



QUALITY SPECIFICATIONS FOR ROADWAY BRIDGES,
STANDARDIZATION AT A EUROPEAN LEVEL

Scientific Report on Short Term Scientific Mission

Researcher
Home Institution
Host Institution
Start Date
End Date
Reference Code

Sérgio Fernandes
ANSER, Lda.
I.M.C. Consultants GmbH
January 20, 2019
January 29, 2019
TU1406_STSM_0000

sergio.cd.fernandes@gmail.com
<http://www.anser.pt>
<http://imc-ch.com/>



ESF provides the
COST Office through a
European Commission contract



COST is supported by
the EU Framework
Programme



CONTENTS

1.	Aims and Objectives	3
1.1.	Background	3
1.2.	Aims and Objectives.....	3
2.	Work carried out.....	4
2.1.	Background Work.....	4
2.2.	Terms and PIs	5
2.3.	Quality Control Framework.....	5
2.3.1.	Quality Control Framework.....	6
3.	Main results	8
4.	Foreseen publications/articles	9
5.	Annexes.....	10
5.1.	Tables.....	10

1. AIMS AND OBJECTIVES

1.1. BACKGROUND

The main objective of COST Action TU1406 is to develop a guideline for the establishment of quality control plans in roadway bridges, focusing on bridge maintenance and long-term performance by comparing performance indicators with performance goals.

Within the work developed by Workgroup 1, each participating country provided information regarding which performance indicators are used in their national assessment procedures and also how they are used. Additionally, information concerning the interpretation of their meaning was also provided.

This data was all collected in a database as a tool for the work to be developed by the subsequent workgroups.

More recently, Workgroup 3 has developed a quality control framework in which the performance indicators obtained in Workgroup 1 can be integrated.

1.2. AIMS AND OBJECTIVES

This Short Term Scientific Mission aims to complement the previous work that resulted in a database of performance indicators and a tool designed as an integrator of the work carried out within the framework of COST Action TU1406.

2. WORK CARRIED OUT

2.1. BACKGROUND WORK

From the work developed by Workgroup 1 (WG1) a list of 385 terms related to performance indicators (PI) and grouped in 11 clusters, from defects to rating and loads, was obtained. Upon further analysis, this list was later shortened to 108 terms.

All this data was collected and inserted in a relational database developed in a previous Short Term Scientific Mission (STSM).

The basis for the subsequent work of Workgroup 3 (WG3) was the extended list for which was assumed that not all of the entries could be considered PIs. Therefore, it was suggested a categorization of this data in order to correspond to the basic structure for the establishment of quality control plans: Design & Construction, Observations, Damage Processes and their symptoms.

This classification allowed to establish the relationship between terms and PIs and was essential to develop the framework.

The developed framework for quality control plans was represented by an Entity Relationship Diagram (R. Hajdin et al, 2018). This framework is presented in Figure 1.

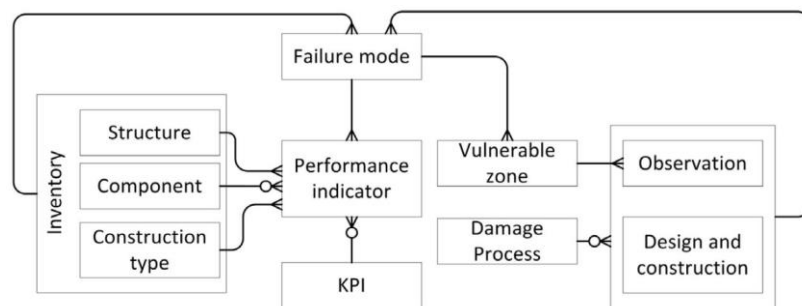


Figure 1. The framework ontology

This framework ontology allowed to present a bridge performance evaluation procedure (R. Hajdin et al, 2018). From this example, given in Figure 2, it was possible to understand how information could be retrieved from data bridge inspections in order to assess bridge performance.

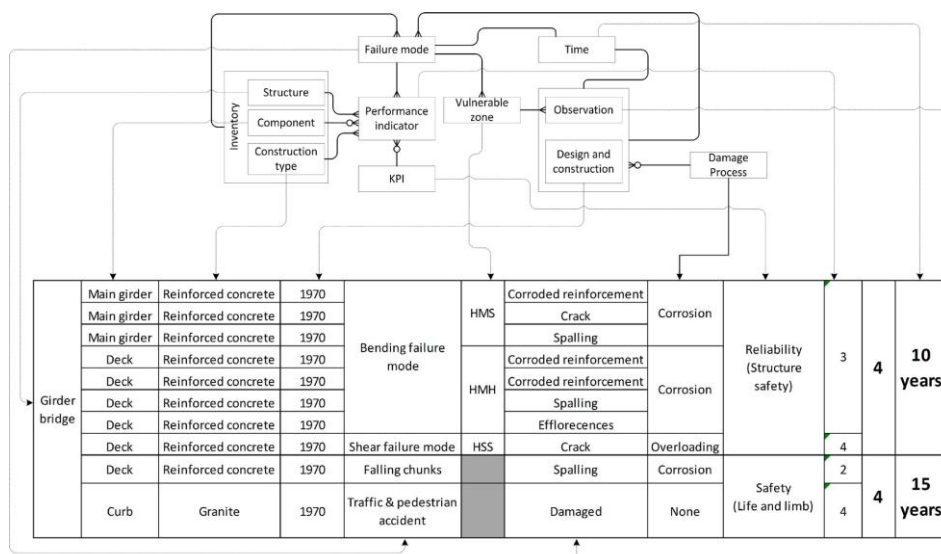


Figure 2. Protocol for performance evaluation

2.2. TERMS AND PIS

Since the work of WG3 was based on the list of 385 terms and WG1 has since shortened this list, it became necessary to assess if any update to the WG3 report was needed.

From this analysis was concluded that from the 108 terms, 45 were already referenced in the WG3 report. For the remaining 63 terms, 39 were considered as already included in the WG3 report proposed clusters: Design & Construction; Damage Processes; Observations/Performance Indicators; and Observations/Symptoms. The remaining 24 terms, listed in WG1 report, were considered to be condition ratings, network related or too ambiguous. All of these terms are shown separately in Table 1, Table 2 and Table 3 respectively.

Additionally, the analysis also included the identification to which key performance indicators (KPIs) of the RASÉE goals belong the 44 referenced terms.

2.3. QUALITY CONTROL FRAMEWORK

The established quality control framework was translated in the entity relationship diagram presented in Figure 1. However, when analyzing this entity relationships diagram in Figure 2 one may find the placement of the entity “Design and Construction” questionable.

Taking a closer look to Figure 2, it seems that’s the data associated to this entity refers to characteristics of the structure. Therefore, this entity should be considered not as an “observation”, but rather as inventory information. In Figure 3 is proposed a new design for the framework ontology.

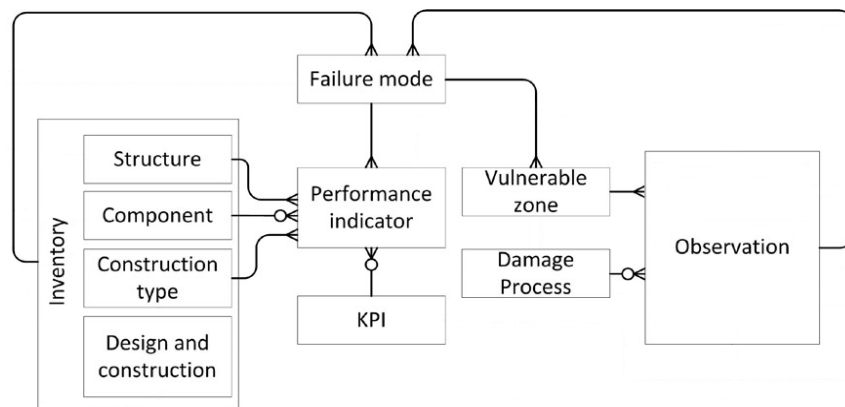


Figure 3. Proposal for the new framework ontology

This change of the framework ontology leads to a change in the example of the adopted protocol which is presented in Figure 4.

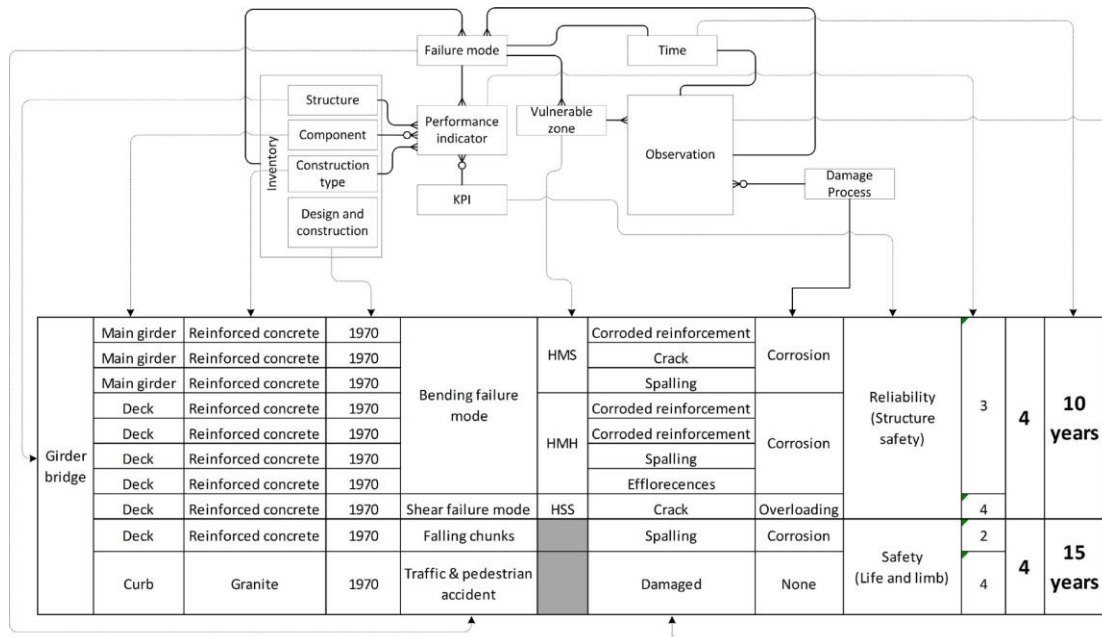


Figure 4. Proposal for the new example of the adopted protocol

2.3.1. QUALITY CONTROL FRAMEWORK

In the same way that for the work carried out by the WG1 a relational database was developed in which all the information obtained was inserted, the same was proposed to perform for WG3.

After an analysis of the report, with special emphasis on the ontology and the example of the developed protocol, a database was created which structure was centered in the information regarding each structure (bridge) and the performed inspections that will allow to determine the performance.

The developed database is shown in Figure 5 where the tables and relation between them can be analyzed.

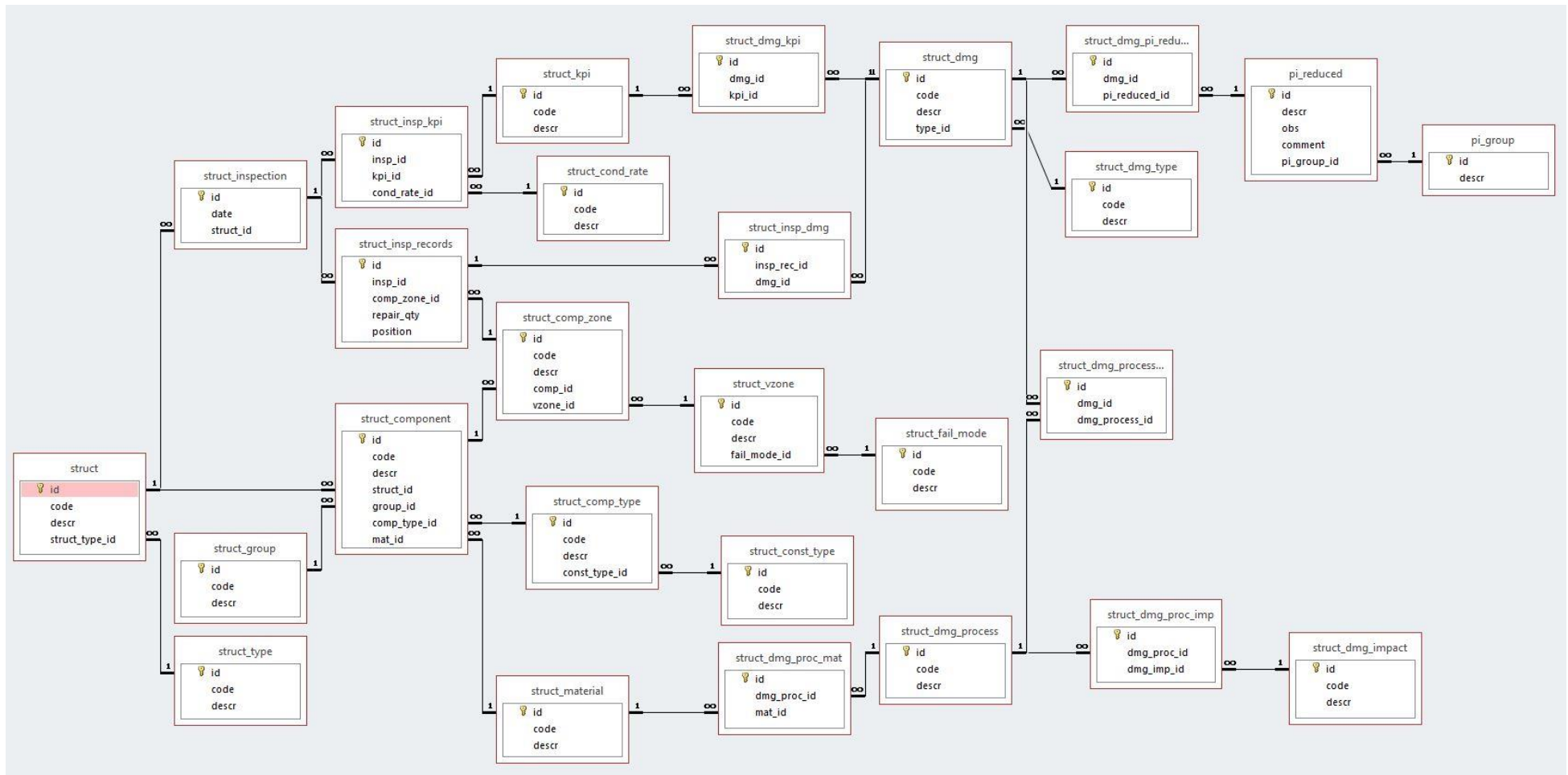


Figure 5. Relational database

3. MAIN RESULTS

The outcome of this STSM is a tool that can easily be distributed to those interested in the subject of COST Action TU1406, making it simple to consult the information gathered by WG3.

The result of the developed work is part of a broader tool which was developed during COST Action TU1406 and can eventually be the basis for future work related to Bridge Management Systems.

4. FORESEEN PUBLICATIONS/ARTICLES

The work carried out during this STSM was developed within the framework of WG3. Therefore, the publication of any information related to its outcomes should be considered in co-authority with parties that had direct involvement in obtaining the results of WG3.

Nevertheless, any joint publication will meet the desired achievements of COST Action TU1406 and will benefit greatly both the researcher and the home institution, giving a broader perspective of the developed work which merged efforts from academics and consultants.

5. ANNEXES

5.1. TABLES

Table 1. Terms referenced in the WG3 report

Workgroup 1		Reliability	Availability	Safety	€conomy	Environment	Workgroup 3	
Performance Indicator	Cluster						Cluster	Observation
concrete cover (insufficient)	defects				x	x	Design & Construction	Insufficient concrete cover
crack form/pattern	defects	x		x	x	x	Observations/Performance Indicators	Cracks
crack formation stage	defects	x		x	x	x	Observations/Performance Indicators	Cracks
crack length	defects	x		x	x	x	Observations/Performance Indicators	Cracks
crack orientation	defects	x		x	x	x	Observations/Performance Indicators	Cracks
crack spacing	defects	x		x	x	x	Observations/Performance Indicators	Cracks
crack width	defects	x		x	x	x	Observations/Performance Indicators	Cracks
cracks related to origin (e.g. due to loading, due to settlement, due to crumbling of concrete,...)	defects	x		x	x	x	Observations/Performance Indicators	Cracks
fatigue cracking	defects	x		x	x	x	Damage Process	Fatigue
settlement	defects	x		x	x	x	Observations/Performance Indicators	Displacement
carbonation depth	related to material properties				x	x	Observations/Symptoms	Chemical parameter
chloride content	related to material properties				x	x	Observations/Symptoms	Chloride content
chloride depth profile	related to material properties				x	x	Observations/Symptoms	Chloride content
concrete strength deficiency	related to material properties				x	x	Design & Construction	Concrete quality insufficient
corrosion	related to material properties		x	x	x	x	Damage process	Corrosion related to equipment made of steel
corrosion related to prestressing steel	related to material properties	x		x	x	x	Damage process	Corrosion related to prestressing steel
corrosion related to protective coating (corrosion stains)	related to material properties	x		x	x	x	Damage process	Corrosion related to equipment made of steel
corrosion related to reinforcement steel	related to material properties	x		x	x	x	Damage process	Corrosion related to reinforcement steel
corrosion related to structural steel	related to material properties	x		x	x	x	Damage process	Corrosion related to structural steel
fatigue (remaining service life)	related to material properties	x		x	x	x	Damage process	Fatigue

pitted corrosion (or corrosion pitting?)	related to material properties	x		x	x	x	Damage process	Pitting corrosion
approach slab settlement	related to equipment & protection	x		x	x	x	Observations/Performance Indicators	Displacement
waterproofing deterioration/loss	related to equipment & protection	x		x	x	x	Observations/Performance Indicators	Waterproofing loss
leaning	geometry changes	x		x	x	x	Observations/Performance Indicators	Displacement
misalignment	geometry changes	x		x	x	x	Observations/Performance Indicators	Displacement
sag / deformation / denivelation	geometry changes	x		x	x	x	Observations/Performance Indicators	Displacement
differential displacement	geometry changes	x		x	x	x	Observations/Performance Indicators	Displacement
bearings displacement	related to bearing capacity, structural integrity and joints	x		x	x	x	Observations/Performance Indicators	Displacement
loss of section (reduced section, section area absence)	related to bearing capacity, structural integrity and joints	x		x	x	x	Observations/Performance Indicators	Loss of section (reduced section)
prestressing cable failure	related to bearing capacity, structural integrity and joints	x		x	x	x	Observations/Performance Indicators	Prestressing cable failure
reinforcement bar failure	related to bearing capacity, structural integrity and joints	x		x	x	x	Observations/Performance Indicators	Reinforcement bar failure/bending
thermal expansion	related to bearing capacity, structural integrity and joints	x		x	x	x	Damage Process	High temperature
concrete cover	related to original construction and design				x	x	Design & Construction	Insufficient concrete cover
frequency	related to dynamic behaviour	x		x	x	x	Observations/Performance Indicators	Frequency
noise	related to dynamic behaviour				x	x	Observations/Symptoms	Sound
vibration level	related to dynamic behaviour	x		x	x	x	Observations/Performance Indicators	Vibrations/oscillations
vibrations/oscillations	related to dynamic behaviour	x		x	x	x	Observations/Performance Indicators	Vibrations/oscillations
freeze-thaw	environmental based	x		x	x	x	Damage Process	Freeze-thaw

	(common appearance)							
temperature	environmental based (common appearance)	x		x	x	x	Damage Process	High temperature
Erosion	sudden events	x		x	x	x	Damage Process	Erosion
Extreme wind	sudden events	x		x	x	x	Sudden Events	Natural Hazard
Impact (e.g. of vehicles or ships)	sudden events	x		x	x	x	Sudden Events	Natural Hazard
Rock fall	sudden events	x		x	x	x	Sudden Events	Natural Hazard
Scour	sudden events	x		x	x	x	Sudden Events	Natural Hazard
seismic activity of the area	sudden events	x		x	x	x	Sudden Events	Natural Hazard

Table 2. Terms not referenced in the WG3 report

Workgroup 1		STSM Consideration	
Performance Indicator	Cluster	Cluster	Observation
water penetrability	defects	Observations/Symptoms	Wet spots
wetting/leaking	defects	Observations/Symptoms	Wet spots
cathodic protection deficiency	related to material properties	Design & Construction	Cathodic protection deficiency
contamination (agent content)	related to material properties	Damage Process	Chemical attack / Biological growth
galvanization deficiency	related to material properties	Design & Construction	Galvanization protection deficiency
prestressing steel ductility deficiency	related to material properties	Design & Construction	Prestressing steel deficiency
prestressing steel strength deficiency	related to material properties	Design & Construction	Prestressing steel deficiency
reinforcing steel ductility deficiency	related to material properties	Design & Construction	Reinforcing steel deficiency
reinforcing steel strength deficiency	related to material properties	Design & Construction	Reinforcing steel deficiency
structural steel ductility deficiency	related to material properties	Design & Construction	Structural steel deficiency
structural steel strength deficiency	related to material properties	Design & Construction	Structural steel deficiency
absence (missing) of equipment component	related to equipment & protection	Observations/Symptoms	Absence of component
blistering of protective coating	related to equipment & protection	Damage Process	Corrosion related to equipment made of steel
deterioration of protective coatings (e.g. corrosion protection, impregnate...)	related to equipment & protection	Damage Process	Corrosion related to equipment made of steel
absent (missing) structural component	related to bearing capacity, structural integrity and joints	Observations/Symptoms	Absence of component
arch ring separation	related to bearing capacity, structural integrity and joints	Observations/Performance Indicators	Cracks or Changing geotechnical properties or Overloading of an element
bearings deformation	related to bearing capacity, structural integrity and joints	Observations/Performance Indicators	Deformation
grouting deficiency	related to bearing capacity, structural integrity and joints	Design & Construction	Grouting deficiency
insufficient height of railing (safety barrier)	related to bearing capacity, structural integrity and joints	Design & Construction	Insufficient material quality
joint deterioration	related to bearing capacity, structural integrity and joints	Observations/Performance Indicators	Deteriorated mortar joints
resistance	related to bearing capacity, structural integrity and joints	Observations/Performance Indicators	Rupture
carrying capacity factor	related to original construction and design	Design & Construction	Design Property

design load	related to original construction and design	Design & Construction	Design Property
ductility	related to original construction and design	Design & Construction	Design Property
excessive strain	related to original construction and design	Design & Construction	Design Property
stiffness	related to original construction and design	Design & Construction	Design Property
damping	related to dynamic behaviour	Design & Construction	Damping
environmental exposure	environmental based (common appearance)	Observations/Symptoms	Silting and vegetation
humidity	environmental based (common appearance)	Observations/Symptoms	Wet spots
redundancy	rating	Design & Construction	Design Property
remaining service life	rating	Design & Construction	Design Property
resilience	rating	Design & Construction	Design Property
road category (roadway width)	rating	Design & Construction	Design Property
bridge length	cost and importance	Design & Construction	Design Property
bridge span	cost and importance	Design & Construction	Design Property
traffic restrictions	cost and importance	Design & Construction	Design Property
traffic volume (annual average daily traffic)	cost and importance	Design & Construction	Design Property
permanent loading	loads	Design & Construction	Design Property
traffic loading	loads	Design & Construction	Design Property

Table 3. Terms not considered to be PIs

Workgroup 1		STSM Consideration
Performance Indicator	Cluster	
material characteristics	related to material properties	Ambiguous
asphalt pavement cracking	related to equipment & protection	Damage within pavement management systems
asphalt pavement wearing and tearing (rutting, ravelling)	related to equipment & protection	Damage within pavement management systems
asphalt pavement wheel tracking and wrinkling and undulation	related to equipment & protection	Damage within pavement management systems
number of failed connectors/fasteners (screw, bolt, rivet, weld,...)	related to bearing capacity, structural integrity and joints	Second level of data collection
advanced deterioration process	rating	Ambiguous
condition rating	rating	Evaluation scale
damage degree/extension	rating	Ambiguous
deterioration index	rating	Ambiguous & Index not a PI
importance of the bridge in the network	rating	Network Related
inadequate clearance	rating	Observations/Performance Indicators
priority repair ranking	rating	Network Related
probability of detection	rating	Ambiguous
probability of failure	rating	Ambiguous
reliability index	rating	Index is an evaluation scale, not a PI
risk	rating	Not a PI as considered by WG3
robustness	rating	Not a PI as considered by WG3
safety index	rating	Index is an evaluation scale, not a PI
element functionality level	cost and importance	Not a PI as considered by WG3
detour distance	cost and importance	Network Related
importance of bridge element	cost and importance	Not a PI as considered by WG3
price of the new element	cost and importance	Not a PI as considered by WG3
sum of costs for repair of individual damages	cost and importance	Not a PI as considered by WG3
Extreme traffic load	sudden events	Not a PI as considered by WG3



TU1406
COST ACTION

WWW.TU1406.EU