ROADMAP FOR THE DIGITAL ADAPTATION OF LOCAL ROADS

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Introduction

The road network plays a priority role in the digital adaptation of mobility. The European Commission, through its Digital Strategy[1], recognises the importance of advancing a transition toward smart and sustainable mobility. It highlights the role of digitalisation in achieving cleaner, safer, and more efficient mobility while emphasising the potential of technologies such as Artificial Intelligence, the Internet of Things, cloud computing, and 5G networks.

To progress toward a model of safe, sustainable, and connected mobility, it is essential to implement a true digital and green transformation of the road sector. It is vital to underscore the significant potential of the local road network in developing technology-based solutions for its internal processes and for infrastructure and mobility management.

The current report is based on the approach adopted in Spain at the Forum of Road Managers of Local Governments, an entity that brings together local road administrations under the coordination of the Spanish Road Association (AEC)[2], a member of the Smart Transportation Alliance (STA)[3]. Within this framework, the "Roadmap for the Digital Adaptation of Local Roads" has been developed through a specific "Digitalisation" working group, with the support of other public and private entities. The "Roadmap for the Digital Adaptation of Local Roads" was presented in May 2024, at the headquarters of Alfonso X University in Madrid, Spain[4].

Global Vision of the Digital Adaptation of Roads

The aspiration of the road network should be to progressively achieve digital transformation by following a three-phase process: data digitalisation, process digitalisation, and digital transformation/adaptation, as shown in Figure 1.

Figure 1: Phases of digital adaptation of roads (own sources)

Currently, most local road administrations have taken initial steps in phase 1 and, in some cases, phase 2. It is therefore necessary to continue advancing progressively through these phases to reach phase 3, optimising the benefits this entails for road management and citizen mobility.

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[1] https://digital-strategy.ec.europa.eu/en/policies/digitalisation-mobility
[2] https://www.aecarretera.com
[3] https://www.smart-transportation.org
[4] Youtube channel of the Spanish Road Association: https://www.youtube.com/live/5SslNU_L2Dw

The digitalisation of roads is closely linked to the availability of data, as well as the communication and management systems required for creating new services or improving existing ones. The definition of data, its compatibility, and its storage are essential. It is critical that the data obtained through various processes is compatible to enable its exploitation and analysis while minimising intermediate processes.

The proper utilisation of data can generate significant value for organisations, making it essential to manage data effectively and efficiently. Data governance refers to the set of policies and best practices that enable processes aimed at promoting data as an asset within the organisation to improve decision-making. Data governance establishes policies that ensure confidentiality, availability, resilience, and transparency of data, while data management focuses on the implementation of these procedures.

When considering the digitalisation of infrastructure and mobility on local roads, two complementary areas of work can be distinguished:

A - Internal Digital Adaptation of Road Management Processes ("Internal" Digital Adaptation):
The use of digital data and technology optimises existing processes, facilitating their execution, reducing the likelihood of errors, and lowering costs and time. It also enables improvements through new processes tailored to the needs of road management. Significant progress has been made in this area in recent years.

B - External Digital Adaptation of Roads ("External" Digital Adaptation):
This refers to the use of technology to improve services for road users, create new services, and develop services unrelated to the traditional uses of roads. The traditional concept of the road as infrastructure enabling mobility is expanded to also consider the road as a data-support platform.

For both internal and external digital adaptation, it is crucial to ensure the appropriate training of those involved to address the challenges of a new approach to road management and optimise the benefits that can be achieved with these new tools.

Internal Digital Adaptation

The management of the road network, traditionally based on routine inspections, traditionally carried out manually and on foot using in-house resources, has evolved to incorporate inspections using increasingly instrumented vehicles. These vehicles leverage technologies such as lasers or image capture, with growing involvement from the private sector. This evolution has not excluded the local road network.

Emerging software systems have optimised the use of this information through asset management programs, enabling better planning and execution of maintenance tasks. These systems are now integrated with Geographic Information Systems (GIS), incorporating multiple useful datasets for network management.

This section includes a proposed set of steps to advance the digital adaptation of road administration processes. It is presented as a suggestion, acknowledging that each administration may decide to begin and continue its digitalisation processes differently, depending on its situation, degree of progress, constraints, objectives, and other factors.

In the context of the "internal" digital adaptation of the local road network, it is important to differentiate between:

- The needs for adapting the infrastructure and its environment.

- Improving the management processes within the administrations themselves.

1.1. Internal digital adaptation of road infrastructure

Following the principles of the mentioned roadmap, the following processes are defined for the internal digital adaptation of road infrastructure, as described below:

Digitalisation of road infrastructure and equipment	→	Digitalisation of public road domain	→	Development of an internal road network management platform

Figure 2: Processes in the internal digital adaptation of road infrastructure (own sources)

1.1.1. Digitalisation of infrastructure and its equipment

The first step is to create a digitised map of the road network and its main elements, serving as the foundation for digitising administrative processes. It includes conducting a parameterisation of the road and a geo-referenced inventory that includes at least the following information:

- Identification of sections: kilometer and hectometer markers, interurban/rural/urban environment.

- Geometric data of the road: width of the cross-section, longitudinal and transverse profiles, superelevation, number of lanes, shoulders, visibility, weaving, overtaking lanes, merges, and diverges, etc.

- Type and condition of pavement: types of deterioration, crack classification by dimension, etc.

- Vertical and horizontal signage: inventory and typology of signs; overtaking zones.

- Vehicle containment systems, including motorcycle protection systems.

- Guidance equipment.

- Lighting.

- Road junctions: type, sections, layout, ramps, auxiliary elements (e.g., additional lanes).

- Public transportation stops.

- Access points.

- Structures.

- Tunnels.

- Roadside margins: walls, cut slopes, embankments, slopes, obstacles, etc.

- Drainage facilities: longitudinal, transverse, and underground drainage systems.

- Infrastructure for vulnerable users.

1.1.2.   Digitalisation of public road domain

This task is focused on taking advantage of data collection to digitise the public road domain and areas of property restrictions regulated by the relevant road legislation, as well as any other additional records or information of interest.

Generally, documentation related to the public road domain of a road network often dates back many years and exists in paper format. To address this, it is necessary to initiate and complete a process of digitising the public road domain and expropriation records for all roads under the administration's jurisdiction.

This activity involves searching for, locating, and scanning all records related to the public road domain, so that progressively, geo-referenced information about the entire road network's surroundings is available and can be easily accessed through a digital archive.

1.1.3.   Development of an internal road network management platform

The digitised map of the road network, its equipment, and the public domain must be integrated into a platform that facilitates asset management and incorporates functionalities of interest for managing administration. This action involves the development and implementation of a digital platform that integrates the geo-referenced information of the road network with data on activities and records. The platform's functional innovations should be reusable by systems developed for road management.

The goal is to have a tool that optimises road network and mobility management, meeting emerging needs and even anticipating issues such as conservation planning. At this stage, it is essential to unify all road network management processes into one (or several) platforms, enabling scalable expansion as new needs and requirements arise. As previously indicated, it is critical to define the data to be included thoroughly to ensure compatibility.

The system should allow access to and visualisation of the geographical information of the network and its integration with activity records and administrative contract files. Additionally,

it should support the incorporation of other data, such as inspection results using drones for specific locations.

It should also allow for the periodic integration of data on traffic, weather conditions, etc.

Within this approach, the progressive implementation of the Building Information Model (BIM) in all activities should be considered, involving both the public and private sectors.

1.2. Internal digital adaptation to improve management processes

Digitalisation of processes is divided in two steps:

Figure 3: Steps for the improvement of management processes (own sources)

1.2.1. Digitalisation of internal processes

The digital adaptation process must include the systematisation of all administrative processes regularly carried out in road administration, ensuring that all of them are managed digitally.

Building on processes already fully implemented today (e.g., electronic invoicing), the goal is for all processes related to the daily activities of road administration to follow a similar path— completely digitalised and managed through a specific platform. This platform will be accessible to all relevant public-sector stakeholders and, where necessary, to the public or other involved private or public entities.

1.2.2. Digitalisation of processes with the involvement of other stakeholders

It is also important to advance the digitalisation of processes involving other stakeholders, whether they are public or private, national or international, to achieve maximum real-time coordination with other participants in road management. These may include public entities (e.g., civil protection, police, traffic management centers, the Spanish Civil Guard (Guardia Civil)[5], along with the respective French and Portuguese administrations in the critical border areas) or private entities (e.g., traffic information providers) via the National Access Point (NAP)[6] for Traffic Data. Additionally, this activity can encompass interactions between different road administrations, optimising tasks such as the transfer of road sections between jurisdictions.

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[5] https://www.guardiacivil.es/es/index.html
[6] https://transport.ec.europa.eu/transport-themes/smart-mobility/road/its-directive-and-action-plan/national-access-points_en

To achieve this, it is crucial to identify communication processes with other actors involved in road management and mobility, as well as the characterisation of input/output data, communication requirements, validation processes, etc. Based on this framework, processes will be enhanced with digital solutions, and various functionalities will be enabled to allow easy access from all computer systems.

External Digital Adaptation

The road infrastructure sector is in the early stages of its journey toward digital evolution. This transformation is currently more evident in high-capacity networks than in local roads, though significant progress is also being made in the latter. This transformation is driven by data, as well as the information and insights that can be derived from it.

Elements such as new data sources, information capture technology, improved processing and storage capabilities, and new business models contribute to a rapidly changing ecosystem. This evolution presents numerous technological, commercial, economic, and legal challenges that also affect the local road network and its key stakeholders. At the same time, these challenges are opportunities to leverage the benefits of digital transformation throughout the entire life cycle of road infrastructure.

Collaboration among all participants in the process is crucial to succeeding in the digital transformation journey. Road managers, traffic managers, policymakers, standardisation authorities, technology providers, and software companies are essential to making the most effective use of new technologies and data in asset management. In this regard, it is beneficial to create joint working spaces to bring the private sector together and establish a vision and roadmap that defines the necessary programs, research, projects, workshops, etc., to move forward.

Once a certain level of maturity in internal digital adaptation has been achieved, it is time to advance processes related to the digitalisation of infrastructure management aimed at user services ("external" digital adaptation). The goal is to improve the quality of the mobility services provided by the local road network and to lay the groundwork for connected and autonomous mobility.

1.3.   External digital adaptation as an improvement in user services

The emergence of new options for data collection, transmission, storage, and utilisation in recent years has enabled the progressive enhancement of services related to road network management and mobility.

1.3.1.   Collection and transmission of new data

The digitalisation of society—through the proliferation of information and communication devices, Internert of Things (IoT), etc.—has generated a set of massive and frequent data sources (Big Data) that hold great value for studying mobility.

In the traditional model, road data collection systems were results-oriented, providing data in standardised formats based on the requirements of management systems to support decision-making. Current models recognise the potential to obtain new types of data from many different sources, supporting a wide range of decisions. These new information sources include vehicle-based inspections, connected vehicles with artificial vision, satellite tracking, drone monitoring, networks of connected sensors in infrastructure, data from sensors in connected vehicles, user phone data, and more.

1.3.2. Deployment of communication networks

Roads are communication infrastructures that connect all communities within a territory. The deployment of fiber optic networks along roads has been ongoing for some time, accelerating the implementation of high-quality broadband internet and high-speed connections for all residents.

5G networks will enable the development of new services. While it is impossible to predict all potential 5G applications, three significant changes are likely:

1. The rise of autonomous and connected vehicles.

2. Smarter and more efficient logistics.

3. Improved urban transportation through the implementation of Mobility as a Service (MaaS) platforms.

1.3.3. Information management

Data management is one of the most important activities in the digitalisation process. To achieve this, storage repositories must be developed to ensure secure data storage, processing, and transfer to third parties and users with added value.

The management platform(s) should include the following capabilities:

- ETL (Extraction, Transformation, and Loading): For data capture.

- Predictive capabilities: To provide information for the different digital services to be implemented.

- Analytical capabilities: For operational monitoring, statistical analysis, and obtaining value-added information.

Security must be a core value, requiring the implementation of robust cybersecurity mechanisms to safeguard against increasing threats. Finally, the platform must be available, robust, and scalable to efficiently meet varied demand.

1.3.4. Optimisation of services through digital solutions

The combination of new data and communication options allows for the management of large amounts of data that can be integrated into the administration of local roads. The management platform becomes a decision-support tool and serves as the foundation for a digital twin virtual representation of the local road network that incorporates multiple data sources to optimise all operations and services carried out by local administrations.

1.4. External digital adaptation to new mobility models

In the near future, an increased level of digital transformation in road infrastructure will be required to support new emerging needs associated with connected and automated mobility.

1.4.1. Definition and characterisation of new services

The roadmap outlines new services that can be provided in the local road network, focusing on environmental sustainability, safety, infrastructure and traffic management, and connected and autonomous mobility.

1.4.2. Programming and development of tests – living labs

To establish areas for testing and demonstrating results in digital road initiatives, it is proposed to define "living labs" where the proposed adaptations and new elements can be installed in infrastructure and tested with prototype connected and autonomous vehicles.

1.4.3. Local roads for autonomous and connected mobility

Without aiming for an exhaustive analysis of the readiness of local roads to support autonomous mobility, this section reflects on how the unique characteristics of these road networks may impact deployment. This includes considerations for physical space, equipment needs, and coexistence with other types of traffic.

Proposal for Designing a Digital Adaptation Plan for Local Roads

The Roadmap outlines a series of steps that should be implemented to create an appropriate institutional context for addressing the challenges of adapting the local road network to

digitalisation. The proposal includes 6 steps for designing a digital adaptation plan for local roads:

- **Step 1:** Establishing a working team to lead the digital adaptation. It is suggested that the team include technological profiles, technical experts in road and mobility, and representatives from local administrations.

- **Step 2:** Conducting a diagnosis of the current situation, aiming at developing a map identifies needs and priorities.

- **Step 3:** Developing a digital adaptation plan for the local road network and its management, establishing clear objectives, priorities, actions to be taken, expected timelines, stakeholders involved, budget, etc.

- **Step 4:** Designing a training plan, including both initial and specific training for the technical team who will directly participate in the digital adaptation process, as well as ongoing training to ensure the optimisation of the benefits of digital adaptation.

- **Step 5:** Continuously evaluate the progress of the plan so that trends can be corrected, action areas can be strengthened, and new needs can be incorporated.

- **Step 6:** Disseminate information and encourage public participation to gain maximum internal support and involve the private sector and citizens in the new way of working.

Conclusions

Digital adaptation is not an area exclusive to large infrastructure projects associated with extensive technological and communication deployments. It also applies to other conventional road networks under state, regional, local, and urban ownership. Numerous references to digital adaptation have been developed within the local administration in recent years, often related to data digitalisation, the creation of management platforms, inventory creation, and even, in some cases, advances in the use of BIM (Building Information Modelling).

The Roadmap aims to support the digital adaptation process, while providing a set of solutions offered by the private sector.

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