actuators (assuming ADAS level 4 and beyond) required for CCAM are expected to cost as much as 5,000-10,000 € per vehicle, so an average of 7,500 € is assumed.

6) Roadside infrastructure

RSU-type ITS stations are in the range of 10,000 € CAPEX and an equivalent aggregated OPEX over 8 years, so the TCO is approximately 20,000 €; however, since RSU deployment is not likely to happen for continuous coverage of the road network, but rather foreseen for bespoke and relevant locations with recurring road incidents or co-located with variable message signs and due to the circumstance that 5GCroCo is not deploying and evaluating RSUs, an economic assessment of RSUs is being omitted. In principle, there is an opportunity to collocate RSUs with 5G base stations in the 3.x GHz, and there are synergies achievable in the area of passive infrastructure, energy supply and (fibre) backhaul, which could help reducing the TCO for RSUs by up to 50%.

Use case (category)-specific elements

1) Vehicle clients

Software development, testing and maintenance of vehicles clients

   a. Horizontal clients (V2X short range, precise positioning, predictive QoS, security)

      A lifetime TCO of 500,000 € including maintenance and updates is assumed.

   b. Use case / category-specific clients

      A life-time TCO of 250,000 € per use case including maintenance and updates is assumed, in total 750,000 € for the three 5GCroCo services; we assume that these services are representative for all CCAM services and SW code can be shared, so adding more, but similar services to the portfolio should not multiply per service, but rather only double the 750,000 €, resulting in a TCO of 1.5 million € for all "day x" CCAM services.

2) MEC and cloud-based server applications

   a. Horizontal applications (service orchestration, application management, security)

      A lifetime TCO of 1 million € including maintenance and updates is assumed.

   b. Use case / category-specific applications

      A life time TCO of 500,000 € per use case including maintenance and updates is assumed, in total 1.5 million € for the three 5GCroCo services; we assume that these services are representative for all CCAM services and SW code can be shared, so adding more, but similar services to the portfolio should not multiply per service, but rather only double the 1.5 million €, resulting in a TCO of 3 million € for all "day x" CCAM services being host in the cloud and edge cloud/MEC environment.

3) Bespoke service centres (e.g., VCoC for ToD)

   a. Infrastructure

      VCoC infrastructure consists of servers and bespoke workstations for ToD. It is assumed that an initial VCoC will consist of 10 workstations for peak hour operation and that it could be serving multiple countries or parts thereof, if considering the limitations of signal distance and routing hops for the bidirectional data transfer between the vehicle and the VCoC. The TCO for this infrastructure is in the range of 200,000 €, including provisions to support non-stop and fail-safe operations.

b. Applications

ToD software is expected to come at a TCO of 500,000 €.

c. Human operators

A 24/7 operations centre with up to 10 workstations being active simultaneously will require up to 60 qualified "remote drivers". The qualification needed and the responsibility coming along with such a profile, it is estimated to incur costs of 5€ per minute of operation (compared to 1 € TCO per minute for call centre agents), all including workspace and overhead costs. In this calculation, an average utilisation of 50% of the workstations is assumed per day, hence 10 (workstations) x 0.5 (average utilisation rate) x 365 (days) x 1,440 (minutes per day) x 5 € will result in an annual TCO of 13.14 million €.

Totals

Network and MEC

5G coverage costs are approximately 13.5 million € per 100 km based on an 8-year TCO

MEC costs including local breakout per MEC location are approximately 250,000 € based on a 5-year TCO; since one MEC location is serving 10,000 km^2 and 20,000 km of roads, the effective cost is 1,250 € per 100 km.

Vehicle

Average incremental system platform costs for CCAM are 7,500 € and assuming a lifetime milage of a vehicle to be 200,000 km, the CCAM cost per 100 km are just 3.75 €.

Services

The cost of CCAM software (vehicle clients and corresponding server applications), plus dedicated service infrastructure like VCoC for ToD, cannot be calculated on a "per 100 km" basis; however, they scale with the number of instances deployed, like number of vehicles, number of MEC/edge cloud or cloud instances. VCoC/ToD comes at a rather high cost compared to the other CCAM services and service categories. These costs need to be set in relation with the costs of recovering a stuck level 4 and putting it back on course as it would be done in the classic case of a broken-down vehicle, requiring on-site mobile repair or towing services. In addition, it is expected that parallel to a growing number of AD vehicles, which could require a capacity and hence cost increase of VCoCs for ToD without further improvements to the AD capabilities, the need for human intervention with ToD will gradually be reduced (a KPI could be the number of ToD interventions per 10,000 km of AD driving) through continuous system/software improvements.

4 Benefit Value Potentials

Up to this chapter, this report has focused on the cost vision needed for the three use cases of 5GCroCo project, with the needed assumptions explained. Now it is time to see what the fruits of the costs and investments shall be evoked formerly. 5G is the common technological enabler used for the deployment of advance connected automotive use cases and the infrastructure deployment efforts needed have been explained. Now, the exercise is to answer the question "what for?". Three different axes are explored to show how 5G and more precisely the three use cases of the project (namely ToD, HD Mapping and ACCA) can provide value to the society and the different stakeholders of the CCAM ecosystem. These three main axes are: the connected vehicle market, a safe mobility and the clean mobility.

- **Connected vehicle market**. Systematically 5G deployment for the automotive vertical is linked to autonomous driving use cases due to the demanding requirements but once the network will be deployed and has a good service level in the different roads, there are other use cases which shall provide business opportunities.
- **Safe mobility**. the EU has defined a long-term goal of moving close to zero fatalities and serious injuries by 2050, the 5GCroCo use cases can definitely be part of the solution to speed up the current fatality figure to converge with the ambitious objective of 2050 and the interim target of a 50% reduction during the current decade.
- **Clean mobility**. different initiatives have been defined to reduce the CO2 emissions linked to the transport. The "Clean Air For Europe" [7] regulation has already started in 2020. There are different activities ongoing to show how connectivity can contribute to a cleaner mobility and the 5GCroCo use cases may be also provide some benefits on this direction.

At the time this report is written, the latest year with road safety information to be taken into account is 2019. In early 2021 the information of 2020 is still not available and due to the strong COVID-19 mobility restrictions applied in the EU states during different months the figures will not be representative. Once this crisis will be over there is a lot of uncertainty about what will happen in the future. The arrival of the remote work will stay beyond the sanitary restrictions and mobility as before shall never be the same. All assumptions will be based on what may be considered the "old reality".

As mentioned in previous paragraphs there are three use cases of the project which can provide benefits for the society. To evaluate if a project is worth more investment, one approach is to take a look at the costs and benefits. A detailed list of all cost drivers is available in chapter 3.5. The major cost driver will be the 5G network coverage costs. They are approximately 13.5 million € per 100 km, based on a 8-year TCO. The network costs based on one year are about 1.69 million € per 100 km. MEC costs, vehicle, and service costs aren´t included in the analysis, because on a one-year basis their influence is negligible.

Measuring the benefits of a project is much more complicated. In order to estimate them as a number let´s try to convert them into a monetary unit. Next to the economic growth of the connected vehicle market – discussed in 4.2 –, 5G can provide a fundamental benefit in the sector "safe mobility". Based on the figures published for 2019, European roads caused external costs beyond 280,000 million € per year. The number shows the external costs for roads in Europe in general. In the cross-border context using this amount is too high. For a more realistic calculation an assumption of 10% external costs in border regions is much more likely. Use cases of 5GCroCo can help to reduce the number of accidents, according to different studies, by 24% up to 70%. Applying these potentials on the external costs of 28,000 million € per year – the assumed 10% fraction –, provides an estimation of the reduction benefits. The result is a range of 6.72 up to 19,600 million € per year, which can be saved due to less road accidents. It´s possible to assume that the number of benefits will increase over time because of better technology standards.

Another use case of CCAM in general is the potential in the sector of "clean mobility". As mentioned in chapter 4.4 transport is responsible for 21 % of the EU´s total emissions of CO2 in 2017. The total amount of CO2 emissions in this year were about 3.72 million metric tons. With the number of 2017 as a reference, about 0.781 million metric tons of CO2 emissions are due to transport. Until 2025 one metric ton costs 25 €. The calculation gives an expression for the total amount of transport emission in €– 19,525 million € per year. Considered 2025 as the first year of the application of the benefits CCAM can give to the society it would be better to use the price of a metric ton of the year 2025, which will be 55 €. This results in a new expression of transport emissions in € – about 43 million € per year. As Figure 4-2 shows, a fraction of 73.4 % of total emissions are due to road transport. This leads to a total amount of about 32.4 million €. This number shows the damage of road transport. In order to estimate the benefits for the society let´s see how the use cases of CCAM can reduce the emissions of CO2. The reduction of emission can be understood as a profit for the society. To give the reduction a value it was necessary to convert it into a money unit. Based on the results from [8] 6% CO2 emissions can be reduced because of a reduction of vehicle dynamics. Another 6% can be reduced due to congestion avoidance. As mentioned in further paragraphs, automated driving systems has potential to reduce GHG emissions through smoother acceleration, vehicle convoys and adaptive cruise control to coordinate driving speed. The emission reduction ranges between 3-7%. Another advantage of coordinated driving speed is to avoid vehicles to stop. This adds up to about 19% CO2 reduction in the sector of road transport, which is about 6.16 million € per year. Because of a further price increase of a metric ton CO2, a reduction will be much more valuable in the future. However, besides the emission reduction there is more benefit to the society. The estimated cost of road congestion in Europe is about 110,000 million € a year. The CCAM use cases can have a great impact in reducing the costs of road congestion. As a first assumption ToD, HD Mapping and ACCA (as examples of all major type of CCAM services) can decrease congestion about 50%, which will benefit the society for 55,000 million € per year. 5GCroCo services contribute to general CO2 and congestion reductions in the way how their use cases are involved in CCAM features.

Road emissions are also a main source of air pollution. Further paragraphs show that air pollution is also responsible for huge economic damage, for example due to higher health care costs or because of extreme weather conditions. The society will benefit in a reduction of air pollution. However, estimating those is not possible at this point, but in our society health and fighting climatic change should have a very high value. In total the estimation of the benefits will exceed 61,730-74,610 million € per year.

Because it´s not possible to turn every benefit into a concrete number, many of them are uncalculated and their value for the society subjective. The connected vehicle market and it´s growth is a first example, which can also have further impacts as a result. 5GCroCo can help to contribute to the “vision zero”. This implies a high value of human lives and health which will give a huge profit for the society as well. Other possibilities to reduce GHG emission such as fuel savings, adoption of electric vehicles or the reduced need for additional road transport infrastructure were not possible to be taken into account. Given all those advantages which couldn´t be measured so far, it´s possible to assume that the benefits will have a much higher value and have the potential to exceed the costs.

4.1 Scalability & Business Model

As there will be large volumes of road, sensor and vehicle data generated, the challenge will be for OEMs to identify a clear business case to develop revenue streams with the additional complexity in deployments in cross-border scenarios and between potentially numerous mobile operators.

Deployment of MEC will help address the technical implementation, however the benefits will be balanced by the higher costs with deploying MEC in lower parts of the mobile network. OEMs will need to balance the cost for the distribution, sharing and updating of road data across borders and network edges while retaining control of the data and meeting privacy regulations. Demands on MEC deployment will follow the applications, being scaled to match the use case in capacity and locations of deployment. Given this scalability, consideration will need to be made for the upscaling of the technical solution, with the high initial costs to be supported until traffic and corresponding revenues rise.

Increasingly OEMs view more advanced services such as HD Mapping and ACCA as attractive to the consumer market while potential revenue streams from making road, vehicle or sensor data available to other stakeholders will help in offsetting higher development, production and maintenance costs on vehicles. These revenue streams may take many forms of alliances or partnerships, but it is clear that OEMs will need to collaborate in order to realise the full business potential.

4.2 Connected Vehicle Market

The connected vehicle market has grown and is forecast to continue to grow rapidly in the coming decade. This will be driven by a number of factors including Infotainment systems, driver assistance systems, anti-theft and vehicle security devices and of course though the adoption of ADAS.

The increasingly cost-effective availability of sensors, cameras and processing platforms for mapping of road conditions and traffic situation will additionally drive this growth along with evolution of governmental regulations demanding greater protection and security for road users and vehicle occupants. This has been seen when the European Commission introduced mandatory eCall systems on all new vehicles from 2018 which has had the effect of forecasting a reduction of road fatalities such as 4 to 8% projected reduction in Finnish [9] fatalities discussed in further detail in the following chapter.

It is forecast that 5G networks with the improved bandwidth and lower latency over older cellular technologies will dominate the implementation of connected vehicles. While this is forecast to be a major driver in developed countries, the lack of cellular coverage, and specifically continuous cover on highways in outer urban areas, and lack of availability of 5G technologies is expected to restrict the rate of growth in developing countries [10].

Given these drivers, the global connected car market is expected to grow at a 26% compound growth rate over the period to 2027 increasing from USD14.34B in 2020 to USD48.77B. In Europe and North America this growth is expected to reach a 90% penetration on new vehicles by 2022 from a base in 2020 of global connected vehicles estimated to be in excess of 180 M [10].

With the growing number of connected vehicles comes the possibility to exchange more comprehensive road and traffic information. Along with the increasing adoption of 5G-V2X and with it the adoption of the higher definition sensors, this will lead to further development of automated driving levels, specifically in regard to Tele-operated Driving, High Definition Map sharing and ACCA [11] .

According to 5GAA, first pilots' deployment of C-V2X cases and in particular Tele-operated Driving and HD Mapping data is anticipated from 2026, with large scale adoption based on 5G is forecast for 2029 onwards [11].

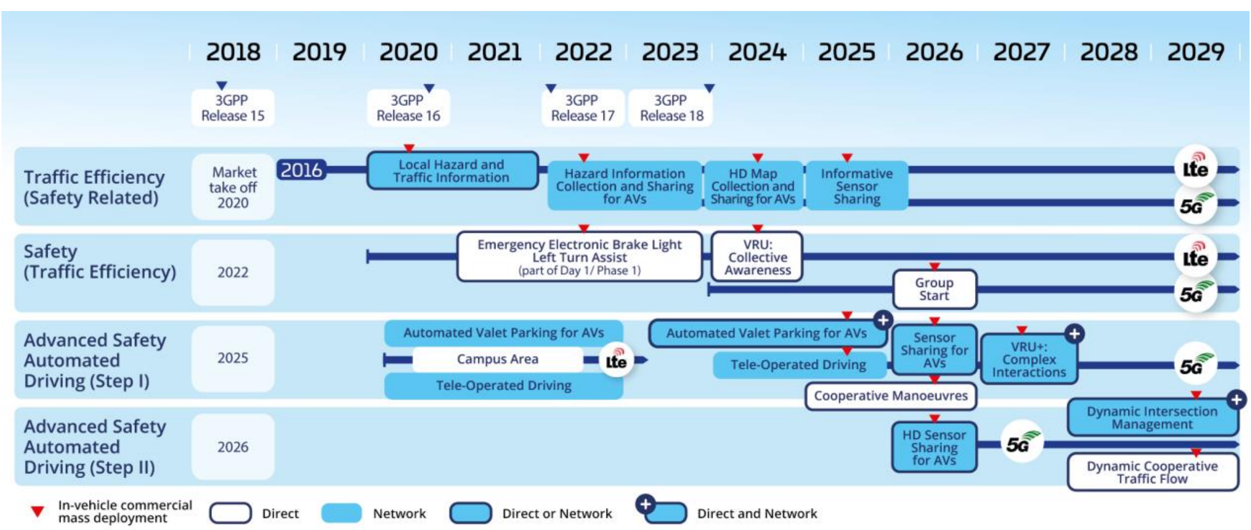

Figure 4-1: Expected Timelines for Mass Deployment of C-V2X Use Cases according to 5GAA [11]

4.3 Safe Mobility

According to the figures published for 2019, more than 20.000 people lost their lives and more than 135.000 suffered serious injuries in the European roads with an overall external cost estimation that goes beyond 280 billion euros per year. This was the safest year in history and Europe is by far the safest region in the world. However, this is not acceptable, not only by the number of lives taken, but also due to a reduction ratio which is not going fast enough. If the 2010 decade is used as a reference, a reduction of 23% has been achieved [12] [13].

To respect the "Vision zero" fatalities and serious injuries objective defined for 2050, the ambitious target for the end of the present decade is to divide by two the current values. In order to do so the EU Commission has proposed a strategy based on two main pillars: safer vehicles and safer roads [14] [15] [16]. For safer vehicles 25 life-saving technologies have been identified to be included in the vehicles. For safer roads a risk mapping definition and the provision for vulnerable road users are proposed.

Using detailed information about the figures in 2018, some important facts must be highlighted in terms of the place, the type of road users and the age of the victims. According to the type of roads, 53% took place in rural areas, 40% in urban areas and only 9% in motorways. The vulnerable road users (pedestrians, bicycles, and motorbikes) represent almost a half of the road fatalities, this ratio goes up to 70% when only urban areas are considered. Finally, more than 28% of the total amount of lives lost were more than 65 years old. Globally, more than 90% of the accidents are linked to human error, providing an impacting clue about the possibilities of the autonomous driving benefits [17] [18] [19].

Contributing crash factors

In the injuries study published by the EC in 2016 [20] a list of 20 different factors contributing to road accidents are listed. Let's see how the 5GCroCo use cases may help to avoid them or at least reduce their potential incidence.

- Road condition, reduced visibility due to road layout or glare, weather condition and wrong way driving. This group of factors can be mitigated thanks to HD Mapping and/or ACCA. The results would be better for AD vehicles, but they are completely applicable for human driven cars. These two use cases would warn the car of an environmental risk perceived thanks to connectivity with anticipation enough to react with safety to the possible threat
- Driver under influence (alcohol, drugs, medication), fatigued driver, medical impairment, distracted driver and inexperience. These factors combined with a driver monitoring mechanism may trigger a tele-operated driving control of the vehicle avoiding the potential accident. The protocols for taking the vehicle control remotely must be defined and their transitions are far from being easily defined. The first step shall be by a conscious decision of the driver by recognizing any of the risk factors evoked. These crash factors could be also mitigated indirectly by notifying to other drivers thanks to ACCA or HD Mapping use cases

As it is mentioned in [21] different studies have been done about the potential of the ITS systems combined with autonomous driving cars to increase road safety. The results vary depending on the study, from a 24% to a 70% accident reduction thanks to the CCAM features where the 5GCroCo use cases are included.

Once there is agreement on the potential benefits of ToD, HD Mapping and ACCA, there are two paramount elements which can modulate and attenuate the benefits: 5G coverage and technology penetration rate in the vehicles. Both factors will delay the positive effects in road safety. In [22] the impact of these two items is studied but for Uu and sidelink communications. For 5GCroCo, only Uu communications are involved therefore no reference to any PC5 link will be considered.

The impact of the coverage is done through a formula where the alert delivery ration is calculated based on the cellular coverage, the service availability and the reliability. All coverage values provided are based on 4G and starting in 2016 around 80% in rural areas and going up to 95% in urban areas, providing a maximum value from 2023 on. For the availability and reliability, the value proposed as objectives to be reached for ITS traffic are 95% and 99% respectively.

The authors in [22] did not take into account ongoing 5G deployments. 5G comes with three “mainstream” frequency bands: 700 MHz, 3.5 GHz and 26 GHz. The deployment of 5G on 700 MHz band in rural areas will ensure similar coverage as the existing 4G coverage. [23]. Therefore, the values proposed for 4G coverage can be assumed as reachable when deployed on the 700 MHz band.

In the case of the pure connectivity penetration rate, due to the eCall from 2018 in EU cars have to be equipped with a modem. The easiest solution in terms of vehicle adoption is the ACCA use case, where thanks to the MEC capabilities, at least the alerts shall be sent to the car. Normally connected cars have procedures to understand an alert received (using the cellular connectivity) and show it to the driver.

Having a look at the figures available from ACEA in 2018, there were 268 million passenger cars in the roads and 19,440 million were sold. This gives a rotation ratio of almost a 9% per year. It is assumed in the industry that from 2022 on, close to 100% of the new vehicles used will be connected [24].

Thanks to Drive C2X, an estimation of the effectiveness of the alert can be estimated and taken the lower value this could be around 65%.

So far, several factors have been identified to reduce the effectiveness of the 5GCroCo solutions. Let’s apply them altogether with conservatives’ values according to the previous paragraphs:

- Coverage 80%
- Availability 95%
- Reliability 99%
- Effectiveness 65%

- Penetration rate 9% from 2022

Let's consider 2025 as the first year of the application of the benefits in road accidents (this means, 36% penetration of connected vehicles). All these factors applied, imply that only the 17% of the potential accidents would be really avoided. By applying this percentage, the external cost per year in 2019 shall represent more than 49 billion €.

If the same consideration is applied for Tele-operated Driving, the potential benefits can be clearly higher going up to 70% as has been shown in previous paragraphs. However, this time, the equipped car penetration rate is really difficult to estimate. This use case should be the preferred mobility solution for elderly people, representing more than 5.600 casualties in 2019 (28% of the victims were more than 65 years old).

Clearly the three 5GCroCo use cases (ToD, HD Mapping and ACCA) are addressing safe mobility in the most challenging/operationally-complex situation, the cross border. The materialization of these applications in the cross-border areas may contribute to the homogenization of the services in the European territory, and support the achievement of the figures presented in this section within a 5–10-year framework, depending on the adoption rate of CCAM enabled vehicles and infrastructures.

4.4 Clean Mobility

CCAM services contribute towards an efficient consumption of fuel in the automotive sector, by improving driving energy profiles (due to smoothing acceleration and braking), or by selecting energy efficient itineraries in real time (for instance avoiding traffic congestions).

In 2017, road transport generated 21% of the EU's total emissions of carbon dioxide (CO2), the main greenhouse gas (GHG). Other transport mean (aerial, maritime, rail) contributed significantly less (around 29% in 2018) towards overall transport GHG emissions in the European Union. In road transport cars and light commercial vehicles (vans), are responsible for around 15% of the EU emission of CO2. Trucks and buses, on the other hand, produce near to 5% of total EU emissions, being responsible of 25% of road transport contribution [25] [26].

Greenhouse gases emission is the cause of climate change [27]. The effects include global warming and the exacerbation of weather conditions (extreme precipitations events, cold waves, heatwaves, etc.). Road transport emissions is also a main source of air pollution. Both have a negative impact on citizens health conditions and longevity. According to the European Environmental Agency (EAA), more than 500,000 people died in Europe in 2015 due to air pollution [28]. Climate change contributes to premature deaths and disease in Europe, being heatwaves the deadliest type of extreme weather (77,637 early deaths in Europe during the period 1980- 2017) [8]. Poor air quality and climate change also causes direct economic losses, for example, through higher health care costs or damages caused by extreme weather conditions like floods. Moreover, adverse weather conditions are highly correlated with traffic accidents and congestions. In 2016, 12% of road fatalities in Europe were caused due to inclement weather conditions (rain, snowfall, wind, fog, etc.) [29] [30]. CCAM services contribute to mitigate climate change induced road hazards, as it is described in Section 4.2, and consequently to alleviate traffic congestions.

After 2017 reports, the estimated time spent by EU citizens in traffic congestion varies from 39 hours per year in Belgium, to 18 hour per year in Finland [31]. The most frequent cause of road congestion in Germany are roadworks and the presence of large number of lorries in the road. The cost of road congestion in Europe is estimated to be over 110,000 million € a year (2012) [32] [33]. This economic damage is calculated taking into account the loss of working time, the waste of petrol/energy and rising prices of goods due to the increase in transport costs, and GHG emissions impact.

Automated Driving systems have prospects to reduce GHG emission by improving fuel savings on road vehicles, e.g. through smoother braking and acceleration compared to human drivers, vehicle convoys and adaptive cruise control to coordinate driving speed and minimize distance between vehicles to reduce wind resistance (Platooning) or avoidance of traffic congestions situations by route recalculation (Green Navigation, SmartR) [32] [34].

As Automated Vehicles are safer than conventionally-driven ones, it might be considered to reduce the vehicle weight while still fulfilling safety standards [35] [36]. A review of studies assessing fuel economy through AD yields fuel savings ranging between 2% and 25% and sometimes 40% [37] [32].

Moreover, driving automation can be a driver for the adoption of electric vehicles through itinerary selection or adaptation of the driving mode to battery life, and thereby enable further GHG emission reductions [37] [32].

A reduced need for building additional road transport infrastructure, thanks to the optimization of road capacity consequence of CCAM services, could have a large impact on GHG emission reduction. For instance, the capacity of a lane at 100 km/h could increase from 2,869 cars/h to 4,103 or even 10,730 cars/h thanks to CCAM services [38] [32].

Other sectors or business, as insurance or public services (traffic police, educational, medical, etc.) might also be affected in the future by the adoption of CCAM services, having an impact on GHG emissions, being early to be forecasted.

Nevertheless, there is a potential risk GHG emission raise due to an increasement of road trips. Automated Driving will help to broader the potential end users, such as elderly and unpaired people which were excluded until now from conventionally driven vehicles. It could also decrease the age allowed to have permission to use private vehicles, when automated driving is available, so also younger people can become new users. In addition, increasing throughput on existing roads, and the transformation of the travel “driving time” to time that can be used to perform other activities might reduce the competitive advantage of public transport [32] [35] [39]. However, the increased use of private vehicles might be mitigated by a more appealing public transport services that can also benefit from CCAM in order to evolve to a more flexible and efficient network (for instance bus itineraries or stops under demand)

5GCroCo use cases can be seen as a needed step towards automated mobility, but they can have an impact in the near future, specially by avoiding traffic congestions in real time for drivers recalculating their routes, and also by alleviating the creation of new traffic congestions.

ToD will help avoiding traffic congestions. A great impact is expected due to the fact, that breakdown service of HAD vehicles can be done remotely, moving the vehicle to a location, where it doesn't interfere with traffic. There will be less demand to physically drive a service car to the location of the vehicle. ToD is foreseen as mandatory functional block for HAD (depending on regulatory obligations for dedicated markets) and will improve traffic efficiency (less cars, less parking issues etc.).

HD Mapping. High definitions maps updated in real time are a necessary service in order to calculate energy efficient itineraries. The dynamic HD map update will lead to an efficient driving with functions like optimal speed adaptation, route optimization, optimal e-horizon support, dynamic parking-lot search etc. Dynamic HD map updates in combination with AI according to data evaluation will also help the route authorities to optimize traffic steering and planning.

ACCA will help reducing congestions by defining optimal manoeuvrers to overpass situations where a collision has occurred, avoiding harsh braking and risky situations. As the potential number of accidents may be reduced, the consequences derived from an accident, even a simple stationary vehicle on the roadside, will be considerably limited, favouring the traffic conditions in the roads.

Derived use cases that benefit from 5GCroCo ones, as Green Navigation or SmartR (Traffic information and Smart Routing) present an estimation reduction in $CO2$ emissions of 1.1-9.5% for the first one, 1.9% reduced emission and fuel for the second [34].

In cross border context, where 5GCroCo has the focus on, mobile network coverage is not always optimum as border areas are under challenging regulations, and not a clear cross border coordination among bordering countries. Network sharing among MNO's might be explored in cross-border regions having a positive impact in the reduction of GHG emissions thanks to avoiding duplicities.

4.5 Relevance in the Cross-Border Scenario

To enable the end consumer to fully enjoy and trust the technical services, it is vital that the solutions continue to work when the vehicle is crossing the border. Due to this aspect, many end consumers may consider it to be a rather basic requirement that any solution that is working within the home-country also continues to work while crossing the border and while remaining in another country or driving along the border.

A system faces challenges in a cross-border situation where it needs to hand over and adopt its procedures from one country to the next without causing any unwanted interruptions that affects the performance of the vehicle. Solutions preventing such interruptions is thereby providing an added value. The three main axes connected vehicle market, safe and clean mobility that were presented in Section 4.2-4.4 can all provide such cross-border benefits. In particular:

- Connected vehicle: the adoption of standardised technologies especially with regard to V2V data sharing increases the integrity of the shared data (in the case of HD Mapping data), lower latency and accuracy (for ToD and HD Mapping). Additionally, the adoption of advanced network optimisation functions in vehicle telematics units specifically those assisting with handovers will minimise services impact at border crossings.
- Safe mobility: Crossing the border brings additional complexities in terms of road signs and markings, regulations, language, which can be resolved by CCAM functionalities through a uniform and standardized services (exchanged messages…).
- Clean mobility: the continuity provision of CCAM services in cross border regions, without connectivity interruptions, will allow to maximize the impact on GHG emissions reduction. This will be materialized by a potential reduction of traffic jams and ensuring that vehicle flows are more stable and thus pollution minimized.

4.6 Potential Revenues

The value potentials are established by the technical solutions that enable benefits such as improved connected vehicles, safer and cleaner mobility. Although it can be enough for some of the vehicles to have technical solutions that work only within its home country, it should be fair to say that there will be an expectation that the vehicles continue to work also while and after crossing borders.

A revenue stream can be generated from the added benefits of the technical solutions. The shape of these revenue streams can for instance be a payments per km fee, a monthly fee or a lifetime fee (that can be included in the price for each new vehicle). The total revenues will be reflected by the advancements of the technical solutions in the form of the end consumers' willingness to pay for the provided services. As an example, the three countries France, Germany and Luxembourg where the 5GCroCo final demonstration takes place have a total population of about 150 million people – with 83.24 million in Germany, 67.39 million in France, and 0.63 million in Luxembourg (World Bank, 2020). By assuming an uptake for the considered type of technical solutions for 10%, 30% and 50% of the population with one vehicle each in the area (i.e. 15 million, 45 million, and 75 million vehicles respectively) together with a monthly fee of 1 €, 10 €, and 25 € the potential total revenue stream per month that can be generated within this region alone is presented in Table 4-1.

Table 4-1: Potential Revenue Stream per Month (based on crude assumptions) in Total, for the region of the three countries France, Germany and Luxembourg.

	10% of population with one connected vehicle (15 million vehicles)	30% of population with one connected vehicle (45 million vehicles)	50% of population with one connected vehicle (75 million vehicles)

1 € per month and vehicle	15,000,000 €	45,000,000 €	75,000,000 €
10 € per month and vehicle	150,000,000 €	450,000,000 €	750,000,000 €
25 € per month and vehicle	375,000,000 €	1,125,000,000 €	1,875,000,000 €

In a situation with advanced features like autonomous driving the end consumer is foreseen to be willing to pay more for a monthly subscription, while less advanced technical services are foreseen to generate less in revenue. No separate revenue part is presented for having cross border and non-home-country solutions as the benefit of having those are considered to be basic requirements that needs to be met by the technical solutions.

5 Summary & Conclusion

In this document, the potential business development directions for the CCAM market have been analysed. There are still numerous uncertainties related to the technology readiness, demand perspectives and regulations, including the overall roadmap of implementation of CCAM. This has been materialized in a collection of assumptions that may drive the market development in the years to come, given that uncertainty is progressively diluted.

The costs associated with deploying 5G network infrastructures including MEC along transportation corridors can be considered to be quantifiable with a robust level of confidence. The picture is less reliable for CCAM capabilities both on the vehicle and applications side, as a clear roadmap of CCAM capabilities and services remains rather vague. Still, the overall cost estimations for starting a deployment of 5G for network infrastructures are sufficiently reliable to start actual planning and prepare for 5G deployment along European road transportation corridors, ahead of the deployment of CCAM services and CCAM-enabled vehicles.

To understand the possible economic benefits of a given market it is important to have a clear map of its costs. These have been clearly addressed in the document, by providing a deep cost breakthrough of the different stakeholder processes and technologies that materialize the CCAM ecosystem. Going further, these assumptions and costs have been mapped to the 5GCroCo cross-border scenarios, as representative examples subject to the cross-border constraints.

Yet the document goes further and presents a Cost/Benefit analysis identifying key directions in which the technology will certainly have an impact. The connected vehicle market, safe mobility, and the efforts done towards clean mobility have been carefully analysed to derive estimated benefits of the full deployment of CCAM ecosystems. While CCAM has the potential to create societal benefits in the range of two-digit billion € annually, the pure revenue potential of CCAM indicate to be in the range of economically challenging up to just sufficient for overall refinancing the TCO of infrastructures and components involved in CCAM at a modest return on investment yield.

Final conclusions indicate that as the business is still immature, there are regulatory, technological and market creation and development uncertainties that need to be addressed from multiple perspectives, especially regulatory and market definitions, in the years to come.

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