TECHNICAL REPORT

European Railway Bridge Problems

Deliverable D 1.3

Project acronym:	**Sustainable Bridges**
Project full title:	**Sustainable Bridges – Assessment for Future Traffic Demands and Longer Lives**
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PRIORITY 6

SUSTAINABLE DEVELOPMENT

GLOBAL CHANGE & ECOSYSTEMS

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1 Introduction

This report comprises deliverable D 1.3 from Work Package 1, defined in the contract documentation as “a report detailing construction and maintenance problems, sub divided into those that are of pan-European relevance and those that are local to a particular country or region”. The data presented within this report has been collected from the 17 European railway administrations that responded to a questionnaire initially formulated following preliminary discussions within WP 1 and amended at the request of the other WP leaders.

The report discusses the methodology used in obtaining the data, the success in obtaining data from those requested to provide information and the reliability of the data obtained. It then goes on to present the analysed data in outline, supported by a series of spreadsheets in appendix A2.

The questionnaire used for this data gathering is presented as appendix A1.

Section 5 of this report reproduces a table extracted from the minutes of a meeting of WP2 held in Malmo in April 2004, which discussed the early survey returns and suggested the appropriate Work Package to deal with the problems identified. The table is shown here to assist the other Work Packages in reviewing their proposed effort in relation to the identified needs of the European railways surveyed.

2 Survey Methodology

2.1 Initial ideas

From the very early meetings to prepare the Sustainable Bridges bid, it was realised that the small number of railway owners represented in the consortium would not be able to give a fully representative view of the problems affecting railway bridges across Europe. The bid thus allowed, within the activities of WP1, for a survey of all major European railways.

It was initially uncertainty whether this survey should be based on face-to-face interviews, telephone interviews or the use of a questionnaire. During contract negotiations with the EU the funding available to the project was reduced from the original bid figure and, in order to reserve as much funding as possible for RTD activities, it was decided that face to face interviews would not be feasible.

Hence, either telephone based interviews or the use of a questionnaire were the options taken forward to the kick off meting.

2.2 Preparation of questionnaire

2.2.1 Barcelona meeting

At the Barcelona kick off meeting, the railway contractors agreed that the best format for the railway survey would be a questionnaire, distributed electronically to selected railways by nominated “partner” railways within the Sustainable Bridges consortium. The leaders of WPs 3 to 9 were asked to let WP1 have details of the initial information that they would require to enable them to make an early start to their work.

The “railway” contractors agreed to meet in early January 2004 in Frankfurt, under the joint auspices of WP1 and WP2, to finalise the creation of the questionnaire and to choose the railways asked for data. In addition, the “technical” Work Packages (WP3, WP4, WP5 and WP 6) arranged a joint meeting in Paris in late January 2004.

To enable WP1 to make a meaningful presentation to the Paris meeting each railway contractor agreed to provide basic statistical data on bridge type, maintenance problems and a list their current research activities to the WP1 leader, by the end of December 2003.

2.2.2 Frankfurt meeting

At the Frankfurt meeting the initial returns from the railway contractors, processed into a Power Point presentation were analysed and discussed, and it was agreed that the leader of WP1 should present these initial findings to the Paris meeting mentioned above. Since two of the WP members were attending the UIC (Union Internationale des Chemins de Fer) Structures Experts’ meeting in Paris they agreed to brief that meeting on the aims of the Sustainable Bridges project and to seek the assistance of the UIC Structures Experts in completing the questionnaire.

The following split of responsibilities for data gathering was agreed;

DB	Switzerland and Austria
SNCF	Italy, Belgium, Holland
NR	Spain, Portugal, Republic of Ireland, Northern Ireland
BV	Denmark, Norway
PLK	Czech Republic, Slovakia, Hungary, Croatia, Slovenia
RHK	Latvia, Lithuania

The meeting agreed that following topic areas, incorporating requests received from other WP leaders, that should be included in the questionnaire.

Statistics of bridge stock: (number, type, typical span range <10m; 10-40m; >40m, age of superstructure)

Problem areas: Can be connected to the structure type - include piers (including columns), substructure, abutment, foundation, bearings. Give some lines to write additional information.

Current research activities financed from Railway owners: Give “tick” options to categorise by different areas such as new materials, surface coatings, design, assessment, and lines for other research, split between theoretical and applied.

Research wish list (5 areas with highest priority)

Existing codes and standards for existing railway bridges:

There was some discussion about enabling of the questionnaire for on line completion. The initial decision was to proceed on that basis but subsequent enquiries into costs showed that it would be uneconomic, since only 24 questionnaires were to be used (six to WP1 members and 18 to other railways).

2.2.3 Paris meeting

Following the Frankfurt meeting outlined above, a first draft of the questionnaire was prepared, and circulated it initially to the WP1 members. After incorporating minor corrections, a modified draft questionnaire was circulated to all the other WP leaders, with a request that they propose further amendments no later than the close of the Paris meeting.

A presentation made to the Paris meeting outlined the initial findings from the partner returns. This showed the likely priority areas to be assessment, dynamic factors and non-disruptive maintenance, all of which align well with the high level objectives of the project and the FP6 call under which it is being funded.

3 Questionnaire circulation and response levels

Following further minor amendments to the questionnaire the final version was placed on the project intranet on 4 February 2004. The six partner railways then approached their 18 nominated contact railways, requesting return of the completed questionnaires by the end of February. Regrettably, there was a quite considerable delay in obtaining completed questionnaires, with seven of the railways originally approached failing to respond by the final cut off date of early May. It is fortunate that all the "non responders" are relatively small railways and their absence should not detract from the conclusions of from the survey.

The completed returns provide a good geographic spread across Europe, spanning from Italy in the South to Finland in the North and from Poland in the East to the Irish Republic in the West, and represent all the major European railways. They also successfully cover several different European climates; hot dry Mediterranean; colder Alpine/Nordic and wet/warm Atlantic seaboard.

An Excel spreadsheet was drawn up to record the data as it was received and three successive versions were placed on the project intranet site between late March and early May 2004. A Power Point presentation was prepared to give the results then available to a meeting of WP6 in Stockholm in March 2004, which was updated for a presentation to WP4 in Copenhagen in April 2004. In addition, at these WP meetings the basic Excel spreadsheet as made available so that the WP leaders could analyse the data in a way more appropriate to their needs, should they so desire.

All the completed questionnaires received have been placed on the project intranet site, so that all partners are able to extract data relevant to their work that is not in an appropriate format on the final spread sheet, which contains information on over 220,000 railway bridges. This final spreadsheet was made available to all partners on the intranet site in May 2004.

The returns received do not show any marked difference in construction and maintenance problems across the railways surveyed, although there are differences in priorities.

4 Survey results

Below there is some general discussion on the survey returns and "headline" outputs under a number of headings that are relevant to this deliverable. The sections of a full Excel spread sheet recording all the data obtained from the survey, divided between responding railways, which form the basis of the following headline outputs are in Appendix A2.

4.1 Discussion on returns

The nature of the questions asked in relation to this deliverable means that the answers are, at least in part, subjective. This means that they represent the views or opinions of the person answering the questionnaire, rather than necessarily representing the "corporate" position of the railway approached and cannot be checked.

It is interesting, in view of the points outlined above, that there is a great measure of agreement on maintenance problems and research priority areas, which, fortunately, agree closely with the preliminary results drawn from the initial returns of the partner railways. This is probably because there is not a great variation in bride types, ages and span lengths across the railways surveyed for this exercise.

The data is presented in outline below under a number of heading that seem relevant to the Sustainable Bridges project. A more detailed analysis, in the form of spreadsheet is in appendix A2. In analysing the results outlined below and in the spreadsheets in the appendix, the following definitions have been used:

"**Maintenance**" means any physical work undertaken to a bridge within the more detailed categories "rehabilitation", "strengthening" or "replacement".

"**Rehabilitation**" means returning the bridge as nearly as possible to its original condition and carrying capacity.

"**Strengthening"** means improving the carrying capacity beyond that for which the bridge was originally designed.

"**Replacement**" means either the replacement of the superstructure or the total replacement of the bridge, either in its original position or in a new position.

There has not been a detailed investigation of "Replacement" activities, since the focus of the Sustainable Bridges project relates to the life extension of existing bridges with the minimum of interruption to the traffic using the bridge. Replacement cannot normally achieve this objective, although it will continue to be a necessary activity as bridges reach the end of their natural life.

4.2 Current maintenance activities

Railways were asked to report their current maintenance activities; sub divided between arch bridges, metallic bridges, concrete bridges and concrete/steel composite bridges. These type categories were then further sub divided between rehabilitation, strengthening and replacement activities.

The intention was to record the relative percentages of each activity, with the total of all activities adding to 100%. This would have established the relative importance of all maintenance activities currently in use. However, the question was not framed in an

unambiguous way and most returns gave the relative importance of each maintenance activity within each bridge sub type. This means that it has been virtually impossible to determine the relative importance of different bridge types in terms of maintenance activity/spend.

4.2.1 Concrete beam bridges

The major current maintenance activity on concrete bridges is rehabilitation, with strengthening also featuring quite highly in a number of cases. Replacement is the major maintenance activity on concrete bridges for two of the respondent railways in Eastern Europe.

4.2.2 Metallic beam bridges

The major current maintenance activity on metallic bridges is rehabilitation, with strengthening and replacement also featuring quite highly in a number of cases. There are no discernible regional trends in the variation of activity.

4.2.3 Masonry arch bridges

The major current maintenance activity on masonry arch bridges is rehabilitation, with replacement also featuring quite highly in a number of cases. A small amount of strengthening activity is also being undertaken. There are no discernible regional trends in the variation of activity.

4.2.4 Other arch types

The major current maintenance activity on other arch bridges (assumed mainly to be concrete) is rehabilitation, with replacement also featuring quite highly in a number of cases. A small amount of strengthening activity is also being undertaken. There are no discernible regional trends in the variation of activity.

4.2.5 Steel/concrete composite bridges

The major current maintenance activity on steel/concrete composite bridges appears to be either rehabilitation or replacement. Virtually no strengthening activity is being undertaken.

There is little middle ground; a railway is either rehabilitating or replacing such bridges. Most replacement activity is being undertaken in central Europe, whilst rehabilitation is the norm in most other areas.

4.3 Current maintenance problems

The railways surveyed were asked to indicate their current maintenance problems with both superstructures and substructures (including bridge ends/transition zones), irrespective of how the problem was physically resolved. The replies were analysed, by simply counting the number of “ticks” recorded against each problem, for sub structures and superstructures and then recorded separately for each major bridge type (superstructures) and element (substructures). This analysis is discussed in more detail below.

4.3.1 Bridge superstructures

Waterproofing is a major maintenance problem and is not limited to one particular type of bridge. For concrete beam bridges the major problems are corrosion of pre-stressing tendons; reinforcement corrosion and cracking/spalling of cover concrete, whilst wrought iron and steel beam bridges suffer from corrosion and fatigue cracking and masonry arches see materials degradation coupled with cracking. Maintenance problems with other bridge types (cast iron, non masonry arches and composite) do not feature greatly in the returns and in most cases the reported problems mirror those of their beam counterparts (concrete spalling, materials degradation etc.).

4.3.2 Bridge substructures and transition zones

For bearings, the biggest maintenance issue appears to be their seizure or fracture, whilst settlement is the major issue with abutments, foundations and transition zones and scour features highly for bridges with abutments or piers in, or close to, rivers.

4.4 Current rehabilitation methods

In order to assess the relative importance of rehabilitation methods currently in use, the railways surveyed were asked to prioritise their activities in this field. This prioritisation was converted into a score out of 10 (with 10 being the most important) and the results recorded.

Six activities stand out as being the most important currently in use. These are (in approximate order of importance): painting of metalwork, concrete repairs, patch repair of damaged brickwork/masonry, patch repairing of corroded metalwork, waterproofing and pointing of brickwork /masonry.

4.5 Current strengthening methods

In order to assess the relative importance of strengthening methods currently in use, the railways surveyed were asked to prioritise their activities in this area. This prioritisation was converted into a score out of 10 (with 10 being the most important) and the results recorded.

Unlike the rehabilitation activities discussed above there is a less clear-cut split between more important and less important. Two activities are clearly very important: replacement of metallic structural members and concrete saddling of arches. The following are less important, but still widely used: arch reinforcement, underpinning of foundations, addition of new metallic members, underlining of arches, increasing the cross section of concrete members and soil improvement.

4.6 Priority needs from Sustainable Bridges

Finally, the railways surveyed were asked to give five priority research topics/outcomes from the Sustainable Bridges project. As this information was not in a standard format it was listed and combined where it seemed appropriate to do so. These results were recorded on a “block chart” under the following main headings; assessments, inspection/monitoring, repair/maintenance, bridge management and new build.

It is clear that the main priority need relates to assessment, with better assessment rules and confirmation of dynamic factors both scoring very highly, with one or the other being mentioned by virtually all respondents. No other theme attracted the same level of response, but better inspection/diagnosis tools, the repair of concrete structures and the use of new materials in both maintenance and new build all appear to be important topics for investigation.

5 Comments from WP2 on survey results

The following table has been extracted from the minutes of a WP2 meeting and is given here so that the "technical" WP leaders are able to understand which topics appear to WP2 to be within the scope of their work packages and the suggested level of detail for their outputs. The table has been split between rehabilitation and strengthening.

5.1 Rehabilitation

Rehabilitation activity	**Description of problem**	**WP?**	**Recommended level of detail for SB work**
Concrete repair			Research
Painting of metalwork	System of corrosion protection. We have systems that work well.	WP6	State-of-the-art report
Waterproofing	How can bridges be modified to avoid water leakage.	WP6	State-of-the-art report
Masonry (Patch repair, pointing, stitching)	Cooperation to the UIC arch bridge project.	WP6	Contact UIC and cooperate with them.
Patch repair of corroded metalwork	Look at new materials- FRP Steel repairing	WP6	
Bearing replacement	Problem in design and in operation/maintenance	WP4 WP5 WP6	Research to develop new methods for replacements
Embankment remediation at bridge ends	Some see no problem Problem if you have a lot of trains with high frequency. Mixed traffic problem. Influence by soil conditions	WP3 WP4 WP6	Research (SGI) Look at different existing solutions.
Underpinning of foundations (strengthening)	Rotting of timber foundations.	WP3	Research
Reinforcement replacement	Repairing methods		State-of-the-art of repair methods.

5.2 Strengthening

Strengthening methods	**Description of problem**	**WP?**	**Recommended level of detail for SB work**
Replacement of metallic structure members/additional structural steel members/FRP strengthening external prestressing		WP6	Research to come up with practical solutions
Arches (saddling, underlining, reinforcement, FRP, external pre-stressing)	In cooperation to UIC arch project. Doubtful to ability to strengthening arches with FRP or other methods.	WP4 WP6	Cooperation with UIC on arch bridges
Underpinning and soil improvement, embankment remediation		WP3 WP6	State-of-the-art (SGI)
Reinforced concrete (additional reinforcement, increased section, FRP, external pre-stressing)		WP4	State-of-the-art

6 Conclusions

Seventeen responses have been received to questionnaire requesting statistical data on bridge types, ages and span characteristics that was circulated to twenty-four European railways. The returns that were not received were from smaller railways and the absence of data from those railways will not significantly affect the data analysis and conclusions drawn.

The data received, which geographically covers most of Europe and its major climate zones, shows that the majority of maintenance activity is related to the rehabilitation of existing bridges. The maintenance problems experience by railway bridge owners across Europe are quite similar and are typical of the kinds of problems that affect ageing bridges. Similarly, the maintenance activities undertaken are generally traditional, well-tried and tested solutions to problems that are quite well understood.

These needs fit in well to the overall objectives of the Sustainable Bridges programme and will be used by WP2 to ensure that the listed priority needs are addressed by the technical work packages. With this in mind, preliminary outputs have already been presented to WP 4 and WP 6 to enable them to check that their proposed work plans remain logical. All work packages should check their work plans against the targets identified by WP2 and reproduced in section 5 of this report to ensure that all the priority areas are being addressed and that the correct level of resources has been allocated.

The data gathering would not have been possible without the support of the railway undertakings who are partners in the Sustainable Bridges consortium; Network Rail Infrastructure Ltd (UK), Banverket (Sweden), Deutsche Bahn AG (Germany), RHK (Finland), Société Nationale des Chemins de fer Français (France)and PKP Polskie Linie Kolejowe SA Poland).

Appendices

A1

Questionnaire blank

Questionnaire for European Railways

Introduction

Sustainable Bridges is an Integrated Project, funded through the EU 6th Framework programme, which is attempting to assist the railways in Europe to meet, with minimum disruption, the European Commission's policy of increasing the use of railways for both passenger and freight traffic. The consortium consists of 32 partners, with the following railway administrations being partners in the project; Network Rail Infrastructure Ltd, Banverket, Deutsche Bahn AG, RHK (Finnish Railway Administration), Société Nationale des Chemins de fer Français and PKP Polskie Linie Kolejowe SA. More information can be found on the project web site http://www.sustainablebridges.net/.

In order to ensure that the project produces results that will be useful to the majority of European railways it is important that the size, type and condition of existing railway bridges is known, that real maintenance problems are addressed and that existing or on going research is not duplicated.

The consortium would be very grateful if you could take a few minutes to answer the following questions (preferably in English) on behalf of your railway, it should not take more than 15 to 30 minutes of your time. When completed please return the questionnaire to the railway partner who approached you initially, either by fax or by e-mail. If you are filling in the questionnaire by hand please print your answers in capital letters.

Firstly, please indicate below your contact details for the person filling in this questionnaire.

Name of Railway	
Address	
Name of contact person	
Job title of contact person	
e-mail address	
Telephone number	
Fax number	

PART 1 - BRIDGE STATISTICS

Superstructure Materials

Please give the total number of bridges owned and maintained by your railway, having a span of more than 2m, divided into the following materials. Please count multi span viaducts as one bridge. For the secondary data, please give this if it is readily available either as a number, or an approximate percentage of the type. The information should be given to the best level of accuracy readily available (the nearest 500 will generally be quite good enough except for the smallest railway administrations).

Bridge type			*Number*
Arch		Type total	
Brick	No. or %		
Natural stone	No. or %		
Concrete	No. or %		
Other material	No. or %		
Concrete beam		Type total	
Reinforced concrete	No. or %		
Pre-stressed or post tensioned concrete	No. or %		
Steel/concrete composite or embedded girder		Type total	
Metallic beam		Type total	
Steel	No. or %		
Wrought Iron	No. or %		
Cast Iron	No. or %		
Other		Type total	
Grand total			

Please indicate in the space below what "other" materials are included above.

Age

Please give below the approximate age profile of each category below by percentage.

	Approximate age			
Category	**<20 yrs**	**20-50 yrs**	**50-100 yrs**	**>100 yrs**
Arch				
Metallic				
Concrete				
Steel/concrete composite				
Sub structure				

Span length

Please give below the approximate span (superstructure) profile of each type of bridge by percentage.

	Span range		
Bridge type	**<10 m**	**10-40 m**	**>40 m**
Arch			
Concrete			
Steel/concrete composite			
Metallic			

Bridge status

Please indicate the percentage of bridges by the following categories.

Category	**% of total**
Under the railway	
Over the railway	

Of those over the railway	**% of sub total**
Carrying public roads	
Carrying footpaths	
Carrying waterways	
Carrying private roads	

New lines

Is your railway building any new railway lines? **Yes/No**

If so, roughly what length is:

Under construction?	Km
Planned?	Km

What is the main bridge type? (For example *post tensioned concrete; steel/concrete composite.*)	

Track gauge

What track gauge(s) exist on your railway? Please indicate the approximate percentage of each gauge if you have more than one.

Track gauge	**Percentage**

PART 2 – BRIDGE INSPECTION & MONITORING

INSPECTION

Please give the normal interval between bridge inspection cycles.

Examination type	**Interval (Years or months)**
Visual (i.e. *without using special access*)	
Detailed (i.e. *at touching distance*)	

Do these intervals vary between different types of bridge? **Yes/No**

If so, please specify by how much and why below;

b) MONITORING

Has your railway ever used monitoring/instrumentation to check bridges? **Y**es/No

Does your railway regularly use monitoring/instrumentation to check bridges? Yes/No

If you have answered "yes" to either of the above, please specify below the reason(s) for using monitoring.

Please say what information that could be obtained by new or improved monitoring systems would improve or reduce the cost of bridge ownership to your railway.

Please indicate below the types of system that are/have been used for bridge monitoring, their usefulness and the approximate number of times per year that they are/have been used.

Monitoring system	**Used**		**Useful**		**Level of use (Times/year)**
	Yes	**No**	**Yes**	**No**	
Strain gauging					
Deflection monitoring - manual					
Deflection monitoring - lasers					
Vibration monitoring					
Crack monitoring - manual					
Crack monitoring - automatic					
Chloride and/or carbonation					
Half cell potential					
Sonic transmission					
Tomography					
Ground probing radar					
Acoustic emission					
Train/axle weight					
Track unevenness (for bridge dynamics)					
Other (please specify)					

Please say below why the monitoring was or was not useful.

Existing bridges

Are you planning to monitor any existing bridges in the next two years? **Yes/No**

Would you be willing to share monitoring data with the project, or would be prepared to make an existing bridge available to the project for monitoring? **Yes/No**

New bridges

Do you have any new bridges planned or under construction that would benefit from monitoring? **Yes/No**

Would you be willing to make a new bridge available for monitoring under the project, if an appropriate type was identified? **Yes/No**

PART 3 - MAINTENANCE ISSUES

Please indicate the major maintenance problems that your railway has with the following types of bridge. If you do not have a particular type of bridge on your railway please enter N/A.

SUPERSTRUCTURES

Pre stressed/post tensioned concrete (For example *inspection of tendons for corrosion; lack of grouting*)

Reinforced concrete (For example *corrosion of reinforcement; fatigue*)

Steel/concrete composite of embedded girders (For example *examination of shear studs*)

Steel (For example *brittle fracture; fatigue*)

Wrought iron (For example *rusting/delamination; rivet condition*)

Cast iron (For example *deterioration of exposed surfaces; sudden failure*)

Brick or stone arches (For example *cracking; distortion*)

Concrete or other arches (For example *water ingress*)

SUBSTRUCTURES

Bearings (For example *lack of movement; difficulty of inspection*)

Abutments (For example *differential movement; embankment settlement*)

Piers/columns (For example *cracking*)

Foundations (For example *settlement; failure of bearing piles*)

Approach embankments/transition zones/bridge ends (For example *settlement; deterioration*)

PART 4 - MAINTENANCE ACTIVITIES

Please indicate, by the use of approximate percentages, the proportion of your railway's bridge maintenance activity undertaken in the following areas.

In this table:

- "Rehabilitation" means returning the bridge as nearly as possible to its original condition and carrying capacity.
- "Strengthening" means improving the carrying capacity beyond that for which the bridge was originally designed.
- "Replacement" means either the replacement of the superstructure or the total replacement of the bridge, either in its original position or in a new position.

	Maintenance activity		
Bridge Type	**Rehabilitation**	**Strengthening**	**Replacement**
Stone or brick arch			
Other arch types			
Concrete			
Steel/concrete composite			
Metallic			

For rehabilitation activities, please indicate if possible the approximate percentage break down of the activities undertaken (by volume or cost), and also the priority order (most important scored 1) of the various activities to your railway; please add to the list as necessary:

Rehabilitation Activity	**%**	*Priority*
Embankment remediation at bridge ends		
Underpinning of foundations		
Pointing of brick or masonry		
Patch repair of damaged brick or masonry		
Stitching of masonry (*Fondedile type*)		
Patch repair of corroded metalwork		
Painting of metalwork		
Concrete repairs		
Re-alkalisation or chloride extraction		
Application of cathodic protection		
Reinforcement replacement		
Tendon replacement		
Waterproofing		
Bearing replacement		
Other (please specify)		

For strengthening activities, please indicate if possible the approximate percentage break down of the activities undertaken (by volume or cost), and also the priority order (most important scored 1) of the various activities to your railway; please add to the list as necessary::

Strengthening Activity	**%**	*Ranking*
Embankment remediation at bridge ends		
Underpinning of foundations		
Reinforcement of arches (within the ring)		
Concrete saddling of arches		
Steel, concrete or brick underlining of arches		
External pre-stressing – concrete bridges		
External pre-stressing – metallic bridges		
Increasing section – concrete bridges		
FRP strengthening - masonry arches		
FRP strengthening-steel		
FRP strengthening-concrete		
Replacement of metallic structural members		
Additional reinforcement		
Additional metallic structural members		
Soil improvement		
Other (please specify)		

PART 5 - RESEARCH ACTIVITIES

Please list briefly below any bridge related research or development funded by your railway that is currently underway. (Do not list any other research that you may know of, since that will be collected separately from Universities and national research bodies.) Pease make the description brief (for instance: new materials, bridge assessment) and indicate whether the research is theoretical (T) or applied (A).

Since two work packages are concerned with monitoring bridges (both existing and new), please specifically list any studies ever undertaken into monitoring.

Please give a contact name, phone number and e-mail address for somebody in your railway who can be interviewed in more detail about projects relevant to Sustainable Bridges.

Please list any other considerations that may affect the installation or use of monitoring systems (for instance: *electrical compatibility with signalling, telephone or traction power systems; special training to go on the track*).

Please also give contact name(s), phone number(s) and e-mail address(es) for people in your railway who can be interviewed in more detail about the issues identified above.

PART 6 - YOUR PRIORITIES FOR THE SUSTAINABLE BRIDGES PROJECT

In order to enable your railway to meet the stated aim of the EU to see a 30% increase in passenger traffic and a trebling of freight traffic on the railways in Europe, without seriously disrupting the day to day operations of the railway network please list, in priority order, your top research or development areas, preferably no more than 5, that should be addressed by the Sustainable Bridges consortium.

PART 7 - EXISTING DOCUMENTS

The Sustainable Bridges project wishes to compare current practice amongst the European railways, with a view to identifying best practice. We hope that your railway will be prepared to make available any existing internal codes, standards, handbooks or guidance dealing with existing railway bridges for inspection. At the moment we are not interested in design codes for new bridges.

Please indicate, by ticking the appropriate boxes, whether you have any documents in the following areas and also whether you would be prepared to make copies available to the consortium. Please also show the date of issue. Please do not include UIC, National or CEN standards, as these will be obtained from other sources.

Topic	Have document		Willing to share		Date of issue
	Yes	No	Yes	No	
Examination (*mainly visual*)					
Monitoring (*mainly using instrumentation*)					
Condition ranking					
Bearing capacity calculation (Assessment)					
Intervention planning					
Maintenance					

For your bearing capacity code (if you have one) please complete the following by ticking the appropriate box.

The safety format used in the code is:

Partial safety factors	
Partial factors + load combination factors	
Allowable stresses	
Reliability indices	
Probability of failure	
Other (please specify)	

If the partial factors were calibrated to a target reliability index, or if a reliability index or probability of failure is directly mentioned in the code, please indicate the value of:

Target reliability index	
Target probability of failure	
Corresponding reference period	

The end - thank you!

This questionnaire was prepared on behalf of the Sustainable Bridges consortium by the leader of Work Package 1, Brian Bell, Structures Research and Development Engineer, Network Rail, London. If necessary, he may be contacted by phone (+44 20 7557 8355), fax (+44 20 7557 9132) or e-mail (brian.bell@networkrail.co.uk).

A2

Detailed questionnaire analysis

Sustainable bridges - Maintenance activity

	Concrete			Metal			Masonry arch			Other arch types			Steel/conc composite		
Railway	**Rehab**	**Str**	**Recon**	**Rehab**	**Str**	**Recon**	**Rehab**	**Str**	**Recon**	**Rehab**	**Str**	**Recon**	**Rehab**	**Str**	**Recon**
Aus	**100%**	0%	0%	n/d	n/d	n/d	n/d	n/d	0%	**100%**	0%	0%	0%	0%	**100%**
Bel	85%	13%	2%	80%	5%	15%	95%	5%	0%	0%	0%	0%	90%	2%	8%
Cz	21%	2%	**77%**	**55%**	0%	45%	**90%**	10%	0%	33%	9%	**58%**	0%	0%	**100%**
Den	**60%**	10%	30%	**75%**	0%	25%	**80%**	10%	10%	0%	0%	0%	**90%**	0%	10%
Ei	**50%**	25%	25%	29%	29%	**42%**	**50%**	0%	**50%**	0%	0%	0%	0%	0%	0%
Fin	**95%**	0%	5%	**90%**	0%	10%	**100%**	0%	0%	**100%**	0%	0%	**90%**	0%	10%
Fra	**90%**	5%	5%	**60%**	10%	10%	**90%**	5%	5%	**95%**	4%	1%	**95%**	4%	1%
Ger	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Hun	**80%**	0%	20%	0%	0%	0%	**50%**	40%	10%	**50%**	40%	10%	**85%**	0%	15%
Ita	80%	0%	20%	10%	0%	90%	75%	5%	20%	0%	0%	0%	0%	0%	0%
Pol	**50%**	10%	40%	30%	**50%**	20%	**70%**	0%	30%	**70%**	20%	10%	**70%**	0%	30%
Por	**95%**	5%	0%	**80%**	15%	5%	**75%**	23%	2%	0%	0%	0%	**95%**	5%	0%
S'kia	20%	20%	60%	40%	50%	10%	80%	15%	5%	0%	0%	0%	20%	20%	60%
Spa	**50%**	32%	18%	**55%**	40%	5%	**64%**	34%	2%	**75%**	24%	1%	0%	0%	0%
Swe	**50%**	5%	45%	34%	4%	**62%**	**60%**	20%	20%	33%	0%	**67%**	**100%**	0%	0%
Swi	40%	**45%**	15%	10%	10%	**80%**	40%	10%	**50%**	**80%**	10%	10%	5%	5%	**90%**
UK	18%	**42%**	39%	29%	**47%**	24%	**84%**	16%	0%	**70%**	0%	30%	0%	0%	0%

Note: Austria (OBB) did not give any percentages, they merely indicated the activities undertaken, which have been converted to % where possible

*Cz**	*12%*	*1%*	***43%***	*5%*	*0%*	*4%*	*18%*	*2%*	*0%*	*4%*	*1%*	*7%*	*0%*	*0%*	*4%*
*Ei**	*10%*	*5%*	*5%*	*20%*	*20%*	***30%***	*5%*	*0%*	*5%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
*Swe**	*10%*	*1%*	*9%*	*25%*	*3%*	***45%***	*3%*	*1%*	*1%*	*1%*	*0%*	*2%*	*1%*	*0%*	*0%*
*UK**	*6%*	*14%*	*13%*	*10%*	*16%*	*8%*	***21%***	*4%*	*0%*	*7%*	*0%*	*3%*	*0%*	*0%*	*0%*

Note: * means activity shown as % of overall activity

Sustainable Bridges - Maintenance problems - Superstructures

Maintenance problem / Railway	Aus	Bel	Cz	Den	Ei	Fin	Fra	Ger	Hun	Ita	Pol	Por	Svk	Spa	Swe	Swi	UK
Non type specific																	
Waterproofing	X	X	X	X	-	-	X	n/d	X	X	X	X	X	X	X	X	X
Vehicular impact	-	-	-	-	-	-	-	n/d	-	-	-	-	-	X	X	-	X
Concrete																	
Tendon corrosion/inspection	-	X	-	-	-	-	-	n/d	X	X	X	X	X	X	X	-	X
Connections	-	-	X	-	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Electrical isolation of reinft	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	X	-
Cracking	-	-	X	-	-	X	-	n/d	-	X	X	X	-	X	X	X	X
Expansion joints	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	X	-	-
Reinforcement corrosion	-	-	-	-	X	-	X	n/d	X	X	X	X	X	X	-	X	-
Spalling/low cover	X	X	-	-	-	X	-	n/d	-	X	X	X	-	-	X	X	X
Carbonation	-	X	-	X	-	-	-	n/d	-	-	-	-	X	-	-	-	-
Composite/embedded																	
Cracking/spalling	-	-	X	-	-	X	-	n/d	X	-	X	-	-	-	X	-	-
Fatigue	-	X	-	-	-	-	X	n/d	-	-	-	-	-	-	-	-	-
Steel/Wrought iron																	
Corrosion/delamination	-	X	X	-	X	-	X	n/d	X	X	X	X	X	X	X	X	X
Brittle fracture	-	-	-	-	-	-	X	n/d	-	-	X	-	-	-	-	-	-
Fatigue cracking	-	X	X	-	X	-	X	n/d	X	X	X	X	-	X	-	X	X
Coating defects	-	-	-	X	-	-	-	n/d	-	-	-	X	-	-	X	-	X
Loose connections (rivets)	-	-	X	-	X	-	-	n/d	-	X	-	X	-	-	X	-	-
Cast iron																	
Fatigue	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	X	-
Corrosion	-	-	-	-	-	X	-	n/d	-	-	-	-	-	-	-	X	-
Risk of sudden failure	-	-	-	-	-	-	X	n/d	-	-	-	-	-	-	-	-	X
Brick or stone arches																	
Degradation of materials	-	X	-	X	X	-	-	n/d	X	-	X	X	-	X	-	X	X
Cracking	-	X	X	-	X	-	X	n/d	X	X	-	X	X	X	-	-	X
Distortion/deformation	-	-	X	-	X	-	-	n/d	-	-	-	-	-	-	X	-	X
Spandrel separation	-	-	-	-	-	-	-	n/d	X	-	-	X	-	-	-	-	X
Fracturing of stone	-	-	-	-	-	-	-	n/d	-	-	-	-	-	X	-	-	-
Ring separation	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	-	X
Punch through of stones	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	X	-	X
Concrete/other arches																	
Cracking	-	-	-	-	-	-	-	n/d	X	X	X	-	-	-	X	-	-
Degradation of materials	-	-	-	X	-	-	-	n/d	X	-	-	-	-	X	-	-	-
Construction joints	X	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	X	-

Sustainable Bridges - Maintenance problems - Substructures

Maintenance problem / Railway	Aus	Bel	Cz	Den	Ei	Fin	Fra	Ger	Hun	Ita	Pol	Por	Svk	Spa	Swe	Swi	UK
Bearings																	
Bearing seizure (corrosion)	-	X	X	X	X	X	X	n/d	X	X	X	X	X	-	-	X	X
Cracked/broken plates	-	-	-	-	-	X	-	n/d	-	-	-	X	X	-	-	-	-
Elastomer/rubber deterioration	-	X	-	-	-	-	-	n/d	-	-	-	X	-	-	X	-	-
Wear to pins, rockers etc	-	-	-	-	-	-	X	n/d	-	-	-	X	-	-	-	-	-
Corrosion	-	-	-	X	-	-	X	n/d	-	X	-	-	-	-	X	-	-
Grouting	X	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Misalignment	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	X	-	-
Abutments																	
Drainage	-	-	X	-	-	-	-	n/d	X	-	X	-	-	X	-	-	X
Differential movement/settlement	-	X	-	-	X	X	-	n/d	-	X	X	-	X	X	X	X	X
Cracks	-	-	X	-	-	X	-	n/d	-	-	X	X	-	-	X	-	-
Pointing	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Vegetation	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Reinforcement corrosion	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	-
Piers/columns																	
Cracks	-	-	X	-	-	X	-	n/d	-	-	X	X	X	-	-	-	X
Material deterioration	-	-	-	-	-	-	-	n/d	-	-	X	X	-	-	-	-	X
Pointing	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Vegetation	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Under capacity for traction forces	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	X	-
Carbonation	-	-	-	X	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Chloride attack from road salts	-	-	-	-	-	X	-	n/d	-	-	-	-	-	-	X	-	-
Bored piles	-	-	-	-	-	X	-	n/d	-	-	-	-	-	-	-	-	-
Foundations																	
Differential settlement	-	X	-	-	X	X	-	n/d	-	X	X	X	X	X	-	X	X
Scour	X	X	X	-	-	-	X	n/d	-	X	X	X	-	X	X	-	X
Lack of load capacity	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Steel hoop rupture	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Ground water	-	-	-	-	-	-	-	n/d	-	-	-	-	X	-	-	-	-
Decay of wooden piles	-	-	-	-	-	-	X	n/d	-	-	-	-	-	-	X	-	X
Transition zones																	
Settlement	-	-	X	-	X	-	X	n/d	X	X	X	X	X	-	X	-	X
Drainage	-	-	X	-	-	-	-	n/d	-	X	-	X	-	-	X	-	-
Deep seated slips	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	-
Loss of embankment material	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	-
Long term consolidation	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	X	-	-
Lack of ballast depth on bridges	-	-	-	-	-	-	-		-	-	-		-	-	-	X	-

Sustainable Bridges - Maintenance problems - Substructures

Maintenance problem / Railway	Aus	Bel	Cz	Den	Ei	Fin	Fra	Ger	Hun	Ita	Pol	Por	Svk	Spa	Swe	Swi	UK
Bearings																	
Bearing seizure (corrosion)	-	X	X	X	X	X	X	n/d	X	X	X	X	X	-	-	X	X
Cracked/broken plates	-	-	-	-	-	X	-	n/d	-	-	-	X	X	-	-	-	-
Elastomer/rubber deterioration	-	X	-	-	-	-	-	n/d	-	-	-	X	-	-	X	-	-
Wear to pins, rockers etc	-	-	-	-	-	-	X	n/d	-	-	-	X	-	-	-	-	-
Corrosion	-	-	-	X	-	-	X	n/d	-	X	-	-	-	-	X	-	-
Grouting	X	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Misalignment	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	X	-	-
Abutments																	
Drainage	-	-	X	-	-	-	-	n/d	X	-	X	-	-	X	-	-	X
Differential movement/settlement	-	X	-	-	X	X	-	n/d	-	X	X	-	X	X	X	X	X
Cracks	-	-	X	-	-	X	-	n/d	-	-	X	X	-	-	X	-	-
Pointing	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Vegetation	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Reinforcement corrosion	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	-
Piers/columns																	
Cracks	-	-	X	-	-	X	-	n/d	-	-	X	X	X	-	-	-	X
Material deterioration	-	-	-	-	-	-	-	n/d	-	-	X	X	-	-	-	-	X
Pointing	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Vegetation	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	X
Under capacity for traction forces	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	X	-
Carbonation	-	-	-	X	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Chloride attack from road salts	-	-	-	-	-	X	-	n/d	-	-	-	-	-	-	X	-	-
Bored piles	-	-	-	-	-	X	-	n/d	-	-	-	-	-	-	-	-	-
Foundations																	
Differential settlement	-	X	-	-	X	X	-	n/d	-	X	X	X	X	X	-	X	X
Scour	X	X	X	-	-	-	X	n/d	-	X	X	X	-	X	X	-	X
Lack of load capacity	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Steel hoop rupture	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	-	-	-
Ground water	-	-	-	-	-	-	-	n/d	-	-	-	-	X	-	-	-	-

Decay of wooden piles	-	-	-	-	-	-	X	n/d	-	-	-	-	-	-	X	-	X
Transition zones																	
Settlement	-	-	X	-	X	-	X	n/d	X	X	X	X	X	-	X	-	X
Drainage	-	-	X	-	-	-	-	n/d	-	X	-	X	-	-	X	-	-
Deep seated slips	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	-
Loss of embankment material	-	-	-	-	-	-	-	n/d	-	-	-	X	-	-	-	-	-
Long term consolidation	-	-	-	-	-	-	-	n/d	-	-	-	-	-	-	X	-	-
Lack of ballast depth on bridges	-	-	-	-	-	-	-		-	-	-		-	-	-	X	-

Sustainable Bridges - Current rehabilitation method - relative importance

Rehabilitation activity / **Railway**	**Aus**	**Bel**	**Cz**	**Den**	**Ei**	**Fin**	**Fra**	**Ger**	**Hun**	**Ita**	**Pol**	**Por**	**Sl'ak**	**Spa**	**Swe**	**Swi**	**UK**
Painting of metalwork	5	9	8	10	9	6	5	n/d	10	10	8	8	5	2	0	10	4
Concrete repairs	5	5	8	10	8	10	5	n/d	5	2	10	8	10	4	2	10	2
Patch repair of damaged brick or masonry	5	7	10	8	6	0	7	n/d	0	0	4	8	10	7	0	10	8
Patch repair of corroded metalwork	5	10	8	8	10	0	9	n/d	0	0	9	8	9	5	0	0	8
Waterproofing	5	6	10	10	0	4	5	n/d	7	4	6	10	2	1	4	10	3
Pointing of brick or masonry	5	8	10	0	4	0	7	n/d	5	2	3	8	8	6	0	10	9
Bearing replacement	5	0	8	8	1	2	3	n/d	3	2	5	10	4	8	6	0	3
Underpinning of foundations	0	0	8	0	0	0	9	n/d	0	6	2	10	7	10	10	5	1
Embankment remediation at bridge ends	0	0	10	6	2	8	5	n/d	6	8	1	8	4	0	8	0	0
Stitching of masonry (Fondedile type)	0	3	8	0	5	0	10	n/d	0	4	0	10	6	9	0	0	4
Reinforcement replacement	5	2	8	6	0	0	2	n/d	0	0	7	8	3	0	0	5	0
Tendon replacement	0	0	6	0		0	7	n/d	0	0	0	8	2	0	0	0	0
Re-alkalisation or chloride extraction	0	0	6	10	0	0	0	n/d	0	0	0	4	1	0	0	0	0
Other (unspecified)	0	0	0	0	0	0	2	n/d	10	0	0	0	0	0	0	0	0
Application of cathodic protection	0	0	6	0	0	0	2	n/d	0	0	0	2	1	0	0	0	0
Other (widening)*	0	0	8	0	0	0	0	n/d	0	0	0	0	0	0	0	0	0
Other (floating slab)	0	0	8	0	0	0	0	n/d	0	0	0	0	0	0	0	0	0

Note: * This is not really rehabilitation

Note: Austrian railway did not rank priorities

Sustainable Bridges - Strengthening method importance

Strengthening method / **Railway**	**Aus**	**Bel**	**CZ**	**Den**	**Ei**	**Fin**	**Fra**	**Ger**	**Hun**	**Ita**	**Pol**	**Por**	**Sl'ak**	**Spa**	**Swe**	**Swi**	**UK**
Replacement of metallic structural members	5	10	8	8	9	n/d	0	n/d	8	0	0	10	10	6	0	10	7
Concrete saddling of arches	5	8	10	10	4	n/d	8	n/d	2	10	0	10	2	9	0	0	6
Reinforcement of arches (within the ring)	0	0	6	8	0	n/d	8	n/d	0	10	8	10	9	7	0	0	3
Underpinning of foundations	0	0	10	0	3	n/d	10	n/d	0	10	0	10	7	10	1	5	2
Additional metallic structural members	5	0	8	0	10	n/d	5	n/d	6	0	0	8	5	1	10	5	3
Steel, concrete or brick underlining of arches	5	0	6	6	1	n/d	0	n/d	10	0	6	10	6	8	0	0	5
Increasing section – concrete bridges	0	0	6	0	7	n/d	0	n/d	0	0	10	8	0	4	6	10	0
Soil improvement	5	4	6	8	6	n/d	5	n/d	0	0	0	8	0	2	4	0	0
Additional reinforcement	0	0	8	0		n/d	0	n/d	0	0	0	8	4	4	8	5	2
Embankment remediation at bridge ends	0	0	10	0	0	n/d	2	n/d	8	0	2	6	0	0	2	0	0
FRP strengthening-concrete	0	6	6	0	0	n/d	4	n/d	0	0	0	4	0	0	0	0	5
FRP strengthening-steel	0	0	6	0	0	n/d	4	n/d	0	0	0	0	0	0	0	0	8
External pre-stressing – metallic bridges	0	0	6	4	0	n/d	0	n/d	0	0	0	6	0	0	0	0	0
FRP strengthening - masonry arches	0	0	6	0	0	n/d	4	n/d	0	0	0	6	0	0	0	0	0
External pre-stressing – concrete bridges	0	0	6	8	0	n/d	1	n/d	0	0	0	0	0	0	0	0	0
Other (Waterproofing)	0	0	10	0	0	n/d	0	n/d	0	0	4	0	0	0	0	0	0
Other (Bearing replacement)	0	0	8	0	0	n/d	0	n/d	0	0	0	0	0	0	0	0	0

Note: OBB did not rank priorities

Sustainable Bridges - Stated needs from Sustainable Bridges Project

Parameter / Railway	Aus	Bel	Cz	Den	Ei	Fin	Fra	Ger	Hun	Ita	Pol	Por	Svk	Spa	Swe	Swi	UK
Assessment																	
Better assessment rules	■	■	-	■	-	■	■	■		-	■	-	-	■	-	-	■
Confirmation of dynamic loadings	■	-	-	■	■	■	-	■	■	-	-	-	-	-	-	-	■
Increased carrying capacity	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-
Increased train speeds	-	-	-	-	-	-	-	-	-	-	-	■	■	-	-	-	-
Ageing & fatigue in concrete	-	-	-	-	-	-	■	■	-	-	-	-	-	-	-	■	-
Fatigue in metallic structures	-	-	-	-	-	-	■	-	-	-	-	-	-	-	-	■	-
Arch serviceability	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	■
Inspection/monitoring																	
Better inspection/diagnosis tools	-	■	-	-	■	-	-	-	■	-	-	-	-	-	-	-	-
Scour detection	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Arch inspection	-	-	-	-	-	-	■	-	-	-	-	-	-	-	-	-	-
Deflection and stress monitoring	■	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Repair/maintenance																	
Less disruptive repairs	-	-	-	■	-	-	-	-	-	-	-	-	-	-	-	-	■
Waterproofing	-	■	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Waterproofing of arches without track removal	-	-	-	-	-	-	■	-	-	-	-	-	-	-	-	-	-
Reinforcement of arches with little cover	-	■	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Foundation reinforcement	-	■	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Lower maintenance needs	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-	-
Use of new materials	-	-	-	■	-	-	-	■	-	-	-	-	-	-	-	-	■
Repair of concrete structures	-	-	-	-	-	-	■	-	■	-	■	-	-	-	-	-	-
Bridge management																	
Replacement cost savings	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-
Maintenance prioritisation	-	-	-	-	-	-		-		-	■	-	-	-	-	-	-
Bridge management systems	-	-	-	-	-	-	-	-	■	-	-	-	-	-	-	-	-
Lower maintenance needs	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-	-
Passenger safety	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-
New build																	
Use of new materials	-	-	-	■	-	-	-	■	-	-	-	-	-	-	-	-	■
Prefabrication of concrete bridges	-	-	-	-	-	-		-	-	-	-	-	-	-	-	■	-
Steel/concrete composite bridges	-	-	-	-	-	-		-	-	-	-	-	-	-	-	■	-