D2.3

PoDIUM availability and cooperation enablers definition and evaluation data specifications

PoDIUM

PDI connectivity and cooperation enablers building trust and sustainability for CCAM

Horizon Innovation Actions | Project No. 101069547
Call HORIZON-CL5-2021-D6-01

Co-funded by the European Union

Dissemination level	Public (PU)
Type of deliverable	R – Document, report
Work package	WP2 – Requirements and specifications
Deliverable number	D2.3 PoDIUM availability and cooperation enablers definition and evaluation data specifications
Status - version, date	V1.0, 30/06/2023
Deliverable leader	VICOMTECH
Contractual date of delivery	30/06/2023
Keywords	PoDIUM – Availability, cooperation, enablers, evaluation data

Quality Control

	Name	Organisation	Date
Peer review 1	Michael Buchholz	UULM	19/06/2023
Peer review 2	Guido Gavilanes	LINKS	19/06/2023

Version History

Version	Date	Author	Summary of changes
01	09/06/2023	All T2.5 partners	First draft for peer review
02	27/06/2023	All T2.5 partners	Version for quality check
03	29/06/2023	All T2.5 partners	Final updated version for submission

Legal Disclaimer

Table of contents

Contents

List of figures

List of tables

List of abbreviations and acronyms

Abbreviation	Meaning
ADAS	Automated Driving Assistance System
C-ACC	Cooperative Adaptive Cruise Control
CAV	Connected Automated Vehicle
CCAM	Cooperative, Connected and Automated Mobility
CDF	Cumulative Distribution Function
CI	Confidence Interval
CSV	Comma-separated Values
CV	Connected Vehicle
DENM	Decentralized Environmental Notification Message
DT	Digital Twin
EV	Emergency Vehicle
IoT	Internet of Things
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LDM	Local Dynamic Map
LL	Living Lab
MEC	Multi-access Edge Computing
OBU	On-Board Unit
ODD	Operational Design Domain
PDI	Physical and Digital Infrastructure
RSU	Roadside Unit
TAM	Technology Acceptance Model
TMC	Traffic Management Centre
TMS	Traffic Management System
TPM	Trusted Platform Module
UC	Use Case
VIMA	VRU Intersection Movement Assist
VRU	Vulnerable Road User

Executive Summary

The main objective of PoDIUM is to demonstrate and validate the applicability and benefits of connected and cooperative automated mobility (CCAM) in real traffic conditions. To achieve this, the facilities of three well-equipped living labs in Germany, Italy and Spain will be used. A rich set of demanding CCAM use cases will be investigated to identify and assess all the connectivity and cooperation enablers and needs that will allow the proposed higher levels of automation.

In this deliverable, we establish the service availability Key Performance Indicator (KPI) for the PoDIUM platform, as well as the performance expectations regarding connectivity and cooperation enablers, including latency, reliability, processing delay, and security. Additionally, specific KPIs are defined for each use case to gauge their individual success. The user acceptance related metrics are also defined to assess the public acceptance of the PoDIUM approach.

The process of collecting evaluation data involves measuring and assessing the system performance through the defined evaluation metrics (a.k.a. KPIs). The data collection process involves three levels of logging: local data logging on the device, edge data logging closer to the CCAM devices, and cloud-based data logging in a cloud platform or service. PoDIUM considers different data logging methods and tools, including data logging APIs, open-source data logging tools like Node-RED, Grafana, and Kibana, and custom data logging solutions tailored to the PoDIUM system. The appropriate file format specification for efficient storage, retrieval, and analysis of the logged data is yet to be decided, with CSV, JSON, and time-series databases identified as the main options. The definitive specification of evaluation data logging tools, file formats, and measurement guidelines will be carried out in the framework of work package 5 (WP5).

1. Introduction

1.1. Project intro

PoDIUM aims to support advanced Use Cases (UC) of connected and cooperative automated mobility in real traffic conditions. Building urban and highway UCs on the facilities of 3 well-equipped Living Labs in Germany, Italy and Spain, PoDIUM will tackle all the different requirements for availability and performance of connectivity as well as the different cooperation enablers per UC. The proposed UCs aim to advance a set of key technologies both in the physical and digital part of the infrastructure. In particular, the following non-exhaustive list of contributions will be pursued:

- A multi-connectivity approach to ensure reliability, availability and redundancy of the PDI system.
- Advance data fusion and integration of Multi-access Edge Computing (MEC) to the proposed hybrid data management environment to enable enhanced environment perception models towards digital twins.
- New C-ITS messages for enabling the specific advanced CCAM use cases.
- Ensure software integrity, trust and truthfulness of CCAM data, their exchange and their processing.
- Demonstration of urban and highway use cases in a diverse set of configurations with integration of Vulnerable Road Users (VRU).

1.2. Purpose of the deliverable

The purpose of the present deliverable is to provide a list of the expected technical Key Performance Indicators (KPI) as quantifiable metrics to evaluate the performance of the PoDIUM platform and the use cases. In addition, this deliverable also introduces how the evaluation data will be collected during the testing activities and how they will be used to produce the KPIs. Finally, the user acceptance related metrics are also defined in this document.

This document is the outcome of Task 2.5 in WP2, and will be used as a basis to start the WP5 evaluation-related tasks. As a consequence, deliverable D5.1 “PoDIUM evaluation methodology” will directly read from this deliverable and keep the nomenclature and KPI IDs to ensure traceability of the overall design-development-evaluation workflow.

1.3. Intended audience

The dissemination level of this deliverable is “public” (PU). It is primarily aimed to be the reference document to be used by the PoDIUM Consortium Members during the evaluation phases of the project. Furthermore, this deliverable is addressed to any interested reader (i.e., public dissemination level) who wants to be informed about PoDIUM’s evaluation methodology.

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

This deliverable is organized as follows:

- Section 2 describes the KPI and evaluation data framework, which is divided into two categories: technical performance assessment and user acceptance assessment.
- Section 3 defines the technical KPIs, classified in KPIs for the Platform evaluation, and KPIs to evaluate the UCs.
- Section 4 defines the user acceptance related metrics.
- Section 5 concludes the document with some insights.

This deliverable is the main input for task T5.1 “Evaluation methodology and plan”, and D5.1 “PoDIUM evaluation methodology”. To this end, the proposed KPI/metric set aims to be extensive enough to enable the thorough assessment of the Platform and the UCs, and spans from purely technical KPIs to user acceptance metrics.

.

2. KPI and evaluation data framework

2.1. Technical evaluation framework

2.1.1. Key Performance Indicators (KPIs)

Key Performance Indicators (KPIs) are used to measure the success of a project or business process, and they are typically based on specific metrics or performance criteria. Requirements, on the other hand, define the desired outcomes or functionalities of a system or process. While requirements and KPIs may seem like separate entities, they are closely related in the sense that the KPIs should be aligned with the requirements to ensure that the project or process is achieving its desired outcomes.

In PoDIUM, KPIs are derived from requirements. First, the key requirements that are critical to the success of the project are identified. These requirements must be Specific, Measurable, Attainable, Relevant and Time-bound (SMART) [1]:

- Specific: Target a specific domain or field.
- Measurable: Quantifiable evaluation.
- Attainable: Achievable with the resources, technology and the time available.
- Relevant: Evaluation and success relevant.
- Time-bound: Values can be collected within time-frames well-aligned with the project course e.g., facility readiness.

Next, the metrics or performance criteria that will be used to measure the achievement of each requirement are determined. For example, if the requirement is “Coverage of the 5G / C-V2X network shall have a 99% availability”, the KPI would be “Network availability”, with a target value of 99%.

Finally, the KPIs need to be tracked and analysed regularly to ensure that the project is on track to meet its technical goals. If the KPIs are not meeting the desired targets, the requirements may need to be revisited and adjusted accordingly. The assessment of KPIs will be done under the framework of work package 5 (WP5), according to the conclusions of work package 2 (WP2).

PoDIUM studied existing work on KPIs from other related European projects and proposes a KPI definition template based on the ones included in 5G-MOBIX’s deliverable D.2.5 “Initial evaluation KPIs and metrics” [2] and in 5G-IANA’s deliverable D5.1 “Initial validation KPIs and metrics” [3]. The proposed KPI definition template, adjusted to the PoDIUM needs, is depicted in Table 1.

Table 1 Technical evaluation KPI definition template

KPI identifier	***Unique identifier for each KPI: KPI_x_y-ShortTitle*** ***x: Technical Evaluation sub-category abbreviation:*** • ***Platform: P*** • ***Use Case x: UCx*** ***y: KPI index within sub-category***
Description	*High level description of KPI*
Context/Use Case	*Associate the KPI with a particular use case or with the platform*
Where to observe/measure/monitor	*Points of observation/measurement (e.g., UEs/OBUs, Application Server, etc) to obtain a KPI "value".*
How to observe/measure/monitor	*A high-level description of the measurement methodology, including (where applicable):* • *Detailed definition of KPI e.g., what timestamps to use for latency, which packets to consider for throughput, etc.* • *Key (functional) requirements for the measurements e.g., endpoint synchronization, background, traffic generation (if any), etc.*
How to Evaluate	*Definition of comparison approach i.e., what values the measured KPI data points are compared against. This can include Target Values or results retrieved by identified alternative setups/experiments.*

2.1.2. Collection of evaluation data

Collecting evaluation data involves measuring and assessing various aspects of the system performance. Once the evaluation metrics (a.k.a. KPIs) are defined, then the evaluation scenarios or test cases will be planned. These scenarios will cover different operational aspects of the system under test, considering both normal and corner cases to simulate real-world scenarios. This helps in capturing a wide range of data for evaluation. Then, the evaluation environment will be prepared, setting up the necessary infrastructure and environment required to execute the evaluation scenarios. This involves deploying devices, configuring network connections, or creating test environments that mimic real-world conditions. Then, the planned evaluation scenarios are executed while monitoring and capturing relevant data. This includes sensor readings, network traffic, system logs, user interactions, and any other relevant information that helps evaluate the system's performance. All these steps will be defined in detail in deliverable D5.1 "PoDIUM evaluation methodology" and are out of the scope of the present deliverable. However, we can anticipate some information about the evaluation data collection process that could be useful for the development stage to prepare in advance the logging mechanisms.

Three different levels of data logging are being considered in PoDIUM, depending on where the data is logged and stored:

- Local Data Logging: In this method, data logging takes place directly on the device (OBU, RSU, etc) itself or in a nearby storage system. The device has built-in memory or storage capabilities to record data locally. This method is suitable when the device has sufficient storage capacity and can handle the data logging process without affecting its primary functions.
- Edge Data Logging: In this method, data logging and storage occurs at the edge of the network, close to the CCAM devices. Edge devices, such as gateways or edge servers, collect data from

CCAM devices and perform local storage and preprocessing before sending it to the cloud or a central server, if needed. This method reduces latency and bandwidth requirements by processing and logging only relevant data.

- Cloud-based Data Logging: With this method, data generated by devices is sent and stored in a cloud-based platform or service. This method offloads the data storage and processing tasks from the CCAM devices to the cloud, allowing for scalability, flexibility, and centralized management of data. However, the required bandwidth is increased significantly. Cloud-based platforms like AWS IoT Core, Microsoft Azure IoT Hub, or Google Cloud IoT Core provide built-in data logging capabilities.

The following data logging methods and tools are being considered in PoDIUM for the collection of evaluation data:

- Data Logging APIs: Many Internet of Things (IoT) platforms and frameworks provide data logging APIs that facilitate easy integration of data logging capabilities. These APIs allow the definition of data points, setting data logging intervals, and retrieving logged data for analysis. Examples include MQTT (Message Queuing Telemetry Transport) protocol, RESTful APIs, or specific platform-specific APIs like AWS IoT Device SDKs or Azure IoT Hub SDKs.
- Open-Source Data Logging Tools: Various open-source tools are available for data logging. For instance, Node-RED provides a visual programming interface to log and process IoT data. Grafana and Kibana are popular open-source data visualization tools that can be integrated with data logging systems to create interactive dashboards and analyze logged data.
- Custom Data Logging Solutions: Depending on the specific requirements, custom data logging solutions tailored to the PoDIUM system under test may need to be developed. This can involve creating dedicated software modules to handle data logging tasks, implementing data buffering techniques for efficient storage, and integrating with existing data storage and analysis infrastructure.

Once defined where the data logging is going to take place (local, edge or cloud), and the measuring tool (custom or existing), the appropriate file format needs to be decided for efficient storage, retrieval and analysis of the logged data. Three main options are being considered in PoDIUM as the selected evaluation data format:

- CSV (Comma-Separated Values): CSV is a simple and widely supported file format that stores tabular data as plain text. Each line of the file represents a data record, and values within each record are separated by commas. CSV files are human-readable, compact, and can be easily opened and manipulated with spreadsheet software.
- JSON (JavaScript Object Notation): JSON is a lightweight, human-readable, and widely used file format for structured data. It represents data as key-value pairs, making it suitable for logging complex data structures. JSON files are text-based and can be easily parsed and processed by various programming languages. JSON files are flexible, extensible, and support a wide range of data types. However, JSON files can be larger in size compared to other file formats.
- Time-Series Databases: Time-series databases (TSDBs) are designed specifically to handle large volumes of time-stamped data points. They are suited for logging and analyzing CCAM data, which is often time-dependent. These databases offer efficient storage, indexing, and querying of time-series data. Two popular TSDBs used for IoT data logging are InfluxDB and Prometheus.

At the moment of writing this deliverable, the design and implementation of the PoDIUM platform is at a very early stage and hence it has not yet been concluded which evaluation data logging tool and file format is going to be used on each KPI measurement. This will be done under the framework of work package 5 (WP5) following the guidelines described here.

2.1.3. Presentation of results

Once the evaluation data have been collected, they will be analyzed using statistical methods and depicted via visualization techniques. The objective is to identify patterns, trends and outliers based on the defined KPIs, and the results will be interpreted in the context of the defined KPI target values. The strengths, weaknesses, and areas for improvement will be identified by comparing the results against the established benchmarks or industry standards, if available. Then, based on the conducted analysis and interpretation, conclusions will be drawn about the performance and effectiveness of the PoDIUM platform and the solutions developed for the use cases. Recommendations will also be provided for the successful deployment of PoDIUM technologies, proposing solutions for any identified issues.

The results and conclusions of each of the KPI evaluation tests will be documented following the same table template (Table 2), which is based on the one used in 5G-MOBIX's deliverable D5.2 "Report on technical evaluation" [4]. This table shows the evaluation results using descriptive statistics and a graphical representation (plot). The descriptive statistics include the total number of samples used for obtaining the results, the mean, the median, the standard deviation, the maximum and minimum values, the confidence interval (CI) at the 95% level and the percentile 95. The plot type will be selected depending on the KPI, but the following ones will be considered: box plots, scatter plots, histograms and Cumulative distribution function (CDF) plots. A KPI is a scalar value providing information on system under-test performance or scenario quality. KPIs can be divided into continuous (metrics) and binary values (pass/fail criteria). In the cases where the KPI has a binary pass/fail criterion, the percentage of times that the KPI criterion has been fulfilled will be used as the evaluation metric and the same statistics described in Table 2 will apply.

Table 2 Template for the presentation of the technical evaluation results

<table>
<tr><th colspan="5">KPI identifier</th></tr>
<tr><td>Target value</td><td colspan="4"></td></tr>
<tr><td rowspan="4">Descriptive Statistics</td><td># total samples</td><td>Mean</td><td>Median</td><td>Std. Deviation</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Max</td><td>Min</td><td>CI 95%</td><td>Percentile 95</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Plot</td><td colspan="4"></td></tr>
<tr><td>Conclusions</td><td colspan="4"></td></tr>
</table>

2.2. User acceptance framework

The public acceptance of the PoDIUM approach will be assessed via user acceptance surveys (questionnaire-based). Questionnaires will be structured in the form of multiple-choice questions to facilitate easy processing and analysis. The results will be collected and summarized in the form of user acceptance metrics. In this section, we describe the basic aspects of the PoDIUM user acceptance framework.

User acceptance metrics determine and illustrate the acceptability of a technology/service. Based on Shade's and Schlag's definitions [5], we describe acceptability as the "prospective judgement" made by a group of potential users regarding the adoption of a given service or technology, whereas acceptance refers to the actual adoption behaviour demonstrated by them when the service or technology is available. Notice that PoDIUM as an Innovation Action does not target to demonstrate real life adoption of the technologies developed, and hence user acceptance will be considered at trial-level evaluation in realistic conditions.
The assessment will build on the user-acceptance models proposed by Venkatesh et al. [6] that correlate acceptance with the constructs of perceived usefulness and perceived ease-of-use. However, PoDIUM aims to advance a set of key technologies both in the physical and digital part of the CCAM infrastructure. Given the safety-critical nature of those technologies and their application in real-life conditions, the integration of trust, reliability and safety overall along with privacy, in the user-acceptance model is necessary in PoDIUM. Thus, we extend the approach of [6] with the recent findings of [7] and [8] and we specify the following KPI categories to be measured:

- Intention to use.
- Perceived usefulness.
- Perceived ease-of-use.
- Trust.
- Reliability.
- Privacy.

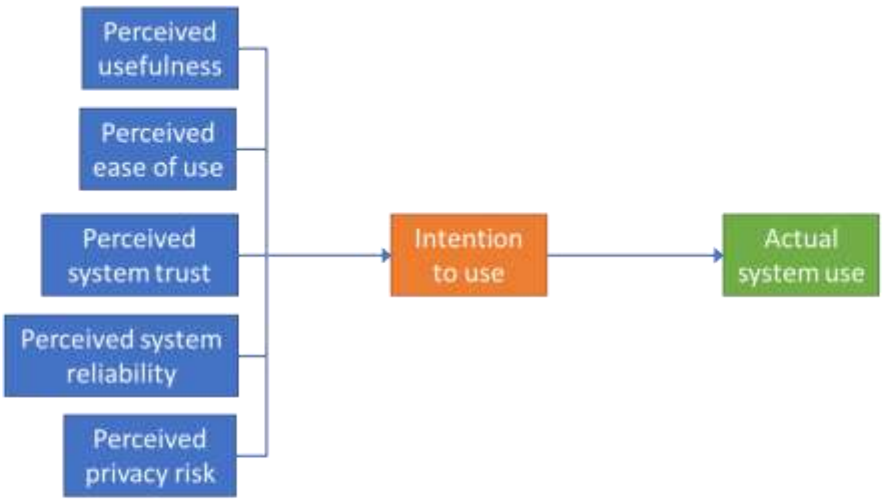

Figure 1: PoDIUM Technology Acceptance Model (TAM). The proposed TAM is compatible with [7], [8].

Figure 1 shows a graphical depiction of the PoDIUM assessment model. The blocks represent the model constructs, while the arrows highlight the known correlations. The evaluation will focus on the Technology Acceptance Model (TAM) blocks. Notice that over [6], the aspects of trust and perceived safety are also determined and included. Besides, the system usability and user privacy are also considered and integrated.

Generally, a psychometric scale composed of a set of questions answered through a Likert scale [6] will be used to assess each identified metric. The complete set of questions addressing all metrics will be contained in a questionnaire provided to end-users. The questionnaires and their exact format will be specified as part of Task 5.3: Public acceptance and impact assessment and will be described in D5.3.

For each of the metrics evaluated through a psychometric scale, a group of questions/statements will be defined based on pre-validated user-acceptance scales, with adaptations (if required) for each specific use-case. For instance, for the first metric (intention to use), the following questions/statements will be used as per [6]:

- Given that I have access to the system, I predict that I would use it.
- Assuming I have access to the system, I intend to use it.

The respondent will answer to each question/statement through a 5-point Likert Scale ("Strongly Disagree -> Strongly Agree"). The use of multiple questions per construct allows for a stronger internal validity and reliability of the scale [9].

The questionnaires will be adjusted to capture the aspects relative to the type of the PoDIUM user, namely CAVs, CVs, normal vehicles, VRUs and the TMC operator. Questionnaires will thus have to be adapted to evaluate those dimensions that can be judged from a potential user perspective, such as perceived usefulness and trust.

Due to logistic and safety limitations, the majority of final trials will be conducted with a reduced number of drivers, limiting the representativeness of the sample. Thus, a larger base of potential users that can answer the questionnaires will be sought after. Certain trials will be performed multiple times with different users to expand the sample site. We will also take advantage of the multiplicity of local test sites in PoDIUM and the pre-evaluation testing performed there. The latter may not be representative of the full capacity of the PoDIUM approach but will be enhancing the confidence due to the larger sample set.

3. Availability and cooperation enablers definition

PoDIUM considers connectivity and cooperation as key enablers for CCAM. For this purpose, KPIs of connectivity and cooperation (e.g. latency, reliability, processing delay, security) are defined for the PoDIUM platform, as well as an availability KPI. In addition, some use-case specific KPIs are defined to assess the performance of the use cases.

3.1. Platform KPIs

The platform KPIs are derived from the platform requirements defined in deliverable D2.2 "PoDIUM platform requirements and specifications". Considering all the information contained in the deliverable D2.2, we describe in this section the KPIs that will be used to measure the success of the platform. In certain cases, depending on the UC, different KPI values have been identified. Notice that we generally indicate a single representative value as target value for each KPI, to be able to accommodate all the use case categories identified in deliverable D2.2.

The first KPI identified in service availability. Service availability for safety-critical applications would normally be close to 100% by applying techniques, such as redundancy and replication, added to the availability analysis of components and their predicted maintenance. In PODIUM, as an Innovation Action, we aim at prototype-level developments with real-life demonstration, which indicates that safety-critical availability is out of the scope of the project. Instead, given the multiple types of services being deployed, the availability will serve to measure the stability of these services during the time they are deployed.

Table 3 KPI_P_1-serviceAvailability

KPI identifier	**KPI_P_1-serviceAvailability**
Description	Service Availability, percentage of time the service is working with respect to the service being down; evaluated during demonstrations/experiments.
Context/Use Case	Platform, it applies to all computing entities that run services within use cases.
Where to observe/measure/monitor	Logging/monitoring of services is necessary to know where the services are down and for how long. A set of acceptable causes of outages might be necessary, such as power outage, maintenance windows, etc. Monitoring might be done externally to services and every service is evaluated individually.
How to observe/measure/monitor	• sum up of all the unacceptable outage time in logs • obtain the elapsed working time (during experiments or demos) • calculate the ratio and outage percentage.
How to Evaluate	Target value: > 95%

Two transport latencies defined as platform KPIs are considered: *updateLatency* and *notificationLatency*. The first is uplink-related, where the PDI is updated about events, and the latter is related with the downlink, that is, the delay of a notification to arrive to the final consumer.

Processing times are kept separated from transport latency as another KPI. The time bases of the relevant endpoints will need to be synchronized in the order of 1ms, so that the comparison between log files coming from different endpoints is consistent, having a bounded drift. Usually synchronization using GNSS receivers or "stratum 1 time sources" would give 1 ms of accuracy.

Table 4 KPI_P_2-updateLatency

KPI identifier	**KPI_P_2-updateLatency**
Description	latency of update messages to the RSU/MEC/cloud/digital twin with sensors/collective perception/data. It is the time gap between the event detection and its availability in a service (cloud, MEC servers)
Context/Use Case	Platform Applies to every update (in uplink), such as VRU crossing with incoming vehicle, sensor information updating digital twins, accident information reaching TMC.
Where to observe/measure/monitor	On MEC, Cloud computing entities
How to observe/measure/monitor	• Sensors record timestamped events, such as road events, (i. e., the incoming of an emergency vehicle in UC2, or irregular crossing of VRU in UC4, or dangerous goods detection on UC5.) • The delays must be calculated between the nearest point of detection of the event and its reception timestamps into the MEC/Cloud service that receives this data. • A maximum value corresponding to the 95% percentile of acceptance over all the measurements represent the KPI value.
How to Evaluate	The target values depend on the particular UC, since more responsive times are required for certain situations such as maneuver coordination and less responsive for traffic management. Target value: < 50ms Remark: for the least demanding services an update latency of 2.5 sec is acceptable.

Table 5 KPI_P_3-notificationLatency

KPI identifier	**KPI_P_3-notificationLatency**
Description	latency of notification messages from a service in the platform (MEC, Cloud) to arrive to its final consumer (CV, VRU).
Context/Use Case	Platform. Any time gap from the generation of a warning/notification/indication to the final provision of indication to the CV, CAV, VRU
Where to observe/measure/monitor	On MEC/Cloud computing entities and message consumers (CV, VRUs, etc.)
How to observe/measure/monitor	Analyze the messages generated within computing entities in the edge or cloud and those received in messages consumers. • Notification transmission and consumption timestamps are recorded. The time gap between these two timestamps are the

	notification latency values. The consumption might occur in ADAS ECU, HMI, or Mobile terminal for VRUs. • A maximum value corresponding to the 95% percentile of acceptance over all the measurements represents the KPI value.
How to Evaluate	The target values depend on the particular UC. Target value: < 50ms Remark: for the least demanding services a notification latency of 2.5 sec is acceptable.

Algorithms and applications contribute to the total end to end delay (between an event detection and the final message consumption. It is useful to measure the delay introduced by these processes to recognize their contribution to overall performance and how experiment's conditions change this performance. The overall execution time strongly depends on the type of the task.

Table 6 KPI_P_4-processingDelay

KPI identifier	**KPI_P_4-processingDelay**
Description	The processing Time required between event (obstacle, VRU, road event) detection and the CCAM message availability for CAV to action, without accounting for transport delay.
Context/Use Case	Platform, in scenarios where road events are detected processed and transmitted to generate vehicle actions/notifications on CAVs, CVs and VRUs. It measures how fast the PDI generates notifications based on existing information, to be communicated to and consumed by users.
Where to observe/measure/monitor	Within processing entities where the inputs from the road side are received and processed to produce an output notification.
How to observe/measure/monitor	• Timestamps during processing in services are necessary, that is, the timestamp when the triggering event was received by MEC/Cloud service and the timestamp of the warning/response/maneuver indication generated. • These time delays do not count delay due to transport. • A maximum value corresponding to the 95% percentile of acceptance is as the KPI value. •
How to Evaluate	The target values depend on the particular UC, since more responsive times are required for certain situations such as maneuvre coordination and less responsive for traffic management. Target value: < 50ms Remark: for certain services a processing delay of up to 2.5 sec is acceptable.

Another crucial aspect is that of communication message reliability.

Table 7 KPI_P_5-comReliability

KPI identifier	KPI_P_5-comReliability
Description	Communication message reliability. It describes how reliable is the PDI to deliver the messages to the users/vehicles/VRUs
Context/Use Case	Platform, in scenarios where redundant messages are sent with the same information in order to reach the target users/vehicles, and vice versa (from sensors/vehicles to edge/cloud).
Where to observe/measure/monitor	In vehicles, and computing entities sending and receiving CCAM messages.
How to observe/measure/monitor	• Logging the sending and reception of CCAM messages and comparing the amount of them with the sent messages for every sensor/RSU/vehicle/computing entity • A maximum value [or 95% percentile of acceptance] over all the measurements represents the KPI value. • It requires that endpoints are logging input and output CCAM messages and be able to identify them uniquely on both ends.
How to Evaluate	The target values depend on the particular UC, since different reliability times are required for certain critical or non-critical situations. Target value: > 99.99% Remark: for the least demanding services a reliability of 90% is acceptable.

Finally, a list of KPIs related to the trust and integrity functionalities of the PoDIUM platform is presented below:

Table 8 KPI_P_6-SealedObject

KPI identifier	KPI_P_6-SealedObject
Description	This KPI represents the capability of the platform to protect sensible data/objects through the Trusted Platform Module (TPM) and its sealing/unsealing features.
Context/Use Case	Platform
Where to observe/measure/monitor	OBU and RSU
How to observe/measure/monitor	Once the developers of the applications have defined the files to be protected, i.e., encrypted with a symmetric key stored into the TPM, the KPI is observed directly on OBU and RSU; sealed objects must be decrypted and used by applications running on OBU and RSU only in trusted states.
How to Evaluate	Testing the sealing and unsealing functions in different trusted and untrusted states. It must be possible to decrypt them for use only in trusted states; Target value> 99% successful tests.

Table 9 KPI_P_7-LoadBootTime

KPI identifier	**KPI_P_7-LoadBootTime**
Description	This KPI evaluate the boot time with and without the Software Integrity Architecture.
Context/Use Case	Platform in UC where software integrity is implemented
Where to observe/measure/monitor	OBU and RSU
How to observe/measure/monitor	This KPI is measured by taking the boot time of an OBU and RSU during all steps of the Bootstrap. The start time is defined by the act of power on and the end time by the OS login screen.
How to Evaluate	Evaluation is performed by comparing the boot time with and without Software Integrity Architecture and then calculating the difference in %. The increasing in boot time should be less than 30% Target value < 30% boot time increase

Table 10 KPI_P_8-LoadRunTime

KPI identifier	**KPI_P_8-LoadRunTime**
Description	This KPI evaluate the additional CPU utilization and memory consumption due to the Software Integrity Architecture.
Context/Use Case	Platform where software integrity is implemented
Where to observe/measure/monitor	OBU and RSU
How to observe/measure/monitor	This KPI is measured by running OBU and RSU common applications/services and recording the CPU load and memory consumption in the two configurations.
How to Evaluate	Comparing CPU load and memory consumption with and without the Software Integrity Architecture. CPU load in % and memory consumption in Byte or multiples; the differences are reported in % *and should be* Target value < 10% (CPU) and Target value < 20% (memory).

Table 11 KPI_P_9-RemoteAttestation

KPI identifier	**KPI_P_9-RemoteAttestation**
Description	The Performance of the Remote Attestation protocol.
Context/Use Case	Platform where software attestation is implemented
Where to observe/measure/monitor	RSU and MEC
How to observe/measure/monitor	This KPI evaluates the performance of the Remote Attestation protocol as the latency between the start of communication between two nodes and the end of the protocol by calculating the time in seconds.
How to Evaluate	Protocol latency Target value < 3s.

3.2. Use Case KPIs

3.2.1. UC1: Cooperative Corridor Management in City of Ulm

Table 12 KPI_UC1_1-Cooperative-Maneuver-CAV

KPI identifier	KPI_UC1_1-Cooperative-Maneuver-CAV
Description	The CAV on the blocked lane is able to pass the obstacle with a cooperative maneuver in at least 75% of the UC passes.
Context/Use Case	UC1
Where to observe/measure/monitor	At the living lab.
How to observe/measure/monitor	Qualitative evaluation of the traffic flow of the use case. An expert marks one pass through the UC as successful or not.
How to Evaluate	Calculate the percentage of passes considered successful over the total. Target value >75%

Table 13 KPI_UC1_2-Cooperative-Maneuver-VRU

KPI identifier	KPI_UC1_2-Cooperative-Maneuver-VRU
Description	The VRU on the free lane is able to pass the obstacle in a complex traffic situation without getting into a dangerous situation. Additionally the CAV on the blocked lane is able to pass the obstacle with a cooperative maneuver.
Context/Use Case	UC1
Where to observe/measure/monitor	At the living lab.
How to observe/measure/monitor	Qualitative evaluation of the traffic flow of the use case. An Expert marks one pass through the UC as successful or not.
How to Evaluate	Calculate the percentage of passes considered successful over the total. Target value >75%

3.2.2. UC2: PDI for User-Centric, CCAM-enabled Traffic Management in Urban Corridors with High Priority Vehicles and VRUs

Table 14 KPI_UC2_1- Traffic_light_flow_improvement

KPI identifier	KPI_UC2_1-Traffic_light_flow_improvement
Description	Percentage of times that EVs find green light when they arrive at a controlled intersection.
Context/Use Case	UC2 Emergency vehicles (EVs) running through a corridor
Where to observe/measure/monitor	EV TMS or DT
How to observe/measure/monitor	Comparison of the logs of the EVs tracking functionality made by EV with the data for the status of traffic lights at each instant provided by TMS.
How to Evaluate	Calculation of the percentage of times that the traffic light is green when EVs reach a junction. Calculation of the same percentage calculated prior to the implementation of the connected EV tracking functionality. Calculate the percentage of the improvement rate with regards to tests prior to implementing the new functionality Target value > 25% improvement with regards to tests prior to implementing the new functionality

Table 15 KPI_UC2_2-Percentage_trips_ok_OD

KPI identifier	KPI_UC2_2-Percentage_trips_ok_OD
Description	Percentage of trips for which the beginning and end is correctly processed by TMS
Context/Use Case	UC2 Calculation of O-D matrices
Where to observe/measure/monitor	CVs (or CAVs) TMS O-D calculation module
How to observe/measure/monitor	Comparison of the timestamps of the beginnings and ends of trips at CVs with the logs of the TMS => calculate the percentage of trips correctly processed
How to Evaluate	Target Percentage > 95%

Table 16 KPI_UC2_3-Percentage_trips_ok_delay

KPI identifier	KPI_UC2_3-Percentage_trips_ok_delay
Description	Percentage of travel times across road links correctly processed
Context/Use Case	UC2 Calculation of average delays and travel times across road links and/or crossing intersections

Where to observe/measure/monitor	CVs (or CAVs) TMS O-D calculation module
How to observe/measure/monitor	Comparison of the timestamps of the passing of through reference CVs with the logs of the TMS => calculate the percentage of trips correctly processed
How to Evaluate	Percentage > 95%

3.2.3. UC3: Responsive PDI enabling Vehicles and Road Users to Self-Manage in Real-time for Mixed Traffic Optimization on the Mediterranean Cross-Border Corridor

Table 17 KPI_UC3_1-Service Time

KPI identifier	**KPI_UC3_1-ServiceTime**
Description	Service delivery time (i.e. the reaction time at service layer) from time of incident detection or other “trigger” for updating the traffic strategy, until incident notification of CVs and updated traffic instructions (“maneuvers”) received by CVs. This KPI refers sets the “pace” of operation within the context of UC3. This time includes communication time, but also internal processing times, according to the following (successive) steps / milestones: 1. Traffic state perception update time: Period between successive updates of the traffic states generated from the Local TMC, using as input the fusion of data from different sources (traffic cameras, vehicle locations, obstacle/incident data). 2. Incident notification relay time: Time elapsed from the time of incident detection until the moment the connected vehicle (CV or CAV) receives an incident notification. 3. Traffic strategy decision time: Period to calculate and update the global traffic strategy within the Global TMC. 4. Strategy relay time: Time elapsed from the time of incident detection (or other strategy update trigger) until the moment the connected vehicle (CV or CAV) receives the updated TMC traffic strategy (maneuver instruction). This is the longest step.
Context/Use Case	Use case 3
Where to observe/ measure/ monitor	Local TMC (Edge), Global TMC (cloud), OBUs of the CAV/CVs
How to observe/ measure/ monitor	From the time of incident detection (as measured by the event timestamp within the MEC), or other “trigger” for updating the traffic strategy, we will measure the following steps: 1. Traffic state perception update time: Measured via timestamps for each updated “traffic state” within the TMC. 2. Incident notification: Measured through the timestamps in the message log of the vehicles (OBUs).

	3. Traffic strategy decision time: Measured via timestamps of the Traffic Strategies calculated, stored and emitted by the TMC. 4. Strategy relay: Measured through the timestamps in the message log of the vehicles (OBUs).
How to Evaluate	Target values for end-to-end Service delivery / reaction times: 1. Local traffic state perception updated within < 1s 2. Incident notification received by CAV/CVs in < 2s 3. Traffic strategy generation updated within < 5s 4. TMC strategy (maneuver instructions) received by CAV/CVs < 6s Multiple measurements (> 10) will take place in virtual simulation (false triggers in pre-demonstration technical trials), where max values must be achieved every time.

Table 18 KPI_UC3_2-Cross-Border Interruption Time

KPI identifier	**KPI_UC3_2-CrossBorderInteruptionTime**
Description	Cross border interruption time (i.e. avoid interruption of service while switching from one country 5G network to the other) While crossing the France-Spain border, ensure that if connectivity via 5G is interrupted (due to switching from one country 5G network to the other), then this will be minimal, and be complemented via C-V2X coverage and will not cause any service interruption.
Context/Use Case	Use case 3
Where to observe/ measure/ monitor	France-Spain cross-border segment of the LL highway
How to observe/ measure/ monitor	Measured through a tool that monitors and logs the connection state of the 5G modem.
How to Evaluate	Target values: • 5G interruption from one country network to the other is < 1s • Parallelization of C-V2X connection will allow to have continuous (seamless) connectivity without interruption → service interruption < 500ms Measurements to take place during 5x cross border crossings with same or different CV/ CAVs via connection monitor log software installed on the OBUs/PCs.

Table 19 KPI_UC3_3-ShuttleSpeed

KPI identifier	**KPI_UC3_3-ShuttleSpeed**
Description	MILLA's CAV Shuttle needs to be capable to achieve 80km/h in SAE 4 autonomous driving conditions.
Context/Use Case	Use case 3
Where to observe/ measure/ monitor	MILLA Shuttle CAV, in a closed circuit & in the selected highway section
How to observe/ measure/ monitor	Measured via the Shuttle's speed log. First, validated in closed circuit trials. Then this shall be demonstrated on a large stretch of the highway (traffic and safety permitting).
How to Evaluate	Target: 80 km/h automated driving

Table 20 KPI_UC3_4-Traffic Strategies Implementation

KPI identifier	KPI_UC3_4-TrafficStrategiesImplementation
Description	Evaluate the implementation of the traffic strategies by the CAV (autonomously) and the CV drivers (manually). The referred traffic strategies that are transmitted to the vehicles are: • Strategy 1: Reduce max speed (thus avoiding a harder braking later on, increased safety) • Strategy 2: Increase distance from car in front (thus avoiding harder braking, more time for reaction, increased safety) • Strategy 3: Change lane i.e. the car should avoid or prefer such lane
Context/Use Case	Use case 3
Where to observe/ measure/ monitor	Within the vehicles (CV & CAV), and/or in the TMC/LDM
How to observe/ measure/ monitor	Once the message is received by the vehicle (via OBU & displayed in the HMI), the CV drivers react based on the indicated strategy ("maneuver") and the CAVs autonomously implement the indicated strategy. How to monitor: - Capturing the timestamps of received messages in the OBU/PC and displayed in the HMI - Capturing by the logged speeds of the connected vehicles (CV & CAV), as stored in the TMC / LDM (for strategy 1 only)
How to Evaluate	Target value: - Delay of CAVs applying indicated strategy < 5s. - Delay of CV drivers applying indicated strategy < 10s (Note: For lane change, this timing may be longer due to surrounding traffic – the maneuver will only take place once it is safe to do so.) For each strategy we will sample at least 3x times the maneuver with all 5 vehicles (CV and CAV) and calculate the time of reaction of the vehicles. In total 45 samples of all 3 strategy implementation maneuvers.

3.2.4. UC4: Trusted Cooperative Perception for Intersection Manoeuvre Assistance

Table 21 KPI_UC4_1-VIMA_detection_performance

KPI identifier	KPI_UC4_1-VIMA_detection_performance
Description	Performance of VRU Intersection Movement Assist (VIMA) application against false positive/negative
Context/Use Case	In UC4, the VIMA application provides the connected and automated vehicle/driver with a warning and a time window to cross, based on VRU detection. Reliability of this service will be assessed.
Where to observe/measure/monitor	At CAV
How to observe/measure/monitor	Perform use case in different scenarios/trials with - expected positive= scenarios in which the system is expected to give a warning and a time to wait indication because the VRU is about to cross and conflicting with vehicle trajectory - expected negative= scenarios in which the system should NOT give any warning or indication because VRU is not about to cross or not conflicting with vehicle trajectory (tested to check for any false warning) Collect data and check true positive/ negative, false positive/negative.
How to Evaluate	Compute the following performance indicators (PI) and compare it with target values. - PI1: true positive rate (probability of detection): true positives over total expected positives - PI2: true negative rate (1-false positive rate) is the number of true negative over total expected negatives - For the current prototype implementation, the target is to have at least 90% of each PI, which in practice means a tolerance of 10% error.

Table 22 KPI_UC4_2-Vehicle_position_accuracy_urban

KPI identifier	KPI_UC4_2-Vehicle_position_accuracy_urban
Description	CAV positioning accuracy at the intersection
Context/Use Case	UC4 advisory depends on lane-level position and direction, thus matching of vehicle position and trajectory to the local topology is crucial. Lane level accuracy (1.5m) is at least needed to interpret the advisory information, but sub-meter accuracy (0.1m, 0.2m tolerated) is recommended for collective perception applied to highly automated driving.
Where to observe/measure/monitor	At CAV
How to observe/measure/monitor	Measure positioning accuracy of the vehicle (both receiving and transmitting) within 2 sigma (95%) in open sky, with at least 7 satellites in view, and elevation mask set to 5°.

How to Evaluate	Accuracy: < 0.2m with RTK correction < 1.5m without RTK correction

Table 23 KPI_UC4_3-VIMA_crossing_time_consistency

KPI identifier	**KPI_UC4_3-VIMA_crossing_time_consistency**
Description	VIMA shall suggest an optimal time range to cross the intersection with and without V2X support.
Context/Use Case	UC4 VIMA application provides warning and a time window to cross, based on VRU detection (possibly also a speed suggestion). Such advisory should be consistent with the real traffic condition, meaning it should not yield maneuvers that differ too much from the ordinary ones. For example, a couple of limit cases could be too long waiting times before crossing, or too risky pass-through at the time limit, etc. This KPI serves both to find a calibration (fine-tune) of the VIMA and to spot intrinsic problems in the application.
Where to observe/measure/monitor	At CAV
How to observe/measure/monitor	Perform VRU crossing trial with approaching vehicle. The vehicle is driven manually without any V2X advisory support. 2 options depending on testing condition: - Case 1 if high control/repeatability of trials is possible (e.g. proving ground or simulation): repeat identical VRU crossing with and without VIMA advisory (2 identical trials) - Case 2 with low degree of control/repeatability (e.g. open road, real scenario): VIMA runs in background (no HMI) and issues indications of time to pass the intersection (1 trial). Measure and compare the waiting time suggestions of the V2X application with the actual timing of crossing without V2X support.
How to Evaluate	Accuracy: < +/-20% deviation in total time to cross

Table 24 KPI_UC4_4-VIMA_timing

KPI identifier	**KPI_UC4_4-VIMA_timing**
Description	End-to-end reaction time from hazard detection at RSU until actuation/warning at CAV.
Context/Use Case	UC4 VIMA, an edge-computing-based application informing of VRU presence at an intersection, should at least perform as good as an Intersection Collision Risk Warning (ICRW) application, as in ETSI TS 101 539-2 V1.1.1 (2018-06)
Where to observe/measure/monitor	At all the involved components
How to observe/measure/monitor	Reaction time will be measured from timestamps. Since the tracking of each piece of information at each step may be difficult to achieve, the mean values of the five following steps will be measured and then summed up:

	(1) At RSU, timing of VRU crossing detection application (2) Latency of RSU-MEC communication (3) at MEC, timing of digital twin and VIMA application (4) Latency of MEC-CAV communication (5) Timing of CAV application
How to Evaluate	Target: < 300ms The aforementioned ETSI document sets a requirement of 300ms delay overall as maximum. Transposed to VIMA, for comparison, the sum of steps 1 to 5 above should not exceed 300 ms.

3.2.5. UC5: Risk Management in a Highway Tunnel

Table 25 KPI_UC5_1-Vehicle_position_accuracy_highway

KPI identifier	**KPI_UC5_1-Vehicle_position_accuracy_highway**
Description	CAV positioning accuracy on the highway
Context/Use Case	UC5 warning and cooperative assistive/automated functions (e.g. C-ACC) can be defined up to the lane-level, along the highway (e.g. lane closure information). The CAV must be capable of understanding which lane it finds itself, meaning positioning has to be <1.5m. Furthermore, outside the tunnel, the CAV can avail of sub-meter accuracy thanks to RTK corrections. Sub meter accuracy (0.1m -0.2m tolerated) is one of the enabling factors of highly automated driving Operational Design Domain (ODD).
Where to observe/measure/monitor	At CAV
How to observe/measure/monitor	Measure positioning accuracy of the vehicle (both receiving and transmitting) within 2 sigma (95%) • in open sky, with at least 7 satellites in view, and elevation mask set to 5° • in tunnel with the two positioning solutions (trilateration and GPS signal creation)
How to Evaluate	Target Value: < 0.2m outside the tunnel with RTK correction < 1.5m outside the tunnel without RTK correction < 1.5m inside the tunnel

Table 26 KPI_UC5_2-Vehicle_position_timing_transient

KPI identifier	KPI_UC5_2-Vehicle_position_timing_transient
Description	CAV positioning availability at tunnel entrance/exits
Context/Use Case	UC5 addresses V2I information about hazards as well as cooperative V2V functions (e.g. C-ACC) at tunnel entrance and exits. GNSS availability impacts on Position and Time reference of V2X OBU. A technical solution for GNSS available in tunnel is provided within PoDIUM. However, a transient condition is expected, where the on-board Position and Timing services changes from GNSS-based position outside the tunnel to the in-tunnel positioning.
Where to observe/measure/monitor	At CAV
How to observe/measure/monitor	Measure - time interval of position and timing unavailability - effect on V2V and V2I exchanged messages and AD functions behaviour
How to Evaluate	Quantitative evaluation of how outage time gaps affect both warning, cooperative functions (e.g. C-ACC) and AD ODD. The goal is to obtain upper limits of acceptability. The ideal target is a time and/or position outage < 0.1s).

Table 27 KPI_UC5_3-Vehicle_counting_accuracy

KPI identifier	KPI_UC5_3-Vehicle_counting_accuracy
Description	Accuracy % in the vehicles counting by roadside sensors of Podium emergency management system
Context/Use Case	UC5 aims at improving the Risk Management in a Highway Tunnel. Among the monitoring sources, dedicated vehicle counters developed within the Project are installed in the tunnel and interfaced with the Digital twin system, to support the Risk Assessment module. Vehicles are counted and classified by its category (motorbike, car, bus or truck).
Where to observe/measure/monitor	At MEC and back-end
How to observe/measure/monitor	Measure vehicle counting e.g. in one hour at the tunnel. Compare it to the measurement of the system already in place on the A22. Calculate the deviation target.
How to Evaluate	Target value: < 10% deviation per each category

4. User acceptance related metrics

In the scope of the user acceptance evaluation activities, we consider as end-users the stakeholders that have direct interaction with the PoDIUM system, namely the users of the CAVs, CVs, normal vehicles, VRUs, and the TMC operator. The initially identified KPI categories for user acceptance are intention to use, perceived usefulness, perceived ease-of-use, trust, reliability and privacy. All the questions will be answered using a Likert scale for ensuring privacy and easy/automated processing.

Table 28: KPI categories for user acceptance

KPI category	Indicative statements
Intention to use	Assuming I have access to PoDIUM platform, I intend to use it in my daily life.
Perceived Ease of Use	I would find the PoDIUM CAV easy to use in my daily life.
	During the test I found it easy to get the PoDIUM CAV to do what I want it to do.
	During the test I found it easy to participate as a VRU in the PODIUM system.
Perceived usefulness	I would find the PoDIUM CAV useful in my daily life/work.
	Using the PoDIUM CAV in my daily life would increase my travel comfort.
	Using the PoDIUM CAV would increase the travel comfort of disadvantaged people, e.g. elderly.
	Using the PoDIUM shuttle would be useful for people with limited sight in their regular transportation needs.
	Using the PoDIUM shuttle would be useful in meeting my regular transportation needs.
Trust	Overall, I could trust the PoDIUM platform.
	During the test I trusted the CCAM service provided by the PoDIUM platform.
	During the test I felt confident using an VRU application deployed on top of the PoDIUM platform.
Reliability	I believe that the PoDIUM platform will perform consistently under a variety of circumstances and use cases.
	I believe that I could depend and rely on PoDIUM CAVs.
	I believe that a PoDIUM CAV is free of errors.
Privacy	I would feel confident disclosing private information to use the PoDIUM platform.
	I would feel confident disclosing private information to use the PoDIUM VRU app.
	Using the PoDIUM platform does not require private information disclosure.

Social inclusion will be addressed as part of the usefulness for specific disadvantaged groups. Since, most probably, no members of a disadvantaged group will be participating as users in the trials, the available users would assess the usefulness also for certain disadvantaged groups.

5. Conclusions

In this deliverable, we have specified the service availability KPI along with the performance expectations of connectivity and cooperation enablers, such as latency, reliability, processing delay, and security, for the PoDIUM platform. Then, for each use case, some use-case specific KPIs have been defined to measure their success. While the present deliverable puts emphasis on purely technical KPIs, it also includes metrics for the support of user acceptance evaluation activities. The current KPI/metric set will be revised and updated for the actual evaluation stage of the project (as well as their target values) by the corresponding partners based on the implementation plans at each test site and will be reported in D5.1 "PoDIUM evaluation methodology", including a fine-grained description of the overall performance evaluation methodology.

This document has also addressed the collection of evaluation data, identifying relevant data logging methods, tools, and file formats. The objective here has been to guide the development process and, when possible, prepare in advance the logging mechanisms necessary to measure the KPIs. The detailed specification of evaluation data collection tools and file formats will be concluded under the framework of Work Package 5 (WP5) and will be reported in D5.1 "PoDIUM evaluation methodology".

6. References

[1] Z. Ishak, S. L. Fong and S. C. Shin, "SMART KPI Management System Framework," 2019 IEEE 9th International Conference on System Engineering and Technology (ICSET), Shah Alam, Malaysia, 2019, pp. 172-177, doi: 10.1109/ICSEngT.2019.8906478.

[2] 5G-MOBIX deliverable D2.5 “Initial evaluation KPIs and metrics” (2019). https://www.5g-mobix.com/assets/files/5G-MOBIX-D2.5-Initial-evaluation-KPIs-and-metrics-V1.4.pdf

[3] 5G-IANA deliverable D5.1 “Initial validation KPIs and metrics” (2022). https://zenodo.org/record/7304938#.Y6w6Z3bMJD9

[4] 5G-MOBIX deliverable D5.2 “Report on technical evaluation” (2022). https://www.5g-mobix.com/assets/files/5G-MOBIX-D5.2-Report-on-technical-evaluation-v3.0_Final_version.pdf

[5] Schade, J., and Schlag, B. (2003). Acceptability of urban transport pricing strategies. Transportation Research Part F: Traffic Psychology and Behaviour, 6(1), 45-61.

[6] Venkatesh, Viswanath; Bala, Hillol (2008): Technology Acceptance Model 3 and a Research Agenda on Interventions. In Decision Sciences 39 (2), pp. 273–315. DOI: 10.1111/j.1540-5915.2008.00192.x

[7] N. Hutchins and L. Hook, "Technology acceptance model for safety critical autonomous transportation systems," 2017 IEEE/AIAA 36th Digital Avionics Systems Conference (DASC), St. Petersburg, FL, USA, 2017, pp. 1-5, doi: 10.1109/DASC.2017.8102010.

[8] Zhang, T., Tao, D., Qu, X., Zhang, X., Lin, R., & Zhang, W. (2019). The roles of initial trust and perceived risk in public’s acceptance of automated vehicles. Transportation Research Part C: Emerging Technologies, 98.

[9] Kline, P. (2000). Handbook of psychological testing (2nd ed.). London, England: Routledge