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TU1406 COST Action – Quality specifications for roadway bridges, standardization at a European level (BridgeSpec)

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Abstract. Asset management strategies rely on maintenance actions to keep infrastructures at desired levels of performance. In case of roadway bridges, specific performance indicators are established for their components and, when combined, allow to evaluate the overall performance. These indicators, which can be qualitative or quantitative based, are obtained during principal inspections through visual examination, non-destructive testing and by temporary or permanent monitoring systems. After being obtained, these indicators are then compared with performance goals in order to evaluate if quality control plans are accomplished. It is possible to verify the existence in Europe of multiple methods used to quantify these indicators and how such goals are specified. COST Action TU1406 aims to establish a European guideline in this matter, addressing new indicators related to sustainable and economic performance of roadway bridges. An overview of this Action, with a special liaison to the sustainability issues, is provided along this paper.

1. Introduction

Roadway bridges are considered to be, in terms of maintenance, one of the most critical components of road infrastructures. Though they belong to the domain of public service, their management mechanism can be conducted by the state or under a private public-partnership model. In both cases, a QC plan, which compares, for each performance indicator, the assessed value with a pre-specified goal, should be accomplished.

However, it is verified that those plans vary from country to country and, in some occasions, within the same country. This is a huge problem, as large variation in the quality of roadway bridges is verified. Also, most of these plans do not incorporate any sustainability issues. Therefore, the COST Action TU 1406 aims to achieve the European economic and societal needs by standardizing the condition assessment and maintenance level of roadway bridges [1]. Moreover, it will be important to address, in such plans, new indicators related to sustainable performance (e.g. noise, carbon retention rates, etc.). This constitutes a scientific advance as, actually, QC plans do not consider them.

In order to establish a standardized procedure for the assessment of performance indicators, namely, those that should be considered in a QC plan, as well as to define the performance goals, a network of experts is needed. Such network should incorporate people from different stakeholders (e.g. universities, institutes, operators, consultants and owners) and from various scientific disciplines (e.g. on-site testing, visual inspection, structural engineering, sustainability, etc.).

To summarize, there is a real problem which is the non-uniform way QC is actually developed for roadway bridges and the non-inclusion of any sustainability indicator. This is surpassed by establishing a guideline, which constitutes the main outcome of this Action. Such guideline will comprise specific recommendations for assessing performance indicators, as well as for the definition of performance goals, being expected the impacts expressed in Table 1.

Table 1. COST Action impacts.

Impact	Description
Sustainability	Decrease the bridge lifecycle, maintenance and repair costs; Increase of service life; Decrease of total energy consumption and carbon footprint; Increase of mechanical, durability and environmental performance.
Economic and societal	Improve user satisfaction; New job opportunities associated with new QC services; Improve economic efficiency; Increase competitiveness in structural engineering industry; Enhance risk management.
Well-being of general public	Decrease of maintenance, repair and reconstruction activities; Decrease of downtime situations; Decrease of disruptions; Increase of user comfort.
Research community	Better perception of real problems; Improve the cooperation between research and practice; Establishment of reliable comparisons between countries; Improvement on research developments and practical procedures; Reduction of the gap between countries.

2. General background

In Europe, as all over the world, the need to manage roadway bridges in an efficient way led to the development of different management systems [2]. Hence, nowadays, many countries have their own system. Although they present a similar architectural framework, several differences can be appointed, for example, with regard to the condition assessment procedure. These differences constitute a divergent mechanism that may conduct to different decisions on maintenance actions.

Within the roadway bridge management process, the identification of maintenance needs is more effective when developed in a uniform and repeatable manner. This process can be accomplished by the evaluation of performance indicators, improving the planning of maintenance strategies. Therefore, a discussion at a European networking level, seeking to achieve a standardized approach in this subject, will bring significant benefits.

In this context, a first step would be the establishment of specific recommendations for the assessment of roadway bridges, namely, used methods for the quantification of performance indicators. A set of reference time periods for these assessment actions should be also presented. A second step would be the definition of standardized performance goals. Finally, a guideline for the establishment of QC plans in roadway bridges would be developed. In these plans, it is emphasized the importance of advanced deterioration predictive models. Moreover, the concept of sustainable roadway bridge management, involving the evaluation of environmental, economic and social performance indicators during the whole lifecycle, is also highlighted.

By developing new approaches to quantify and assess bridge performance, as well as quality specifications to assure an expected performance level, bridge management strategies will be significantly improved, enhancing asset management of ageing structures in Europe.

3. Current state of knowledge

Within last years, significant research has been developed worldwide regarding the condition assessment of roadway bridges, namely through the use of non-destructive tests, monitoring systems and visual inspection techniques. Obtained values, which will provide information regarding the assessed bridge state condition, were then compared with previously established goals. As a result, there are nowadays several ways of evaluating a bridge condition.

More recently, the concept of performance indicators was introduced, simplifying the communication between consultants, operators and owners. However, large deviations are still verified on how these indicators are obtained and, therefore, specific actions should be undertaken in order to standardize this procedure.

It is verified that QC plans should always address the assessed performance indicators and pre-specified goals. However, these latter values are even more difficult to obtain as they are highly subjective. As a result, a dispersion of QC plans is verified. Once roadway concession contracts are based on such plans, this may become an enormous problem for the future of our society.

It is known that in the past a similar problem was addressed with roadway pavements. Although this was verified worldwide, in Europe it was solved through COST Action 354 (performance indicators for pavements) [3]. In a similar way, during this Action, a network of experts in the field of roadway bridges will establish specific recommendations for assessing performance indicators as well as for the definition of corresponding goals. This activity will be supported in a data basis, gathered from different COST countries. The objective is to develop, for the first time, a guideline for the establishment of QC plans in roadway bridges.

Moreover, it will be also analyzed the possibility of incorporating new indicators related to sustainable performance of roadway bridges. Some of these indicators were evaluated with success within the COST Action C25 (sustainability of constructions: integrated approach to life-time structural engineering) [4]. The final purpose is to establish detailed recommendations for assessing them as well as for the definition of specific goals, in a similar way as for the other indicators, and then integrating it in the developed guideline.

4. Objectives

The main ambition of the Action is to develop a guideline for the establishment of QC plans in roadway bridges, by integrating the most recent knowledge on performance assessment procedures with the adoption of specific goals. This guideline will focus on bridge maintenance and lifecycle performance at two levels: (i) performance indicators, (ii) performance goals. By developing new approaches to quantify and assess the bridge performance, as well as quality specifications to assure an expected performance level, bridge management strategies will be significantly improved, enhancing asset management of ageing structures in Europe.

In order to reach this main general aim, the following more specific objectives/deliverables have been considered: (i) to systematize knowledge on QC plans for bridges, which will help to achieve a state-of-art report that includes performance indicators and respective goals; (ii) to collect and contribute to up-to-date knowledge on performance indicators, including not only technical indicators but also environmental, economic and social ones; (iii) to establish a wide set of quality specifications through the definition of performance goals, aiming to assure an expected performance level; (iv) to develop detailed examples for practicing engineers on the assessment of performance indicators as well as in the establishment of performance goals, to be integrated in the developed guideline; (v) to create a data basis from COST countries with performance indicator values and respective goals, that can be useful for future purposes; (vi) to develop a webpage with information about the Action and its participants, as well as, video-streaming from presentations at training schools, workshops and conferences, e-lectures, written material (e.g. technical reports), etc.; (vii) to support the development of technical/scientific committees; (viii) to disseminate activities, such as Short-Term Scientific Missions (STSM), training schools and other teaching activities (e.g. e-lectures), for practicing

engineers and researchers, regular workshops, a conference and special sessions at international conferences.

5. Target groups/end users

The target groups and end users who will exploit the outcome of this Action are: (i) public/private owners, as their assets will be maintained in an upscale level; (ii) operators, as standardized procedures for reducing maintenance costs, guaranteeing the same quality-level, will be introduced; (iii) design and consultant engineers, as the assessment of roadway bridges performance will be established in a uniform way, according to the developed guideline; (iv) equipment and software companies, as a new perspective will be given, regarding the most suitable equipment and software for the assessment of roadway bridges; (iv) academics and researchers engineers, as they will take an advantage of their involvement in the guideline preparation; (v) students, as they will benefit from COST tools (e.g. training schools) and from the contact with different stakeholders, involved in this Action; (vi) relevant European, international and national associations, with which the main outcomes of this Action will be shared; (vii) standardization bodies and code writers, which will benefit from the developed guideline.

6. Scientific programme

The scientific focus of the Action is centered in the production of a guideline for the establishment of QC plans for roadway bridges across Europe. In this context, this Action deals with recent developments on bridge safety, maintenance and management, according to a lifecycle outlook, aiming to define a standardized procedure for performance assessment as well as for the establishment of performance goals in order to accomplish a pre-specified service level. Moreover, it is intended to demonstrate the applicability of the developed guideline, and other recommendations, with case studies.

The scientific work plan of this Action ensures the working progress in support of the objectives established. It is organized, based on the division of tasks (and subtasks) allocated for each WG, and according to a timetable.

6.1. WG1: Performance indicators

It is known that management systems are supported in QC plans which in turn are supported by performance indicators. Therefore, it is highly important to analyze such indicators in terms of used assessment frameworks (e.g. what kind of equipment and software is being used), and in terms of the quantification procedure itself. In this particular work group, the objectives will be the definition of:

(a) Technical indicators: the goal in the first step is to explore bridge structures performance indicators, in the course of international research cooperation, which capture the mechanical and technical properties and its degradation behavior. Moreover, environmental condition, natural aging, and material quality regarding to some indicators will be investigated and evaluated in their meaningfulness. These considerations, however, also include service life design methods, aimed at estimating the period of time during which a structure or any component is able to achieve the performance requirements defined at the design stage with an adequate degree of reliability. On the basis of the quality of input information (mainly concerning with the available degradation models), as sketched in the above description, it is possible to distinguish among deterministic methods, usually based on building science principles, expert judgment and past experience, which provide a simple estimation of the service life, and probabilistic methods;

(b) Sustainable indicators: in addition to technical performance indicators, which characterize the ultimate capacity as well as serviceability conditions, environmental-based sustainability indicators, will be also formulated. These variables characterize the environmental impact of a structure in the course of its total lifecycle, expressed in terms of total energy consumption, carbon footprint (CO2 emission), raw materials balance, etc. These indicators can be separated into direct and indirect

indicators, where the former are related to the construction/maintenance itself and the latter are caused e.g. as a consequence of limited functionality;

(c) Other indicators: other sustainable indicators, economic and social based, may be used to evaluate a bridge performance. These indicators, based on the technical performance of a structure, capture additional aspects that may influence the decision process and typically represent the discounted (accumulated) direct or indirect costs associated with construction and maintenance. Summed up over the full life-time, they represent part of or the full lifecycle costs. They can, in the context of multi-objective optimization, be understood as a weighting scheme to arrive to a single objective function to be minimized.

The milestone for this task is the publication of a report on these performance indicators until the end of year 1. Such report will address a general description, how they are assessed (e.g. visual inspection, non-destructive tests and monitoring systems), with what frequency, what values are generally obtained and, finally, some general recommendations. This outcome will be one of the main inputs of WG5, being also used by WG3.

6.2. WG2: Performance goals

The main objective of this workgroup is to define a set of goals for previously identified indicators in WG1. These goals will vary according to technical, environmental, economic and social factors. Specific recommendations will be given in order to ensure that the definition of such goals should be the most generalized as possible. In particular, it will be established:

(a) Technical goals: it will be analyzed what goals are actually used for technical performance indicators in roadway bridges and its components (e.g. bearing, joint, etc.). It will be also evaluated which are being defined in the course of international research cooperation. There will be an open discussion within the experts' network in this field, in order to determine the most important factors for the definition of such goals as well as the most suitable threshold values. It will be established goals, both for deterministic and probabilistic methods, for time-varying indicators and for different assessment procedures (e.g. visual inspection, non-destructive tests and monitoring systems);

(b) Sustainable goals: specific goals will be defined for sustainable indicators, environmental based. This task is much more difficult to perform than for technical indicators, as the historical data basis is much smaller. Nevertheless, an open discussion will be established within a network of experts in this field, in order to identify the most important factors for the definition of these goals as well as the most appropriate threshold values;

(c) Other goals: the definition of goals for other sustainable indicators, economic and social based, is extremely difficult as it largely depends on the established agreement between the owner and the roadway operator (concession model). Nevertheless, it will be important for the future of Europe to define such goals, or at least to provide some recommendations, so that standardized procedures can be implemented. In order to achieve this objective, an open discussion will be developed among a network of experts.

The milestone for this task is the publication of a report on performance goals until the end of year 2. Such report will address a description of the most important technical, environmental, economic and social factors, how to compute each goal, with what frequency, what values are generally obtained as well as some general recommendations. This outcome will be one of the main inputs of WG5, being also used by WG3.

6.3. WG3: Establishment of a QC plan

The desired service quality of the whole bridge can be affected by a single dysfunctional component or by the combination of several dysfunctional components. The decrease in bridge service quality clearly depends on the degree of components' dysfunctionality. This dependency can be modelled, among others, by Bayesian nets, which provide the time variation of each bridge component performance.

However, in order to assure a desired service quality with minimum interruptions, bridge owners launch preventative actions when the risk of service impairment, interruption or losses in lifecycle costs reaches some predefined level. Implicitly the owners define herewith the accepted risk which can be different from country to country, based on social equity principles. This accepted risk depends upon the established performance goals for each component or combination of bridge components.

The QC plan mirrors these findings and is used for maintenance planning by defining a criteria for triggering maintenance interventions. Clearly, these QC plans have to be established for each individual bridge. They perform the basis for the asset management of this type of roadway infrastructure. The objective of this task is to establish a procedure, based on Bayesian nets or other heuristic rules used worldwide, which would allow the bridge owner to define a QC plan for each individual bridge.

The milestone for this task is to prepare a report with detailed explanation of the steps towards the establishment of a QC plan for different types of bridges until the middle of year 3. This outcome will constitute the basis of WG5, being also used by WG4.

6.4. WG4: Implementation in a case study

During this task a set of roadway bridges, belonging to different COST countries and preferably with identical typologies, will be identified. Then, for those bridges, it will be obtained the performance indicators (identified in WG1). Such values will be then compared with pre-specified goals (identified in WG2) and, finally, a QC plan will be implemented (detailed description at WG3). Different methodologies for obtaining such indicators, as well as different threshold values, will be used as the basis for benchmarking.

At the end of this task, a QC plan will be applied to such bridges, according to the recommendations established by WG3. The main objective of this study is to show the existing dispersion between obtained performance indicator values and its goals. It is important to note that this will reflect the existing dispersion among QC plans. Also, it will be tested and validated the implemented QC plan, according to the recommendations given by WG3. Obtained results will be discussed within a high level of network of experts in this field.

There are several ongoing national research projects in COST countries with which a close interaction may be established within the scope of this task. Namely, some of the roadway bridges which will be used as case study may be selected from those projects. Additionally, there will be several people from industry (e.g. owners, operators, etc.) involved in this working package.

The milestone of this task is to prepare a data basis from benchmarking, until the middle of year 4. Obtained results will validate the outcomes of WG1, WG2 and WG3, and will be used by WG5.

6.5. WG5: Drafting of guideline/recommendations

In this task it will be joined the work developed in other working packages (especially from WG1, WG2 and WG3) with the objective of writing a guideline, and recommendations, for the implementation of a QC plan for roadway bridges that could be adopted by several roadway agencies. The main goal will be the preparation of a document that can be easily adopted by engineers facing the management of new and existing bridges.

Therefore, the format and content should follow the existing codes / guidelines / recommendations used today by agencies. Hence, the first step will be the analysis of existing documentation and work developed in other similar research programs and by standardization committees at national and international level.

Due to the objective proposed, this working package will have a strong interrelation with all the other working packages, becoming an output for WG6 (dissemination). Finally, the milestone of this task is the development of a new guideline for the establishment of QC plans in roadway bridges until the end of year 4.

7. Dissemination plan

The Action will enable useful synergies and disseminate the results to several target groups and end users. In order to achieve this, a specific *WG6: dissemination of results*, was introduced. This WG will assure the effective dissemination mechanisms to publish the progress and results of the Action. Among these tools are: (i) website, leaflets, posters, TV channels, radio stations, newsletters and online service news; (ii) workshops, conferences, training schools and STSM (Short Term Scientific Missions); (iii) Conferences, peer-reviewed articles and reports issued by the Action; and (iv) Guideline and link to standardization.

A website was developed – http://www.tu1406.eu – containing information about the Action itself which will be continuously updated. Any expert may join the action by filling a google form which is available in this website. Also available are a facebook page and a LinkedIn account accessible by https://www.facebook.com/tu1406ca and https://www.linkedin.com/company/tu1406.

Workshops, conferences, training schools and teaching activities will allow to explain the performed scientific work between researchers, industry and stakeholders, as well as the practical approach of the developed guideline. STSM are specially promoted to early-stage researchers that encourage the synergy among institutions, accelerate the learning of students and provide academia and industry with highly trained staff.

The achievements of this Action will be published in international conferences, as they bring together researchers, academia and industry in an open-discussion forum, in peer-reviewed articles, as they are an important tool to prove the impact and accuracy of obtained results and to make them available for the future, and in technical reports (state-of-art reports and others) which will have the involvement of peer-reviewers from other countries.

The guideline to be achieved will include the establishment of QC plans in roadway bridges, comprising performance indicators assessment and its goals, as well as the obtained results. This recommendation report will be developed in close cooperation with scientific and practicing community and linked to European and international standards.

8. Framework

The Action proposal arose due to the existing concern from owners, operators, consultants and researchers regarding the existence of multiple methodologies to assess and classify roadway bridges state condition. Within an R&D project developed in Portugal (SustIMS – Sustainable Infrastructure Management System; https://www.youtube.com/watch?v=Ls1W5oxVD8w), which aims to develop a cross-asset management system for highways [5], it was identified the idea of standardizing the existing practice.

In a first stage, a national analysis to assess the potential of the idea was performed, having been addressed two entities for the purpose: the Portuguese Association of Highway Operators and the Portuguese Roadway Agency (now Infrastructures of Portugal), that confirmed the same concern.

Having obtained a positive feedback, some contacts were performed at European level and a first team, with experts from different European countries, research fields and stakeholders, was established to work on this issue. Within this team was considered that the COST Association platform would be the most suitable framework to support this project.

The proposal as described, achieved a high rating during the evaluation process, especially due to the innovative character of the new concepts approach such as the study and evaluation of sustainable performance indicators. From the approval of the proposal resulted the Action's Memorandum of Understanding which is available in the official website of COST Association in http://www.cost.eu/COST_Actions/tud/TU1406 and also on the Action official website [1].

The Action was officially started in April 16, 2015 and will last for four years, ending on April 15, 2019. After the initial kick-off Meeting, the Action will be carried out according to the timetable provided in Table 2 (in bold, current status). A first workshop was developed with success in Geneva, 21-22 September 2015. During this workshop 34 contributions were received from several experts. It was also defined the main guidelines towards the WG1 database development.

Table 2. COST Action timetable.

Description	Month															
Activity/Months	3	**6**	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Meeting	x			x		x		x		x		X		x		x
Workshop				x				x				x				x
Conference																x
Training School								x				x				x
STSM	x	**x**	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Website	x			x		x		x		x		x		x		x

Currently are involved 174 experts from 44 different countries, distributed between the Management Committee and the various working groups. Some of these experts represent the Mediterranean Countries. An attempt is being now made in order to involve more people from the Mediterranean NNC (Near Neighbor Countries).

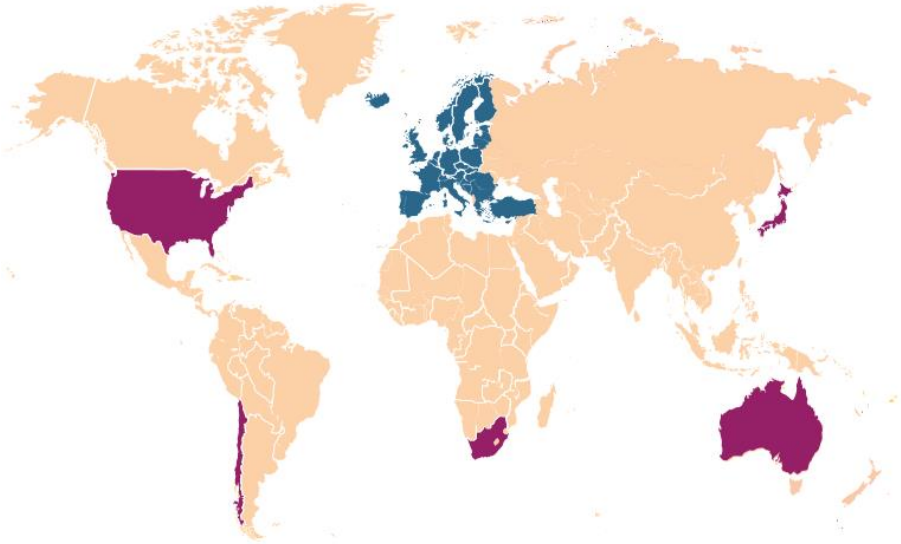

Figure 1. COST Action TU1406 countries.

Acknowledgments

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