TU1406

COST ACTION

QUALITY SPECIFICATIONS FOR ROADWAY BRIDGES,
STANDARDIZATION AT A EUROPEAN LEVEL

Scientific Report on Short Term Scientific Mission "Calibration and adaptation of the SB Method and Tool for bridge projects"

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1. AIMS AND OBJECTIVES

As stated in the proposed motivation letter and workplan, the STSM conducted at the University of Minho, in between the 9th of January and the 17th of February of 2017, under the supervision of Assistant Professor José C. Matos, TU1406 Chair, was based on the current needs of COST Action TU1406 and its principal aim was the creation of an adapted performance and quality appraising methodological and computational framework, aiming at bridge projects. It was based on the processing of performance indicator values and the combination of various methodologies, and it can possibly be used beneficially as an auxiliary blueprint and applicational draft for the work conducted by both WG2: Performance goals and WG3: Establishment of a Quality Control Plan.

Specific objectives of this STSM, which were successfully fulfilled, were:

- To utilize, enrich, update and critically comment on the latest research results and list of Performance Indicators (PIs) and Key Performance Indicators (KPIs) produced by WG1: Performance indicators
- To homogenize, calibrate, integrate and adapt into a single methodological framework and computational procedure a variety of diverse methodologies, which are robust, concise, tested and fit for use with PI checklists. The methodologies thus combined was the SB Method (developed by iiSBE and refined for Portugal by iiSBE Portugal), the Analytic Hierarchical Process (AHP) of both the Eigenvector Method (EVM) and Row Geometric Mean Method (RGMM) variations, an adapted AHP results consolidation methodology featuring the Weighted Geometric Mean Method (WGMM), and the weighted sum functions of the utility functions set
- To fully conceptualize and establish the created framework, in addition to its robust founding on updated theoretical bases
- To use as input values for the corresponding variables real PI-related data, obtained through a variety of ways (e.g. visual inspection, analytical calculations, expert input etc.)
- To apply it to a real bridge case study
- After its application, to check its validity, applicability and predictability, through the comparison of its computed results with the ones produced by the official system of the agency which provided the real case study data

The applicant, throughout the development of this STSM and its successful completion, tried to not only enrich the scope and applicational field of TU1406, but also to furtherly develop the scope of his own doctoral thesis (as stated in the prerequisites of the motivation letter), by learning and gaining access to established methodologies, relative useful data and real case studies.

2. WORK CARRIED OUT

The work conducted is delineated in the following steps:

1. Obtainment of the latest research results by WG1, namely the final compact list of PIs and KPIs, their definitions, characteristics and aspects, and their way of interconnection and utilization
2. Online and offline targeted literature review for deep understanding of the subject under research, conceptualization of its theoretical framework, founding of its basic methodological aspects and bringing it up to date with the rest of the relative current research. Namely, the directions of the initial literature review were:
   - Studying the definitions and applicational fields of quality control plans and asset management systems and finding their interconnections, their combined application in the national and international level, and the discrepancy which is a product of the different approaches regarding the relative field
   - Realizing and stating the role of TU1406 in the lessening of the fragmentation of the aforementioned research and applicational field and in the standardizing of the relative theoretical and practical framework, as well as developing databases and methodological and computational applications
   - Cross-referencing and better understanding of all the theoretical bases used for the work of WG1, and also for the work of WG2 and WG3 which is currently underway
   - Further studying of PI-related methodologies and reaffirming that the SB Method is suitable (as stated in the workplan) for the methodology and framework intended to be devised

- Studying of the SB Method itself and working out of all its attributes and procedural steps that needed to be adapted so that it was suitable for bridges in general and the specific approach of TU1406 in particular
- After finding out about the prerequisites of the SB Method adaptation, studying of the AHP (both EVM and RGMM), the AHP consolidation methodology and the weighted sum utility functions

3. Devising of the following methodological and computational framework:
   - Simultaneous discretization of the PIs among the relative KPI groups and bridge components
   - Assignment of three benchmarking values per PI: real practice, standard practice and best practice. Then, using of the Diaz-Balteiro equation of the SB Method to produce a normalized PI value in the interval of [0,1]:
     (real practice – standard practice) / (best practice – standard practice)
   - Calibration scheme of the produced results, in order to satisfy upper and lower boundary constraints suggested by the SB Method
   - For each component, use of the weighted sum utility function to produce the weighted average of all the PIs appointed to each KPI group. This weighted average is the respective quality value of the corresponding KPI for the current component
   - For each component, use of the weighted sum utility function to produce the weighted average of all the KPIs. This weighted average is the respective quality value of the corresponding component
   - In the system level, use of the weighted sum utility function to produce the weighted average of all the components. This weighted average is the respective quality value of the whole bridge in the system level

   The weighted sums were utilized in place of the simple average in each case, because the respective values of the PIs with regard to the KPIs, of the KPIs to the components and of the components to the system are not equally important.
4. Obtainment, through the collaboration with Infraestruturas de Portugal (INFRAPOR) with real data concerning bridges built in Portugal. The attributes and usage of the relative data are described thus:
   - General data (type of bridge, morphology and typology, construction year, construction cost, type of deck cross-section, width, number of spans, maximum span, total span length, material used, number and date of inspections, condition rating, managing owner etc). This data was used to filter out and find the specific case study upon which the computational framework would be tested, following the STSM supervisor's suggestions. The bridge that was finally chosen is an overpass reinforced concrete bridge constructed in 1983. The bridge is of the continuous span type, and it features three spans with a total span length of 28.8 m. Its width is 8.2 m, its maximum span is 14.4 m and the deck cross-section is of the slab type. The system is discretized in the following components: retaining walls, slopes, abutments, piers, deck, cornices, guard railings, safety railings, sidewalks, pavement and drainage system.
   - PI-related data for the chosen bridge case study. Namely, this set of data consisted of inspection and structural health monitoring data (with the last inspection being on the 30th of March 2016 and producing a condition rating of 3, in the 0-excellent to 5-poor condition rating scale utilized by INFRAPOR), technical drawings, computational manuals and requirement checklists for both the system as a whole and the separate components. With the aforementioned data, most of the PI values (real, standard and best practice ones) were assigned
5. Devising of expert interviews, featuring TU1406 colleagues from Portugal, Estonia and Greece, and fellow engineers from INFRAPOR. It was requested from the experts to:
   - Match and update the PI checklist in relation to the specific case study chosen (elimination of redundant PIs, appointment of the remaining ones according to the bridge components)
   - Weight, using a 5-point Likert scale, of the PIs in relation simultaneously to the KPIs and to the components
   - Suggest any missing real, standard and best practice PI values not available in the dataset provided by INFRAPOR

   The weights obtained were processed with the AHP for each expert, and the relative PI weights for the KPIs and the components per expert were produced. Then, with the use of the AHP consolidation methodology, the final set of the aforementioned relative weights, emanating from the input of all experts, was produced.
6. Devising of an anonymous questionnaire survey, aiming to TU1406 colleagues, and fellow engineers from INFRAPOR. It was requested from the experts to:

- Weight, using a 5-point Likert scale, of the KPIs in relation to the components and of the components in relation to the system

A total of 23 answers were obtained. The weights were processed with the AHP for each expert, and the relative KPI and component weights per expert were produced. Then, with the use of the AHP consolidation methodology, the final set of the aforementioned relative weights, emanating from the input of all experts, was produced. The questionnaire results were anonymously disseminated among the respondents.

7. With all the weights and the PI values obtained, applying of the computational procedure outlines in step (2).
8. Production of the final results depicting the quality rating of the bridge components and the whole bridge as a system
9. Comparison of the results with the specific case study condition rating produced by the in-house rating system used by INFRAPOR, for validation purposes
10. Presentation of the work conducted to the supervisor
11. Writing of a complete manuscript to be submitted as a journal article, also co-authored by Prof. Matos, Prof. Braganca (faculty member of the University of Minho and also core member of iiSBE Portugal) and Prof. Xenidis (the applicant’s thesis supervisor at the Aristotle University of Thessaloniki)

It should be noted that not all of the steps delineated as of above were executed consecutively, but some were being developed in parallel.

3. MAIN RESULTS

The final bridge quality rating score was normalized in the interval [0,1]. The numerical value was 0.56, indicating a bridge of acceptable to adequate performance, but also with both serious and minor damages affecting several of its components, as also witnessed in certain photographic data. Performance issues evident in both the structural health monitoring files and the visual inspection data were also affecting the quality score and were apparent at the PI values used in the calculations.

The computed score was compared with the one posed in the transposed rating scale provided by INFRAPOR. The latter scale features both the 0-5 (from excellent condition to poor condition) qualitative score, and its inverse transposition in the [0,1] interval. It should be noted that the intervals in between the rating levels are not equal. Since the official rating of the bridge was 3, which is transposed, according to INFRAPOR, in the interval [0.35, 0.60), it is evident that the currently produced score of 0.56 is well within the correct margins and thus well validated. For reasons of completion, the produced score was also translated in the intervals of the SB Method qualitative scale, resulting in a quality rating of B.

As a final proposition, the applicant constructed a new quality rating scale with the combination of the SB and INFRAPOR scales, for better use and understanding of the results of the developed methodology.

As a result, a complete methodological and computational framework, using real quantified PI values and producing normalized qualitative quality ranking, was developed, tested, applied in a case study and validated. This framework fulfills the aim stated in the STSM.

4. FUTURE COLLABORATION

The applicant is in the course of discussing with the supervisor of the STSM, his thesis supervisor and occasionally other colleagues, the possibility of extending the research conducted in this STSM. The context of such an extension (e.g. generalization of the methodology to other bridge typologies, inclusion of probabilistic considerations etc.) is, also, under discussion (e.g. co-authored publications etc.)

5. FORESEEN PUBLICATIONS/ARTICLES

A complete manuscript to be submitted as a journal article is fully written by the applicant already, and is in the process of being reviewed by the co-authors. The target journal, at this point, is the *ASCE Journal of Bridge Engineering*.

In addition, a short paper related to the STSM is scheduled to be written for the TU1406 meeting to be held in Riga, Latvia, in November of 2017.

6. ANNEXES

6.1. CONFIRMATION BY THE HOST INSTITUTION ON THE SUCCESSFUL EXECUTION OF THE STSM

The confirmation letter by the STSM supervisor, Assistant Professor José C. Matos, TU1406 Chair, of the host institution of the University of Minho, is uploaded as a separate file according to the STSM instructions, in addition to the current STSM technical report.

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