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IN2CCAM

D2.2

Study questions and KPIs of CCAM ecosystem

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ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
AI	Artificial Intelligence
ARCADE	Aligning Research & Innovation for Connected and Automated Driving in Europe
AV	Automated Vehicle
CAV	Connected and Automated Vehicle
CAD	Connected and Automated Driving
CCAM	Cooperative, Connected and Automated Mobility
CCAV	Cooperative, Connected and Automated Vehicle
C-ITS	Cooperative Intelligent Transport Systems
FAME	Framework for coordination of Automated Mobility in Europe
FESTA	Field opErational teSt supporT Action
FOT	Field Operational Test
GLOSA	Green Light Optimal Speed Advice
HMI	Human Machine Interface
ICT	Information and Communications Technology
IoT	Internet of Things
KPI	Key Performance Indicator
LL	Living Lab
MaaS	Mobility-as-a-Service
ML	Machine Learning
MONKEY	MObility Network: KEY smart solutions

NDS	Naturalistic Driving Study
OBU	On-Board Unit
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PM	Particulate Matter
QoS	Quality of Service
RCC	Remote Control Centre
ROC	Remote Operation Centre
RSU	Roadside Unit
SPAT	Signal Phase and Timing
SUMP	Sustainable Urban Mobility Plan
SVR	Traffic Supervisor
TCC	Traffic Control Centre
TLCM	Traffic Light Control and Management
TMC	Traffic Management Centre
UTC	Urban Traffic Control
UVAR	Urban Vehicle Access Restriction Area
V2X	Vehicle to everything
V2I	Vehicle to infrastructure
VMP	Vehicle Management Plan
VRU	Vulnerable Road User
WP	Work Package

1 EXECUTIVE SUMMARY

Connected, Co-operative, and Automated Mobility (CCAM) EU pilot projects, among others, require the definition of *Study Questions* and *Key Performance Indicators (KPIs)* to serve as a roadmap for effectively monitoring and evaluating their progress in terms of different categories. Establishing a robust monitoring and evaluation framework allows project stakeholders to assess the alignment with project objectives and evaluate their impact on various areas such as mobility, society, economy, environment, and others.

In this project, the Study Questions and associated KPIs have been selected in relation to a set of *Use Cases* and *Test Scenarios* that each Living Lab (LL) has defined according to the available CCAM infrastructure and vehicles, their expertise, and their aspirations towards their next planned steps in automated driving applications and urban mobility plans in general. The use cases and test scenarios are discussed in detail in D2.3 ‘Use cases definition’.

All the LLs, except for the Follower LL of Quadrilátero, will be conducting pilot trials of innovative services in real-life conditions. In addition, the LLs of Trikala, Turin, Bari, Vigo, and Quadrilátero will utilise simulation models in some or all of their test scenarios in order to scale up and assess their broader impact. Those use cases have been instrumental in shaping the formulation of the Study Questions and KPIs.

The methodological framework for the definition of the Study Questions and KPIs is based on the guidelines of Micro-FESTA (Barnard et al., 2021), a condensed version of the FESTA (Field opErational teSt supporT Action) methodology, which is suitable for small pilot projects testing CCAM.

The Study Questions and KPIs have been defined to correspond with the objectives of the project. These measurable indicators are designed to gauge the impact of IN2CCAM and they can either be:

- usage (e.g., trip characteristics such as speed and travel time),
- quality of service,
- traffic safety and efficiency,
- acceptance,
- environmental, or
- economic indicators.

Overall, this deliverable discusses the output of Task 2.4 ‘Study questions, impact areas, and KPIs of CCAM ecosystem’. Subsequent tasks, such as Task 4.4 ‘Data collection monitoring and systems refinement’ and Task 5.1 ‘Methodology for impact assessment’ will refine the indicators and delve into greater detail.

2 INTRODUCTION

2.1 Project intro

The IN2CCAM (Enhancing Integration and Interoperability of CCAM eco-system) project is an Innovation Action referring to the Horizon Europe call HORIZON-CL5-2022-D6-01-04: Integrate CCAM services in fleet and traffic management systems (CCAM Partnership).

The IN2CCAM consortium aims to develop, implement, and demonstrate innovative services for connected and automated vehicles, infrastructure, and users. This is all in accordance with the vision of the Horizon Europe framework programme (2021-2027), which seeks to accelerate the implementation of innovative CCAM technologies and systems for passengers and goods.

At the core of IN2CCAM there are a total of six LLs, which will implement a full integration of CCAM services in their transport systems. A set of physical, digital, and operational solutions will be proposed and implemented in four Lead LLs: Tampere (Finland), Trikala (Greece), Turin (Italy) and Vigo (Spain). Furthermore, two Follower LLs will take part in the design phase by providing ideas and data assessed by simulation test and validation: Bari (Italy) and Quadrilátero (Portugal).

As a whole, the IN2CCAM consortium expects that the full integration of CCAM services in future mobility will primarily benefit: (a) safety (i.e. reducing the number of road accidents due to human error); (b) the environment (i.e. reducing transport emissions and congestion by smoothening traffic flow and avoiding unnecessary trips); and (c) inclusiveness (i.e. ensuring inclusive mobility and good access for all).

2.2 Purpose of the deliverable

Deliverable 2.2 is the second out of the three deliverables submitted in Work Package 2 (WP2). Following the methodological framework and the guidelines described in previous European projects relevant to automated driving, a set of Study Questions and KPIs have been selected specifically for each of the LLs of IN2CCAM. The purpose of this deliverable is to define those indicators and to discuss how and why they have been selected. Essentially, this deliverable presents the output of Task 2.4 ‘Study questions, impact areas, and KPIs of CCAM ecosystem’ which involved extensive discussions and engagement with the LLs in the previous months.

2.3 Intended audience

The dissemination level of D2.2 is public (DU), although it is primarily meant for the members of the IN2CCAM project consortium. The Study Questions and KPIs discussed in this deliverable will be used in subsequent tasks in WP4 and WP5, mainly in the following:

- Task 4.4 ‘Data collection monitoring and systems refinement’ which will, among others, deliver the tools for collecting, storing, and managing the data from the demonstrations and for calculating the KPIs.
- Task 5.1 ‘Methodology for impact assessment’, which will define the methods to calculate the KPIs, the data which are going to be required, the data formats, the relative weights of importance, and the sample sizes, among others.
- Task 5.3 ‘A posteriori users’ attitudes and social acceptance’, which will evaluate the social acceptance and social impact of the IN2CCAM innovations. The process of analysing and assessing acceptance will use the outputs of Task 2.4 as input.
- Task 5.5 ‘Traffic efficiency improvements evaluation’, which will utilise the KPIs to evaluate the integration of the CCAM services with existing platforms and traffic control centres of the LLs by determining the KPIs described in T2.4 and computed by the data collected in T4.4.

2.4 Structure of the deliverable and its relation with other work packages/deliverables

Following this introduction, Chapter 3 discusses the methodology used for the selection and definition of the Study Questions and the KPIs in the six Living Labs of IN2CCAM.

Chapter 4 discusses the Use Cases and Test Scenarios that the Living Labs have selected to research and implement.

Chapter 6 includes the conclusion of the deliverable.

3 METHODOLOGY

The methodological framework used for the selection and definition of the Study Questions and the KPIs) in the six Living Labs of IN2CCAM is discussed in this chapter.

The EU has been investing in the continuous development of a knowledge base on Connected and Automated Driving (CAD), first with the Horizon 2020 action ARCADE, and currently, with the FAME project. In this collection of knowledge, one can find guidelines and evaluation methods, among others, including the FESTA (Field opErational teSt supporT Action) Handbook, a detailed guideline on how Field Operational Tests (FOTs) and Naturalistic Driving Studies (NDSs) should be conducted.

The **FOTs** are described, according to the 8th version of the FESTA Handbook as *'studies undertaken to evaluate a function, or functions, under normal operating conditions in road traffic environments typically encountered by the participants using study design so as to identify real-world effects and benefits'* (FESTA et al., 2021). In other words, FOTs refer to 'large-scale' testing programmes that aim at a comprehensive assessment of the efficiency, quality, robustness, and acceptance of ICT (Information and Communications Technology) solutions in transport (e.g. navigation, traffic information) (FOT-Net Wiki, 2011).

The **NDSs** involve equipping the participants' personal vehicles with unobtrusive devices that continuously monitor various aspects of their driving behaviour, all without the need for a supervisor (Winkelbauer et al., 2010).

The **FESTA** project (2007 - 2008) was commissioned to provide comprehensive guidance for the successful delivery of the first European FOTs (FESTA et al., 2021). Since then, it has been updated by several organisations, including research institutes, OEMs (Original Equipment Manufacturer), and other stakeholders. Its latest version (version 8 at the time of writing) incorporates some of the best practises based on the experience and knowledge from numerous FOTs (FESTA et al., 2021).

However, FESTA is focused on large-scale FOTs, whereas small pilot projects testing CCAM do not have the necessary resources to utilise the FESTA approaches entirely (Barnard et al., 2021). To this aim, **Micro-FESTA**, a more condensed version of FESTA, was published. The latest version of Micro-FESTA is version 2 (at the time of writing) published in 2021.

In the context of IN2CCAM, the six participating Living Labs have defined a set of **Use Cases** and **Test Scenarios** that they will implement. Due to the small scale of those scenarios, it is more appropriate to follow the guidance and methodological framework described in Micro-FESTA.

3.1 The FESTA methodology

The FESTA methodology is summarised in the so-called FESTA V in Figure 1.

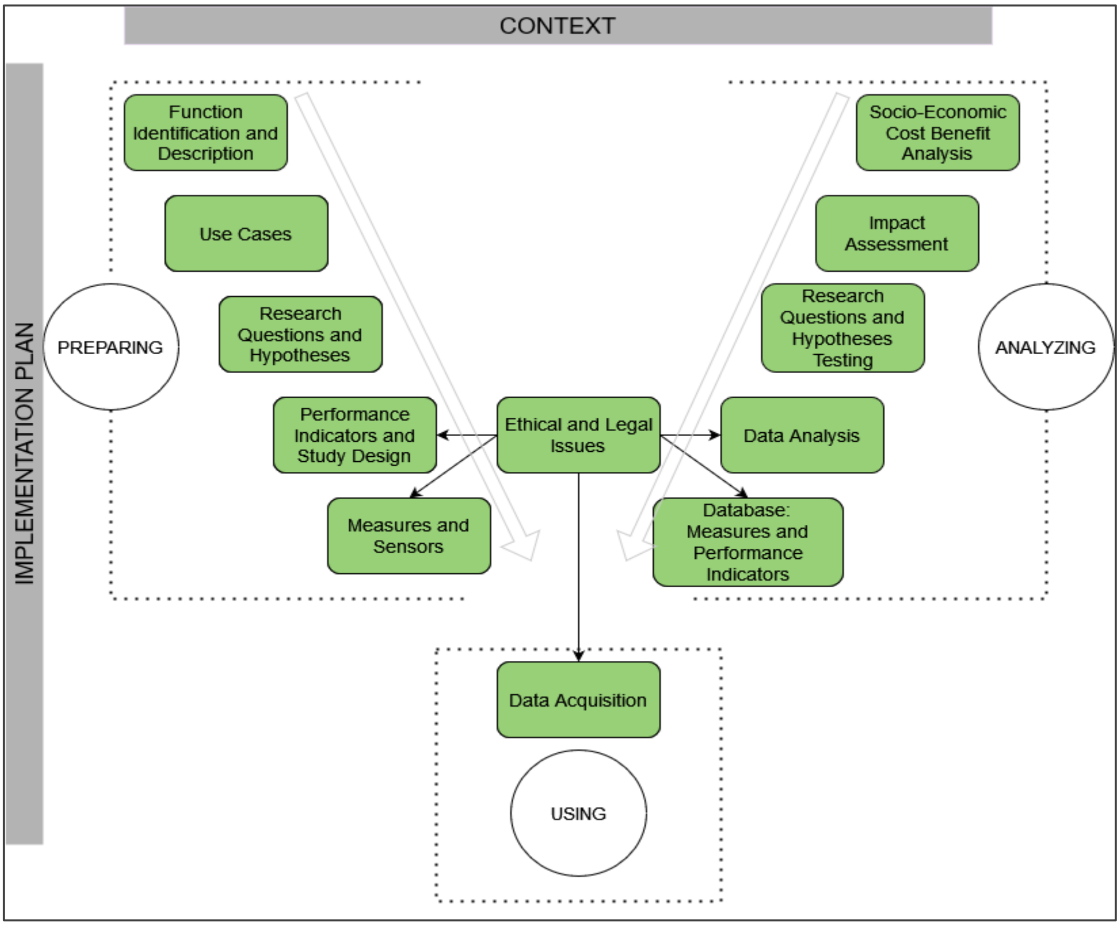

Figure 1: The FESTA V diagram

This methodology, inspired by traditional impact areas of vehicle ICT, such as safety, mobility, environment, and efficiency, highlights the importance of defining research questions and hypotheses, (Barnard et al., 2021).

The **Micro-FESTA** approach uses the three main phases of the FESTA V and discusses their use in pilot projects (Barnard et al., 2021).

1. Preparing

- **Micro-FESTA methodology**
  - **Defining the pilot** (functions, use cases, research questions)

    In this first step, the functions to be tested must be properly defined; this can be anything from a pioneer automation function to a whole automated service. Afterwards, specific use cases and the conditions under which those functions or services will be tested are defined. Then, the research questions that the pilots are going to answer are defined. This is a crucial and usually time-consuming and iterative process. Each pilot can address a numbered set of research questions and it is the responsibility of the stakeholders to prioritise the ones which are the most important to them.

- **Preparing the pilot** (performance indicators, study design, measures/sensors, recruiting participants)

  This stage includes defining and describing the performance indicators as well as how they will be measured and the study procedure, stating information such as the location, the duration, and the participants of the pilot. Study design parameters should take into consideration data adequacy, safety aspects, as well as legal and ethical issues, among others. The tools needed to measure the indicators, such as sensors or cameras, and the expected cost of purchasing them are also parts of the preparation. Lastly, if people external to the project must be involved (e.g., to answer a questionnaire), recruiting them and creating a perfectly balanced sample could be a time-wasting task.

- **In the case of IN2CCAM**

  All the LLs in this project have CCAM as an important aspect of their future mobility planning and have participated in previous relevant EU Horizon projects. Hence, different types of infrastructure, automated vehicles, experience, and expertise were already available. The IN2CCAM use cases and scenarios were designed according to the available resources and the future planning of each LL towards connected, co-operated, and automated mobility.

  Specifically, a number of *automation functions*, such as:
  - Green Light Optimal Speed Advice (GLOSA),
  - interaction between Automated Vehicles (AVs) and public transport,
  - awareness of Vulnerable Road Users (VRUs),
  - dynamic AV re-routing,
  - remote monitoring and supervision of Connected and Automated Vehicles (CAVs), and
  - AV platoon coordination,

  along with *automated services* like:
  - last-mile deliveries with automated vehicles and
  - a demand-responsive journey planner,

  will be researched and developed. The services that each Living Lab will develop in this project are discussed in detail in D2.3 ‘Use cases definition’.

  The *indicators* which have been introduced for the evaluation of the progress of those Use Cases are related (but not limited) to one or more of the following categories:

(a) usage (e.g., trip characteristics such as speed and travel time); (b) quality of service; (c) traffic safety and efficiency; (d) acceptance; (e) environmental; and (f) economic.

The quantitative data needed to calculate the KPIs will be collected via different systems. Some of them are collected using cameras (e.g., detection of VRUs at crossroads), sensors, or other on-board units (OBU), while others are the result of interaction between a traffic management system and a fleet of CAVs. In addition, qualitative data will be collected via surveys that will be circulated during and following the pilots to gauge user acceptance.

2. Using

- **Methodology**
  - **Pre-test procedures**

    To ensure that everything is ready for the pilots to begin, pre-testing is required as unexpected difficulties may arise even in the case of the most carefully planned trials. The researchers should be careful, critical, and precise during trials, especially when they test novel and prototype systems. In addition, data management and evaluation methods are also within the scope of pre-testing to ensure that the appropriate data will be collected during the pilots and their potential to yield meaningful results.

  - **Perform the tests and collect the data**

    Test pilots like these involve real users. Keeping a detailed log of what is happening during the pilots, especially significant events like system breakdowns, extreme traffic, and unusual weather conditions may prove important in the post-pilot analysis. Furthermore, patterns and insights which were not originally expected might arise while analysing the observed datasets. Lastly, any significant changes to the tested systems should be avoided or at least kept to minimal level during this stage to prevent difficulties in data analysis later.

- **In the case of IN2CCAM**

  The circulation of AVs in mixed traffic conditions carries a great responsibility for all the LLs. All the tests need to be pre-defined and an abundance of safety systems should be in place. Bad user experience, or even accidents, should be avoided by all means. The Living Labs and the technical partners involved need to perform adequate pre-testing in controlled environments (e.g. pre-testing the driving functions in dedicated areas without traffic) and familiarise with all the systems and infrastructure involved, the data exchanges, and the C-ITS communications to minimise the risk of unseen challenges. In addition, before deploying the services at full scale, the pilots should begin with smaller scale tests during quiet times and in uncrowded places.

3. Analysing

- **Methodology**
  - **Analysing the data** (data storage and processing, data analysis, answering research questions)

    Due to the large number of stakeholders, even in small-scale projects, data must be stored safely and securely, always aligned with regulations about data protection and privacy. The data management practises must be agreed at the very initial stages of the project and the relevant data, metadata, and processing steps should be well documented. The analysis, which is usually conducted by specialists, mainly comprises a combination of statistical and descriptive methods and leads to providing concise and clear answers to the research questions posed. The results should be presented in comprehensible ways, so that stakeholders can understand them. Indicators are measured at this stage and specialised software may be needed to calculate them.

  - **Determining the impact** (impact assessment, deployment scenarios, cost-benefit analysis)

    In the last phase, the results must be scaled up and the impacts of a wider use of those systems should be considered. Mathematical modelling, simulations, and future scenarios involving different penetration rates and stricter or looser regulations, among other scenarios, are some of the ways to estimate future impacts. In addition, a stakeholder analysis, throughout the duration of the project, is required to ensure the continuous engagement of the different stakeholders and to indicate which groups can benefit and what the impacts of those services are going to be for the all the relevant parties involved. Lastly, the costs and benefits of deploying those services should be studied in a Cost and Benefit analysis and, in communication with the stakeholders, the future roadmaps and business models should be developed.

- **In the case of IN2CCAM**

  Starting with data, all the details regarding storing and managing the relevant dataset are detailed in the Data Management Plan of IN2CCAM. Then, in terms of indicators, the project will evaluate the performance of the LLs and the test scenarios according to the KPIs which are discussed in Chapter 4. In addition, hypothetical scenarios with large fleets of AVs or other services which are difficult to test in real-life (e.g., changing parking availability) will be simulated using state-of-the-art traffic simulation software (e.g., PTV VISSIM, AIMSUN). Lastly, WP6 ‘Evidence-based guidance, policies and regulatory recommendations for CCAM services’ will develop an evidence-based governance framework, business models, and policy and regulatory recommendations for a widespread uptake of the IN2CCAM services and applications.

4 STUDY QUESTIONS AND KPIS

This chapter discusses the *Study Questions* and *KPIs* that were selected in Task 2.4 of WP2. Their selection is directly influenced by the *Use Cases* and *Test Scenarios* that the Living Labs will be implementing in later stages of IN2CCAM. Their definition is the result of constructive discussions and an ongoing dialogue with each of the LLs. In this way, they are well-aligned with the project's objectives and grounded in real-world application.

Each of the LLs will be deploying, developing, and testing different technologies and services. Except for Quadrilátero, one of the two Follower LLs, all the other LLs will be conducting pilot trials of innovative services in real-life conditions. In addition, the LLs of Trikala, Turin, Bari, Vigo, and Quadrilátero will utilise simulation models in a few or all the Test Scenarios.

These measurable indicators are designed to gauge the impact of IN2CCAM in various aspects such as usage, traffic efficiency and safety, acceptance, quality of service, environment, and economy.

However, it is important to highlight that the objective of Task 2.4 is to prepare the Study Questions and give an overview of the KPIs which will be evaluated, rather than providing a detailed description of those. The KPIs will be discussed in detail in a subsequent task of the project, namely in Task 5.1 'Methodology for impact assessment'. Task 5.1 will define the methods to calculate the KPIs, the data which are going to be required, the data formats, the relative weights of importance, and the sample sizes, among others.

The *Study Questions*, the *Use Cases*, and the *Test Scenarios* that each Living Lab has decided to focus on are presented in the following sections of this chapter.

4.1 Tampere

Tampere is a large city in Finland with a population exceeding 200,000. The pilot use case is conducted in Hervanta LL Test Bed for CCAM, and the main stakeholders involved are Finntraffic TMC, City of Tampere and the Finnish Transport Infrastructure Agency. A few key information about Tampere and its Use Case are discussed below.

ICT platforms, Infrastructure, equipment and AVs

The Traffic Management Centre (TMC) operates 24 hours a day; a fibre optical network connects the TMC with Roadside Units (RSUs) and traffic lights all over the city. The Remote Operation Centre (ROC) has a 5G network connection with CAVs and the Hervanta Digital Twin is hosted within the ROC. Fintraffic is responsible for collecting and analysing data, including traffic and weather conditions in the network, as well as sending warnings and messages via appropriate protocols. A traffic light equipped with LTE/5G communication platform and a camera system for monitoring and incident detection are the main infrastructures utilised on the planned CCAV routes. The fleet comprises of 5 SAE Level 4 automated shuttles, owned by both public and private mobility stakeholders, equipped with environment perception sensors, and capable to send and receive messages related to mobility, manoeuvring, and course deviating.

Proposed Use Case

The cooperation between the TMC and the ROC allow the successful monitoring of the CCAM fleet and improve the citizens' mobility. A digital twin for modelling, service optimisation, and simulation, along with a 3D high-definition map, are the main components of the platform run by the LL. Furthermore, a new Mobility Hub integrating public transport, CCAV, bicycles, micro mobility devices and pedestrians is deployed. The demonstration is expected to last 1 year, after 6 months of set up and calibration.

4.1.1 Use Cases and Test Scenarios

Use Case 1: Integration of traffic and CCAM fleet.

*Table 1: Test Scenario 1 – **GLOSA for Automated Vehicle** (Lead LL of Tampere)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How does the automated vehicle change **behaviour** in response to the warnings and information provided by the service? • Is the vehicle's **speed** compliant with the suggested speed? • Does the vehicle start quicker after the traffic light turns green?	**TAM.1.1.01** **Speed adaptation** (i.e., difference between the speed of the vehicle before and after the C-ITS message, instantaneous accelerations and decelerations)	Usage	Real
	TAM.1.1.02 **Difference** between the **speed** suggested by GLOSA and the speed implemented by the vehicle or the safety driver	Usage	
	TAM.1.1.03 The **frequency** of uninterrupted vehicle crossings through traffic lights due to speed adaptation (compared to crossings without the use of GLOSA)	Usage	
	TAM.1.1.04 **Intersection crossing time** (compared to crossings without the use of GLOSA)	Usage	
	TAM.1.1.05 **User acceptance** of the app that the safety driver will be using	User Acceptance	

*Table 2: Test Scenario 2 – **Public Transport vehicle crossing alert for AV** (Lead LL of Tampere)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How does the automated vehicle change **behaviour** in response to the warnings and information provided by the service?	**TAM.1.2.01** **AV driving adaptation** (difference between the AV starting time from the bus stop before and after the C-ITS message).	Usage	Real
	TAM1.2.02 **Stopping time** and impact on the **AV travel time**.	Usage	

• How does this service affect the **travel time** of the AV? • How does this service affect the **travel time** of the tram?	**TAM1.2.03** **Impact on the tram travel time**	Traffic Efficiency	
	TAM1.2.04 **User acceptance** of the app that the safety driver will be using	User Acceptance	

*Table 3: Test Scenario 3 – **AV detected event** (Lead LL of Tampere)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How **accurate** is the AV in detecting obstacles or events on the road? • Does this service improve the **response time** to mitigate the detected event?	**TAM1.3.01** **Success rate for obstacle or event detection** (difference between the number of detections by AV environment perception and detections by the safety operator)	QoS	Real
	TAM1.3.02 **Number of messages** between the **vehicle** and the Remote Operation Centre (**ROC**)	Usage	
	TAM1.3.03 **Reaction of the ROC operator** (i.e., manual remote operation of AV to overtake the obstacle, informing the public transport management centre, etc.)	Traffic Safety	

4.2 Trikala

Trikala is a city located in the centre of continental Greece, inhabited by approximately 80,000 people. The pilot use case is conducted in a pre-determined line connecting a suburban area with the town centre, where the terminal of the intercity bus station is located.

ICT platforms, Infrastructure, equipment and AVs

A Remote Control Centre (RCC) is deployed close to the town centre; from there, a controller monitors the AV fleet, and intervenes when needed, either using a manoeuvres execution mechanism or via an emergency button in order to immobilise the AV. The Trikala Fleet Management platform operates inside the RCC infrastructure, and along with the Traffic Management Centre (TMC), can provide event, traffic, and route-related reports as well as real-time geolocation of the AV fleet. Finally, the cloud-hosted Traffic Light Control and Management (TLCM) platform will: (a) allow for a two-way communication with traffic light controllers, (b) implement specific traffic signalling programs, (c) interact with the TMC, and (d) monitor the operation of signalised junctions, among others.

In addition, the SMARTA 2 project has developed a smartphone application that provides Mobility-as-a-Service (MaaS) solutions. In IN2CCAM, a more advanced journey planner, which is expected to include on-demand CCAM as well, will be developed. The platform will inform the end-user about expected arrival and travel times, along with other traffic-related information.

The communication, in the form of Cooperative Intelligent Transport Systems (C-ITS) messages, between the RCC and the fleet of AVs is served by a commercial 4G/LTE network and a 5G test network, while wireless vehicles' detection sensors, wireless transponders for this type of sensors, and wireless access points are deployed across Trikala. The fleet consists of 2 6-seated autonomous minivans with a SAE level of autonomy equal to 4.

Proposed Use Case

The remote monitoring of the AV fleet, based on real-time information, and the efficient communication between vehicles and RSUs are prominent goals of the use case conducted by the Trikala LL. The AV fleet will be prioritised via the exchange of messages between the TMC and the TLCM, and traffic-based 'green wave' will be implemented to improve the journeys made with AVs. In addition, a journey planner, which will integrate public transport and on-demand AV services, will be developed.

4.2.1 Use Cases and Test Scenarios

Use Case 1: Remote monitoring and supervision of AVs fleet for safe and efficient operations, and real-time communication between vehicles and infrastructure.

*Table 4: Test Scenario 1 - **Traffic-based green wave via the Trikala TMS** (Lead LL of Trikala)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How are the **travel times** of the AV affected by the implementation of a traffic-based green wave? • How is the **travel experience** of the passengers affected by the implementation of a traffic-based green wave (i.e., smoother travel experience due to less decelerating and accelerating at the signalised junctions)?	**TRI.1.1.01** **Travel time** (i.e., changes to the overall travel time due to the optimisation of the phases at the signalised junctions)	Usage	Real
	TRI.1.1.02 The **frequency** of uninterrupted vehicle crossings through traffic lights due to the traffic-based green wave in place	Traffic Efficiency	

*Table 5: Test Scenario 2 – **GLOSA for AV** (Lead LL of Trikala)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How do vehicles change their **behaviour** in response to the warnings and information provided by the service? • Is **safety** affected by changes in driver behaviour due to GLOSA?	**TRI.1.2.01** **Speed adaptation** (i.e., difference between the speed of the vehicle before and after the C-ITS message, instantaneous accelerations and decelerations)	Usage	Real
	TRI.1.2.02 **Difference** between the speed suggested by GLOSA and the speed implemented by the vehicle or the safety driver	Usage	
	TRI.1.2.03 The **frequency** of uninterrupted vehicle crossings through traffic lights due to speed	Traffic Efficiency	

• Is the vehicle's **speed** compliant with the suggested speed? • Does the vehicle start **quicker** after the traffic light turns green?	adaptation (compared to crossings without the use of GLOSA)		
	TRI.1.2.04 **Intersection crossing time** (compared to crossings without the use of GLOSA)	Traffic Efficiency	
	TRI.1.2.05 **User acceptance** of the GLOSA app that the safety driver will be using	User Acceptance	

*Table 6: Test Scenario 3 – **VRU detection and warning for AV** (Lead LL of Trikala)*

Research Questions	**KPIs**	**Focus Areas**	**Real/ Sim**
• How do vehicles change their **behaviour** in response to the warnings and information provided by the service? • Is **safety** affected by changes in driver behaviour due to GLOSA? • How **safe** and **comfortable** do VRUs feel when they cross the road with this service in place?	**TRI.1.3.01** **Speed adaptation** (i.e., difference between the speed of the vehicle before and after the C-ITS message, instantaneous accelerations and decelerations)	Usage	Real
	TRI.1.3.02 The **frequency** of interrupted vehicle crossings (e.g., the vehicle had to decelerate or completely stop to allow the VRU to cross safely)	Traffic Safety	
	TRI.1.3.03 **User acceptance** of VRUs (i.e., how safe and comfortable do they feel when they cross the road with this service in place)	User Acceptance	

*Table 7: Test Scenario 4 – **Journey planner interconnecting autonomous, demand-responsive solutions with available public transport services** (Lead LL of Trikala)*

Research Questions	**KPIs**	**Focus Areas**	**Real/ Sim**
• Is the service considered **valuable** or **beneficial** by its users? • Do users perceive the deployment of this service as **advantageous** in **promoting** further	**TRI.1.4.01** **User acceptability, acceptance, and appropriation** before, during, and after the pilots (in terms of performance, efficiency, safety, comfort, user-friendliness of the app, etc.)	User Acceptance	Real

utilisation of IN2CCAM services? • How **pleasant** was it to use the service? • Was the **service available** when the service was needed? • Was the **information correct** when the service was active? • Was the **service accurate**? • Was the **service up-to-date**?			

*Table 8: Test Scenario 5 – **Simulation of future scenarios with larger fleets of AVs** (Lead LL of Trikala)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• Are the findings of the previous scenarios **dependent** on the **fleet size** of AVs? Would the results be **different** if **larger fleets of AVs** were used instead? • What would be the impact on **traffic congestion** if **larger fleets of AVs** were used instead? • What would be the impact on **emissions** and **air pollution** if **larger fleets of AVs** were used instead?	**TRI.1.5.01** Impact on **traffic congestion** (i.e., travel times, queues, delays, LOS of intersections) if **larger fleets of AVs** were used instead.	Traffic Efficiency / Economic	Sim
	TRI.1.5.02 Impact on **emissions and air quality** (e.g., total CO2, NOx, PM emissions) if **larger fleets of AVs** were used instead.	Environ-mental	

4.3 Turin

Turin is an important town of north-western Italy, hosting more than 800,000 inhabitants. 5T, a publicly owned company, in cooperation with the Municipality of Turin, monitors the mobility and info-mobility services of the city. 5T is also implementing C-ITS services under the framework of the C-Roads Italy 2 and SHOW projects.

ICT platforms, Infrastructure, equipment and AVs

Across the city of Turin, several platforms and services are deployed and installed:

- The most prevalent of them is the Urban Traffic Control (UTC), an adaptive traffic light management system that, among others, adjusts the traffic light programs and gives priority to public transport.
- The Traffic Supervisor (SVR) is a platform that creates short-term forecasts by retrieving data from the Traffic Control Centre (TCC).
- DATEXII Node, a system responsible for successful communication with other traffic information centres, along with an underpass monitoring system that triggers C-ITS messages, and more than 100 traffic monitoring cameras.
- 5G service that allows efficient vehicle to infrastructure (V2I) short-range communication, with messages mostly related to safety.

The fleet consists of 1 SAE level 3 autonomous shuttle carrying at least 10 people, which will circulate in real mixed traffic with 1 month of setup and 2 months of operation.

Proposed Use Case

The LL of Turin proposes a dynamic traffic management pilot case, where many novel functions will be integrated within the Turin Traffic Control Centre (TCC), in order to provide safety-related, in-vehicle information via V2I technologies. Information retrieved from the CCAVs will be utilised to enhance routing and navigation, safety, and sustainability, and several scenarios will be implemented in traffic simulators. Parking availability and Urban Vehicle Access Restriction Areas (UVARs) are two aspects strongly taken into consideration in the design of the scenario.

4.3.1 Use Cases and Test Scenarios

Use Case 1: Dynamic re-routing.

*Table 9: Test Scenario 1 – **Dynamic re-routing (base scenario = no rerouting)** (Lead LL of Turin)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• What would be the impact on **traffic conditions** due to the dynamic re-routing? • What would be the impact on **safety** due to the dynamic re-routing? • What would be the impact on **emissions and energy consumption** due to the dynamic re-routing? • What would be the impact on the **service** of **data availability and consistency**?	**TUR.1.1.01** Impact on the **CAV energy consumption** of rerouting strategies.	Economic / Environ-mental	Real/ Sim
	TUR.1.1.02 **Travel time for CAVs** (i.e. changes to the overall travel time due to the dynamic re-routing strategy).	Usage	Real/ Sim
	TUR.1.1.03 Impact on **traffic congestion** (i.e. travel times, queues, delays, LOS of intersections) of rerouting strategies **if larger fleets of CAVs** were used instead (different penetration rates will be investigated).	Traffic Efficiency / Economic	Sim
	TUR.1.1.04 Impact on **emissions and air quality** (e.g. total CO2, NOx, PM emissions) of rerouting strategies **if larger fleets of CAVs** were used instead (different penetration rates will be investigated).	Environ-mental	Sim
	TUR.1.1.05 The **frequency** of green-light intersection crossings due to managed traffic-light priority service for CAVs.	Traffic Efficiency	Real/ Sim
	TUR.1.1.06 Impact on **safety** (e.g. accidents, conflicts) of rerouting strategies **if larger fleets of CAVs** were used instead (different penetration rates will be investigated).	Traffic Safety	Sim
	TUR.1.1.07 Impact on rerouting **algorithm efficiency** of data availability **V2X communication**.	Usage	Sim

*Table 10: Test Scenario 2 – **Parking and UVAR publication** (Lead LL of Turin)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• What would be the impact on **traffic conditions** due to the dynamic re-routing? • What would be the impact on **safety** due to the dynamic re-routing? • What would be the impact on **emissions and energy consumption** due to the dynamic re-routing? • What would be the impact on the **service** of **data availability and consistency**?	**TUR.1.2.01** Impact on the **CAV energy consumption** of rerouting strategies.	Economic / Environ-mental	Real/ Sim
	TUR.1.2.02 **Travel time for CAVs** (i.e. changes to the overall travel time due to the dynamic re-routing strategy).	Usage	Real/ Sim
	TUR.1.2.03 Impact on **traffic congestion** (i.e. travel times, queues, delays, LOS of intersections) of rerouting strategies **if larger fleets of CAVs** were used instead (different penetration rates will be investigated).	Traffic Efficiency / Economic	Sim
	TUR.1.2.04 Impact on **emissions and air quality** (e.g. total CO2, NOx, PM emissions) of rerouting strategies **if larger fleets of CAVs** were used instead (different penetration rates will be investigated).	Environ-mental	Sim
	TUR.1.2.05 The **frequency** of green-light intersection crossings due to managed traffic-light priority service for CAVs.	Traffic Efficiency	Real/ Sim
	TUR.1.2.06 Impact on **safety** (e.g. accidents, conflicts) of rerouting strategies **if larger fleets of CAVs** were used instead (different penetration rates will be investigated).	Traffic Safety	Sim
	TUR.1.2.07 Impact on rerouting **algorithm efficiency** of data availability **V2X communication**.	Usage	Sim
	TUR.1.2.08 Impact on **rerouting strategies** of **UVAR/Parking** data availability **V2X communication**.	Usage	Sim

4.4 Vigo

Vigo is a highly industrial and commercial city located in north-western Spain, populated by about 300,000 people.

ICT platforms, infrastructure, equipment and AVs

MISTRAL Smart City platform controls the TMC of Vigo; this platform can perform traffic lights actuation and Vehicle Management Plans (VMPs). In general, it is able to vertically integrate information from different mobility actors. A hybrid C-ITS platform equipped with Day 1 and Day 1.5 C-ITS services is also deployed in the city, while 170 traffic light controllers are connected to the TMC, 110 CCTV cameras have been placed along the city, and 86 RSUs have been installed across intelligent corridors. In addition, there are more than 10 OBU-equipped emergency vehicles. Vigo has been interconnected with more than 150 kms of fibre optic network and several IoT services have been implemented. The CCAV fleet includes two vehicles.

Proposed Use Cases

The first use case focuses on the data interchange between vehicles, infrastructure, and pedestrians or cyclists, with the aim of building a virtual and precise map that will be shared among all the connected users. The installed infrastructure sends information related to traffic lights, roadworks, road incidents, major delays, VRUs, and emergency vehicles to the fleet of AVs. At the same time, AVs send information to the infrastructure such as real-time position and velocity, interactions with vehicles or other road users, and scheduled routes.

In the second use case conducted by Vigo, the traffic management strategy will adapt to CCAM, aiming to enhance the circulation of CCAVs in the city. The prioritisation of CCAVs in signalised intersections as well as the coordination between CCAVs, traffic lights, and emergency vehicles are some of the tools which are going to be tested. The minimisation of the CCAV fleet energy consumption, the effective traffic regulation, the reduction of emissions, and the maximisation of safety are among the goals of this use case.

The fleet consists of 1 CAV SAE level 3-4 from VICOM and 1 CAV SAE level 3-4 from AKKA to demonstrate the Use Cases for 6-7 months of setup and 2 months for demonstration and data collection.

4.4.1 Use Cases and Test Scenarios

Use Case 1: Mutual awareness between CCAM fleet, infrastructure, and other users.

*Table 11: Test Scenario 1 - **Data interchange** (Lead LL of Vigo)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• Is **data sharing** between the CCAV, the vehicles with the Vigo Driving App, Emergency Vehicles using ITS-G5, and the traffic management system **feasible** in Vigo? • Will the implementation of such an ecosystem **increase** the **overall awareness** in the ecosystem and ensure **smooth**, **safe**, and **efficient** trips?	**VIG.1.1.01** **Messages** between the **vehicles** (CCA fleet, cellular-connected vehicles and ITS-G5 connected Emergency Vehicles) and the **traffic management system** (e.g., warnings of approaching emergency vehicles, VRUs, accidents, road works, emergency status activation, real-time position of vehicles, routes).	Usage	Real

Use Case 2: Management strategy adapted to CCAM based on V2I interaction.

*Table 12: Test Scenario 1 – **Traffic light priority for specific CCAM fleet** (Lead LL of Vigo)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How do vehicles change their **behaviour** in response to the information provided? • Is **safety** increased due to avoiding mixed traffic in complex intersections? • How are the **travel times** of the AV affected by the implementation of a traffic light priority system?	**VIG.2.1.01** **Speed adaptation**.	Usage	Real
	VIG.2.1.02 **Travel Time / Average Speed**.	Usage	Real
	VIG.2.1.03 Reduction in **mixed traffic interactions**.	Traffic Safety	Real / Sim

*Table 13: Test Scenario 2 – **Green phase extension for platooning** (Lead LL of Vigo)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How are the **queues of CAVs** affected by the adjustment of green phases?	**VIG.2.2.01** **Number** of **CAV platoons** split by a red light.	Traffic Efficiency	Real

*Table 14: Test Scenario 3 – **Simulation of CCAV reaction to an EV entering a roundabout** (Lead LL of Vigo)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How do vehicles change their **behaviour** in response to the information provided by the service? • Is **safety** increased by allowing EVs to enter roundabouts without conflicting with CCAVs?	**VIG.2.3.01** **Speed adaptation**.	Usage	Sim
	VIG.2.3.02 Reduction in **mixed traffic interactions**.	Traffic Safety	

*Table 15: Test Scenario 4 – **Dynamic re-routing of AV based on traffic load** (Lead LL of Vigo)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How do vehicles change their **behaviour** in response to the information provided by the service? • How does this service affect the **travel time** of the AV? • What would be the impact on **traffic conditions** due to the dynamic re-routing?	**VIG.2.4.01** **Number** of **re-routing messages** received by CCA fleet.	Usage	Real/ Sim
	VIG.2.4.02 **Travel time**.	Usage	
	VIG.2.4.03 **Transferred traffic load** in terms of average daily load (vehicles/day).	Traffic Efficiency	

4.5 Bari

Bari is a densely populated city located in south Italy and has a population of over 300,000 people.

ICT platforms, infrastructure, equipment and AVs

In light of the project MONKEY (MObility Network: KEY smart solutions), a Smart Traffic Management Unit, a traffic control and management application, and the Enabling Platform of Middleware, a platform that allows different urban information systems to communicate effectively via 5G network, have been deployed in the city. Many traffic lights turned into smart ones, while cameras have also been located in various intersections. The public-private partnership Bari Open Innovation was necessary for the innovations and novelties to be carried out.

Proposed Use Cases

The Bari LL will develop a route planner to enhance inclusivity and overcome possible user acceptance barriers. This platform will be able to calculate and propose in real-time routes based on user profile, preferences, and real-time traffic conditions. Special attention will be given in the planner for people with disabilities and those facing gender issues. The platform utilises Artificial Intelligence (AI) and Machine Learning (ML) techniques for the selection of the optimal route in each case.

The second Use Case is about a truck-and-robot system with robot depots that can potentially enable significant cost and traffic reduction compared to classic truck deliveries. The system relies on small autonomous delivery robots to cover the last leg of the delivery process.

4.5.1 Use Cases and Test Scenarios

Use Case 1: Developing and simulating of a Route Planner.

*Table 16: Test Scenario 1 – **CCAV carrying a single able-bodied passenger** (Lead LL of Bari)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• Is the Route Planner **efficient**? In other words, does it successfully select the **optimal route** according to a set of given parameters?	**BAR.1.1.01** **Success** in finding an **optimal route** (i.e. does the simulator always suggest an optimal route without errors?).	Usage	Sim
	BAR.1.1.02 **Computation time** required for the Route Planner to find the optimal route given the number of conditions (e.g., curvatures, slopes, traffic light timings).	Usage	
	BAR.1.1.03 Surveys to assess **user acceptance** in areas where this scenario could be implemented.	User Acceptance	Real

*Table 17: Test Scenario 2 – **CCAV carrying a single passenger with disabilities** (Lead LL of Bari)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• Is the Route Planner **efficient**? In other words, does it successfully select the **optimal route** according to the **increased** set of parameters?	**BAR.1.2.01** **Success** in finding an **optimal route** (i.e. does the simulator always suggest an optimal route without errors?).	Usage	Sim
	BAR.1.2.02 **Computation time** required for the Route Planner to find the optimal route given the **increased** number of conditions (e.g., curvatures, slopes, traffic light timings, safety, comfort, time, energy).	Usage	
	BAR.1.2.03 Surveys to assess **user acceptance** in areas where this scenario could be implemented.	User Acceptance	Real

*Table 18: Test Scenario 3 – **CCAV carpooling** (Lead LL of Bari)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• Is the Route Planner **efficient**? In other words, does it successfully select the **optimal route** according to the **increased** set of parameters? • How does carpooling affect **travel time** compared to using a non-carpooling service? • What is the **impact** of carpooling in the **reduction** of **emissions** and the **number of trips**?	**BAR.1.3.01** **Success** in finding an **optimal route** (i.e. does the simulator always suggest an optimal route without errors?).	Usage	Sim
	BAR.1.3.02 **Computation time** required for the Route Planner to find the optimal route given the increased number of conditions.	Usage	
	BAR.1.3.03 Impact on **travel time** compared to using a non-carpooling service.	Usage	
	BAR.1.3.04 **Estimation** of the **reduction of total emissions** (e.g., CO2, NOx, PM) due to carpooling based on saved km.	Environ-mental	
	BAR.1.3.05 **Reduction** of **total number of trips** made	Traffic Efficiency	
	BAR.1.3.06 Surveys to assess **user acceptance** in areas where this scenario could be implemented	User Acceptance	Real

Use Case 2: Innovative urban freight transport and logistics.

*Table 19: Test Scenarios 1 & 2 – **Delivery in standard conditions & Robot delivery** (Lead LL of Bari)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• Is the use of robots in goods delivery **efficient**? In other words, do the **delivery times and costs improve** when robots are used in the delivery process? • What are the **impacts** on **traffic congestion** and **pollution** within urban areas?	**BAR.2.1.01** **Difference** in **efficiency** between the two delivery systems (e.g., delivery times, punctuality, damages, etc.).	QoS	Real
	BAR.2.1.02 **Impact** on **reducing traffic congestion** within urban areas.	Traffic Efficiency	
	BAR.2.1.03 Surveys to assess **user acceptance** in areas where this scenario could be implemented.	User Acceptance	

4.6 Quadrilátero

Quadrilátero is a non-profit association in Portugal, formed to enhance the partnership network between Barcelos, Braga, Famalicão and Guimarães.

ICT platforms, infrastructure, equipment and AVs

The association has developed an Intelligent Mobility Centre that works as a supportive tool for Sustainable Urban Mobility Plans (SUMPs). The type of real-time data it collects is relevant to traffic conditions, accidents, traffic light asset management, and general information for commuters. Its aim is to enhance urban accessibility and multimodality.

Proposed Use Cases

The Follower LL of Quadrilátero is proposing a simulation engine capable to estimate the performance and impact of different routes to help determine the best one for CCAM, while also considering traffic light control and management. It should allow users to simulate traffic flow in different scenarios, including various vehicle types, traffic rules, and infrastructure layouts.

The simulation capabilities must be highly customisable, allowing users to specify parameters such as vehicle behaviour, traffic light timing, and road networks. The simulations are going to be microscopic, hence they will simulate the movement of individual vehicles in any given traffic scenario. This simulation engine must allow the simulation of CAV behaviour in urban traffic as well. It should model the behaviour of CAVs in different traffic scenarios, such as platooning, merging, and lane changes. It should also simulate the communication between CAVs and infrastructure, such as traffic lights and road sensors, allowing for testing new CAV technologies and traffic management systems.

The simulation results provided by the engine have the potential to assist researchers, engineers, and city planners in the design and enhancement of transport systems, as well as in assessing the impact of new policies and technologies. Furthermore, they can contribute to the improvement of traffic flow and safety within the urban regions of Quadrilátero.

4.6.1 Use Cases and Test Scenarios

Use Case 1: Simulation of CCAM impact on traffic flow and potential congestion in urban and peri-urban areas.

*Table 20: Test Scenario 1 - **Blocking roads and lanes for pedestrians and CAVs** (Lead LL of Quadrilátero)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How does blocking roads and lanes to be utilised by pedestrian and CAVs impact **traffic congestion** nearby? • Is the **accessibility** of pedestrians and VRUs upgraded by those interventions?	**QUA1.1.01** Impact on **traffic congestion** nearby (e.g. queues, travel times, average speed).	Traffic Efficiency	Sim

*Table 21: Test Scenario 2 - **Changing parking availability from curbs to assess traffic performance** (Lead LL of Quadrilátero)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• What is the impact of the **available on-street parking space** on traffic congestion? • How is such a measure going to be implemented? How **straight-forward** is it going to be for road-users to **adopt** quickly and safely to the changing parking conditions? • Is it going to be **accepted by public** (especially in areas where parking spaces are already limited)?	**QUA1.2.01** Impact on **traffic congestion** (e.g., travel times, queues, delays, LOS of intersections).	Traffic Efficiency	Sim
	QUA1.2.02 **Survey** to collect feedback and assess **user acceptance** in areas where this measure could be implemented (e.g., stated-preference surveys)	User Acceptance	Real

*Table 22: Test Scenario 3 - **Adapting public transportation for CCAM by adding, changing or removing stops, and reserving lanes for vehicles** (Lead LL of Quadrilátero)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• Do the **number** and the **frequency** of public transport options affect the deployment of CCAVs (i.e., CCAVs will first be deployed in areas with inadequate public transport options)?	**QUA1.3.01** **Frequency** and **number of AVs** according to the availability of public transport options in the area.	QoS	Sim

*Table 23: Test Scenario 4 – **Creating low-emission zones** (Lead LL of Quadrilátero)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How does the **creation** of **low-emission zones** impact the utilisation of AVs? • What is the **impact** on **traffic congestion**? • What is the **impact** on **air pollution**?	**QUA1.4.01** Survey to assess **user acceptance** of low emission zones.	User Acceptance	Real
	QUA1.4.02 Impact on **traffic congestion** on the affected parts of the network.	Traffic Efficiency	Sim
	QUA1.4.03 Impact on **emissions** and **air quality** (e.g., total CO2, NOx, PM emissions).	Environ-mental	

*Table 24: Test Scenario 5 – **Running ad-hoc simulations with files previously created** (Lead LL of Quadrilátero)*

Research Questions	KPIs	Focus Areas	Real/ Sim
• How to organise an **efficient system** that can conduct **several model runs** (e.g., required to test several different scenarios) with little or no manual effort?	**QUA1.5.01** Impact on **effort** and **time** required to set up and run several traffic models.	QoS	Sim

5 CONCLUSION

A set of *Study Questions* and *KPIs* for each LL of IN2CCAM have been identified in this deliverable. The LLs of Tampere, Trikala, Turin, Bari, and Vigo will be conducting pilot trials of CCAM services in real-life demonstrations in the following stages of the project. At the same time, the LLs of Trikala, Turin, Bari, Vigo, and Quadrilátero will develop simulation models to test various scenarios, either by utilising observed traffic data or by assuming future conditions.

The *LL of Tampere* will focus on real-life demonstrations, testing innovative systems like GLOSA, the interaction between AVs and the city's tram, and the capability of the AVs to detect obstacles or events on their routes. Therefore, the majority of the Study Questions and KPIs which have been defined are technical (e.g. speed adaptation, intersection crossing times, impact on the travel time of tram, etc.).

The *LL of Trikala* will combine real-life demonstrations of technical CCAM innovations (e.g. GLOSA, traffic-based green wave, VRU detection), the development of a demand-responsive journey planner, and the simulation of future scenarios which will assume larger fleets of AVs. Again, the majority of KPIs are technical (e.g. travel times, speed adaptation, intersection crossing times, etc.) and there are also indicators about the user acceptance of the relevant applications (e.g. how safe do VRUs feel when they cross the road with this system in place?).

The *LL of Turin* will focus on re-routing algorithms by deploying real test pilots and simulations. The impact on travel times, traffic congestion, emissions, safety, and energy consumption with different levels of AV fleets and in different scenarios (e.g. different parking lot availabilities, different vehicle restriction zones) are some of the indicators which have been defined and they will be measured.

The *LL of Vigo* will focus on the development of an advanced Traffic Management Centre along with a set of services to improve the circulation of AVs in the network. Technical indicators such as the frequency of C-ITS messages, travel times, speed adaptation, and the reduction of mixed traffic interactions have been included in this case.

The *LL of Bari* will develop a Route Planner which will be able to calculate the optimal route given a set of parameters and available routes. In addition, it will deploy robot deliveries in real test pilots. The indicators which have been selected relate to the efficiency of the simulator in finding the best routes, even when several parameters are considered, and the difference in efficiency between the standard and the robot delivery systems.

Lastly, *the LL of Quadrilátero* will focus on simulations of different scenarios which involve CAVs. The indicators chosen in this case mainly refer to the evaluation of the outputs in terms of traffic congestion and emissions.

Overall, the active engagement with the six Living Labs throughout the process of developing the Study Questions and KPIs has been vital. The LLs, as real-world testing grounds for the project, have provided essential feedback, insights, and practical knowledge. In this way, the Study Questions and KPIs are well-aligned with the project's objectives and grounded in real-world application.

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