Improved Robotic Platform to perform Maintenance and Upgrading Roadworks: The HERON Approach

Grant Agreement Number: 955356

D1.5: Quality Assurance Report

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Activity	Task 1.3: Quality and Ethics assurance
Deliverable	D1.5: Quality Assurance Report
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Document Control Sheet

Version history table			
Version	**Date**	**Modification reason**	**Modifier**
0.1	03/04/2023	Initial Table of Contents and basic structure of the deliverable	Iason Katsamenis
0.2	02/05/2023	Project Management	Nikos Bakalos
0.3	08/05/2023	Communication Channels among Partners	Nikos Bakalos
0.4	12/05/2023	Deicision process and Information Flow	Nikos Bakalos
0.5	15/05/2023	Deliverables, Reporting, and Risk Management	Nikos Bakalos
0.6	18/05/2023	Conlusions	Nikos Bakalos
0.7	30/05/2023	Minor updates	Iason Katsamenis
1.0	31/05/2023	Final version ready for submission	Anastasios Doulamis, Nikolaos Bakalos

Legal Disclaimer

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Abbreviation Lists

Abbreviation	Definition
AB	Advisory Board
CA	Consortium Agreement
DCM	Dissemination and Communication Manager
DL	Deliverable Leader
EB	Ethics Board
ER	External Relations
FCO	Financial Control Office
GA	Grant Agreement
HDS	Help Desk Secretariat
IEM	Innovation and Exploitation Manager
KPIs	Key Performance Indicators
PC	Project Coordinator
PCT	Project Coordination Team
PO	Project Officer
RI	Road Infrastructure
QAP	Quality Assurance Plan
QM	Quality Manager
TC	Technical Committee
TL	Task Leader
TM	Technical Manager
WP	Work Package
WPL	Word Package Leader

Short name	Participant organization name
ICCS	Institute of Communications and Computer Systems
ACCI	Acciona Construcción S.A.
OLO	Olympia Odos Operation S.A.
UGE	Université Gustave Eiffel
ETHZ	Eidgenössische Technische Hochschule Zürich
ROB	Robotnik Automation
CORTE	Confederation of Organisations in Road Transport Enforcement
STWS	SATWAYS - Proionta Kai Ypiresies Tilematikis Diktyakon Kai Tilepikinoniakon Efarmogon Etairia Periorismenis Efthinis EPE
RISA	RisaSicherheitsanalysen Gmbh
INAC	InnovActs
IKH	Ainoouchaou Pliroforiki SA -IKnowHow-
RG	Resilience Guard Gmbh

Executive Summary

This report provides updates on the quality assurance of the HERON research project, in alignment with the previously submitted D1.1 quality assurance plan. It highlights the current status of project components, changes implemented since the last reporting period, and any new risks or issues encountered. It showcases the effectiveness of our ongoing quality assurance measures, and explains any modifications made to the original quality assurance plan as a response to evolving project needs. Although specific risks and updates are addressed, unchanged elements from the D1.1 plan are not reiterated for brevity. This report outlines our ongoing efforts to uphold the quality standards of the HERON research project. It details changes made to meet project needs and demonstrates our commitment to adapting our approach to achieve the best possible outcomes.

1 Introduction

1.1 Purpose of the Document

The purpose of the specific document is to update on the adopted quality assurance processes that were described in D1.1, titled “Quality Assurance Plan”.

In a nutshell, this deliverable reports on updates in:

- Project management processes and structure.
- Communication channels between partners.
- Periodic review of the project plan.
- Updates on internal review procedures of all deliverables.
- Risks and mitigation strategies

The remainder of this document is organized as follows:
Initially, Section 2 briefly discusses updates project management structure, while Section 3 presents communication channels among HERON partners. Subsequently, Section 4 outlines the decision process and information flow In parallel, Section 5 describes the management of deliverables and other various project items, while Section 6 discussed the reporting procedures, whereas Section 0 gives updates on the project’s risk registry. Lastly, Section 8 concludes this deliverable report.

1.2 Intended Audience

The document’s target is the HERON consortium partners, as it contains all quality procedures, results, and indicators pertaining to WPs, tasks, deliverables, milestones, etc. of the original project plan. Moreover, risk management plans for each WP are developed.

1.3 Interrelations

This deliverable interacts with all other project activities, as it presents project management structure results and the organizational and procedural means for achieving it.

2 Project Management

2.1 Project's Management Structure

There were no updates in the project management structure. The overall process that was described in D1.1 and presented in Figure 1.

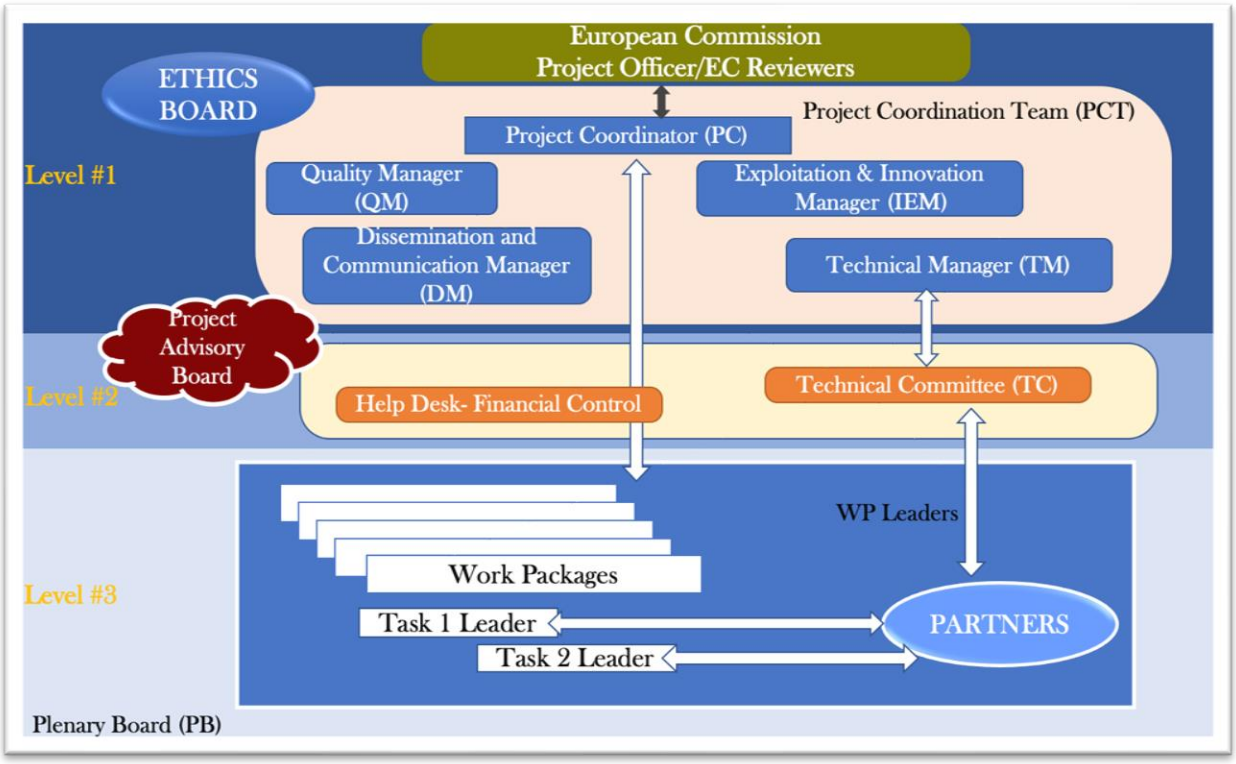

Figure 1: HERON management structure.

3 Communication Channels among Partners

No significant changes have been made in the communication procedures.

3.1 Mailing List

The project mailing lists are constantly updated to include new team members. The lists are presented in Table 1: HERON distribution mailing lists.

Table 1: HERON distribution mailing lists

Mailing List Name	Distribution List Address	Description
heron_all	all@lists.heron-h2020.eu	Main contact persons, per organization, in HERON
heron_wp1	wp1-request@lists.heron-h2020.eu	WP1 contact persons
heron_wp2	wp2-request@lists.heron-h2020.eu	WP2 contact persons
heron_wp3	wp3-request@lists.heron-h2020.eu	WP3 contact persons
heron_wp4	wp4-request@lists.heron-h2020.eu	WP4 contact persons
heron_wp5	wp5-request@lists.heron-h2020.eu	WP5 contact persons
heron_wp6	wp6-request@lists.heron-h2020.eu	WP6 contact persons
heron_wp7	wp7-request@lists.heron-h2020.eu	WP7 contact persons
heron_wp8	wp8-request@lists.heron-h2020.eu	WP8 contact persons
heron_wp9	wp9-request@lists.heron-h2020.eu	WP9 contact persons
heron_wp10	wp10-request@lists.heron-h2020.eu	WP10 contact persons

3.1.1 Meetings

A number of periodic online meetings take place in order to monitor project progress and inform partners about matters relevant to all aspects of endeavors. The regurarly scheduled meetings are the following:

Meeting	Period	Relevant WPs	Description
Management Meeting	Monthly	All WPs	Takes place the first Monday of every month. Discusses issues anything related to the management of the project.
Technical Meeting	Three times a month	WP3,4,5,6	Takes every Monday except if there is a Management meeting (every Monday except the first Monday of each month). Discusses all technical aspects of the project.
WP6 meeting	Weekly	WP6	Takes place weekly, and discusses the communication of components, and the HERON front end tools.
Dissemination and Exploitation Meeting	Monthly	All WPs	Takes place the first Wednesday of every month. Discusses dissemination actions, opportunities and everything relevant with the dissemination and exploitation of project results.

The report herein presents the most recent outline of our periodic online meetings. Please note that this schedule, while currently effective, retains flexibility for adaptation to the evolving needs of our project. As we progress with the technical developments of individual components, we anticipate a gradual shift in focus during our technical meetings. Rather than dwelling solely on individual parts, we will increasingly turn our attention to integration issues, primarily concerning the communication between different components. Concurrently, the role of our integration meetings will evolve to concentrate more on the practicalities of deployment at the trial site. This progression represents our commitment to addressing emerging challenges and refining our approach to ensure the smooth culmination of our project.

3.1.2 Best practices

All best practices reported in D1.1 are followed. All project partners confirm that they currently adhere to what was established in the Quality Assurance Plan

4 Decision Process and Information Flow

The decision and conflict resolution processes as described in D1.1 and shown in Figure 2. continue to apply.

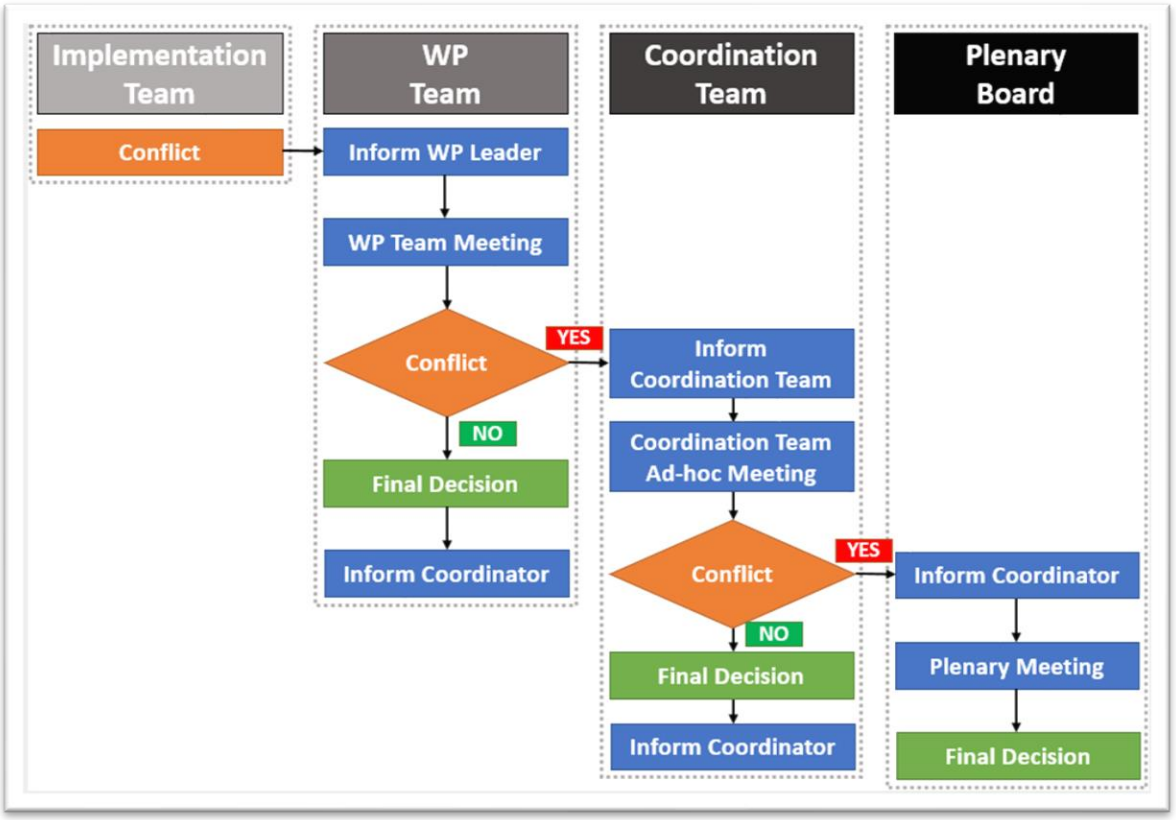

Figure 2: Conflict resolution procedure to be followed in the HERON project.

5 Management of Deliverables and other Project Items

No significant updates are reported to what was planned in D1.1. The quality assurance procedure has been used in all submitted deliverables. Figure 3 illustrates the flowchart of the document deliverable handling procedure, through which the deliverable should be produced.

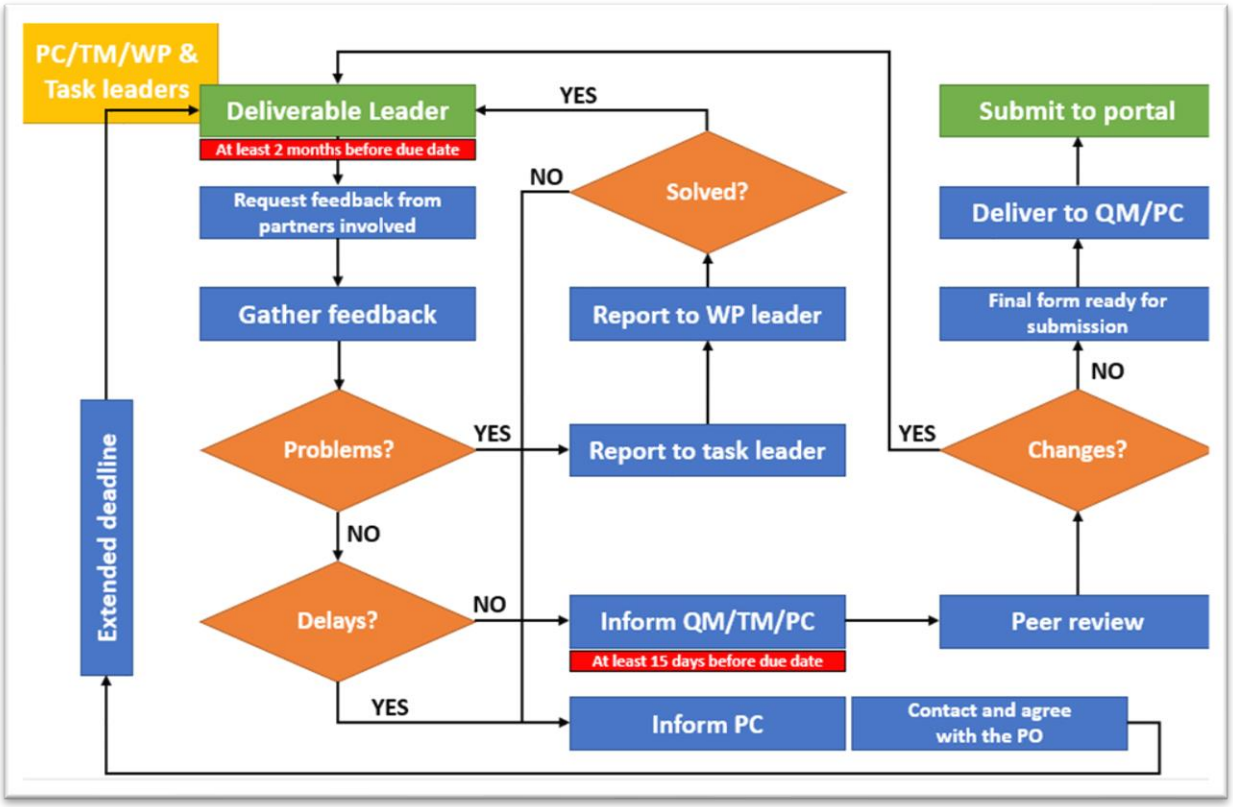

Figure 3: Deliverable handling process.

5.1 Deliverable Peer Review

As described in D1.1 two reviewing organisations have been selected per deliverable. The list of reviews is shown below.

Table 2: HERON deliverables' reviewers

WP No	Del Rel. No	Title	Lead Beneficiary	Est. Del. Date	Reviewer 1	Reviewer 2	Status
WP1	D1.1	Quality Assurance Plan	ICCS	31 Oct 2021	RG	CORTE	Approved
WP1	D1.2	Data Management Plan (first version)	ICCS	30 Nov 2021	ACCI	OLO	Approved
WP1	D1.3	Societal impact report (version 1)	ICCS	31 May 2023	RISA	STWS	Pending
WP1	D1.4	Societal impact report (version 2)	ICCS	31 May 2025	ACCI	OLO	Pending
WP1	D1.5	Quality Assurance Report (version 1)	ICCS	31 May 2023	INAC	RISA	Pending

WP1	D1.6	Quality Assurance Report (version 2)	ICCS	31 May 2025	UGE	CORTE	Pending
WP1	D1.7	Project Management Plan (version 1)	ICCS	31 Jul 2021	ICCS	RISA	Approved
WP1	D1.8	Project Management Plan (first period)	ICCS	30 Nov 2022	INAC	RISA	Approved
WP1	D1.9	Project Management Plan (second period)	ICCS	31 May 2024	ROB	ETHZ	Pending
WP1	D1.10	Project Management Plan (Final period)	ICCS	31 May 2025	STWS	IKH	Pending
WP1	D1.11	Data Management Plan (second version)	ICCS	30 Nov 2022	RISA	UGE	Approved
WP1	D1.12	Data Management Plan (third version)	ICCS	31 May 2024	RG	ROB	Pending
WP1	D1.13	Data Management Plan (fourth version)	ICCS	31 May 2025	ETHZ	UGE	Pending
WP2	D2.1	End-user needs and KPIs report	UGE	31 Aug 2021	ICCS	RISA	Approved
WP2	D2.2	Architecture specification	INAC	31 Oct 2021	ROB	ETHZ	Approved
WP2	D2.3	Geographic data and services inventory	ICCS	31 May 2022	STWS	IKH	Approved
WP3	D3.1	AI - driven image segmentation and feature extraction	ICCS	31 May 2022	ROB	ETHZ	Approved
WP3	D3.2	Software for refinement of segmentation results	IKH	31 Oct 2022	STWS	RISA	Approved
WP3	D3.3	Point of interest recognition and classification software	IKH	30 Apr 2023	UGE	RG	Submitted
WP3	D3.4	Point of interest georeferencing and precise localisation software	ICCS	31 Jul 2023	ROB	ETHZ	Pending
WP3	D3.5	High level planner	ETHZ	30 Nov 2023	ICCS	IKH	Pending
WP4	D4.1	Design and Implementation of the low-level controller	ROB	31 Aug 2022	IKH	ICCS	Approved
WP4	D4.2	Motion Planning and Learning Manipulation Actions	ETHZ	31 Mar 2023	STWS	INAC	Submitted
WP4	D4.3	Representation for high level planning	ETHZ	31 Aug 2023	INAC	ICCS	Pending
WP5	D5.1	3D Mapping and Autonomous Navigation	ROB	30 Sep 2023	STWS	ICCS	Pending
WP5	D5.2	Drones Implementation	ICCS	30 Sep 2023	STWS	ROB	Pending
WP5	D5.3	Design and Development of the	ROB	31 Mar 2024	UGE	STWS	Pending

		Robotic Platform with adaptive and enhanced capabilities					
WP5	D5.4	Development of the AR components	STWS	31 Mar 2024	INAC	IKH	Pending
WP6	D6.1	Secure Communication and Networking infrastructure	INAC	30 Jun 2023	ICCS	STWS	Pending
WP6	D6.2	Middleware and DF services	RISA	31 Jan 2024	IKH	INAC	Pending
WP6	D6.3	COP and Customized IMS for RI operations	STWS	31 Mar 2024	ACCI	OLO	Pending
WP7	D7.1	Definition and testing of the interfaces of the HERON subcomponents	INAC	31 Mar 2024	IKH	ICCS	Pending
WP7	D7.2	Report on the system configurations for the field trials and deployment at the demonstration sites	INAC	31 May 2024	ROB	RISA	Pending
WP7	D7.3	First version (V1) of the HERON System	ROB	31 Aug 2024	UGE	STWS	Pending
WP7	D7.4	Final version (V2) of the HERON System	ROB	28 Feb 2025	ACCI	OLO	Pending
WP7	D7.5	Acceptance tests for the HERON system	ROB	30 Nov 2024	ETHZ	UGE	Pending
WP7	D7.6	Reports on pilot testing (version 1)	INAC	30 Nov 2024	CORTE	RG	Pending
WP7	D7.7	Reports on pilot testing (final version)	INAC	31 May 2025	ICCS	CORTE	Pending
WP7	D7.8	Trials assessment and recommendations	RG	31 May 2025	CORTE	UGE	Pending
WP7	D7.9	Training Package and Consensus building workshop notes	RG	31 May 2025	CORTE	UGE	Pending
WP8	D8.1	Corporate identity and general templates for dissemination material	RG	31 Aug 2021	ICCS	RISA	Approved
WP8	D8.2	Project Website	RG	31 Aug 2021	ICCS	RISA	Approved
WP8	D8.3	Dissemination and Communication (first version) Plan	CORTE	30 Nov 2021	IKH	RG	Approved
WP8	D8.4	Dissemination and Communication Plan (second version)	CORTE	31 May 2023	STWS	ACCI	Pending

WP8	D8.5	Information Packs for referenced and networked communication amplifiers	ICCS	31 May 2022	RG	CORTE	Approved
WP8	D8.6	Annual Magazine issued (first version)	ICCS	31 May 2022	ETHZ	CORTE	Approved
WP8	D8.7	Report on the project clustering activities (first version)	CORTE	31 May 2023	RG	ICCS	Pending
WP8	D8.8	Report on the project clustering activities (final version)	CORTE	31 May 2025	INAC	STWS	Pending
WP8	D8.9	Annual Magazine Issues (second version)	ICCS	31 May 2023	UGE	CORTE	Pending
WP8	D8.10	Annual Magazine Issue (third version)	ICCS	31 May 2024	ETHZ	CORTE	Pending
WP8	D8.11	Annual Magazine Issue (Fourth Version)	ICCS	31 May 2025	RG	CORTE	Pending
WP9	D9.1	Exploitation Strategy (version 1)	RG	30 Nov 2022	ACCI	OLO	Approved
WP9	D9.2	Exploitation Strategy (second version)	RG	31 May 2025	UGE	ROB	Pending
WP9	D9.3	Market Analysis and Business Plan (first version)	ROB	30 Nov 2022	ETHZ	RG	Approved
WP9	D9.4	Market Analysis and Business Plan (second version)	ROB	31 May 2025	INAC	STWS	Pending
WP9	D9.5	Workshop Documentation	RG	31 May 2025	CORTE	ICCS	Pending
WP9	D9.6	The HERON Roadmap	RG	31 May 2025	CORTE	ICCS	Pending
WP10	D10.1	H - Requirement No. 1	ICCS	30 Nov 2021	RG	CORTE	Approved
WP10	D10.2	POPD - Requirement No. 2	ICCS	30 Nov 2021	ETHZ	STWS	Approved
WP10	D10.3	EPQ - Requirement No. 3	ICCS	30 Nov 2021	ACCI	OLO	Approved

5.2 Supporting Tools and Artefacts

The online repositories and tools reported on D1.1 still apply.

5.3 Key Performance Indicators (KPIs) and Evaluation

The KPIs are strongly related to the different functionalities of HERON's platform's components. As such, further details will be provided once the first trials in controlled environment took place (laboratory scale, WP7).

* **KPI_1 – Maintenance operators' collaboration**: Manual tasks and tools will be integrated with the robotic manipulator. Its expected impact in their work: * **hazards related to manual**

usage and direct exposure to traffic due to automated visual inspections reduced by 75% according to risk assessment; * perceived **easiness of usage greater than 6/10**, and ⁎ **50% increase in typical maintenance/upgrading** tasks per day.

Progress: In collaboration with infrastructure operators and maintenance companies (OLO and ACCI) and the partner responsible for modular pavements (UGE), a set of KPIs for Road Infrastructures and Modular Pavements were defined as part of D2.1. This preliminary list has been discussed in the context of their relevance to HERON activities and their effectiveness in providing quantitative, useful indicators for future deployment. Consequently, each KPI has been clearly defined, including its scope, detailed description, and measurement method.

Changes to initial indicators have been agreed upon to better cater to the needs of road infrastructure maintenance companies and asset owners, such as substituting "Reduction of traffic jams" with two new indicators: 1) "Impact on network capacity linked to potholes and cracks repairs and rejuvenation treatments" and 2) "Clearance time linked to incident management". Additional KPIs covering previously unaddressed areas will be included in the revised list.

⁎ **KPI_2 – Manipulation tasks:** The integration of a new generation collaborative robotic arm will foster the added value of operators work that will perform complex tasks while the robot takes care of repetitive, heavy duties. The number of different predefined manipulation tasks is expected to be **at least 3**. The speed of this action is expected to be improved, resulting in up to **50% faster maintenance and upgrading** tasks.

Progress: Several tasks for the robotic arm have been identified, including the placement and removal of cones, sealing road cracks, and possibly painting road markings, replacing removable urban pavements, and leveling potholes. The goal is high autonomy, relieving road workers from these tasks.

⁎ **KPI_3 – Improved CV & ML**: Novel learning methods for probabilistically detecting surface defects and potential pavements failures in RIs in near RT (just in time) processing complexity. We target to **minimize both false positive and false negative rates (target below 25%)***;*

Progress: During this reporting period, we've tested multiple computer vision algorithms for object detection and semantic segmentation tasks related to various road-related points of interest. Specifically, the YOLOv5 model has been employed for real-time traffic cone detection, real-time road defect detection, and real-time road surface monitoring using UAV images. The SegFormer model has been utilized for pixel-level crack and pothole semantic segmentation, lane segmentation, and precise pixel-level pothole and crack semantic segmentation. The R2AU-Net model has been tested for precise pixel-level crack semantic segmentation.

These machine learning networks have demonstrated performance in terms of F1-score as follows:

- YOLOv5 for real-time traffic cone detection: 100%
- YOLOv5 for real-time road defect detection: 80.72%
- YOLOv5 for real-time road surface monitoring: 67.82%
- SegFormer for pixel-level crack and pothole semantic segmentation: 75.94%
- SegFormer for lane segmentation: 99.11%
- R2AU-Net for precise pixel-level crack semantic segmentation: 72.43%
- SegFormer for precise pixel-level pothole semantic segmentation: 77.24%

Please note, F1-score is the harmonic mean of precision and recall. A low precision score suggests a high number of false positives, while a low recall score indicates a high number of misses (false negatives). Further details about the work and corresponding performance metrics can be found in deliverables D3.1 and D3.2.

* **KPI_4** – SLAM accuracy and robustness: **At least 3** different SLAM algorithms will be compared. The final solution will guarantee a localization/ mapping **mission failure rate of 5%** while having a maximum localization error of **less than 0.2 m**.

Progress: Four different SLAM algorithms have been selected for testing via simulation. A process for benchmarking and comparing these algorithms is planned.

* **KPI_5 – Visibility enhancement**: Use of gradient-based processing applied to near-IR (NIR) and RGB data will improve visibility under fog, rain, haze, etc. The same amount of visual content will be obtained at **30% longer distances**.

Progress: As analyzed in deliverables D3.1 and D3.2, various datasets with images from diverse sources and sensors were utilized to improve the generalization capabilities of the integrated AI models. Additionally, data augmentation techniques have been employed to further generalize the AI networks.

* **KPI_6 – Cognition devices integrated**: The usage of different data sources in automated vehicles will be key to achieve the relevant goals of the project. The number of sensors providing point-clouds, images and other data sets will be **greater than 6,** also considering hardware and software aspects (such as power, cabling, and interfaces).

Progress: The need for at least one RGB and depth sensor on the robotic arm's wrist and one on the body has been identified. A lidar sensor will be mounted at the front

* **KPI_7** – **Interactive operating center**: Minimum 20 frames-per-sec (FPS) on any area of the globe with a sub-metric precision. Time to correctly localize the displayed situation and synthesis of the major RI elements under maintenance or upgrading < 5 sec. Reduced intervention time and costs.

Progress: Based on findings in D3.1 and D3.2, for detection/segmentation problems, the processing time required per image is less than 0.2 seconds. The corresponding times for 3D information extraction will be ascertained in the upcoming period. This KPI is closely related to tasks 6.1 and 6.2, which are scheduled to begin at M20, outside of the current reporting period. As such, the benefits of the interactive operating system are currently unable to be measured. Future reports will include this data as these tasks progress.

6 Reporting

The project has successfully completed the periodic reporting and the first official review. This was accomplished by following the procedures laid out in D1.1 and other WP1 deliverables. These procedures were used for producing all necessary official and internal reports. The consistent application of these guidelines has aided in ensuring a smooth process and a positive outcome for the project.

7 Risk Management

In this section, we provide an update on the risk registry initially outlined in D1.1. To maintain conciseness, this report will focus solely on new risks, changes in likelihood or impact of existing risks, and risks that have been removed due to irrelevance. Please note that any risks unmentioned here continue as per the descriptions and management strategies stated in D1.1, and have not experienced significant alterations in their status or impact on the project.
Specifically, Risk 1.6 is no longer relevant as the World Health Organization ended the global emergency status of COVID-19. The likelihoods of failure and underperformance of the computer vision system has been reassigned as low, since the results reported on WP3 deliverables are all very promising. A new risk was added in WP7 that has to do with relevant permits that might inhibit trial activities. This risk mainly applies to the use of drones, that might be subject to differing national laws and require additional permits and/or licences. The consortium will keep track of this and if such an issue creates delays in the execution of the trial, the omitted aspect will be reassigned to a future trial activity.

Table 3: WP1, Project Coordination and Management, risks, and mitigation strategies

Risk ID	Description of risk	Likelihood	Impact	Mitigation strategies
~~**1.6**~~	~~Impossibility to complete the peer-to-peer activities between partners, case studies due to the COVID-19 situation, or other various causes.~~	~~Low~~	~~Medium~~	While similar events might happen, the likelihood of an event in the scale of what happened in 2020 and 2021 is unlikely. This risk might be reestablished based on current conditions.

Table 4: WP3, AI-based algorithms and tools Recognition, Classification and Localisation of the Points of Interest, risks, and mitigation strategies

Risk ID	Description of risk	Likelihood	Impact	Mitigation strategies
3.4	Failure of CV algorithms.	Low	Medium	Fusion with other types of sources and the use of the 3D models.

3.6	Underperformance of the AI features.	Low	Medium/ High	Re-training of the models with new datasets will take place. In the case that this mitigation fails, the focus will be given to the further improvements of the ones with the best performance.

Table 5: WP7, Field integration, demonstration and validation activities, risks, and mitigation strategies

Risk ID	Description of risk	Likelihood	Impact	Mitigation strategies
7.5	Issues with permits inhibiting specific aspects of the trial	Medium	Low	A replacement trial will be selected based to host the untested components/scenarios

8 Conclusions

The specific deliverable updates and reports on the adopted Quality Assurance Plan (QAP) of the HERON project.

In conclusion, this report has detailed our continued dedication to the quality assurance of the HERON research project. It has showcased the necessary adjustments made in response to project developments and highlights our willingness to adapt for optimal outcomes. It underlines our persistent effort in maintaining project standards, thereby ensuring the project's success.