

Deployment Enablers and roll-out studies

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Olga E. C. Segou, PhD
Senior RID Specialist
Netcompany-Intrasoft



5GMOBIX



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Deployment Enablers

Ensure the project maximises its impact and takes a detailed look on technical, cooperation, business, standardization and policy/regulatory recommendations



Our work at a glance

- **Provide recommendations and deployment options for the proposed technologies**
 - Challenges/Recommendations for deployment and roll-out
 - Focuses on technical issues
 - Provided a micro (project-specific) and macro (ecosystem-specific) view of challenges and recommendations
 - Provided prioritisation of recommendations based on utility, cost and ranking of the criticality of the challenges (performed through stakeholder inputs)
- **Foster the adoption of innovative business models for 5G-enabled CCAM**
 - Explain value chain created by the *project user stories
 - Provide tentative business plans
 - Provide customer exploration maps

Our work at a glance

- **Contribute to the relevant standardisation bodies and spectrum allocation bodies**
 - Monitor partner inputs to standardisation bodies
 - Explore standardisation gaps
 - Explore issues of spectrum availability and capacity
- **Provide recommendations to policy makers for the adoption of 5G-MOBIX solutions**
 - Explore regulatory and policy ecosystem
 - Explore cooperation issues among stakeholders
 - Provide challenges and recommendations across the value chain
- **Deployment study & ICT-18 Deployment Metastudy**
 - Additional activities mandated by the EC
- **Various dissemination and exploitation activities**

Overview



Initial recommendations

ID	Issue name	Recommendations
L1	Lack of unified regulation about traffic rules	<ul style="list-style-type: none"> Identification and development of legal instruments, additional to spectrum management, that are necessary to provide an appropriate legal framework that provides the legal certainty required to facilitate the investments necessary for the deployment of 5G technologies. Define requirements and potential needs for the development and function on public roads. Develop different design strategies depending on the use case. Enable the transition in the most efficient way to the new infrastructure (markings, road signs, layout, etc.)
L2	Liability of MEC applications for CCAM	<ul style="list-style-type: none"> Under discussion
L3	Responsibility of Vehicle Control	<ul style="list-style-type: none"> With a regulation, collision avoidance responsibilities can be separated between vehicle and infrastructure.
L4	Consideration of constraints related to 5G/EMF emission limits	<ul style="list-style-type: none"> See L7.
L5	Networks densification implications for regulation	<ul style="list-style-type: none"> Under discussion
L6	Lengthy engagement and procurement exercises	<ul style="list-style-type: none"> Under discussion
L7	Human exposure to radiofrequency electromagnetic fields (EMF)	<ul style="list-style-type: none"> Where new antennas are added, all regulatory requirements should be applied during the deployment phase to respond to any public concern. Important to include national authorities at the local level to assess and monitor the exposure levels. Limits are more restrictive than those in the ICNIRP recommendations.
L8	Wireless operators may not have the right to install small cell or radio apparatus onto street furniture such as lampposts	<ul style="list-style-type: none"> Policymakers that offer streamlined and efficient procedures to benefit the most from the innovation and economic growth.
L9	Net neutrality	<ul style="list-style-type: none"> Under discussion.
L10	Not optimized access to spectrum	<ul style="list-style-type: none"> Access to localised spectrum is more likely to be used in different areas, however there is a need for a more compatible with localised solutions. Relative to virtualised and distributed infrastructure after 5G.
L11	Approval by regulatory authorities Harmonized regulatory framework for CCAM application within the EU	<ul style="list-style-type: none"> A regulatory framework for 5G CCAM application harmonized at least on a European level - ideally at global level.

ID	Issue name	Recommendations
Als	V2X Continuity	<ul style="list-style-type: none"> "Fail safe" strategy for critical applications so that connectivity failures may cause accidents or safety issues. Proactive: Known events communication in handover areas. Extrapolation of trajectory of "lost" vehicles.
Als	Dynamic QoS Continuity	<ul style="list-style-type: none"> Under discussion.
Als	Data Interoperability	<ul style="list-style-type: none"> Defining a "Master ITS centre" to Conflict resolution techniques for DENM/CAM messages. Push for standardized data formats / APIs. Transition SW into single format for border areas. 3rd party reference clock. Pro-active clock drift compensation based on analytics.
Als	Stack Interoperability	<ul style="list-style-type: none"> Under discussion.
Als	Time Interoperability	<ul style="list-style-type: none"> Under discussion.
Als	Accurate Geo-Positioning	<ul style="list-style-type: none"> Under discussion.
Als	Geo-driven Discovery	<ul style="list-style-type: none"> Coordinated geo-distribution mechanisms among network components, RSI and MEC between countries. Single digital image of the cross-border environment. Enhanced positioning accuracy via differential GPS and camera/radar relative positioning. Proactive pre-allocation of resources in new spectrum.
Als	Real-time Multi-tier Processing	<ul style="list-style-type: none"> Under discussion.
Als	On-demand Processing	<ul style="list-style-type: none"> Under discussion.
Als	Service Specifications	<ul style="list-style-type: none"> Under discussion.
Als	MNO agreements for edge computing	<ul style="list-style-type: none"> Open standards and EC-level agreements to encourage the implementation of MEC solutions.
Als	State transition between MECs for stateful Applications when crossing the border	<ul style="list-style-type: none"> Harmonized application level solution needed (ideally following indications from ETSI/5G MEC).
Als	KPI measurement synchronization across different components and across neighbouring 5G networks	<ul style="list-style-type: none"> Common clock reference, such as GPS timing, might be a solution but it is not always possible as low tier/low-cost devices may not be capable for this.
Als	Dependability requirements of CCAM services	<ul style="list-style-type: none"> Fault-prevention and fault-tolerance mechanisms, for instance redundant 5G networks, are typically employed to ensure such high dependability requirements. In order to prove the correct operation of the system, fault-injection procedures may be employed to shorten the testing and verification period.
Als	Fallback in case of network outage	<ul style="list-style-type: none"> Fall-back to 4G or national roaming.
Als	Dimensioning of critical V2X communications	<ul style="list-style-type: none"> Priority mechanisms in case of congestion of the V2X slice using different classes for the most critical communication scenarios.
Als	Quicker network handover as cross-border scenarios	<ul style="list-style-type: none"> RAN configuration of neighbours between cross border cells should be defined in order to reduce interruption time during Handover procedure. Requires interconnection (S1-M interface) between the Home Operator and the Visited Operator.
Als	URLLC V2X traffic classification	<ul style="list-style-type: none"> Standardization of CCAM traffic profiles that defined which critical traffic should be mapped on URLLC slice and non-critical on eMBB or mMTC slices.
Als	Coordinated V2X Sidelink resources among operators across borders	<ul style="list-style-type: none"> To ensure the continuity of V2X services, not only the frequency bands used need to be coordinated, but also the Sidelink Resource pools are defined. This could be achieved by having one universally coordinated resource pool dedicated in both the SIB or the dedicated RRC configuration for cases of potential communication with vehicles operated by another mobile operator.

73 Recommendations:

- Legal
- Deployment
- Data Quality-Validity
- Data Property Management
- Application and interoperability
- Fixed On-Board infrastructure
- Cybersecurity recommendations

GOLD (macro) recommendations (15)

ID	Issue name	Recommendations
DPM1	Data Barriers: <ul style="list-style-type: none"> Combating GDPR fragmentation Combined use of AI, automation and responsible analytics 	<ul style="list-style-type: none"> The organizational level of CCAM/5G services. The type of interoperation. The type of data. The mode of data sharing.
DPM2	Responsible AI: <ul style="list-style-type: none"> The impact of using AI for data analysis needs to be determined Data quality needs to be assured Accountability & Transparency 	<ul style="list-style-type: none"> Recent efforts in methodology effort could be used to develop algorithms and data quality development. Accountability & Transparency also addressed.
DPM3	Open Data Sharing: <ul style="list-style-type: none"> Standardised data access, use of open data and ensuring data quality Anonymisation on-the-fly Access to a data economy/platform. Data Sharing among public and private actors. 	<ul style="list-style-type: none"> The multi-stakeholder and multi-product nature of CCAM/5G services. Data Proxies should be used to facilitate data sharing among different parties. Benefit from an "Ethical Data Economy".
DPM4	Source platforms	<ul style="list-style-type: none"> The data governance and security of the platforms, which will allow the data to be shared. Well defined framework (policy and regulation) is needed to encourage the different parties (including services users) to share their data. As data sharing has a significant impact on privacy and security, policies and rules are needed to ensure appropriate use of the shared data.

considered at each level of the value transport infrastructure including the protection of users' privacy and security.

penetration testing) by measures (e.g. effects on latency, security, etc.).

EU-level approaches, agreements and standards to ensure the continuity, availability of communication services and a minimum quality of service (QoS) for critical services.

Best security tools like firewalls and intrusion detection to ensure the network is protected against DDoS attacks so that 5G services are not interrupted with zero interruption. Risk assessment with zero interruption. Risk assessment like threat modelling, which allows to map the risk of an attacker in order to stop them.



Example: Prioritisation of x-border issues and recommendations

ID	X-border Issue Title	Considered solutions	GR-TR				ES-PT			
			U	C	F	IMPACT	U	C	F	IMPACT
XBI_1.1	NSA Roaming interruption	1) Inter-PLMN HO using extra interface between the 2 PLMN + Release with redirect	4,3	2,9	1,5	5	4,0	2,6	1,5	4
XBI_1.2		2) Single modem with application to steer connectivity	4,0	2,5	1,6	4	3,0	4,0	0,8	2
XBI_1.3		3) Multi-modem / multi-SIM implementation	3,7	2,8	1,3	4	4,0	3,2	1,3	3
XBI_2	SA Roaming interruption	1) Requirements and proposed architecture for inter-PLMN handover with SA networks	4,3	2,9	1,5	5	4,0	2,7	1,6	4
XBI_3.1	Inter-PLMN interconnection latency	1) Considering the low latency possible with a direct connection (theoretical lower limit).	4,1	2,4	1,7	5	3,0	2,2	1,6	2
XBI_3.2		2) Comparing impact when using a shared connection (not optimized for latency, e.g., Internet based), giving a worst-case scenario	2,3	2	1,1	2	2,0	1,4	1,8	2
XBI_4.1	Low coverage Areas	1) Satellite connectivity	3,6	3,2	1,1	4	4,0	3,1	1,3	4
XBI_4.2		2) Multi-modem / multi-sim	3,7	2,8	1,3	4	3,0	3,2	1,2	4

NOTE. Corridor Impact:

Score	Definition
1	Has not impact
2	Has little impact, brings awareness to a specific gap
3	Has average Impact - somewhat limits an existing gap
4	It has the potential to simplify CAM deployment
5	Has great Impact - will greatly help 5G for CAM deployment plan

Analytical tools

● Customer Exploration Map

- With the help of this tool, we will be able to see interactions among stakeholders, compare existing and new proposed solutions, what customers like and dislikes etc..

- Value chain representation & Business Model Canvas to understand the stakeholder ecosystem and business models arising from our user stories

Customer Exploration Map



<p>Who is our customer / user / stakeholder ? <small>Be specific: for a person - age, origin, job, interests for a company - size, industry, purpose</small></p>	<p>What are his likes and dislikes ? <small>Related to the general character of the person / stakeholder</small></p>
<p>Jobs to be done & challenges <small>Functional / social / emotional / supporting needs in a specific situation e.g. I need fast transport / good reputation / security / help to... Quotes, that could be typical for this person</small></p>	<p>What we don't know <small>Assumptions, black spots Why / when is something a challenge / a good experience...?</small></p>
<p>Existing solutions <small>Any kind of solution that could help to fulfill the needs</small></p>	<p>THIS WOULD BE GAME CHANGING! <small>Empathize with your customer / user / stakeholder What would be the perfect solution, situation or experience?</small></p>

Standardisation gaps and spectrum issues

Standardization Gaps	
Integration of satellite access in 5G	Ubiquitous 5G coverage can be enabled by integration of non-terrestrial communication capability.
Seamless cross-border roaming in 5G	A tight integration and exchange of information between the bordering MNOs is required.
IPv6-based 5G for Connected & Automated Mobility	Migration to IPv6 will be required with the proliferating number of connected devices. How will CAM be affected?
Dynamic Service Discovery and Placement in C-V2X Slice for CAM	A service discovery method is explored for establishment of C-V2X slices.
ETSI ITS Services	Advanced Driving use case design and performance should be investigated with 5G connectivity.
ETSI MEC	The requirements from the ETSI MEC architecture should be revisited for cross-border settings.

Policy recommendations

The recommendation section of D6.8 provides 18 selected key roles recommendations for policy makers and 19 for regulatory authorities. For the presentation purpose 3 recommendations from each section were selected.

Selected recommendations for regulatory authorities			Selected recommendations for policy makers
Vehicle certification/Type approval. Vehicles that rely on V2N and V2V communications should be subject to some level of certification for the whole vehicle, not just the modem component or the OBU.	Target area: CAM Timeline: Long term	Target area: 5G Timeline: Medium term	For CAM services, policy makers have to ensure that MNOs provide consisted coverage along relevant routes.
Coverage cannot be guaranteed 100%, thus mechanisms should be designed so that autonomous vehicles (different levels of autonomy Regulators 6g may have different requirements) are capable of safely coping with coverage loss or signal degradation.	Target area: 5G Timeline: Long term	Target area: 5G Timeline: Medium term	There is a need to increase 5G coverage in the motorways and other roads where there is no coverage. Policy makers need to play a relevant role to improve the situation. In any case, the networks deployed need also to be commercially viable.
5G is still in its early phases but LTE is mature. The recommendation is to foster the deployment of 5G networks.	Target area: 5G Timeline: Short term	Target area: CAM MNOs, Authorities 68 Timeline: Short term	Prioritization towards the most relevant use cases, including the definition of the corresponding architectures and validation methods.

5G-MOBIX Deployment Study



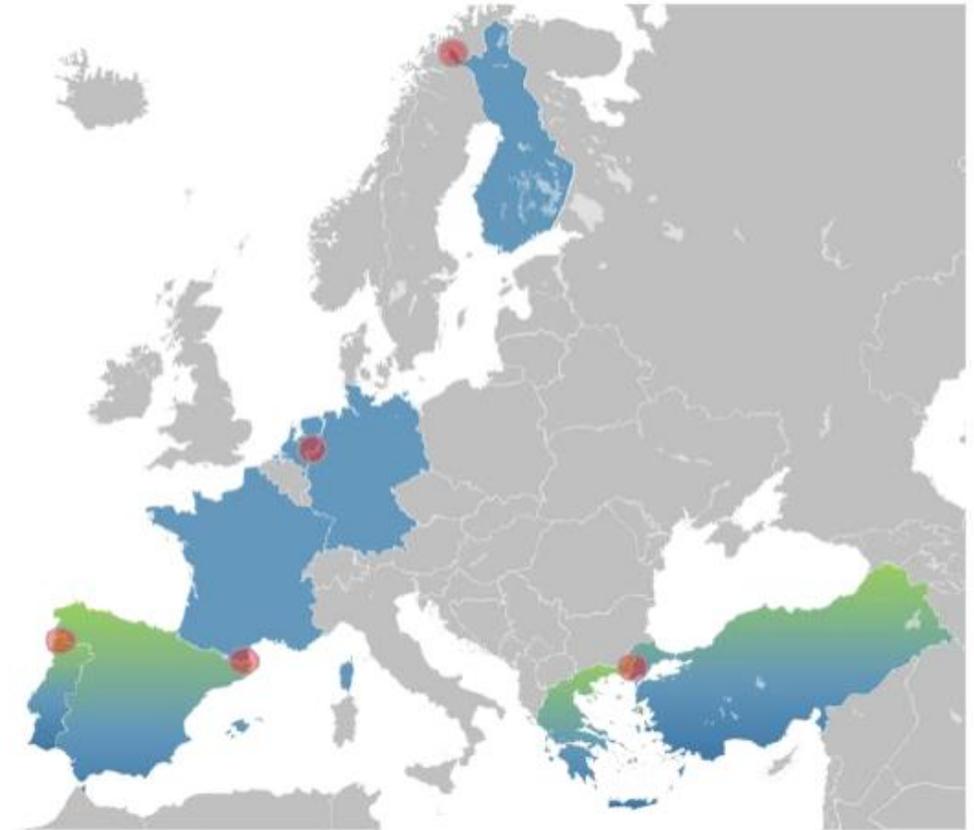
Geographical scope

~40km section (20km on each side of the border) of each of the following five CBCs was assessed as part of this study.

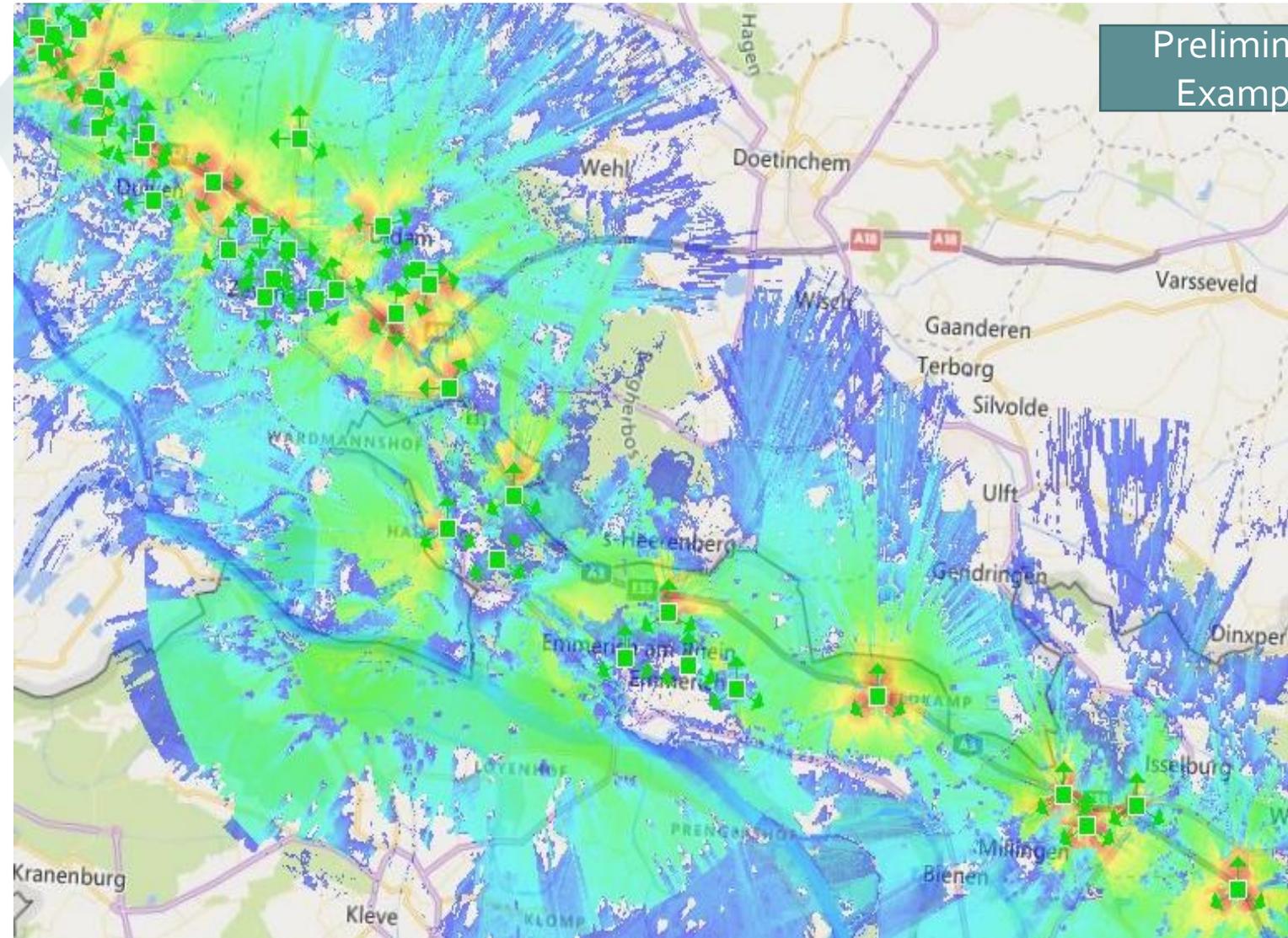
- **ES-PT:** Tui/Valenca(Vigo–Porto)
- **GR-TR:** Kipoi/Ipsala(Alexandroupoli–Kesan)
- **DE-NL:** Veldhuizen(Emmerich–Arnhem)
- **FI-NO:** Kilpisjärvi(Skibotn–Muonio)
- **ES-FR:** LePerthus(Figueres–Perpignan)

- Mandated at the initiative of the European Commission
- Scope: Estimate the investment “delta” to provide adequate 5G coverage and capacity on Cross-border Corridors, serving the needs of advanced CAM
- Undertaken by DETECON Consulting on behalf of 5G-MOBIX after a public RFQ process

Geographical Overview:

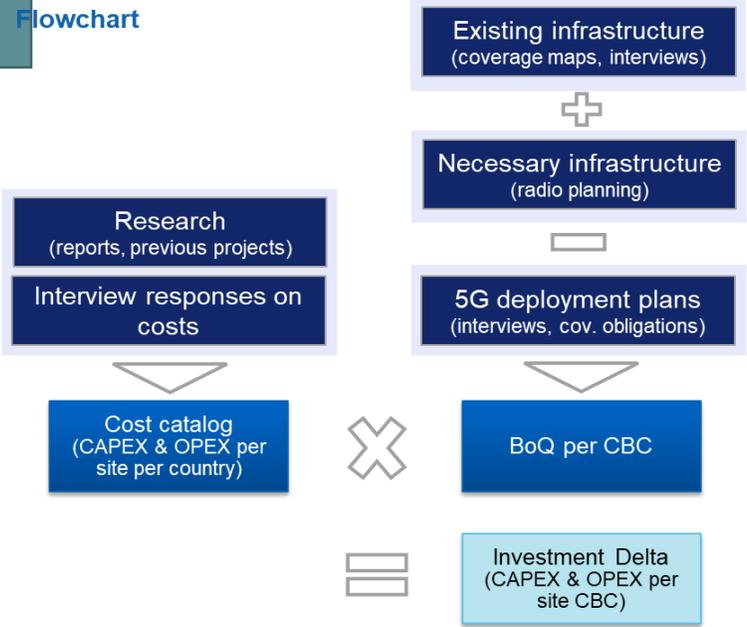


Existing sites in DE-NL, 5G NR 3500 MHz TDD radio coverage simulation



Preliminary Example

Flowchart



LEGEND

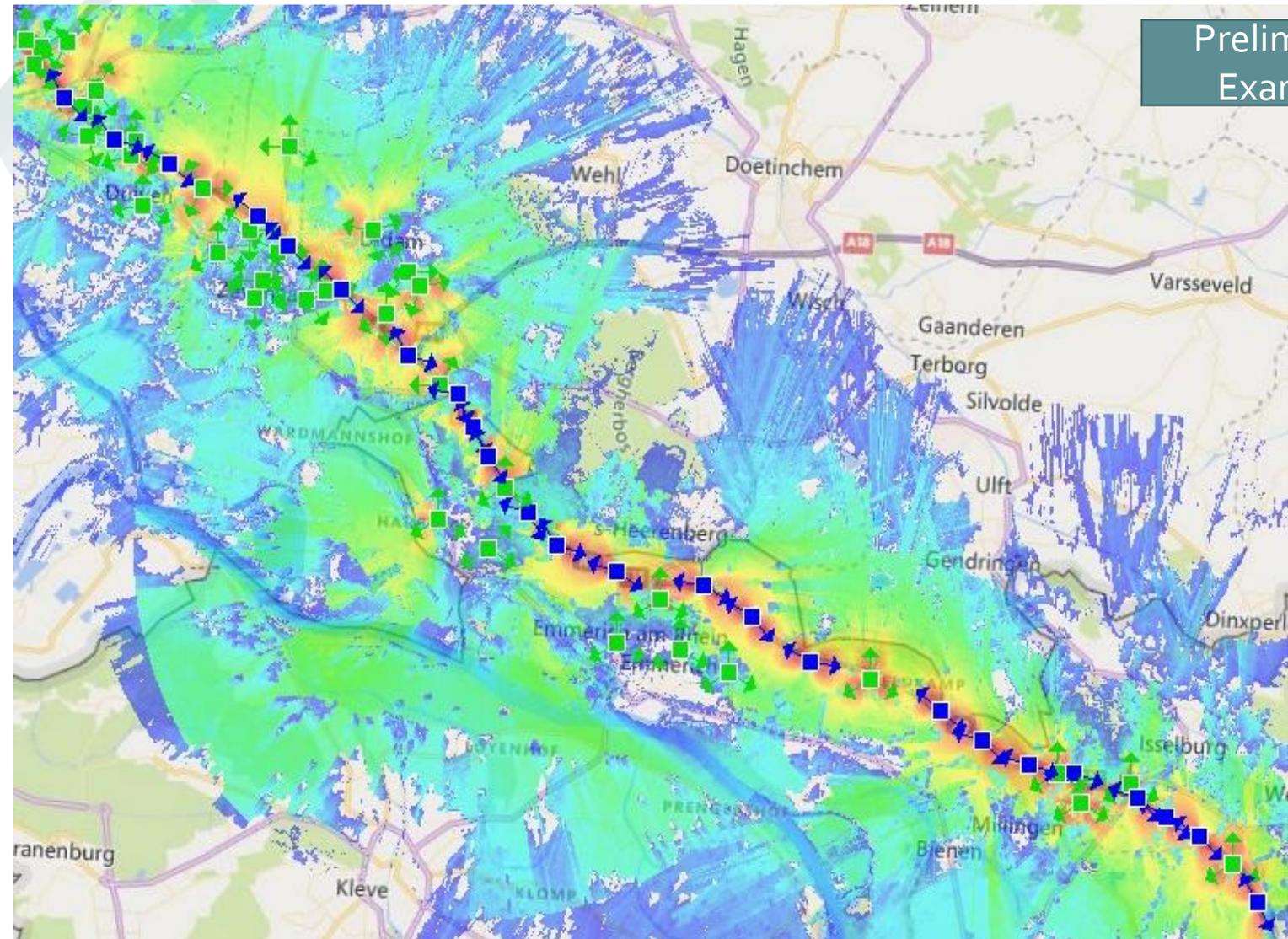


RSRP	Interpretation	Color code
- 60 dBm	Excellent	Brown orange
- 72 dBm	Very good	Orange
- 90 dBm	Good	Green
-111 dBm	Low	Light-blue
122 dBm	Poor	Dark blue



Existing and new sites in DE-NL, 5G NR 3500 MHz TDD radio coverage simulation

Preliminary Example



- Existing sites could be upgraded to 5G: 12 on the German side, 2 on the Netherlands side
- 12 new sites were added and distributed along the road in order to provide seamless coverage: 8 along the German stretch of the corridor, 4 along the Netherlands stretch of the corridor
- Fleet share estimates, vehicle traffic estimates, CAM requirements

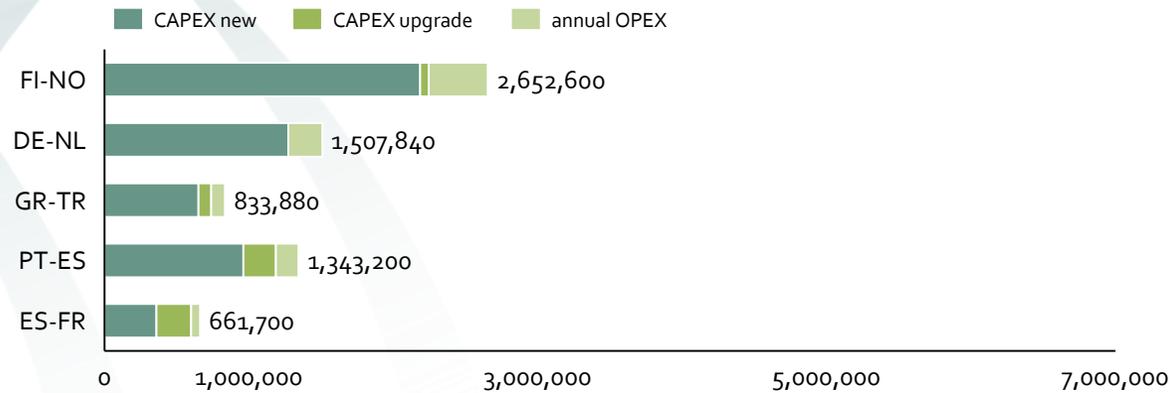
LEGEND



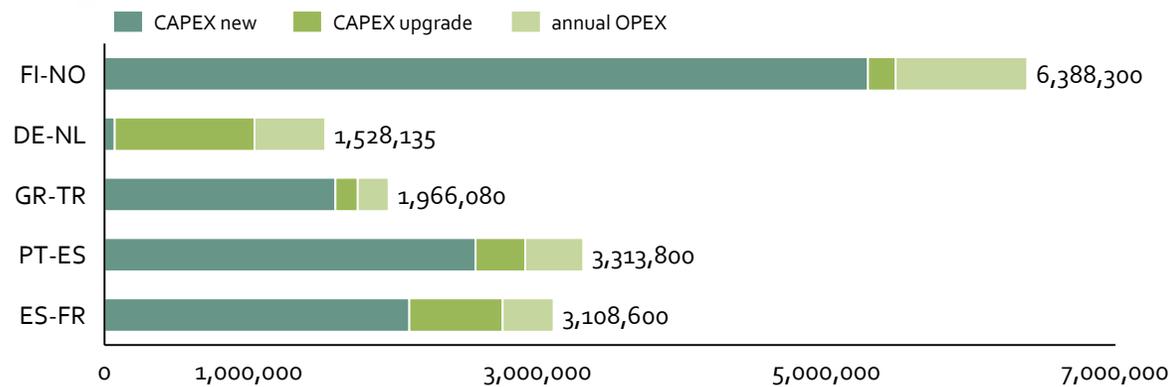
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Comparing the costs of 5G-MOBIX shows major corridor cost differences.

Deployment cost for the 700MHz scenario, on all corridor



Deployment cost for the 3.5GHz scenario, on all corridor



- » The costs have been compared considering the 2023 deployment scenario
- » Each corridor is 40km, approximately 20km on each side
- » For each corridor the deployment planned and obligations have been deducted to obtain the investment delta:

$$\Delta = RAN_{required} - (RAN_{planned} + RAN_{existing})$$

- » Cost varies drastically between corridors showing the impact of:
 - Existing infrastructure
 - Price differences between countries
 - Geographic surroundings

ICT-18 Deployment Meta-study



Deployment Metastudy Objectives

- The overall objective of the metastudy is to **compare the three underlying studies, consolidate their results, identify methodological and analytical gaps**
- The metastudy reflects the diversity of the three different approaches in order to arrive at a consolidated perspective on 5G deployment and related investment estimates with respect to the CEF2 Digital deployment.
- The study is available [online](#) [pdf]
- DETECON was subcontracted by 5G CroCo to perform this task
- The three ICT-18 projects, along with DETECON, organised a panel during EuCNC 2022 and have submitted a paper to IEEE Future Networks 2022 which has been accepted.

Comparative Analysis

Comparison Between the Deployment Studies



- 700MHz and 3.5GHz deployment in 2023 or 2025
- Precise radio planning using the HTZ simulation tool
- Cost Δ calculated considering planned and existing sites



- Coverage, with IsD of 3km, and high throughput, with IsD of 1km, 3.xGHz scenarios
- Cost calculation attributing a percentage of the costs to CAM (10% to 50% of CAPEX)



- Continuous 700MHz and 3.7GHz deployment between 2021 and 2025
- Precise radio planning
- Costs calculated per year with 15% planned upgrades and revenue from 5G services

Gap Analysis Between the Studies

Technical Gaps

CAM requirements	Cross-border handover
Cross border handovers	Satellite Comms
Network sharing	MEC

Regulatory Gaps

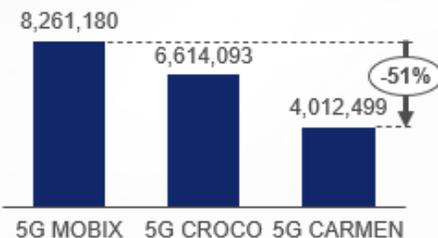
Roll out obligations	Regulatory uncertainty
Environment impact	Cross border data policies
Alignment of the NRAs	Access to RO network

Financial Gaps

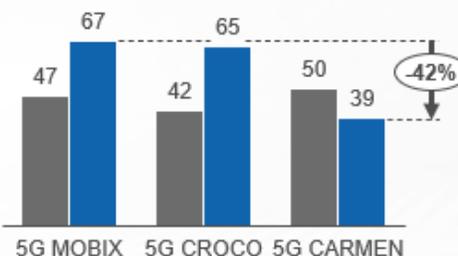
Role of big tech	Price evolution and inflation
Revenue model of CAM	Availability of space on BS
Communal benefits	Role of logistic companies

Cost Comparison Between the Studies

Average costs of the corridors per 100km (high density case*)



Average upgraded (grey) and new (blue) sites per 100km (high density case*)



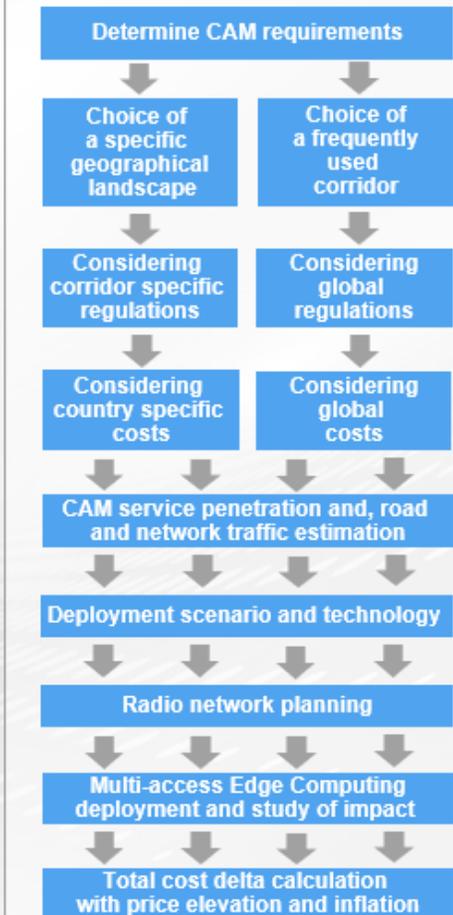
- *High density case:
- 3.5GHz deployment in 5G MOBIX
 - High throughput case in 5G CROCO
 - Optimistic approach in 5G CARMEN

Key Findings

- Costs vary depending on the location and geographic specificities of the corridor
- There are several key steps in estimating the investment delta that all three studies have in common
- Differences are mainly within the applied methodology for each step
- Generally, estimations of the investment deltas align among the three studies

- Defining CAM requirements for each service provided.
- Specifying the geographical landscape where the deployment will be done.
- Considering country-wise regulations to estimate time and dependencies for deployment.
- Considering Country-wise financial aspects to estimate overall cost.
- Studying CAM penetration in market to calculate road and network traffic demand.
- Determine what kind of deployment scenario will be undertaken.
- Radio network planning and capacity planning for the corridor/border area.
- Calculating the cost Multi-access Edge Computing to support CAM.
- Cost and delta calculation for the entire planning and deployment process.

Future Framework



IsD: Inter-site Distance; RO: Road Operators; BS: Base Station

Several issues and cost drivers remain unclear. They can be grouped into three larger categories: technical, regulatory and financial gaps.

Technical gaps



Unclear CAM requirements



Cross-border handovers and network reselection



Assumption of availability of space on base station site

Regulatory gaps



Roll-out obligations



Regulatory-legal uncertainty



Alignment between NRAs

Financial gaps



Revenue models for CAM services



Potential investment in alternative technologies



Price Evolution and Inflation

The cost comparison has been made between the average case of the three deployment studies and the EU CEF2 baseline report.



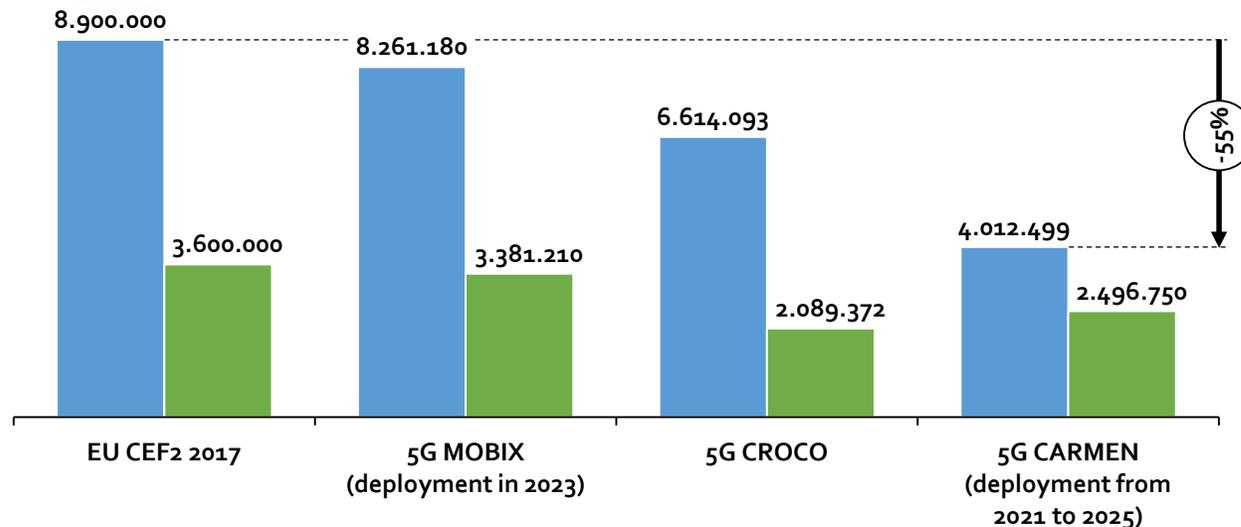
We choose for each of the studies the **average of all corridors or segments** normalized to 100km to compare the results for each density scenario and compare it to the cost per 100km estimated in 2017 by the EU CEF2 report



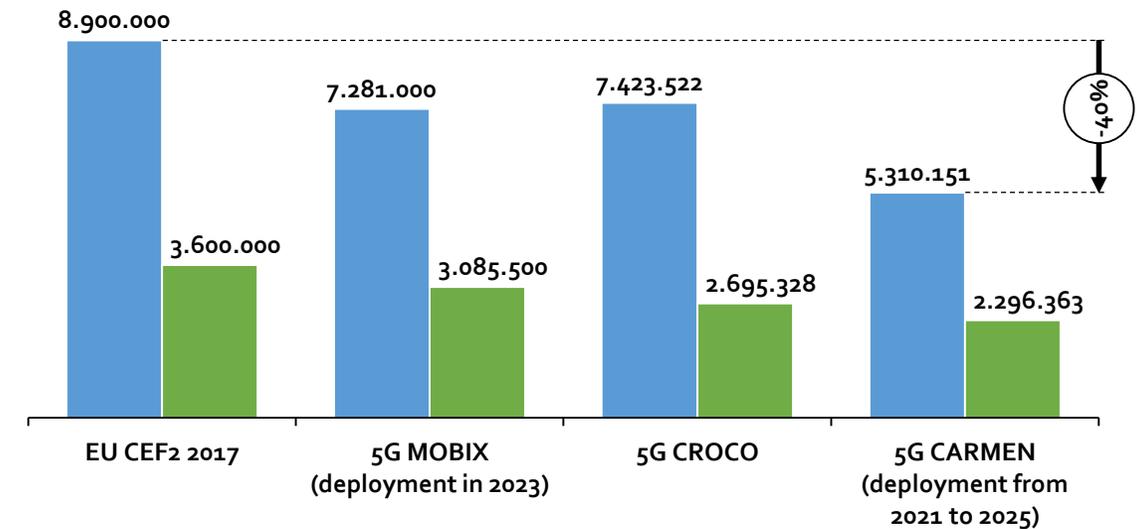
We choose for each of the studies a **similar geographical corridor or segment** normalized to 100km to compare the results for each density scenario and compare it to the cost per 100km estimated in 2017 by the EU CEF2 report.

Average deployment cost of all corridors per 100km

■ CAPEX in EUR for a high-density deployment per 100km
 ■ CAPEX in EUR for a low-density deployment per 100km



Average deployment cost for specific corridor per 100km



5G MOBIX



5G CroCo



5G CARMEN



European Commission

Thank you



www.5g-mobix.com



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