# 5G-CCAM Business Case Analysis

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# 5GCAR Background
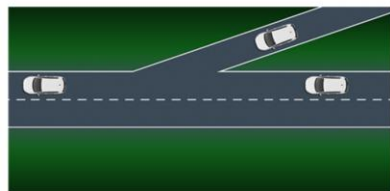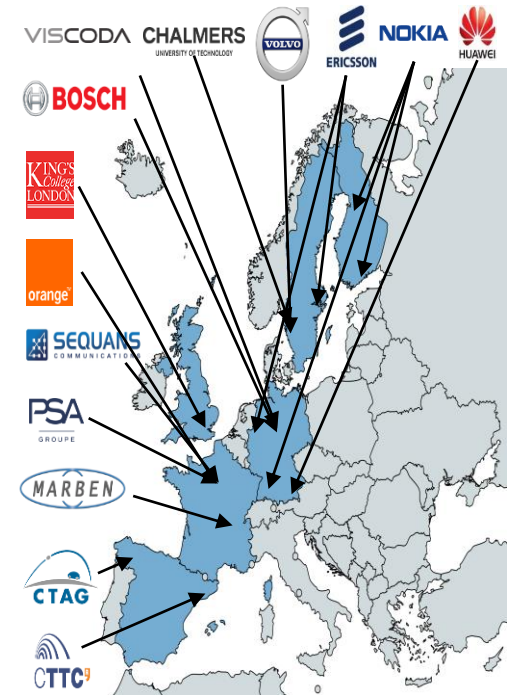
## Objectives

- Develop an overall 5G V2X system architecture
- Interworking of multiple Radio Access Technologies
- Develop an efficient, secure and scalable sidelink interface
- 5G radio-assisted positioning techniques
- Identify innovative business models
- Demonstrate and validate the developed V2X concepts
- Contribute to 5G Standardization and regulation
- Integrate of the 5GCAR concepts in the 5G PPP

## Methodology

A. Definition of V2X scenarios, requirements and KPIs

B. Design and validation of innovative technical solutions

C. Proof-of-concept and demonstration

Demonstrate three advanced V2X use cases
- ✓ Lane merge
- ✓ Cooperative perception for manoeuvres of connected vehicles
- ✓ Vulnerable road user protection

## R&I Activities

- Business models for 5G V2X
- Spectrum for 5G V2X
- Infrastructure-based communication for 5G V2X
- Sidelink-based communications for 5G V2X
- Positioning for 5G V2X
- 5G Architecture for V2X
- Demonstrations for 5G V2X

## Ambitions

1. End-to-end latencies, below 5 ms
2. Ultra-high reliability, close to $10^{-5}$
3. Very large density of connected vehicles
4. Positioning accuracy (VRUs: 10 cm, Vehicles: 30 cm)

**5GCAR**
- From June 2017 to July 2019
- 28 full-time equivalents

https://5gcar.eu/

**5G PPP Phase 2 Projects**

https://5g-ppp.eu/5g-ppp-phase-2-projects/

VISCODA  CHALMERS  VOLVO  ERICSSON  NOKIA  HUAWEI

BOSCH

KING'S College LONDON

orange

SEQUANS

PSA GROUPE

MARBEN

CTAG
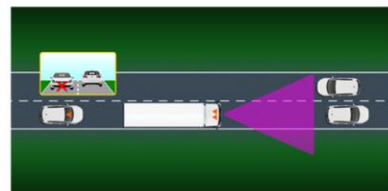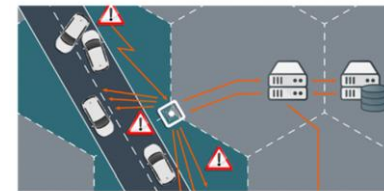
CTTC

Lane merge

See-through

Network assisted vulnerable pedestrian protection

High definition local map acquisition

Remote driving for automated parking

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# Infrastructure Supported Automated Driving

| | Level | Name | Description | Digital information provided to AVs | | | |
|---|---|---|---|---|---|---|---|
| | | | | Digital map with static road signs | VMS, warnings, incidents, weather | Microscopic traffic situation | Guidance: speed, gap, lane advice |
| Digital infrastructure | A | Cooperative driving | Based on the real-time information on vehicles movements, he infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow | X | X | X | X |
| | B | Cooperative perception | Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time | X | X | X | |
| | C | Dynamic digital information | All dynamic and static infrastructure information is available in digital form and can be provided to AVs | X | X | | |
| Conventional infrastructure | D | Static digital information / Map support | Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs | X | | | |
| | E | Conventional infrastructure / no AV support | Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs | | | | |

Source: inframix.eu/infrastructure-categorization/

# EU Smart Highway Market Projections

**EUROPE SMART HIGHWAY MARKET REVENUE, BY COUNTRY, 2018 2026 ($MILLION)**

| COUNTRY | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | CAGR% (2019-2026) |
|---|---|---|---|---|---|---|---|---|---|---|
| UK | 1,783.31 | 2,083.79 | 2,436.32 | 2,851.07 | 3,340.85 | 3,921.94 | 4,614.79 | 5,445.81 | 6,447.71 | 17.5% |
| Germany | 1,376.77 | 1,622.89 | 1,914.39 | 2,260.66 | 2,673.54 | 3,168.13 | 3,763.59 | 4,484.74 | 5,362.70 | 18.6% |
| France | 1,122.46 | 1,332.00 | 1,581.84 | 1,880.56 | 2,239.05 | 2,671.23 | 3,194.82 | 3,832.86 | 4,614.42 | 19.4% |
| Italy | 464.7 | 556.86 | 667.7 | 801.36 | 963.09 | 1,159.62 | 1,399.58 | 1,694.20 | 2,057.78 | 20.5% |
| Spain | 565.56 | 685.14 | 830.18 | 1,006.52 | 1,221.58 | 1,484.89 | 1,808.69 | 2,209.01 | 2,706.29 | 21.7% |
| Rest of Europe | 874.95 | 1,044.05 | 1,246.68 | 1,490.17 | 1,783.79 | 2,139.42 | 2,572.26 | 3,102.06 | 3,753.89 | 20.1% |
| Total | 6,187.75 | 7,324.73 | 8,677.11 | 10,290.34 | 12,221.89 | 14,545.22 | 17,353.74 | 20,768.67 | 24,942.80 | 19.1% |

**TOP 5 Countries:**
**UK, Germany, France, Italy, Spain**
**CAGR: 2020 –2026 > 19%**
**2020 market > USD 8 billion**

| TECHNOLOGY | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | CAGR (2019-2026) |
|---|---|---|---|---|---|---|---|---|---|---|
| Intelligent Transportation Management System | 2,426.24 | 2,808.87 | 3,274.21 | 3,819.84 | 4,461.81 | 5,220.75 | 6,122.33 | 7,199.62 | 8,556.62 | 17.2% |
| Intelligent Traffic Management System | 1,675.39 | 1,973.05 | 2,321.64 | 2,734.65 | 3,225.85 | 3,812.75 | 4,517.54 | 5,368.96 | 6,389.92 | 18.3% |
| Communication System | 999.68 | 1,218.64 | 1,472.94 | 1,781.49 | 2,157.17 | 2,616.31 | 3,180.08 | 3,875.97 | 4,702.08 | 21.3% |
| Monitoring System | 740.23 | 916.08 | 1,118.61 | 1,366.17 | 1,669.63 | 2,042.98 | 2,504.23 | 3,076.93 | 3,751.40 | 22.3% |
| Others | 346.21 | 408.09 | 489.71 | 588.19 | 707.43 | 852.43 | 1,029.56 | 1,247.19 | 1,542.78 | 20.9% |
| Total | 6,187.75 | 7,324.73 | 8,677.11 | 10,290.34 | 12,221.89 | 14,545.22 | 17,353.74 | 20,768.67 | 24,942.80 | 19.1% |

Source:
SMART HIGHWAY MARKET
Global Opportunity Analysis and Industry
Forecast, 2019-2026
Allied Market Research, 01.2020

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# SDOs for CCAM

| Standardization area | Related SDO in Global (red: SDO in Europe) | Logo |
|---|---|---|
| Sensors | **ISO**; NTCAS |  |
| HD Map | **NDS; TISA; SENSORIS; ISO;** CAICV |  |
| In-board Ethernet | IEEE; **ISO**; CAICV/CSAE; Open Alliance |  |
| AD functions and tests | **ISO**, NTCAS, **ASAM, ADASIS** |  |
| Policy & Regulations | **UNECE WP.29, CLEPA, VDA,** NTCAS |  |
| Automotive software architecture and OS | **AUTOSAR; ISO;** NTCAS |  |
| Functional Safety | **ISO**; NTCAS; **AUTOSAR** |  |
| Security | NTCAS; CCSA; **ISO** |  |
| V2X/Vehicle Infrastructure cooperation | **ETSI**; CCSA; NTCAS; C-ITS/ITS Standard Committee; CAICV/CSAE; **5GAA**; etc. |  |
| Research & Eco system | **ERTICO, ECLIPSE** |  |

# 5G Infrastructure Supported Automated Driving
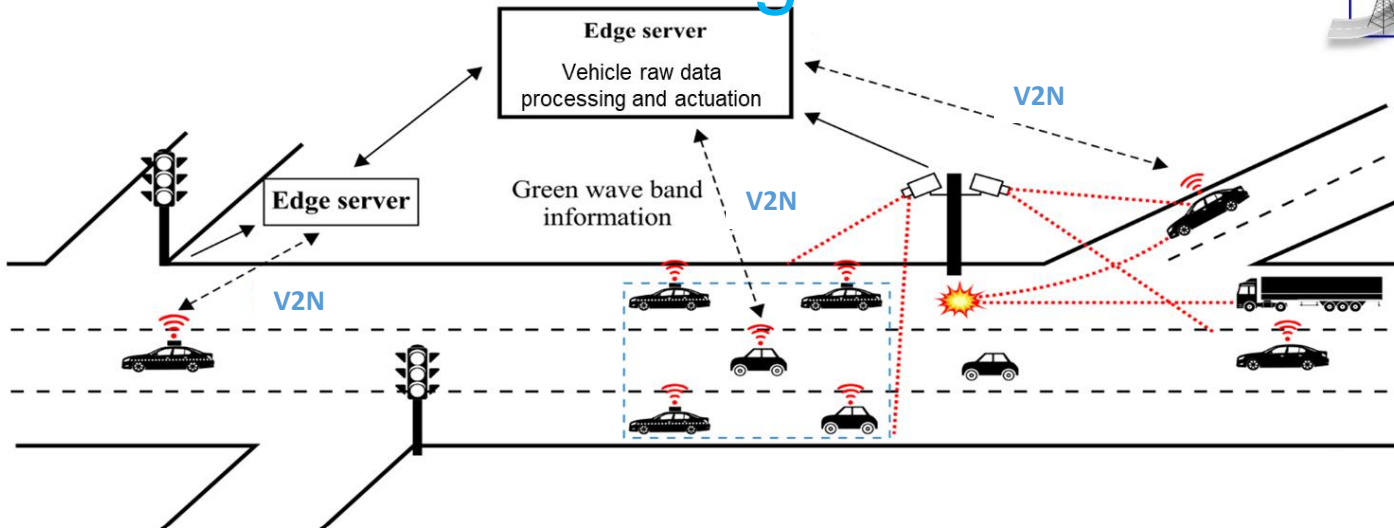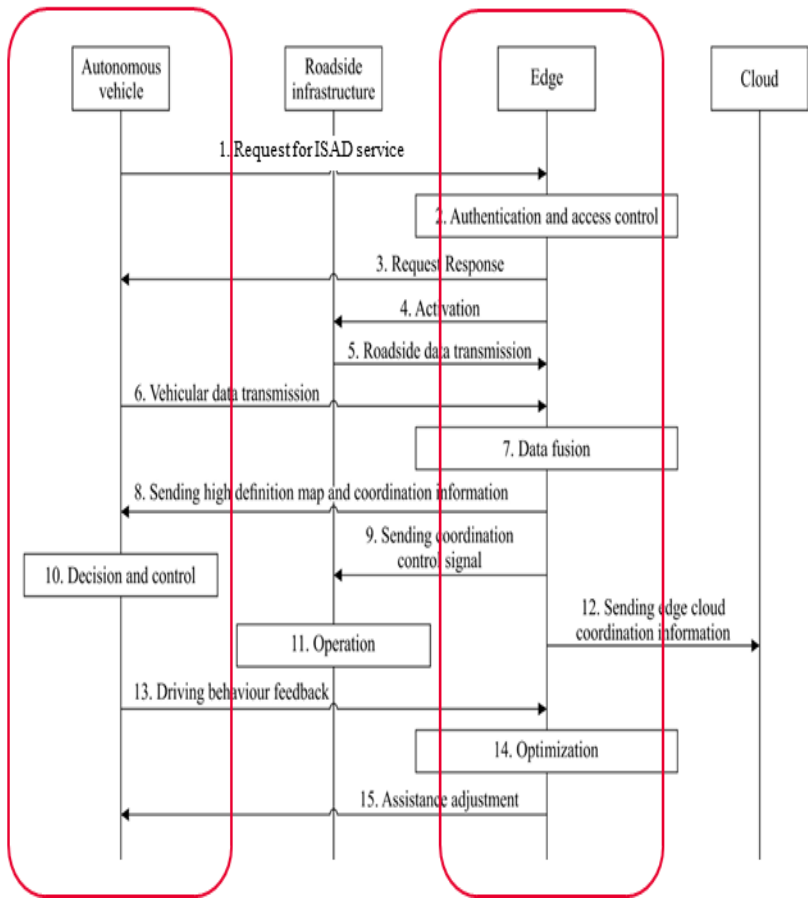




**Spectrum estimates by 5GAA 2020**

|  |  | Spectrum needs (MHz) | | |
| --- | --- | --- | --- | --- |
|  |  | Rural | Urban | Dense urban |
| V2N | Software Update of Reconfigurable Radio System (DL) | 12 | 2 | 3 |
|  | Autonomous Vehicle Disengagement Report (UL) | 13 | 4* | 4* |
|  | Patient Transport Monitoring (UL) | 25 | 8* | 8* |
|  | Tele-Operated Driving (UL) | 100 | 30* | 30* |
|  | Obstructed View Assist (DL) | ** | 45 | 90 |
|  | Infrastructure Assisted Environment Perception (UL) | ** | 92 – 184 | |
|  | In-vehicle entertainment (DL) | ** | 450 | 900 |
|  | High Definition Map Collection and Sharing (UL) | ** | 360 | 720 |
|  | * The urban and dense urban sectors must both support at least one user. <br> ** To meet the use case requirements, an increased spectrum availability is not sufficient in itself, but needs to be complemented with improved network and device capabilities, and is under consideration by 5GAA. | | | |
| V2V/I/P | 70-75 MHz of ITS spectrum in the 5.9 GHz band (allocated in many regions and under consideration in other regions) is needed to support the basic safety and advanced use cases under consideration today. This demand is valid for all geographical areas. | | | |

# ISAD components and requirements in China
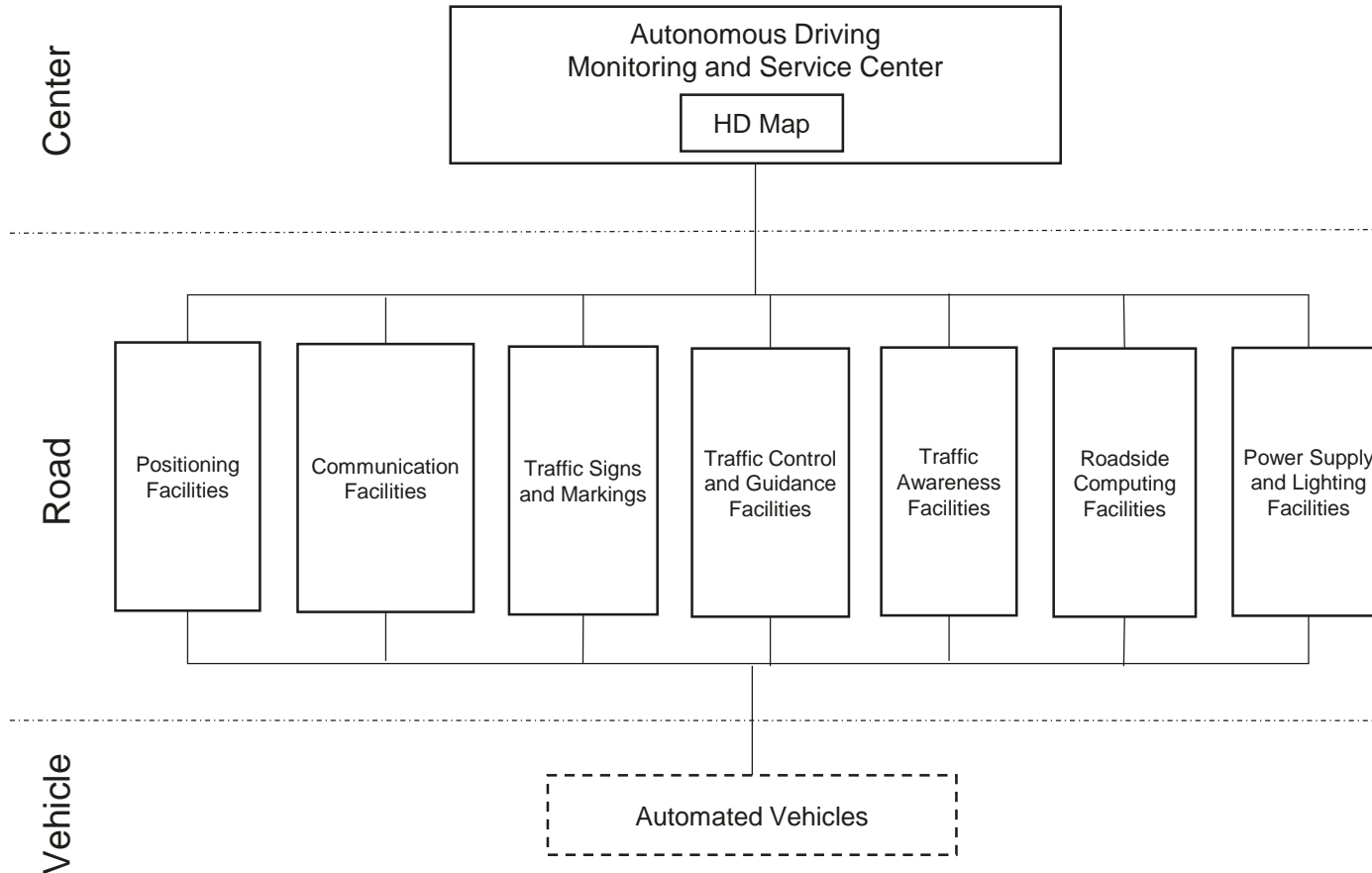


## Some concrete requirements:

- Absolute precision >=1 m, and a relative error <= 0.1 m for every 100 m.

- For warning type I2V services: Freq. Band: 5905~5925MHz, Broadcast, Comm. distance >=300m, BLER<=5%, Latency <= 50ms
- For higher level AD services: Broadcast and Unicast, 5G+I2V, latency <=10ms

- The cyber security level of the autonomous driving monitoring and service center should not be lower than the level-3 security requirements in Information Security Technology - Basic Requirements for Cyber Security Graded Protection (GB/T 22239).

# 5GCAM, Safety and Infotainment Services
## (Integrated view)



Service Provider-5GCAM

MNO frequencies

Infotainment

Safety

5GCAM
(e.g. truck platooning, teleoperated driving, AD support)

f1 — MNO1 + 5GCAM | MNO1 | MNO1 + 5GCAM

f2 — MNO2 | MNO2 + 5GCAM | MNO2

ITS 5.9 GHz

Safety | Safety | Safety

x km

MNO1/RO site | MNO2/RO site | MNO1/RO site

Highway Segment 1
e.g. 100 km | HS 2 | HS 3

MNO/RO costs sharing model for fiber, power, stationary road sensors, 5G sites

RO: Road Operator, MNO: Mobile Network Operator

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# Total Cost of Ownership for 100 km Smart Road type A

| 100km costs [Euro] | Percentage |
|---|---|
| Spectrum | 1% |
| Sites | 99% |
| MEC | 0.0147% |
| Supplementary CCAM service costs per vehicle | 0.0001% |
| Network CCAM service costs | 0.0000% |
| ToD human driver | 0.0038% |
| Total | 100% |

**100km road building costs: 600 Meuro – 2 Beuro !!**
**5G site costs vs road costs: 0.55 % - 1.8 %**
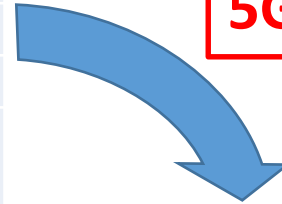
5G average site costs:

| | Parameter | Value | Unit |
|---|---|---|---|
| Deployment costs | 5G site (CAPEX) | 64 000 | Euro per site |
| | Civil works (CAPEX) | 20 500 | Euro per site |
| | Fibre backhaul (CAPEX) | 23 000 | Euro per km |
| | Network operation (OPEX) | 10 | % of total CAPEX |
| | Site lease (OPEX) | 5 700 | Euro per site |

Assumptions:
- Spectrum costs based on German auction in 2019 for C-Band (3.x GHz)
- 1 MEC for 20000 road km
- 5G sites: 80 % new sites and 20% upgraded sites for 100 sites / 100 km
- Teleoperated driver for L4/5 as backup service

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# Main Business Setup for the Network Deployment Analysis
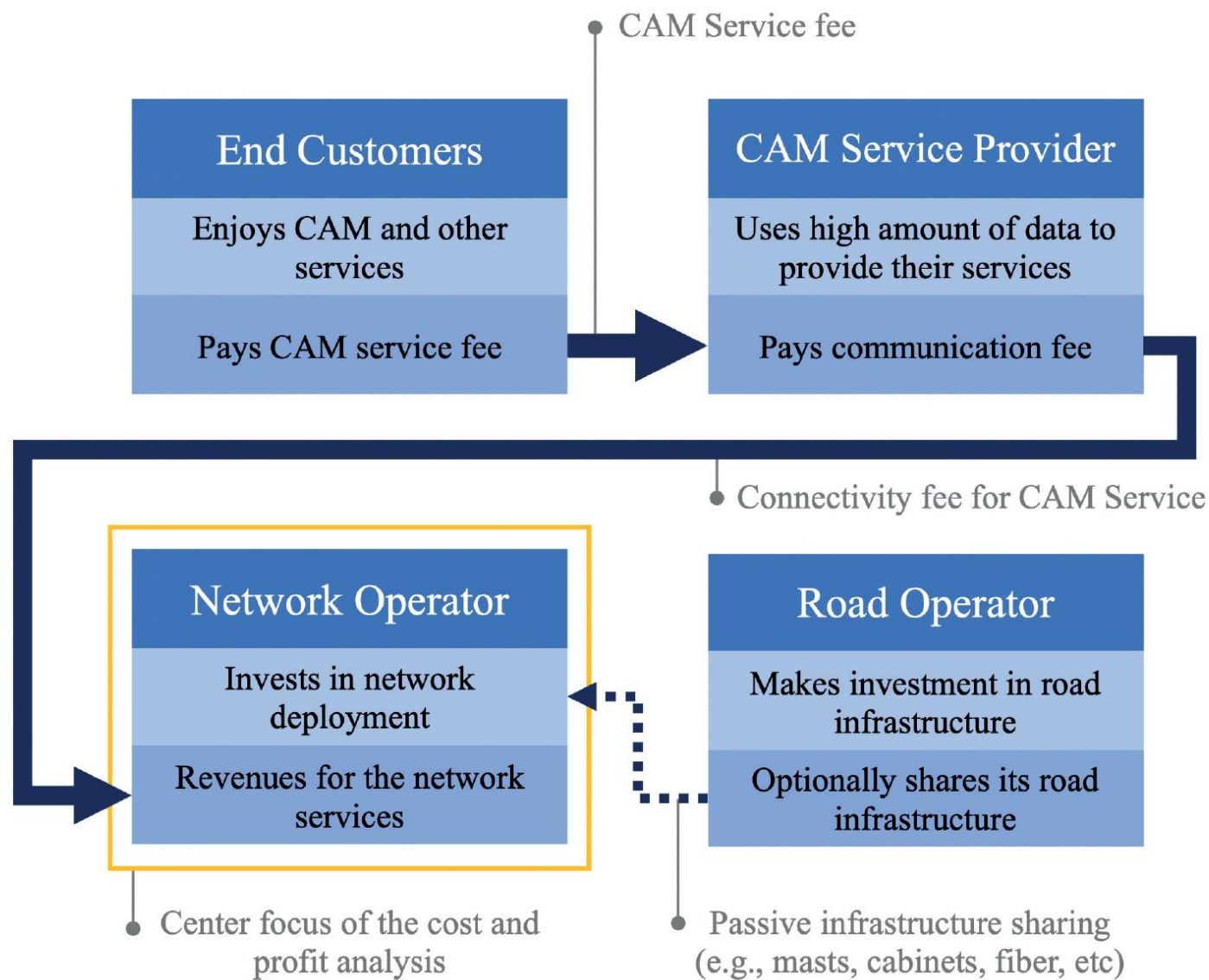
# Deployment and Sharing Options

| | Revenue 1 | Revenue 2 |
|---|---|---|
| **Deployment 1** | A single network operator makes a full deployment and provides connectivity to all vehicles on the highway.<br><br>This can be interpreted as the case where all vehicles are served by the same network, using **national roaming**. | More than one network operator makes a full deployment, each provides connectivity only to its subscribers on the highway.<br><br>In a realistic interpretation, this could be the case of parallel network deployments with **no investment nor network sharing**. |
| **Deployment 2** | A single network operator makes a deployment, sharing road infrastructure; it provides connectivity to all vehicles on the highway.<br><br>This can be the case where all vehicles are served by the same network by using **national roaming and passive sharing** with the road operator. | More than one network operator makes a deployment, sharing road infrastructure; each provides connectivity only to its subscribers on the highway.<br><br>In a realistic interpretation, this could be the case of parallel network deployment; with **passive sharing** of elements with the road operator. |
| **Deployment 3** | | More than one network operator makes a deployment, sharing network and road infrastructure; each provides connectivity only to its subscribers on the highway.<br><br>In a realistic interpretation, this could be the case of **active network sharing**. |

# 5G V2X Business Case for Pay-As-You-Drive
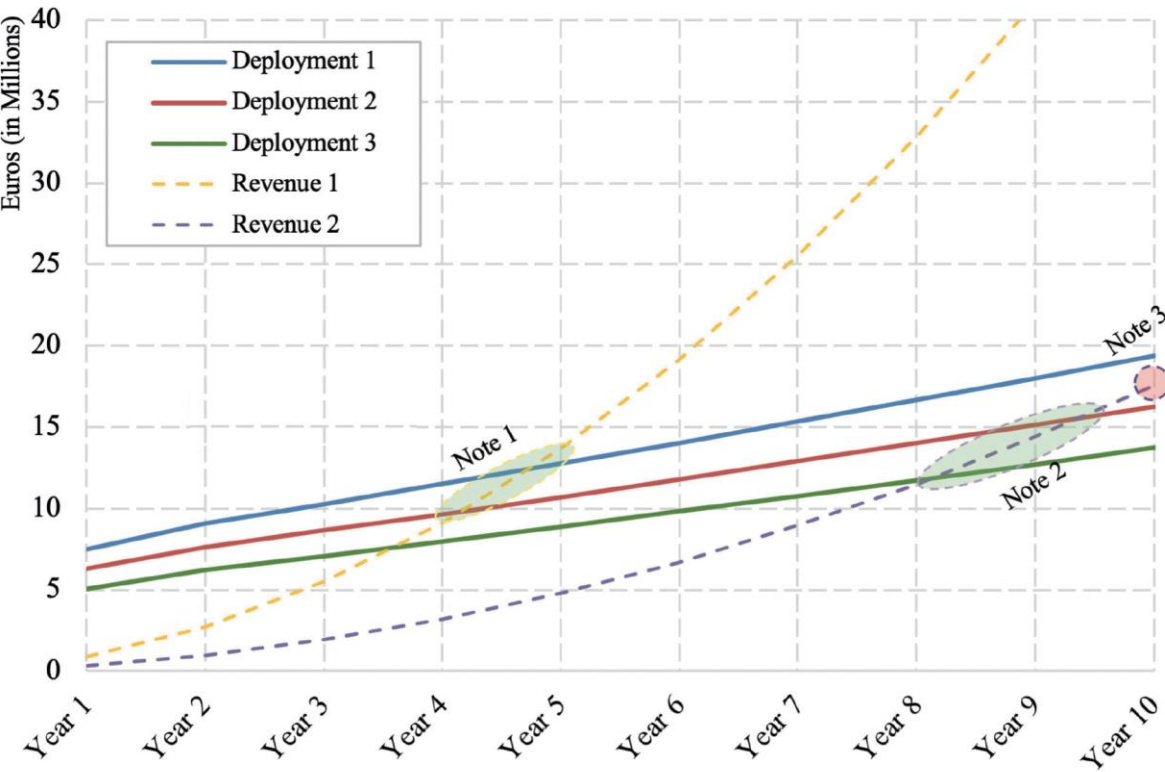


Return-Of-Investment

| | Parameter | Value | Unit |
|---|---|---|---|
| Area and capacity demand | Inter-site-distance (ISD) | 1 | km |
| | Deployment length | 100 | km |
| | Number of vehicles | 50 000 | Vehicles/100km/day |
| Deployment rate | Connectivity and CCAM costs | 0.5 | Euro per 100 km |
| | Network deployment rate | 55 | % for year 1 for coverage |
| | | 5 | % from year 2 to 10 for capacity |
| | Fiber deployment rate | 80 | % year 1 |
| | | 20 | % year 2 |
| | Yearly penetration rate | 10 | % from year 1 to 10 |
| Costs evolution | CAPEX Yearly price evolution | -3 | % from year 1 to 10 |
| | OPEX Yearly price evolution | 3 | % from year 1 to 10 |

Investment Assumptions

# Thank You

https://5gcar.eu/