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Omicron. Intelligent road management platform

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Omicron. Intelligent road management platform

ABSTRACT

OMICRON's objective is the development of an Intelligent Road Management Platform based on a portfolio of innovative technologies to improve the construction, maintenance, renewal, and rehabilitation of the European road network. The project covers the entire asset management chain, focusing on four pillars: modular bridge construction, digitisation of inspection, predictive maintenance, and automated execution of maintenance activities.

This article first carries out a general description of the project, followed by a more detailed analysis of three technologies, including: the Modular Robotic Platform, a support system in the paving process (SASPI) and related developments. a Digital Twin and Decision Support System in road maintenance planning.

OMICRON's Intelligent Platform will make it possible to digitise and automate a large number of road management tasks that are still labour-intensive. In this way, OMICRON intends to pave the way towards the roads of the future, promoting Industry 4.0 and sustainability.

1. Pavasal works on the development of the robotic system (modular robotic platform) applied to sealing cracks and erasing, cleaning and placing signage.
2. Eiffage is developing a real-time decision support system to enhance the paving process. This system utilizes data from various sensors and analysis of AUTL semi-hot and recycled mixes.
3. Tekniker works jointly with EIFFAGE and PAVASAL as the primary technological partner, leading the tasks for implementing robotic technology and artificial intelligence systems necessary for developing the foreseen use cases.
4. Cemosa focuses on the development of both the Digital Twin and Decision Support Tool for highways, consolidating all project advancements. Furthermore, Cemosa assumes the role of coordinator for the OMICRON project.

16 partners from 7 European countries participate in this project, with demonstrators aiming to reach TRL (Technology Readiness Level) 7, tested in pilots in Portugal, Spain and Italy.

1.INTRODUCTION

The general context of development in the European continent means that investment in transport infrastructure, in general, and in road infrastructure, in particular, is focused mainly on the comprehensive management of existing road assets. Apart from ordinary road maintenance tasks, the ageing of a large part of the existing infrastructure makes it very necessary to carry out major rehabilitation interventions. In addition, the fight against climate change highlights the need to reduce emissions in all aspects related to road infrastructure management. In this way, the intelligent conservation of pavements and other assets has great potential to reduce associated CO_2 emissions (EAPA, EUPAVE, FEHRL, 2016).

Thus, the emergence of Industry 4.0, which involves the use of robots, digitalization, and artificial intelligence, along with the effort to combat climate change by reducing emissions, has altered the approach to technical specifications for roads and asset conservation techniques. The road infrastructure sector needs technology that can manage and maintain roads while meeting the following requirements:

- Improve services in terms of security and connectivity.

- Reduce the costs derived from the high volume of conservation activities that will be necessary in the coming years.
- Increase network capacity, making more intelligent use of it.
- Allow sustainable management of assets, advancing towards decarbonisation in accordance with the European Green Pact (European Commission, 2019).

The OMICRON project (OMICRON H2020, 2021), financed by the Horizon 2020 Research and Innovation Program of the European Union, arises in this context with the aim of responding to the needs of the processes of design, construction, and maintenance of roads, and coordinates a range of innovative inspection technologies, digitisation of assets and execution of conservation activities. The OMICRON project started in May 2021 and will conclude in October 2024.

2. THE OMICRON PROJECT

The OMICRON project aims to tackle multiple challenges through the development of advanced technologies. One such technology is a road asset management platform that can automate, optimize and robotize management processes. The platform is built on four essential pillars that cover construction, inspection, maintenance and conservation activities, as illustrated in Figure 1.

Pillar 1. Modular bridge construction. The project focuses on this aspect in the development of a methodology for the modular construction of highway overpasses, improving the connections between metal and reinforced concrete beams in hybrid-type bridges. The underlying objective, in this case, is the improvement and digitisation of the construction process in order to reduce construction times and the effects on traffic.

Pillar 2. Inspection digitisation. The project develops technologies for automating road inspection and increasing the safety of said processes using both ground monitoring vehicles and aerial robotics. The concept includes connecting such systems with connected intelligent transportation systems (C-ITS) and vehicle-to-everything (V2X) communications to improve driver interaction.

Pillar 3. Predictive maintenance. Our platform, OMICRON, operates using a Digital Twin of roads, which creates a digital copy of the asset and a decision support system for road maintenance planning. Our goal is to deliver accurate information on the condition of road assets, such as pavements and structures, and optimize maintenance planning using artificial intelligence and optimization techniques, among other tools.

Pillar 4. Intelligent road intervention. This pillar is based on a set of intelligent tools for the execution of maintenance activities, including the development of a modular robotic platform capable of executing different ordinary, extraordinary, and emergency maintenance tasks on roads; a decision support system in the paving process; and a system based on virtual reality and augmented reality to support staff in carrying out maintenance activities on the road.

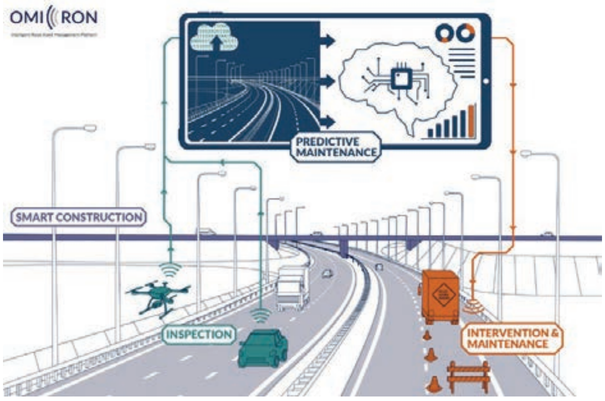


Figure 1. Omicron project concept

The development of such a transversal portfolio of technologies requires the work of interdisciplinary teams. The OMICRON project is made up of 16 entities from 7 European countries, where collaboration between small and medium-sized companies, large corporations, technology centres and universities stand out. PAVASAL, EIFFAGE, TEKNIKER, and CEMOSA are four Spanish organizations that are working on this project in lines of research closely linked to the pavement.

PAVASAL is working on the development of a robotic system (modular robotic platform) applied to sealing cracks and erasing and placing signage.

EIFFAGE works on a decision support system to improve the paving process in real-time, using information from different sensors, as well as the study of semi-hot and recycled Asphalt UltraThin Layers (AUTL).

TEKNIKER works jointly with EIFFAGE and PAVASAL as the main technological partner, leading the tasks for the implementation of robotic technology and artificial intelligence systems necessary for the development of the foreseen use cases.

CEMOSA is involved in creating the Digital Twin and Decision Support Tool for roads, which bring together the various project developments. Additionally, CEMOSA serves as the coordinator for OMICRON.

The following sections go into more detail in describing these technologies.

3. MODULAR ROBOTIC PLATFORM FOR ROADS

Until now, automation in the road construction and maintenance industry has been restricted to road assessment and enhancing the spreading and compacting process of pavement layers. This automation has improved key aspects such as regularity, gradient geometry, and control of compaction and temperature during the process. Even with these advances, the machinery used requires strict human control, and there are also a multitude of operations that continue to have a strong manual nature. This means that labour continues to have a very important weight in productivity and cost control in this type of process. An aspect that is even more important is the overexposure of all these personnel to the risks inherent to the activities on site and, above all, to the traffic present in conservation activities, "The main determining factor of being run over is the multitude of activities carried out on open traffic roads" (Gonzalez Lourtau, 2015).

Due to the significant reliance on humans and the safety issues that come with it, it is wise to think about incorporating new technologies to help mitigate these concerns. One option is to introduce robotic components, along with employing virtual reality (VR) or augmented reality (AR) technologies. These tools can aid operators and technicians in their work environment, as well as during training and learning processes.

The number of existing robotic applications in the field of construction is limited. An example of this is a roof drilling robot developed by Nlink (NLink, 2015), capable of drilling precise and continuous series of holes in concrete ceilings based on the information provided by BIM models or construction drawings. Likewise, the "In-Situ Fabricator" (In situ Fabricator, 2016) is a robotic mason developed by the Digital Fabrication laboratory of the Swiss National Center for Research Competence (NCCR), which can build non-standard designs on site. Another example is the Brokk 50 demolition robot (weighing 500 kg) (Brokk 50, 2010) which was initially designed to remove tiles in bathrooms, as it can fit through 60 cm wide doors. Both Brokk and Husqvarna have successfully marketed these robots in different sizes, but they are still teleoperated machines with no autonomous features. In general, all these solutions are focused on closed work environments (building), where geometry and environmental conditions tend to be more controlled, while robotic developments in open-type works are, in most cases, in research and development processes still not very marketable.

Similarly, the use of virtual and augmented reality technologies has proven their effectiveness in various sectors. VR is used in sectors that require a simulation of the real environment such as training, greatly reducing subsequent errors in execution, or teleoperation, facilitating safe execution in dangerous environments. The AR is used in sectors that need an improvement in efficiency by incorporating support instructions in real-time. Here again, the application of these technologies continues to be in controlled environments, leaving out work environments such as the one discussed in this communication.

Using the technologies described above, the OMICRON project is designing and developing a multipurpose modular robotic platform capable of carrying out different road maintenance actions, in which virtual and augmented reality systems are also incorporated. The general approach proposed to achieve this is to use commercial components to build a platform consisting of a robotic arm and other accessories that can be attached to a standard truck using the "Multilift" system (https://www.hiab.com/en-gb/our-brands/multilift). This platform can be used in various road maintenance scenarios, offering a modular, flexible, safe, and low-cost solution.

Figure 2. Representation and images of the multipurpose robotic platform.

The final design proposed at OMICRON consists of a container with a rear platform, where a robotic arm is placed to carry out the different maintenance operations. This container contains enough space to house all the elements that make up the system that is being designed "ad hoc" to meet the requirements of the operations. The platform has a system of hydraulic cylinders, which allow vertical and horizontal displacement that is added to the 6 degrees of freedom of the robotic arm. Most of the planned actions can be performed autonomously thanks to the combination of vision tools and artificial intelligence using perception systems and deep learning algorithms that allow the automatic detection of cones, traffic signs, and pavement cracks. In addition, the tools that will be coupled to the robot are being manufactured for the manipulation of the necessary elements that allow the different maintenance operations to be carried out. For the operation of the robot, a software architecture has been designed in ROS (Robot Operating System), which allows for obtaining a solution independent of the manufacturer. Finally, the use of VR or AR allows human supervision carried out from a safe distance in the vehicle cabin or even remotely in any other location, thus eliminating the risk posed by the operating environment and excessive exposure of personnel to traffic.

The maintenance interventions that will be covered by the OMICRON robotic platform are described below.

3.1 Support in the installation of safety barriers

Replacing safety barriers is a frequent task in highway maintenance, whether due to an accident or natural wear and tear. To install and remove the barriers, operators must suspend and support their weight until they can securely anchor them with screws to the posts and adjacent barriers. Assisting operators in effectively and practically sustaining loads can yield remarkable ergonomic enhancements. Consequently, this can lead to favourable outcomes such as improved health, accident prevention, and reduced sick leave attributed to the ergonomics of these tasks. This assistance is the one that is intended to be implemented in this first use case of the OMICRON project with the use of the robotic arm placed on the truck bed described above. Thus, according to an established placement protocol, similar to the one currently used (General Directorate of Roads, Ministry of Public Works), the robotic arm assumes the heavy part of said operation, first unloading the barrier and positioning it at the correct height. At that moment, the arm remains in a suspension or weightlessness mode and can be easily redirected by the operator until it locks into the correct position without having to make any support effort, allowing the fasteners to be placed easily and safely. Once this process is finished, the robot releases the barrier to continue with the next installation.

Figure 3. Left.: Attachment tool with the robotic arm; Centre: Robotic arm positioning the metal barrier; Right.: Virtual Reality for training operators in the installation of metal security barriers.

During these operations, the robot employs a specialized tool to securely grip the metal barrier. (as seen in Figure 3 on the left). The robot is controlled remotely through AR technology, which guides the operator through each step of the intervention. This assistance improves efficiency and safety by reducing the time spent on-site.

Instructions for AR can be provided in various ways such as through text, visual aids, images, videos, 3D virtual object animations, or overlays of actual process parts shown in the real world. These provide guidance to the operator on how to use the parts or suggested tools. Additionally, the interfaces enable the operator to control the robot using gestures. Alerts and V2X information communication enhance safety. For example, when the robot is moving, the AR application displays the robot's range by showing its path and alerts the operator if they are too close. Moreover, real-time traffic information is displayed to inform the operator of any potential danger.

For this case, the use of AR is planned through the use of "Hololens2" type glasses, although the use of a "tablet" is also possible, as is the case with other project operations. Virtual Reality (VR), in this use case, is used for the training and education of the personnel in charge of carrying out maintenance operations (Figure 3 Right).

3.2 Installation of roadside signs: placing and collecting cones

Before carrying out any maintenance work, the placement of the relevant signage is mandatory in accordance with current legislation (Instruction 8.3-IC) (BOE, 1987). This signalling orders traffic, informing and warning users about which lanes are still working and which will remain closed. The placement of this signalling also entails a significant risk for workers since, on occasions, they must carry heavy signals across several lanes, or it is necessary to quickly place or remove the line of cones that separate the working lanes from the cut ones.

For these operations, a solution is also being developed within the OMICRON project that, through the use of the robotic platform, allows these signals to be downloaded or the line of cones to be extended and removed automatically without the intervention of any operator.

Figure 4. Left.: Cone identification; Centre: Cone placement using the robotic arm; Right.: Representation of the tool for placing and picking up the cones

For the task of removing cones, a unique tool is being created (shown on the right in Figure 4) that works with the robot. This tool enables the cones to be placed or removed at the same speed as the truck, just like how it is done with systems where a person sits in the back of a van to do it. The recognition system powered by artificial intelligence can detect the cones (as shown in the centre of Figure 4), estimate the distance at which they need to be placed or removed, and give commands to the robot to execute the operation.

3.3 Vertical road sign cleaning

Road maintenance often involves cleaning vertical signs, a task currently performed by operators who use pressurized water spray systems. In this case, the robotic arm will assume the cleaning operation of these road assets, minimizing the exposure of workers to traffic. In the same way as in the previous cases, the system uses a set of cameras that provide the images so that the AI is able to recognize the signal, its type and dimensions and sequence a path with the robotic arm to cover the entire area of the same until completely cleaned. This cleaning will be carried out with the incorporation of a pressurized water lance attached to the head of the arm.

3.4 Elimination of horizontal road markings by laser

Maintenance operations often require changes to the layout or width of lanes, which may involve removing existing horizontal markings. It is also common to remove outdated detour signs or stop signs. Currently, there are two primary techniques for addressing these situations.

1. One of the most affordable and commonly used methods for updating signs is to simply repaint them with black paint. However, this can lead to confusion for drivers and autonomous driving systems, as the contrast between the sign and the road surface can create shadow-like reflections. Depending on the angle and direction of sunlight, these reflections can cause confusion and affect driver safety. Additionally, when repainting signs, there is a tendency to make them larger than the original, which can lead to a loss of friction and pose safety risks for drivers.
2. The second most widespread option is milling the surface of the sign or using high-pressure water using pressure washers. With these mechanical systems, it is possible to remove the paint and, although they improve the appearance of friction, they cause further deterioration of the surface. In addition, due to this superficial deterioration, the shadow of the original shape of the signal continues to be appreciated (Figure 5 Right).

Figure 5. Left and Centre: Repainted signs with black paint; Right.: Continuous white line removed with pressurized water.

To solve this problem, the OMICRON project has started a research study in which it is trying to eliminate these horizontal marks by using laser techniques. The idea is that, through laser technology, greater sensitivity can be obtained when removing the desired thickness of the paint layer and, therefore, improve the quality of the intervention, trying to reduce the reflection of the shadow without impairing the surface or affecting surface friction.

Once the appropriate laser system has been developed, the project plans to incorporate it into the robotic platform as occurs with the cases shown above. Currently, a multitude of tests have been carried out in the laboratory where all the variables that can affect the process have been identified and modified (General Directorate of Highways, General Subdirectorate of Conservation, 2015):

- Type of paint (acrylic, plastic and two components).
- Paint color (white, yellow, and blue).
- Additives incorporated into the paint (with and without spheres).
- Thickness of the paint layer.
- Type of surface texture of the mixtures: AC (closed texture), BBTM (open texture) and AUTL (small aggregate sizes).
- Different methods of laser paints (combustion and ablation), different parameters, and different densities (modifying areas of the beam, speed of the mirrors).

Figure 6. Left. Representation of the laser tool coupled to the robotic arm for the platform on site; Centre: Laser paint removal process and test results at different parameters; Right.: Laser with robotic arm in the laboratory.

After conducting various tests in the laboratory, certain conclusions have been drawn regarding the variables involved. It has been observed that the system's functionality is heavily influenced by the thickness of the paint, the type of laser used, and the texture of the surface. However, it is found that the color and type of paint do not significantly affect the system's performance. Figure 6 shows some images where it can be seen that it is possible to obtain good results using this laser technique.

3.5 Crack sealing maintenance operations

The last use case for the robotic platform of the OMICRON project is the one corresponding to the sealing of cracks. This is an operation that is very dangerous on-site, not only because the operators are exposed to the dangers inherent to the work in terms of traffic, but also because the execution itself carries an aggravated intrinsic risk, which is spillage. Manual of liquid bituminous materials at high temperatures. The complete operation can be divided into four main stages:

- Firstly, a process in which it is necessary to clean and heat the crack. This is done with cold compressed air, but when heating is required, it is done using a thermal lance (a propane combustion lance). In this operation, it is possible to remove the dirt and heat the surface to favour the penetration of the bituminous mastic. The use of this pressurized air implies risks of projections for the operators and the possibility of burns with the thermal lance.
- The second process is the current sealing in which a previously melted mastic is applied through a lance. Here the main risk is that of suffering burns from the hot material, which is approx. 180-200ºC. In addition, burns with bituminous materials are usually serious, since this material adheres to the skin, so the burn continues until the temperature is reduced.
- The last two stages of the process are the dispensing of the cover aggregate manually to eliminate shadows and improve adhesion and the measurement of the sealed length. Typically, 3 or 4 operators are needed to complete these tasks. They must remain on the lane being sealed (closed to traffic), putting them at risk of being run over. Therefore, utilizing a robotic platform that eliminates the need for direct human involvement in the sealing process is highly beneficial, particularly for occupational safety.

The designed platform, equipped with the sealing machinery and the modifications that are being made for its automation, allows the robotic arm to perform all these functions: blowing with heating, mastic application and aggregate dispensing jointly and automatically. To do this, the project is designing a tool that, coupled with the robot, is capable of performing all these operations sequentially (see tool design in Figure 8). The platform features an AI-based perception

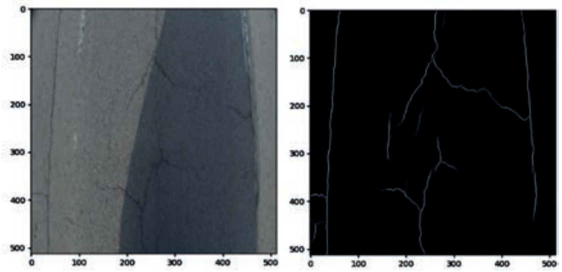


Figure 7. Left.: Real image captured by the camera; Right.: mask resulting from the AI where it identifies the existing cracks.

system that enables the identification and spatial referencing of cracks with high precision.

The process works discontinuously where the system first guides the truck driver to the intervention area. Once there, the built-in cameras take an image where the AI recognizes the cracks it contains (susceptible to being sealed) and establishes precise references, in addition to preparing the intervention sequence and commanding the robot to carry out the operations. Once the process is finished, the system guides the driver back to the next intervention point. All this automatic process is supervised by the operator through VR and AR systems on a tablet from the truck cabin, being able to interrupt it and correct it if necessary (Figure 8).

Figure 8. Left: Representation of the sealing tool attached to the robotic arm; Centre: VR footage of the crack sealing process; Right.: In-cab VR monitoring system.

4. SASPI. SMART AUTOMATION SOLUTIONS OF PAVING INTERVENTIONS

Many factors are associated with pavement construction quality. Although a well-established pavement construction control system exists in Europe, its monitoring procedures have two shortcomings: firstly, despite the use of some automatic detection equipment, such as the Pavement Quality Indicator for Asphalt mixes density measurement in the field, the system is highly dependent on manual data collection, with this having low cost-efficiency, as well as being inaccurate. Secondly, manual quality control can test limited samples of the project rather than monitoring and testing the entire project. As the sampling rate is low, resolution of data is not as high as required.

In recent years, the construction industry has adopted various real-time support systems for paving and compaction using asphalt mixtures. Studies have demonstrated that implementing these systems can give paver and roller operators a better understanding of their tasks, leading to enhanced operating strategies. In addition, it has been shown that operators who receive more and better information can prevent excessive, insufficient and/or deficient compaction of an asphalt mixture layer, which contributes to the quality of the process and the final product.

Considering the exposed premises, one of the objectives of the OMICRON project is the development of intelligent solutions to support decision-making in the replacement of surface layers of asphalt pavements, using automation technologies and promoting the use of AUTL (Asphalt for Ultra -Thin Layers).

The data that is collected and stored during the mixture production phase and during the construction phase can be integrated into the platform developed in the project for the development of a digital replica of the infrastructure.

4.1 Background

In order to ensure the best performance of the pavement, it is essential to meet the initial limit condition of producing a final product of high quality. This means that the final product must meet or exceed the predetermined quality standards set during the design phase. This is valid for the pavement structure as a whole, but it also applies to all of the individual layers that make up a pavement. In order to achieve the desired quality of the final product, the quality of the paving process and compaction must be controlled.

Figure 9. Paving and compaction detail of an asphalt mixture

Regarding the paving operation, the temperature of the mixture and the speed of the paver, and environmental conditions, such as air temperature, wind speed and other weather-related parameters, are important factors that affect the paving extended operation.

With respect to the compaction operation, proper compaction equipment, compaction techniques, and mixture compaction temperatures are essential to ensure effective compaction and surface macrotexture to achieve the desired results. Some advanced types of roller compactors are equipped with special vibration detection devices that can measure the degree of compaction of the asphalt mixture. However, in real construction environments, it is very difficult to establish calibrations with the various combinations needed to incorporate different types of mixtures, rollers, and ever-changing compaction temperatures. In addition to this, in the compaction of wearing courses of low thickness, roller compactors are used without vibration.

4.2 Description of the automation-monitoring system for paving and compaction

The asphalt pavement construction automation-monitoring system covers the following steps of the process:

- Tack coat (emulsion) application,
- Asphalt mix laydown and,
- Compaction operation.

The purpose of this system is to perform automatic data collection and data transmission and should automatically provide feedback to the construction site for real-time asphalt pavement construction control and automation.

The major challenge today in automating the control process is the automated measurement of project performance indicators (PPIs). The effective control of these indicators requires information in real-time. To this end, a sensor system has been designed that collects said information in real-time. Furthermore, this information is stored and analysed, providing feedback to the operators or parties involved in the process. The system design and its development process have focused on its feasibility, providing a quality control system that is stable, reliable, easy to use and reproducible (Figure 10 and Figure 11).

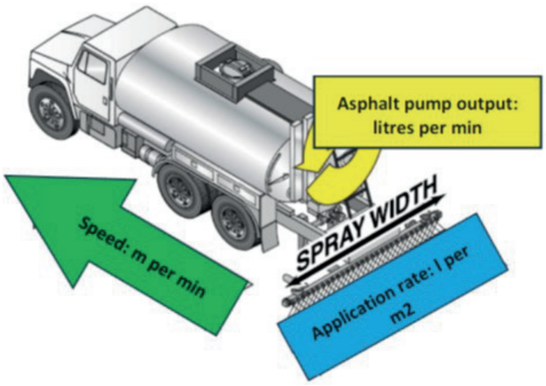


Figure 10. General emulsion distributor monitoring scheme.

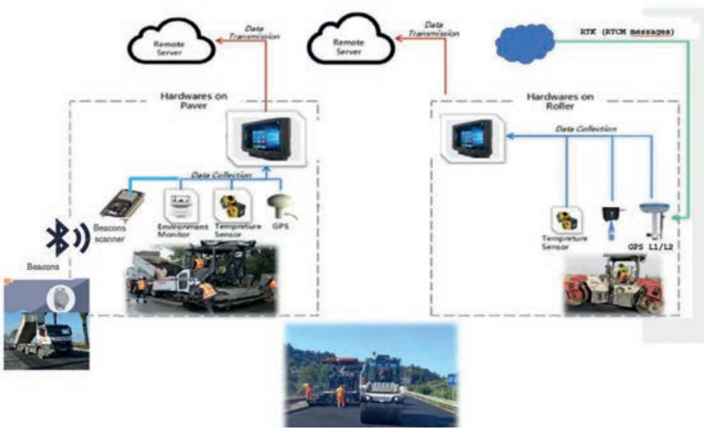


Figure 11. General paving and compaction monitoring scheme

The functionality of the system consists of three layers as shown in Figure 12.

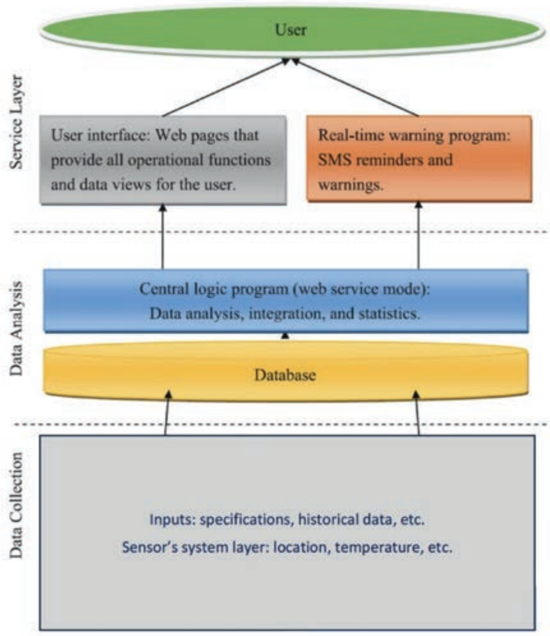


Figure 12. System functional layers.

- Data collection layer: This is the most basic layer, responsible for collecting and uploading data in real-time.

- Data analysis layer: It is the central component, formed by the database and the central logic program. This program is developed in web service mode, which does not directly interact with users, but provides a variety of function interfaces to the service layer.

- Service layer: This layer, which communicates directly with users, is made up of the alert program for web pages and SMS messages. Web pages are responsible for requesting data from user instructions and displaying the results through a graphical user interface. The SMS warning program takes care of constantly checking the latest data and sending SMS messages to certain people when necessary.

Under this architecture, the tasks of each module are clear, and the integration of tasks with each other reduces the overall tasks. Internal optimisation, maintenance or improvement in any module will not affect the normal operation of other modules or the entire system.

4.3 Developments and innovations of the automation-monitoring system for paving and compaction

4.3.1 Asphalt mixture thermal control

One of the requirements or specifications for the application of asphalt mixture is its thermal control during paving operations. For this purpose, the system has been outfitted with two thermographic cameras on both the paver and compactor units. For the thermal control of the mixtures and the integration of the thermographic cameras, the UNE 41265-1 IN standard has been considered, which allows continuous measurement on the surface with IR sensors. In this instance, the chosen thermographic cameras are the LIR 320 model, capturing a static image of the temperature distribution across the asphalt mixture layer.

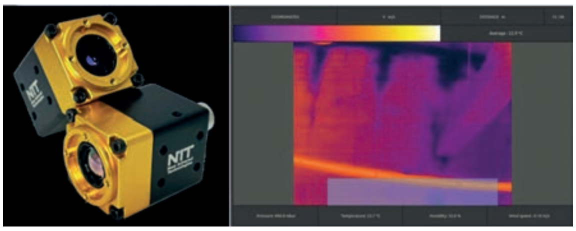


Figure 13. Details of thermal imaging camera and viewing platform

4.3.2 Positioning, trajectories, and speed of the paving and compaction machinery

Paver geolocation is also a system functionality intended to control various aspects of paving operations. On one hand, we will have geolocated the measurements and data taken in real-time by the sensors integrated into the system during paving and compaction operations. On the other hand, it is recommended that the paver run continuously at a constant speed, if possible. Therefore, by monitoring the continuous data of the Global Positioning System (GPS) it is possible to determine the speed and stop times of the paver. In our scenario, to determine the geographic position of the paving equipment, we have opted for the GlobalSat BU-353-S4 GPS receiver. Through the conducted tests, this receiver has consistently delivered accurate and stable data for geolocation and speed estimation.

Figure 14a. GPS test details

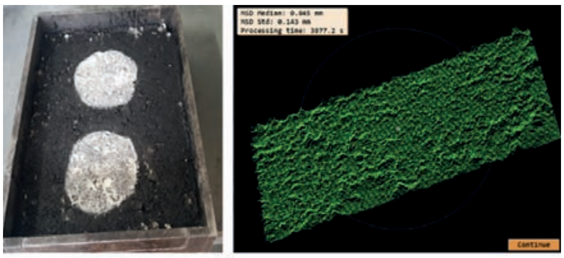
Asphalt mix compaction level depends, among other factors, on the number of compaction roller passes, or what is the same, on the force applied to the material to be compacted. Therefore, a study is being carried out to develop the part of the system that monitors the trajectories of the compactor's movement and visually shows them to the operator. For this, the GPS receiver mounted on the roller compactor uses a differential GPS technology (GPS + RTCM message), which allows improvement in the precision of the position of the compaction equipment. In this way, we will obtain the data on the number of passes of the compacting roller for each square meter of surface, and we can analyse different aspects, like the homogeneity, of the compaction process.

4.3.3 Macrotexture monitoring

Asphalt pavement surface macrotexture has an important role in traffic safety. It contributes to skid resistance, especially on roads where higher speeds are developed and in wet surface conditions, due to its influence on water drainage and the reduction of the hydroplaning effect. Consequently, a sufficient level of surface macrotexture reduces the risk of traffic accidents. The compaction mode is a construction-related factor which significantly influences the achieved texture depth in the field With this consideration in mind, an on-site macrotexture monitoring system is currently under development within the framework of sensor integration. For this, the solution adopted is the installation and integration of a laser scanner (Gocator 3D) with structured light projection technology to measure the macro texture of the surface according to the UNE-EN ISO 13473-1 standard during the compaction process. This scanner is going to be installed on the roller compactor.

Figure 15a. 3D sensor

The tests conducted thus far at the laboratory level provide reliable and stable macrotexture measurements on asphalt mixtures using unmodified bitumen, as depicted in Figure 15b.



Lab. slab	MTD (laboratory)	MTD (Gocator 3D scanner)
Sample 1	0.55 (0.52, 0.57)	0.60
Sample 2	0.69 (0.74, 0.64)	0.67
Sample 3	0.83 (0.86, 0.81)	0.84

Figure 15b. Details and results of macrotexture measurements with a laser scanner and comparison of results with the sand patch test

On the other hand, regarding the result obtained for tests carried on site (Figure 15c), the main conclusions until today are as follows:

- There appears to be a reduction in on-site test data when compared to laboratory data, likely arising from differences in surface (asphalt) temperature and brightness. Nevertheless, there is still an adequate amount of data to facilitate measurements throughout the process. Study of other conditions, changing certain sensor parameters are ongoing.
- Drawing a comparison with the outcomes of the sand patch test poses challenges due to significant variations in results depending on the operator conducting the test. Additionally, there is not a complete alignment between the surface measured by the sensor and the sand patch.

Figure 15c. Details and results of macrotexture measurements with a laser scanner and comparison of results with the sand patch test

4.3.4 Comprehensive analysis of the automation-monitoring system for paving and compaction

The main contributions of the monitoring system platform being developed at OMICRON are its ability to carry out real-time detection and issue warnings of certain anomalies that are occurring during asphalt pavement construction, allowing for corrections. timely. More importantly, the fact that the entire data set obtained during pavement construction monitoring can be stored permanently and can be consulted and analysed at any time, has important positive implications for the maintenance and management of the pavement during its life. of operation. This data is valuable for the subsequent management of pavement maintenance after the pavement has been opened to traffic.

In short, the SASPI system (Smart Automation Solutions of Paving Interventions) aims to contribute to the leap from the concept of Quality Control to the concept of Quality Assurance and Management in the commissioning of asphalt mixes and the construction of asphalt pavements.

5. PREDICTIVE MAINTENANCE: DIGITAL TWIN AND DECISION SUPPORT

5.1 Highway Digital Twin

The information captured by the inspection technologies developed in the project, as well as the data coming from legacy systems or the modular robotic platform (section 3) and the SASPI system (section 4), are exploited for the generation of an OMICRON Highway Digital Twin, conceived as a digital replica of the infrastructure in an environment that combines:

1. The BIM representation of singular assets, such as bridges or tunnels.
2. The GIS representation of linear assets.
3. Static and dynamic data from the infrastructure.
4. The information and analysis carried out on said data, for example, in terms of structural analysis or prediction of the condition state of pavements.

The Digital Twin data management system acts as a key element to ensure data is interoperable and facilitates its use and integration. In this way, the system incorporates data related to the geometric characteristics of the assets, the status of the different subsystems and historical maintenance information, among other related data sources.

These sources of information provide large volumes of data to generate that digital representation of the infrastructure. OMICRON has defined an innovative workflow in the Digital Twin broadly composed of:

- A graph-oriented database to imitate real road assets in all their relevant aspects, including their geometry, their condition and all the necessary first-hand information for their exhaustive analysis.
- A set of storage elements and databases of different types in which the lowest level information is stored, which is always not necessary in the Digital Twin, such as maintenance records older than five years.In this way, it seeks to optimize processes, costs and waiting times to the maximum when interacting with the Digital Twin.

In this context, the digital inspection technologies described in section 2 are coordinated in such a way that the inspection vehicle provides a detailed representation of the pavement while the UAVs provide an overview of the rest of the assets, including bridges and surrounding structures. The necessary processing chains have been defined (including different layers of data management, integration and services) to process and store data from inspection activities and other sources and turn them into information available in the Digital Twin and in the different flows of data analysis (Figure 16).

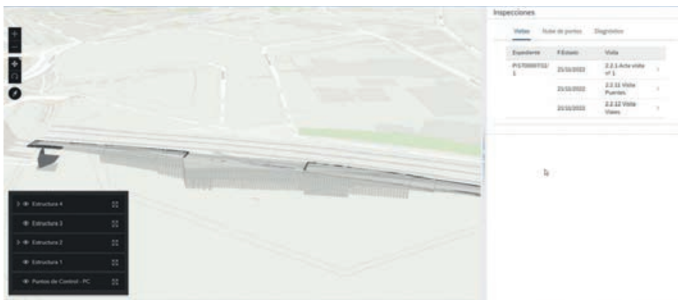


Figure 16. Visualization of the Digital Twin under development by CEMOSA. Example of information from inspections and used in the Decision Support System

5.2 Decision Support System

Infrastructure information from the Digital Twin is used to feed OMICRON's Intelligent Decision Support System. The ultimate objective of this system is to manage maintenance interventions in road infrastructures, coordinating with the rest of the project's intelligent intervention solutions (Consilvio, et al., 2022).

OMICRON develops a tool for the optimal planning of interventions and resources, considering the different sources of uncertainty, including the prediction of the state of assets and other factors of the operating environment. This system improves existing intervention planning workflows and seeks to create a stable link between data collection, the extraction of information and knowledge about the road network, and the automated execution of interventions.

a. The bases of this system under development at OMICRON are:

b. The prediction of the state of the infrastructure.

c. The evaluation of the risk of failure.

d. The creation of a planning procedure to improve the availability and reliability of the infrastructure while maintaining security levels.

In addition, the impact on traffic and the optimization of resources are considered in line with the information from the previously described Digital Twin. The system uses Artificial Intelligence algorithms both for the evaluation of the state of the infrastructure and for the decision-making process. In addition, advanced optimization techniques are used to progress in the automation of decision-making. In this way, the decision support system must adapt to the planning procedures in the short, medium and long term in a flexible way, for which four main use cases have been orchestrated:

Use case 1: Pavement condition status. The objective of this case study is the development of predictive models to calculate the condition state of pavements based on historical information related to parameters such as IRI, CRT and deflections (Figure 17).

Figure 17. Visualization of the decision support system. Example related to use case 1 where several road sections with different condition states are displayed.

Use Case 2: Monitoring of the structural health of bridges. This case study uses information from IoT sensors installed on bridges and connected to the OMICRON platform to perform advanced dynamic analysis on their structural integrity.

Use Case 3: Processing of information from digitized inspections. This use case uses the information from the inspection systems using UAVs and ground vehicles developed at OMICRON to assess the condition status of the infrastructure.

Use Case 4: Execution of maintenance. This use case uses the information from the previous use cases as well as the information related to traffic and the history of maintenance interventions to improve future planning of conservation activities for different assets such as pavements or bridges.

The connection of the Digital Twin and the Decision Support System aims to optimize maintenance execution, reducing costs and taking into account the resources available at all times, while ensuring an optimal level of service on the road.

CONCLUSIONS

This article has provided a concise overview of the OMICRON Intelligent Road Management Platform, highlighting three of the project's developed technologies:

- Modular Robotic Platform for roads.
- SASPI. Smart Automation Solutions of Paving Interventions.
- Digital Twin and Decision Support System.

Thus, OMICRON is a market-oriented project where the demonstration and evaluation of the technologies are planned in three stages with the aim of reaching TRL7 (demonstration in an operational environment) in different pilots in Portugal, Spain and Italy.

- Phase 1. The first tests of the project are being carried out between TRL 4 and 5, addressing the different OMICRON developments. The main objective is to enrich the data-based technologies of the project.
- Phase The second phase focuses on the technical demonstration of technologies

individually with the aim of allowing the transition between TRL 5 (laboratory tests) and TRL 7 (tests in operational environment). These pilots will take place on the A3 motorway in Portugal; on the A-2 in Guadalajara; on the A-92 in Seville; and on the A-7 in Valencia.

- Phase 3. The final demonstration of the project will take place on the A1 motorway between Florence and Bologna. This pilot will evaluate the entire asset management platform.

In conclusion, the OMICRON project aims to have a significant impact on road management in different areas, which can be summarized in four main areas:

1. Reduction of fatal accidents related to conservation work.
2. Reduction of traffic congestion derived from maintenance.
3. Reduction of conservation costs.
4. Improvement of the capacity of the network with respect to the levels measured without the use of the technologies of the project.

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