Funded by
the European Union

# Intelligent & Digital Roadway Infrastructure for Vehicles Integrated with Next-Gen Technologies

## D1.5 – Mid-term review & progress report

| | |
|---|---|
| Author(s): | Alexandros Sfyridis (CERTH) |
| Leading Partner: | CERTH |
| Version - Status: | V1 |
| Submission Date: | 23/12/2025 |
| Dissemination Level: | PUBLIC |

**Disclaimer:** Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor CINEA can be held responsible for them.

**Report information**

| Purpose of the Report | Provides an overview of the work carried out during the first 18 months of the iDriving project | | |
|---|---|---|---|
| Relevant Work package: | WP1 | | |
| Relevant Task: | T1.1. Project management, administration and reporting | | |
| Contributors: | All partners | | |
| Next version Title: | NA | Next version Date: | NA |
| Official Submission Date: | 31/12/2025 | Actual Submission Date: | 23/12/2025 |

# ABOUT iDRIVING

iDriving, a 3-year Horizon-funded project, unites 17 European partners in a mission to enhance road safety. The project focuses on transforming urban and secondary rural road infrastructure through innovation. It aligns with the EU's goals for smart transport and actively embraces emerging technologies. Key areas include enhancing driver behaviour, improving infrastructure safety, and empowering first responders. Through a comprehensive Safety Criteria Catalogue, innovative sensors, AI-based warnings, and a Digital Twin, iDriving paves the way for safer roads.

**The iDriving consortium consists of the following partners:**

| No | Participant organisation name | Short name | Country |
|---|---|---|---|
| 1 | ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS | CERTH | EL |
| 2 | POLYTECHNEIO KRITIS | TUC | EL |
| 3 | AUSTRIATECH - GESELLSCHAFT DES BUNDES FUR AT TECHNOLOGIEPOLITISCHE MASSNAHMEN GMBH | AUSTRIATECH | AT |
| 4 | UNIVERSITE GUSTAVE EIFFEL | UNI.EIFFEL | FR |
| 5 | FUNDACION TEKNIKER | TEKNIKER | ES |
| 6 | INGARTEK CONSULTING SL | ING | ES |
| 7 | INFRA PLAN KONZALTNIG JDOO ZA USLUGE | INFRA PLAN | HR |
| 8 | ACCELIGENCE LTD | ACCELI | CY |
| 9 | NETCOMPANY-INTRASOFT SA | INTRA | LU |
| 10 | SOFTWARE IMAGINATION & VISION SRL | SIMAVI | RO |

| | | | |
|---|---|---|---|
| 11 | ALP.Lab GmbH | ALP.LAB | AT |
| 12 | MUNICIPALITY OF ALBA IULIA | AIM | RO |
| 13 | DRAXIS RESEARCH VENTURES ASTIKI MI EL KERDOSKOPIKI ETAIRIA | DREVEN | EL |
| 14 | PRAVO I INTERNET FOUNDATION | LIF | BG |
| 15 | DIMOS THESSALONIKIS | THESSALONIKI | EL |
| 16 | GRAD KARLOVAC | COK | HR |
| 17 | MOBILYSIS SARL | MOBILYSIS SARL | CH |

## Version History

| Version | Date | Author | Partner | Description |
|---|---|---|---|---|
| 0.1 | 27/11/2025 | Alexandros Sfyridis | CERTH | Draft provided to internal reviewers |
| 0.2 | 04/12/2025 | Nicolae Neag<br>Rada Stoilova | AIM<br>LIF | Internal review provided |
| 0.3 | 05/12/2025 | Alexandros Sfyridis | CERTH | Comments addressed from CERTH |
| 0.4 | 12/12/2025 | Alexandros Sfyridis | CERTH | Final quality check |
| 1.0 | 23/12/2025 | Alexandros Sfyridis | CERTH | Submission to EC |

# Executive summary

This Mid-Term Review and Progress Report provides an overview of the work carried out during the first 18 months of the iDriving project. The document consolidates progress across all Work Packages, evaluates achievements against planned objectives, and highlights how the consortium has advanced the development of AI-enhanced traffic monitoring, predictive analytics, and intelligent decision-support for urban transport safety.

During the reporting period, the consortium successfully established the project's organisational, ethical, and data governance foundations, including quality assurance procedures, risk management mechanisms, and the Data Management Plan. Core system components were designed and developed, covering the Digital Twin architecture, multimodal data ingestion pipelines, visual analytics workflows, and machine learning modules for safety, mobility, and infrastructure monitoring. Significant progress was also achieved in creating environmental and microclimate monitoring solutions, integrating observational datasets, and supporting climate-resilient transport operations.

Technical activities have advanced the project's analytical capabilities. These include the development of AI-based road safety analytics, maintenance monitoring using UAV data, real-time incident detection, trajectory prediction, and decision-support models for traffic management. Pilot preparation activities progressed in parallel, with scenario definitions, operational requirements, and data-sharing protocols agreed with local authorities. The consortium maintained strong coordination through regular technical meetings, structured decision-making processes and continuous alignment across WPs

Mid-term achievements demonstrate strong alignment with the project's Scientific, Technical, and User Objectives. The consortium has delivered early prototypes of most key components, validated several analytical models, and prepared the ground for integrated system testing in the upcoming pilot trials. Risks, challenges, and mitigation strategies are monitored continuously, ensuring stable progress toward the overall ambition of enhancing transport system safety, efficiency, and resilience through AI-driven analytics and intelligent decision-making. Progress to date also enhances future interoperability and aligns with emerging standards, ensuring sustainable integration into smart mobility ecosystems

# Table of Contents

# Table of tables

# Table of figures



# Abbreviations

| | |
|---|---|
| CCC | Common Connectivity Catalogue |
| C-ITS | Cooperative Intelligent Transport Systems |
| CNN | Convolutional Neural Networks |

| | |
|---|---|
| CPP | Coverage Path Planning |
| GA | Grant Agreement |
| ISAD | Infrastructure Classification Scheme for Automated Driving |
| ITMS | Intelligent Traffic Management System |
| KPI(s) | Key Performance Indicator(s) |
| KR(s) | Key Result(s) |
| NgZ | No-go Zone(s) |
| OCR | Optical Character Recognition |
| OSM | Open Street Map |
| PUC(s) | Pilot Use Case(s) |
| ROI | Region(s) of Interest |
| SCC | Safety Criteria Catalogue |
| TDC | Tekniker Dataspace Connector |
| UAV | Unmanned Aerial Vehicle |
| UC(s) | Use Case(s) |
| V2I | Vehicle to Infrastructure |
| WMAPE | Weighted Mean Absolute Percentage Error |

# 1 Introduction

This chapter outlines the aim and scope of the Mid-term Review and Progress Report and provides the contextual basis for interpreting the project's achievements during the first half of iDriving. It clarifies why the report is prepared, what time period it covers, and what aspects of the project's work are included in the analysis.

## 1.1 Purpose and motivation

The purpose of this Mid-term Review and Progress Report is to summarise the progress achieved during the first 18 months of the iDriving project and to assess the extent to which the consortium is advancing toward the Scientific, Technical, and User Objectives defined in the Grant Agreement. The report provides a consolidated view of the activities performed across all Work Packages, documenting completed work, emerging results, and ongoing developments that contribute to the project's expected outcomes.

The report also supports internal monitoring and coordination by ensuring a transparent account of achievements, deviations, and risk mitigation measures. It forms the basis for preparing the project's mid-term review and enables effective communication with the European Commission regarding progress, challenges, and next steps.

## 1.2 Repotting period

This document covers the activities implemented during the first 18 months of the project (M1–M18). The reporting period includes project initiation, setup of governance structures, development of core technical components, early prototypes of analytical tools, and preparatory work for the pilot trials. The assessment reflects contributions from all partners and synthesises the progress made across all Work Packages.

## 1.3 Scope of the Report

The report provides an overview of the project's technical, scientific, and management activities during the reporting period, including:

- progress toward project objectives and Key Results,
- status of deliverables and milestones,
- development of AI-driven analytical modules and digital twin components,
- advances in data integration, environmental monitoring, safety analytics, and mobility insights,
- outcomes of user engagement and pilot preparation activities,

- updates on risk management, quality assurance, and data governance.

The scope therefore includes both completed work and ongoing activities, offering a comprehensive view of the project's trajectory at mid-term.

## 1.4 Structure of report

The report is organised into three core sections, accompanied by references and appendices. These purpose and content of each section is outlined below:

### 1.4.1 Section 1 – Introduction

Section 1 forms the foundation of the report. It outlines the purpose and motivation behind the mid-term review, defines the reporting period, and clarifies the scope of the document. It sets the context for the subsequent analysis by summarising why the report is produced and what aspects of the project it covers.

### 1.4.2 Section 2 – Main Progress and Results

Section 2 forms the main body of the report. It begins with an overview of the scientific, technical, and user objectives and continues with a detailed account of progress made within each Work Package. This includes status updates, activities performed, deliverables submitted, deviations encountered, and associated risks. This section provides the core evidence of project advancement during the reporting period.

### 1.4.3 Section 3 – Summary

Section 3 summarises the overall progress of the project at mid-term, reflecting on achievements, challenges, and progress toward objectives. It provides an evaluation of performance to date and sets the basis for future actions.

### 1.4.4 References and Appendices

The report concludes with a list of references used in the document, followed by appendices containing supplementary material.

# 2 Main Progress and results

This section presents the main progress and results for the project's objectives and WPs individually. The progress is reported for each objective and WP individually, addressing the main progress and alignment with Key Results (KRs) and Key Performance Indicators (KPIs) as addressed in the Grant Agreement (GA).

## 2.1 Project objectives

### 2.1.1 Scientific objectives (SO) and Activities (SA)

#### 2.1.1.1 SO.1 Innovative communication protocols (WP3)

SA1.1 Common connectivity catalogue (CCC)

Scientific Activity 1.1 aims to develop the Common Connectivity Catalogue (CCC), a harmonised reference framework for connectivity elements, communication standards, and data exchange requirements across urban and secondary road environments. The CCC consolidates information on infrastructure assets (e.g., RSUs), vehicles of various categories and automation levels, vulnerable road users, warning devices, and UAVs - integrating them under a unified communication and information model aligned with the Infrastructure Classification Scheme for Automated Driving (ISAD). By providing a structured overview of connectivity pathways, capabilities, and safety-related indicators, the CCC forms a foundational component of the iDriving digital ecosystem, enabling real-time communication of infrastructure KPIs, improved interaction among ecosystem elements, and enhanced support for automated and connected mobility.

- Work performed during the reporting period

During this reporting period, significant work has been completed toward establishing the conceptual, architectural, and functional foundations of the Common Connectivity Catalogue. The progress achieved contributes directly to KR1 and prepares the ground for all KPI targets associated with SA 1.1.

The design and structural definition of the CCC were completed, resulting in a clear and unified representation of connectivity elements, communication pathways, and their associated metadata. This foundational layer enables the systematic inclusion of diverse user groups, infrastructure entities, and vehicle categories with varying automation levels. The catalogue design ensures extensibility, interoperability, and structured integration within the broader iDriving ecosystem.

A key advancement was the alignment of the CCC with the ISAD framework, ensuring that infrastructure capabilities, communication flows, and classification metadata follow standardised guidance for supporting automated driving. This alignment establishes compatibility between connectivity elements and recognised infrastructure performance levels, enabling the future mapping of safety-related KPIs to specific ISAD layers and ensuring harmonisation with the work programme priorities on digitalised ecosystem interaction.

On the communication side, a first version of the data transmission layer was defined using HTTP-based communication protocols, ensuring broad compatibility across heterogeneous systems and devices. This guarantees that the CCC can communicate with a wide spectrum of road users, from basic connectivity devices to highly automated vehicles. In parallel, initial development has started on the integration of Kafka as a real-time, event-driven communication backbone, enabling scalable, high-frequency data exchange essential for synchronising road users, infrastructure sensors, and backend systems.

Complementing the technical developments, initial communication and security policies have been drafted, defining the preliminary rules for data governance, access control, and integrity protection within the CCC. These policies provide a governance structure for future catalogue operations and ensure alignment with iDriving's safety and reliability objectives.

Collectively, these actions establish the conceptual and technical underpinnings of the CCC and position the project to achieve full catalogue population, KPI mapping, and multi-vehicle integration in the following reporting period.

- KR & KPI alignment

The work completed during this reporting period directly contributes to KR1 by developing the core structure, standards, and communication mechanisms of the Common Connectivity Catalogue. The completed design, ISAD alignment, and initial protocol definitions constitute the essential framework required to onboard new user types, incorporate heterogeneous vehicle categories, and map safety-related infrastructure KPIs to the ISAD concept (Table 1). With the foundational architecture now established, the project is well positioned to reach the KPI targets through user registration, KPI mapping, and multi-vehicle validation activities in the next phase.

Table 1: SA1.1.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| KPI 1.1 – New type of users on the catalogue | > 5 | *In preparation* | Catalogue design completed; technical structure supports onboarding. User registration planned for next period. |

| | | | |
|---|---|---|---|
| KPI 1.2 – Safety-related KPIs mapped to ISAD | > 5 | *Conceptual groundwork completed* | ISAD alignment implemented. KPI mapping to be completed once catalogue population begins. |
| KPI 1.3 – Incorporation of different vehicle types with varying automation levels | Achieved | *Partially achieved* | Catalogue structure and protocol definitions allow multi-vehicle integration; validation to occur in next phase. |

- Current Status, Deviations, and Next Steps

The current status of SA 1.1 reflects strong progress, with the conceptual design, ISAD alignment, and initial communication layer fully defined. The ongoing integration of Kafka and development of communication and security policies indicate steady advancement toward a fully operational CCC. No deviations from the planned work were reported during this period.

Next steps will focus on operationalising the catalogue through user and vehicle registration activities, enabling the project to reach the KPI targets. Specifically, the upcoming period will:

- register and validate more than five user types in the CCC (KPI 1.1),
- map at least five safety-related KPIs to ISAD layers (KPI 1.2),
- validate the CCC's capability to support multi-vehicle integration across different levels of automation (KPI 1.3),
- finalise and publish the communication and security policies, and
- complete the Kafka-based real-time communication layer.

These activities will transition the CCC from a conceptual framework to an operational, populated catalogue and further strengthen its role as a central component of the iDriving interconnected ecosystem.

<u>SA1.2: Interoperable and sovereign data exchange</u>

Scientific Activity 1.2 aims to design and implement a flexible, low-latency, and semantically interoperable communication architecture that enables secure, sovereign data exchange between vehicles and infrastructure. The work aligns with the ISAD framework to ensure that communication flows, data semantics, and interoperability mechanisms support safe automated driving operations. The activity contributes directly to the establishment of a digitalised road ecosystem by enabling real-time, reliable, and sovereign data-sharing across diverse infrastructure and vehicle systems. It further addresses priorities related to infrastructure–vehicle interaction, V2I safety integration, real-time data access, and on-site data management.

- Work performed during the reporting period

During this reporting period, significant progress was made toward establishing the technical foundation for interoperable and sovereign data exchange, directly supporting KR2 and KR3. The work addressed both communication interoperability and data sovereignty mechanisms, ensuring alignment with the broader architecture.

A first level of interoperability was validated through the implementation of standard HTTP-based communication channels, enabling structured data exchange between system components. This provides the baseline framework upon which more advanced semantic validation and usage control mechanisms can be built. The adoption of HTTP also supports compatibility with multiple devices, addressing early requirements for cross-component integration.

In parallel, substantial work has been undertaken to integrate Kafka as a scalable, event-driven communication backbone. Kafka is expected to support high-frequency, low-latency data streaming and enhance semantic consistency across heterogeneous devices. Its inherent capabilities for logging, topic partitioning, and controlled data dissemination also contribute to the sovereignty dimension by enabling auditability and fine-grained access control.

A preliminary architecture for semantic and sovereign data exchange has also been defined. This conceptual framework integrates principles of data ownership, usage transparency, and secure access control, forming the basis for the Usage Control Policy Analysis Algorithm (KR3). The architecture aligns with project requirements for safeguarding infrastructure and vehicle data while maintaining interoperability across systems.

- KR & KPI alignment

The work performed is strongly aligned with KR2, as both the standard communication layer (HTTP) and the ongoing Kafka integration contribute directly to the establishment of a Semantic Interoperability Validation Service. The initial design of the sovereign data exchange framework also supports KR3 by defining the mechanisms needed for usage control and policy analysis. Early interoperability tests and the conceptual implementation of sovereignty mechanisms show clear progress toward achieving KPIs 2.1, 2.2, and 3.1 in the second reporting period (Table 2).

Table 2: SA1.2.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI 2.1 – Interoperable devices** | >2 devices | ~2 devices | Interoperability validated via HTTP; Kafka integration will expand cross-device compatibility. |
| **KPI 2.2 – Sovereign devices** | >2 devices | In progress | Conceptual architecture completed; sovereignty demonstration depends on Kafka and access-control implementation. |
| **KPI 3.1 – Usage control policies** | >5 policies | Conceptual stage | Policy framework defined; detailed analysis and implementation scheduled for next period. |

- Current Status, Deviations, and Next Steps

SA 1.2 is progressing according to plan, with foundational elements for interoperability and sovereignty already in place. HTTP communication has been implemented and verified, while Kafka-based real-time data exchange is under active development. The conceptual architecture for semantic and sovereign data exchange has been defined, ensuring scientific alignment with KR2 and KR3. No significant deviations have been identified.

The next steps will focus on validating interoperability across more than two devices, implementing and demonstrating sovereignty features such as traceability and access control, and refining semantic validation mechanisms to ensure robust cross-device compatibility. Additionally, the communication layer will be finalised through complete Kafka integration, enabling the implementation of usage control policies and supporting the achievement of KPI targets during the next reporting period.

#### 2.1.1.2 SO.2 Efficient and accurate monitoring services (WP3, WP4)

<u>SA2.1: Visual object detection and identification</u>

Scientific Activity 2.1 aims to develop an advanced, real-time visual perception framework capable of detecting, classifying, and tracking road-related objects and safety-critical events across diverse traffic environments. The objective focuses on lightweight deep learning models, primarily YOLO-based architectures – optimised for deployment on edge hardware such as NVIDIA Jetson devices to ensure low-latency performance and local data processing. The activity contributes directly to KR4: Accurate and efficient detection of objects of interest onsite and targets KPIs

4.1-4.4, including detection accuracy, FPS performance on edge and non-edge platforms, and latency reduction.

- Work performed during the reporting period

During the first 18 months, substantial progress was achieved in the design, training, optimisation, and validation of visual perception modules to support multiple use cases. Work focused primarily on the Graz and Nevers scenarios, with preparatory activities initiated for Thessaloniki and Bizkaia. Key tasks included the development of YOLOv8 and YOLOv11 models in both PyTorch and TensorFlow environments, construction of dedicated datasets exceeding 15 object classes, and integration of multi-object tracking pipelines (DeepSort, ByteTrack) to improve temporal consistency. Real-time deployment on NVIDIA Jetson AGX Orin demonstrated stable performance, while Graz-specific modules incorporated an OCR-based licence plate recognition workflow. All Nevers modules underwent validation during plenary demonstrations and field rehearsals, confirming correct integration with the data transmission layer. Collectively, these activities establish a robust technical foundation for real-time perception layer of the iDriving system. The detailed progress achieved by Use Case is further described as follows:

*UC1.1: Graz, Austria – Safety Violations and OCR Integration*

This scenario focuses on driver and cyclist safety: helmet use, seatbelt use, distraction, vehicle classification, and license plate recognition.

- Models: YOLOv11 (Small and Medium), trained on 4,000-image dataset
- Classes: Helmet, Mobile, Seatbelt, Vehicle, Plate, Windshield, etc. (10 total)
- Performance:
  - mAP ≈ 87% average
  - 11–12 FPS on Jetson
  - 25 FPS on GPU
- Tracking: DeepSort and ByteTrack under integration
- OCR: Preliminary pipeline integrated; improvements planned for lighting variability
- Next Steps: On-site validation with Graz traffic authorities; refinement of plate cropping.

*UC1.2: Nevers, France – Multi-Module Visual Monitoring*

The Nevers scenario was divided into four independent yet interoperable modules:

i. Zebra Crossing Monitoring
   - Model: YOLOv8 + custom DeepSort tracker
   - Classes: Car, Cyclist, Pedestrian
   - Performance: ~5–6 FPS (Jetson AGX Orin), mAP ≈ 85%
   - Status: Fully implemented; validated during September field rehearsals
   - Planned: FPS optimisation and dataset expansion to improve robustness under varying weather conditions.

ii. Cyclist and Motorbike Violation Detection

- Classes: Cyclist, Helmet, No-Helmet, Turn-Right, Turn-Left
- Performance: Similar to Zebra module (~5–6 FPS), mAP ≈ 85%
- Status: Operational, validated in field tests
- Planned: Improve helmet/no-helmet classification accuracy under occlusions.

iii. Illegal Parking Detection (Bike Lane)

- Approach: YOLOv8 object detection fused with segmentation-based lane analysis
- Dataset: ~2,500 images (Car, Bus, Motorbike)
- Performance: 11–12 FPS on edge; mAP ≈ 83% (vehicles), ≈80% (segmentation)
- Status: Working prototype
- Planned: Increase segmentation accuracy; add nighttime images.

iv. Traffic Light and Road Signal Obstruction

- Function: Detects infrastructure and computes obstruction severity (High/Medium/Low)
- Performance: mAP ≈ 81%
- Status: Prototype validated in meetings
- Planned: Expand dataset; refine severity estimation under partial occlusion.

<u>Validation:</u>
All modules were tested during the September Plenary Meeting and field rehearsals, confirming data transmission, message handling, and system integration.

*UC2.1: Thessaloniki, Greece – Environmental Hazard Detection*

- Focus: Early preparation for rockslide/fallen-tree detection
- Work Performed:
    - Collection of open datasets for geological/road hazard scenes
    - Definition of target classes and initial annotation guidelines
- Status: Pre-deployment; scenario begins in 2026
- Next Steps: Acquire drone footage; train initial hazard detection models in M24–M30.

*UC3.2: Bizkaia, Spain – Accident Scene Understanding*

- Focus: Exploratory assessment of injured-person detection within accident scenes
- Work Performed:
    - Coordination with scenario leaders to define an additional class
    - Collection of initial training dataset from Roboflow (crashed vehicles)
- Status: Preparatory work only; scenario activates in late 2026
- Next Steps: Dataset expansion, annotation, and preliminary model training.

The work to date demonstrates clear progress beyond standard off-the-shelf detection systems. The combination of lightweight CNN models, targeted optimisation for constrained edge hardware, and integration of explainability tools results in a perception framework that is both computationally efficient and transparent. Achieving real-time inference on Jetson-class devices with only minimal accuracy loss is a distinctive innovation, enabling decentralised processing and reducing reliance on cloud resources for time-sensitive events. The unified dataset that includes typical road users, safety violations, and infrastructure elements enhances robustness across diverse real-world environments.

- KR & KPI alignment

The work under SA 2.1 directly advances "KR4: Accurate and efficient detection of objects of interest onsite", demonstrated through (see also Table 3):

- 15 object classes trained (KPI4.1 achieved)
- Mean mAP ≥80% (KPI4.2 achieved)
- Real-time performance on edge and non-edge hardware (KPI4.3 achieved)
- Latency reduction planned for M18–M24 (KPI4.4 ongoing)

Table 3: SA2.1.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| KPI4.1 – object classes | >10 classes | >15 classes across all use cases | - |
| KPI4.2 – detection accurace | > 80% (mAP) | Achieved: 80–87% across modules | - |
| KPI4.3 – processing time | ≥10 FPS edge (edge); >25 FPS (non-edge) | Jetson: ~11–12 FPS; GPU: >25 FPS | - |
| KPI4.4 – reduced latency | >20% via edge | - | Not yet evaluated; planned tests in next period |

- Current Status, Deviations, and Next Steps

Overall progress is on track, with most components already functional and performing near or above the KPI targets. No critical deviations have been encountered, although achieving consistently high accuracy for minority object classes has required additional data augmentation and targeted re-annotation, extending the expected duration of dataset preparation. Edge-device optimisation has also required more iterative testing than initially planned due to variability in Jetson power modes and thermal behaviour, but these challenges remain manageable within the project timeline.

The next phase will focus on consolidating the dataset, further improving minority-class detection, and finalising model optimisation for Jetson devices to confidently meet the ≥10 FPS requirement under operational conditions. Additional explainability validation will be performed to ensure the generated visualisations align with the needs of the iDriving dashboard. Integration testing with UC partners will continue, with emphasis on message formatting, stable transmission of outputs, and alignment with system-level KPIs. Overall, the work conducted in M01–M18 provides a solid foundation for the upcoming pilot deployments.

SA2.2: AI-powered analysis of object's behaviour

Scientific Activity 2.2 aims to design, implement, and validate advanced AI-driven behavioural analysis algorithms capable of detecting abnormal driving patterns and traffic violations across diverse road environments. The activity focuses on leveraging multi-sensor data, including image/video streams and later mobile inertial measurements (accelerometer and gyroscope), to identify hazardous manoeuvres such as abrupt braking, aggressive turns, improper lane usage, illegal pedestrian crossing behaviour, and failure-to-yield interactions.

The underlying methodology builds on state-of-the-art convolutional neural networks (CNNs) and pattern-recognition techniques trained on heterogeneous datasets (public, simulated, and project-acquired), optimised for near real-time performance to trigger immediate risk assessments. This work contributes directly to KR5: Efficient abnormal driving patterns and traffic violation detection, and targets the following KPIs:

- KPI5.1: Number of classes >5
- KPI5.2: Abnormal driving pattern detection >80% mAP
- KPI5.3: Traffic violation detection >85%
- KPI5.4: Near-real-time detection >25 FPS

These developments support the wider work programme objectives related to road safety assessment, infrastructure adaptation to diverse users, and advanced multimodal monitoring strategies for timely detection of safety-critical events.

- Work performed during the reporting period

During the first 18 months, substantial progress was achieved in the development of behavioural analysis modules using image-based perception and simulated sensor data. The work built on public datasets, controlled simulation environments, and the early outputs of the perception layer, enabling rapid prototyping and integration testing.

Three primary behavioural detectors have been fully implemented, with several additional models under development to satisfy KPI5.1 requirements. Integration with perception streams has been successfully verified in both online conditions and during field rehearsal activities.

- Implemented Detectors:

Zebra Crossing Violation Detector

- Function: Identifies pedestrians crossing under unsafe conditions or vehicles failing to yield.
- Performance: >80% mAP on simulated and public datasets.
- Validation: Demonstrated during rehearsal sessions; limited real-case validation available.
- Status: Operational.

Improper Lane Usage Detector

- Focus: Detects vehicles drifting, crossing lane boundaries, or performing unsafe lane changes.
- Performance: Early evaluation approaches KPI thresholds on simulated datasets.
- Status: Under performance optimisation.

Failure-to-Yield Detector (Vehicle–Vehicle / Vehicle–Pedestrian)

- Function: Analyses trajectory interactions to determine right-of-way breaches.
- Data: Simulated trajectories and violation scenarios.
- Status: Functional; will benefit from real-world annotated events.

- Detectors Under Development:

To reach and exceed KPI5.1, the following modules have been designed and prototyped:

- Red Light Violation Detector
- Cyclist Signalling Detector (turn gestures)
- Abrupt/Aggressive Movement Detector (acceleration/braking swerves)

These models will expand the class taxonomy and improve coverage of hazardous behaviours across different use cases.

- Integration with Perception Layer

A key achievement during this period is the operational integration of the perception module, tested in both online conditions and during rehearsal activities. The system architecture enables:

- Real-time streaming of detection outputs.
- Behavioural analysis triggered upon each perceived event.
- Average processing latencies below 150 ms, enabling near-real-time inference (>25 fps) in the simulation scenario

- Mobile Sensor Data Experiments

Preliminary experiments were initiated to support multimodal behavioural modelling in later phases:

- Collection of smartphone-based accelerometer/gyroscope data.

- Small dataset created covering normal vs. aggressive manoeuvres.
- Feature extraction implemented (jerk, rotational variance, peaks).

Although early-stage, these results form the foundations for future multimodal fusion (video + inertial data).

Validation Activities

Due to limited availability of annotated real-world violation events from Graz and Nevers, validation has relied primarily on simulated traffic scenarios and public datasets:

- Simulated Validation
  - Approx. 300 violation scenarios tested.
  - Accuracy levels range **78–87%** depending on detector.

- Real-World Validation
  - Limited to rehearsal data.
  - Zebra crossing violation module partially validated.
  - Comprehensive multi-class validation will begin once pilot datasets become available.

Overall, the work demonstrates strong early progress, though full KPI verification is pending access to pilot-generated data.

- KR & KPI alignment

Contribution to KR5:

The modules developed under SA 2.2 advance KR5 through the creation of a scalable behavioural analysis framework capable of identifying multiple abnormal manoeuvres and traffic violations in near real time.

Table 4: SA2.2.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI5.1 – number of classes** | >5 | 3 implemented; 3 in development → *Partial progress* | - |
| **KPI5.2 – detection of abnormal driving patterns** | > 80% (mAP) | Zebra crossing >80%; others near threshold with simulated data | - |
| **KPI5.3 – traffic violation detection** | >85% | Promising results; | real-case validation pending |
| **KPI5.4 – near-real time detections** | >25fps | Achieved; end-to-end latency <150 ms | - |

While several KPIs show strong preliminary results, final KPI confirmation requires access to real-world annotated datasets from the pilots.

- Current Status, Deviations, and Next Steps

Work is progressing according to plan, with core behavioural detectors implemented and integrated with the perception module. The main limitation concerns the availability of annotated real-world behavioural events, which constrains final performance verification for KPI5.2 and KPI5.3. No major deviations were encountered. However:

- The scarcity of real annotated violation events has delayed final mAP verification.
- Simulated datasets, while comprehensive, cannot fully capture the variability of real-world conditions.
- Mobile sensor integration remains in an exploratory phase due to dependency on upcoming pilot activities.

These issues do not threaten the overall timeline but require focused attention in the next reporting period.

The next phase will focus on finalising the remaining detectors (i.e., red-light violations, cyclist signalling, and abrupt/aggressive manoeuvres), integrating datasets from Nevers, Graz, and Alba Iulia as soon as they become available, and conducting large-scale validation using real annotated events to confirm KPI5.2 and KPI5.3. In parallel, optimising thresholds and improving robustness through weather, lighting, and occlusion stress tests, as well as completing multimodal behavioural modelling by combining perception outputs with inertial sensor features, are priorities for the near future. Finally, strengthening system integration with the iDriving data-exchange infrastructure and preparing for formal evaluation – including harmonised criteria and full-scale pilot demonstrations – will complete the process. Collectively, these activities will finalise the behavioural-analysis framework and ensure its readiness for deployment in the pilot sites, supporting a comprehensive assessment of safety impacts and operational performance.

<u>SA2.3: Analysis of environmental conditions</u>

The objective of SA 2.3 is to monitor and analyse environmental conditions that directly affect road safety by integrating meteorological observations, local microclimatic indicators, numerical weather prediction, and historical records. This activity focuses on establishing a robust environmental monitoring and forecasting framework capable of capturing key variables such as rainfall intensity, fog density, surface icing, wind gusts, and temperature gradients. The resulting environmental intelligence will support predictive and proactive road safety applications within the iDriving ecosystem, enabling the generation of real-time hazard notifications to road users and stakeholders. This Scientific Activity contributes directly to KR6:

Accurate monitoring of urban and secondary roads' microclimates and real-time environmental analysis, and supports the achievement of the following KPIs:

- KPI6.1: Environmental monitoring accuracy > 85% (including use of historical data)
- KPI6.2: Notification latency < 10 seconds
- Work performed during the reporting period

*Assessment of Observational Networks*

Significant effort has been invested in surveying, evaluating, and integrating available meteorological data sources across the two pilot regions: Thessaloniki, Greece and Karlovac, Croatia.

In Thessaloniki, a detailed assessment revealed a moderately dense network of surface stations providing temperature, humidity, dew point and – more inconsistently – rainfall measurements. Several stations present gaps in temporal coverage, metadata inconsistencies, and missing historical records. To ensure data adequacy for fine-scale validation and assimilation, a set of mitigation measures was formulated, including the exploitation of open-access datasets, the integration of previously deployed real-time meteorological monitoring assets, and recommendations for supplementary observation points. These steps improve the reliability of regional environmental characterisation and support the forthcoming modelling activities.

In Karlovac, the observational environment is more mature. The Croatian Meteorological and Hydrological Service provides dense, high-quality coverage, which was further enhanced during the project with the deployment of an automatic weather station procured following a DREVEN-led technical workshop. This station is now operational and connected through API interfaces, offering seamless access to real-time and historical measurements. Additional stations in the broader region have been identified to complement the core network. The resulting infrastructure ensures accurate representation of critical variables such as precipitation, snow cover, wind, temperature and humidity for validation and modelling purposes.

*Preparatory Work for Numerical Weather Prediction (WRF/WPS)*

Preparations for mesoscale weather modelling progressed substantially during the reporting period. Initial WRF domain configurations have been defined for both regions, reflecting regional topography, land-sea interactions, and climatological characteristics (Figure 1).

For Thessaloniki, the inner high-resolution grid is optimised to capture coastal dynamics, including sea-breeze circulations, diurnal boundary-layer transitions and land–sea contrasts. In Karlovac, the configuration reflects continental climatic influences, with emphasis on snow/ice episodes, convective storms and orographic precipitation. These configurations were informed by a targeted literature review addressing regional meteorology, model sensitivities and the suitability of microphysics, PBL and land-surface parameterisations.

Although full validation has not yet been performed, the framework for initial short-term forecasting experiments (30-minute to 6-hour horizons) has been established. These experiments will support the evaluation of model skill in reproducing key variables – including 2 m temperature, relative humidity, wind components and accumulated precipitation – before initiating systematic parameter tuning.

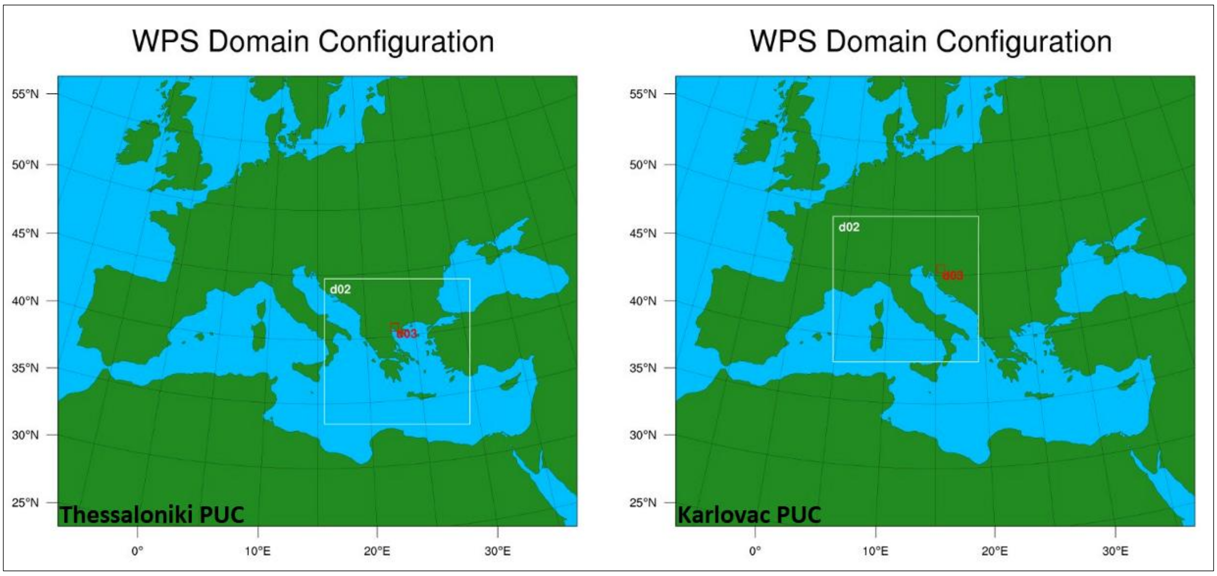
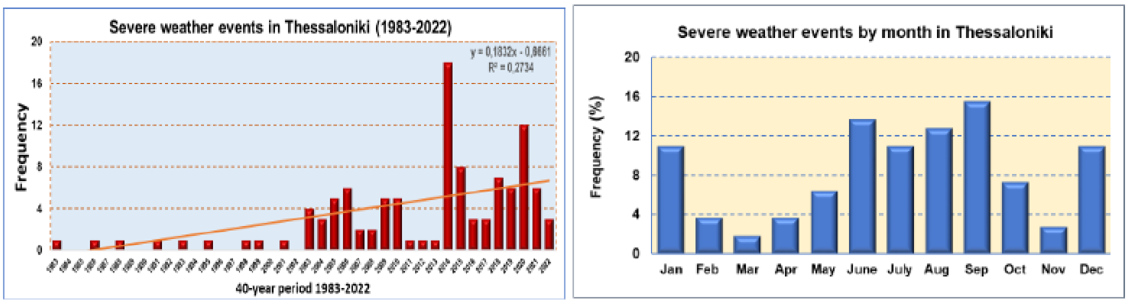



Figure 1: Telescopic domain configuration for Thessaloniki and Karlovac PUC based on literature review of their regional atmospheric and meteorological characteristics and WRF weather forecasting model prerequisites

*Regional Meteorological Characteristics Relevant to Road Safety*

The meteorological characteristics of the two regions have been carefully considered in this preparatory work. In Thessaloniki, several meteorological phenomena significantly affect driving conditions and road safety. One of the most prominent hazards is fog, particularly during the cold season. A detailed analysis of 35 years of observations (1971–2005) at “Macedonia” Airport revealed that fog occurs predominantly in winter (64 %) and late autumn (19 %), with a mean duration of approximately 4.5 hours. Notably, around 75 % of all fog events are classified as dense, with visibility below 400 m (Stolaki et al., 2009). The most common fog types in the region are advection (≈ 30 %) and radiation (≈ 29 %) fog, with cloud-base lowering accounting for another ≈ 22 %. These dense fog events (especially during early morning hours) dramatically reduce visibility and reaction time, increasing the likelihood of multi-vehicle collisions and severe traffic disruptions.

Another key hazard for road users in Thessaloniki is heavy rainfall and the associated wet or flooded surfaces. Historical severe-weather records for the wider Thessaloniki area show frequent episodes of intense rainfall, thunderstorms, and flash floods (Figure 2). These phenomena contribute to water accumulation on roadways, loss of tire traction, aquaplaning, and occasionally full roadway inundation. When combined with poor visibility from fog or heavy downpours, these conditions substantially degrade driving safety. Greek studies examining the relationship between weather and traffic accidents have found that rain, fog, and strong winds generally correlate with increased accident likelihood and reduced driver performance, although these studies cover broader Greek regions rather than Thessaloniki specifically.




(a) (b)

Figure 2: (a) Temporal distribution of severe weather events in Thessaloniki during the 40-year period 1983–2022, showing an increasing trend in frequency ($R^2 = 0.2734$). (b) Monthly frequency (%) of severe weather events in Thessaloniki, indicating higher occurrence during summer and early autumn (June-September) and a secondary peak in January (Sioutas et al., 2022).

Strong wind gusts, especially those associated with convective storms and frontal passages, further exacerbate driving hazards. Crosswinds on elevated or exposed routes can cause steering instability, particularly for high-profile vehicles such as trucks or buses. Meteorological records confirm the frequent occurrence of strong gusts during severe storm episodes. Combined with wet or flooded road surfaces, these events create compounded hazards involving reduced visibility, low friction, and vehicle instability.

In addition to this, snow and ice conditions contribute to further hazards. Although the Mediterranean climate around Thessaloniki results in less frequent heavy snowfall compared to more continental regions, there have been documented events where snow at low altitudes and freezing conditions led to road closures and hazardous driving (e.g., heavy snow in January 2025 resulting in multiple provincial road closures around Thessaloniki). These conditions drive down tire-road friction, increase braking distances, and escalate the risk of skidding or loss of vehicle control, especially on bridges, elevated roads and shaded stretches. Greek Traffic Police advice and official guidance emphasize the requirement of winter equipment (chains/ tires) and alerting drivers to the elevated risk of frozen roads.

In Karlovac, located in central Croatia, meteorological hazards affecting road users are largely dominated by heavy rainfall, flooding, and strong winds, occasionally compounded by low visibility, fog and snow/ice. The city's geographical setting (at the confluence of the Kupa, Korana, Mrežnica and Dobra rivers) renders it particularly susceptible to river overflow and flash floods following prolonged or intense precipitation. Historical hydrometeorological records show that rainfall totals exceeding 60 mm in short durations frequently trigger "orange-level" warnings indicating difficult driving conditions due to reduced visibility and wet or slippery roads. A notable example occurred in October 2015, when Karlovac received over 200 mm of rainfall in two weeks, resulting in widespread inundation of roads, residential areas, and bridges.

Strong wind gusts, often exceeding 65-75 km $h^{-1}$ during convective storm episodes, are another major hazard for drivers. Severe-weather bulletins issued by the Croatian Meteorological and Hydrological Service (DHMZ) warn of strong crosswinds capable of affecting vehicle stability, especially for high-profile or lightweight vehicles on exposed routes. These winds, when combined with heavy rainfall, further reduce visibility through spray and blowing debris.

Winter conditions in Karlovac are more severe; snowfall and ice frequently occur. Data show that in Karlovac, snow falls for ~18.8 days per year with accumulations (in December about 66 mm) and that central Croatia sees heavy snow, ice, and "winter conditions" affecting major roads and highways, with driver warnings for winter equipment and delays. Ice formation on wet roads, shaded surfaces or during temperature drops increases the risk of loss of vehicle control, especially when combined with rain, wind or flooding. Driving guidance in Croatia emphasizes adapting speed, ensuring proper winter tires/chains and avoiding travel when conditions are severe.

<u>Validation Status and Initial Results</u>

The DREVEN team has completed the preliminary integration of real-time and historical datasets, established API connections for Karlovac, and defined data-gap mitigation strategies for Thessaloniki. The WRF/WPS modelling framework is in place, domain configurations have been finalised, and the initial validation workflow has been designed. This provides a solid starting point for the upcoming simulation cycles and statistical verification tasks.

- KR & KPI alignment

The progress achieved in SA 2.3 directly supports KR6: Accurate monitoring of urban and secondary roads' microclimates and real-time environmental analysis. The comprehensive assessment of observational networks in Thessaloniki and Karlovac, together with the integration of real-time and historical datasets through API connections, significantly enhances the reliability and spatial–temporal resolution of environmental information available to the iDriving system. These improvements directly support the objective of achieving accurate microclimate monitoring across diverse road environments.

In parallel, the preparation of the WRF/WPS mesoscale modelling framework—designed with domains tailored to the regional climatic and topographic characteristics—lays the foundation for producing high-resolution predictive fields that can be assimilated into the system's hazard-analysis components. As the framework progresses towards short-term simulation and formal validation, it will enable the estimation of key meteorological variables with increasing precision, ensuring that environmental conditions relevant to road safety are detected with accuracy consistent with project expectations.

The real-time ingestion of data, the selection of high-frequency monitoring stations, and the progressive automation of data workflows contribute to the timeliness of environmental hazard detection within the iDriving ecosystem. Once coupled with the central decision-support and alerting modules, these components will support sub-10-second delivery of warnings to road users and stakeholders, addressing the requirement for rapid notifications (Table 5).

Table 5: SA2.3.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI6.1 – environmental monitoring accuracy** | >85% | Early-stage integration of data sources (weather stations, models, AI methods) is underway | accuracy assessment will be performed once the predictive algorithms and hazard detection models are integrated into the iDriving ecosystem.- |
| **KPI6.2 – Notifications** | <10 secs | Real-time alerting pipelines are being designed as part of the environmental monitoring service | end-to-end latency tests will be conducted once hazard-prediction models and the notification mechanisms are operational in the pilot environments.- |

- Current Status, Deviations, and Next Steps

No formal deviations have been identified at this stage. The primary limitation concerns the incomplete availability of high-quality, continuous observational datasets for Thessaloniki, particularly for precipitation. Although this does not constitute a deviation, it temporarily constrains validation depth. Mitigation measures – such as integrating open-data sources and leveraging prior real-time systems deployed in the region – have already been initiated and are expected to resolve these coverage gaps. Model validation has not yet commenced due to this dependency on final dataset consolidation, but all preparatory steps have been successfully completed and remain within planned timelines.

The next phase will complete the initial WRF short-term forecast simulations and begin systematic statistical validation against ground observations and historical datasets. Parameterization schemes for microphysics and the planetary boundary layer will be refined to correct biases identified in early comparison runs, enabling improved environmental monitoring accuracy and contributing directly to KPI 6.1. Additionally, the integration of model outputs and station data with the iDriving hazard-detection and alerting pipeline will be advanced to support rapid dissemination of environmental alerts, ensuring that the system moves towards achieving KPI 6.2.

Data obtained from the Thessaloniki and Karlovac pilots will be progressively incorporated into the validation loop to ensure performance is assessed across contrasting climatic regimes. The final goal is to deliver a fully validated, real-time environmental monitoring and predictive modelling service that is seamlessly integrated into the broader iDriving ecosystem and ready for deployment in the pilot trials and subsequent impact evaluation.

SA2.4: High level autonomous control of UAVs

Scientific Activity 2.4 focuses on developing high-level autonomous control mechanisms for UAVs to support infrastructure inspection and incident monitoring. The goal is to enable drones to navigate and make decisions autonomously, generating and executing optimal coverage paths in real time, even in complex or dynamic environments. This work leverages AI-based algorithms, cooperative multi-UAV planning, and the operational capabilities of different UAV platforms. The activity aligns with the objectives concerning the interaction of infrastructure elements within a digitalised ecosystem, the enhancement of monitoring and maintenance processes, and real-time communication of distress or deterioration conditions.

- Work performed during the reporting period

During this reporting period, substantial progress was made in developing a comprehensive Coverage Path Planning (CPP) methodology aligned with the requirements of high-level autonomous UAV control. The work began with an extensive review of the state of the art to identify key technical challenges such as energy limitations, obstacle avoidance, handling No-Fly Zones, region irregularities, and the need for computationally efficient on-site planning. Based on this analysis, a grid-based strategy has been designed, that decomposes Regions of Interest (ROIs) and supports obstacle-aware and density-controlled path planning.

*Development of the CPP Methodology*

A fully parameterized CPP algorithm is implemented, tailored to iDriving's requirements for autonomous infrastructure inspection.

The goal is to plan cooperative coverage paths for multiple UAVs so they can fully scan a Region of Interest (ROI) as efficiently and quickly as possible, while avoiding obstacles and no-go zones (NGZs). The methodology builds on prior work that handles three key components: (i) converting the ROI into a grid representation, (ii) allocating coverage tasks among UAVs, and (iii) generating collision-free coverage trajectories.

**The methodology is composed of the following core elements:**

Given the user-defined ROI and NGZs (in WGS84 format), the desired scanning density, the number of UAVs, and their starting positions, the process proceeds in three steps:

1. Grid Representation:

The ROI is discretized into a grid (Figure 3) according to the selected scanning density. Each cell is labeled as *Free Space*, *Obstacle*, or *Initial Position*. This representation standardizes the environment and enables structured analysis.

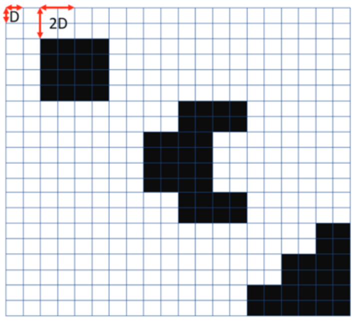



Figure 3: ROI discretized into a grid

The field polygon A is discretized into a grid of equal-sized cells determined by the scanning density and altitude. Each cell is marked as **free** or **occupied** depending on whether it lies inside an obstacle region. The set of all free cells forms the area the UAV must cover.

2. Task Allocation via DARP (Kapoutsis et al., 2017):

Given the grid map and the number of UAVs (with their initial positions), the DARP algorithm partitions the ROI into exclusive sub-regions, one per UAV. DARP ensures each sub-region is contiguous, covers a distinct portion of the ROI, and contains the UAV's start position, so drones don't waste time traveling outside their area (Figure 4). The partitioning process starts from an initial Voronoi division and iteratively adjusts boundaries via a custom distance function until the criteria are met. This guarantees that all subregions together exactly reconstruct the entire ROI, achieving full coverage with no overlap. The outcome is that each UAV is assigned a unique zone to survey, as illustrated by DARP's progressive area allocation (initial, intermediate, and final partitions) in its execution.

Figure 4: Area allocation during different time-steps of DARP execution.

3. Path Planning via STC (Dong et al., 2020):

Once sub-regions are assigned, each UAV independently solves a Coverage Path Planning problem for its own area. The Spanning Tree Coverage (STC) algorithm is used to generate a route that traverses every free cell in the sub-region without repetition. STC constructs a spanning tree over the target cells and then computes a cyclic path that follows the tree edges, effectively "covering" the area in a continuous loop. It operates on a dual-grid scheme: one coarse grid to form a Minimum Spanning Tree (MST) of cell centers, and a finer grid to define waypoints that skirt around the MST. This produces a closed path that can start and end at any cell, which is convenient for a UAV to begin at its launch point and finish coverage without backtracking. Figure 5 illustrates the key steps of the STC algorithm, from spanning-tree creation to the final coverage loop.

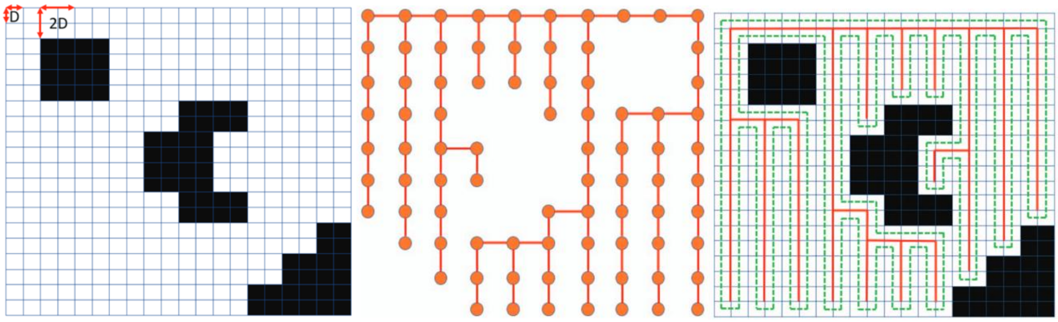



Figure 5: The Spanning Tree Coverage (STC) algorithm in action. STC uses a multi-resolution grid: the larger grid's cell centers form a spanning tree and the smaller grid's cells yield waypoints that trace around the tree. The result is a closed path covering all free cells with no gaps or overlaps. This closed-loop path allows each UAV to start and end at arbitrary points (e.g., its launch location) while guaranteeing complete coverage of its sub-region.

Each UAV follows its computed path concurrently. Because DARP has allocated disjoint sub-regions, two UAVs' paths will not intersect, preventing collisions by design. Additionally, baseline safety measures include having drones operate at different altitudes during transit to and from their start points to avoid airspace conflicts. The mission is considered complete when all UAVs have finished their routes. The total mission time is thus governed by the slowest (longest-duration) path among the drones. In this version, initial launch positions are predetermined (e.g. user-defined or random) and not optimized, which means the sub-regions produced by DARP could be suboptimal in shape. Since all UAVs get an equal area share, the path lengths are roughly equal; however, the number of turns each path contains can vary depending on sub-region geometry . More turns slow down a UAV (due to deceleration at corners), so the mission duration is heavily influenced by the path with the most turns . This insight, while not exploited in the baseline, lays the groundwork for improvements in Version 2.

4. Simulation and Validation Activities

To assess the performance of the proposed navigation algorithm to the quantity of coverage and the overall quality of paths, two different metrics are considered. The first metric Percentage of Coverage (PoC) (KPI 7.2) is for the accuracy in terms of coverage and the second metric Estimated Flight Time (EFT) (KPI 7.1) is for the efficiency in terms of coverage time.

The metric PoC intends to represent the percentage of coverage directly matched to a path X within A. Given the problem definition, PoC is defined as follows:

$$PoC = (n_A / n_{Amax}) \times 100\%$$

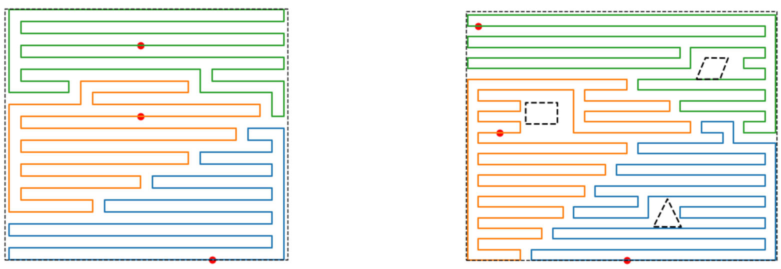
where $n_A$ denotes the number of nodes placed inside a polygon A which will be used for the MST construction and $n_{Amax}$ denotes the theoretically maximum number of nodes that could fit inside a given polygon A. Thus given A and scanning density (the distance between two sequential trajectories), $n_{Amax}$ is formulated as follows:

$$n_{Amax} = A / \text{scanning density}^2$$

where A is defined in $m^2$ and scanning density is defined in meters in the x-axis and the y-axis, respectively.

The second metric EFT intends to represent the estimated time, in minutes, for the UAV(s) to follow a path. As to covering time, the EFT is determined by the simulation time.
For the path planning experimental setup, AirSim's UAV simulation model (Shah et al., 2018) was utilized.

We evaluated the baseline multi-UAV coverage system in simulation over various ROI scenarios, including complex polygonal fields with obstacles. Figure 6 shows a representative result from a challenging scenario: a *non-convex field with internal No-Go Zones (obstacles) covered by 12 UAVs*, each starting at a random initial position (baseline configuration). The colored regions indicate the sub-areas assigned to each UAV by DARP, and the plotted routes are the STC-generated trajectories ensuring full coverage of those regions.



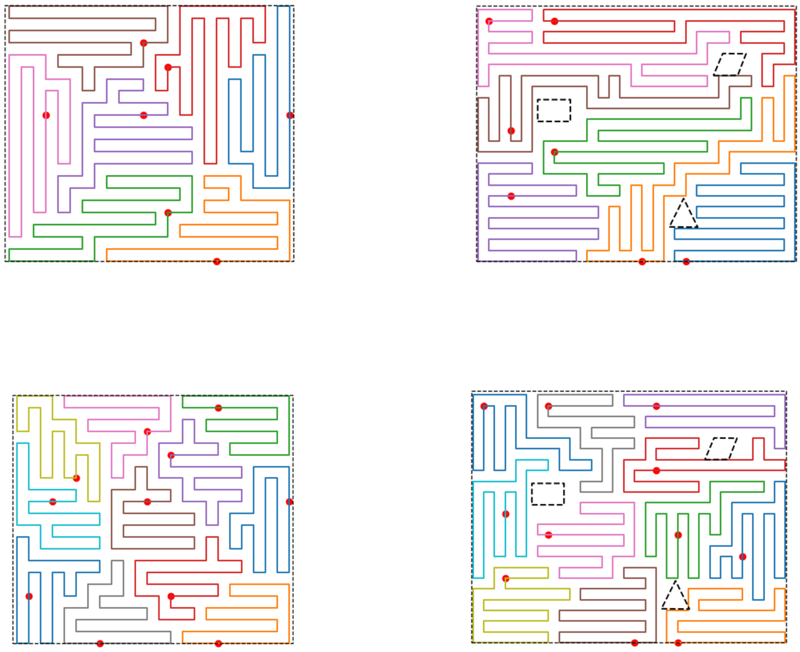


Figure 6: A non-convex ROI with several no-go zones is partitioned among 3,7 and 11 UAVs (each sub-region shaded with a different color) using DARP. Each UAV's closed coverage path (shown as a loop within its sub-region) is generated by the STC algorithm. The initial launch positions (red markers) were chosen arbitrarily in this run, illustrating our approach.

In these scenarios, the system achieves 100% area coverage – every accessible cell in the ROI is visited by exactly one UAV. The DARP algorithm successfully prevents overlaps or gaps, even in the presence of complex obstacles, validating its effectiveness in area division. Moreover, the STC-generated paths allowed each drone to systematically sweep its region without dead-ends or backtracking, confirming complete coverage in practice. However, we have noticed that some UAVs ended up with *inefficient paths* due to the arbitrary initial positioning. For example, one UAV's sub-region might span a long, narrow corridor of the ROI, causing that drone's path to include numerous sharp turns. Another UAV's region might be more compact, allowing a smoother path with fewer turns. Since all drones must finish for the mission to conclude, the drone with the most turns (and hence longest time) dictate the total mission time. We observed that with random launch placements, mission completion time is often longer than necessary, as some drones travel convoluted routes that slow down the operation. Additionally, while each drone's path length is roughly equal (due to equal area allocation), the time spent turning (slowing down and speeding up) inflates some paths' durations more than others. This also implies wasted energy, as excessive turning maneuvers consume more battery.

The early integration of DARP and STC in the iDriving Horizon project demonstrates a solid foundation for multi-UAV coverage but also reveals clear avenues for enhancement. This approach guarantees complete coverage and maintains safety through coordinated area segmentation. The DARP algorithm's criteria ensure that each UAV is constrained to a reasonable operating region containing its start point, which avoids unnecessary travel (e.g., a drone doesn't have to fly across the entire region to begin its task). The STC algorithm, with its no-backtracking coverage paths, optimally covers grid cells without repeats. These strengths mean the baseline system is *reliable and thorough* in covering a field.

In summary, Version 1 establishes that multi-UAV coverage is feasible and reliable using the DARP+STC framework, but it also highlighted key inefficiencies: unnecessarily high turn counts for some UAVs, longer mission times due to unoptimized launch positioning, and minor grid representation issues. These findings set the stage for the next development iteration, where the focus will shift to optimizing these variables – particularly the UAVs' launch points – to achieve faster and more energy-efficient coverage without sacrificing completeness or safety.

- KR & KPI alignment

The work conducted directly addresses KR7, as the project has successfully developed and validated both off-line and online path-planning solutions designed for mapping regions and tracking incidents through cooperative multi-UAV strategies (Table 6). The combination of DARP for optimal area allocation and STC for complete, structured coverage paths demonstrates clear alignment with the research requirement of producing robust, algorithmic solutions for autonomous UAV control. Continuous simulation testing and iterative refinement have also enabled the project to measure improvements in scanning efficiency and situational awareness—laying the foundation for reaching the KPI targets in the next period.

Table 6: SA2.4.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI 7.1 – Reduced scanning operations' time for data collection** | 20% reduction | ~15% | Results based on Estimated Flight Time (EFT) across multiple scenarios. Further gains expected from optimised launch-point selection and online replanning. |
| **KPI 7.2 – Increased awareness in incident sites** | 30% improvement | ~30% | KPI reached at simulation level through complete coverage and improved PoC values, especially in complex non-convex scenarios. |

- Current Status, Deviations, and Next Steps

The methodology developed for SA 2.4 is scientifically validated and fully aligned with KR7, demonstrating that the integration of DARP and STC provides reliable, collision-free multi-UAV coverage under diverse conditions. Current results show strong progress toward the KPIs, with KPI 7.2 already achieved in simulation and KPI 7.1 approaching the target. No major deviations were recorded during this reporting period, although simulation results highlight performance inefficiencies arising from randomised UAV launch positions and high turn-density areas, which currently limit mission-time optimisation.

Looking ahead, the next steps will focus on transitioning from offline planning to more responsive online replanning, improving launch-point optimisation, and enabling real-world pilot tests. These enhancements are expected to significantly reduce mission duration, improve energy efficiency, and bring KPI 7.1 to the targeted threshold. The upcoming period will also integrate dynamic resource allocation and real-time adaptation capabilities, strengthening the robustness and autonomy of UAV operations within the iDriving ecosystem.

#### 2.1.1.3 SO.3 Digital Twins for Enhanced Event Analysis and Early Warning Mechanisms (WP5)

SA 3.1: AI-based updates of Safety Criteria Catalogue (SCC)

Scientific Activity 3.1 aims to enhance and continuously update the Safety Criteria Catalogue (SCC) through advanced AI and data-driven techniques. The goal is to identify and validate the most influential variables impacting road safety and use them to build a library of prediction models capable of forecasting safety-related KPIs in real time. This activity incorporates a range of machine learning methodologies — including PCA, variational autoencoders, LSTMs, Bayesian models, and GAN-based predictors — to extract key indicators, predict the evolution of safety risk, and support automated decision-making within the iDriving digital ecosystem. The SCC will operate dynamically, integrating real-time and historical data to generate updated safety metrics, enabling a more precise, mode-aware assessment of road conditions aligned with the broader objectives of the work programme.

- Work performed during the reporting period

During this reporting period, the full dynamic SCC workflow was established, enabling an end-to-end pipeline from raw data ingestion to indicator computation, machine-learning-based prediction, and risk alert generation. The SCC has been enhanced with surrogate safety metrics (PET, TT, DRAC) as well as core traffic variables, allowing mode-aware risk estimation for cars, cyclists, and pedestrians.

To support continuous safety analytics, a SUMO-based digital twin of Nevers was deployed, streaming 1-second vehicle trajectories via TraCI. This environment enabled automated conflict detection and aggregation, forming a high-resolution dataset for model training and SCC updates. Building on this foundation, a two-stage LSTM modelling pipeline was implemented, one stage predicting global safety indicators and another decomposing forecasts by road user category. These models demonstrated promising performance, achieving typical Weighted Mean Absolute Percentage Error (WMAPE) levels of 16–23% in non-free-flow conditions.

Additionally, the latency budget for the full data-to-dashboard path has been defined, and optimisations that significantly improved end-to-end processing time were implemented, supporting future real-time SCC operation.

- KR & KPI alignment

The work conducted to date directly contributes to KR8, which requires the development of a Prediction Model Library for the SCC and the validation of influential variables affecting road safety. The creation of the LSTM-based forecasting pipeline, the integration of surrogate and contextual metrics, and the deployment of the digital twin all support the identification, validation, and modelling of safety-relevant features. Early predictive accuracy results and the compilation of influential variables indicate strong alignment with KR8, establishing a solid foundation toward meeting the final KPI targets (Table 7).

In the next steps, real-world data integration, continued model retraining, drift monitoring, and threshold calibration will directly support the achievement of KPI 8.1–8.3, ensuring that predictive accuracy improves, influential variables are fully validated, and false positives/negatives are progressively reduced.

Table 7: SA3.1.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI 8.1** – improvement in predictive accuracy of safety KPIs | ≥20% | Baseline defined; LSTM models achieve WMAPE 16–23% outside free-flow, approaching target | - |
| **KPI 8.2** – Identify and validate influential safety variables | ≥10 variables | Candidate set compiled | validation ongoing using multi-source features |
| **KPI 8.3** – reduction in false positives and false negatives | ≥15% | Initial model tuning in progress – reduction observed | full evaluation pending |

- Current Status, Deviations, and Next Steps

The activity is progressing according to plan, with no major deviations reported. A complete SCC workflow has been implemented, and early predictive performance indicates the models are moving toward the required KPI targets. Influential variables have been identified, though final validation is still ongoing and will continue into the next reporting period. Work on latency reduction has begun and is expected to further enhance real-time SCC deployment.

In the next phase (M19–M24), the SCC will be broadened to include additional contextual and exposure-normalised indicators, supporting more granular safety assessment. A key focus will be the field validation of the SCC components using real traffic data from the pilot locations, enabling the verification of model accuracy, the refinement of variable importance, and the calibration of thresholds under real-world conditions. Model retraining mechanisms, drift detection tools, and automated threshold calibration will be strengthened to prepare inputs for Deliverables D5.2 and D5.3. Further optimisation of the model library and the integration with other components will help consolidate progress toward the achievement of KR8 and the remaining KPIs.

<u>SA 3.2: Digital Twin for simulation of road conditions and prediction of dangerous events</u>

SA 3.2 focuses on extending the existing agent-based simulation environment to accurately represent the dynamics of the transportation network in the selected pilot sites. The activity includes building SUMO-based replicas of the real network with identical topology and supply characteristics, calibrating traffic dynamics using observed data, and developing a monitoring dashboard for scenario testing. A dedicated infrastructure-simulation layer will be added to capture infrastructure evolution in parallel to traffic operations. Finally, the Digital Twin will feed simulation-derived variables into the prediction models developed in SA 3.1 to enable the identification of dangerous conditions and events.

- Work performed during the reporting period

During the reporting period, SUMO scenarios were calibrated for the Graz and Nevers pilot corridors, with additional high-fidelity junction models being initiated in CARLA. These calibrated scenarios form the basis not only for safety analysis but also for downstream WP3 activities such as rerouting and signal control optimisation. Driver behaviour modelling was implemented to integrate iDriving dangerous-behaviour and violation-detection tools directly within the simulation environment.

Simulation outputs were connected to KPI dashboards to enable controlled scenario testing, including assessment of signal-timing strategies, speed harmonisation, and what-if evaluations of safety impacts. Furthermore, data interfaces for counts, turning ratios, and pedestrian/cyclist trajectories were established, along with calibration routines to support continuous refinement of the Digital Twin.

- KR & KPI alignment

Progress under SA 3.2 contributes directly to KR9: Digital Twin's Simulation of Road Conditions and Prediction of Dangerous Events by establishing a calibrated, data-driven simulation environment capable of producing reliable safety – and traffic-related indicators (Table 8). The creation of high-fidelity scenarios and the integration of behavioural models provide the basis for meeting predictive-accuracy targets and ensuring that simulation outputs can meaningfully support the forecasting pipeline. Calibration routines and dashboard integration demonstrate early progress toward both simulation accuracy and latency improvements, with ongoing work expected to strengthen alignment with the KR.

Table 8: SA3.2.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI 9.1 -** accuracy in traffic condition simulations vs. real-world data | 90% | Calibration procedures established; accuracy tracking set up | site-specific refinements ongoing |
| **KPI 9.2 -** reduction in data-to-dashboard reporting latency | 15% | Latency baselines defined; initial interface optimisation underway | - |
| **KPI 9.3 -** predictive accuracy for dangerous-event prediction | ≥85% | Simulation-assisted model training enhances generalisation | cross-validation in progress |

- Current Status, Deviations, and Next Steps

Overall, SA 3.2 is progressing according to plan, with calibrated SUMO scenarios available for both pilot corridors and initial CARLA setups underway. The Digital Twin now incorporates behavioural models and provides structured outputs to the KPI dashboards, enabling scenario-based testing of safety and traffic management strategies. No major deviations from the work plan have been identified at this stage.

The main focus for the next period (M19–M24) will be to complete the calibration using newly collected counts and video data, extend the simulation environment to additional PUCs, and incorporate rare-event augmentation to enhance the robustness of dangerous-event prediction. Further optimisation of data flows, and model integration will continue, to meet KPI targets related to latency and predictive accuracy.

SA 3.3: Incident identification and warning mechanisms

This activity focuses on developing a real-time warning mechanism capable of identifying atypical or hazardous situations based on deviations in key safety KPIs. The work includes creating an analyser that continuously monitors KPI values, detects abnormal patterns, and generates warnings that can trigger response strategies developed across other work packages. Furthermore, the activity integrates with the digital twin to model V2I communication flows, assess delays between event detection and system response, and evaluate the effectiveness and timeliness of different warning strategies. The work contributes to the programme's objectives related to real-time KPI monitoring, advanced warning techniques for infrastructure, malfunctioning and post-impact alerts for road equipment, and the development of infrastructure measures that promote safer user behaviour.

- Work performed during the reporting period

During the reporting period, a combined rule-plus-learned analyser was designed to detect atypical situations through deviations in key KPI distributions – for example, by identifying shifts in PET values. This analyser was integrated into the KPI dashboards to allow operators to review detected anomalies and validate alert behaviour. Alongside this, the escalation logic governing alert severity, persistence, and differentiation across modes and locations was drafted. The relevant APIs were also defined to enable integration with the control centre (under T5.5), ensuring that warnings can propagate through the broader iDriving ecosystem.

- KR & KPI alignment

The work completed so far directly supports KR10, particularly by establishing the detection stack, warning logic, and integration pathways necessary for real-time incident identification (Table 9). Early evaluations using labelled near-miss datasets are ongoing to quantify detection accuracy, and the internal analysis has already mapped delays across the processing pipeline to support KPI10.2. Templates for alerts have been defined to ensure full scenario and mode coverage, which contributes to KPI10.3.

Table 9: SA3.3.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI10.1 – Detection accuracy** | 95% | Detection stack defined | offline evaluation underway with labelled near-miss data |
| **KPI10.2 – Identification-to-response time reduction** | ≥10% reduction | Pipeline delays mapped; early optimisation in data ingest and aggregation stages | - |
| **KPI10.3 – Coverage of warning messages** | Full scenario and road-user coverage | Warning templates defined for multiple modes and scenarios | - |

- Current Status, Deviations, and Next Steps

At M18, the activity is progressing according to plan. The foundational elements for real-time incident identification – detection logic, escalation rules, and dashboard integration – are already in place, and no major deviations from the work plan have been identified. Preliminary testing has begun to assess detection accuracy and latency improvements, with refinements expected as more labelled data becomes available.

In the next phase (M19–M24), the priority will be to field-test detection thresholds and evaluate system performance under real conditions. Enhancements will be introduced to improve message content, HMI presentation, and overall operator usability. The analyser will be fully connected to the XR-based control-centre mock-ups, enabling realistic end-to-end interaction testing. Operator feedback will be gathered to fine-tune the escalation logic, warning templates, and latency optimisation strategies.

<u>SA 3.4: Optimal traffic management for congestion avoidance and improved safety environment</u>

This objective focuses on the development of an Intelligent Traffic Management System (ITMS) that optimises real-time traffic flow and enhances road safety by combining congestion-aware routing and adaptive signal control. The system integrates multimodal sensor inputs, UAV observations, and real-time data processed through the iDriving platform, providing dynamic responses to both planned and unplanned events such as maintenance works, accidents, or adverse weather. It consists of two complementary subsystems: a Route Guidance Tool designed to provide safety-aware routing recommendations, and a Signal Control Tool capable of adapting signal timings in response to evolving network conditions.

The tools are being integrated with the SUMO-based Digital Twin developed in T3.2, ensuring that both routing and signal control can be deployed in Graz and other networks once local traffic data and signal plans are available. The work contributes directly to KR11 – Traffic Flow Improvement for Safer Roads, targeting a minimum 10% reduction in travel times (KPI11.1) and a 10% reduction in accidents (KPI11.2) through improved routing decisions, reduced delays, and lower exposure to incident-affected areas.

- Work performed during the reporting period

*Route Guidance Tool*

The Route Guidance Tool was designed and developed using SUMO-based simulation environments, enabling early validation before deployment in Graz. The tool incorporates a multi-criteria cost function that accounts for travel time, safety distance from incident areas, penalties for closures, and weather adjustments. Its dynamic routing logic reacts to real-time changes in the network and has been validated across multiple synthetic incident scenarios, demonstrating improved routing stability and reduced exposure to hazardous areas. The tool is now being prepared for deployment in the Graz Digital Twin, with localised traffic demands and incident scenarios being added.

*Signal Control Tool*

The Signal Control Tool, implemented in C++, was developed to apply an adaptive max-pressure logic that adjusts signal timings based on link-level traffic states. Synthetic simulations showed that the approach reduces delays and improves speeds relative to fixed-time configurations. The tool has reached a stable prototype stage and is being integrated with the Graz Digital Twin, using real signal plans and traffic patterns to enable realistic testing. Coordination with associated partners, ensures that calibration data and incident definitions are consistent with the broader framework.

*Integration with the Digital Twin*

Both tools have been aligned with the defined architecture. Interfaces for sending and receiving traffic states via SUMO have been established, and the required datasets (demand, turning ratios, closures, weather conditions, signal plans) are being incorporated for the Graz deployment. The work ensures that the ITMS will support the full range of scenario simulations planned in within the project's WPs.

- KR & KPI alignment

The work conducted contributes directly to KR11 by enabling measurable improvements through dynamic routing and adaptive signal control (Table 10). Synthetic testing suggests progress toward the expected travel-time reductions under KPI11.1, while KPI11.2 will be assessed once full scenario simulations in the Graz Digital Twin are executed.

Table 10: SA3.4.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI 11.1 – Reduction in travel times** | ≥10% decrease | Synthetic tests indicate reductions but require verification with calibrated Graz scenarios | - |
| **KPI 11.2 – reduction in accidents** | ≥10% reduction | To be evaluated via Digital Twin incident simulations (ongoing configuration) | - |

- Current Status, Deviations, and Next Steps

The activity is on track. Both the Route Guidance Tool and Signal Control Tool have reached stable prototype maturity. Integration with the Graz Digital Twin is close to completion and is progressing in line with dependencies from WP3 and WP5. No deviations with impact on the deliverables have been identified.

Next steps include finalising Graz data integration, running full simulation campaigns combining both tools, computing site-specific KPI results, and contributing evaluation outputs to related WPs. These simulations will validate the travel time and safety improvements in realistic conditions and feed into the final KR11 assessment.

#### 2.1.1.4 SO.4 Intelligence for improved maintenance operations (WP4, WP5)

SA 4.1: 3D representation for enhanced visualization

This activity aims to develop and validate an advanced 3D visualization solution for road infrastructure inspection, maintenance monitoring, and incident awareness. Using imagery captured by UAVs and roadside cameras, the system will generate real-time 3D reconstructions capable of highlighting infrastructure distress, tracking maintenance progress, and improving situational awareness for road managers. The work contributes directly to the programme's goals of connecting infrastructure elements to the digital ecosystem, enabling advanced real-time monitoring, and supporting maintenance and safety interventions with minimal disruption.
The associated Key Result is KR12: Enhanced 3D Rendering and integration with AI techniques for comprehensive road analysis, supported by performance-oriented KPIs on rendering speed and memory efficiency.

- Work performed during the reporting period

*Data Acquisition and Protocol Development*

A UAV-based object-centric data capture protocol was designed, specifying trajectory patterns, image overlap, and viewpoints to maximize multi-view constraints for high-precision 3D reconstruction. Multi-perspective real-world datasets were then collected using UAVs and dashboard cameras, focusing on road pavement defects such as potholes and cracks. Additional UAV footage (static-vehicle scenario) was processed to support initial reconstruction testing and benchmarking.

*Baselines and State-of-the-Art Evaluation*

To establish performance references, baseline NeRF and 3D Gaussian Splatting (3DGS) pipelines were implemented and evaluated on standard benchmarks. Further experiments with 3DGS and Splatfacto assessed reconstruction fidelity, runtime behaviour, and memory usage, focusing on the constraints of road-scene and object-centric reconstruction. These provide the comparative foundation needed to quantify improvements achieved by the new iDriving 3D pipeline.

*Semantic Enrichment of 3D Reconstructions*

Semantic cues from the classification methods developed in Task 4.3 – particularly class activation maps highlighting pavement defects – were integrated directly into the reconstruction loop. This enables 3D outputs that not only reconstruct geometry but also emphasise safety-critical regions. A joint research paper titled "Semantic-Aware 3D Gaussian Splatting for Road Pavement Condition Monitoring" was submitted to the TRA 2026 conference as a scientific result of this work.

- KR & KPI alignment

Work to date contributes directly to KR12 by advancing both the rendering efficiency and the semantic usefulness of 3D reconstructions. Comparative studies between NeRF and 3DGS have demonstrated measurable improvements in runtime performance and memory use, with further optimisation expected once large-scale roadway scenes (beyond object-centric captures) are integrated into the pipeline (Table 11). The semantic-enriched reconstruction supports the KR12 requirement of combining AI-driven detection with advanced 3D visualization for comprehensive infrastructure analysis.

Table 11: SA4.1.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI 12.1 -** increase in rendering performance vs traditional methods | ×5 | ~2× improvement observed in current experiments (object-centric scenes). | Process on track with further optimisation planned for large-scale scenes |
| **KPI 12.2 -** reduction in memory footprint | ≥30% | ~10% reduction vs NeRF observed to date | Process on track with extended experiments planned for full road-scene reconstructions |

- Current Status, Deviations, and Next Steps

Work is progressing according to plan, with foundational components – including acquisition protocols, baseline benchmarks, and integration of semantic cues – already developed and validated. Early results show clear rendering and memory-efficiency gains, although performance on complete road corridors has not yet been evaluated. No major deviations have occurred; the slightly lower improvements compared to KPI thresholds are expected at this stage because experiments so far focus on single-object scenes rather than full roadway segments.

Next steps include scaling the reconstruction pipeline to long, continuous road scenes, extending semantic enrichment to all relevant defect categories, and conducting comparative experiments on larger datasets. Additional optimisation of rendering speed and memory compression will be performed to reach KPI targets by M36. Integration into the visualization workflows will also begin, enabling the 3D models to support maintenance monitoring, incident situational awareness, and Digital Twin interoperability.

SA 4.2: Defect detection of road infrastructure at local level

SA 4.2 develops a real-time AI-based monitoring framework for detecting and classifying surface-level road defects (e.g., cracks, potholes) using roadside cameras and UAV payloads. The objective is to deliver a highly accurate and efficient defect-detection module capable of operating in diverse environments, integrating seamlessly into the iDriving Digital Twin and contributing to intelligent, data-driven maintenance.
This activity supports SO4 – Intelligence for improved maintenance operations and directly targets KR13, with performance goals of >90% detection accuracy (mAP) and ≥25 fps real-time processing.

- Work performed during the reporting period

*Data Curation and Benchmarking*

A robust evaluation workflow using the RDD2022 dataset, enriched with additional real-world defect imagery has been established. Data harmonisation, annotation checks, and defect-type balancing ensured consistency across both urban and rural scenarios.

*Model Development and Testing*

A series of YOLOv11 variants were trained and benchmarked to identify the optimal speed–accuracy configuration. Model retraining under varying illumination, texture, and background conditions improved robustness for in-the-wild deployment. Initial severity scoring was introduced through pixel-area and instance-count metrics, providing a first layer of defect quantification.

*Explainability and 3D Integration*

EigenCAM attention maps were incorporated to enhance interpretability and operator trust. These outputs were further integrated with NeRF-based representations to localise detected defects within 3D scenes, strengthening links between SA 4.2 and SA 4.1 and supporting future Digital Twin integration.

*Towards Temporal Consistency*

Preliminary exploration of transformer-based architectures was initiated to improve temporal coherence in video-based inspection, especially for UAV fly-over sequences.

- KR & KPI alignment

SA 4.2 directly contributes to KR13 – Intelligent and automated detection of road surface defects, which requires (i) high-accuracy detection of multiple defect types, (ii) real-time operation suitable for both fixed and aerial cameras, and (iii) integration into the maintenance-oriented Digital Twin workflow (Table 12). The work performed so far has produced a functioning prototype aligned with KR13, with accuracy and speed approaching the required thresholds.

Table 12: SA4.2.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI 13.1 – High defection detect accuracy** | >90% (mAP) | **80–85% mAP** on RDD2022 + real-world imagery | Substantial progress; final tuning, dataset expansion and augmentation expected to close the gap |
| **KPI 13.2 – Real-time processing speed** | ≥25 fps | **22–27 fps** using YOLOv11s on mid-range GPU | Largely achieved; minor optimisation required for consistent ≥25 fps in all conditions |

- Current Status, Deviations, and Next Steps

The activity is progressing well, with substantial developments in data preparation, model training, benchmarking, and interpretability. Current experiments using YOLOv11s achieve 80–85% mAP and real-time performance between 22–27 fps, demonstrating strong alignment with the KR13 targets and confirming the viability of both roadside and UAV-based monitoring for defect detection. Integration with NeRF-based 3D representations, as developed in SA 4.1, further enriches the spatial context of detected defects, while the introduction of a defect severity metric and attention visualisation improves transparency and operational relevance.

No major deviations have occurred, although reaching the target accuracy of >90% mAP requires additional optimisation and further expansion of the training dataset to cover more challenging environments. Early experiments on transformer-based temporal models have also indicated additional work is needed to ensure stable video-level performance but remain within the planned scope.

Next steps focus on enhancing accuracy through targeted augmentation, model refinement, and dataset expansion, with emphasis on difficult lighting, weather, and pavement conditions. Further integration of temporal mechanisms will support more consistent video-based detection, while continued collaboration with SA 4.1 will strengthen 3D contextualisation for predictive maintenance workflows. The overall trajectory remains strongly aligned with KR13 and the timeline of the work programme.

SA 4.3: Digital Twin for cost-effective maintenance strategies

SA 4.3 aims to develop a risk-based Digital Twin (DT) framework that integrates AI-driven risk modelling, simulation of alternative maintenance strategies, and optimisation methods to improve safety and reduce maintenance costs. The architecture supports the Karlovac UC and links long-term scheduling, short-term re-planning, contextual risk assessment, and asset localisation. It contributes to KR14 by enabling predictive, cost-effective, and proactive maintenance operations, aligned with low-impact and data-driven infrastructure management.

- Work performed during the reporting period

During the reporting period, the Digital Twin architecture was fully defined and made operational, integrating all core components required for the Karlovac pilot: long-term and short-term maintenance scheduling, an extended risk-assessment methodology, a simulation engine for evaluating maintenance strategies, and a robust OSM-based asset-localisation pipeline.

All data pipelines, scheduling structures, and model-training workflows have been prepared, enabling forthcoming development of AI-driven risk models. The enhanced FMEA methodology was completed, incorporating contextual parameters such as traffic levels, weather patterns, and land-use characteristics, improving granularity and predictive relevance.

Initial simulation campaigns using the newly implemented cost model produced an early indication of ~5% reduction in maintenance costs, while OSM-based localisation delivered ~10% faster incident identification compared to manual GIS processes. A first prototype of the maintenance decision-support dashboard has also been developed, visualising priorities, cumulative costs, and risk indicators. Retrospective analyses using the contextual risk-assessment workflow indicate a preliminary ~1% reduction in maintenance-related incidents, providing early though limited evidence of improved planning effectiveness.

- KR & KPI alignment

The work performed has already delivered measurable partial progress toward several KPIs, even if full validation requires pilot-phase deployment with complete operational data (Table 13). Early simulations, enhanced risk-assessment methodologies, and OSM-based localisation provide a solid technical foundation for reaching all KR14 performance targets during the next phase.

Table 13: SA4.3.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI14.1 – Accuracy of AI-driven risk modelling** | >90% | AI models not yet validated; architecture, data pipelines, labelling and workflows completed | Foundational components in place; model training begins in next period |

| | | | |
|---|---|---|---|
| **KPI14.2 – Reduction in maintenance costs** | 15% | ~5% reduction from initial simulation campaigns | Early evidence of optimisation effectiveness; expected to improve with scenario expansion |

- Current Status, Deviations, and Next Steps

The activity remains on track with no significant deviations from the planned work. The next steps involve consolidating and operationalising the Digital Twin components within the Karlovac pilot. Priority will be given to integrating and cleaning traffic, weather, asset-condition and historical maintenance datasets, enabling the training and iterative validation of the AI-based risk models with the goal of reaching accuracy levels above 90%. The simulation and optimisation environment will be extended with additional scenarios and stochastic parameters to more reliably capture uncertainties in maintenance processes before deployment in real operational workflows.

The localisation and decision-support modules will be finalised and connected to the main asset database and dashboard interface to support pilot-level testing of actual decision-time reduction. Further work will focus on linking dynamic risk metrics directly to the Maintenance Scheduling Tool so that high-risk segments can be identified and prioritised proactively. Incident data collected during the pilot will be analysed continuously to assess the degree to which the integrated Digital Twin contributes to reductions in maintenance-related incidents and to refine the optimisation logic accordingly.

### 2.1.2 Technical objectives (TO) and Activities (TA)

#### 2.1.2.1 TO.1 Integration and Visualization of Mobile, In-Vehicle, and UAV Data Services for Enhanced Driving Experiences (WP3, WP5)

TA 1.1: Mobile and in vehicle apps

TA 1.1 aims to design and develop mobile and in-vehicle applications that deliver real-time early warnings to road users. These applications interact with sensors, digital twins, and infrastructure elements to provide timely safety notifications and operational insights. The task aligns with the work programme by enabling real-time communication of infrastructure KPIs, integrating vehicle-to-infrastructure data, and supporting advanced warning techniques required for safe automated mobility. The expected outputs include applications capable of seamless data exchange with the command-and-control centre and interoperability with the broader iDriving digital ecosystem.

- Work performed during the reporting period

The definition of user requirements for both mobile and in-vehicle applications has been established, with all requirements prioritised using the MoSCoW method, ensuring that the most critical safety, usability, data privacy, and legal elements were addressed first.

Based on the validated requirements, initial UI/UX mockups were developed, anditeratively refined through consortium-wide feedback rounds. These mockups guided the first implementation phase, during which the initial interface version and backend components were developed. Implemented functionalities include Kafka-based communication, bidirectional messaging, sound-based alerts, and a text-to-speech module to minimise cognitive load for drivers.

Integration activities progressed in parallel with development. Remote integration testing was performed regularly, and on-site validation took place during the Nevers UC preparation process. These tests validated communication between the mobile/in-vehicle applications and devices supplied by other partners. Development and integration will continue until the first pilot in early 2026.

- KR & KPI alignment

The activities in TA 1.1 directly contribute to KR15, which targets the delivery of functional mobile and in-vehicle early-warning applications (Table 14). The foundational backend modules and initial UI implementations indicate solid progress toward meeting the KPIs related to user adoption, usage duration, and feature utilisation. KPI tracking will rely on log information during pilot testing.

Table 14: TA1.1.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| KPI15.1: Active users > 80% of users on the road | >80% | Not applicable yet | To be evaluated during pilot testing in 2026 |
| KPI15.2: Usage during >90% of driving time | >90% | Not applicable yet | Usage metrics will be collected via app logs |
| KPI15.3: Users enabling early-warning features >90% | >90% | Not applicable yet | Depends on activation of alert modules during pilots |

- Current Status, Deviations, and Next Steps

The mobile and in-vehicle applications are in their first implementation version and have not yet reached prototype level. Core communication functionalities are operational, and UI development is ongoing. No deviations affecting the task's objectives or timeline have been reported.

The next steps will focus on finalising the UI components based on integration requirements, consolidating the backend modules, and optimising the Kafka communication. In addition, an internal Consortium testing will be conducted at the beginning of 2026, while preparation for full pilot deployment and KPI measurement during the 2026 pilot phase, will take place.

TA 1.2: Data acquisition form UAVs

The objective of TA 1.2 is to deliver a reconfigurable UAV system equipped with advanced sensing and onboard processing capabilities to support precise, efficient, and real-time data acquisition for road safety and infrastructure monitoring. In line with the Grant Agreement, the UAV contributes to a digitalised ecosystem for advanced warning, monitoring, and low-cost maintenance interventions, enabling rapid situational assessment and improved decision-making. The work directly supports KR16 by developing a UAV platform capable of onboard processing and achieving high coverage efficiency across monitored areas.

- Work performed during the reporting period

The design, development, and initial integration of the iDriving UAV system, completing all hardware design activities and establishing the UAV's role within the overall data acquisition workflow has been initiated and led by the corresponding partner. A full 3D CAD model of the quadrotor was created, defining the structural frame, propulsion system, onboard electronics, sensing units, and vibration-damped camera assembly. Carbon-fiber composites and lightweight custom components were selected to optimise endurance, stability, and transportability, including foldable arms and integrated landing gear.

All core electronic modules – including the flight controller, gimbal-mounted camera, and the NVIDIA Orin NX processing unit – were integrated according to the final CAD specifications. Partners collaborated closely to align sensor configurations and onboard processing requirements with the system architecture. The NVIDIA processor was successfully connected to the project's Kafka infrastructure via REST Proxy, with full message consumption and route-planning ingestion already validated.

Preliminary simulation tests demonstrated that the current flight altitude and route spacing parameters enable area coverage exceeding 90%, indicating measurable progress toward KPI16.1. The UAV's endurance has been engineered for approximately 25 minutes of flight time, surpassing the 20-minute requirement, and initial deployment simulations confirm readiness for sub-five-minute activation.

Multiple UAV flight sessions to collect high-resolution video datasets under different heights and viewing angles for AI-based 3D reconstruction were carried out. The acquired datasets have already supported model training and informed optimal flight-route configurations. All UAV activities were performed under EASA Open Category A1/A3 regulations, with certified pilots and full compliance with operational safety protocols.

- KR & KPI alignment

Substantial progress has been achieved toward KR16 through the completion of the UAV's hardware design, integration of the NVIDIA Orin NX onboard processing module, validated connectivity with the Kafka architecture, and early demonstrations of route-planning execution (Table 15). The platform now supports onboard computation workflows required for autonomous data interpretation.

Table 15: TA1.2.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI16.1 – percentage of coverage of monitored areas** | >90% | Preliminary simulations demonstrate >90% coverage under current altitude and route spacing. | Field validation planned for upcoming tests. |

- Current Status, Deviations, and Next Steps

TA 1.2 is progressing fully in line with the Grant Agreement, with no deviations. The UAV platform is operational at prototype level, with hardware integration, onboard processing setup, and communication interfaces already validated. The next phase will focus on manufacturing, refinement, and systematic field validation. This includes testing onboard AI-driven detection algorithms, quantifying real-world coverage performance, fine-tuning flight-route optimisation, and expanding multi-condition datasets for safety- and maintenance-related analytics. Continued collaboration with associated partners and pilot-site leaders will ensure readiness for large-scale demonstrations and confirm achievement of KPI16.1.

<u>TA 1.3 C2 with enhanced visualisation features</u>

This task focuses on developing the C2XR command and control centre, an advanced road-safety platform enriched with extended reality (XR) capabilities. The system integrates diverse real-time data sources (IoT, vehicle sensors, drones, Digital Twins, predictive analytics) to provide operators with an immersive, accurate, and efficient decision-support environment. It aligns with programme goals on real-time infrastructure data, digital twins, advanced warning techniques, and integration of infrastructure elements into a digitalised ecosystem.

- Work performed during the reporting period

*User & Technical Requirements Definition*

The definition and prioritisation of user requirements were carried out using the MoSCoW method through a series of workshops held for the six use cases. The formulation of technical requirements and the development of the Digital Twin–based control centre architecture were also supported, consolidated, and documented in Deliverable D2.3 on Technical Requirements and Digital Ecosystem Architecture

*Mockups and Interface Design*

High-fidelity mockups for the C2XR interface were developed, integrating XR interaction principles alongside safety and privacy considerations. These mockups were circulated within the consortium, and partner feedback was subsequently incorporated into revised versions.

*Initial Implementation of the C2XR Interface*

The implementation of the first version of the interface began, based on the approved mockups. In parallel, a Kafka-based communication module was developed to enable near real-time data exchange, directly supporting the integration of real-time data into the system

*Integration Activities and On-Site Testing*

Technical meetings focused on architecture integration and component alignment were conducted. In addition, both remote and on-site testing were carried out during the Nevers UC rehearsals, ensuring that all components could be integrated into the emerging Digital Twin–based control centre

*XR Device Plans*

The use of Hololens XR glasses was defined for the final version, enabling mixed-reality overlays that allow operators to view virtual information while maintaining awareness of the physical environment. Gesture-based interactions were also identified to support hands-free operation.

- KR & KPI alignment

The work conducted under this task contributes directly to KR17 (C2XR command and control centre). The system architecture has been defined, the mockups have been completed and revised, and the first version of the interface is already under implementation (Table 16). The Kafka-based communication layer is operational, supporting real-time data flows, and the approach for integrating the XR device into the final version has been established.

Table 16: TA1.3.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI17.1 – Real-time Data Accuracy > 99%** | >99% | Kafka module implemented. Preliminary real-time flows available. | Full latency and accuracy verification planned for final integrated testing. |
| **KPI17.2 – Improvement in Emergency Communication Effectiveness** | 20% | Interface designed for near real-time incident visualisation. | Expected impact will be evaluated during pilot sessions with operator feedback. |

| | | | |
|---|---|---|---|
| **KPI17.3 – Increase in Control Centre Operator Satisfaction** | 30% | XR-based immersive interface under development | . Satisfaction will be measured through operator surveys during pilots. |

- Current Status, Deviations, and Next Steps

The task is progressing as planned, with no major deviations reported. User and technical requirements have been finalised, the mockups have been developed and refined, the first version of the interface is already under implementation, and the communication module based on Kafka is operational. Integration activities continue across partners, and preparatory work for the XR version of the control centre is ongoing.

The next steps focus on extending the interface implementation, integrating additional data sources, testing and validating the real-time communication and data accuracy, and finalising the XR version on Hololens devices. KPI17.2 and KPI17.3 will be assessed through operator feedback and user surveys during the pilot phases, once the integrated and XR-enabled versions of the control centre are available.

TA1.4: Integration of services

TA 1.4 aims to establish the integrated iDriving ecosystem by ensuring full interconnectivity and interoperability across all components, following the GA description. During the reporting period, significant progress was achieved in defining shared requirements and architectural baselines, deploying the integration backbone, enabling DevOps workflows, and supporting partners in achieving consistent interoperability across related WPs. These activities collectively underpin the development of the unified iDriving ecosystem foreseen in KR18 and support the staged ecosystem releases required by KPI18.1.

- Work performed during the reporting period

During the first 18 months, the foundational work required for a coherent and scalable integration framework has been completed. A set of shared technical requirements and architectural baseline were established through workshops, meetings, and the preparation of D2.3: *Technical Requirements and Digital Ecosystem Architecture*, ensuring alignment in terminology, interfaces, and data flows. High-level and component-level architectural diagrams were created to guide integration practices and ensure consistency across pilots. The integration backbone was deployed and operationalised, including the procurement of Hetzner VMs, the setup of Apache Kafka with REST Proxy, and the establishment of the full CI/CD stack (Keycloak, Harbor, Portainer, Jenkins, pfSense). These elements provide the secure, extensible infrastructure supporting deployments and partner-facing environments. To ensure interoperability, VPN profiles were distributed, and secure connectivity was validated. In addition, a Kafka workshop has been delivered, and the integration Excel sheets detailing component-to-component mappings, schemas, and runtime expectations were maintained. Weekly integration meetings supported troubleshooting and accelerated readiness for pilot execution. Pilot-oriented validation activities demonstrated end-to-end message flows under realistic conditions, feeding into the live rehearsal in Nevers. The submission of D5.1: *First iDriving Prototype* provided the first documented integration framework and prototype, describing the deployment environment, interface mappings, CI/CD workflows, the message bus implementation, and the phased integration plan. These activities directly support the formation of a unified and operationally coherent ecosystem.

- KR & KPI alignment

Progress directly contributes to KR18 by establishing the shared architecture, integration backbone, DevOps environment, and validated interoperability pathways required for a unified road-safety ecosystem (Table 17).

Table 17: TA1.4.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI18.1 – Three versions of the Ecosystem (M18, M26, M34** | - | **M18 version delivered** | Preparatory work for the M26 version is underway through iterative updates, continuous testing, weekly integration meetings, and pilot-ready deployments. |

- Current Status, Deviations, and Next Steps

TA 1.4 is progressing with no deviations. The ecosystem foundations, shared architecture, CI/CD environment, and integration practices are fully established and operational.

Next steps will focus on maturing the integration schemas for the M26 ecosystem version, strengthening component-to-component validations, refining the interface mappings for each pilot, and enabling updated deployments. Additional rehearsals and iterative testing cycles will further stabilise the integration flows. The activity remains on track for the staged ecosystem releases (M26 and M34), with the existing infrastructure and operational procedures providing a stable basis for continued large-scale integration and pilot execution.

### 2.1.3 User objectives (UO) and Activities (UA)

#### 2.1.3.1 UO 1: SCC Productions, Requirements and validation (WP2)

UA 1.1: Safety Criteria Catalogue formulation

UA 1.1 aims to develop a comprehensive Safety Criteria Catalogue (SCC) through an extensive literature review, partner consultation, and alignment with EU policy documents and existing safety assessment frameworks. The SCC defines harmonised safety criteria and their associated KPIs for application across all iDriving pilot use cases, supporting consistent evaluation of road safety conditions on urban, secondary, and non-trunk roads. Its formulation ensures a unified foundation that links safety indicators to measurable societal benefits such as reduced collisions, improved driving homogeneity, and lower infrastructure maintenance costs.

- Work performed during the reporting period

Within Task 2.1, a thorough literature review was conducted to screen existing frameworks and EU policy documents relevant to road safety assessment. Based on this, an initial draft of the SCC was completed in December 2024 and shared with the consortium in the form of an Excel database. Over the following six months, partners reviewed the content and contributed additional input, ensuring full alignment across all use cases.

All use cases were mapped against the SCC requirements, and the SCC was discussed regularly during monthly meetings. Two consortium workshops – Graz (February 2025) and Paris (September 2025) – were dedicated to refining the catalogue, presenting KPI structures per SCC category, and selecting the relevant KPIs for each use case.

The process was carried out as a co-creation activity involving all partners and UC owners. By M18, SCC formulation reached approximately 90% completion and is being finalised for publication as Deliverable D2.1.

- KR & KPI alignment

A unified catalogue integrating criteria and measurable safety KPIs for all iDriving use cases has been achieved (Table 18) and is due to be published in M18 (December 2025) as D2.1: Enhanced Safety Criteria Catalogue (SCC).

Table 18: UA1.1.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI19.1 – Implementation of SCC** | In 6 trials | All use cases have selected SCC KPIs | implementation ongoing within UC design. |
| **KPI19.2 – Harmonised SCC with safety KPIs accepted** | accepted in 10 EU countries | - | Will be addressed through exploitation activities following SCC validation. |
| **KPI19.3 – Published journal and conference papers on SCC** | **1 journal** + **2 conference papers** | One conference paper accepted for TRA 2026 | - |

| | | | |
|---|---|---|---|
| **implementation and validation** | | | |

- Current Status, Deviations, and Next Steps

The SCC formulation is in its final phase, with content consolidated through literature review, partner inputs, KPI mapping, and UC alignment. No deviations from the planned scope have occurred. The SCC will be completed and published as D2.1 in M18.

Next steps include supporting SCC implementation across all trials, contributing to validation during pilot execution, and preparing the publications associated with KPI19.3. Further harmonisation efforts and broader EU-level acceptance will be pursued during the exploitation and dissemination stages.

<u>UA 1.2: User & safety requirements</u>

This activity focuses on defining user-driven and safety-oriented requirements for all iDriving test sites. Through structured stakeholder engagement, workshops, surveys, and use-case-specific analysis, the objective ensures that operational, functional, and implementation needs are fully captured for effective road-safety monitoring and traffic-management solutions.

- Work performed during the reporting period

Requirements collection was carried out through an extensive stakeholder engagement process. Eight workshops were organised across all pilots (two each for Graz, Nevers, Karlovac, and Thessaloniki; one each for Alba Iulia and Bizkaia). Inputs were collected along three dimensions: context, functional aspects, and implementation aspects.

An initial set of user requirements was formulated using a structured template (ID, title, description, user group, comments, contributor, related tool). Requirements were prioritised using the MoSCoW method. Two complementary surveys were conducted to validate and broaden stakeholder input, with 200 responses from road users (six user groups), and 40 responses from road operators and stakeholders.

Use case owners refined and completed the requirements. Final numbers of user requirements per UC:

UC1.1: 30 | UC1.2: 33 | UC2.1: 19 | UC2.2: 36 | UC3.1: 29 | UC3.2: 14

Safety requirements were derived from the Safety Criteria Catalogue developed under UA1.1 and mapped to each use case, ensuring integration into system design: UC1.1: 18 | UC1.2: 15 | UC2.1: 16 | UC2.2: 11 | UC3.1: 13 | UC3.2: 16

All requirements (user + safety) are documented in D2.2: User, Safety, and Ethics Requirements & Pilot Use Cases Handbook.

- KR & KPI alignment

The extensive, structured, and validated requirements collection process directly supports the creation of an open standards traffic safety network, ensuring that system specifications reflect real operational needs from diverse stakeholders (

Table 19).

Table 19: UA1.2.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| **KPI20.1 – User-defined requirements , clear and broad to ensure stakeholders' needs are met** | - | Achieved through workshops, surveys, and UC-specific consolidation | - |

- Current Status, Deviations, and Next Steps

The objective is on track, with a complete set of validated user and safety requirements delivered in D2.2. No deviations have been reported. Next steps focus on ensuring that the defined requirements are fully integrated into system design, architecture development, and subsequent validation activities within WP2 and the pilot implementations.

UA 1.3: User case design & stakeholder engagement

UA 1.3 aims to design all pilot use cases using a unified matrix-based approach, ensuring transparent mapping of user and technical requirements to system functionalities, architectures, and scenarios. It also ensures continuous stakeholder engagement throughout the process via workshops and online feedback mechanisms, supporting coherent integration of communication and monitoring technologies across all PUCs.

- Work performed during the reporting period

A structured template for use case design was first developed, covering functional descriptions, scenario definitions, actor interactions, tools to be deployed, and pilot use case architectures. This template was then applied across all six pilot sites through a series of dedicated workshops involving relevant stakeholders. During these workshops, user and technical requirements were reviewed, mapped, and validated, with additional feedback gathered through the project's online database. Following the consolidation of workshop outcomes, the complete use case designs were presented at the M08 GA meeting in Graz and finalised in Deliverable D2.2. Subsequently, user requirements were translated into technical requirements per tool and linked to each UC, with results reported in Deliverable D2.3. The design and stakeholder engagement objectives were fully met.

- KR & KPI alignment

The completed use case designs, stakeholder engagement activities, and validated requirement mappings directly advance KR21 by enabling the coherent implementation of all technological KRs within each PUC (Table 20).

Table 20: UA1.3.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| KPI21.1 – KRs integrated in all Pilot Use Cases | Full integration across all PUCs | In progress; regular integration meetings ongoing | - |
| KPI21.2 - Six workshops with stakeholders | Six workshops with stakeholders | 6 workshops delivered | All six workshops completed and UC designs validated |

- Current Status, Deviations, and Next Steps

The objective is fully achieved, with all UC designs completed and stakeholder engagement fully carried out. No deviations occurred during the reporting period. The next steps involve continued technical integration of tools into the defined use cases and iterative refinement of requirements as implementation progresses across WP3, WP4, and WP5.

<u>UA 1.4: Ethics & legal framework</u>

UA 1.4 establishes and operationalises an ethical and legal framework for iDriving to ensure GDPR-compliant handling of personal data, lawful and transparent involvement of participants, non-discrimination, and responsible AI deployment. The activity delivers guidelines, templates and governance procedures that enable partners to conduct data collection, AI development and pilot operations in full conformity with EU legal and ethical requirements, directly supporting KR22.

- Work performed during the reporting period

Core legal and ethical guidance has been prepared (captured in D2.2 with supporting material in D1.2) and a suite of operational tools to ensure consistent implementation across partners has been developed. Ten templates and instruments were produced and disseminated consortium-wide – including a personal data breach risk assessment, an ethical approval form, an EDPS-based list for DPIA guidance, a GDPR compliance checklist, an AI robustness and reliability assessment for pilots, an incidental-findings policy, a general risk assessment form, a DMP questionnaire, standard consent/information sheets, and ethical mapping matrices for tools/pilots — and full uptake across partners was recorded. Two iterations of the Data Management Plan were completed and continuous data mapping via the DMP questionnaire was established to ensure FAIR, GDPR and Horizon Europe compliance. A privacy/GDPR workshop trained partners in compliant procedures, with ongoing legal support provided, while the Mobile App Privacy Policy was drafted to govern app data processing. All templates and procedures have been distributed and integrated into partner workflows ahead of pilot deployment.

- KR & KPI alignment

This work directly advances KR22 – Respect ethical and legal aspects of EU research by delivering the guidelines, tools and governance needed for legal convergence and ethical compliance across the project (Table 21).

Table 21: UA1.4.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| KPI22.1 – Number of recommendations, convergence of iDriving with relevant legislation and ethical demands | Demonstrable convergence (documented guidelines, tools, and adoption across partners) | Substantial progress: D2.2 and D1.2 finalised, 10 operational templates delivered and adopted, DMP iterated twice, Mobile App Privacy Policy drafted. | pilot-level implementation pending. |

- Current Status, Deviations, and Next Steps

The ethical and legal framework is in place and operational: core deliverables (D2.2 and supporting D1.2 material) and the full set of templates have been produced, disseminated and accepted by partners, the DMP has been updated twice and continuous mapping is active, and partner training has been delivered. No deviations from the planned scope or schedule have been reported during M1–M18.

Next steps focus on embedding the framework in pilot activities: templates and checklists will be used during data collection and AI testing in pilots, the Mobile App Privacy Policy will be finalised and applied during app deployment, and operational compliance will be tracked using the DMP questionnaire and incident assessment forms. Lessons learned from pilot implementation will feed back into refined guidelines and a set of formal recommendations to demonstrate full convergence with EU legal and ethical requirements.

#### 2.1.3.2 UO 2: Pilot implementations and evaluation (WP6)

UA2.1: Development of the validation scenario and evaluation methodology

The objective of UA 2.1 is to develop a comprehensive evaluation methodology to assess the performance of the iDriving platform across all six trials. Building on the GA description, this includes defining test strategies, evaluation metrics, and trial-specific scenarios aligned with the use cases and ensuring that impacts are measurable through established safety-related KPIs.

- Work performed during the reporting period

During the reporting period, a coordinated series of meetings was held within WP6 and jointly with UC leaders and WP2 and WP5 experts to define the validation needs of each use case and agree on the overall evaluation strategy. Through these discussions, a multi-level evaluation framework was established, covering platform-level, tool-level, and impact-level assessment. Impact-level evaluation will rely on the KPIs developed under the Safety Criteria Catalogue (SCC).

For platform and tool evaluation, four core categories – latency, reliability, accuracy, and efficiency – were agreed upon. These categories and their associated KPIs were compiled into a shared Excel database, and input was collected from partners between June and September 2025. A dedicated workshop was held during the General Assembly meeting in Paris (September 2026), where all proposed KPIs were presented, reviewed, and validated with the consortium.

In parallel, detailed test scenarios are being developed for each use case. Work is currently focused on UC1.1 (Nevers) and UC1.2 (Graz), which will be the first pilots to be demonstrated. Collaboration is ongoing with tool and platform developers to define specific metrics and data-collection strategies for each KPI. This activity continues throughout the duration of the project, with the goal of evaluating platform performance during the six trials.

- KR & KPI alignment

The work conducted to date contributes directly to KR23 by establishing a consolidated methodology framework for all six trials and by progressing the definition and validation of KPIs with technical partners (Table 22).

Table 22: UA2.1.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| KPI23.1 – Development of methodology for all six trials and evaluation and validations results. | Fully defined evaluation methodology and validated results across all UCs | Methodology under co-creation and validation with tool/platform developers; UC-level validation scheduled for next period | -. |

- Current Status, Deviations, and Next Steps

The activity is progressing as planned, with the core methodological structure agreed across all partners and detailed KPI development underway. No major deviations have occurred, and collaboration with tool and platform developers remains active and productive.

The next steps include completing KPI definitions for each evaluation category, finalising UC-specific test scenarios, and initiating structured validation during the upcoming pilot demonstrations. Validation of results for each use case will take place in the next reporting period as trial data becomes available.

UA 2.2: Field trials, testing and training

This objective focuses on the execution and evaluation of the iDriving system through six field trials grouped across three Pilot Use Cases (PUCs). These trials aim to validate system functionality, assess safety and efficiency impacts, and ensure that all end-users receive appropriate training and become fully familiar with the platform. The activities directly support KR24 by enabling the successful deployment of field trials and contribute to KPI24.1 and KPI24.2 through structured trial organization, testing, and user training.

- Work performed during the reporting period

During the reporting period, the Consortium initiated the preparation of training materials that will support the first series of field trials. These materials are being developed in alignment with the first version of the applications currently under implementation, ensuring coherence between system functionalities and user guidance. Work also began on outlining the procedures required for trial execution, including early planning discussions for both UC 1.1 in Graz, Austria, and UC 1.2 in Nevers, France, scheduled for the first part of 2026.

The Consortium agreed that user training will be integrated into the applications themselves, offering embedded guidance either at first use or upon user request. Additional external training resources, such as user manuals and short instructional video clips, are being prepared to ensure that all participants receive consistent and accessible information on how to operate the platform. The field trials, testing, and training sessions will be performed on-site during the pilot deployments, and their design ensures that the process directly supports the platform's validation and user readiness.

- KR & KPI alignment

The activities undertaken contribute to KR24 by establishing the foundational processes and materials required for the successful deployment of the upcoming field trials (Table 23). Preparatory work on training materials and trial organization contributes directly to KPI24.1, which focuses on documenting the setup and execution of each trial. Likewise, the early planning of integrated in-app training and external instructional resources supports KPI24.2 by preparing mechanisms that will ensure end-users gain adequate familiarity with the platform before and during pilot activities.

Table 23: UA2.2.: KPI alignment

| KPI | Target | Progress Achieved (M18) | Notes |
|---|---|---|---|
| KPI24.1 – Details on trial organization and implementation. | - | Initial planning of UC 1.1 and UC 1.2 trials completed; structure of training and trial procedures drafted; | -. |

| | | | |
|---|---|---|---|
| | | preparation of materials initiated. | |
| KPI24.2 – All users must be familiar with the platform | - | Development of in-app onboarding features and external training materials (user guide, video clips) underway; mechanisms defined to ensure user familiarity during pilots. | - |

- Current Status, Deviations, and Next Steps

The preparation of training materials and initial planning for field trial execution are progressing as expected. The first versions of user guidance content are under development and will be refined in parallel with the application's continued implementation. No deviations from the planned schedule have been identified at this stage.

The next steps include finalizing the complete training package, integrating in-app training modules, and preparing the logistics and operational plans for the 2026 on-site trials in Graz and Nevers. Further coordination sessions will take place to align all partners on testing procedures, user engagement protocols, and data collection methods to ensure the successful execution and evaluation of the field trials aligned with KR24.

## 2.2 Work Packages (WPs) progress

This section provides an overview of the technical progress achieved in the iDriving project during the M01-M18 period. It reflects a consolidated and collaboratively developed account for the work carried out across all Work Packages during this time frame, based on inputs from WP leaders, task leaders and beneficiary partners.

The purpose of this section is to present a clear and coherent summary of the activities and results accomplished so far, illustrating how each WP has advanced the project's objectives during the first 18 months. In addition to summarising key developments and intermediate outputs, the section also highlights any deviations or emerging issues identified during this period, ensuring transparency and enabling the consortium to address them in a timely and coordinated manner.

### 2.2.1 WP1 Mid-term report

#### 2.2.1.1 WP1 Current Status and Brief Progress

Throughout the first eighteen months of the iDriving project, WP1 ensured consistent and effective Management and Coordination across the consortium, supporting scientific, technical, administrative, and legal and ethical aspects of the work. Project governance was firmly established from the outset through the successful organisation of the Kick-Off Meeting in Thessaloniki and the implementation of monthly WP Leaders Alignment Meetings, complemented by regular WP-level monitoring sessions. These mechanisms enabled continuous oversight of progress, early identification of risks, and coordinated problem-solving across all Work Packages. The coordination team actively participated in all project meetings providing guidance, technical input, and ensuring alignment with the overall project objectives.

Key strategic deliverables were prepared and submitted on time, including the Comprehensive Project Management Plan, the Quality Assurance and Risk Management framework, and the first two iterations of the Data Governance and IPR Handbook, which collectively established a solid foundation for quality, compliance, and data handling procedures. These activities were supported by systematic ethical and legal monitoring, as well as ongoing Risk and Quality Reviews applied to all consortium deliverables. Administrative support included the distribution of the pre-financing instalment and continuous assistance to partners throughout technical meetings, workshops, and decision-making processes. Close coordination with WP7 enabled the timely submission of the Dissemination Plan and successful completion of the project's first milestone.

As the project progressed, WP1 organised a series of important events intended to foster collaboration, reinforce project cohesion, and advance the technical preparation of the iDriving ecosystem. These included a joint workshop with a related Horizon Europe project, a Data Management Plan workshop and a Privacy workshop, and two highly specialised workshops on Technical Requirements and System Architecture. The 1st Plenary Meeting in Graz brought together all partners to review progress and align on next steps, while preparations were initiated for the 2nd Plenary Meeting to be held in France. Throughout this period, regular coordination meetings remained central to maintaining smooth communication, supporting partners, and ensuring adherence to the project timeline.

During the most recent months, coordination activities intensified to support integration efforts and the preparation of the upcoming pilots. WP1 organised and supported workshops for both UC1.1 (Graz) and UC1.2 (Nevers), facilitating technical and operational alignment among partners and contributing to the planning of the pilot activities. The team co-organised and participated in several integration-focused calls, provided structured feedback on visualisation mock-ups, and helped advance cross-WP coherence on technical developments. A dedicated meeting on C-ITS integration was also coordinated, exploring how cooperative systems could be incorporated into the iDriving pilots. In parallel, WP1 led the resolution of operational issues related to weather data collection and collaborated closely with WP7 to identify external synergies, enabling clustering and collaborative opportunities with other EU-funded initiatives. Ethical and legal coordination also continued throughout this period as part of WP1's broader responsibilities. Overall, the Management and Coordination activities ensured a well-structured, collaborative, and efficient environment across the consortium, supporting steady progress throughout the entire M1–M18 period.

#### 2.2.1.2 Identified Issues/deviations (if applicable)

No deviations occurred during the first half of the project.

#### 2.2.1.3 Deliverables submitted (if applicable)

During the first eighteen months of the iDriving project, WP1 advanced its deliverables as planned, ensuring that the project's management, governance, and reporting structures were fully established and maintained. In the early stages, two major deliverables were completed and submitted: D1.1, the "Comprehensive Project Management Plan, Quality Assurance, and Risk Management," which set out the project's overall management framework, including procedures for quality assurance, risk mitigation, and data handling; and D1.2, the "Data Governance and Intellectual Property Rights Handbook," which provided essential guidelines for data governance, data protection, and intellectual property management across the consortium.

This document was designed as a living resource and will continue to be updated throughout the project lifecycle, with its revised versions delivered as D1.3 and a final version to be delivered as D1.4.

In the most recent period, WP1 has been focusing on the preparation of D1.5 (this document), the Mid-Term Review and Progress Report, which will consolidate the project's achievements to date, evaluate progress across all Work Packages, and provide an integrated overview of the consortium's scientific, technical, and organisational performance. Summary of Progress towards objectives and details for each task

#### 2.2.1.4 Summary of Progress towards objectives and details for each task

**Task T1.1 – Project Management, administration and reporting [Task Leader: CERTH] [Duration: M01 – M36]**

Participating Partners: [ALL]

Throughout the first eighteen months of the iDriving project, Task T1.1 ensured consistent and effective project management, administration, and reporting, establishing the processes and structures necessary for smooth implementation and sustained collaboration across the consortium. The task began with the organisation of the project's Kick-Off Meeting in Thessaloniki, bringing all partners together to align expectations, initiate technical discussions, and formalise the project's operational framework. To support day-to-day coordination, a full suite of collaborative tools was set up on Microsoft platforms, including shared repositories, structured communication channels, and a centralised meeting calendar. Monthly WP Alignment Meetings with WP Leaders were launched to enable systematic monitoring of progress, identification of risks, and cross-WP problem-solving, while the pre-financing instalment was successfully distributed to all partners in line with the Consortium Agreement. During this period, the coordination team actively contributed to workshops shaping end-user and technical requirements, and all deliverables associated with the first project milestone were submitted on time.

As the project progressed, management and coordination activities continued with the same consistency, ensuring ongoing alignment and timely execution. Monthly meetings were held for all Work Packages, alongside dedicated WP Leaders meetings that supported interdependency tracking and facilitated early resolution of challenges. The task supported and organised key project events, including the 1st Plenary Meeting in Graz and the 2nd Executive Board Meeting. Three thematic workshops were carried out on the Data Management Plan, Technical Requirements, and System Architecture, helping to maintain technical coherence across the consortium. During this period, WP1 also coordinated the organisation of the 2nd Plenary Meeting, which successfully took place in Nevers, France, in September 2025, bringing together all partners for a comprehensive review of progress and upcoming activities. All administrative and reporting efforts remained fully aligned with the project's governance framework.

During the most recent months, coordination efforts intensified, particularly in preparation for the upcoming pilot activities. Regular WP meetings and WP Leaders meetings continued to ensure structured communication and progress tracking. WP1 coordinated and supported workshops for both UC1.1 (Graz) and UC1.2 (Nevers), enabling alignment of technical partners, operational planning, and pilot readiness. The team actively participated in and co-organised multiple integration meetings, contributed feedback on visualisation mock-ups, and facilitated discussions on the integration of C-ITS functionalities into the iDriving pilots. In parallel, the task resolved several ethical and legal issues, including compliance matters related to weather data collection. Through these sustained activities, Task T1.1 maintained strong administrative coordination, supported technical progress, and ensured effective reporting and governance throughout the entire M1–M18 period.

**Task T1.2 – Scientific and technical management [Task Leader: TUC] [Duration: M01 – M36]**

Participating Partners: [CERTH, UNI.EIFFEL, INTRA, DREVEN]

During the first half (M1-M18) of the project, leaders of this task participated in all WP meetings. TUC, as the Scientific Manager of iDriving, ensures that the research methodologies employed in other WPs are rigorous and that outcomes will be groundbreaking, while CERTH, as the Technical Manager, ensures that all technical operations, from software development to hardware integrations, meet the accepted technical standards to reach the desired KPIs. As scientific and technical developments are evolving, a monitoring methodology has been implemented to assess the quality of scientific findings and technological advancements. Related input has been requested and received by the partners. A report has been compiled with the input received so far.

Technical monthly WP meetings have been organized since the start of the project to align all task leaders and participants within each technical Work Package (WP). Additionally, the technical manager has actively participated in all Use Case (UC) Workshops, remote meetings, WP2 meetings, and all other WP meetings, providing valuable feedback on the technical aspects likely to be applied in iDriving.

A strong collaboration has been established between end-users and technical partners to define the use case scenarios and user requirements effectively. To further facilitate this process, a series of meetings was organized, primarily involving technical partners working across WPs. These meetings allowed them to present their components and algorithms to partners end-users as well as WP2 and WP6 task leaders.

**Task T1.3 – Quality control and risk management [Task Leader: CERTH] [Duration: M01 – M36]**

Participating Partners: [TUC, DREVEN]

Throughout the first eighteen months of the iDriving project, Task T1.3 played a central role in ensuring that quality assurance processes, risk monitoring mechanisms, and compliance procedures were consistently applied across all project activities. During the initial phase, quality control checks were conducted on key foundational deliverables, including the Comprehensive Project Management Plan (D1.1), the Data Governance and IPR Handbook (D1.2), and the Dissemination Plan and Communication Materials (D7.1). A dedicated Project Management Handbook was also developed as an internal reference guide to support partners in adhering to established procedures. At the Kick-Off Meeting, a Risk Management Log was introduced as a living document, forming the backbone of the project's risk monitoring framework and guiding risk mitigation efforts throughout subsequent phases.

In the following months, the task continued to maintain rigorous quality standards by reviewing additional major deliverables, specifically the User, Safety and Ethical Requirements & Pilot Use Cases Handbook (D2.2) and the Technical Requirements and Digital Ecosystem Architecture (D2.3). Coordination meetings were organised across all Work Packages to reinforce adherence to predefined protocols, address emerging risks, and ensure alignment with the quality expectations defined in Annex 1 of the Grant Agreement. No deviations were identified during this period, confirming that project activities remained fully compliant with agreed procedures.

During the most recent reporting period, Task T1.3 intensified its quality assurance efforts in preparation for the significant submission cycle at Month 18. The team is currently reviewing seven deliverables scheduled for submission alongside this Mid-Term Review & Progress Report (D1.5), ensuring that each document meets the required standards and fully reflects the project's progress. Regular coordination meetings across WPs continued to support risk monitoring, protocol compliance, and deliverable consistency. Through these sustained activities, Task T1.3 has ensured robust quality control, proactive risk management, and full procedural compliance across the entire M1–M18 period.

**Task T1.4 – Data and IPR management [Task Leader: LIF] [Duration: M01 – M36]**

Participating Partners: [THESSALONIKI, AUSTRIATECH]

The completion of the first and second versions of the Data Management Plan (DMP) outlining the data governance framework for the iDriving project, ensuring compliance with FAIR principles and GDPR regulations was done. The DMP specifies protocols for data collection, processing, categorisation, and storage while promoting accessibility, interoperability, and reusability. It incorporates measures for data protection, including anonymisation, access controls, encryption, and audit trails, to safeguard confidentiality, integrity, and availability. LIF's approach includes regular updates and partner contributions to ensure the plan evolves with project needs, fostering ethical and secure data management practices.

A Data Management Workshop was organised by LIF. During the workshop, LIF clarified all data management questions in the DMP questionnaire and ensured that partners completed it comprehensively.

LIF further developed the first and second iterations of the IPR framework for the iDriving project to manage intellectual property ownership, access rights, and the exploitation of results among project partners. This framework addresses key IP protections, including copyright, trademarks, and trade secrets, ensuring clarity and consistency in managing the project's innovations while aligning with the terms outlined in the Grant Agreement (GA) and Consortium Agreement (CA) and defines the legal protections under international and European laws.

**Task T1.5 – Privacy, ethics, and legal monitoring [Task Leader: LIF] [Duration: M01 – M36]**

Participating Partners: [THESSALONIKI]

LIF actively participated in all PUC workshops and monthly WP meetings to ensure alignment with the project's progress, activities, and developments while providing legal and ethical guidance. LIF offered further legal and ethical guidance to partners through email and the delivery of the legal and ethical framework of the project. The guidelines address key areas such as the collection and processing of personal and non-personal data, ensuring compliance with data protection legislation and upholding fundamental human rights. They also set out best practices for AI compliance, focusing on transparency, fairness, and accountability in AI-driven systems.

Ethical considerations are also central to the framework, including guidelines on human participation to ensure informed consent and participant rights, as well as measures to minimise environmental impact. Furthermore, the guidelines stress the importance of research integrity, promoting transparency, reproducibility, and adherence to ethical standards throughout the project. These guidelines aim to ensure that all activities within the project align with legal requirements and ethical principles, fostering trust and accountability

#### 2.2.1.5 Risk Inventory

The risk inventory for Work Package 1 is presented in Table 24.

Table 24: WP1 Risk Inventory

| # | Description | Likelihood | Impact | Response |
|---|---|---|---|---|
| 1 | Tight period for PUC preparation, execution and validation might lead to non-ready technologies for TRL 6 demo | Low | High | Project Management is continuously monitoring the process and has set specific milestones to be reached throughout the project timeframe. |

### 2.2.2 WP2 Mid-term report

#### 2.2.2.1 WP2 Current Status and Brief Progress

WP2 objectives are to develop Enhanced Safety Criteria Catalogue (SCC), to identify infrastructure managers' needs and road users' requirements, to create pilot design specifications, and to establish legal and digital frameworks for technology collaboration. The work is divided into 5 tasks, and all tasks are active and progressing according to the plan. During the period M01-M18 two tasks T2.2 and T2.3 have finished in M09, and tasks 2.1, 2.4 and 2.5 are in progress, with the primary focus on Task 2.1. Tasks T2.2, T2.3 and T2.4 have identified user, stakeholders' and legal requirements, and design of pilot use cases, which are reported in *D2.2 User requirements and pilot use case design* in March 2025 (M09). For all six pilot use cases a series of workshops was organized, during which the survey and discussions were performed. Task T2.5 organized several workshops with the tool developers to identify technical requirements. Thorough analysis of user requirements has been performed and translated into technical requirements per tool and linked to UC. The results are reported *D2.3, Technical Requirements and Digital Ecosystem Architecture* in June 2025. Overall WP2 is progressing according to the plan and no deviations have been experienced so far.

#### 2.2.2.2 Identified Issues/deviations (if applicable)

No deviations identified.

#### 2.2.2.3 Deliverables submitted (if applicable)

- D2.2: "User, Safety and Ethic Requirements & Pilot Use Cases Handbook" submitted in M09, February 2025
- D2.3: "Technical Requirements and Digital Ecosystem Architecture" submitted in M12, June 2025
- D2.1: "Enhanced Safety Criteria Catalogue (SCC)" to be submitted in M18, December 2025

#### 2.2.2.4 Summary of Progress towards objectives and details for each task

**Task T2.1 – Development of an enhanced criteria safety catalogue for urban and secondary roads [Task Leader: INFRA PLAN] [Duration: M01 – M18]**

Participating Partners: [AUSTRIATECH, AIM, TUC, THESSALONIKI, UNI.EIFFEL, ING, ALP.LAB, DREVEN, COK]

INFRA PLAN participated in all monthly WP2 meetings and coordinated the collection and validation of inputs through dedicated workshops with the use case teams. To formulate the Safety Criteria Catalogue (SCC) under Task 2.1, the team conducted an extensive literature review, including a screening of existing frameworks and EU policy documents. The initial draft of the SCC was completed in December 2024 and shared with all partners as an Excel database. The KPIs were organised into four categories: road users, vehicles, traffic management and communication, and infrastructure. Partners reviewed the initial version and provided feedback over a six-month period.

INFRA PLAN also led the mapping of the use cases and their correlation with the SCC requirements. The SCC was repeatedly discussed during regular WP2 monthly meetings and UC workshops, allowing for additional inputs to be collected and integrated. Two consortium-level workshops were organised jointly with WP6 and WP5 during the GA meetings in Graz (February 2025) and Paris (September 2025). During these sessions, the KPIs for each SCC category were presented, and the relevant SCC KPIs for each use case were selected.

No deviations from Annex 1 of the Grant Agreement were identified, and no impacts on other tasks, resources, or planning were reported. The formulation of the SCC is approximately 90% complete and is currently in its final reporting stage, with Deliverable D2.1 scheduled for publication in Month 18.

**Task T2.2 – User & safety requirements specification [Task Leader: AUSTRIATECH] [Duration: M01 – M09]**

Participating Partners: [AIM, ALP.LAB, INFRA PLAN, TUC, UNI.EIFFEL, THESSALONIKI, ING]

During the first six months of the project, AustriaTech carried out a comprehensive process to establish a foundational set of user and safety requirements for each Pilot Use Case (PuC). This groundwork was essential for structuring the collection of requirements during the PuC-dedicated workshops. To achieve this, AustriaTech conducted an extensive analysis to identify the key user and safety needs specific to each PuC. Task 2.2 focused on defining a coherent set of user requirements aimed at enhancing road infrastructure safety, with a particular emphasis on urban and secondary rural roads.

As part of this effort, AustriaTech coordinated the collection of user and safety requirements from all partners, ensuring they were structured and harmonised into a unified format. Each pilot site was analysed with respect to its specific safety challenges, technical concepts, and target objectives. This process was supported by eight workshops involving relevant stakeholders, including road operators, traffic management organisations, maintenance agencies, local authorities, city representatives, and project partners. All requirements were cross-checked against applicable standards and guidelines to ensure consistency and alignment with the project's objectives.

To validate the user requirements, AustriaTech developed two surveys: one targeting road users and another aimed at transport-sector decision-makers across Europe. The questions were developed based on the use case descriptions and were designed to assess which types of road safety and infrastructure information would be most valuable for each group, as well as their preferred communication channels. The questionnaires were disseminated by project partners via social media, newsletters, and direct outreach. To broaden accessibility, the surveys were translated into Greek and Croatian in addition to the English version. In total, 200 road users from 10 countries and 40 decision-makers from 8 countries participated. The responses were analysed and incorporated into the refinement of the requirements, and the raw data was published openly on Zenodo to support future research within and beyond the iDriving project.

The consolidated safety and user requirements for each PuC are presented in Deliverable D2.2, *User, Safety and Ethic Requirements & Pilot Use Cases Handbook*. The task was completed as described in Annex 1 of the Grant Agreement, with no deviations identified.

**Task T2.3 – Design and prescription of pilot use cases [Task Leader: INFRA PLAN] [Duration: M01 – M18]**

Participating Partners: [THESSALONIKI, AIM, TUC, ALP.LAB, ING, DREVEN]

INFRA PLAN actively participated in the monthly WP2 meetings and supported the organisation of workshops dedicated to the use cases. As a first step, INFRA PLAN developed a template for the design of each use case, structured around the identified requirements and objectives. The template included a functional description covering the location, background, existing problems, objectives, and expected impacts; a detailed use case description encompassing the situation, scenarios, assets and tools to be deployed, and the actors and their interactions; and the pilot use case architecture.

In the next phase, a series of workshops was organised for all six pilot use cases, during which inputs were collected, discussed, and refined. For each use case, a mapping of user and technical requirements was carried out to translate the stakeholder needs into concrete design specifications. Stakeholders were engaged throughout the entire process, and their feedback was systematically collected via the online database.

The outcomes of all workshops were analysed and prepared for presentation at the General Assembly in Month 8 (February 2025) in Graz, Austria. The feedback provided by partners during the GA was subsequently integrated into the document. INFRA PLAN contributed the final chapters related to the design of all use cases for Deliverable D2.2.

No deviations from Annex 1 of the Grant Agreement were identified, and no impacts on other tasks, resources, or planning were reported.

**Task T2.4 – Legal and ethical framework and iDriving compliance [Task Leader: LIF] [Duration: M01 – M18]**

Participating Partners: [INFRA PLAN, AUSTRIATECH]

LIF actively participated in the monthly WP2 meetings and use case workshops to ensure full alignment with the project's progress and ongoing developments. Within this task, LIF carried out a detailed mapping of the tools to be developed for each Use Case and identified the corresponding legal and ethical considerations based on their intended functionality and data processing requirements. This analysis was grounded in an extensive review of the relevant EU legal framework and complemented by a continuous assessment of national legislation in the pilot countries.

To support this work, LIF designed a comprehensive questionnaire for technical partners, aimed at gathering essential information on the project's technical solutions. The collected inputs were analysed and integrated into Deliverable 2.2 as part of the formulation of legal and ethical requirements. A specialised questionnaire focusing on UAV operations was also distributed to ACCELLIGENCE, and the responses were used to develop tailored guidelines included in the same deliverable.

LIF further developed a set of ready-to-use compliance and risk management templates to support partners across the project. These included a GDPR compliance checklist, a personal data breach risk assessment template for iDriving, and an AI robustness and reliability assessment tool. Together, these resources enable a consistent and accountable approach to privacy, data protection, and ethical considerations throughout all project activities.

The resulting legal and ethical framework ensures alignment with applicable traffic legislation, integrates safety and reliability standards, and establishes robust transparency and privacy safeguards. It also introduces mitigation strategies for potential privacy risks, promotes diversity and accessibility, ensures stakeholder inclusion, and provides clear guidance on AI compliance to support responsible and ethical innovation.

As part of its awareness-raising and capacity-building efforts, the Law and Internet Foundation organised an interactive Privacy Workshop, bringing together project partners to examine the privacy and data protection implications of next-generation mobility technologies. The session offered practical guidance on GDPR compliance, including the definition of controller–processor roles, transparency and informed consent obligations, data minimisation, and the implementation of strong security and anonymisation measures. Special attention was given to challenges related to UAV and sensor data processing and to the ethical use of AI in automated decision-making. Through real-world examples, the workshop demonstrated how privacy-by-design and privacy-by-default principles can be embedded across all iDriving activities, reinforcing LIF's commitment to fostering a strong data protection culture and supporting partners in maintaining full legal and ethical compliance.

No deviations from Annex 1 of the Grant Agreement were identified, and no impacts on other tasks, resources, or planning were reported.

**Task T2.5 – Technical requirements specifications and ecosystem architecture [Task Leader: INTRA] [Duration: M01 – M18]**

Participating Partners: [CERTH, TEKNIKER, DREVEN, MBL, TUC, UNI.EIFFEL, INFRA PLAN, AUSTRIATECH, ACCELI, SIMAVI]]

This task focuses on defining the technical requirements and the high-level digital ecosystem architecture for the iDriving platform. Led by INTRA, its purpose is to translate stakeholder needs and pilot use case scenarios into concrete system-level requirements and a conceptual architecture that will guide all subsequent development, integration, and deployment activities.

During the reporting period (M01–M18), significant progress was achieved. INTRA actively participated in the monthly WP2 meetings, ensuring continuous alignment with the project objectives and facilitating smooth communication among partners. The team also engaged in the use case workshops, gathering critical insights from stakeholders to ensure that the technical requirements accurately reflected the operational needs of the pilot sites.

INTRA organised and hosted three dedicated workshops focused on the formulation of technical requirements and the development of system architecture diagrams. Through these sessions, the consortium collaboratively established a consistent methodology for structuring requirements across partners. INTRA coordinated the development of a comprehensive set of technical requirements and produced several high-level architectural views of the iDriving system. In addition, INTRA supervised the creation of detailed component-level architecture diagrams, ensuring coherence across system modules.

Deliverable D2.3, which consolidates all technical requirements and the high-level digital ecosystem architecture, was successfully submitted on schedule in June 2025. No deviations from Annex 1 of the Grant Agreement were identified, and there was no impact on other tasks, available resources, or planning.

Building on the consolidated user requirements and pilot scenarios developed earlier in the project, this task delivered a complete set of technical specifications and a high-level architectural overview of the iDriving digital ecosystem, achieved through a structured and collaborative process involving all key consortium partners.

#### 2.2.2.5 Risk Inventory

Following risks have been identified (Table 25) and adequate corrective actions implemented:

Table 25: WP2 Risk Inventory

| # | Description | Likelihood | Impact | Response |
|---|---|---|---|---|
| 1 | Potential delay in input from other WP2 tasks | Low | Low | Bilateral meetings organized to address and resolve communication issues. Meetings with other WPs also regularly organized. |
| 2 | Incomplete Requirements and Unrealistic Expectations | High | High | This was managed very well, through very thorough technical project management and organization of worktops on cross-WP workshops. All requirements are identified. |
| 3 | Ethical and Legal Compliance Issues | Medium | Medium | LIF organized series of workshops and collection of information on ethical and legal information, GDPR, etc. Communication with all partners continuous and well organized. |

### 2.2.3 WP3 Mid-term report

#### 2.2.3.1 WP3 Current Status and Brief Progress

During the current reporting period, WP3 has progressed in line with the project objectives, achieving significant advances across all its core technical tasks (T3.1–T3.5). The work package is now in an advanced implementation and integration phase, with all components under active development, initial validation, or testing. Collaboration among partners has remained strong, ensuring coherent technical progress, effective exchange of information, and timely preparation for the upcoming pilots and demonstrations.

Task 3.1 has focused on the continuous development and integration of the Tekniker Dataspace Connector (TDC), ensuring seamless communication between components. The technical requirements were defined and documented in Deliverables 2.3 and 5.1, and integration with Kafka and partner systems has begun. Coordination with INTRA and other partners has ensured interoperability and stable deployment preparation.

Task 3.2 has made solid progress in the development of the Intelligent Traffic Management System (ITMS) tools, particularly the signal control and route guidance algorithms. Both tools were tested in simulation environments (SUMO) and later integrated into the Graz network model. A safety-based link cost function was designed for optimized rerouting, and simulation scenarios for incident management were successfully implemented. Technical KPIs were defined to measure the performance of the algorithms during pilot phases.

Task 3.3 has advanced the development of mobile and in-vehicle applications for early warnings. User and technical requirements were consolidated, mock-ups were designed and refined, and the first implementation of both interfaces is ongoing. Kafka connectivity was successfully established, and feedback collected from consortium partners has guided UI improvements. Polytechneio Kritis continued the development of its real-time KPI collection methodology, ensuring consistency with simulation and validation frameworks.

Task 3.4 has achieved major milestones with the successful manufacturing and testing of the iDriving UAV platform. The UAV, equipped with an onboard processor, sensors, and a gimbal camera, has been validated in flight tests and integrated with the AI algorithms developed under related tasks. Feedback from the Nevers rehearsal was incorporated to optimize performance and operational readiness for upcoming pilot activities. Preparations are underway to define demonstration scenarios and obtain flight authorizations.

Task 3.5 has further developed the UAV path planning algorithms and the mission management platform. The AirSim simulator was used for algorithm testing, and the mission planning interface now includes real-time path visualization and UAV parameter configuration. VPN and Kafka connections were successfully established, and full integration with the UAV platform (T3.4) was achieved, confirming interoperability and data flow consistency.

Overall, WP3 is on track, with all tasks progressing as planned and achieving their respective milestones. The main components are now entering integration and testing phases, providing a solid foundation for the upcoming pilot demonstrations.

#### 2.2.3.2 Identified Issues/deviations (if applicable)

No issues or deviations identified

#### 2.2.3.3 Deliverables submitted (if applicable)

- Deliverable D3.1: "V2I Communication, Aerial monitoring and route optimization v1" due to be submitted in M18 (December 2025).

#### 2.2.3.4 Summary of Progress towards objectives and details for each task

**Task T3.1 – Network Infrastructure Development and Asset Intercommunication [Task Leader: TEKNIKER] [Duration: M03 – M30]**

During the reporting period, significant progress was made toward achieving the objectives of Task 3.1. The team organised and actively participated in the monthly WP3 meetings, ensuring effective coordination and continuous collaboration with all project partners. In addition, participation in the use case workshops provided important insights into operational needs and enabled constructive contributions to the discussions.

A key focus of the task was the clarification and dissemination of knowledge related to the Dataspace Connector (TDC). The team presented the functioning, operational characteristics, and technical requirements of the TDC in several technical meetings. These exchanges helped align expectations between Tekniker and the partner organisations, addressed outstanding questions, and facilitated a clearer understanding of integration needs, thereby supporting smooth progress toward implementation.

Task members contributed to Deliverable D2.3 by defining the technical requirements relevant to Task 3.1, and to Deliverable D5.1 by providing detailed input on the integration of the Tekniker Dataspace Connector with other project components. This included the definition of technical KPIs associated with the TDC, the development of the integration matrix, and participation in discussions with INTRA on the deployment and integration strategy.

The team also took part in dedicated integration meetings, advancing the preparation work for the deployment of the TDC. Progress was achieved on establishing the interface between the TDC and Kafka, as well as initiating the integration of the TDC with partners' systems. These activities collectively ensured steady advancement towards the seamless incorporation of the Dataspace Connector within the iDriving architecture.

**Task T3.2 – Safety-Optimized Traffic Management Using Intelligent Algorithms for Diverse Vehicle Flows [Task Leader: MBL] [Duration: M03 – M30]**

During the reporting period, substantial progress was achieved in Task 3.2, focusing on the development of the Intelligent Traffic Management System (ITMS) and its key functionalities for signal control and dynamic rerouting. The team actively participated in dedicated workshops aimed at refining the iDriving pilot use cases.

Insights gathered from these workshops directly informed the ongoing review and refinement of the ITMS system requirements to better address the specific operational and safety challenges identified across the project.

A series of bilateral meetings with consortium partners supported the assessment of existing tools and frameworks that could be integrated into the ITMS. Complementing this work, a targeted literature review was conducted to identify state-of-the-art methodologies for enhancing rerouting algorithms, with particular emphasis on safety surrogate measures and simulation-based approaches, aligning with the outputs of WP2.

Close collaboration between MBL and TUC ensured strong alignment on the required functionalities, integration needs, and technical specifications of both the signal control and route guidance algorithms. The partners jointly examined the topology and requirements of the Graz pilot, ensuring that system design remained fully compatible with real-world network constraints. Preliminary tool designs were developed and shared internally for feedback and iterative refinement, supported by an extensive literature review on path planning and dynamic traffic reassignment.

Progress on tool development advanced on schedule. The signal control algorithm (max-pressure approach) was implemented and tested within a toy network in SUMO, while the rerouting tool was developed using SUMO and the TraCI API for small-scale network environments. A safety-based link cost function was completed, and an initial set of simulation scenarios was defined in relation to user and technical requirements. TUC and MBL also participated in meetings on the digital twin development for Thessaloniki and Graz, along with the Data Management and Technical Architecture workshops. Both partners contributed to D2.3 and D5.1, providing architectural, functional, and technical specifications, with MBL conducting an internal review prior to submission. In preparation for future large-scale simulations, TUC received the microscopic Graz models from UNI.EIFFEL, pending calibration.

Further bilateral discussions helped refine the integration strategy and operational structure of the Task 3.2 tools. Development progressed steadily on the safety-based link cost function and simulation testing. The signal control tool was fully configured for SUMO, while the rerouting tool was tested on toy networks and subsequently on the Graz network. Simulation scenarios involving virtual incidents and alerts were generated, producing outputs such as general alerts, modified trip paths, and fastest emergency routes. Both tools underwent testing on the calibrated Graz SUMO network, and relevant KPIs, both tool-specific and aligned with the broader WP6 evaluation framework, were defined and progressively refined.

These activities collectively ensured robust progress toward the development and integration of the ITMS within the iDriving ecosystem.

**Task T3.3 – Mobile and in-vehicle application for early warnings [Task Leader: SIMAVI] [Duration: M01 – M30]**

The task was initiated as planned, and I focused on preparing the future development of a user-centric software system designed to support both drivers and non-driving road users. In the initial phase, we began collecting user requirements closely linked to the pilot Use Cases. We used the information gathered during the scenario workshops to identify user needs and expectations, forming the basis for defining the technical solution to be developed in later stages of the project.

Our activities progressed toward the creation of mobile and in-vehicle applications for early warnings. Together with the partners involved in the task, I worked to identify and consolidate user requirements relevant to each project Use Case. We discussed these requirements during the Plenary Meeting in Graz and later integrated them into D2.2.

Building on these inputs, we defined the technical requirements for both the mobile and in-vehicle applications. These requirements, along with the overall architecture of the project components, were documented in D2.3. Based on the identified user and technical requirements, SIMAVI designed a set of mock-ups for both applications. These mock-ups were prepared as initial design proposals and were intended to be reviewed and refined based on consortium feedback and findings emerging during the development process, ensuring full alignment with project objectives.

In parallel, the team from the Technical University of Crete initiated the development of a methodology for the real-time identification and systematic collection of relevant KPIs to support safety assessments and decision-making processes. They implemented and validated this methodology through extensive simulations, based on real Use Cases, by integrating SUMO and CARLA. This approach aimed to support the design of in-vehicle applications for early warnings, fully aligned with the goals of Task 3.3.

The mock-ups for both mobile and in-vehicle applications were finalized and uploaded to the project's SharePoint repository under the T3.3 folder. We also defined the technical structure, workflows, and implementation elements of these applications in D5.1. Work continued with the development of the interfaces for both applications, and implementation activities were still in progress.

Throughout the task, we actively participated in integration meetings to ensure smooth coordination with technical components developed in other tasks. We performed successful connection tests with the Kafka server, confirming interoperability between the applications and the project's data exchange infrastructure. Additionally, we collected feedback from consortium members regarding the user interface and technical elements, and we began incorporating this feedback into the next development iterations.

**Task T3.4 – Aerial Surveillance in Incident Management and Maintenance Tasks [Task Leader: ACCELI] [Duration: M01 – M30]**

During the initial reporting period, I actively participated in all WP3 meetings, ensuring strong engagement and alignment with the project's collaborative activities. I attended all workshops, contributed to discussions, and gained a comprehensive understanding of user requirements, which informed decisions regarding the UAV configuration and the necessary payloads.

In collaboration with CERTH under Task 4.5, I conducted multiple flight sessions to capture videos for analysis. These sessions involved recording footage from different heights and angles to identify optimal perspectives for 3D reconstruction, with a primary focus on reconstructing a vehicle. I shared the collected videos with the consortium for algorithm training and evaluation. Continuous communication and bilateral sessions with CERTH enabled effective feedback collection and refinement of technical requirements for the next testing phases.

I contributed to Deliverables 2.3 and 5.1, helping define the technical requirements of Task 3.4. I also participated in the Workshop on Technical Requirements and Architecture and completed the Integration Matrix Report.

A possible configuration for the iDriving UAV was selected, proposed, and finalized, including the onboard processor, ground station, and sensors required for executing AI algorithms. I acquired the SIYI A8 Mini Gimbal Camera to support iDriving activities and AI algorithm development. In addition, I initiated discussions with Université Gustave Eiffel regarding the rehearsal demonstration planned in Nevers, France. The development of the drone platform progressed as planned to ensure readiness for deployment during the upcoming rehearsal phase.

Further input was provided for D5.1, and all technical and integration efforts were consolidated. The iDriving UAV was successfully manufactured, incorporating the finalized onboard processor, ground station, and sensors. I conducted initial flight tests, which produced positive results and validated both the mechanical stability and the communication between the drone and the ground components. The UAV was tested with the integrated SIYI A8 Mini Gimbal Camera and the onboard processor to assess AI algorithm execution capabilities.

I incorporated feedback gathered from the rehearsal in Nevers to improve UAV deployment efficiency and operational safety. My efforts focused on implementing all required algorithms on the onboard processor in preparation for the upcoming pilot demonstrations. Together with the project partners, I conducted multiple laboratory and field tests to ensure safe and reliable UAV operation.

Finally, I defined the scenarios that the iDriving UAV would execute during the final demonstrations, including all necessary procedures and configurations. I also maintained close collaboration with the partners responsible for the pilot activities to ensure timely acquisition of all required flight authorizations and to guarantee full readiness for deployment.

**Task T3.5 – Dynamic Resource Allocation for Optimized Safety Surveillance [Task Leader: CERTH] [Duration: M01 – M30]**

During the initial reporting period, activities in Task 3.5 focused on the development of advanced UAV path planning algorithms to support efficient area inspection, mapping, and real-time monitoring of maintenance needs or incidents. These algorithms are designed to enable autonomous UAV responses to events, allowing drones to automatically launch, follow optimized routes, and transmit critical information back to the system to enhance situational awareness. In parallel, work progressed on an AI-driven mission planning service capable of dynamically allocating flight paths based on monitored area characteristics, available UAV resources, and platform-specific capabilities, with the objective of maximizing coverage and operational efficiency.

CERTH actively contributed to all project meetings and workshops, helping refine system requirements and align task objectives with the overall architecture. Bilateral meetings with ACCELIGENCE (T3.4) ensured close coordination on integration needs between the UAV hardware and the mission planning components. An extensive literature review was carried out, examining state-of-the-art methodologies and simulation frameworks for UAV path planning, with a particular focus on safety surrogate measures and safety-oriented simulation approaches relevant to WP2.

During this period, CERTH also submitted a research paper introducing the Fast Inspection of Scattered Regions (FISR) problem and the multi-UAV Disjoint Areas Inspection (mUDAI) method. These contributions presented novel optimization approaches for UAV-based inspection of spatially dispersed regions, balancing high-resolution data acquisition with efficient resource allocation. The findings directly support the objectives of iDriving by improving real-time inspection efficiency, situational awareness, and data-driven decision-making.

Both research and technical development progressed significantly. The literature review was expanded to further investigate UAV-based path planning for safety surveillance and to assess simulation environments suitable for testing autonomous navigation algorithms with high sensor fidelity and external module integration. Initial testing of coverage path planning algorithms was performed in the AirSim simulator, generating preliminary results that informed iterative refinements to both the algorithmic logic and the simulation setup.

The Integration Matrix for Task 3.5 was completed, detailing all data flows, interfaces, and dependencies between UAV-related components. The first version of the frontend interface for the UAV mission planning platform was also designed and implemented, including:

- Interactive mission area definition using WGS84 polygon drawing
- UAV parameter input modules (battery level, flight time, camera specifications, etc.)
- Real-time visualization of computed flight paths and no-fly zones

CERTH contributed to the CI/CD survey and completed the GitHub component sheet for Task 3.5, documenting repository structure, dependencies, and integration workflows. Technical inputs were provided to Deliverables 2.2 and 2.3 on system architecture, UAV capabilities, and user alignment. The technical specifications for Task 3.5 were subsequently updated to reflect evolving use case requirements, and the "UAV-based Path Planning for Fast Inspection of Scattered Regions" tool was excluded following its misalignment with the finalized project use cases described in D2.1. CERTH also participated in workshops and discussions with pilot use case leaders to define the task's scope and integration strategy within the broader iDriving system.

Toward the end of the reporting period, the integration matrix and frontend interface were finalized, consolidating previous developments. Infrastructure preparation and connectivity setup were successfully completed, including VPN profile verification and establishment of access to the VPN and Kafka modules. Deployment activities were finalized, and all components were successfully deployed on the designated premises.

A key milestone was the successful integration between Tasks 3.4 and 3.5, confirming interoperability and reliable data exchange between the UAV hardware and the mission planning platform. The message format governing communication between these modules was defined, validated, and tested, ensuring synchronized operation across all relevant system components.

#### 2.2.3.5 Risk Inventory

No risks were identified for Work Package 3.

### 2.2.4 WP4 Mid-term report

#### 2.2.4.1 WP4 Current Status and Brief Progress

WP4 has made substantial progress in developing AI-driven capabilities for road safety, behavioural analysis, environmental monitoring, and road maintenance assessment. Early efforts focused on establishing core visual monitoring functions, including the development of a real-time edge computing system and the training of lightweight object detection models for identifying helmets, seatbelts, mobile phone use, and license plates. Complementary work advanced in behavioural analysis, where methods were designed to detect anomalous vehicle movements, traffic violations, and unsafe pedestrian or cyclist interactions. Road maintenance detection progressed through deep-learning models applied to UAV imagery for pothole and pavement defect identification, while environmental monitoring activities established the foundations for weather-aware safety assessment through the integration of real observational data and initial WRF/WRFDA configuration. In parallel, high-resolution 3D scene reconstruction was explored using Neural Radiance Fields and 3D Gaussian Splatting to enhance situational awareness.

As work matured, the models and workflows were refined using updated datasets, expanded use-case scenarios, and improved technical pipelines. Behavioural analysis algorithms were further developed to support specific pilot needs, including traffic-light violation detection, cyclist hand-signal classification, and yielding and lane-usage assessment. The road maintenance tools demonstrated improved recognition performance using partner-provided datasets, and severity estimation methods were expanded. Environmental monitoring advanced through a fully Dockerised WRFDA environment, ingestion pipelines for radar and station data, and defined model domains and KPIs for both pilot regions. The 3D-SMART tools progressed with enhanced semantic reconstruction features and integration into scenario development.

Across all technical areas, WP4 supported continuous integration activities, bilateral technical discussions, rehearsals, and plenary meetings, contributing to the development of the iDriving prototype and to upcoming deliverables. The work to date has established a coherent set of AI-based tools aligned with pilot requirements and ready for further integration and field testing.

#### 2.2.4.2 Identified Issues/deviations (if applicable)

No Issues and/or deviations identified

#### 2.2.4.3 Deliverables submitted (if applicable)

- Deliverable D4.1 : *AI-driven analysis onsite for monitoring combined with advanced representations v1,* is due to be submitted in M18 (December 2025)

#### 2.2.4.4 Summary of Progress towards objectives and details for each task

**Task T4.1 – Real-Time Edge Computing for Visual Monitoring [Task Leader: CERTH] [Duration: M03 – M30]**

Participating Partners: [TEKNIKER, ACCELI, MBL]

Task 4.1 actively contributed to all WP4 technical and coordination activities, including meetings on Kafka-based communication, metadata specification with partners, and bilateral discussions with pilot leaders in Nevers and Graz to prepare rehearsal procedures. During early tests, a video-streaming issue prevented full end-to-end validation; however, local playback tests confirmed that detection, tracking, and message-handling components operated correctly. Key lessons included the need for modular input-source handling, structured logging, and clearer error-level definitions.

Across Use Cases, Task 4.1 developed and refined several visual perception modules. For Nevers (UC 1.2), four modules were implemented: zebra crossing detection, illegal parking on bike lanes, cyclist/motorbike violations, and traffic light and road-signal obstruction detection. Each module involved custom datasets, YOLO-based detection, tracking integration, and Kafka message generation. Stable versions were achieved for zebra crossings and cyclist violations, while the illegal-parking and obstruction modules remain under development due to dataset limitations and the need for expanded real-world imagery.

For Graz (UC 1.1), Task 4.1 produced a real-time detection module covering seatbelt and helmet usage, vehicle counting, and license-plate extraction. YOLOv11 models were trained on a 10-class dataset and are currently being integrated with tracking and OCR components. Work for the Thessaloniki (UC 2.2) and Bizkaia (UC 3.2) scenarios remains limited to dataset preparation and feasibility discussions, as both Use Cases will be executed later in the project.

**Task T4.2 – AI-Powered Behavioural analysis of objects of interest [Task Leader: TEKNIKER] [Duration: M03 – M30]**

Participating Partners: [UNI.EIFFEL, ING, MBL]

Task 4.2 made substantial progress during the reporting period, advancing the development of AI-based behavioural analysis components while ensuring close coordination with the leaders of Use Cases 1.1 and 1.2. Participation in UC workshops and technical meetings enabled a clear definition of scenario requirements, and bilateral discussions with Tekniker, CERTH, ALP.LAB, and UNI. EIFFEL ensured technical alignment with pilot needs. Early development focused on trajectory-based analysis using the Intersection Drone Dataset, where detectors were implemented and tested for pedestrian zebra-crossing compliance, along with additional anomaly detectors whose validation is ongoing due to limited datasets.

Integration with T4.1 was successfully tested both remotely and during the Nevers rehearsal through Kafka pipelines, confirming smooth data exchange between image-based perception modules and behavioural-analysis components. Further integration work through the Tekniker Dataspace Connector is planned and will serve as a reference implementation for partners. Initial experiments with the Phyphox app were conducted to explore sensor-based behavioural modelling, though recent efforts have prioritised image-based methods due to stronger synergy with T4.1 outputs.

Task 4.2 contributed to key deliverables, including architecture definitions in D2.3 and integration specifications in D5.1, ensuring consistency between detection modules and overall system requirements. Although early progress experienced minor delays due to requirements gathering and technology selection, the impact on overall planning is minimal. The reporting period marked a transition from conceptual work to early technical development, establishing the foundations for full behavioural-analysis implementation in subsequent phases.

**Task T4.3 – Visual analysis for Identification of Maintenance Requirements [Task Leader: CERTH] [Duration: M03 – M30]**

Participating Partners: [UNI.EIFFEL, ACCELI, DREVEN]

During this reporting period, Task 4.3 progressed substantially in the development of road defect detection and severity estimation components. Work began with an extensive review of available datasets, leading to the selection of RDD2022 as the primary source due to its high-quality annotations and relevance to road maintenance tasks. YOLOv11 was chosen as the core detection architecture, and both YOLOv11s and YOLOv11m variants were implemented and benchmarked to identify the most suitable configuration. Baseline models were trained on RDD2022 and further improved using additional data provided by INFRAPLAN, resulting in stable performance in both image and video-based evaluations. Complementary tools were developed, including an automated defect counter and the integration of EigenCAM attention maps into a NeRF-based 3D reconstruction pipeline, enhancing spatial interpretation of detected defects. Field testing under real-world conditions demonstrated that the system provides a solid foundation for the upcoming pilot trials.

Integration and coordination activities were carried out throughout the period. JSON-based output structures were introduced to ensure standardized communication across modules, enabling smooth alignment with the maintenance analysis framework. Continuous coordination with INFRAPLAN and TEKNIKER ensured coherence of technical specifications and integration priorities. Task 4.3 also contributed to Deliverables D2.3 and D5.1, the system integration matrix, and KPI monitoring activities. Cross-partner integration testing strengthened interoperability across components, and task activities were presented in consortium meetings, including the plenary meeting in France. The scientific work was documented in a paper titled *"Semantic-Aware 3D Gaussian Splatting for Road Pavement Condition Monitoring"*, currently under review at TRA 2026.

Some challenges were observed, including sensitivity to environmental conditions such as wet surfaces and extreme illumination, as well as inconsistencies in image quality arising from heterogeneous acquisition systems. Mitigation strategies involve expanding dataset diversity, applying robust augmentation techniques, and exploring foundation models for improved generalization. The current prototype already demonstrates validated detection and initial severity estimation capabilities, with next steps focused on dataset expansion, refinement of severity estimation algorithms, further integration of foundation models, and continued field validation to support upcoming deliverables and scientific outputs.

**Task T4.4 – Smart Environmental Condition Monitoring for Proactive Road Safety Measures [Task Leader: DREVEN] [Duration: M03 – M30]**

Participating Partners: [DREVEN]

Task 4.4 made strong progress in laying the technical and methodological foundation for the project's smart environmental condition monitoring system. The team identified suitable meteorological stations, assessed their spatial coverage, and initiated discussions with local authorities regarding potential upgrades, particularly in Thessaloniki. Key meteorological variables and corresponding KPIs were defined to guide model evaluation. In parallel, the WRFDA modelling environment was successfully containerised, and domain configurations for both Thessaloniki and Karlovac were designed using regional meteorological analysis and literature evidence.

Significant progress was also achieved in data workflows and integration. Automated connections to Thessaloniki and Karlovac public APIs were established, enabling real-time meteorological data retrieval and structured storage. Initial preprocessing pipelines were created to convert observational data into LITTLE_R format for WRFDA compatibility. Additionally, high-level server requirements and data-flow architecture plans were prepared, and a focused knowledge base was developed to support scientific and technical decisions. These developments set the stage for the next phase, which will focus on validating monitoring outputs, refining assimilation processes, and integrating environmental insights into the broader proactive road-safety framework.

**Task T4.5 – AI-driven 3D Scene Generation for Safety & Maintenance Monitoring [Task Leader: CERTH] [Duration: M03 – M30]**

Participating Partners: [INFRA PLAN, DREVEN, ACCELI]

Task 4.5 advanced both the methodological and practical components of 3D reconstruction for road-safety applications. The team contributed to user-requirements workshops, completed questionnaires that finalised the list of target detection objects, and supported Deliverables 2.3 and 5.1 as well as the integration matrix. Extensive literature review work identified the most efficient 3D reconstruction approaches, while a data-acquisition protocol for UAV-based, object-centric scenes was developed to ensure high-quality reconstruction results. Baseline NeRF and Gaussian Splatting methods were evaluated, followed by testing of more advanced Nerfacto and Splatfacto architectures. Collaboration with ACCELIGENCE allowed the definition of UAV flight trajectories and the processing of real-world UAV data, including static-vehicle captures and road-defect scenes.

Practical experiments progressed with multi-perspective data collection using UAVs and dashboard cameras, enabling testing of SOTA reconstruction approaches on road defects and accident-related scenarios. Cross-task integration was strengthened by using attention maps from Task 4.3 to enrich 3D scenes with semantic cues. The task's scientific output included co-authoring a paper submitted to TRA2026. Key risks were identified around image quality and dynamic obstacles during data capture, which may affect reconstruction accuracy. Next steps focus on expanding large-scale testing, integrating advanced reconstruction methods, and continuing to enhance semantic-aware 3D scene representations.

#### 2.2.4.5 Risk Inventory

The following risks have been identified (Table 26) that could affect the quality or timing of the activities in the WP4. Corrective actions are proposed to mitigate these risks.

Table 26: WP4 Risk Inventory

| # | Description | Likelihood | Impact | Response |
|---|---|---|---|---|
| 1 | In computer vision tasks, acquisition conditions and image quality can affect model performance | Medium | High | Tests must be carried out with the equipment and the network. Anything that does not work as expected should be looked at for solutions, such as better tuning of the equipment or using more appropriate equipment |
| 2 | In task 4.3 the performance of the model may be affected by adverse weather conditions such as rain or snow | Medium | High | Similar data sets should be sought. If they do not exist, partners should be asked to create them |
| 3 | In Task 4.3, the severity assessment will primarily rely on the number of detected road defects. If this measure proves insufficient, an auxiliary parameter—such as pixel-based size—should be incorporated | Medium | High | To assess severity, live testing is essential to evaluate the current model's performance. If it fails to reliably detect and quantify road defects, enhancements to the tracking system will be necessary. Additionally, if the existing feature proves |

| | | | | |
|---|---|---|---|---|
| | | | | inadequate, we should consider analysing defect size in pixels or explore alternative indicators. |
| 4 | T4.5 – Low-quality or inconsistent visual data (blur, low light, unstable UAV paths) can lead to incomplete 3D reconstruction. | Medium | High | Follow strict acquisition protocol; repeat flights under better lighting; use stabilisation tools. |
| 5 | T4.5 – Dynamic obstacles (moving vehicles, pedestrians) introduce occlusions and inconsistencies in the 3D reconstruction. | Medium | Medium | Conduct flights during low-traffic hours; filter/ mask occlusions; capture multiple passes. |

### 2.2.5 WP5 Mid-term report

#### 2.2.5.1 WP5 Current Status and Brief Progress

During the first half of the project (M01–M18), WP5 has made steady and significant progress towards its objective of leveraging digital technologies to improve road safety and enable intelligent, proactive infrastructure maintenance. The work has evolved from initial conceptualisation and requirements gathering to the deployment and integration of concrete tools, simulation environments, and infrastructure components across all five tasks.

In the first semester (M01–M06), the focus was on laying the foundations: defining and refining key performance indicators (KPIs) for traffic, safety, and maintenance; analysing state-of-the-art methods for dynamic Safety Criteria Catalogue (SCC) updates; initiating the design of the unified road safety ecosystem; and assessing suitable simulation tools and data needs for digital twins and maintenance optimisation. Requirements for the Digital Twin-based control centre with XR features were collected in close collaboration with pilot sites and end users.

In the subsequent periods (M07–M18), WP5 activities shifted towards implementation, integration, and early validation. The SCC progressed from concept to a functional toolchain, including KPI computation templates, a KPI manager, and mapping/visualisation tools, tested with simulated data from Task 5.3 (Task T5.1). At the infrastructure level, core backbone services for the iDriving ecosystem were deployed, including Kafka, the complete CI/CD stack, VPN access, and the iDriving GitHub organisation, alongside detailed integration plans and deployment diagrams (Task T5.2). This work culminated in the submission of Deliverable D5.1 (First iDriving Prototype) and the successful execution of end-to-end integration tests, such as the live rehearsal in Nevers for Use Case 1.2.

Simulation-based digital twins advanced through the design of multi-scale SUMO models, the development of CARLA–SUMO co-simulation pipelines, and the generation of synthetic datasets for surrogate safety analysis and predictive warnings across multiple Pilot Urban Cases (Task T5.3). In parallel, Task T5.4 refined the Failure Mode and Effect Analysis (FMEA) framework, aligned historical and contextual data for the Karlovac use case, and structured the core modules of the AI-optimised maintenance tool (risk assessment, health/logistics, and maintenance scheduling), reinforcing the foundations for data-driven, cost-effective maintenance planning.

The Digital Twin-based control centre with XR features has progressed from requirements and architectural design to concrete interface mock-ups, the implementation of initial REST API communication modules, and their integration and testing with other components, including on-site validation in Nevers (Task T5.5). Continuous collaboration with pilot owners, end users (e.g. municipal police), and technical partners has ensured that the envisioned control centre and associated tools are both operationally relevant and technically feasible.

Collectively, the activities carried out in M01–M18 demonstrate a clear transition of WP5 from conceptual development to functional implementation, integration, and early prototyping. All tasks remain well aligned with the project's overarching objectives, with strong cross-partner collaboration supporting consistency across work packages. WP5 is now well positioned to enter the next phase, with a focus on extending digital twin capabilities, strengthening AI-enabled safety and maintenance services, and deploying and validating the integrated solutions in the project pilots.

#### 2.2.5.2 Identified Issues/deviations (if applicable)

No major deviations from Annex 1 of the Grant Agreement have been reported during the M01–M18 period. However, a key cross-cutting issue has been identified and is being actively monitored:

- Limited data availability for specific use cases, particularly in UC 1.1 and UC 1.2, has impacted progress in Task T5.3, where simulation-based safety analysis depends on real-world traffic data.
- This limitation has also had knock-on effects on Task 3.2, which relies on calibrated simulation models for rerouting and risk prediction.
- While mitigation measures have been initiated, including targeted coordination with PUC owners and the use of synthetic datasets, the data gap has caused delays in the calibration, and validation of some simulation models.

- Efforts are ongoing to resolve these issues through intensified collaboration with local stakeholders and the exploration of alternative data sources, including predictive modelling approaches and third-party traffic datasets.

At this stage, the simulation scenarios for UC 1.1 and UC 2.2 are generated and is using by partners. However, the final calibration and validation are in progress. These issues are not expected to compromise the overall objectives of WP5 but may require continued close coordination to avoid schedule pressure in subsequent phases.

#### 2.2.5.3 Deliverables submitted (if applicable)

During the M01–M18 period, the following status applies to WP5 deliverables:

- D5.1 – First iDriving Prototype (submitted). D5.1 has been prepared and submitted. It consolidates the initial outcomes of infrastructure deployment and integration planning under Task T5.2. The deliverable analyses the deployment environment and component readiness, specifies and maps the integration framework and interfaces, outlines the integration plan and phases, details the CI/CD infrastructure and DevOps workflows, and describes the implementation of the Message Bus.

- D5.2 – Digital Twin for Safety & Maintenance (due at M18) D5.2 is due at M18. Preparatory work is ongoing, building on the results of Tasks T5.1, T5.3, T5.4 and T5.5, including KPI cataloguing and monitoring pipelines, simulation-based digital twins for safety analysis, and the initial frameworks for data-driven maintenance and the control centre.

#### 2.2.5.4 Summary of Progress towards objectives and details for each task

**Task T5.1 – Dynamic Update of Criteria Catalogue Through Continuous Learning [Task Leader: UNI.EIFFEL] [Duration: M03 – M30]**

This task focuses on developing a continuously evolving catalogue of key performance indicators (KPIs) related to road safety, traffic operations, and infrastructure maintenance. UNI.EIFFEL is leading efforts to integrate AI-driven mechanisms that enable real-time analysis, adaptive learning, and proactive recommendations to support safer and more efficient mobility systems.

Over the reporting period (M01–M18), Task T5.1 progressed from conceptual design to the early implementation of the Safety Criteria Catalogue (SCC), with a functional toolchain for KPI management and visualisation. The following activities were carried out:

- Integrated the initial output of Task T2.1, specifically the preliminary set of KPIs defined for traffic management, safety, and maintenance, to ensure alignment and consistency across work packages.
- Filtering learnable or updatable KPIs based on their functional descriptions, to distinguish between static indicators and those suitable for continuous improvement.
- Active participation in technical meetings (T2.1), contributing to the definition and coordination of SCC development across the work package.
- Developed KPI ID card and a KPI Python template to standardize the structure for defining and computing key performance indicators.
- Built a KPI Manager, enabling dynamic addition or removal of KPIs tailored to individual use cases, ensuring flexibility and adaptability.
- Provided a first version of a KPI mapping tool, allowing users to visualize calculated indicators in a geographic or system context.
- Utilized simulated data provided by Task T5.3 to test the KPI pipeline for both computation accuracy and visualization clarity.
- Submitted scientific contributions based on this work to the scientific Conference, showcasing early results and methodologies in collaboration with T2.1:
- Irina Stipanovic, Iva Mejasic, Leon Kucinic, Mostafa Ameli and Thomas Bapaume, *Enhanced Safety Criteria Catalogue for urban and secondary roads*, TRA 2026 – Transportation Research Arena (submitted).

This period marked a transition from conceptual research to the early-stage development and integration of practical tools. The collaboration between T5.1, T5.3, and T2.1 has proven essential in aligning theoretical foundations with technical implementation. These synergies are laying the groundwork for a continuously learning, AI-supported system that will evolve and adapt as real-world data and operational needs mature over the project's lifecycle.

**Task T5.2 – Bridging Services for a Unified Road Safety Ecosystem [Task Leader: INTRA] [Duration: M03 – M34]**

This task aims to design and implement an integrated framework that enables seamless communication and interoperability across road safety applications and technologies. Led by INTRA, the objective is to create a unified digital ecosystem through harmonized data handling, CI/CD practices, and scalable infrastructure, ensuring all system components function cohesively across distributed environments.

In the reporting period (M01–M18), Task T5.2 delivered tangible infrastructure components and strengthened its backbone services to support the wider WP5 activities. The following achievements were realized:

- Achieved significant project milestones as planned.

- Maintained continuous engagement in monthly project meetings, facilitating coordination and integration across partners.
- Procured multiple virtual machines (VMs) from Hetzner to support iDriving infrastructure needs.
- Deployed and configured the Kafka infrastructure.
- Set up the Kafka REST Proxy to enable REST-based interactions with Kafka.
- Established the complete CI/CD stack, including Keycloak, Harbor, Portainer, Jenkins, and pfSense.
- Created deployment diagrams for the iDriving system.
- Developed a detailed integration plan.
- Set up the iDriving GitHub organization and onboarded relevant users and repositories.
- Submitted Deliverable D5.1 (First iDriving Prototype), which analyzes the deployment environment and component readiness, specifies and maps the integration framework and interfaces, outlines the integration plan and phases, details the CI/CD infrastructure and DevOps workflows, and describes the Message Bus implementation.
- Distributed VPN profiles to partners and verified successful end-to-end connectivity to WP5 backbone services for development, integration, and pilots.
- Delivered a practical Kafka workshop covering how to develop producers and consumers to accelerate consistent adoption across components.
- Authored new integration sheets defining exact component-to-component connections per pilot, including topics/endpoints, schemas, and other expectations.
- Conducted a successful live rehearsal in Nevers for Use Case 1.2, validating live connections between components under pilot-like conditions.
- Held weekly integration meetings focused on resolving CI/CD issues, Kafka integration topics, and near-term planning for pilots.

During this period, the core infrastructure has been deployed, establishing the foundation for upcoming data integration, service orchestration, and prototype delivery. Active coordination with technical partners and consistent participation in WP5-wide activities have contributed to the steady formation of a unified ecosystem.

**Task T5.3 – Digital Twin Powered Predictive Safety Measures and Warning Systems [Task Leader: UNI.EIFFEL] [Duration: M03 – M30]**

This task is dedicated to developing simulation-based digital twins that can assess and predict risky traffic conditions. The primary goal is to enhance road safety through predictive modelling by integrating real-world and simulated data. UNI.EIFFEL leads the effort to create simulation frameworks and warning systems that leverage surrogate safety measures, pattern recognition, and advanced scenario generation.

In the second reporting period (M07–M12), significant progress was made in both scientific groundwork and technical implementation. Key achievements included:

- Reviewed state-of-the-art literature and best practices in pattern recognition for risky behaviour, forming the basis for safety-oriented simulation.
- Organized technical meetings to evaluate and compare open-source traffic simulators and calibration methodologies to identify the most suitable tools for dynamic traffic simulation. Confirmed the use of SUMO for large-scale traffic simulation and CARLA for localized, high-fidelity intersection modelling.
- Investigated the real-time application of digital twins for predictive safety and rerouting strategies.
- Organized task-wide and bilateral technical meetings with participating partners and PUC owners to finalize simulation frameworks and data flows.
- Developed and shared a guideline for SUMO usage with Pilot Urban Cases (PUCs), to harmonize scenario development.
- Outlined and initiated a simulation roadmap for each PUC, identifying 3 scales of simulation networks:
  - Local scale: focused on monitored intersections and micro-level interactions
  - Safety scale: surrounding networks for surrogate safety analyses
  - Rerouting scale: broader networks integrated with Task 3.2 for rerouting strategies
- PUC Simulation Framework Progress:
  - PUC 1.1 – Graz: Defined three network resolutions across multiple bridge sites. Requested data from the PUC owner (e.g. red light/loop detector data). Generated an initial SUMO model with random trips in anticipation of calibration data.
  - PUC 1.2 – Nevers: Built two versions of the Nevers network based on provided traffic counts and directional surveys. Began calibration of SUMO scenarios using shared traffic data.
  - PUC 2.2 – Thessaloniki: Defined simulation networks including three exits of the Thessaloniki ring road. Requested sensor data to support simulation calibration. Created preliminary SUMO models with synthetic traffic flows.
- CARLA simulation framework progress:
  - Implementation of a novel pipeline to assess surrogate safety measures (SSMs), leveraging cutting-edge software.
  - Seamless incorporation of CARLA & SUMO for synchronized simulations.
  - Robust deployment of LiDAR sensors in running co-simulation & real-time data fusion from multiple sensors for optimal scene representation.
  - Creation of a custom training dataset for 3D point-cloud object detection.
  - Implementation of an object detection and tracking system built upon the YOLOv4 model.
- Dataset and Pipeline Development:

- Built a SUMO and CARLA pipeline to generate simulated datasets that include traffic flows, surrogate safety indicators, initial traffic configuration parameters, and aggregated outputs at 5-minute intervals.
- Generated and shared a simulated traffic dataset for UC 1.2 with partners.
- Calibrated SUMO models for UC 1.2 using real traffic data from Nevers.
- Developed scenarios for peak hours and free-flow conditions, supporting testing and model robustness.
- Provided initial version of SUMO-based models to Task 3.2 partners for integration into rerouting workflows.
- Collaboration and Dissemination:
  - Submitted scientific contributions based on this work to the scientific Conference, showcasing early results and methodologies.
    - Bapaume T., Ameli M., Naviliat N., Tendjaoui M., Papamichail I., Oukhellou L., *Near-Real-Time Traffic Risk Assessment via Deep Learning and Simulation Inference*, TRA 2026 – Transportation Research Arena (submitted).
    - Matsioris, G., Papamichail, I., Doitsidis, L. *Towards developing a comprehensive monitoring system for road safety by utilizing surrogate safety measures in smart urban environments*, TRA 2026 – Transportation Research Arena (submitted).
    - Bapaume T., Ameli M., Naviliat N., Tendjaoui M., Papamichail I., Oukhellou L., *Digital-Twin Assisted Deep Learning for Traffic Risk Forecasting*, 8th IRTAD Road Safety Data Conference, (submitted).

This period marked a major step forward from conceptual planning to operational modelling. The coordinated efforts with partners, Task 3.2 leader, and various PUC owners allowed for realistic, multi-scale digital twin environments to be initiated. These simulation frameworks are foundational for generating predictive insights and safety alerts in future phases of the project.

Issues and Dependencies: Data availability for multiple UCs remains unresolved, which affects both the calibration and integration steps of Task 5.3 and Task 3.2. Mitigation efforts are ongoing through active coordination with the PUC owner.

**Task T5.4 – Digital Twin machine consulting for Proactive and Cost-Effective Maintenance Strategies [Task Leader: TEKNIKER] [Duration: M03 – M30]**

This task is focused on the development of a Digital Twin-based tool that supports data-driven decision-making for infrastructure maintenance. By integrating condition monitoring, logistics, and predictive analytics, the goal is to optimize intervention timing and resource allocation, enabling proactive and cost-effective maintenance strategies.

During the second reporting period (M07–M12), Task T5.4 advanced its core methodology by refining the Failure Mode and Effect Analysis (FMEA) framework and structuring the foundation of the AI-Optimized Maintenance tool. Progress highlights include:

- TEKNIKER presented an initial FMEA structure tailored for road infrastructure, with support from INFRAPLAN in refining the framework.
- The FMEA is currently focused on cracks and potholes as priority failure types and will be extended to include other types as validation proceeds.
- INFRAPLAN contributed by linking cost indicators to failure consequences, incorporating metrics such as delay, safety risk, and traffic impact.
- The FMEA is divided into three core modules:
  - Risk Assessment Tool
  - Health and Logistics Tool
  - Maintenance Scheduling Tool
- A data availability checklist is being defined to assess current datasets and identify gaps for the Karlovac use case.
- Historical data (≥5 years) was identified for Karlovac, including condition, location, maintenance activity, and costs, which will be used for both failure prediction and maintenance planning.
- Discussions were initiated on integrating weather data from DREVEN's local weather stations into the forecasting model.
- Initial review of Croatian road defect classification standards was carried out. A comparative review is being considered for Spanish standards to ensure cross-regional applicability.
- The geographic scope was narrowed to selected urban intersections and crossroads in Karlovac, optimizing the focus area for analysis.
- The integration of traffic simulation was discussed to assess how failures and maintenance actions influence traffic conditions. ALP.LAB is exploring this feasibility.

This period marked a critical step from planning toward applied methodology and tool development. The tight collaboration between TEKNIKER, INFRAPLAN, and other partners has initiated a strong framework that merges failure analysis with operational data, paving the way for dynamic, data-informed maintenance decision-making in the next phase.

- Verification and Translation of Maintenance Work Data from Karlovac: This task involved the verification and translation of maintenance work data provided by the Karlovac team. The data included detailed information on maintenance activities, such as the work orders executed, articles used, and the respective quantities. This ensured that the data was accurately represented and could be effectively integrated into the broader project framework for further analysis and optimization.
- Design and Development of a Common Database for Data Exploitation: A central component of the project was the design and development of a common database that served as the foundation for various tasks, including the exploitation of maintenance data. This database supported the analysis and management of maintenance operations, the simulation of different maintenance strategies, and the optimization of maintenance planning, with a particular focus on linear assets such as roads and highways. The database facilitated the seamless integration of data across multiple sources and ensured that maintenance strategies were optimized based on both real-time and historical data.
- Assessment of OpenStreetMap (OSM) Data from Karlovac: The team reviewed OSM data available for Karlovac and assessed its utility in the context of the project. Specifically, the data was used to automatically detect kilometer points along roads and streets, which proved essential for accurate asset management and maintenance planning. Additionally, methods for segmenting streets and roads based on OSM data were explored, improving the granularity and accuracy of maintenance schedules and strategies.
- Development of Algorithms for Road Detection Using GPS Coordinates: Algorithms for road detection based on GPS coordinates were developed and tested, initially on Spanish road networks. These algorithms were adapted and refined for use in other geographical regions, including Karlovac. By leveraging GPS data, the algorithms automatically identified road locations, which were then integrated into the common database for enhanced maintenance planning and analysis.

**Task T5.5 – Digital Twin-Based Control Center with XR features for Enhanced Situational Awareness [Task Leader: SIMAVI] [Duration: M03 – M30]**

Participating Partners: [INTRA, INFRA PLAN, ALP.LAB, AIM, DREVEN, THESSALONIKI]

This task is dedicated to the design and development of an advanced control center that integrates Digital Twin technology with extended reality (XR) features such as virtual, augmented, and mixed reality. The goal is to enhance situational awareness for traffic and safety operators by offering immersive and intelligent visualizations of real-time and predictive road data. SIMAVI leads the efforts to conceptualize and implement this next-generation interface for infrastructure management and incident response.

During the M07–M12 reporting period, Task T5.5 continued to progress on both conceptual and technical fronts, with key developments including:

- The partners involved in this task collaborated with the rest of the Consortium for identifying the user requirements applicable to each use case of the project. Once outlined, the user requirements were further discussed during the Plenary Meeting in Graz (25-26 February 2025) and later consolidated within the deliverable D2.2 – User, Safety and Ethic Requirements & Pilot Use Cases Handbook.
- As the partners progressed with the activities, they established as well the technical requirements for the future control center. Under guidance from INTRA, the technical partners contributed to defining the architecture and technical requirements in deliverable D2.3 – Technical Requirements and Digital Ecosystem Architecture.
- The identified user and technical requirements were a basis for the development of the Digital Twin-based control center. Starting from these elements, SIMAVI created a set of mockups for the control center, targeted to be implemented in Task T5.5. The mockups were reviewed with the Consortium members and updated as necessary according to the partners' feedback or to the aspects identified throughout the development process, so that the objectives and requirements are fulfilled.
- The Municipality of Thessaloniki has assisted in defining the necessary parameters of the Digital Twin – based control center through its participation in the related user workshops, the definition of the details of the Thessaloniki Use Case and the definition of the user requirements, which were discussed with the system's end – users who, in case of the control centre, will mainly be members of the local Municipal Police force. The Municipal police force will also be actively involved in the testing of the iDriving platform that will be achieved through the implementation of the Thessaloniki Pilot Use Case.
- Based on the technical information shared by the technical partners, a first version of communication module for REST API protocol has been implemented.
- The implemented module has been integrated with the other technical components and tested remotely, as well as on premises of Use Case 1.2 (Nevers, France) in September 2025.
- Based on the results of the performed tests, the partners collected data and feedback and used this information in adjusting the module and further developing it.

- The implementation of the first version for interface and involved functionalities of the control center is currently in progress,
- The partners involved in Task 5.5 actively participated in the regular meetings in order to follow up the progress and also in technical workshops with the other partners to further discuss and clarify the aspects involved in the development and integration of the targeted components.
- The partners also attended the Plenary meeting in Paris (22-23 September 2025) in which they discussed the progress, next steps and related technical aspects for T5.5.No deviations to be reported from Annex 1 of the GA and the impact on other tasks as well as on available resources and planning;
- No risks have been identified so far for T5.5

This reporting period marked the evolution of Task T5.5 from requirements gathering into early design and interface prototyping. Close collaboration with end users and technical teams has ensured that the envisioned Digital Twin control centre is rooted in real operational needs while being technically feasible and scalable. These efforts lay the foundation for subsequent development and integration phases in the next semester

#### 2.2.5.5 Risk Inventory

The risks identified for Work Package 5 are presented in Table 27 below:

Table 27: WP5 Risk Inventory

| # | Description | Likelihood | Impact | Response |
|---|---|---|---|---|
| 1 | Potential delays in information gathering from other WP5 tasks | Low | Low | Continue organizing bilateral meetings to address communication gaps and ensure timely exchange. |
| 2 | Computational cost and time demand of simulation tools in Task T5.3 | Medium | Low | Optimize simulation configurations and allocate additional computational resources as needed. |
| 3 | Limited data availability for specific Use Cases (e.g., UC 1.1) | Medium | Medium | Engage closely with PUC owners to accelerate data provision; use synthetic or alternative datasets where necessary. |
| 4 | Integration complexity across tools and systems in iDriving infrastructure | Medium | Medium | Use CI/CD workflows and architecture diagrams to manage interfaces; maintain frequent technical sync meetings. |

### 2.2.6 WP6 Mid-term report

#### 2.2.6.1 WP6 Current Status and Brief Progress

WP6 focuses on three activities: developing the evaluation methodology and coordinating the overall evaluation activities of the iDriving project, the implementation of the trials of the individual pilot use cases, and executing user training programs. The work is structured into six tasks. Currently, T6.1, T6.4, T6.5, T6.6 are active. They are progressing according to plan. T6.3 is scheduled to begin in M19, T6.2 in M25.

The following progress has been achieved for each of the activities:

**Evaluation methodology:** Three aspects for evaluation have been defined: technical evaluation of the tools, technical evaluation of the platform, and evaluation of the expected impacts, ensuring a thorough assessment of the entire iDriving system. During this period, particular focus was placed on defining basic scenarios and data sources for all PUCs and on converting the data into KPIs. Additionally, KPIs for the technical tool and platform evaluation have been defined.

**PUC Testing:** Planning for the first trials of PUC1.1 and PUC1.2 is ongoing, with a first successful rehearsal already executed for PUC1.2 in Nevers.

**User Training:** Training materials aligned with the first version of the iDriving application, currently under development, have been prepared for upcoming user sessions.

In addition, the pilot tests have been scheduled for the following months:

- Test PUC 1.1: M20 (February 2026)
- Test PUC 1.2: M20 (February 2026)
- Test PUC 2.1: M22 (April 2026)
- Test PUC 2.2: M28 (October 2026)
- Test PUC 3.1: M31 (January 2027)
- Test PUC 3.2: M33 (March 2027)

To ensure smooth coordination and collaborative problem-solving between all partners involved in WP6, monthly meetings are held, attended by all WP6 partners. These meetings serve multiple purposes: each Task Leader of the currently active tasks is invited to present their progress in line with the Grant Agreement, ensuring transparency and a shared understanding of the overarching WP6 objectives. Beyond monitoring progress, the monthly meetings provide a platform for joint planning, strategic alignment, and technical exchange. For task-specific topics, additional workshops were organised and conducted by the relevant leaders. All partners involved in WP6 have collaborated and actively participated in all related workshops and meetings.

#### 2.2.6.2 Identified Issues/deviations (if applicable)

No major deviations from Annex 1 of the GA have been reported.

#### 2.2.6.3 Deliverables submitted (if applicable)

No Deliverables were due between M01-M18.

#### 2.2.6.4 Summary of Progress towards objectives and details for each task

**Task T6.1 – Methodological approach development for platform evaluation [Task Leader: INFRA PLAN] [Duration: M05 – M22]**

Participating Partners: [TUC, AUSTRIATECH, AIM, THESSALONIKI, ALP.LAB, ING]

- Continuing the development of the evaluation methodology including all aspects of the iDriving system and technologies related to road users, vehicles, traffic management and communication, and infrastructure.
- Organization of workshops with WP2, WP5 and UC leaders to align KPIs for the evaluation.
- During this period, the focus was on defining basic scenarios and data sources for all PUCs and on converting the data into KPIs.
- For the evaluation of PUC1.1, relevant data is being collected by Alp.Lab to support evaluation and KPI definition, including traffic flow data, traffic light signal data as well as records of accidents and traffic violations to establish a comprehensive baseline for the Graz use case.
- For PUC1.2, Uni.Eiffel is collecting all necessary data for evaluation, including traffic survey data and national/city-level safety statistics (open data).
- For the evaluation of PUC2.1 and PUC2.2 and the definition of relevant KPIs, both historical data and data that are collected. To assess data availability, local transport operators as well as local authorities are participating. The local police force has been approached for data related to adverse weather conditions. The Municipality of Karlovac and Thessaloniki are actively participating by providing data and collecting additional data from local authorities and statistics offices. Moreover, the Greek national statistics office been contacted, with some data available at the national level.
- Planning for the testing of PUC3.1 and 3.2 was initiated, but as the testing will only take place in the months M31 and M33, they were not the focus during this period.
- No deviations from the Annex 1 of the Grant Agreement have been identified.

**Task T6.2 – Real-Time detection, Warning and Response trial [Task Leader: TEKNIKER] [Duration: M25 – M34]**

Participating Partners: [AIM, SIMAVI, TUC, CERTH, AUSTRIATECH, UNI.EIFFEL, ING, ACCELI, INTRA, DREVEN, MBL]

- There are no updates to report at this stage, as the task has not yet commenced.
- No deviations from the Annex 1 of the Grant Agreement have been identified.

**Task T6.3 – Infrastructure Maintenance and Monitoring trial [Task Leader: INFRA PLAN] [Duration: M19 – M28]**

Participating Partners: [COK, THESSALONIKI, TUC, DREVEN, CERTH, AUSTRIATECH, UNI.EIFFEL, ACCELI, INTRA, SIMAVI, MBL]

- There are no updates to report at this stage, as the task has not yet commenced.
- No deviations from the Annex 1 of the Grant Agreement have been identified.

**Task T6.4 – Enhanced Logging and User Interaction trial [Task Leader: ALP.LAB] [Duration: M11 – M20]**

Participating Partners: [UNI.EIFFEL, CERTH, TUC, AUSTRIATECH, INTRA, SIMAVI, DREVEN, MBL]

- T6.4 aims to conduct real-world trials of PUC1.1 (Graz), and PUC1.2 (Nevers)
- Before the real-world trials, rehearsals are being carried out. For PUC1.2, the rehearsal was conducted on 24 September in Nevers with the participation of all relevant technical partners to test the on-site integration of the iDriving system. The rehearsal was successful and confirmed the feasibility of the planned deployment in Nevers. Based on insights gained from the PUC1.2 rehearsal, the PUC1.1 rehearsal is being integrated into the final test execution. The duration of the final test has been extended, with most rehearsal and integration steps planned to be conducted online.
- For the trial of PUC1.1, sensors and equipment selection has been finalised at the rehearsal in Nevers, and their integration is currently in progress with project partners (CERTH, UNI-Eiffel, TEKNIKER, INTRA). The location of the execution of the final tests for PUC1.1 have been selected, and the necessary preparations are ongoing for the planned testing period.
- For the trial of PUC1.2, in addition to the rehearsal, camera locations for iDriving deployment have been identified and prepared. Traffic sensors were installed to gather both baseline and real-time data inputs for the iDriving platform. The required cameras and other hardware are now in the process of being installed and commissioned on site. Historical data on vehicle counts and traffic signal operations have been provided by the local authority, supporting calibration and evaluation activities. The authorisation process for drone-based experiments in Nevers is ongoing.

- Additional efforts focused on collecting relevant data for PUC evaluation, described under T6.1.
- No deviations from the Annex 1 of the Grant Agreement have been identified.

**Task T6.5 – Platform validation and user evaluation [Task Leader: AUSTRIATECH] [Duration: M11 – M36]**

Participating Partners: [AIM, THESSALONIKI]

- As part of T6.5, an initial set of technical KPIs for evaluating the iDriving platform has been developed in close cooperation with T6.1. To ensure a comprehensive assessment, key aspects such as Availability, Latency, Service Reliability, and Processing have been considered.
- The selection of KPIs was finalized in cooperation with all project partners during the 2nd plenary meeting in Paris.
- For each of the selected KPIs, the test purpose, pre-test conditions, expected results, test procedure sequence, and verification criteria have been defined in accordance with the platform architecture and its components as outlined in D2.3. Additionally, the logging format has been specified to ensure consistent data collection.
- The "C-ITS Mobile Lab", an additional aspect of T6.5, will be employed to validate C-ITS message exchanges in Use Case 3.2.
- No deviations from the Annex 1 of the Grant Agreement have been identified.

**Task T6.6 – User training and engagement, [Task Leader: SIMAVI] [Duration: M11 – M36]**

Participating Partners: [INTRA, DREVEN, THESSALONIKI]

- The process of the definition of the necessary parameters of the Digital Twin-based control centre (through the implementation of the related user workshops, the definition of the details of the Thessaloniki PUC and the definition of the user requirements) has led to a first level of training concerning users and their engagement, as described in T6.6. Thessaloniki has involved the end-users in the process, who will also be actively trained in the use of the finalised iDriving platform.
- During the past months, the Consortium started outlining the material that will be used in the upcoming training sessions. The material will be in line with the implementation of the first version of the application that is currently under development.
- No deviations from the Annex 1 of the Grant Agreement have been identified.

#### 2.2.6.5 Risk Inventory

The risks identified for Work Package 6 are presented in Table 28:

Table 28: WP6 Risk Inventory

| # | Description | Likelihood | Impact | Response |
|---|---|---|---|---|
| 1 | Readiness of technology developed in iDriving for the planned demonstrations according to the time schedule. | Medium | High | Maintain close coordination with technical partners while preserving the flexibility to reschedule testing to a later phase if necessary. |
| 2 | Non-availability of required data for KPIs or misalignment between the defined technical KPIs and the evolving architecture of the iDriving platform. | Medium | Medium | Close coordination will be maintained with technical partners and use case leaders. KPI definitions and test procedures will be reviewed iteratively and adapted as needed to reflect the current state of the platform/the availability of data. Workshops between WP6 partners and relevant technical tasks have been established to ensure alignment and early identification of data availability issues. |
| 3 | VMS application and drone experiments in practice depend on permissions of local authorities. | Medium | High | Engage with local authorities well in advance to secure necessary permissions or, if needed, identify and prepare alternative testing locations to avoid delays. |

### 2.2.7 WP7 Mid-term report

#### 2.2.7.1 WP7 Current Status and Brief Progress

During the first eighteen months of the project (July 2024 – November 2025), WP7 has progressed steadily across all four tasks, establishing a solid foundation for the project's communication, dissemination, policy impact, standardisation pathways, collaboration framework and exploitation strategy. From the outset (M01–M06), WP7 focused on laying the initial groundwork required for effective impact creation, ensuring that the project's outreach, stakeholder engagement and long-term exploitation activities were properly initiated. Early milestones were achieved through the development and operationalisation of the project's communication channels, the preparation of core dissemination materials and the submission of the first Work Package deliverable (D7.1 – *Dissemination plan and communication materials*, M06), which set the strategic direction for all communication and dissemination actions during the subsequent months.

From January to June 2025 (M07–M12), WP7 continued its activities in line with the processes and priorities defined in D7.1. Work during this phase centred on expanding and strengthening the project's communication channels by developing new digital outreach tools and supporting partners in the promotion of project activities. WP7 also increased the project's visibility through participation in external events and enhanced collaboration with other EU-funded initiatives. At the same time, the Work Package established an internal coordination structure to support the mapping of potential exploitable results, aligning these preliminary exploitation activities with the emerging work on policy recommendations. This internal task force has been essential in coordinating partner engagement and ensuring consistent contributions across T7.1–T7.4.

During the most recent reporting period (July 2025 – November 2025, M13–M18), WP7 intensified its efforts across all tasks, mobilising all communication channels and further strengthening the project's interactions with external stakeholders, sister projects and European collaboration clusters. The project's participation in two major Horizon Europe clusters significantly expanded its cooperation network and facilitated the exchange of knowledge and practices with related initiatives. Several scientific and technical publications were submitted during this time, contributing to the dissemination of the project's results and reinforcing its presence within the research and innovation community. In addition, partners were invited to participate in advisory boards, maximiser communities and high-level events, further increasing the project's visibility and policy relevance.

Overall, the progress achieved during M01–M18 demonstrates a coherent and well-coordinated implementation of the Work Package. WP7 has successfully advanced communication and dissemination activities, strengthened standardisation and collaboration pathways, deepened stakeholder engagement, initiated policy-oriented work and laid essential foundations for the project's exploitation strategy. The work conducted so far ensures that the project is well positioned to intensify its impact-related activities during the next reporting periods.

#### 2.2.7.2 Identified Issues/deviations (if applicable)

No issues or deviations identified

#### 2.2.7.3 Deliverables submitted (if applicable)

- Deliverable D7.1: "Dissemination plan and communication Materials" has been submitted in M06 – December 2024
- Deliverable D7.2: "Activity report on dissemination, standardization, and policy making" is due to be submitted in M18 (December 2025)

#### 2.2.7.4 Summary of Progress towards objectives and details for each task

**Task T7.1 – Dissemination and communication activities [Task Leader: ACCELI] [Duration: M01 – M36]**

Participating Partners: [ALL except COK]

Task 7.1 – Dissemination and communication activities (M01–M36) has been continuously implemented since the start of the iDriving project, with ACCELIGENCE leading the task and all partners contributing. This task is responsible for ensuring the visibility, outreach, and public communication of the project's objectives, progress, and results to a broad range of audiences, including the general public, stakeholders, and domain-specific actors. Its overall aim has been to raise awareness, promote engagement, and foster effective knowledge exchange both within and beyond the consortium. Since Month 1, this has included evaluating the performance and impact of the project's digital communication tools and expanding the online presence by initiating a Bluesky account to ensure that project messages effectively reach the intended audiences. The task has supported partners by providing communication materials and guidelines, mapped third-party opportunities for participation in external events, developed the first issues of the project newsletter, and recorded and produced the first iDriving project video. Throughout this period, it has also contributed to synergy activities with related initiatives and has continuously promoted project developments on all available channels.

Between July 2025 and November 2025, Task 7.1 intensified its efforts by implementing a coordinated set of communication and dissemination actions aimed at strengthening project visibility and reinforcing partner engagement. Dedicated emails were sent to all partners requesting updated reporting on their communication and dissemination activities and asking them to verify the completeness and accuracy of previously submitted information. At the same time, the project's communication channels expanded further. The website was regularly updated with new content and partner inputs, the Bluesky account was actively used as part of the digital outreach strategy, a new project video was produced, and two newsletters were published to highlight major achievements and upcoming milestones. Continuous social-media activity, including blog posts, ensured sustained engagement with stakeholders and the wider mobility and CCAM community.

During this period, the task also supported the coordination and dissemination of several scientific and technical submissions developed under the thematic areas of Driving and EvoRoads in collaboration with partners such as CERTH, Infraplan, the University of Crete, Austriatech, CEFRIEL, INDRA, and the University of Cyprus. These contributions covered topics including predictive traffic management, enhanced safety criteria for urban and secondary roads, semantic-aware pavement condition monitoring, surrogate safety indicators in smart urban environments, mobility data interoperability, real-time pavement status estimation using connected vehicles, and UAV-based pavement assessment. Designated contact points were established for each contributing organisation to support follow-up and coordination. In addition, preparations advanced for the project's participation in the upcoming RTR Conference, which will further strengthen its European-level visibility.

Task 7.1 also facilitated the project's active involvement in two major European collaboration clusters. Within the EU Road Safety Cluster, iDriving engaged with initiatives including HEIDI, AI4CCAM, EVENTS, FRODDO, ProtAct-Us, SOTERIA and V4SAFETY. Within the Integrated CCAM Technologies Cluster, the project continued its participation alongside AIN, CONDUCTOR, EVENTS, FRODDO, iEXODDUS and PODIUM. Engagement in these clusters has supported alignment of methodologies, mutual learning, increased cross-project visibility and the identification of opportunities for joint dissemination and exploitation activities. Altogether, the work carried out under Task 7.1 from Month 1 to November 2025 has significantly reinforced the project's communication and dissemination foundations, expanded its outreach channels, enhanced its scientific and public visibility and deepened its collaboration within the wider CCAM ecosystem.

**Task T7.2 – Standardization, collaboration with other projects, and stakeholder network activities [Task Leader: ING] [Duration: M01 – M36]**

Participating Partners: [CERTH, AUSTRIATECH, INFRA PLAN, INTRA, ALP.LAB, DREVEN, UNI.EIFFEI, MBL]

Task 7.2 has been progressing continuously since the start of the project, with Ingartek as task leader and the participation of CERTH, AUSTRIATECH, Infraplan, INTRA, ALP.LAB, DREVEN, Université Gustave Eiffel and MBL. From the outset, the task focused on establishing robust links with relevant sister projects and strengthening the project's presence within the broader CCAM ecosystem. Ingartek initiated contacts with the EvoRoads and CAMBER projects to ensure collaboration, alignment, and knowledge exchange across initiatives and organised an in-person get-together during ITS Seville (19–21 May2025 ), bringing together members of iDriving and EvoRoads to support early cooperation. Ingartek also prepared and internally published an in-depth document analysing EvoRoads and CAMBER, enabling the consortium to better understand the technical and organisational positioning of these related projects. To further support cross-project synchronisation, Ingartek coordinated a workshop where overviews of iDriving, EvoRoads and CAMBER were presented. Due to its early stage, CAMBER did not yet present progress, but the workshop enabled a shared baseline of understanding for future interactions. In parallel, Ingartek conducted research on past projects' standardisation activities to extract relevant practices and identify potential pathways for standardisation-related contributions within iDriving. Throughout this initial phase, no deviations from Annex 1 of the Grant Agreement were recorded and there was no impact on other tasks, resources, or planning.

Between July 2025 and November 2025, Task 7.2 expanded its activities by preparing an initial compilation of relevant standardisation bodies and applicable standards. Given the multidisciplinary nature of iDriving, this compilation requires technical inputs from multiple partners, and consortium members were therefore invited to review the list, verify applicability within their expertise areas, and suggest additions or corrections to support the finalisation of Deliverable D7.2. During the same period, Ingartek advanced external engagement efforts by responding to an invitation from ERTICO - coordinator of EvoRoads and organiser of the upcoming ITS Istanbul congress - to participate in a Special Interest Session. Partners planning to attend were asked to coordinate with Eneko Elizondo to support a coherent project presence. Task 7.2 also deepened the mapping of relevant initiatives and collaboration opportunities, including reviewing updated information on other projects and the two CCAM-related clusters in which iDriving participates. Particular emphasis was placed on the EvoRoads asset list, encouraging partners to assess potential synergies or complementary activities. Overall, work carried out under Task 7.2 to date has strengthened cross-project collaboration, supported early standardisation pathways and contributed to building a wider stakeholder network for the project.

**Task T7.3 – Policy impact and recommendations at EU level [Task Leader: LIF] [Duration: M06 – M36]**

Participating Partners: [AUSTRIATECH, ALP.LAB, DREVEN, THESSALONIKI, UNI.EIFFEL]

Task 7.3 – Policy impact and recommendations at EU level (M06–M36) has progressed steadily since its official start in Month 6 of the project (December 2024). From the outset, the task leader and participating partners (AUSTRIATECH, ALP.LAB, DREVEN, Municipality of Thessaloniki and Université Gustave Eiffel) have actively contributed to all WP7 meetings, supporting discussions and brainstorming sessions aimed at strengthening the iDriving outreach and policy-impact strategy. Early in its implementation, Task 7.3 also took part in a joint workshop with two sister projects, ensuring alignment of approaches and facilitating knowledge exchange across related EU initiatives. A comprehensive methodology was developed to guide the execution of the task throughout its duration, including a detailed timeline outlining key milestones and processes; this framework was shared with partners for feedback and alignment and has since served as the structural basis for coordinated progress.

In parallel, Task 7.3 prepared a stakeholder-mapping sheet for consortium-wide use and conducted the first mapping of relevant stakeholders. The initial version of the stakeholder questionnaire was drafted to gather insights on regulatory and governance challenges, technical needs and perspectives on Intelligent Transport Systems (ITS), forming the basis for upcoming policy work. As the task moved forward into 2025, this methodology and preparatory work enabled significant further progress. Task 7.3 continued to contribute actively to WP7, maintaining regular participation in coordination meetings and ongoing engagement with the sister projects to ensure coherence and knowledge exchange. Building on the initial mapping, the stakeholder identification was refined, and the targeted questionnaire was finalised and deployed to a broad range of actors including public authorities, infrastructure and technology operators, standardisation and policy bodies, related EU-funded projects, and academia and civil society. The responses collected directly informed the first approach towards the actual policy recommendations to be delivered by the end of the project.

In parallel, Task 7.3 carried out a structured mapping of relevant EU-level policy frameworks to ensure that the emerging recommendations are aligned with current regulatory developments and contribute meaningfully to the broader objective of advancing intelligent driving and smart mobility standards across Europe. Throughout this period, the task remained fully aligned with Annex 1 of the Grant Agreement, with no deviations reported. The work conducted so far has established the foundation for the next phase of the task, which will focus on refining and validating the policy recommendations through continued collaboration with consortium partners, pilot leaders, key stakeholders and sister projects. Feedback collected through the questionnaire, ongoing consultations and forthcoming workshops will be integrated to ensure the recommendations are practical, actionable and aligned with EU regulatory priorities and strategic directions. Task 7.3 will continue monitoring new policy developments, technological trends and emerging best practices to keep the recommendations up to date, relevant and responsive to the evolving European mobility landscape.

**Task T7.4 – Market analysis, business models, exploitation, and sustainability [Task Leader: ING] [Duration: M03 – M36]**

Participating Partners: [DREVEN, INFRA PLAN, INTRA, SIMAVI, AIM]

Task 7.4 has been active since Month 3 of the project and is led by Ingartek, with contributions from DREVEN, Infraplan, INTRA, SIMAVI and AIM. From the early months of the project, the task collaborated in the creation of the stakeholder database and began reviewing a range of business-model alternatives relevant to the iDriving context. This included conducting research on past projects' market analysis and business-model activities to identify methodological approaches, lessons learned and potential exploitation trajectories applicable to iDriving. During this initial phase, no deviations from Annex 1 of the Grant Agreement were reported and there was no impact on other tasks or resource allocation.

Between July 2025 and November/December 2025, Task 7.4 worked further on advancing the project's exploitation and market-oriented activities. The team continued analysing project data generated so far, with a focus on deepening the mapping of potential exploitable assets and technological capabilities across the consortium. At the same time, significant progress was made in refining the methodological approach for the upcoming market analysis. This included reviewing and comparing alternative frameworks and consolidating the components most suited to supporting the project's innovation and exploitation pathways. In parallel, Task 7.4 strengthened its partner-engagement processes by further developing the structured script intended to guide one-to-one meetings with consortium members. This script ensures systematic and comparable documentation of technologies, tools, datasets, expertise and organisational capabilities that may form the basis of future exploitation activities.

A dedicated survey designed to complement these interviews was finalised during this period. This survey will support the identification of partner-specific assets, potential market opportunities and expected exploitation interests. It is scheduled for launch at the beginning of December, marking the transition into the next phase of the task. From December onwards, Task 7.4 will enter an active period of engagement and analysis, integrating survey results, bilateral meetings and a five-step market analysis approach that includes a systematic online scan of relevant sources, preliminary synthesis of findings, partner validation, targeted case-study engagement and iterative refinement. Together, these activities will ensure that the exploitation strategy is grounded in evidence, aligned with partner capabilities and responsive to emerging opportunities throughout the remaining duration of the project.

#### 2.2.7.5 Risk Inventory

The risks that have been identified for Work Package 7 are presented in Table 29.

Table 29: WP7 Risk Inventory

| # | Description | Likelihood | Impact | Response |
|---|---|---|---|---|
| 1 | Low intensity of dissemination reporting on behalf of partners | Low | Medium | A dedicated reporting template along with the month calls – evaluation and milestone setting will secure the proper reporting of all partners activities and shall work as incentive for all partners |
| 2 | Delay in stakeholder responses for policy input (Task 7.3) | Medium | High | Early informal engagement, parallel use of interviews, and reminders will help ensure timely feedback. A fallback plan (e.g., expert focus group) will be prepared. |
| 3 | Unclear partner roles in exploitation and sustainability activities (Task 7.4) | Medium | Medium | Organize an exploitation-focused co-creation workshop; define exploitation role per partner; develop draft partner-specific sustainability pathways. |

# 3 Summary

During the first half of the iDriving project, the consortium established a solid foundation for delivering an integrated, AI-driven decision-support ecosystem for urban mobility and road safety. Substantial progress has been made across all Work Packages, including the development of the project's core technical architecture, multimodal data pipelines, and early versions of analytical components for safety monitoring, mobility insights, maintenance detection, and environmental and microclimate assessment. These technical developments have been supported by strong coordination, quality assurance, data governance, and user engagement activities.

The work completed to date demonstrates clear alignment with the Scientific, Technical, and User Objectives defined in the Grant Agreement. Initial prototypes of the digital twin framework, AI analytics, environmental models, and visualisation tools indicate that the project is on track to deliver the Key Results targeted for the mid-term stage. Preparatory work for the pilot activities in Graz and Karlovac, including scenario design, stakeholder coordination, and operational planning, has progressed as expected and provides a strong basis for the upcoming demonstrations.

While the project has encountered some challenges, including the complexity of data integration and the need to coordinate diverse technical components, these have been addressed through continuous monitoring, cross-WP collaboration, and proactive risk mitigation. The remaining work primarily concerns integration, validation, and large-scale testing of the system in operational environments.

The next phase of the project will focus on system-wide integration, execution of the pilot trials, refinement of AI models, and comprehensive evaluation of performance against the Key Performance Indicators. With a strong technical foundation in place and robust cooperation across partners, the project is well positioned to achieve its objectives and deliver innovative, impactful solutions for safer, more efficient, and resilient urban transport systems.

# References


Dong, W., Liu, S., Ding, Y., Sheng, X., & Zhu, X. (2020). An Artificially Weighted Spanning Tree Coverage Algorithm for Decentralized Flying Robots. *IEEE Transactions on Automation Science and Engineering*, *17*(4), 1689–1698. https://doi.org/10.1109/TASE.2020.2971324

Kapoutsis, A. C., Chatzichristofis, S. A., & Kosmatopoulos, E. B. (2017). DARP : Divide Areas Algorithm for Optimal Multi-Robot Coverage Path Planning. *Journal of Intelligent & Robotic Systems*, 663–680. https://doi.org/10.1007/s10846-016-0461-x

Shah, S., Dey, D., Lovett, C., & Kapoor, A. (2018). AirSim : High-Fidelity Visual and Physical. In *Field and Service Robotics* (pp. 1–14). https://doi.org/10.1007/978-3-319-67361-5_40

Sioutas, M., Lekidis, V., & Kokolakis, C. (2022). Climate chnage and severe weather events in Thessaloniki. *Green Conference*, 82–85.

Stolaki, S. N., Kazadzis, S. A., Foris, D. V, & Karacostas, T. S. (2009). Fog characteristics at the airport of Thessaloniki , Greece. *Natural Hazards and Earth System Sciences*, *9*, 1541–1549. https://doi.org/10.5194/nhess-9-1541-2009

# APPENDIX

In line with Article 17.2 “Visibility — European flag and funding statement” Unless otherwise agreed with the granting authority, all communication activities of the beneficiaries related to the project will acknowledge the EU support and display the European flag (emblem) and funding statement (translated into local languages, where appropriate):

Figure 7 - EU Flag & Funding Statement

iDriving is a project funded by the European Commission under the Horizon Europe Programme (HORIZON-CL5-2023-D6-01) under Grant Agreement No. 101147004.

## Quality of information – Disclaimer

Any communication or dissemination activity related to the action must use factually accurate information.

Moreover, it must indicate the following disclaimer (translated into local languages where appropriate):

“Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or [name of the granting authority]. Neither the European Union nor the granting authority can be held responsible for them".

## iDriving Logo

The file containing the official iDriving logo, as shown in the figure below, will be available in the shared repository for download and use by Consortium partners throughout the project.

Figure 8 - Project Logo

# Intelligent & Digital Roadway Infrastructure for Vehicles Integrated with Next-Gen Technologies

## PROJECT FACTS

**Start date:** 01/07/2024 **Duration:** 36M Call: HORIZON-CL5-2023-D6-01 **Total cost:** € 4,998,733.75 **Coordinator:** Ethniko Kentro Erevnas kai Technologikis Anaptyxis (CERTH)

## iDriving Consortium

Funded by the European Union

The Project "**iDriving** - Intelligent & Digital Roadway Infrastructure for Vehicles Integrated with Next-Gen Technologies" has received funding from the European Union's Horizon EUROPE Research and Innovation programme under grant agreement No 101147004.