IMPROVED EFFICIENCY OF THE BRIDGE MANAGEMENT SYSTEM OF THE SPANISH NATIONAL ROAD NETWORK

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ABSTRACT

The Spanish national road network comprises approximately 28,000 km of carriageways and about 33,000 bridges. The magnitude of this important asset, combined with its diversity, considering that it comprises structures of different age, type, span and dimensions, as well as a wide variety of materials, brings along a considerable complexity in the management of its preservation.

Moreover, it should be considered that the road asset preservation in each province of Spain is subdivided into 3 or 4 sectors, each of them responsible for the maintenance of between 150 and 220 km of the network. In total there are 160 maintenance sectors[1] under the responsibility of one coordinator per province.

Considering the above, it is necessary to implement an effective Bridge Management methodology, which makes it possible to successfully deal with the vast capital asset of the General Road Directorate and the diversity of the professionals involved in its preservation. The success of this methodology is based on the coordination and on the use of new technologies, which have proven to be fundamental for effective cooperation.

Although the purpose of this article is not to describe a Bridge Management System, which is considered to be sufficiently well-known, the BMS implemented in the General Road Directorate will be briefly described in the following paragraph.

Subsequently, certain efficiency measures that have contributed to a significant improvement of the Bridge Management System in use by the General Road Directorate will be presented in detail. These improvements have made the BMS more reliable, effective, homogeneous, cheaper and more adapted to the Spanish reality.

Keywords*: management, bridges, efficiency, coordination, training*

[1] Each sector is managed by means of a service contract which encompasses the road serviceability support activities and the normal conservation activities intended to delay the degradation processes of the elements of the road infrastructure.

1. DESCRIPTION OF THE BRIDGE MANAGEMENT SYSTEM

Capital assets do not remain forever unchanged. The preservation state of the bridges evolves constantly due to their use, the course of time (ageing), various incidents (impacts, accidents, vandalism, etc.), modifications of the structures due to widening or other interventions in the road, and the evolution of standards.

The efficient management of a set of bridges includes various organisational as well as administrative and technical activities, which result is an adequate policy and planning of maintenance, repair and refurbishment. The following is necessary to optimise these tasks:

- Knowing the assets: an inventory of all bridges with their location within the network and their structural, functional and geometrical characteristics.
- Managing its preservation:
  - Establishing an inspection programme that provides the data necessary to know the state of the bridge
  - Quantifying the level of functionality and safety of each structure objectively
  - Establishing intervention criteria

A specific tool that streamlines and optimises maintenance management for a large number of structures with minimal costs is required to facilitate these tasks. The BMS (Bridge Management System) should therefore allow us to use the collected information to plan and project the interventions needed to adequately maintain the assets, according to the established policy and to available resources.

Figure 1 – Operating diagram of the maintenance management

The General Road Directorate has been implementing a BMS for the national primary road network since 1999, initially with technical support from the company *Torroja Oficina Técnica*, later with support from the joint venture of *GEOCISA* and *INES Ingenieros* and currently with the assistance of *GEOCISA*. Over the years the available historical data have been standardised, coordinated and incorporated into the BMS and new items have been introduced in order to respond to current preservation management needs. This BMS is based on:

- The **inventory** of all the structures of the network, including location, type of structure, dimensions, functionalities, elements and materials, photographs and existing documentation.

- Systematic **inspections** of bridges, divided into three different levels: Basic (or Routine) Inspections, Main Inspections and Special Inspections.

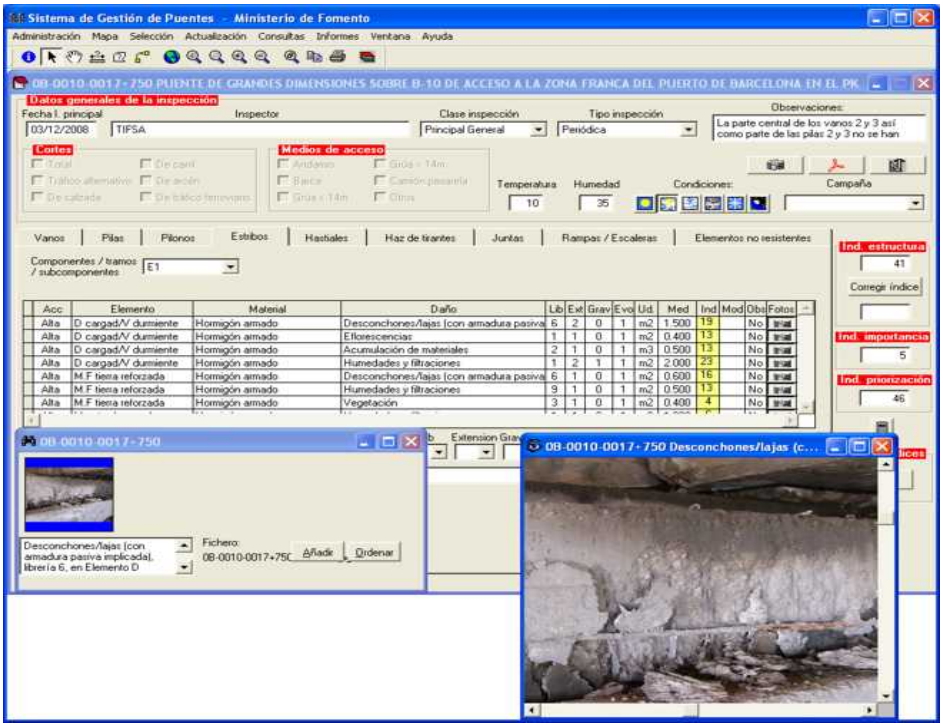

Figure 2 – Screenshot of the BMS software. "Main Inspection Module: Damage in the abutments"

- The systematic evaluation of damage to the bridge elements. A catalogue of **potential pathologies** has been developed, with their probable causes and the criteria to be applied to determine the importance of the detected damages. This helps the inspectors unambiguously characterise the damage detected during the main inspection.

- The estimate of the condition of the bridge, by assigning a structural **state indicator** which is obtained based on the extension, severity and evolution of the damage, and according to the importance of the type of damage and the affected element. This quantification is relatively objective and allows the conservation state of the bridge to be determined and correlations with other deteriorated structures to be established.

- Setting **priorities for repairs**, by establishing weighted structural state indicators by means of factors for security, functionality, traffic density, the importance of the path where the structure is located, the possibility of alternative routes, the value of the bridge as cultural heritage, etc. Furthermore, selection of various repair options, including their costs, considering the extent of the damage, the accessibility to the elements under repair. Finally, full intervention programmes adapted to the available budget can be developed.

- **The control and follow-up of the intervention programme.** Although this is the last item in this list, it is a crucial element in the management system, as it serves to verify, calibrate and determine the effectiveness of the interventions performed and their correct selection and planning.

Finally, it is important to note that the concept of management of different elements of a road is often confused with the handling and use of management support software. However **it is important to emphasize that the true management involves the**

decision-making process by the manager. In this respect, ever more automated management systems are an indispensable complement to human work, and then ensure that these decisions are made in an objective, rational and effective way.

2. IMPROVEMENT OF THE EFFECTIVENESS OF THE BMS

2.1. GENERAL APPROACH

As mentioned before, the high number of bridges existing in a network, combined with their heterogeneity (ages, types of structures, materials, dimensions) as well as the large number of professionals involved in the tasks to be performed make the management of their preservation a highly complex task.

Experience has shown that, in order to effectively manage a vast amount of information originating from a considerable collection of bridges, the truly crucial aspect is not the implementation of complex theoretical algorithms for data processing, but insisting on efficient data collection, on the processing and the systemisation of the methods, as a way of knowing the condition of the bridges and being able to take swift preventive actions. This objective has been attained by working on the optimisation of the following essential concepts:

- Coordination of the activities
- Unification of the criteria
- Training of the personnel involved
- Use of various software tools

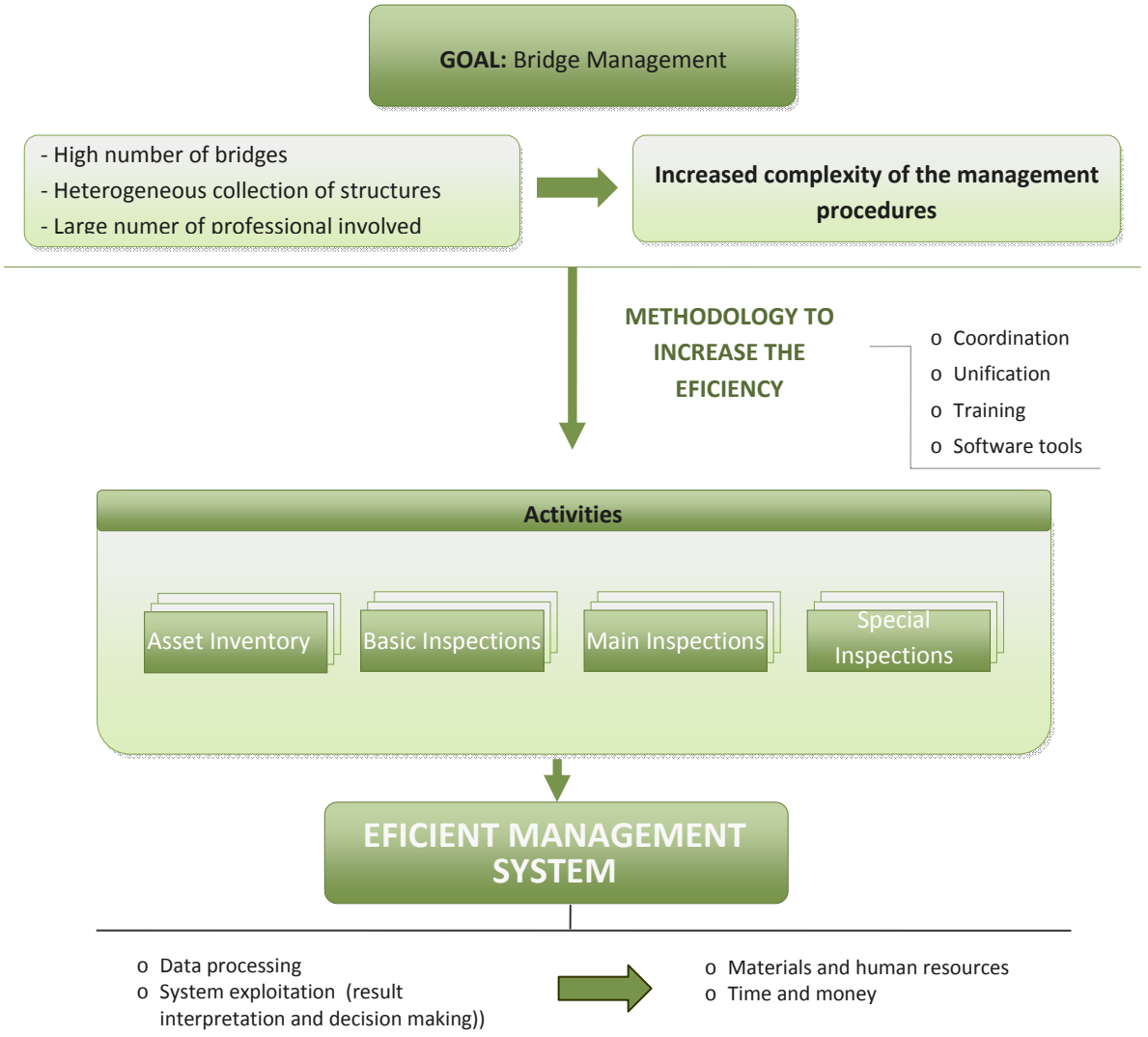

Figure 3 – Operating Scheme of the Management System

2.2. METHODOLOGY APPLIED TO THE ACTIVITIES

2.2.1. INVENTORIES

The inventories are performed by specialised personnel and consist of the location and characterisation of the bridges (typology, functionality, geometrical data, characteristic elements and materials).

A guidebook has been published in which the required criteria for the successful performance of the inventories are described.

Figure 4 – Cover of the Inventory Guide

2.2.2. BASIC INSPECTIONS

The basic (or routine) inspections are performed by personnel in charge of the preservation and surveillance of the road, without a specific technical education (the preservation sectors). Their goal is to perform a proper monitoring of the conservation state of the bridges in order to detect as soon as possible occurrences of damages or failures which may produce considerable costs for maintenance or repair if no actions are taken in time. Therefore, the different parts of the bridges are explored and possible deteriorations are recorded. Damage that appears serious is reported to the person responsible for preservation.

As a consequence of these inspections, generally routine maintenance operations are undertaken. However, the inspection may also highlight the need to perform a more advanced inspection.

One of the ways used to improve the effectiveness of the Basic Inspections consists of standardising criteria, by making them more objective through the elaboration of “standard sheets” and inspection guides.

The standard sheets used for the basic inspections generally consider the following aspects:

Road surface of the bridge and its access ramps: presence of potholes, rutting, decompressions, broken approach slabs, erosion of embankments, etc.
Sidewalks: condition of the surfacing, presence of vegetation, etc.
Drainage of the bridge deck: water drainage elements, condition of the sumps, shoots, drains, connections to headers, etc.
Parapets, railings and barriers: verticality, longitudinal alignment, impact damage, loss of elements, corrosion, insufficient protection, condition of the anchors, etc.
Joints: condition of the roadway surface, cleanliness, water tightness, excessive joint closures or openings, noise, deteriorated or missing elements, loose anchoring zones, etc.
Support areas: deformations of the supports, drains, cleanliness, foot walls, pier heads, presence of vegetation, etc.
Bridge deck and load-bearing structure: spalling, humidity, vehicle impacts, stains, scumming, stalactites, cracking, exposed reinforcement, loss of material, weathering, etc.
Abutments and piers: impacts, leaks and runoffs, guards, loss of elements or material, incorrect alignment of pillars and abutments, collapses, etc.
Foundations: visible erosion and undermining, collapse, degradation, etc.

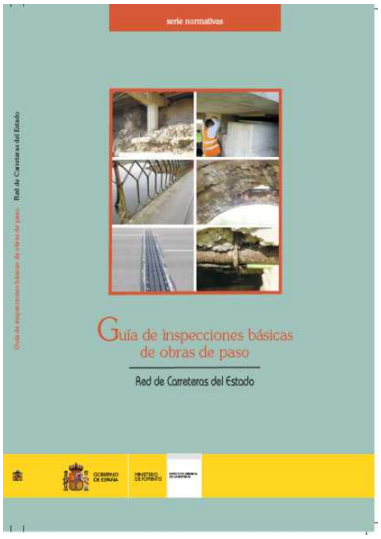

Figure 5 – Cover of the Basic Inspection Guide

The Guidelines for Basic Inspections of Bridges in the national road network[2] have been written as part of the training of the involved personnel so they know the followed methodology and to unify criteria. This guide describes the general guidelines and procedures to be followed in this type of inspection.

On the other hand, the information obtained from the Basic inspections needs to be transferred homogeneously and congruently to the person responsible for the system, so an effort has been made to improve the coordination of these activities. In this respect, a software application has been developed (Basics Inspector Program) which is at the disposal of the personnel in charge of maintenance, so that all data generated from these inspections are stored in the same electronic format. Once the data are processed, they will be integrated into the central database of the General Road Directorate.

An important contribution to the aforementioned improved effectiveness is made by the creation of a Web page, which helped to improve the quality of the work in various ways:

- The web page contains a section where the personnel responsible for preservation in each province, or in each preservation sector, can retrieve the main data (inventory and conservation) of the bridges under their responsibility. This section is continuously updated with the data from new inspection campaigns, so that the information on the structures is always reliable and up to date. It is possible to create queries using filters or user-defined criteria like location, type of structure, preservation state, etc. In addition it is possible to export the information to reports in PDF or XLS format.

[2] The full version of this Guidebook (in Spanish) can be downloaded through the following URL: http://www.fomento.es/MFOM/LANG_CASTELLANO/DIRECCIONES_GENERALES/CARRETERAS/NORMATIVA_TECNICA/OBRAPASO/CONSERESTRUC/

Figure 6 – Query web page. Display of inventory data of a bridge.

- The web page includes a technical forum to solve any queries regarding both methodological issues as well as software-related problems. With more than 850 entries in the last campaign, this forum has proven to be extremely helpful for the successful execution of the inspection campaign and is now a crucial part of the on-going training of the personnel involved in the basic inspections.

- There is a special section for the uploading of the standard sheets generated during the Basic Inspections, with the help of the aforementioned *Basic Inspector Program.*

- The page contains a repository with the Guidebooks on the Inspection methodology and the User manual for the Inspector Program, as well as the software updates of the mentioned program.

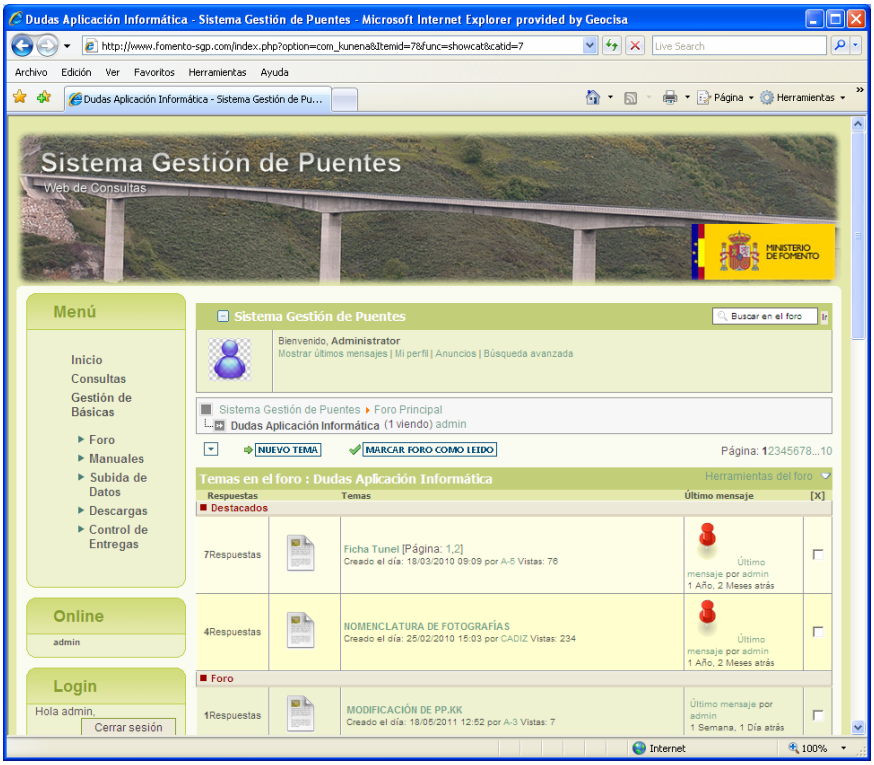

Figure 7 – Display of technical forum (Web page)

The improved efficiency of the working methodology has made a fruitful basic inspection campaign on the 33,000 bridges in the network possible in only 2 months, with the cooperation of all preservation sectors.

A functional chart of a generic basic inspections campaign is presented in the following figure as a summary:

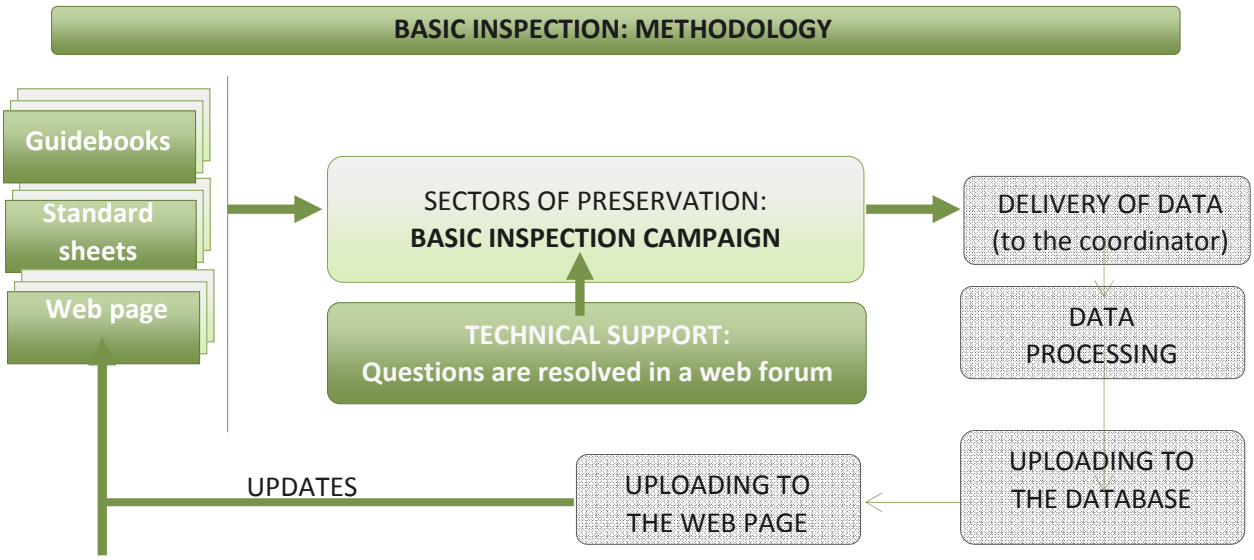

Figure 8 - Diagram of Basic Inspections

2.2.3. MAIN INSPECTIONS

The main inspections are based on the detailed observation of the condition of all elements of the bridge. The detected damage is evaluated and the probable cause is determined by the inspector. These inspections are performed by specialized personnel, although no special equipment[3] is used. For the Main Inspection, the bridge is subdivided in four zones: foundation, substructure, superstructure and components. A series of elements, whose level of deterioration can affect, to a greater or lesser extent, the functional and structural performance of the bridge are identified within each zone.

The main inspections are performed every five years, unless they are required as a consequence of an incident or the result of a basic inspection. Normally, these inspections are performed by specialised companies and contracts and they are grouped by itineraries which comprise approximately 2,500 bridges each.

The main inspections highlight the need for repairs. In some cases, it may be necessary to perform a Special Inspection in order to design the repair measures, according to the implemented Bridge Management System.

The Main Inspection forms a truly detailed visual inspection of the structures, performed by a trained and competent professional. The visual nature of the inspection brings along a certain degree of subjectivity, so the “Catalogue of Damage and Deteriorations” is used to make the inspection as objective as possible.

The effectiveness of the Main Inspection Campaigns is based on the following pillars:

Unification of the criteria and training: both items are closely related. It implies a professional Management[4], with authority and adequate response capabilities, that establishes the goals and guidelines and at the same time makes a continuous effort to transmit these guidelines to the complete organisation of inspectors and preservation personnel, either by means of the forum or through training courses held at each of the contracted companies. This is achieved through:

- Theoretical and Field Training courses for inspectors, given by qualified engineers from the coordinating company
- Use of standard sheets for data registration in the main inspections
- Inspection Guidebooks and Catalogue of Damage

Coordination of activities:

- Within the company charged with the main inspections, by means of continuous and swift data transfer between the field and office teams, which allows continuous and immediate supervision of damage found during field inspections. The main inspections are currently equipped with “Microsoft Sharepoint Workspace” (a platform for collaboration and document management), which enables information to be shared in real time and promotes the cooperation within the group.

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[3] There is a special kind of Main Inspection that provides the same kind of information and for which special equipment is used in order to obtain access to the elements to be inspected, which otherwise could not be reached. These “detailed main inspections” are performed in a specific campaign of a previously established selection of singular bridges.

[4] Management includes the administration of the General Road Directorateand the managing company (Technical Assistance Contract)

- Between the company charged with the inspection and the managing company, which solves any queries that may arise during the execution of the inspection campaigns.

Software tools:

- The data from the main inspections are introduced in the “Main Inspection Inspector Program”, which ensures homogeneity of the data.
- The company that performs the inspections can access the query website to support the inspection campaign.

Below is a diagram that represents the process of the Main Inspection campaigns:

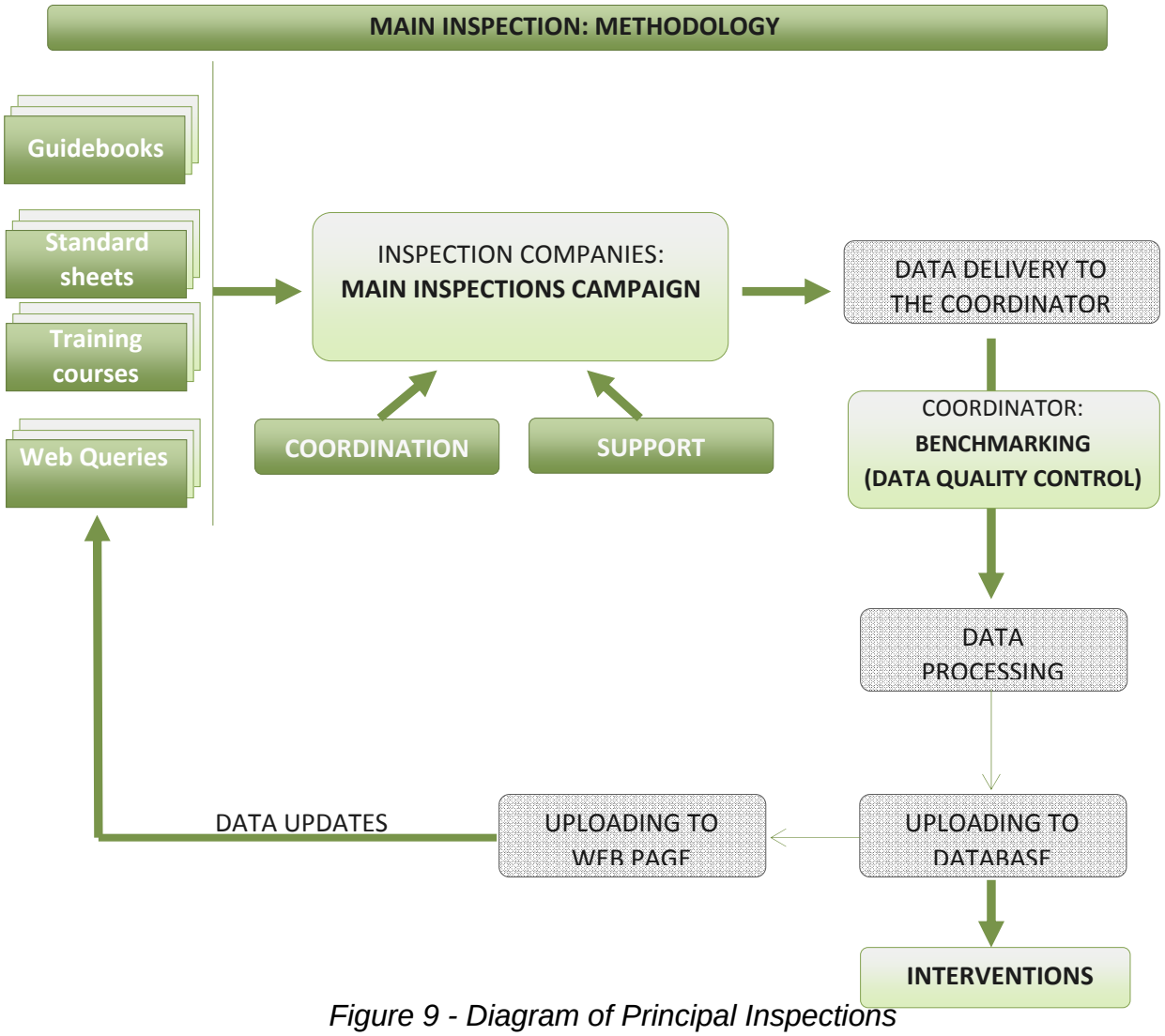

Figure 9 - Diagram of Principal Inspections

2.2.4. SPECIAL INSPECTIONS

Special inspections arise as a consequence of special or accidental situations or as a result of a decision taken because of a main inspection where important damage has been encountered and the pathology study and subsequent refurbishment require it. They are detail inspections and therefore do not necessarily involve the presence of special equipment or personnel. They are thus not systematic.

The Special Inspections include a preliminary study of the bridge with the aim of determining the activities or investigations that have to be carried out, such as:

- Detailed recording of the geometry and the damage in the bridge
- Underwater inspections of submerged foundations.
- Sampling and material load-bearing characterisation testing, as well as physical-chemical testing.
- Material sampling, boring, and geotechnical characterisation tests on the foundation terrain.
- The execution of static and/or dynamic load tests in order to establish the load-bearing capacity of the bridge.
- On-site testing with specialised inspection equipment, to measure the movement of joints, cracking, deformations, etc.

The capacity for document management has eventually increased considerably with computer programmes, so it is now possible to store all documentation digitally and provide access to these resources via the web application by introducing the corresponding bridge code.

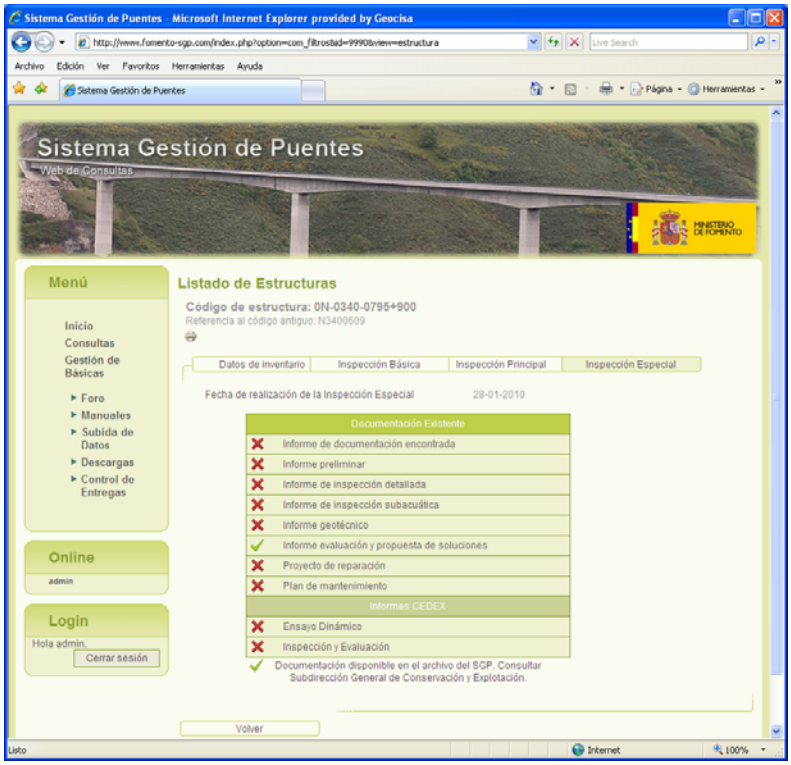

Figure 10 - Screenshot of the web application, showing the types of documents associated to a Special Inspection

Furthermore, the increased monitoring of the preservation state of the bridges, by means of adequate coordination and systemisation of the basic and main inspections, ensures an improved effectiveness of the special inspections, which are ever more aimed at knowing the actual behaviour of the bridges, as a function of their typology and to study the evolution of the damage. Moreover, the way has been opened to a new field of activity towards the prevention of damage and the updating of the infrastructure.

3. CONCLUSIONS

The management of the conservation of bridges within a network as big and varied as the Spanish National road network requires the implementation and operation of a Bridge Management System that allows for the processing and consultation of a huge amount of data, in accordance with some previously-defined criteria.

The commitment of the General Road Directorate in Spain towards this issue is very strong, and is shown by the ongoing support, the resources applied and the investments made over the time.

The true operation of a management system of these characteristics within the large network mentioned before, with around 33,000 bridges, is not immediate, even in this age of “new technologies”, but instead requires a constant effort over several years. Therefore, a series of measures have been taken in recent years to really achieve an effective bridge management. These measures can be summarised as follows:

- **Unification of the criteria and continuous training** of the different professionals involved, both maintenance engineers as well as the engineers in charge of the bridge inspections. It would be otherwise impossible to achieve homogeneous and reliable data. This information is channelled through Guidebooks on the inspection

methodology, standard inspection sheets, courses and conferences, specific training courses and technical and information and documentation exchange forums on the website.

- An **effective coordination** of the large team of professional involved in the preservation tasks. Firstly, through swift data transfer between the field team and the office, which allows for a continuous supervision of the inspection activities. On the other hand, on a higher level, the coordination company centralises and homogenises the results of the different activities that have been carried out. In this respect, the use of the query web site (with different user profiles) has been encouraged because it allows instant accessibility of the inspection data, both for the central coordinator as well as for the provincial coordinators. In this way, the person who actually needs to take further actions (repair interventions on the bridges or the planning of more elaborate inspections) has all the relevant data directly at his disposal.

- Various customised **software tools** for management, data acquisition, processing and display. In this respect, several programs have been developed in recent years: the main management software is the (BMS) Bridge Management System and there are other specific programs for each of the different types of inspections. Moreover, the aforementioned query web site has been developed and it is constantly updated and upgraded to adapt to the latest technologies and systems.

It is also worth mentioning that the effectiveness and efficiency of the management system is not achieved by merely following the aforementioned procedures and using the tools described in this article. For this it is necessary to achieve a more difficult task: **their on-going implementation and use.**

Therefore, the experience with the Spanish model, which is in accordance with other international models, allows progress towards a greater specialization in the knowledge on the bridges in the Spanish road network, which in turn provides increased security and an improved service level for the users of the infrastructure, with tighter and better-controlled costs for the Administration.

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