

IQRN 3D: A TOOL FOR BETTER MANAGEMENT OF FRENCH ROAD ASSETS

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ABSTRACT

135 billion euros is the estimated value of the French road network. This road network, one of the pillars of the French economy, induces significant maintenance costs, valued at 10 billion euros per year for all roads (excluding bridges and road structures).

These ever-increasing road maintenance needs and the will to optimise its maintenance works in a long-term perspective led the French State to set up in 1992 an evaluation of its network, called IQRN for “Image Qualité du Réseau National” (National Network Quality Index).

In 2015, in order to improve the relevance of the indicator, the French State asked Cerema to develop and produce the third generation of the IQRN methodology.

In 2018, Cerema introduced the IQRN3D methodology.

Based on Pavometrics Laser Crack Measurement System (LCMS) sensors and an accurate GNSS localization system, Cerema has designed two new inspection vehicles called AIGLE 3D. To make the 35,000 km annual measurement campaign more reliable, we have implemented an optimized organization and significant improvements such as remote maintenance and a merged tool controlling all vehicles sensors.

Pavometrics, a partner of Cerema, has developed the LCMS system and new 3D features for measurements up to 130 km/h. This set (LCMS sensors, localization) provides a 3D model of the road instead of considering it as a single wire. Thus, we obtain an accurate representation of the data collected with the system. It is also possible to analyse the data as closely as possible to reality, to understand the 3D behaviours of the road, to evaluate the evolution of degradation between several surveys and especially to ensure exceptional repeatability.

Based on these data, Cerema has developed a methodology and indicators to:

- Report annually on the condition of the network to the national contracting authority, through a condition index characterizing the level of pavement degradation;
- Assess the financial resources needed to maintain the network and ensure an objective territorial distribution;
- Manage risks by developing an indicator characterizing vulnerability to climate hazards and heavy traffic;
- Monitor the condition of the network and the effectiveness of maintenance.

This integrated heritage management methodology will make road asset management more efficient in the short term by helping to understand pavement deterioration mechanisms. Finally, the impact of public policies undertaken or to be undertaken will be analysed.

1. MAIN NEEDS IN THE FIELD OF INFRASTRUCTURE ASSET MANAGEMENT

Thanks to an extraordinary collective effort from the 1960s to the 1990s in France, the road network was developed according to a proactive technical policy that created a new method of road construction, with moderate costs, without neglecting the quality of the work, and anticipating future maintenance needs.

The quality of the constructions of this first phase of modernisation and the implementation of rational maintenance policies have enabled us to be in a simple maintenance cycle for twenty years, with an exceptional service versus maintenance cost ratio.

Today, a large majority of road components has far exceeded their design service life.

Moreover, for pavements, for example, successive maintenance work has changed their behaviour, generating significant heterogeneities. The impact of heavy goods vehicle traffic has evolved very strongly towards a much more aggressive approach. This does not mean that all pavements must be rebuilt. Indeed in this field the notion of service life covers a relative reality. On the other hand, this means that road assets have entered a regeneration cycle.

This observation does not only concern pavements, but can also extend to other equally important objects, such as blue areas around roads. Indeed, dysfunctional drainage can lead to the loss of even new pavement, and the dysfunctional surface water drainage can lead to insecurity for users.

However, the current road estate is not the same as in the 1960s; the approaches used at that time are clearly inadequate for the current situation. Maintaining this estate in operational conditions and making it sustainable are therefore challenges in themselves.

Finally, our heritage is facing a new era: societal changes (social acceptability, accessibility, roads for all, reserved lanes...), technological developments (connected vehicles, BIM, e-Navigation of ships, open data and big data...), new climate conditions. These are considerable challenges that must be met while saving resources, both in terms of financing and raw materials.

2. LIMITATIONS OF CURRENT APPROACHES

For several decades, the scientific and technical services have been working on the development of materials capable of accurately characterizing the condition of the road estate. Regarding degradation inspections, technological developments have reduced operators' exposure to road risks. By encouraging image-based laboratory surveys, it was not possible to avoid the operators' "eyes" sensor. Despite training efforts and regular cross-testing, the reproducibility values obtained through visual surveys influenced the quality of the results obtained. They also limited the possibilities for periodic monitoring of the road estate. Finally we faced a lack of knowledge and we were not able to anticipate disruptions such as those that have occurred in recent winters (Figure 1).



Figure 1 : Potholes occurring on the road.

With regard to other characteristics, the limited needs of project managers in road asset management during the 2000s did not lead to a dynamic auscultation market.

The new devices are in line with existing French LPC test methods without compromising their fundamentals. However, this can be qualified by a change in the longitudinal evenness of the LPC test method n°46-2 of July 2009, and the addition of a module on the evaluation of high-traffic pavements. This use of longitudinal profile, although relevant and simple to implement, remains poorly known and little used today.

The 2000s did not therefore mark the field of auscultation with an evolution in the performance of measuring equipment. On the contrary, they have led to the emergence of tools with limited performance, certainly offering managers access to data but whose quality is not fully controlled.

In 2006, in response to the changing organizational context and pavement testing technologies, the French State asked scientific and technical staff to modernize the national road network assessment methodology - IQRN.

The experts were able to update the methodology thanks to the knowledge developed since the 1990s, when the IQRN was built. Hypotheses on the degradation process have then been retained. However, regarding the association of specific tyre tread cracking with foundation problems, the feedback from experiments reflects the limitation of this hypothesis (Figure 2). Indeed, several studies have highlighted different cases of longitudinal cracking specific to the tyre treads, which does not reflect problems of pavement fatigue but a thermal phenomenon of the surface that seems to affect only the integrity of the upper-layer. Unfortunately, it is difficult today to extend this phenomenon to the national road network scale. This phenomenon probably varies according to the regions and materials used. Moreover, with regard to transverse deformations, taking into account the simple creep of the surface layers is not sufficient with regard to the structural pathologies observable on the network. Deformations such as punctual subsidence of tyre treads often require heavy intervention by managers.

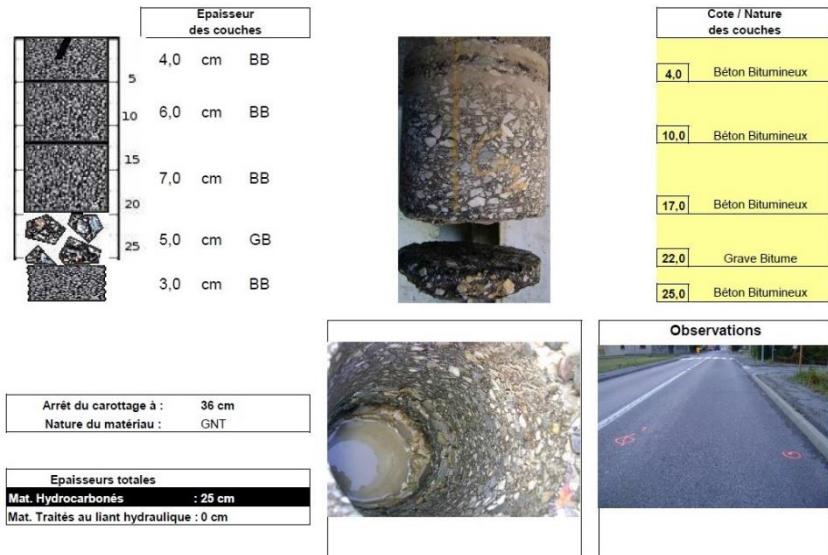


Figure 2 : Cracking in the tyre lanes that only affect upper-layer of the road.

All descriptive information of pavement conditions is now reported to a wired system. However, the transverse heterogeneities linked to the supporting ground, generated during the construction or operation phases by the variety of vehicle silhouettes and the absence of channelled traffic, highlight the need for a surface approach for a "realistic" characterisation of the condition of the pavement structure.

Finally, the entire road community agrees on the need for preventive maintenance to optimize the management of road assets. The questions are: do the indicators available today make it possible to anticipate what road degradation is? Does the cracking correspond to an already advanced state of structural degradation?

3. MODERNIZATION OF MANAGEMENT METHODS

Since 1992, Cerema has been working on the Public National Road Network (PNRN) to evaluate its condition. An indicator, the National Network Quality Image (French: IQRN), is published annually based on the evaluation of one third of the network.

In 2015, the French State asked Cerema for a major change: being able to evaluate all the slow lanes of the PNRN as well as the so-called expressways and ramps each year. This challenge then involves modernizing inspection vehicles (equipment), data processing and asset management methods.

3.1. New high speed inspection vehicles : Aigle 3D

As early as 2016, Cerema chose LCMS© technology (Figure 3) to equip its new inspection vehicles: Aigle 3D. These sensors make it possible to model the pavement surface in 3 dimensions with a resolution of one point every mm and a relative accuracy of about 0.25mm for altitude. They can also be operated day and night at a speed of 80 km/h or even 130 km/h depending on the configuration.

These sensors are associated with algorithms that make it possible to detect automatically:

- Surface degradations including cracks, potholes, macrotexture, etc..;
- Deformations of the pavement including rutting and longitudinal deformations;

- The geometry of the pavement with the slope, cross-slope and curvature.



Figure 3 : LCMS Sensors of Pavometrics© company

A satellite positioning system (GNSS: Global Navigation Satellite System) equips the Aigle 3D measurement system. To improve the quality of data location, each LCMS© sensor is equipped with an inertial sensor. This instrument allows integrating the movements of the sensors (acceleration, angular velocity). Thus, their orientation, speed and position are estimated more precisely. The absolute positioning accuracy of the acquired data is 1 to 3 meters depending on the measurement conditions.

In the processing chain, a device for post-processing location data completes the on-board measuring instruments. It provides optimized location results through corrections applied to the measurements. These corrections are derived from a network of GNSS reference stations. The solution chosen ensures a very regular implementation throughout the French territory. Practically, this system improves absolute accuracy to less than 50 cm.

The prototyping and development of the Aigle 3D vehicles was entirely carried out by Cerema teams, which allowed innovative technologies to be tested.

The integration of Pavometrics LCMS© sensors was carried out entirely by a Cerema's Prototype Design and Construction Centre, on vehicles custom-made by Renault Tech according to Cerema specifications.

Thanks to constructive exchanges and long-term collaboration, the sensors and associated softwares have undergone numerous technical improvements, both by Pavometrics exclusively for Cerema and internally.

In addition, an annual inspection and calibration of the LCMS© sensors by Pavometrics guarantees the proper functioning and quality of the acquisitions made.

Among the tools developed at Cerema, the 3D Eagle (Figure 4) exploits to the maximum all the advantages associated with the Tool Holder Architecture (French *Architecture Porte Objet: APO*). It allows to control all sensors and embedded equipment, combined with decimetric GNSS and route guidance.

Finally, the implementation by the Prototype Design and Construction Centre of "low level" remote maintenance and telemetry makes it possible to carry out remote diagnostics in the event of malfunctions. In many cases, it is even possible to intervene without repatriating the vehicles.

All these improvements are part of safety objectives for road operators and users, but also to guarantee the quality of the data produced.



Figure 4 : Aigle 3D inspection vehicle developed by Cerema and equipped with LCMS© sensors.

3.2 Data collection and exploitation process

After their acquisition, the data collected by the Aigle 3D inspection vehicles are transferred to a dedicated servers centre owned by Cerema for processing and exploitation (Figure 5). It makes it possible, among other things, to process large amounts of data and make them available for better infrastructure asset management.

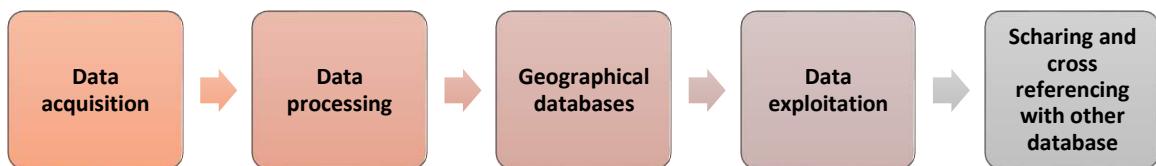


Figure 5 : Global process for data collection and exploitation.

Thus we can distinguish 5 steps in the processing process:

- Data acquisition with Aigle 3D vehicles
- Data processing via algorithms to detect damage, deformations, signs of pavement fatigue, geometry and objects on the pavement (horizontal signs, sewer drains, etc.).
- Precise geolocation of the data collected in this way to create geographical databases.
- Data exploitation and analysis to work on the creation of relevant information, indicators and tools for infrastructure asset management.
- Sharing and cross-referencing of results with other databases, including potentially those of managers. This step is ensured in particular by the interoperability of the data produced.

3.3 Data collection with this new system

The data processing system developed at Cerema makes it possible to precisely geo-locate all degradations, deformations, geometry and objects present on the roadway.

These data can be visualized in a geographic information system (GIS) and directly exploited. In Figure 6, two types of elementary descriptors can be observed: cracking (black lines) and longitudinal deformation of the pavement (gradient from green to red) on a bidirectional pavement. The entirety of the two lanes is assembled using two Aigle 3D runs (one in each direction).

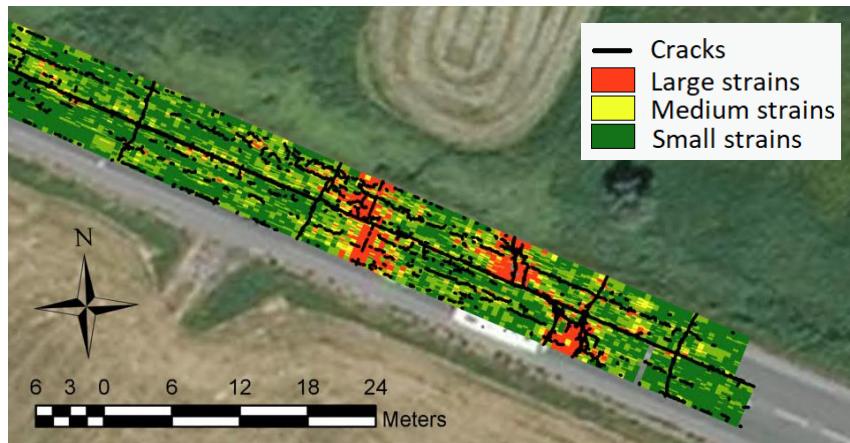


Figure 6 : Two lanes road and the representation of degradation (strains and cracks) made from two Aigle 3D runs.

All data are geolocated. It is therefore possible to store them in geographical databases. These are structured to allow a fine exploitation of the acquired and processed data.

This data structuring makes it possible to ensure, among other things:

- The possibility of adapting to a large number of road standards, making it possible to meet the needs of road managers,
- The validity and durability of the data and their location over time,
- Precise monitoring of the evolution of pavement condition data,
- The possibility of integrating future approaches still in development, such as BIM (Building Information Modeling).

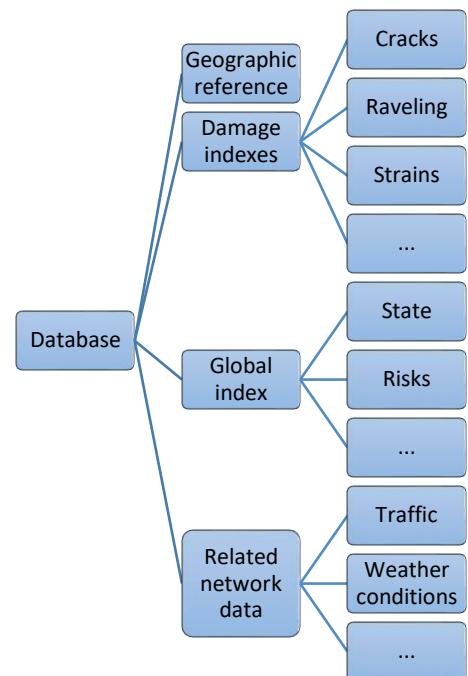


Figure 7: Exemple of a geographical database.

Figure 7 shows a typical schema of the data structuring implemented in the context of Aigle 3D data exploitation.

The data acquired with the Aigle 3D inspection vehicles also make it possible to model the road surface in 3D with a resolution of 1cm. This allows for a precise analysis of the road pavement geometry. Figure 8 shows an example of 3D data processing with the cracking data superimposed.



Figure 8 : 3D view of the road with cracks from Aigle 3D measurements

It is also possible to reconstitute complete platforms by aggregating several successive runs. Once reconstituted, the 3D model of the pavement surface is modelled by a cloud of geolocated point with excellent absolute and relative accuracy. This data allows a global analysis of the platform.

This accuracy of the representation of the damage, or object identified, whether in terms of location or shape, has made it possible to design descriptors and indicators, slightly smoothed to allow direct monitoring of the evolution over time, which in the context of the IQRN are annual.

The visual result allows the actors to understand the behaviour of their pavement in all its dimensions and to compare the evolution between two passages spaced one year apart.

In the first feedback, the finesse of detail of the Aigle 3D data, coupled with their ability to scan a large surface, has produced descriptors that are sensitive to damage that have so far been poorly identified with high performance, or even poorly quantifiable with traditional tools.

Still on the subject of the descriptors and indicators produced, the comparison tests between successive passages show that these objects, descriptors or indicators, which are surface and geocoded, have a robustness that has not yet been achieved. To such an extent, that fine monitoring of the damage over several years and over the entire population is finally possible. The mass of information thus produced will make it possible to quickly initiate predictive maintenance approaches and enter a new cycle of maintenance rationalization.

From a human point of view, after a long period of mistrust in the face of a total reversal of the way of modelling a pavement, the first elements produced are very well received, particularly by managers, and even generate new requests for the exploitation of these new objects in non-traditional approaches.

4. ROAD ASSETS MANAGEMENT OF THE FRENCH ROAD NETWORK

4.1. First lessons from the IQRN modernization

The first lessons of the ongoing work on the modernization of the IQRN indicator confirm all the hopes placed in this heavy investment.

Cerema's objective is to develop the use of its new tools for all types of pavements, including motorways, departmental roads, ports and airports. These tools are designed in a sufficiently flexible way so that this development can adapt to each project owner. The results of such partnership work will lead to the definition of indicators able to support the technical policy that the project owner wishes to implement. Thanks to its strengths, the system will lead to new Cerema services such as long-term data hosting for multi-year section monitoring, the production of behaviour laws and the definition of technical recommendations.

A rapid appropriation of a surface approach is now possible to all types of actors. The technologies implemented in the computer centre seem to be able to propose a new type of pavement management system, by making strong links between all people involved in pavement maintenance.

4.2. Results and short-term outlooks

The quality and accuracy of the data acquired with the Aigle 3D inspection vehicles and processed with a server centre and geographical databases makes it possible to develop surface approaches and no longer just linear as before.

Methodologies based on the surface description of the pavement and its 3D modelling make it possible to report the real pavement conditions. Thanks to these more detailed approaches it will soon be possible to monitor changes in pavement conditions or the risks due to climatic hazards for example. These indicators are essential components in the process of adopting a complete wealth management approach of a network.

The richness and reliability of this data also makes it possible to adapt the tools according to the use and objectives of each network manager. As a result, the system can be adapted to the needs of every project owners. Indicators can be designed to support a technical policy, its monitoring and its evaluation over time.

Figure 9 shows an example of a pavement condition indicator designed from elementary descriptors describing the pavement. Three states (green, orange and red) can be distinguished related to the level of perceived degradation of the pavement surface.

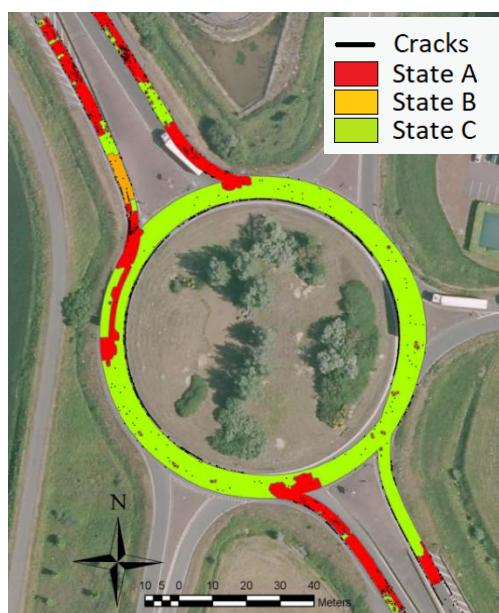


Figure 9 : Cracking and surface indicator of a road pavement.

These developments are now leading to new assets management systems related to each manager wishes. These tools enable infrastructure managers to make right decisions about the management of their network.

Figure 10 shows an example of one road section represented with a surface shaped diagram of the state of the pavement. Three states are once again represented. The indicator is represented for two successive years (2017 and 2018). The evolution of the indicator between two passages of the Aigle 3D inspection vehicles is then characterized.

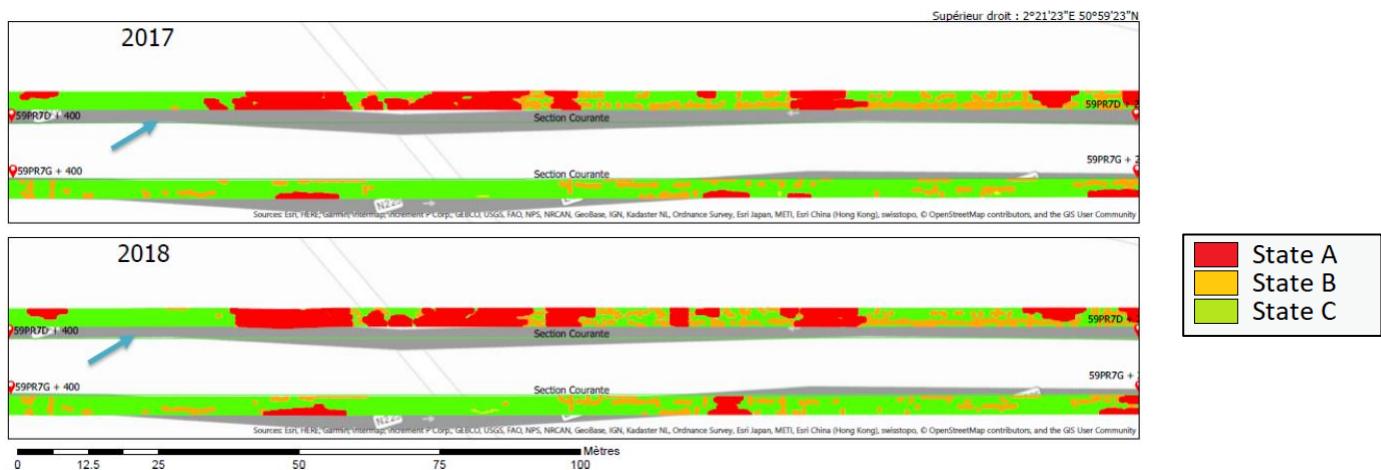


Figure 10 : Comparison of the state indicator between two runs made in 2017 and 2018 with Aigle 3D inspection vehicles.

In the very near future, these tools will allow a detailed analysis of the evolution of pavement conditions. The knowledge acquired with these tools should lead us to the definition of pavement behaviour laws. These laws will serve as a basis for simulations of the evolution of the state and will contribute to the development of predictive methods for infrastructure assets management.

5. CONCLUSIONS

One of the major lessons from the modernization of the IQRN indicator is that today the context makes a major overhaul of road asset management realistic. This necessary overhaul ensure that this management is in line with current challenges.

The development of the inspection vehicles called Aigle 3D is a first step that allows us to consider new solutions in the field of infrastructure asset management. It will serve as a solid basis for developing further responses for road network managers, whatever the type of network, its scale, the use of data and the objectives pursued in terms of asset management.

Finally, the system can be adapted to meet the challenges of digital model development (BIM). More generally, it can be integrated into broader visions such as integrated asset management and the resilience of transport infrastructures.