Recognising the transformative potential of 5G in the field of mobility, the Commission aims at making Europe a world leader in the deployment of 5G networks and services enabling Connected and Automated Mobility (CAM). Considering this objective, the purpose of this input paper is to provide elements for common understanding on objectives and cooperation options in rolling-out 5G along transport paths in the period 2020-2025: A Strategic Deployment Agenda (SDA).

More specifically, such an agenda should unlock the significant private investments required to build the infrastructure. It should be the basis for a public-private partnership to coordinate a “pipeline” of projects for the optimum use of the co-funding of 5G corridors as proposed in the next CEF Digital programme.
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1. Introduction

The 5G Action Plan for Europe (5GAP) calls for actions to ensure that the EU can use advanced 5G connectivity as a strategic advantage to lead in digital transformation, in particular in vertical industries, and in support of key societal objectives. One of these strategic sectors, with strong public interest, is Connected and Automated Mobility (CAM). Recognising the transformative potential of 5G in the field of mobility, and driven by the opportunity to make Europe a world leader in CAM products and services, the Commission in 2016 has set ambitious Gigabit connectivity objectives\(^1\), starting with a coordinated launch of 5G in all EU Member States by 2020 and a comprehensive deployment by 2025 to ensure full urban coverage as well as uninterrupted 5G coverage along main transport paths (roads and railways).

In the area of mobility, the Commission adopted its strategy for Connected and Automated Mobility in May 2018\(^2\), underlining the societal benefits as well as economic opportunities for Europe in this field. In particular, the Commission emphasised its commitment to work with Member States and stakeholders to develop a network of pan-European 5G corridors for large-scale testing and early deployment of advanced connectivity supporting CAM. For such a pan-European network to emerge it is necessary to start at early stage with 5G cross-border sections first for experimentation through Horizon 2020 and then deployment through CEF Digital\(^3\). Public intervention at EU level is therefore justified on these “5G cross-border corridors”.

A milestone in this process has been the Letter of Intent signed in April 2017 at the occasion of the first Digital Day in Rome by 27 EU countries, plus Norway and Switzerland, agreeing to enhance cross-border cooperation in the field. To date, a total of ten 5G cross-border corridors have been agreed among neighbouring states across Europe. Four of those are covered by the first set of Horizon 2020 trial projects (see Annex 1).

The CEF proposal for the next EU budgetary period 2021-2027 already indicates two lists of corridor segments, one covering a first set of cross-border sections for large-scale experimentation and one with longer segments for deployment and early use of CAM and the full range of other 5G services. The latter is mainly based on TEN-T (see Annex 1). In addition, during the CEF legislation negotiations with the Council, Member States have added potential corridors to this indicative list.

The overall aim is to ensure uninterrupted coverage of the full pan-EU network, using CEF mainly to drive investments in cross-border sections in complementarity with private investment projects in the commercially viable areas. National programmes could be mobilised to support investments in the remaining challenge areas.

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\(^1\) COM(2016) 588 final
\(^2\) COM(2018) 283 final
\(^3\) COM/2018/438 final
2. Service requirements

2.1. Identification of main services sharing the common 5G infrastructure

A key step in the strategy setting will be to get a common understanding on the evolving role of 5G connectivity infrastructure along transport paths in the provision of CAM services over time, alongside a broad range of digital services in vehicles. While these services can not be predicted today with great certainty, it is however important to ensure that the planned 5G infrastructure will be sufficiently “future-proof” to address a broad range of “high level automation services” that will emerge in the next decade. The SDA should identify the key requirements and attributes of these future service categories including their main functionalities, estimated time-to-market (and possible intermediate milestones), overall investment requirements and revenue potential, degree of reliance on cellular infrastructure, geographical usage patterns, etc.

Such information will be essential to optimize the deployment of 5G connectivity infrastructure with a European-wide perspective, provide for a step change to mobile services available today, and protect the long term financial viability of the investments.

In conclusion, the SDA should include the identification of the main broad categories of services in a forward looking way, and lead to a common understanding on their impact on 5G connectivity needs.

Examples of open questions:

✓ What are the services that could make use of an advanced 5G network infrastructure along transport paths? Can they be regrouped into generic categories?
✓ How will these services contribute to public objectives in the area of CAM and more broadly to societal goals?
✓ What are the key attributes that would help defining and prioritising the retained services?
✓ What service categories are the most likely to stimulate private investments?
✓ Which services rely the most on economies of scale and network effects? How can we ensure that these efficiencies will be fairly distributed in the value chain? What are possible synergies between service categories?

2.2. Connectivity performance levels and minimum Quality of Service

Another important requirement for the planning of the future 5G infrastructure along transport paths is the need to ensure specific network performance levels and Quality of Service. This will largely determine the kind of 5G infrastructure that needs to be deployed. The analysis should not only address the various needs for CAM service implementation (various driving automation levels, platooning, etc) but also for other relevant services that could be delivered (e.g. “infotainment” on board, public safety, and mobile office in the longer term).

The main requirements for CAM are a sufficiently dense network allowing for highly reliable uninterrupted service, sufficient performance as regards capacity, speed, latency and number of connections, as well as advanced service features such as network slicing to guarantee the quality in
a multi-service environment (in relation to non-CAM services like infotainment provided over the same infrastructure).

The SDA should explicitly address network performance levels and Quality of Service, as well as attempt to link specific performance needs to identified service categories in a multi-service environment.

Examples of open questions:

✓ What are the core CAM specific requirements (with time dimension, as requirements will evolve from now until fully automated driving)?
✓ What are the main non-CAM performance requirements?
✓ Is it possible to determine a minimum common level of technical characteristics and performance (including QoS) for 5G networks along transport path that would be appropriate for use cases? How would this evolve in time?
✓ How could such a common set of performance requirements look like?
✓ Are there broad strategies that could be used to optimise the delivery of network performance across application requirements e.g. (priority management, capacity pre-emption, real time pricing incentives, etc).

2.3. Technical characteristics of 5G networks for CAM

This step in the SDA development should focus on the generic technical elements that should be part of a shared reference model to describe the cellular infrastructure for CAM along 5G corridors. It should extend beyond the 5G base station and also include spectrum aspects (e.g. suitable bands), backhauling requirements, and possibly some additional technical elements, as appropriate, such as equipment to support Mobile Edge Computing (MEC) functionalities, network slicing capabilities, interfaces to road sign equipment or any other relevant infrastructure elements other than 5G-specific equipment such as specific software components, etc.

Examples of open questions:

✓ What are the categories of network infrastructure elements and their broad technical specifications to meet the CAM requirements?
✓ What is the required network topology to deliver CAM services, including base station density, spectrum bands used, need for stand-alone architecture to enable network slicing?
✓ Would other services than CAM significantly affect the technical infrastructure approach/strategy? How?

3. Deployment scenarios

3.1. Corridors identified by the Commission and Member States

The principle of the 5G infrastructure initiative envisaged is to seize market opportunities and societal benefits of CAM services and of other (commercial) services. The logic of investment should therefore follow a private-sector 5G investment roadmaps, while also meeting public interest
objectives. The coordination with public-sector driven infrastructure projects is highly relevant, especially regarding the reuse of road infrastructure and common planning of civil engineering. The Annex of the CEF Digital proposal contains two sets of cross-border corridors, which are part of major transport paths across Europe. They are of strategic importance from the public perspective, inter alia to make sure that CAM services develop at pan-European level. This should also be of interest to the private sector.

3.2. Predicted investment plans and market failure areas

As already stated, the investments necessary to meet EU 5G deployment objectives will mainly have to come from the private sector. According to first estimates, the investment required (combining private/public) to cover pan-EU corridors with 5G would be in the order of at least €10 billion, whereas the investment required for a deployment including rail and larger national roads would amount to the order of €100 billion. Dedicated 5G coverage obligations in spectrum auctions, e.g. as already envisaged in Germany by BNetzA, are promising to play a significant role in guiding MNO investments and will have an impact on the deployment strategies of mobile network operators, including on the definition of priority areas such as major transport paths and cross-border corridors. However, it is desirable that commercially-viable services also contribute to the stimulation of investments for 5G coverage along major transport routes. In this respect, emerging ecosystems around cars offer broad business opportunities for market players. These include enabling CAM services, but also a wide range of digital services to passengers in cars, in particular when passengers in cars will become less active as drivers. These go beyond transport-related services and include for example mobile office, entertainment, etc.

Nevertheless, the specific features of 5G corridors for CAM, as compared to “normal” 5G network deployment addressing consumer and business markets, may entail higher risk levels and longer payback periods, which could hinder and delay the deployment. We can already anticipate in particular:

- Need for an uninterrupted 5G connectivity coverage along transport paths to ensure CAM business continuity, i.e. independently from the nature of the crossed areas, (e.g. rural, mountains, cross-border etc.) and related prospects of return on investment

- Different categories of actors involved on both sides of 5G CAM markets, with their respective – and distinct – economic models and related business plans, e.g. road operators, telecom operators, specialised CAM service providers, car manufacturers/OEM, fleet/freight companies etc.

- Effectiveness of CAM solutions only from a certain penetration rate of 5G CAM-equipped vehicles (active).

The above factors could delay the potentially huge market opportunities and societal benefits of 5G-based CAM. Against this background, coordination at EU level, coupled with targeted financial support for deployment based on CEF2 Digital seems indispensable.

Clear indications of market failure to reach the full set of deployment targets combined with the strong public interest for CAM services as well as the need for a European dimension amply justify the consideration for public funding of 5G cross-border segments.
Such public funding should therefore be used to create a positive momentum in the market by catalysing and coordinating the investments from stakeholders.

The SDA should present a common understanding on the various market situations and how public funding could complement private investments, coherent with EU competition law principles.

### 3.3. Assessment of capital and operating costs

The SDA should provide information on the cost of deployment of the 5G infrastructure, at the least in terms of CAPEX, as well as include projections on potential revenues from the delivery of related services.

Generic estimates of the cost were done in the context of the 5G PPP White Paper on the automotive vertical (Annex 4). These estimates could be used as a basis for the common SDA but, beforehand, they should be refined and validated by the wider constituency.

When deepening the cost analysis, it should be first taken into account that, where coverage obligations will exist along the corridor, only the cost of deployment going beyond the coverage and service requirements required by the spectrum license will be eligible for the public grant.

As far as the use of CEF Digital funding is concerned, the coherence with competition law principles will probably require demonstrating how the infrastructure “step change” will be achieved by the investment, as compared to existing or planned cellular networks along similar corridors. The step change can relate to network coverage and performance, but also service features such as network upgrades allowing for advanced network slices for CAM.

Even though funding through the proposed CEF Digital programme as part of the EU budget will not directly be subject to State Aid, its design needs to be coherent with competition law principles: it will normally entail that some form of access is granted to users by any economic actor receiving CEF2 funding for its connectivity infrastructure. In this context, public funding of passive infrastructure will be the easiest case. The SDA should therefore elaborate on the choices regarding which active infrastructure option is relevant to be fundable in the future CEF Work Programmes. DG CONNECT has launched a study (WIK/Ecorys), which will identify costs and provide estimates for relevant 5G corridor scenarios in this context of the future CEF programme and define a methodology for assessing the conditions pursuant to which a CEF Digital funding could intervene, in particular in cases where parts of a 5G corridor would not be economically viable for deployment. The work has been kick-started in December and the first interim results will be made available by April 2019. This could be useful for the stakeholders.

### 3.4. Resulting cost for deployment scenarios, listed by corridors

Eventually, the SDA should provide an estimation of the above cost of deployments for each of the specific 5G corridors which are considered in the context of this public-private initiative.
3.5. Other geo-priorities and deployment topology

The SDA should include a comprehensive network deployment strategy with a pan-European perspective, beyond the corridors already identified, and spanning from the launch of 5G by end 2020 up to the full deployment of uninterrupted 5G coverage along all transport paths. This should include a discussion on best scenarios for the progressive build-up of the infrastructure addressing geographical priorities and type of deployment topologies that can be envisaged over the successive time periods between now and 2025, and even beyond if appropriate. This should take into account the identification of areas and corresponding business cases where there is a lack of financial viability and hence where public funding would be most appropriate.

Examples of open questions in relation to deployment strategies:

- How can connectivity for CAM be financed, deployed and used? Possible models matching the different categories of services and geographical areas? Telco investing, joint investment telco/automotive sectors and others including road operators, fleet/freight managers, Member States, etc?
- What are the expected sources of revenues and cost elements?
- What role for public financing? What cooperation options under CEF2?

4. Cooperation models

4.1. Deployment cooperation scenarios

The SDA should provide guidance on what cooperation models could be envisaged. This could include provision of passive infrastructure, active infrastructure made available at wholesale level, complete 5G networks on infrastructure sharing basis, or other type of 5G infrastructure. There will probably be at least three categories of situations: cases where private investments are sustainable, cases where only one shared infrastructure can be financed by the private sector and cases where there is no profitable business model without the support of public funding (market failure).

The cooperation model chosen may also be influenced by the fact that a consortium member would need to provide some forms of access to interested users, and EU funding could be conditioned to some forms of access requirements. To the extent that a consortium might involve more than one horizontal competitor (e.g. network sharing by MNO participants), antitrust issues and safeguards might also need to be considered in setting out the model.

As far as public support is concerned, activities under CEF2 Digital on CEF Corridors are expected to have a significant budget (planned for at least €1 billion). Deployment activities unlocked by the programme of such scale will have a structuring effect on markets for connectivity and involve a broad range of stakeholders from various sectors as well as public authorities.

When the particular use of CEF funding is being considered, the project should make clear upfront how the infrastructure will be used after the project is finished. Details on cooperation arrangements could be specified between participants in a consortium agreement. The project needs to demonstrate how the infrastructure will contribute to the public policy objectives in the context of
CAM. While recognising that the 5G infrastructure is "multi-service" including a broad range of commercial services, it should not only serve the commercial purposes of the owner of the infrastructure. Concrete commitments for the provision of CAM services or for enabling services for players inside or outside of the consortium will be necessary.

The preparation of the SDA is an opportunity to review the above cooperation challenges from a multi-stakeholders' perspective.

4.2. Ecosystem: stakeholder categories and roles (with focus on use of infrastructure)

It is essential to involve the appropriate set of stakeholders in the elaboration of the proposed SDA. In addition to the two obvious sectors which are at the core of CAM deployment, the automotive industry and the telecom/IT sector, it is expected that road infrastructure operators and suppliers will also be key partners in the approach. It would also be appropriate to involve other relevant communities, in due time, such as technology/service innovators, local public authorities, infrastructure investors (distinct from network operators), road safety authorities, public transport operators, manufacturers of road signage installations, road police authorities. It will be the responsibility of the participants to ensure an open and balanced representation of all concerned parties.

It would be helpful if the SDA could clearly identify the categories of stakeholders and pave the way for a proper framework to support a wide and effective cooperation between all interested parties.

4.3. Ensure “service continuity” between network operators

This is a particular case of cooperation that will require innovative business approaches to be applicable on a large-scale basis, and enable service continuity across borders and across types of road infrastructures.

5. Regulatory aspects

5.1. Introduction

There is a clear contrast between the significant societal benefits expected from CAM and the strategic risks incurred by early investors in 5G corridors: regulatory-enabled cooperation models may play an important role to address this externality, and more generally to incentivise investments.

The possible regulatory approaches to help bridging the gap between investments and full benefits should preferably be considered “upfront” in the SDA framework. In this context, it is anticipated that the CEF programme will offer concrete opportunities to test, in a “green-field” scenario environment, new regulatory approaches supported by the modernised telecom rules.
5.2. Specialised services

As most CAM services are “mission-critical” they are expected to represent a prominent example of 5G specialised services implemented with so-called “network slices”. A common understanding of the main features of such network slices accepted by stakeholders and regulators as compliant with the net neutrality rules and modernised BEREC guidelines could help to provide legal certainty for specialised services in the CAM context, as well as for other 5G specialised services. Approaches that prove appropriate in this context could be taken up in other network or service environments. They could also feed into guidelines of national and European regulators. On a wider basis, models for specialised services approved at EU level would contribute to legal certainty in this field.

5.3. Co-investment models

The recently adopted European Electronic Communication Code (‘the Code’) contains a number of new regulatory innovations, such as co-investment arrangements, infrastructure sharing, wholesale-only network provision, open access approaches. It also includes provisions to serve transnational demand (i.e. cross-border) with harmonised wholesale access products, spectrum issues and open numbering resources with extra-territoriality features for connected vehicles. Some of these rules could be relevant beyond fixed broadband networks and be used in 5G scenarios where they could incentivise investment in 5G corridors.

5.4. Spectrum issues

The SDA can be instrumental to specify the needs with regard 5G spectrum bands as well as the regulatory conditions, e.g. types of bands, spectrum sharing conditions, etc..

The SDA should also identify the various requirements of market actors regarding test licenses and access to spectrum for longer-term services.

5.5. C-ITS Regulation

Another important aspect is the C-ITS legal framework and associated delegated acts. Whereas 5G systems for CAM go beyond the scope of C-ITS, progress in 5G corridors can be an important element for the review or revision of such legislation. Relevant legal aspects in the broader field of CAM, such as data sharing, cyber security, etc. could also be addressed in the context of the SDA.
Annexes

Annex 1: Maps of envisaged trial corridors and pan-EU corridors

A. CEF Digital Category 1 corridors for CAM experimentation

Source: European Commission, DG CONNECT
B. CEF Digital Category 2 corridors for large-scale deployment

List of CEF2 Digital corridors based on Council position of 3rd December on the amended CEF 2 Regulation (Annex part V): Indicative list of 5G corridors eligible for funding

“In line with the Gigabit society objectives set out by the Commission to ensure that major terrestrial transport paths have uninterrupted 5G coverage by 2025, actions implementing uninterrupted coverage with 5G systems pursuant to Article 9 paragraph 4 (c) include, as a first step, actions on the cross-border sections for CAM experimentation, and, as a second step, actions on more extensive sections in view of a larger scale deployment of CAM along the corridors, as indicated in the table below (indicative list). The TEN-T corridors are used as a basis for this purpose but the deployment of 5G is not necessarily confined to those corridors. “

Core network corridor "Atlantic"

Cross-border sections for CAM experimentation
Porto-Vigo and Merida-Evora and Aveiro – Salamanca
More extensive section for larger scale deployment of CAM
-Bilbao – Madrid – Lisbon
Core network corridor "Baltic – Adriatic"
Cross-border sections for CAM experimentation
- More extensive section for larger scale deployment of CAM

Core network corridor "Mediterranean"
Cross-border sections for CAM experimentation
- More extensive section for larger scale deployment of CAM
Budapest – Zagreb – Ljubljana / Rijeka / Split

Core network corridor "North Sea – Baltic"
Cross-border sections for CAM experimentation
Warsaw – Kaunas – Vilnius/Klaipėda
More extensive section for larger scale deployment of CAM
Tallinn – Riga – Kaunas – LT/PL border – Warsaw
BY/LT border – Vilnius – Kaunas – Klaipėda

Core network corridor "North Sea – Mediterranean"
Cross-border sections for CAM experimentation
Metz-Merzig-Luxembourg
Rotterdam-Antwerp-Eindhoven
More extensive section for larger scale deployment of CAM
Amsterdam - Rotterdam – Breda – Lille – Paris
Brussels – Metz – Basel
Mulhouse – Lyon – Marseille

Core network corridor "Orient/East-Med"
Cross-border sections for CAM experimentation
Sofia-Thessaloniki-Belgrade
More extensive section for larger scale deployment of CAM
Berlin – Prague – Brno — Bratislava — Košice
Timisoara – Sofia – TR border
-Sofia – Thessaloniki – Athens

Core network corridor " Rhine – Alpine"
Cross-border sections for CAM experimentation
Bologna-Innsbruck-München (Brenner corridor)
More extensive section for larger scale deployment of CAM
Rotterdam – Oberhausen – Frankfurt (M)
Basel – Milan – Genova

Core network corridor "Rhine – Danube"
Cross-border sections for CAM experimentation
- More extensive section for larger scale deployment of CAM
Frankfurt (M) – Passau – Wien – Bratislava – Budapest – Osijek - Vukovar - Bucharest – Constanta
Karlsruhe – München – Salzburg – Wels
Frankfurt (M) – Strasbourg

Core network corridor "Scandinavian – Mediterranean"
Cross-border sections for CAM experimentation
Oulu-Tromsø
Oslo-Stockholm-Helsinki
More extensive section for larger scale deployment of CAM
Turku – Helsinki – Russian border
Stockholm/Oslo-Malmo
Malmo – Copenhagen – Hamburg – Würzburg
Nürnberg – München – Verona
Rosenheim – Bologna – Napoli – Catania – Palermo
Napoli – Bari – Taranto
Via Carpathia Klaipėda – Kaunas – Elk – Białystok – Lublin – Rzeszów – Barwinek
Annex 2: List of 5G CAM cross-border corridors and related EU-funded projects

Version updated on 22/11/2018

<table>
<thead>
<tr>
<th>5G Corridors</th>
<th>Political Commitment</th>
<th>Selected H2020 ICT-18 Proposals (Grants to be signed in November)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E8 &quot;Aurora Borealis&quot;: NO-FI</td>
<td>C-ITS-TEN-T legacy. First 10km Aurora open in FI for testing since Nov. 2017. Lol not yet signed</td>
<td>None</td>
</tr>
<tr>
<td>Nordic Way2: NO-SE-FI-DK</td>
<td>Follows-on Nordic Way 1, funded under C-ITS/CEF, which demonstrated that providing C-ITS services over cellular networks works.</td>
<td>None</td>
</tr>
<tr>
<td>Brenner Corridor: IT-AT-DE</td>
<td>Ahead of DD2, Italy and the three presidents of Euroregion Tirol-Südtirol-Trentino have confirmed their intention to work, in</td>
<td><strong>5G-Carmen</strong>: €18M budget (€ 15M H2020 funded). Consortium: DT, TIM, T-Mobile AT, BMW, FIAT Autostrade del Brennero (Brenner-Autobahn) NEC, Nokia,</td>
</tr>
</tbody>
</table>
### Cooperation with other interested Member States, on the development of the 5G Corridor on the Brenner pass motorway

However, no LoI signed yet.

**Qualcomm, CEA, IMEC. Support from IT Ministry of Transport, Euregio Tirol-Südtirol-Trentino, Bavarian Road Administration.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
<th>MoU/LoI Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE-LV-LT Via Baltica (E67) Tallinn (EE) – Riga (LV) – Kaunas (LT) – Lithuanian/Polish border</td>
<td></td>
<td>MoU signed on 28 Sept. 2018 in Riga at the 5G Techritory event. Although focused on C-V2X, elements of the Riga-Tallinn segment builds upon Smart E67 project (ITS).</td>
</tr>
<tr>
<td>LT-PL Via Baltica Kaunas-Warsaw, and further a national extension between Kaunas and Vilnius (LV)</td>
<td></td>
<td>LoI signed on 5 Sept. 2018. Goal is to cooperate in V2X, C-ITS, 4G LTE, LTE Advanced and 5G with the view to promote CAD.</td>
</tr>
<tr>
<td>Greece-Turkey (8 km segment across the border)</td>
<td></td>
<td>The Greek Ministry of Transport and the Greek Ministry for Digital policies, and the Turkish ICT Authority (BTK) have expressed support to the proposal from 5G-Mobix (see 3rd column).</td>
</tr>
</tbody>
</table>

Annex 3: Executive outline of 5G SDA for CAM prepared by the drafting group

5G Strategic Deployment Agenda

Draft outline – to be presented at EC workshop on February 7, 2019

Introduction
The European Commission has selected the pan-European 5G\(^4\) (cross-border) corridors as the initial flagship digital transformation project for Europe. The business case for smart mobility in 5G will require to shape a new ecosystem with the participation of multiple players: OEMs (car manufacturers), road and network infrastructure companies, IT technology vendors and licensed mobile operators among others.

The deployment of 5G connectivity infrastructure along major transport paths is a prerequisite for the advent of connected and automated driving/mobility (CAM) solutions in Europe. The progressive uptake of these solutions has not only the capacity to bring down the number of road facilities, reduce road congestion and harmful emissions, but also to shape at large the future of mobility in Europe.

As there is an expected market failure in the deployment of 5G along Europe’s highways, the Commission is proposing a 1.5 billion EUR budget line in the Connecting Europe Facility (CEF) Digital, to co-finance 5G infrastructure in view of accelerating the deployment of 5G CAM corridors. The Commission has also asked the 5G-PPP Automotive Working Group in cooperation with key stakeholders (such as the GSMA and 5GAA) to develop a common Strategic Deployment Agenda (SDA), which defines the roadmap towards establishing pan-EU 5G Corridors for CAM.

The 5G SDA concentrates on the 5G Corridors for Connected and Automated Mobility to establish an agreed deployment roadmap, while at the same time using it as a sandbox to test innovative regulatory models and investment ecosystems. This agenda should be driven by private investments supported by public funding where appropriate and should be complementary to private 5G investments in other promising areas such as cities and local industrial sites.

Problem analysis, shared vision (and objectives)
Today, there is a lack of roadside information readily available and accessible, e.g. over Internet. At the same time, it is costly to roll-out network deployment, in particular in low-demand areas.

Step 0 in implementation milestones (i.e. objectives):
- Initial deployment focus should be on upgrading the roadside infrastructure (cabinets, road signs, etc) and communicate to central systems such as traffic control centers.
- Physical/reusable infrastructure along roads can then be used by different MNOs or any communication supplier and it will reduce the network deployment cost, making it a feasible deployment option

Step 1 in implementation milestones:
- When infrastructure is connected to central servers one can select radio technology among the different available options in the market
- Security by design must be considered and implemented to a consistent level and from end-to-end of each service

\(^4\) 5G contains both NR and e.g. LTE-A
Step 2 in implementation milestones:

- Ensure minimum acceptable quality targets and service levels across the system

Current status: Available roadside infrastructure

A lot of existing fiber on highways is under utilised or not connected to anything external. 5G Trial sites for experimenting and validation Automated Driving are deployed in Europe with various types of infrastructures already in place. These trial sites include all types of roads i.e. motorways, interurban and urban roads. Motorway infrastructures, like in Portugal are equipped with optical fiber, cabinets and power supplies. Exiting LTE micro/small cells are upgradable to 5G NR, either in high band (e.g. 3.5 GHz) or low band (e.g. 700-800 MHz) with RRUS, also consider as pre-5G networks. Beyond the commercial radio component, some trial sites use their own SDR based gNB small cells, as well as C-RAN Ultra Dense Networks with 5G Roadside units deployed on lampposts. SDN/NFV based network slicing architectures; including MEC servers are complementing the 5G radio components on the trial sites. The road infrastructures on all these trial sites are equipped with a wide variety of sensors, mostly cameras, to detect vehicles, pedestrian and other obstacles, using GPUs for the video analysis. In urban trial sites, the IT architectures are oft complemented with AI HPC to allow analysing traffic, traffic light phases and parking usage with deep learning techniques.

Identification of a targeted pan-European network (based on current status)

5G corridors as well as urban pilot site targeted 5G architecture for CCAM will build on the network and roadside infrastructure already deployed (see paragraph above) and upgrade existing LTE nodes to 5G NR gNB with micro cells or small cells. Network operations are forecast in the low band and high band frequencies for V2I (Uu). V2V, PCS operations in the 5.9 GHZ band are also foreseen. The network architecture will include servers to implement the complete set of network virtualization functionalities to operate high performing multiple, network slices, with eMBB, uRLLC and mMTC and Mobile Edge computing will be globally deployed. CCAM scenarios are widely expected to require the most stringent requirement for 5G and the road infrastructure for enabling high level of automation and even more driverless operations. There might be business case challenges for rolling out 5G along highways because of the limited amount of use cases.

Targeted functionalities: Goals and the need for investments

In order to justify such infrastructure investments, use cases and applications would be necessary to facilitate a demand side pull. Connected and Automated Mobility (CAM) is such an area given technology enablers and proper market conditions for the CAM ecosystem across all its components. The ability to deliver attractive NaviTainment services is thus crucial. Furthermore, finding appropriate business logic that drives the infrastructure investment needed for the requirements of autonomous vehicles and traffic safety. 5G infrastructure is well suited to serve applications such as autonomous vehicles, traffic safety and NaviTainment. Ensuring regulation, stimulate the ecosystem investments, not restrict or hamper what would be necessary for the market actors to invest in all parts of the ecosystem.

Cooperation models for infrastructure and network

The possibility to incentivise mobile network expansion can be enhanced by the following mechanisms:

- Agreements with road infrastructure providers (such as towers companies, fiber network connectivity or energy provision) on leasing exceptions supported by RTAs or revenue sharing schemes.
- Network sharing options allowing cost sharing alternatives among MNOs, e.g.:
  - MOCN (Multi-Operator Core Network): elements of the core network are shared by several MNOs.
- Active infrastructure sharing without spectrum sharing: active elements of the cellular network such as base stations are shared. Each operator is still transmitting on his own spectrum.
- Active infrastructure sharing with spectrum sharing: active elements such as base stations are shared. One single operator operates the dedicated spectrum. The RAN connects to the core network of the different MNOs.

These models would have significant implications on the investment require to deploy and operate 5G V2X networks. Sharing alternatives within a clear regulatory framework could encourage the deployment of mobile networks in areas where ITS traffic demand would not justify a complete network roll-out from a single entity.

**Spectrum needs to be ensured**

Streamline network deployment as operators are still rolling out 4G infrastructure in most markets, with 5G as the evolutionary step with newer equipment added to earlier-generation sites. 5G will reach its full potential if sufficient harmonised spectrum is made available. Maintain regulatory flexibility to enable innovative automotive propositions. It is also important to ensure that spectrum is affordable to encourage and enable network investments.

**Security**

Security is crucial for all the Automotive use cases. Therefore the "built in" security of 5G is crucial in this respect, as this must be handled in scale across all of Europe and in collaboration across all brands as they will use the same roads, the same radio spectrum and the same 5G technology. The cellular networks and standards to already today provide a billion-user secure platform for the current use cases. A similar approach would be necessary for future use cases where Automotive is one particularly demanding area.

The GSMA IoT Security Guidelines could be useful in this regard. They include 85 detailed recommendations for the secure design, development and deployment of IoT services, cover networks as well as service and endpoint ecosystems, address security challenges, attack models and risk assessments an provide several worked examples. The organisation also developed an assessment scheme for IoT Security, which is based on a structured approach and concise security controls. It covers the whole ecosystem, can fit into a supply chain model and provides a flexible framework that addresses the diversity of the IoT market.

**Enabler: Technology**

Avoid negative lock-in effects or silos in the deployment. Technology to serve as a platform for future applications. Continuous improvement in guarantee minimum level of services. In the end, how can we already leverage on existing networks and what is the best approach for technology investments in 5G V2X?
Annex 4: 5G PPP Automotive White Paper of February 2018
The document is available on 5GPPP Web site at the [enclosed link](#).

**Important note:** This paper being revised at the moment. The 5G-PPP has announced that a version 2 should be published before the Mobile World Congress 2019.