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

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Abbreviation List

Abbreviation	Definition
AI	Artificial Intelligence
AR	Augmented Reality
CA	Consortium Agreement
CMS	Content Management System
CUD	Chaussée Urbaine Démontable (Demountable Urban Roadway)
DCM	Dissemination and Communication Manager
DoA	Description of the Action
EC	European Commission
FEHRL	Forum of European Highway Research Laboratories
FOR	Forever Open Road
GA	Grant Agreement
IAP	International Advisory Panel
IEM	Innovation Exploitation Manager
KPI	Key Performance Indicator
OS	Operating System
PB	Plenary Board
PC	Project Coordinator
PCT	Project Coordination Team
PIC	Project Implementation Committee
PO	Project Officer
PoI	Point of Interest
QM	Quality Manager
ROS	Robot Operating System
TC	Technical Committee
TM	Technical Manager
TMC	Traffic Management Service
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UI	User Interface
URL	Uniform Resource Locator
V2I	Vehicle To Infrastructure
WBS	Work Breakdown Structure
WP	Work Package
WPL	Work Package Leader

Executive Summary

This report is written in the framework of WP2 - End-Users Requirements, Metrics and System Design of HERON project under Grant Agreement No. 955356.

This deliverable provides a detailed description of the three pilots of the HERON project, as well as the corresponding stakeholders' expectations from the system to be implemented. Based on these expectations a list of use cases are described. The enlisted actions correspond to the stakeholders' needs that are highly priorised, and for which the automation of the tasks is the most expected and desired. This makes it possible to list functional and non-functional specifications, which will the basis for the following tasks within WP2, but also for the rest of the technical WPs in HERON.

1 Introduction

1.1 Purpose of the Document

The purpose of this document is to describe the User Requirements and to define the Use Cases and KPIs. This is done based on the three pilots proposed within HERON. Therefore, the document aims to be a first step towards the definition of the functional and non-functional specifications and the architecture of the HERON platform.

The remainder of this document is organized as follows: Initially, Section 2 discusses the context of this work and the general needs of Road Infrastructure managers/owners, while Section 3 lists some European and national Research projects whose results will be used for project HERON. Section 4 describes the three pilots, namely the test sites of Acciona (Spanish test site), Olympia Odos (Greek test site) and Transpolis/RUP (French test site). Section 5 describes the needs and expectations of the stakeholders for these pilots. Section 6 describes the traditional way of performing road maintenance and repair actions for the pilots, while Section 7 gives a first draft of functional and non-functional specifications. Lastly, Section 8 concludes this report.

This document is the first draft of D2.1 that will remain an open/living document in order to be further improved and enriched until the 2nd HERON workshop. The next version to be communicated to EC wiil integrate the inputs from the other technical WPs and precisely define the use cases.

1.2 Intended Audience

The document's target is HERON consortium partners. This report presents all the use cases which will be used for the definition of the specifications (WP2) and the technical works (WP3-6).

1.3 Interrelations

This deliverable interacts with all other technical WPs, namely WP3-6. The definition work within WP2 needs the input of WP3-6 on their implementation possibilities, while its outcomes will feed their work.

2 Context

At a time of zero tolerance (zero accidents, zero operating restrictions, zero ice on our roads, etc.), it is increasingly necessary to control risks and to improve our knowledge of the condition of structures in order to organise preventive and/or predictive maintenance that minimises risks at an acceptable cost.

Instrumentation, particularly in the context of preventive monitoring, is an important tool, as are risk analysis approaches. It allows, in this case, to better understand the behaviour of structures, to know their condition, and thus to provide reliable input data for a robust risk analysis.

Project HERON also adds the concept of repair and/or replacement actions, which will then be decided and implemented automatically and autonomously.

In this frame, the concept of Forever Open Road (FOR), with its national declinations (R5G in France for example) has been developed by the association of European Road Research Laboratories (FEHRL). HERON tackles the three concepts of FOR, namely the resilient road, the automated road, and the adaptable road. More information can be found on the FOR webpage, www.foreveropenroad.eu/

Moreover, as proposed within FOR, HERON implements and/or involves existing technical blocks, like existing on-the-shelf technologies or results of finished or ongoing research projects.

3 Previous Projects

HERON is the continuation of finished and ongoing research projects. It is also based on their outcomes, as well as on outcomes from already existing running projects. The basis EU funded projects are the following ones:

- Aerobi (https://cordis.europa.eu/project/id/687384/fr), 2015-2018, has developed some technologies and methodologies for the inspection of civil engineering structures using drones,
- ROBO-SPECT (https://cordis.europa.eu/project/id/611145/fr), 2013-2016, has developed a robotic arm for the inspection of civil engineering structures,
- PANOPTIS (https://cordis.europa.eu/project/id/769129/fr), 2018 – 2022, has developed a platform for the management of road infrastructure, based on many sensors and tools, among which cameras.

4 Description of pilot sites

The HERON pilots will be managed by ACCIONA and OLYMPIA ODOS, two relevant operators and relevant maintenance companies in Spain and Greece respectively.

ACCIONA is one of the major infrastructure companies Spain and is present in the pilot site covering both the role of private operator subcontracted by the Spanish Ministry of Transport (owner of the asset) and the role of road maintenance responsible.

The company has AENOR certification for Quality Management and Companies Committed to the Environment implemented in the company in accordance with regulations ISO-9001, ISO-14001 and ISO 45001, holding certificate numbers ER-1179/2000 and GA-2000/0181.

Figure 1. Quality Management and Companies Committed to the Environment

It also holds the official Management System for the Prevention of Occupational Risks certificate in compliance with the requirements set forth in the OHSAS 18001:2007 and ISO 45001:2018 (SPRL-153/2010) standard.

Considering the previous information, all tasks included in the HERON project validation will be monitored in terms of Quality, Environmental impact and health and safety aspects to undertake zero risks demonstration activities.

Finally, considering the ethics aspects linked to the presence of private vehicles in the active motorway and the use of visual systems and drones, ACCIONA will follow the ethics recommendations fixed by the relevant HERON work package.

OLYMPIA ODOS. Since Concession Commencement on August 2008, along with the construction launch, a permanent Operation organisation - the Operator (OLYMPIA ODOS LITOURGIA S.A.) - was established in order to provide operation and maintenance services on behalf of the Concessionaire (OLYMPIA ODOS S.A.), such as toll collection, traffic management & safety and routine maintenance. The head count at the end of 2020 reaches 468 employees, among them patrollers, intervention teams

and technical maintenance personnel, and in collaboration with approximately 150 additional persons from specialized subcontractors (light and heavy vehicles recovery, green maintenance, cleaning of the road, tunnel systems maintenance, winter maintenance etc.) and the emergency services (Traffic Police and Fire Brigade), the Operator works ceaselessly around the clock and throughout the year for the unobstructed operation, the provision of high level services for road assistance and safety to the motorists, as well as for achieving a high level of corrective and preventive maintenance.

Since April 2015 the Operator holds a certified quality system ISO 9001:2008. In July 2016 the Road Safety System was certified according to ISO 39001:2012, as well as the Health & Safety System according to OHSAS 18001:2007. In 2018, the Quality System was recertified according to the updated ISO 9001:2015 and the Environmental Management System was certified according to ISO14001:2015. In 2019, both the Road Safety System was recertified according to ISO 39001:2012 and the Health & Safety System according to ISO 45001:2018. Today the Operator holds a certified Integrated Quality, Environmental, Road Safety and Health & Safety Management System.

Université Gustave Eiffel (UGE) proposes two pilots, which make it possible to test infrastructure elements and/or methods that are still in pre-industrial stage. More precisely, Transpolis is a proving ground (or living lab) to test autonomous vehicles. The RUP (Removable Urban Pavements) are currently deployed on several sites, belonging to test sites or being part of smart cities. Indeed, their price is currently too high compared to bituminous pavements, for installation on conventional roads. They are now being investigated for addition of other functionalities (e.g., anti-pollution coating).

4.1 Spanish site

4.1.1 General description of the site

The pilot will be deployed in the A2 Motorway stretch maintained by the company (R2–CM42 stretch, coming from Madrid, and finishing in the limit between the provinces of Guadalajara and Soria, Spain), and in the traffic control centre of the stretch located near the village of Torija. The motorway is owned by the Spanish National Road Authority and the section selected has a length of 77.5 km, and the formal name of the contract is: ***"Awarding of public works contract for the maintenance and exploitation of the A-2 dual carriageway from p.k. (mileage marker) 62.0 to 139.50. Section: R2 - L.P. Soria/ Guadalajara"***

The section has four lanes (two per traffic direction) and crosses a region with Continental-Mediterranean climate, with long and severe winters, long, dry and hot summers and high heavy traffic levels, so pavement is exposed to severe requirements and maintenance is crucial to preserve the optimum pavement conditions required. A2 is one of the main motorways in Spain, connecting Madrid with Barcelona, it is part of the Trans-European Transport Network (TEN-T) and the CEF corridor.

Figure 2. Overview of A2 motorway

The contract is managed from the ACCIONA headquarter in Madrid and from the traffic control centre located in the small village of Torija. The traffic control centre is in charge of monitoring the motorway status, visualizing and assessing the data provided by CCTV, inductive loops, GPS-based fleets,

weather stations, weigh in motion systems etc. It is also the basecamp for all assets needed for maintenance (e.g., machinery).

Figure 3. The Torija traffic control centre

The ACCIONA Group is the private managing company of the motorway with presence with both as operator (ACCIONA Concesiones) and as maintenance contractor (ACCIONA Mantenimiento de Infraestructuras - AMISA). The main objectives of the contract are to facilitate the normal working of the motorway in a safe, comfortable and smooth way and to grant the preservation of the asset. In order to accomplish these objectives, the most relevant activities included in the routine operation, maintenance and upgrading of the motorway are:

- Activities to support Traffic control and network monitoring. This includes:
  - Support, communication and attention to motorway users;
  - Patrolling and control of the CCTV and weather stations in the motorway;
  - Management of emergency incidents and accidents;
  - Quick maintenance and repairs of urgent failures on pavements, safety elements, road markings, lighting, ventilation and signalling;
  - Winter road maintenance.
- Inspection, corrective and preventive maintenance. Including pavements, bridges, tunnels, drainage systems, operations on edges, roadsides and slopes (concerning both earthworks and vegetation control and monitoring) and other road elements;
- Upgrading works and activities to increase safety such as improvements of route design, intersections and links, access to secondary roads, etc.;
- Supervising tolls, service and other influence areas;
- Operation and maintenance of vehicles and facilities.

4.1.2 Main pilot activities planned

It is intended to validate the whole HERON system as required by the consortium and technical leaders, but considering the complexity of the system, the key functionalities to be validated in A2 are:

- Visual inspection of pavement damages, including indicatively: deformation and reduced skid resistance of the wearing course, any type of cracking (longitudinal, oblique, alligator cracks etc.), any

other wear, such as potholes, asphalt bleeding, detachment/separation of particles etc. and loss of operational characteristics (texture depth, lateral skidding, surface regularity) and depression, edge uplift, cracks, condition of joints of rigid pavements and implementation of maintenance works by sealing pavement cracks and patching potholes and asphalt rejuvenation.

- The semi-automated dispatch and removal of the traffic cones to increase the safety of the workers during the maintenance roadworks.

- Support to inventory and general patrolling tasks, this include the detection of all kind of obstacles (debris, tires, animals, rubbish, etc.), the definition of the of state of road edges (height of vegetation, presence of vegetation that influences safety (e.g. covering signalling, beaconing, reducing road users visibility)) and the detection of state, presence/absence of signalling, safety barriers/protection measures/guardrails, bollards, bumps, beaconing, etc.,

These functionalities can be validated at two scales: 1) In a controlled environment and 2) in the active A2 motorway

4.1.3 Activities in a controlled environment

In a controlled environment there will be two main sites or scenarios:

- First, the parking and internal streets within the traffic control centre of Torija,

Figure 4. Internal streets in the Torija traffic control centre

- In addition, a second scenario will be a 7km stretch of the old A2 national motorway currently closed to live traffic.

Figure 5. Active A2 Motorway and old A2 National road for trials in a controlled environment (2 lanes rightmost) for the HERON trials. Image from the CCTV

The second scenario will be quite relevant to undertake all the necessary trials in a realistic environment as the dimensions, road marking, edges, guardrails etc. together with the typical pavement and surface failures will be equivalent to those expected in current roads and motorways and will not require any permit from the relevant authorities as it does not affect live traffic. This trial will be very important to show the relevant road authorities the potential of the HERON system and that trials have no-risks and that it will be feasible to have a 100% safe demonstration in the active motorway.

Note: If there is a particular need or demonstration requirement, it will be feasible to simulate pavement failures (e.g., pothole of a particular size), presence/absence or bad state of road elements (e.g., signalling, road markings, etc.), among others.

4.1.4 Activities in the active motorway

The activities to be undertaken in the active A2 motorway will be discussed with the road owner and the traffic authority, focused on the conditions and requirements for the validation of the different functionalities. Real conditions and works will be performed including the system operation during the night shift, when many maintenance and upgrading works take place to minimize traffic disruptions.

Figure 6. A2 motorway for trials under live traffic. Night shift

Considering the complexity of the HERON system, in Month 2 of the project Development (July 2021) it was organised an internal workshop within ACCIONA, to define the main interest of the parties involved in the operation (Acciona Concesiones) and maintenance (Acciona Mantenimiento de Infraestructuras (AMISA)) of the motorway. The results of that workshop are summarised as follows, including a summary table establishing priorities and relevance for each role considering the different functionalities of the HERON system.

Overall comments ACCIONA CONCESIONES

- The use of drones is very interesting as an alternative to general patrolling and for the detection of incidents. The company has experience in that field, but currently they cover distances around 60-70km, the target would be to reach 150km.
- Linked to general patrolling, inventory tasks are interesting as well to detect changes in the road (signals and barriers damaged, small bumps, beaconing, vegetation in edges, etc.). This will support and enhance maintenance planning.
- The cones functionality is ok to enhance the safety of workers and road users in case of works or traffic incidents that require cones to warn users.
- Particular interest on the detection of all kind of failures: “It is always positive to know the status of the road, in order to make preventive maintenance feasible instead of the traditional corrective maintenance”. Moreover, the most important indicators of the contract with the road owner (Transport Ministry) are linked to pavement status (I1: Skid resistance, I2, Texture; I3 IRI, I4: Structural capacity; I5: Rutting; I6 Cracking; I10: Potholes)
- Painting is interesting but it is normally subcontracted.
- Asphalt rejuvenation is interesting to recover texture properties and extend pavements’ durability. The company has used this kind of treatments, but they are not common and are expensive.

Overall comments AMISA

- Cones functionality is the most relevant for AMISA. They have been exploring different automated systems but no decision has been made, so the HERON development is timely and a priority.
- HERON developments in terms of maintenance and upgrading of pavements are more than welcome. Repairing potholes and cracks are day to day business operations for AMISA, but they remarked that the system should be competitive in terms of cost and working times.

- Support to inventory tasks and detection of pavement failures are ok and will support and reduce inspections times and cost.
- Asphalt rejuvenation is interesting as well to recover texture properties but here the decision maker is Acciona Concesiones.

Table 1. Preliminary interest of the Operator and Maintenance companies in A2 Motorway

FUNCTIONALITIES		Acciona Concesiones (Operator)	AMISA (Maintenance)
Pavements			
Cracks	Precise detection of cracks		
	Repair of cracks		
Potholes	Precise detection of potholes		
	Repair of potholes		
Rutting	Precise detection of rutting		
Ageing	Precise detection of aged sections (e.g by colourometry)		
	Detection of Inadequate Roughness (IRI)		
	Detection of Inadequate texture (macrotextures, skid resistance, friction)		
	Asphalt rejuvenation		
Road markings			
Detection of road markings	Detection of reduced luminiscence		
	Detection of reduced retro-reflectivity		
Repair of road markings (painting)			
Continuous communication through V2I			
Road			
Support to general patrolling	Detection of all kind of obstacles (debris, tires, animals, rubbish, etc.)		
	Detection of state of road edges (vegetation, debris, rubbish, etc.)		
	Detection of road failures		
	Detection of problems, presence/abscence of signalling, safety barriers/protection measures/guardrails, bolards, bumps, studs, etc		
Support to inventory tasks	Detection of presence/abscence of signalling, safety barriers/protection measures/guardrails, bolards, bumps, studs, etc		
Cones			
Installation or removal of cones	Installation of cones		
	Removal of cones		
	Highest interest	High interest	Low interest

4.1.5 Permits Procedure

ACCIONA will provide a part of the motorway, where extensive tests of the automated vehicle can take place. For this purpose, issuing the necessary permits in cooperation with the relevant authorities (Road and Traffic authorities) will be mandatory, ensuring safety conditions both for the road users and the people working for the project. The permits procedure will be established internally undertaking an internal assessment involving both technical, operational and administrative staff from ACCIONA Concesiones, AMISA and the HERON technicians. After that assessment a detailed plan of the pilot activities will be drafted and presented to the relevant authorities, refining it accordingly (based on authorities' inputs and comments) to obtain the required permits to perform the HERON pilot activities.

4.2 Greek site

4.2.1 General Description of Olympia Odos Motorway

Olympia Odos is a Motorway Concession Project of particular strategic importance on national and regional level for the development of the Peloponnese and Western Greece, as it connects Athens with North Peloponnese, Western Greece and the Port of Patras.

Figure 7. Map of Olympia Odos Motorway

The Motorway is 202 km in length and comprises of two existing motorway sections, i.e. Elefsina - Korinthos (ELKO) 64 km long and Patra by Pass (PbP) 18 km long, along with 120km of the new Korinthos-Patra (KOPA) motorway, whose construction was completed in 2017, apart from the area of Rio I/C, that was completed in February 2018.

Figure 8 ."Elefsina – Korinthos" Existing Section "Patra bypass" Existing Section

Figure 9. "Korinthos – Patra" New Motorway Section

4.2.2 Vehicles and Machinery

For the operation and maintenance, as well as the provision of quality road assistance services to the users, the operator has a fleet of specialized vehicles and equipment and cooperates with specialized subcontractors for specific matters (e.g., road assistance, special maintenance issues, etc.). The fleet includes 43 patrol and intervention vehicles equipped with yellow beacons, electronic signs, flashing safety devices, special internal arrangement, radio communication system, automatic vehicle location system (AVL), mobile road safety equipment, such as cones, signs, portable electronic signs etc.

Figure 10. Operator's Yellow Marked Vehicles

The machinery fleet includes:

- 3 UNIMOG machines of multiple functions for cleaning the road pavement, the toll stations and tunnels and which can also operate as snow-ploughing machines, once fitted with the appropriate equipment (blade, salt spreader)
- 2 sweepers for the execution of maintenance works such as cleaning the pavement
- 2 telescopic booms for the execution of works at height
- 3 big loaders & 2 small loaders for loading and transporting materials

- 6 trucks for transporting materials which with the necessary equipment can also operate as snow ploughing machines

Additional equipment is also provided by external subcontractors according to the needs. Especially for winter maintenance, the Operator uses both privately- owned and leased by subcontractors equipment (21 big trucks and 4 salt loaders).

4.2.3 Facilities

For the needs of the Operation the Project has been divided into two Districts with facilities as shown in the following diagram (see Figure 11).

Figure 11. Project Operation diagram into two Districts

For Traffic Police needs 3 Motorway Police Departments operate in Nea Peramos, Kiato and Rio, which cover the whole Project, while for the fire fighting needs there are 3 exclusive Fire Stations at Nea Peramos, Akrata and Rio, as well as the Fire Brigade of Kiato.

The main installations of the Operation and Maintenance Centre (OMC) are located in the area of Ano Vlychada, Megara Municipality, on the 32nd km of the Athens-Korinthos NNR at the north service road. Apart from the central administrative services of the Operation company, the OMC houses: one of four technical bases, competent for patrolling, inspection and maintenance works in the section from Elefsina to Epidavros, workshop area, parking area for project machinery and other company fleet vehicles, central warehouse and salt-shed for the winter maintenance needs.

Figure 12. Operation and Maintenance Centre (OMC)

In the nearby area the modern facilities of the Attica Motorway Traffic Police are constructed and operating, but also there is an area, where the competent Fire Brigade is installed. The OMC also houses the new modern Traffic Management Centre (TMC) of District 1, which operates 24/7 all year through.

4.2.3.1 Toll Stations

Five (5) Mainline Toll Plazas and eighteen (18) Ramp Toll Plazas operate along the Project. In total, there are 135 toll lanes available, some of which are reversible, some can operate electronically and some are equipped with Automatic Payment Machines.

4.2.3.2 Traffic Management Center

In the TMC, the traffic management cameras project to a modern video wall comprising of 12 screens of 60''. It has 4 workstations, one of which is exclusively a snow ploughing and winter maintenance centre. It has an updated automatic incident detection system and a new system of equipment control and management, which allows the remote operation of fire-fighting, irrigation, road lighting, tunnel safety and dynamic signage systems. The TMC is connected to the new meteorological stations along the Project, which render possible the direct provision of information, aiming at the timely diagnosis and dealing with dangerous weather conditions. The TMC specialized personnel replies to the emergency 1025 calls, as well as to the new Emergency Roadside Telephones calls. The TMC personnel cares for the smooth operation of the motorway by collecting, analysing and transmitting information in order to coordinate incident dealing actions by using the company measures, as well as the emergency services when required. Another two Technical Bases are located at Kiato and Akrata, while in Rio the second OMC is located.

4.2.3.3 Traffic Management & Maintenance

Approximately 200 employees of the Operator are working in the motorway's traffic management, safety and maintenance.

- 66 (TMC personnel, Patrollers) dealing exclusively with traffic management;
- 66 (Foremen & Intervention Teams) dealing with maintenance, but they are involved in traffic management & road safety when needed;
- 37 (EEM personnel) dealing with maintenance;
- 17 middle and high level managers who may be involved, if required, in management of severe accidents or large scale events and
- 14 persons for administrative and technical support.

Their main objective is to fulfill:

- Traffic control and network monitoring;
- Management of emergency incidents, accidents and planned activities;
- Inspection, corrective and preventive maintenance;
- Operation and maintenance of vehicles and facilities; and
- Routine works (e.g., cleaning, gardening etc.).

4.2.4 The Pilot Site at Olympia Odos

The Pilot Site is proposed to be at "Elefsina – Korinthos" section. As already mentioned, the whole length of this section is 64 km with the following characteristics:

- Dual carriageway with 3 lanes (3,50m width left lane, 3,75 m. with middle and right lane) & 1 Emergency Lane (varies from 2,50 to 4,50 m.) per direction, with concrete New Jersey safety barriers in the central axis of the motorway;
- Kakia Skala tunnel complex (5 tunnels of total length ~4,5km) and 16 bridges;
- 2 large mainline toll plazas and 3 pairs of ramp toll plazas.

4.2.5 Permits Procedure

OLO will provide a part of the motorway, where extensive tests of the automated vehicle can take place, issuing the necessary permits in cooperation with the relevant Authorities (public service and traffic police) and ensuring safety conditions both for the road users and the people working for the project. Due to the high traffic with an average annual daily traffic of more than 20.000 vehicles per direction, which may reach 60.000 vehicles during peak period of exit or return to Athens, it is suggested to limit the area of the pilot studies at the right lane and emergency lane, with relevant closures. It is intended to validate the whole HERON system as required by the consortium and technical leaders, but considering the complexity of the system the key functionalities to be validated in the above area are:

- **Visual inspection of horizontal signing damages**, including (not an exhaustive list): local discolouration or wear, reduced retro-reflectivity, reduced luminescence and reduced antiskid properties of the marking and implementation of maintenance works by painting of road marking.
- **Visual inspection of pavement damages**, including (not an exhaustive list): deformation and reduced skid resistance of the wearing course, any type of cracking (longitudinal, oblique, alligator cracks etc.), any other wear, such as potholes, asphalt bleeding, detachment/separation of particles etc. and loss of operational characteristics (texture depth, lateral skidding, surface regularity) and depression, edge uplift, cracks, condition of joints of rigid pavements and implementation of maintenance works by sealing pavement cracks and patching potholes.
- The **semi-automated dispatch and removal of the traffic cones** to increase the safety of the workers during the maintenance roadworks.

4.3 French sites: Transpolis and RUP

UGE proposes **two test sites** that correspond to different needs in terms of implementation and testing.

4.3.1 Transpolis

Transpolis is a proving ground of more than 80ha which has been created by 5 entities among which Univ. Eiffel and has been opened officially in 2019. It is typically used to test autonomous vehicles in a secure and controlled environment thanks to several kilometers of road (notably 12 km in the “city area”) and all reinforced concrete buildings. Many types of Vehicle to Everthing (V2X) and Vehicle to Infrastructure (V2I) communication means are also available, as well as camera monitoring.

Figure 13: Aerial view of Transpolis site

Concerning telecommunications, Transpolis is equipped with more than 320 km of optical fiber that allows access to an Ethernet network at almost any point of the tracks. Thanks to an open LoRa network that covers the whole proving ground, a wide range of Internet of Things (IoT) sensors can be installed and used on Transpolis. Transpolis is also covered by a 5G network coming from an antenna located in the middle of the tracks. As far as energy is concerned, a private electrical distribution network guarantees power supply on the whole proving ground, especially in the “city area”.

Figure 14: Several types of road markings at Transpolis

Transpolis will provide the proving ground for several use cases, namely:

- Detection and repair of road markings,
- Detection and repair of reinforced concrete cracks,
- Continuous V2I communication, between the vehicle and road side units.

4.3.2 RUP installed in a smart city

UGE is involved in several implementations of the concept of smart city. Some of them are quite small implementing one given functionality, while others implement and test several functionalities of the road of the future, resilient, adaptable and automated. Among those, the site LaVallée, also called E3S, is an urban development project at the former place of Ecole Centrale de Paris where several new mobility infrastructures and services will be implemented to create an evolutive, energy-neutral and cooperative road.

Figure 15. Construction site LaVallée - E3S

In particular, in the frame of this pilot of the city of the future, the concept of urban removable pavement will be studied, using hexagonal concrete slabs prefabricated. These removable tiles allow quick access to networks, improve durability of surface properties roadways and can be recycled. Their prefabrication should make it possible to offer other integrated functions (various textures, porous, silent or depolluting surfaces, insertion of sensors, etc.). Currently, this CUD concept is not fit for TEN-T traffic, so inspecting these tiles regularly for cracks and repairing them is crucial.

Figure 16. Photo of the installation of RUP

Two structural working of these RUP are possible:

- The slabs may be independant. In this case, the installation and the removal are quite easy. But there is a risk of flapping, so the slab have to be of big dimensions. This implies heavier loads (700kg) and more difficulties to handle the slabs. A site using independant RUPs is available in Saint Aubin, near the city of Rouen (France). This site is 12-year-old, and shows good durability. Nevertheless elastomer seal have been added at the connections.

- The slabs may be interconnected. The slabs can then be smaller, and therefore less heavy (250kg). The installation and removal of the slabs needs to follow a given path. Two sites equipped with these slabs are available: In Nantes, a 12m x 7m site and at the pavement fatigue carrousel at the Nantes campus of UGE (2m x 8m site).

Figure 17. RUP slab with connectors

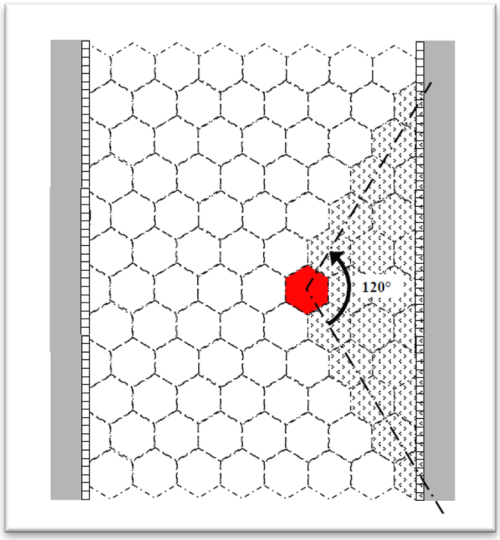

Figure 18. Path of installation or removal of the interconnected RUP slabs

Traditionally, the RUP slabs are not porous which makes it possible to install or remove them using suction. Among the latest innovations, porous slabs have been proposed for better durability of the structure and in this case manual arms with clamps have been developed.

Figure 19. Removal of a RUP slab, using an arm equipped with a suction cup

The damages or defects that can be detected are:

- gaps between the slabs,
- differential settlements between the slabs,
- spalling of the slabs,
- rattling/flapping of the slabs.

4.3.4.1 Specific Needs of the specific pilot

These pilots make it possible to demonstrate various HERON use cases in a semi-controlled environment. The following technical objectives could be set:

- Inspection and renewal of road markings,
- inspection of reinforced concrete wall and filling of cracks,
- testing of positioning of the robotic vehicle and its components.
- V2I communication,
- replacement of part of the infrastructure (RUP).

4.3.4.2 Existing infrastructure and Current Practices

Currently Transpolis is used as a proving ground for autonomous driving use cases, and it is at the disposal of project HERON for testing critical functionalities before introduction on roads under traffic. LaVallée is currently a construction site, where connected features are being installed. There are no features in terms of inspection of the infrastructure.

4.3.4.3 Evaluation of results and specific KPIs (metrics)

- Detection of cracks in reinforced concrete (90% of all cracks with a width over 0,5mm),
- Inspection of road marking and reporting through V2I (1km in less than 1h, comprehensive and continuous reporting),
- Inspection of CUD pavements (1 km in less than 1h, comprehensive and continuous reporting),
- Autonomous replacement of CUD elements (one element in less than 30 minutes).

For this French pilots, the preferences about the use cases to be implemented are given in the table 2.

Table 2 Use cases to be implemented in French pilots

Pavement		Transpolis	RUP
Cracks	Detection of cracks		
	Repair of cracks		
Potholes	Detection of potholes		
	Repair of potholes		
Rutting	Detection of rutting		
Ageing			
	Detection of Inadequate Roughness (IRI)		
	Detection of Inadequate texture (macrotextures, skid resistance, friction)		
	Asphalt rejuvenation		
Road markings			
Detection of road markings	Detection of reduced luminiscence	x	
	Detection of reduced retro-reflectivity	x	
	Detection of friction		
Repair of road markings (painting)		x	
Road			
Support to general patrolling	Detection of all kind of obstacles (debris, tires, animals, rubbish, etc.)		
	Detection of state of road edges (vegetation, debris, rubbish, etc.)		
	Detection of problems, presence/abscence of signalling, safety barriers/protection measures/guardrails, bolards, bumps, studs, etc		
Support to inventory tasks	Detection of presence/abscence of signalling, safety barriers/protection measures/guardrails, bolards, bumps, studs, etc		
Continuous communication through V2I & I2V			
Reinforced concrete			
Detection of RC cracks		x	
Repair of RC cracks		x	
RUP			
Inspection	Detection of cracks		x
	Detection of material removal (at the interface)		x
Replacement	Installation of RUP		x
	Removal of RUP		x
Cones			
Installation or removal of cones	Installation of cones		
	Removal of cones		
	Highest interest	High interest	Low interest

5 Needs and expectations from infrastructure stakeholders

5.1 ACCIONA Needs

As described previously, the main objectives of the contract are to facilitate the normal working of the motorway in a safe, comfortable and smooth way and to grant the preservation of the asset.

In order to accomplish these objectives, the most relevant activities included in the routine operation, maintenance and upgrading of the motorway are always necessary to be revised and updated to include new procedures, technologies, materials, machinery and inspection methods to gain competitiveness, reduce costs and maintenance activities times and increase safety of both road users and workers at A2 contract.

As a result, a major need of ACCIONA will be to understand the potential and competitiveness of all HERON system functionalities in order to assess if each of them is suitable or not to achieve the mentioned objectives.

For this purpose, a comparison exercise between current technologies and procedures and the new ones proposed in HERON will be necessary including impact in cost, operation times and safety.

Other particular needs of ACCIONA, will be linked to two strategic objectives of the company:

1. Support the Zero accidents at work objective: This a major target for ACCIONA; as a result, the direct human intervention and operators exposure will be assessed and compared with traditional procedures to quantify the potential impact of HERON system

2. Sustainability promotion: This is the strategic business model of the ACCIONA Group, as a consequence, an additional need of ACCIONA will be to evaluate the impact of HERON on sustainability considering its different pillars (environmental, social and economic pilars). It will be evaluated to:

- Select the materials for demonstrative purposes (e.g. selecting patching materials including RAP, and bio-rejuvenators instead of petrol derived rejuvenators).
- Maximise saves on fuel and energy consumptions due to the reduction of patrolling, inspection and inventory
- Minimise traffic disruption, reducing the impact on road users commuting

5.2 OLYMPIA ODOS Needs

OLYMPIA ODOS OPERATION S.A. has adopted an Integrated Quality, Environmental, Road Safety and Health & Safety Management System for the operation, according to the requirements of the standards ISO 9001:2015, ISO 14001:2015, ISO 39001:2012 & ISO 45001:2018 respectively, committing itself to observe specific procedures for the management and monitoring of the project's operation and maintenance, for the safe accommodation of the vehicles through the motorway, for the constant improvement of the environmental management system on every level and for the safe circulation of its marked vehicles, as well as for the care taken for the health and safety of the entire human power, responding fully to the rules of art and science.

As far as the routine maintenance of the motorway is concerned the main strategic objectives which also express our needs and expectations from the HERON project include:

- to maintain the Concession Project, in order to prevent its early wear and restore any damage, wear or malfunction may be presented in an effective and efficient way;
- to operate the Project at a high level of service and to keep a smooth and continuous traffic flow under normal operation conditions and ensure, to the extent possible, that these flow conditions are maintained under any conditions (e.g. lane closures for routine maintenance activities) and that the delays are minimised as much as possible;

- to zero the incidents with implication of its personnel;
- to save natural resources, prevent pollution and reduce its negative environmental impact and protect third parties' assets, in the areas of the company's operation

Under this framework the HERON's system is expected to:

- improve the cost of maintenance activities, by reducing mainly the required human resources
- reduce the time period of road/lane closures and the relevant road users' annoyance
- minimise personnel's exposure to risks both due to maintenance activities and adjacent traffic
- minimise environmental pollution and ensure sustainability

5.3 UGE Needs

UGE needs are the followings:

- Simplified installation and removal of RUP slabs: currently, these operations are hard work (the slabs are heavy), and take a long time. Even if the tasks are not completely autonomous at the end of the project HERON, having them simplified would be an important step.
- Continuous and real-time communication from the HERON vehicle to Road-Side Units for the information on the tasks performed by the HERON vehicle.

5.4 Expectations from infrastructure stakeholders

ACCIONA and OLYMPIA ODOS arranged an internal meeting to define the expectations of the two infrastructures companies in HERON to define their expectations on the project results.

ACCIONA remarked that the HERON system has a significant potential for both operation and maintenance activities. Considering current state of the art and the experience in the field of various HERON partners, it is desirable to finalize the project with a competitive and functional system to undertake the key functionalities of the proposed system. For ACCIONA it is ok to count on both: 1) a modular system that can be coupled to tows, maintenance vehicles or drones depending on the functionality and needs and 2) an integrated system to perform the required activities. It is very important to remark that it is important to concentrate efforts on developments that can be scalable to replicate the pilots in other motorways and roads operated and maintained by the company.

OLYMPIA ODOS considers that the HERON system should be applicable and useful for the company. As individual systems for various operation & maintenance activities already exist in the market, it is considered of high importance to be an "all in one" unit, which could support for example the placing of cones to protect the area where works should take place and then the same unit to undertake the necessary maintenance activities (ex. Detection / repair of potholes, painting of road marking etc.).

UGE has evaluated the different functionalities that would be relevant for infrastructure stakeholders interested in modular pavements. It has concluded that these pavements, while expensive nowadays, could be interesting if functionalities making these pavements "smart" could be included. For example, the autonomous inspection, repair and/or replacement of the RUP slabs would be an incentive to pay their price.

As a final and main output of this internal meeting, Table 3 has been created to summarise the expectectation of the infrastructure stakeholders on what the HERON system must and should provide by the end of the project and set up other interest and additional expectations considered as "wishes" for the partners involved in this meeting.

Table 3 Summary of the ACCIONA OLYMPIA ODOS discussion

		REQUIREMENTS		
Pavement		**Must**	**Should**	**Wish**
Cracks	Detection of cracks	x		
	Repair of cracks	x		
Potholes	Detection of potholes	x		
	Repair of potholes	x		
Rutting	Detection of rutting	x		
Ageing	Detection of Inadequate Roughness (IRI)		x	
	Detection of Inadequate texture (macrotextures, skid resistance, friction)			x
	Asphalt rejuvenation		x	
Road markings				
Detection of road markings	Detection of reduced luminiscence			x
	Detection of reduced retro-reflectivity			x
	Detection of friction			x
Repair of road markings	Painting	x		
Road				
Support to general patrolling	Detection of all kind of obstacles (debris, tires,rubbish, etc.)		x	
	Detection of state of road edges (vegetation, debris, rubbish, etc.)		x	
	Detection of problems, presence/abscence of signalling, safety barriers/protection measures/guardrails, bolards, bumps, studs, etc		x	
Support to inventory tasks	Detection of presence/abscence of signalling, safety barriers/protection measures/guardrails, bolards, bumps, studs, etc	x		
Reinforced concrete				
Detection of RC cracks				x
Repair of RC cracks				x
RUP				
Inspection	Detection of cracks	x		
	Detection of material removal (at the interface)	x		
Replacement	Installation of RUP	x		
	Removal of RUP	x		
Cones				
Installation or removal of cones	Installation of cones	x		
	Removal of cones	x		

6 Traditional road maintenance and operation activities

6.1 Pavements and surface inspections

6.1.1 Pavements surfaces management activities

Pavements surfaces management activities include aggregate surfaces, asphalt and concrete pavements, roadway shoulders and all roadway surface-related concerns. These activities are designed to preserve the structural integrity of the roadway system and to provide for the safety, mobility and comfort of the roadway user.

Pavement and surface failures are detected following regular inspections and planned assessment of certain parameters normally included as contract requirements. As an example, some of the key requirements are:

1. Skid resistance,
2. International Roughness Index (IRI),
3. Deflections,
4. Settlements,
5. Cracking and other surface failures below a certain limit,
6. Retro-reflectivity and luminance for road markings.

The companies in charge of the operation and maintenance of roads and motorways are responsible for both: inspection, maintenance and major repairs. The following subsection summarizes the different traditional systems to detect and record the failures mentioned and the equipment used to verify the specified contract requirements.

6.1.2 Surface failures detection in pavements

- **Visual inspection and general patrolling**

Visual inspections and the general patrolling (both live during the patrolling where the technician can detect failures and remote (checking the records if the patrolling van is equipped with front and/or rear cameras) are the main frequent pavements and surface failures detection procedure.

Figure 20. Traditional visual inspection (right) and typical general inspection van

- **Devoted advanced equipment**

There are complex inspection systems that include a combination of visual systems (rgb cameras), GPS, surface radar array to detect large distresses, tire pressure sensors to detect IRI and even ground penetration radar array to detect pavement thickness.

Figure 21. Streetscan, one of the most advance inspection systems

Apart from those complex systems, there are devoted equipment to assess the different road parameters included in the maintenance contract. The most relevant are:

Skid resistance machine: Detection of Inadequate texture (macrotextures, skid resistance, friction):

Figure 22. SCRIM skid testing machine for texture measurements

Deflectometers:

Figure 23. Tow impact deflectometer

Perfilometers to detect IRI and rut depth and data processing

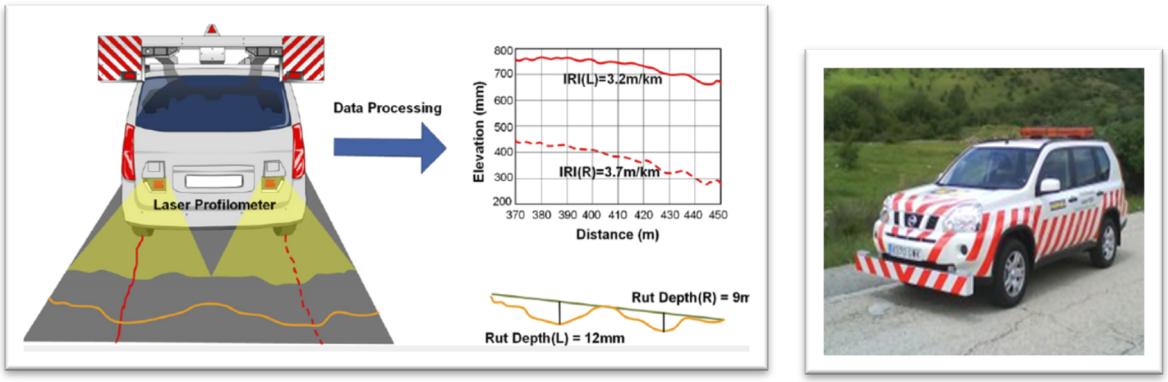

Figure 24. Perfilometer functioning (up) and standar vehicule for IRI detection (down)

6.2 Cracks repair

Cracks filling is an essential application in addition to sealcoating for long term pavement protection. Sealings provide a protective barrier against moisture intrusion into pavement surfaces as they are mostly composed of mineral filler and bitumen (both conventional penetration grade binders and polymer or rubber modified bitumen). Traditional cracks repairs are quite manual as described in Figure 25 and the repairing procedure is quite simple: First: pour the sealing agent and finish the surface with a squeegee and Second: allow material to dry before opening to traffic.

Figure 25. Traditional cracks filling

In areas where cracks have degraded the pavement surface are repaired in a similar way than potholes, using cold or hot mix asphalt (using low particle size gradings (fine-graded asphalt concrete mixtures), but there are or even semi-automatic systems (see Figure 26) that can cover large areas in a small period of time and require less workforce.

Figure 26. Semi-automatic cracks repairs

6.3 Potholes repair

The procedure as in the case of cracks, is quite simple as well:

1. Clean pothole. Remove large loose rocks and other debris (there are patch materials that cure even with presence of water)
2. Fill in the pothole with the patching materials making sure that you use sufficient material to allow compaction
3. Compact material with hand tamper, car tires or another suitable compaction method

Again, it can be considered that the method is quite manual. Concerning materials, there are different systems including the use of patching materials in buckets or bags, cold mixture manufactured in cold asphalt concrete plants and in certain cases even concrete can be used to fill in the pothole.

Figure 27. Use of potholes patching materials

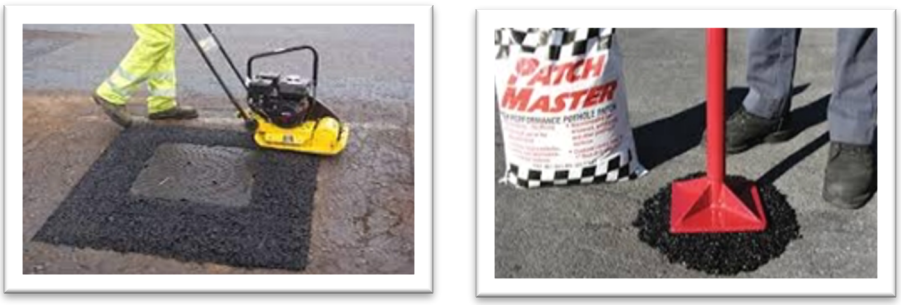

Figure 28. Most common potholes compaction methods

As described for cracking, there are semi-automatic systems that are well implemented in certain US States, Canada or UK.

Figure 29. Semi-automatic potholes repairs

6.4 Asphalt rejuvenation and sealing

Weathering and ageing of motorways accelerates deterioration of pavement structures. Moisture, UV radiation and high temperatures exposition change bitumen chemistry and its mechanical and chemical properties. Currently there are systems in the market that restore the original properties of bitumen and compensate ageing, extending the service life of the pavement, providing an economical and environmentally friendly alternative to the high cost of asphalt overlays.

Figure 30. Commercial sealing and asphalt rejuvenation treatment systems

6.5 Pavements inspections

The most usual damages that the road pavements (flexible and rigid) may sustain are indicatively the following:

- Any type of cracking (longitudinal, oblique, alligator cracks, etc.)
- Any other wear, such as: potholes, detachment/separation of particles, etc.
- Loss of operational characteristics (texture depth, lateral skidding, surface regularity)
- Deformation and reduced skid resistance of the wearing course
- Depression, edge uplift, cracks, condition of joints of rigid pavements.

Table 4 presents the inspection of pavements for the Olympia Odos pilot site is taking place in accordance to a specific procedure.

Table 4 Pavement detection/inspection to Olympia Odos programme

INSPECTIONS			
TYPE OF INSPECTION	**INSPECTION FREQUENCY**		**EXECUTING PARTY**
Scheduled	3 times/ year, (visual inspection for damages)	4 Months	Operator personnel
	1 time/5 years (measurements of functional features: skidding, surface regularity)	5 Years	Specialised Subcontractor
Extraordinary	Extraordinarily, following an accident	E/FA	Operator personnel/ Specialised Subcontractor
Special	When the conditions impose so for the collection of specialized data	CI	Specialised Subcontractor

6.6 Routine Maintenance

Table 5 Routine maintenance works are in accordance to the table below

INTERVENTION/WORK	WORK FREQUENCY		MAINTAINED ITEMS	EXECUTING PARTY
Local restoration of minor potholes (flexible), sealing/filling of small linear cracks (Flexible and rigid), maintenance/restoration of joints (rigid)	3 times/ year after inspection	4 Months	Flexible and rigid pavements	Operator personnel/ Specialised Subcontractor
	Following an accident within 2 days	FA		
Restoration of pavement wears such as depression, different type of cracks, decay, pebbles detachment (flexible), unsealable cracks by resin (rigid)	3 times/ year after inspection	4 Months	Flexible and rigid pavements	Specialised Subcontractor

Regular Maintenance Method Statement:

- **Restoration of minor distortions:**
  - Settlement: Immediate intervention is required, which includes re-leveling of the surface by addition of asphalt layers.
  - Rutting: Low rutting of a short length, which has been stabilising over time, is treated by application of a seal coat of limited area over the relevant location, in order to cover the elevation variation.
  - Reduced skid-resistance of wearing course: Over a limited area, the wearing course is scraped off and reconstructed.
- **Restoration of minor cracks:**
  - Alligator cracks: restoration is achieved by reconstruction of the section surrounding the perimeter of the damaged surface, down to the depth of the layer beneath the layer which is responsible for the cracking, performed either by the Intervention Teams (limited area) or by subcontractors (extensive total area).
  - Longitudinal – Sidelong: small cracks < 3 mm, sealed with asphalt sealant or modified bitumen and large cracks > 5 mm, sealed with sand asphalt fill (modified bitumen and silica sand)
- **Restoration of other minor damages:**
  - Potholes: Immediate intervention is performed by Operator's workers, for temporary treatment. Final restoration is performed through a scheduled intervention, by either the Operator's workers or Subcontractors. Potholes are dug down to the depth of the layer responsible for their appearance and are subsequently configured with an asphalt cutter so as to assume a rectangular shape, of a width at least 15cm beyond the excavation border. After removal of all the waste material potholes are subsequently filled with asphalt mixture by giving a slight lift, 1-2cm, from the road surface. Afterwards the added mixture is compacted with a vibrating plate machine and the final surface is levelled with the existing surface. The most common material that is used for such maintenance interventions is the Bitumix (cold repair asphalt mix) – product leaflet is available.
  - Asphalt emersion (bleeding): Operator's workers proceed to a scheduled intervention, in case this affects a limited area (local or overall). Large surfaces (local or overall) are treated by subcontractors. 5-9 mm clean hot chippings (rice), of the same colour as the wearing

course, are spread on the emerged section (at the hottest time of the day) and slightly rolled. Application of a tack coat is avoided, so as not to aggravate the problem. This procedure can be repeated, if so required.

The equipment that is used is the following:

- For Inspections: Cameras, Tape measures, Straight edges
- For Routine Maintenance: Cold application asphalt mix (Bitumix type), Straight edge, Asphalt cutter, Vibrating/compaction plate

Figure 31. Asphalt cutter and vibrating/compaction plate

6.7 Road markings

Horizontal signing consists of the road markings on the main Carriageway and the Interchanges (ICs), as well as any type of road safety equipment, such as: delineators, pavement reflective studs (cat's eyes), flexible bollards, speed bumps, etc. Road marking's most usual damages are the following:

- Local discoloration or wear of the marking;
- Reduced retroreflectivity;
- Reduced luminescence;
- Reduced anti-skid properties.

6.7.1 Regular Inspections

Road marking detection/inspection to Olympia Odos is taking place in accordance to the table below:

Table 6 Inspections schedule and staff involved

TYPE OF INSPECTION	INSPECTION FREQUENCY		EXECUTING PARTY
Scheduled	1 time/6 months (visual inspection)	6 Months	Operator personnel
	1 time/ 24months (measurements of retroreflectivity, luminescence and friction coefficients)	24 Months	Operator personnel/ Specialised Subcontractor
Extraordinary	Extraordinarily, following an accident	E/FA	Operator personnel
Special	When the conditions impose so for the collection of specialized data	ODO	Specialised Subcontractor

The equipment that is used for Inspections is the following:

- Camera
- Retrometer (measurement of RL index)
- Reflectometer (measurement of QD index)

Figure 32. Commercial road markings inspection vehicles

6.7.2 Routine Maintenance

Road marking maintenance to Olympia Odos is taking place in accordance to the table below:

Table 7 Road marking maintenance for Olympia Odos pilot

INTERVENTION/ WORK	MAINTENANCE FREQUENCY		EXECUTING PARTY
Restoration of small scale damages (i.e. cleaning, local surfacing)	2 times/ year after inspection, (indicatively in April and in October)	6 Months	Operator personnel/ Specialised Subcontractor
	Cleaning as required to maintain the visibility	AR	
	Following an accident within 2 days	FA	

Regular Maintenance Method Statement:

In cases of local soiling, causing the blackening of the white road marking:they are treated locally and with care, through cleaning or local application of paint, in order to avoid differentiating the colour and reflectivity of the small bullets from the existing road marking.

Regular Maintenance Remark:

Within the framework of routine maintenance for horizontal road marking, Scheduled checks / measurements shall be executed (every 24 months), by a specialised subcontractor or the Operator, for the purpose of checking the following indices:

- Retro-reflectivity factor RL – minimum limit 150 mcd/lum.m2.
- Brightness factor B – minimum limit 0,30 mcd/lum.m2.
- Brightness factor Qd – minimum limit 130 mcd/lum.m2.
- Friction factor SRT (< 0.45).

All checks shall be conducted in accordance with the requirements of European Norms EN1436: Road Marking Materials – Performance for Road Users and EN1824: Road Marking Materials – Road Trials for Road Marking, which have been certified by the Hellenic Organisation of Standardisation (ELOT) as national standards.

- The equipment that is used for Routine Maintenance is the following:
- Washer
- Mechanical Sweeper

Figure 33. Washer and Mechanical Sweeper

As far as the paint is concerned, High performance Waterborne paint is used which is composed of two materials: the paint and the glass beads. It is type I marking system according to EN 1436. It has been certified according to EN 1824 as R4, Q2 (class P5).

The main characteristics of the paint are :

1. Compliant to EN 1436, EN 1824 and EN 1871
2. Excellent Durability (category P5 – 1000000 wheels over, tested on in situ conditions according to EN 1824 for one 1 year);
3. High Retro reflectivity (class R4);
4. Very Fast Drying Time : less than 5 minutes to minimize operational disturbance;
5. Environmentally friendly paint in terms of reduced emissions of VOCs volatile organic compounds.

The glass beads will be certified according to EN 1423 with the following properties:

- Roundness ≥ 80%;
- Refractive index ≥ 1.5 It is Class A according to EN1423;
- Luminosity: maximum 500mcd;
- Specific Weight: 2.5gr/cm3;
- Granulometry: 180-500 microns;
- Physical and chemical resistance according to EN 1423.

The product will be compatible with existing old paint product (acrylic, solvent based paint or thermoplastic).

Table 8 Minimum requirement vales of road marking visibility

Characteristic	**Standard**	**Required minimum value**	
Traffic class	EN 1824	≥ 1000000 wheel over, tested on in situ conditions according to EN 1824 for one 1 year	
		At the end of 3 month	At the end of the guarantee period (30 months)
Qd (day visibility)	EN 1436	Qd ≥ 100/120 mcd	Qd ≥ 100 mcd
RL (night visibility -Dry)	EN 1436	RL ≥ 200 mcd	RL ≥ 100 mcd

Rw (night visibility - Wet)	EN 1436	N/A	N/A
SRT (anti skid resistance)	EN 1436	≥ 45	

Figure 34. Road marking devices

6.8 General patrolling and inventory tasks

One of the main activities in road maintenance and operation contracts are linked to control and monitoring of the asset. It implies activities mainly undertaken patrolling the road/motorway to detect any deficiency, defect or anomaly in the road and edges, including all aspects concerning traffic: incidents, accidents and other disruptions to traffic.

Other key element of this kind of tasks are linked to programming routine maintenance activities and the study and analysis of potential upgrading of the asset.

The following are examples of routine activities performed:

- Detection of all kinds of obstacles (debris, tires, animals, rubbish, etc.);
- Detection of state of road edges (vegetation, debris, rubbish, etc.);
- Detection of problems, presence/absence of: signalling, safety barriers/protection measures/guardrails, bollards, bumps, studs, etc.

6.9 Reinforced concrete

Transpolis test site presents several old reinforced concrete buildings, which makes it possible to test the detection and the repair of cracks.

6.9.1 Detection of RC cracks

Currently, no detection of reinforced concrete cracks is done on the buildings of Transpolis site.

6.9.2 Repair of RC cracks

Currently, no repair of reinforced concrete cracks is done on the buildings of Transpolis site.

6.10 Removable urban pavements (RUP)

6.10.1 Detection of cracks on RUP

No detection of cracks is done currently, either automatically or not. The HERON could perform autonomous and automated crack detection based on images and videos taken by the PANOPTIS tool. This would correspond to an improvement to the current PANOPTIS solution.

6.10.2 Detection of material removal on RUP

No detection of material removal of the RUP slabs is done currently, either automatically or not. The HERON could perform autonomous and automated crack detection based on images and videos taken by the PANOPTIS tool. This would correspond to an improvement to the current PANOPTIS solution.

6.10.3 Installation of RUP

To build or rebuild the structure, it is necessary to slide the tabs of each slab under that of the neighbouring slabs at a small angle. The final adjustment is done using a large wooden hammer as the workers who pave the streets traditionally do.

6.10.4 Removal of RUP

The hexagonal concrete slabs are interlocked together thanks to top and corresponding bottom tabs on the border of the slabs. This interlocking is necessary to bear the traffic and avoid slab rocking. However, that complicates the dismantling. You can no longer remove a slab from the middle like for independent slabs. It is necessary to dismantle the slabs from the border. The longitudinal borders are equipped with paving blocks to release the first space to allow the relative sliding between the slabs. Both installation and removal jobs, in their present state, need a lot of human manual effort and skill. These jobs can be seen and downloaded in three different videos in this link: https://cud.ifsttar.fr/films/

6.11 Cones: Installation or removal of cones

The installation and removal of traffic cones in the motorways for the needs of performing inspection and maintenance works is a basic and ordinary activity. At the same time this constitutes a dangerous activity since during this action the personnel is exposed to traffic.

The classic method, which is provided for in the approved manuals of the Project, but it is also implemented by all Concessions in Greece and internationally, is the manual one, which means that the Operator's Employee, who is inside the load area of a VAN, places manually the cones on the road while his colleague drives the car at a particularly low speed using all the safety equipment (flashing arrows, flashing beacons) and the safety procedures.

Traffic cones that are used in Olympia Odos are size 2, with height of 750mm and weight of 5.2kg. PVC traffic cones with two reflective stripes of type II and 100% thermoplastic recyclable base according to EN 13422.

Advantages:

1. Direct coordination between driver and operator.
2. Quick and easy refill of cones.
3. Exact placement of the cones, regarding the location and the distance between them.
4. Large vehicle capacity, as the space is not limited by the existence of any other system.
5. Possibility of transporting the vehicle's permanent equipment as well (i.e. signs - tools cabinets, etc.)

6. Possibility to work under any conditions.

Disadvantages:

1. Unsafe work in case of an accident as the employee placing the cones is standing on an upright position.
2. Low back strain for the Intervention team employees due to the necessary bending, in order to place or remove the cones, especially during extended signing activities.
3. Low speed and respective capacity.

The following figures summarise the traditional and advanced system for placing cones in roads and motorways

Figure 35. Traditional use of cones

Figure 36. Advanced systems to limit the human intervention associated to the use of cones

7 Specifications for the HERON system

The initial specifications as discussed within the HERON workshops in WP2 can be summarised to the following.

7.1 Functional specifications

- Speed of the ground autonomous vehicle;
- Autonomy of the drones;
- Images and video quality;
- Communications systems;
- Area of intervention;
- Operational capacity (i.e.minimum patching materials storage capacity, autonomy, compaction capacity, cutting and milling capacity, pumping/praying/conveying capacity.

7.2 Non-functional specifications

- Personnel safety;
- Data integrity;
- Performance monitoring;
- Combined inspection & maintenance works for different assets – less traffic disruption as less working time is needed.

These specifications will be updated based on the outcomes of the two WP2 workshops, to be planned during M5 and M8 of the project.

7.3 Key Performance indicators (from the proposal)

7.3.1 Infrastructure operators and maintenance companies (OLO and ACCI)

Evaluation of results and specific KPIs percentage of:

- increase of maintenance and upgrading tasks versus traditional procedures;
- increase of area covered by inspections versus traditional visual inspection;
- decrease of human intervention during maintenance, upgrading and inspection of RI;
- decrease of human intervention during operation, patrolling, inventorying and inspection activities;
- cost reductions of maintenance and upgrading of RI versus traditional costing;
- cost reductions of operation, patrolling, inventorying and inspection activities;
- reduction of traffic jams.

7.3.2 From UGE

Evaluation of results and specific KPIs:

- Detection of cracks with a width over 0,5mm in reinforced concrete,
- Inspection of road marking and reporting through V2I (Inspection of 1km of road in less than 1 hour, comprehensive and continuous reporting),
- Inspection of CUD pavements (Inspection of 1km of road in less than 1 hour, comprehensive and continuous reporting),

- Autonomous replacement of CUD elements (Replacement of one element in less than 30 minutes).

These metrics are still to be precised in the upcoming months.

8 Conclusions

This report is a first choice and definition of the use cases to be implemented within project HERON. The current version list these use cases and gives first descriptions and definitions.

The inputs from the other WPs has been incorporated to define their needs and a prioritization in terms of implementation tasks.

This work has made it possible to define the first use cases to be tackled, namely the work on cones and the repair of road markings. The other use cases still need more information to decide the technical possibilities to answer the stakeholders' needs.

This report will be updated continuously in the forthcoming months, and will be finalised shortly after the 2nd HERON workshop.

ANNEX 1: EXAMPLES OF TECHNICAL SPECIFICATIONS OF MATERIALS IN HERON

A. Asphalt rejuvenation agents: e.g. Biorestor:

Biorestor Asphalt Rejuvenator

BIORESTOR Safety Data Sheet

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

Revision Date: 04/25/2014 Date of issue: 04/25/2014 Version: 1.0

SECTION 1: IDENTIFICATION

Product Identifier

Product Form: Mixture

Product Name: Biorestor Asphalt Rejuvenator

Intended Use of the Product

For professional use only.

Name, Address, and Telephone of the Responsible Party

Company

BioBased Spray Systems, LLC.
2506 Fair Rd
Sidney, Ohio 45365-7523
+1 (888) 743-7319

Emergency Telephone Number

Emergency number : Chemtrec (800) 424-9300 Outside USA (703) 527-3887

SECTION 2: HAZARDS IDENTIFICATION

Classification of the Substance or Mixture

Classification (GHS-US)

Flam. Liq. 3 H226
Skin Irrit. 2 H315
Skin Sens. 1 H317
Asp. Tox. 1 H304

Label Elements

GHS-US Labeling

Hazard Pictograms (GHS-US) :

Signal Word (GHS-US) : Danger

Hazard Statements (GHS-US) :
H226 - Flammable liquid and vapor
H304 - May be fatal if swallowed and enters airways
H315 - Causes skin irritation
H317 - May cause an allergic skin reaction

Precautionary Statements (GHS-US) :
P210 - Keep away from heat, hot surfaces, open flames, sparks. - No smoking
P233 - Keep container tightly closed
P240 - Ground/bond container and receiving equipment
P241 - Use explosion-proof electrical, lighting, ventilating equipment
P242 - Use only non-sparking tools
P243 - Take precautionary measures against static discharge
P261 - Avoid breathing mist, spray, vapors
P264 - Wash hands, forearms, and exposed areas thoroughly after handling
P272 - Contaminated work clothing should not be allowed out of the workplace
P273 - Avoid release to the environment
P280 - Wear eye protection, face protection, protective clothing, protective gloves
P301+P310 - IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician
P302+P352 - IF ON SKIN: Wash with plenty of soap and water
P303+P361+P353 - IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower
P321 - Specific treatment (see Section 4)
P331 - If swallowed, do NOT induce vomiting

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P332+P313 - If skin irritation occurs: Get medical advice/attention
P333+P313 - If skin irritation or rash occurs: Get medical advice/attention
P362+P364 - Take off contaminated clothing and wash it before reuse
P370+P378 - In case of fire: Use appropriate media for extinction
P391 - Collect spillage
P403+P235 - Store in a well-ventilated place. Keep cool
P405 - Store locked up
P501 - Dispose of contents/container according to local, regional, territorial, provincial national, and international regulations

Other Hazards

Other Hazards Not Contributing to the Classification: Exposure may aggravate those with pre-existing eye, skin, or respiratory conditions.

Unknown Acute Toxicity (GHS-US) Not available

SECTION 3: COMPOSITION/INFORMATION ON INGREDIENTS

Mixture

Name	Product identifier	% (w/w)	Classification (GHS-US)
D-Limonene	(CAS No) 5989-27-5	75	Flam. Liq. 3, H226 Skin Irrit. 2, H315 Skin Sens. 1, H317 Asp. Tox. 1, H304 Aquatic Acute 1, H400 Aquatic Chronic 1, H410
Soybean oil, methyl ester	(CAS No) 67784-80-9	20	Not classified
Styrene-butadiene copolymer	(CAS No) 9003-55-8	5	Not classified

Full text of H-phrases: see section 16

SECTION 4: FIRST AID MEASURES

Description of First Aid Measures

General: Never give anything by mouth to an unconscious person. If you feel unwell, seek medical advice (show the label if possible).

Inhalation: Remove to fresh air and keep at rest in a position comfortable for breathing. Obtain medical attention if breathing difficulty persists.

Skin Contact: Immediately remove contaminated clothing. Rinse immediately with plenty of water. Obtain medical attention if irritation develops or persists.

Eye Contact: Rinse cautiously with water for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Obtain medical attention.

Ingestion: Do NOT induce vomiting. Rinse mouth. Immediately call a POISON CENTER or doctor/physician.

Most Important Symptoms and Effects Both Acute and Delayed

General: Causes skin irritation. May cause an allergic skin reaction. May be fatal if swallowed and enters airways.

Inhalation: May cause respiratory irritation.

Skin Contact: Causes skin irritation. May cause an allergic skin reaction.

Eye Contact: May cause eye irritation.

Ingestion: May be fatal if swallowed and enters airways.

Chronic Symptoms: None expected under normal conditions of use.

Indication of Any Immediate Medical Attention and Special Treatment Needed

If you feel unwell, seek medical advice (show the label where possible).

SECTION 5: FIRE-FIGHTING MEASURES

Extinguishing Media

Suitable Extinguishing Media: Dry chemical, carbon dioxide, water spray, foam, fog.

Unsuitable Extinguishing Media: Do not use a heavy water stream. Use of heavy stream of water may spread fire.

Special Hazards Arising From the Substance or Mixture

Fire Hazard: Flammable liquid and vapor.

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Explosion Hazard: May form flammable/explosive vapor-air mixture.
Reactivity: Flammable liquid and vapor.

Advice for Firefighters

Precautionary Measures Fire: Exercise caution when fighting any chemical fire.
Firefighting Instructions: Use water spray or fog for cooling exposed containers.
Protection During Firefighting: Do not enter fire area without proper protective equipment, including respiratory protection.
Hazardous Combustion Products: Hydrocarbons. Carbon oxides (CO, CO_2). Oxides of citrus terpenes.
Other information: Do not allow run-off from fire fighting to enter drains or water courses.

Reference to Other Sections

Refer to section 9 for flammability properties.

SECTION 6: ACCIDENTAL RELEASE MEASURES

Personal Precautions, Protective Equipment and Emergency Procedures

General Measures: Avoid all eye and skin contact and do not breathe vapor and mist. Use special care to avoid static electric charges. Keep away from heat/sparks/open flames/hot surfaces. – No smoking. Do not allow product to spread into the environment.

For Non-Emergency Personnel

Protective Equipment: Use appropriate personal protection equipment (PPE).
Emergency Procedures: Evacuate unnecessary personnel.

For Emergency Personnel

Protective Equipment: Equip cleanup crew with proper protection.
Emergency Procedures: Ventilate area.

Environmental Precautions

Prevent entry to sewers and public waters. Avoid release to the environment.

Methods and Material for Containment and Cleaning Up

For Containment: Contain any spills with dikes or absorbents to prevent migration and entry into sewers or streams.
Methods for Cleaning Up: Clear up spills immediately and dispose of waste safely. Collect the residue by means of a non-combustible absorbent material. Use only non-sparking tools. Eliminate all ignition sources.

Reference to Other Sections

See heading 8, Exposure Controls and Personal Protection.

SECTION 7: HANDLING AND STORAGE

Precautions for Safe Handling

Additional Hazards When Processed: Handle empty containers with care because residual vapors are flammable. Do not puncture or incinerate container. When heated, material emits irritating fumes. Any proposed use of this product in elevated-temperature processes should be thoroughly evaluated to assure that safe operating conditions are established and maintained.
Hygiene Measures: Handle in accordance with good industrial hygiene and safety procedures. Wash hands and other exposed areas with mild soap and water before eating, drinking, or smoking and again when leaving work. Contaminated work clothing should not be allowed out of the workplace. Do not eat, drink or smoke when using this product.

Conditions for Safe Storage, Including Any Incompatibilities

Technical Measures: Proper grounding procedures to avoid static electricity should be followed. Ground/bond container and receiving equipment. Use explosion-proof electrical, ventilating, and lighting equipment.
Storage Conditions: Store in a dry, cool and well-ventilated place. Keep container closed when not in use. Store away from direct sunlight or other heat sources. Store away from incompatible materials. Store away from ignition sources.
Incompatible Materials: Strong acids. Strong bases. Strong oxidizers.

Specific End Use(s)

For professional use only.

SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Control Parameters

No Occupational Exposure Limits (OELs) have been established for this product or its chemical components.

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Exposure Controls

Appropriate Engineering Controls: Ensure adequate ventilation, especially in confined areas. Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Ensure all national/local regulations are observed. Gas detectors should be used when flammable gases/vapours may be released.
Personal Protective Equipment: Protective goggles. Gloves. Protective clothing. Insufficient ventilation: wear respiratory protection.

Materials for Protective Clothing: Chemically resistant materials and fabrics.
Hand Protection: Wear chemically resistant protective gloves.
Eye Protection: Chemical goggles or safety glasses.
Skin and Body Protection: Wear suitable protective clothing.
Respiratory Protection: Use a NIOSH-approved respirator or self-contained breathing apparatus whenever exposure may exceed established Occupational Exposure Limits.
Environmental Exposure Controls: Do not allow the product to be released into the environment.
Consumer Exposure Controls: Do not eat, drink or smoke during use

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

Information on Basic Physical and Chemical Properties

Physical State	:	Liquid
Appearance	:	Pale yellow
Odor	:	Citrus
Odor Threshold	:	Not available
pH	:	Not available
Relative Evaporation Rate (butylacetate=1)	:	Not available
Melting Point	:	Not available
Freezing Point	:	Not available
Boiling Point	:	Not available
Flash Point	:	Not available
Auto-ignition Temperature	:	Not available
Decomposition Temperature	:	Not available
Flammability (solid, gas)	:	Not available
Lower Flammable Limit	:	Not available
Upper Flammable Limit	:	Not available
Vapor Pressure	:	2 mm Hg
Relative Vapor Density at 20 °C	:	Not available
Relative Density	:	0.881 (Water=1)
Solubility	:	Not available
Partition coefficient: n-octanol/water	:	Not available
Viscosity	:	Not available
Explosion Data – Sensitivity to Mechanical Impact	:	Not expected to present an explosion hazard due to mechanical impact.
Explosion Data – Sensitivity to Static Discharge	:	Not expected to present an explosion hazard due to static discharge.

SECTION 10: STABILITY AND REACTIVITY

Reactivity: Flammable liquid and vapor.
Chemical Stability: May form flammable/explosive vapor-air mixture.
Possibility of Hazardous Reactions: Hazardous polymerization will not occur.
Conditions to Avoid: Open flame. Ignition sources. Incompatible materials. Direct sunlight. Extremely high or low temperatures.
Incompatible Materials: Strong acids. Strong bases. Strong oxidizers.
Hazardous Decomposition Products: Hydrocarbons. Carbon oxides (CO, CO_2). Oxides of citrus terpenes.

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SECTION 11: TOXICOLOGICAL INFORMATION

Information on Toxicological Effects - Product

Acute Toxicity: Not classified

LD50 and LC50 Data: Not available

Skin Corrosion/Irritation: Causes skin irritation.

Serious Eye Damage/Irritation: Not classified

Respiratory or Skin Sensitization: May cause an allergic skin reaction.

Germ Cell Mutagenicity: Not classified

Teratogenicity: Not available

Carcinogenicity: Not classified

Specific Target Organ Toxicity (Repeated Exposure): Not classified

Reproductive Toxicity: Not classified

Specific Target Organ Toxicity (Single Exposure): Not classified

Aspiration Hazard: May be fatal if swallowed and enters airways.

Symptoms/Injuries After Inhalation: May cause respiratory irritation.

Symptoms/Injuries After Skin Contact: Causes skin irritation. May cause an allergic skin reaction.

Symptoms/Injuries After Eye Contact: May cause eye irritation.

Symptoms/Injuries After Ingestion: May be fatal if swallowed and enters airways.

Chronic Symptoms: None expected under normal conditions of use.

Information on Toxicological Effects - Ingredient(s)

LD50 and LC50 Data:

D-Limonene (5989-27-5)	
LD50 Oral Rat	4400 mg/kg
LD50 Dermal Rabbit	> 5 g/kg
Styrene-butadiene copolymer (9003-55-8)	
IARC Group	3
D-Limonene (5989-27-5)	
IARC Group	3
National Toxicity Program (NTP) Status	Evidence of Carcinogenicity.

SECTION 12: ECOLOGICAL INFORMATION

Toxicity

D-Limonene (5989-27-5)	
LC50 Fish 1	0.619 - 0.796 mg/l (Exposure time: 96 h - Species: Pimephales promelas [flow-through])
LC 50 Fish 2	35 mg/l (Exposure time: 96 h - Species: Oncorhynchus mykiss)

Persistence and Degradability Not available

Bioaccumulative Potential Not available

Mobility in Soil Not available

Other Adverse Effects

Other Information: Avoid release to the environment.

SECTION 13: DISPOSAL CONSIDERATIONS

Waste Disposal Recommendations: Dispose of waste material in accordance with all local, regional, national, and international regulations.

Ecology – Waste Materials: Avoid release to the environment.

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SECTION 14: TRANSPORT INFORMATION

14.1 In Accordance with DOT

Proper Shipping Name : TERPENE HYDROCARBONS, N.O.S.(d-limonene solution)

Hazard Class : 3

Identification Number : UN2319

Label Codes : 3

Packing Group : III

Marine Pollutant : Marine pollutant

ERG Number : 128

14.2 In Accordance with IMDG

Proper Shipping Name : TERPENE HYDROCARBONS, N.O.S.(d-limonene solution)

Hazard Class : 3

Identification Number : UN2319

Packing Group : III

Label Codes : 3

EmS-No. (Fire) : F-E

EmS-No. (Spillage) : S-D

Marine Pollutant : Marine pollutant

14.3 In Accordance with IATA

Proper Shipping Name : TERPENE HYDROCARBONS, N.O.S. (d-limonene solution)

Packing Group : III

Identification Number : UN2319

Hazard Class : 3

Label Codes : 3

ERG Code (IATA) : 3L

Marine Pollutant : Marine pollutant

14.4 In Accordance with TDG

Proper Shipping Name : TERPENE HYDROCARBONS, N.O.S.(d-limonene solution)

Packing Group : III

Hazard Class : 3

Identification Number : UN2319

Label Codes : 3

Marine Pollutant (TDG) : Marine pollutant

SECTION 15: REGULATORY INFORMATION

US Federal Regulations

Biorestor Asphalt Rejuvenator	
SARA Section 311/312 Hazard Classes	Fire hazard
Styrene-butadiene copolymer (9003-55-8)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory	
Soybean oil, methyl ester (67784-80-9)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory	
D-Limonene (5989-27-5)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory	

US State Regulations

Styrene-butadiene copolymer (9003-55-8)
U.S. - Texas - Effects Screening Levels - Long Term
U.S. - Texas - Effects Screening Levels - Short Term