COST ACTION TU1406
QUALITY SPECIFICATIONS FOR ROADWAY BRIDGES,
STANDARDIZATION AT A EUROPEAN LEVEL

TU1406 WG4 Final report Appendix A6

Bridge Case study

Road concrete arch bridge, ''Carinski Bridge'' Mostar, Bosnia and Herzegovina

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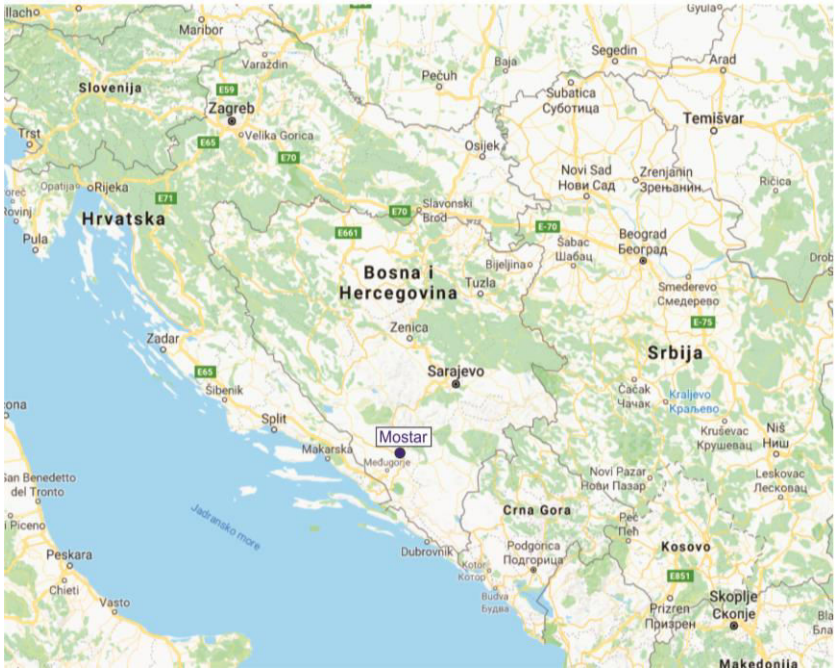
CONTENTS

1. GENERAL DATA OF THE BRIDGE

1.1. THE ORIGINAL BRIDGE

Carinski Bridge is situated in Mostar, Bosnia and Hercegovina. The bridge over Neretva river was constructed in the Secession style during the First World War from 1916 to 1918 (Figure *1*-). The original bridge had two concrete arches, one of 54.28 m over the Neretva and 34.80 m above the inundation. Fences and kiosks at the entrance were richly decorated in surface treatment with washed concrete. The bridge was originally designed for railway traffic but was never used for that purpose and it was adapted for traffic road. Location of the bridge is presented below:



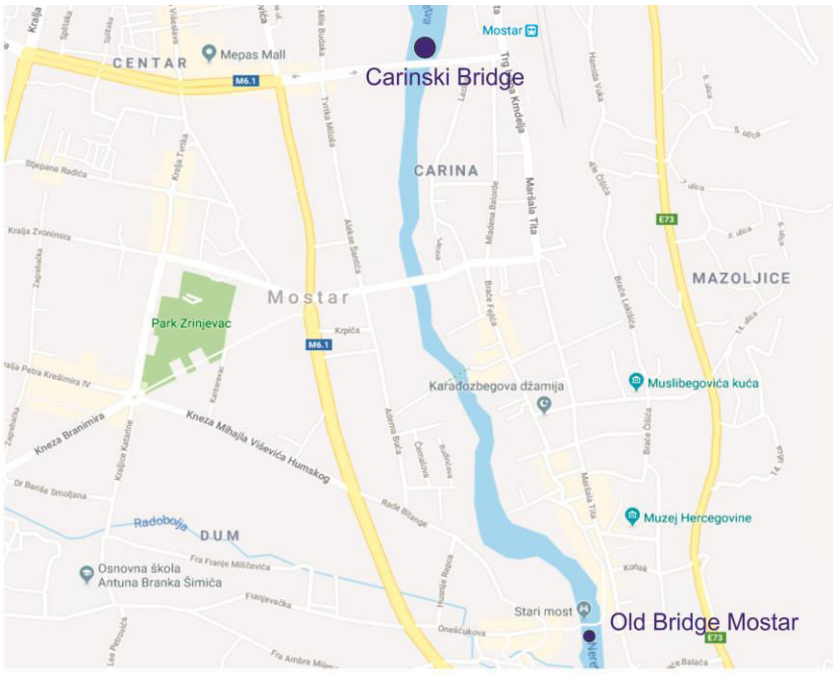


Figure 1-1 Bridge location

During the war conflicts in Mostar on June 11, 1992, the large arch of the ***Carinski Bridge*** over the Neretva was destroyed (Figure *1*-).

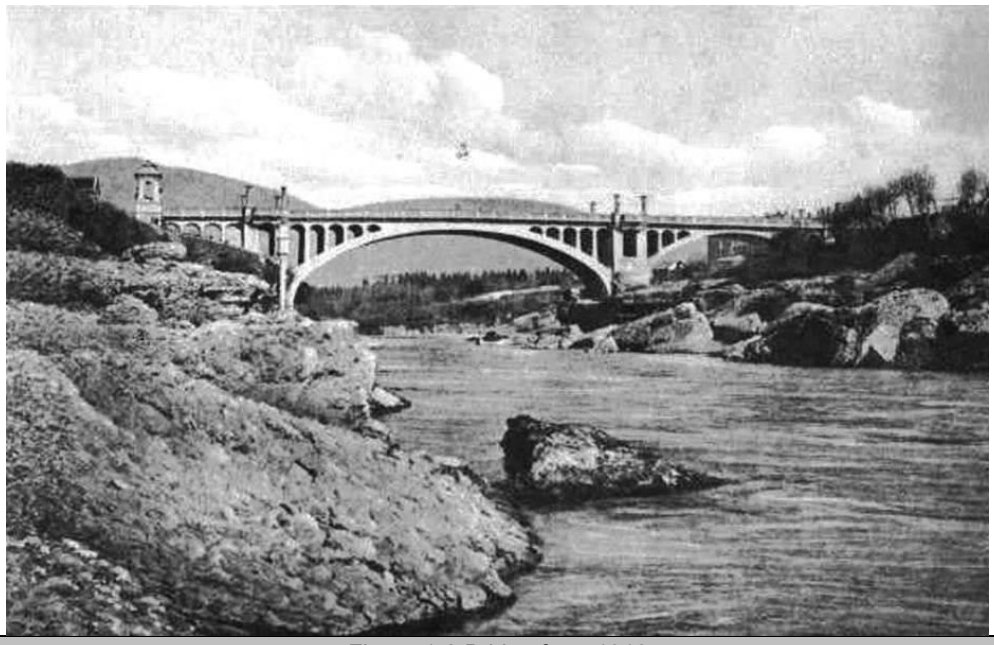


Figure 1-2 Bridge from 1918

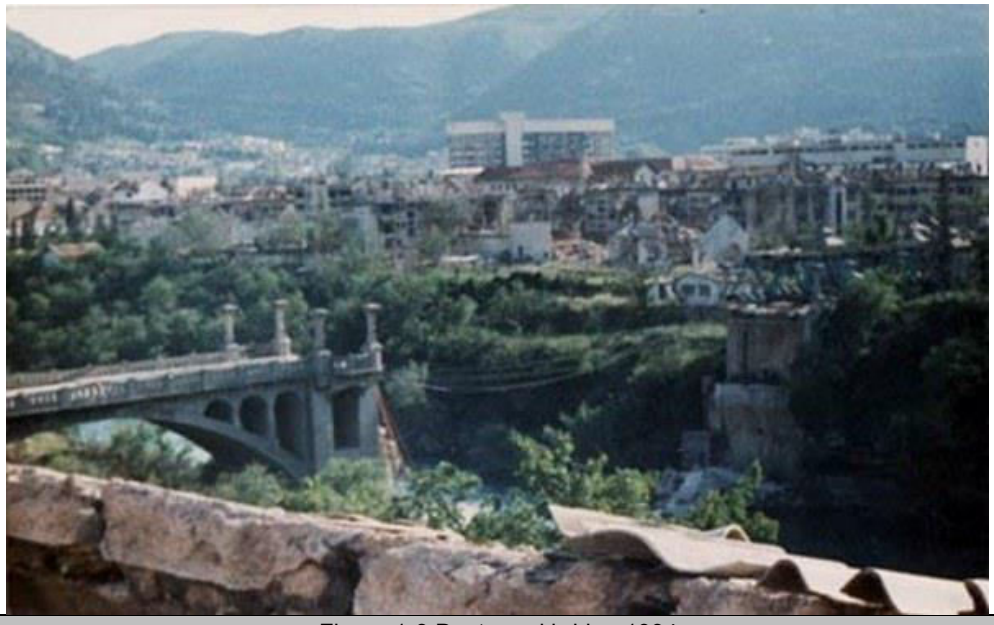


Figure 1-3 Destroyed bridge 1994

1.2. THE NEW CARINSKI BRIDGE

The New ***Carinski bridge*** was reconstructed from 1995 to 1996 and it was officially opened on May, 1st 1996 (Figure *1-*). The new bridge in respect to the old bridge is widened for 1 m due to traffic requirements. Figure *1-* shows the original and the new bridge over the Neretva River in Mostar.

Figure 1-4 New Carinski Bridge

Figure 1-5 A view along the road (direction East)

Figure 1-6 The Original and New Carinski Bridge

1.3. BRIDGE CONSTRUCTION

Since the original technical documentation of the bridge was not available except for a few photographs, parts of the original sketches and the remaining parts of the bridge. It was decided to conduct photogrammetric and geodetic survey of the existing state of the bridge structure. Geotechnical investigations were carried out to determine the soil bearing capacity and the actual depth of foundation of the middle pillar foundation and the actual quality of the concrete parts of the bridge that were intended to be retained. At the same time, the design of the new bridge was done. The bridge was calculated for the load according to the British standards (BS 5400) and with the dimensioning, was done according to DIN 1045. Prior to the construction of the new bridge, demolition and removal of the bridge remains as well dismantling of the temporary prefabricated steel bridge was done.

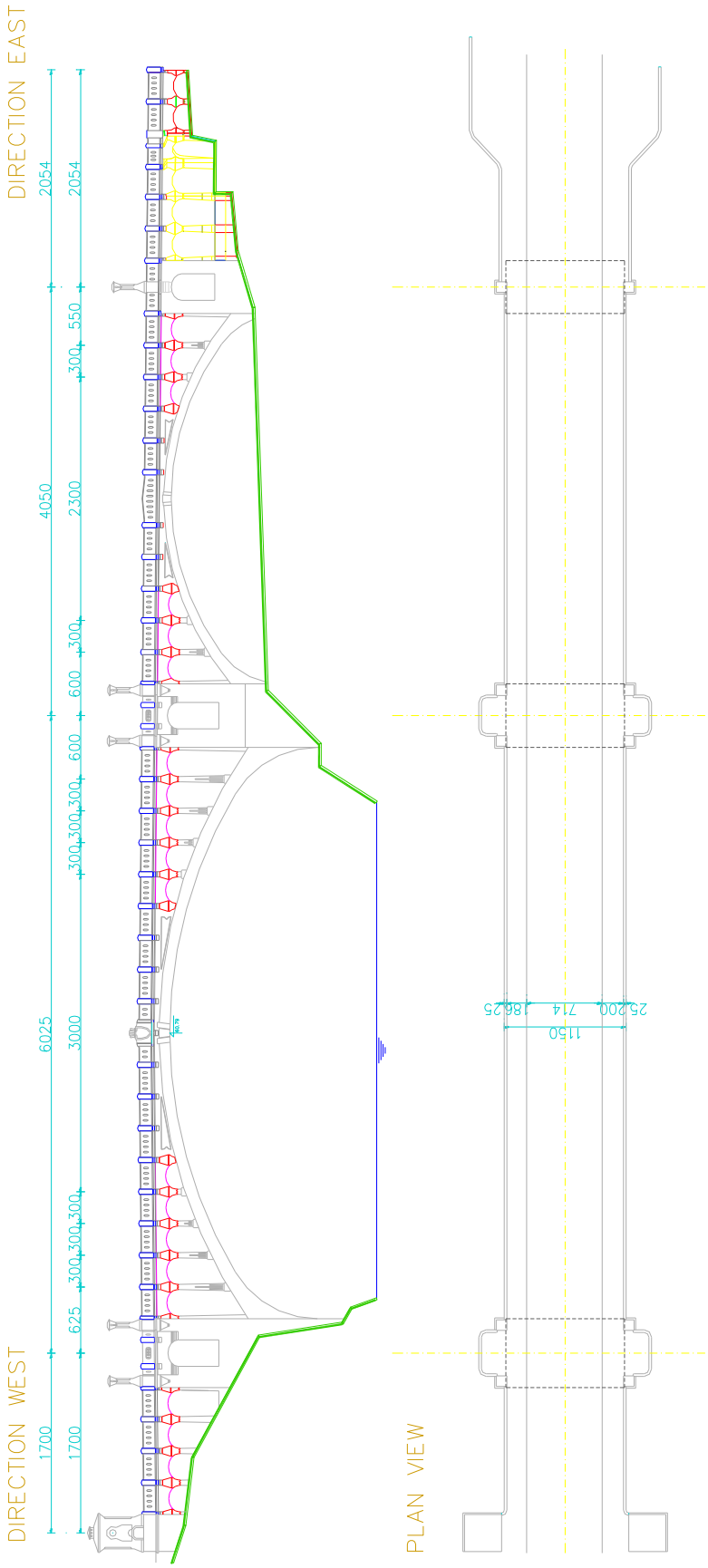


Figure 1-7 Bridge longitudinal and plan view

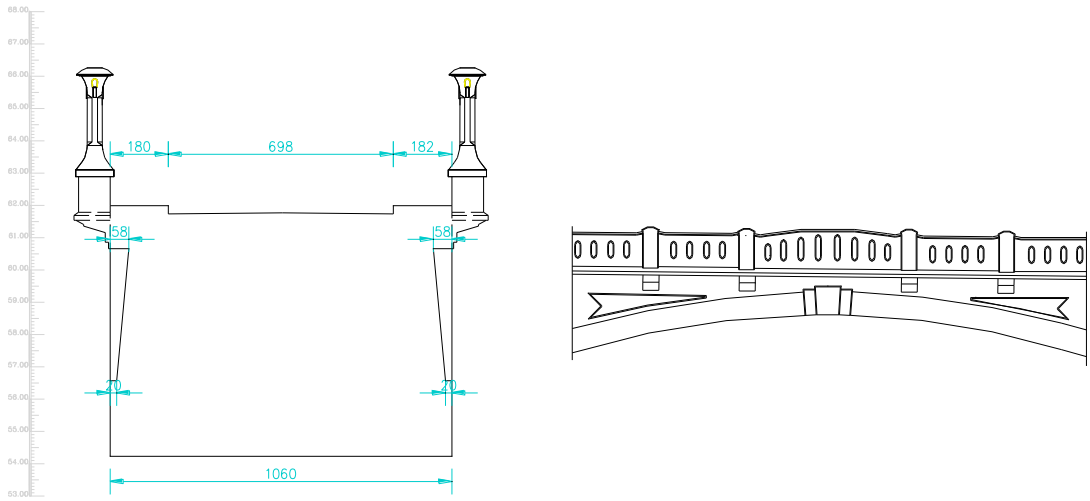


Figure 1-8 Bridge Cross Section and Fence Detail

1.4. FOUNDATION

After the removal, cleaning and preparation of the site for construction of the new bridge, investigations were done. In order to determine the soil characteristics and actual depth of foundation two bores holes were drilled near the middle column. It was decide to keep the existing foundations and the wing walls of the old bridge. The new foundations were placed above the existing ones. The connection of the old and new foundations was done by anchors made of ribbed reinforcement RA 400/500 and the holes were filled with mortar.

1.5. SUBSTRUCTURE AND SUPERSTRUCTURE

The main goal of the construction process was use the existing equipment and to apply modern technology to build a replica of the secession bridge. The optimum technological model of construction was chosen, full prefabrication of all the elements with their construction outside the construction site.
After making the abutment on the west side and the middle column, prefabricated arches were set. They are interlinked with diaphragm in the middle and with the steel stringer bracing. Afterwards they were lowered towards the end of the arch and connected to the cross girder. The procedure is repeated for each pair of prefabricated arches (Figure *1*-9 and 1-10).

Figure 1-9 Building phases of the New Bridge

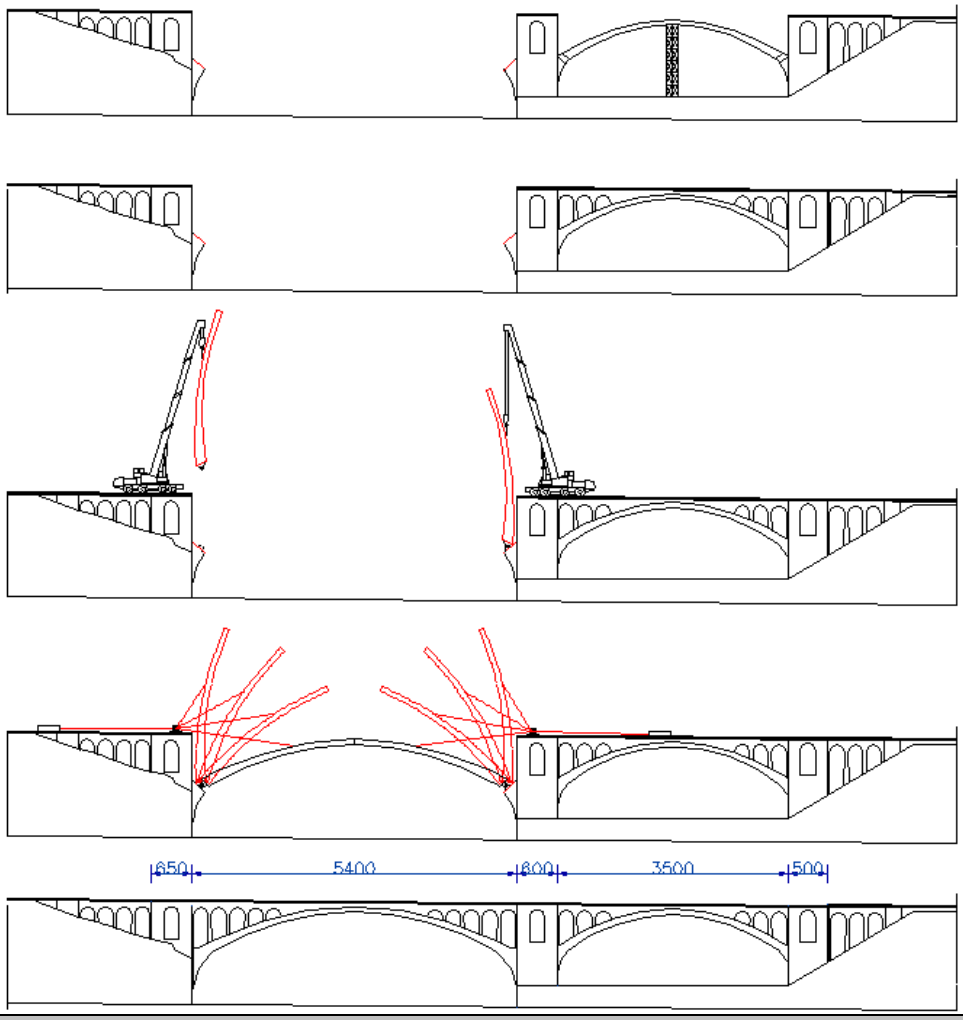


Figure 1-10 Building phases of the New Bridge (shematic presentation)

Once the “Omnia” slabs were laid on the cross girders concreting of the lower and then the upper slab of the arch started. Once the slabs of the upper and lower arches were completed construction of columns and arcades. The columns are monolithized through the tubes places at the center of the cross section. The arcades are monolithized by tie beam and tie column. After the assembly of the masks above the columns, cantilevers on the arcades and the “Omnia” slabs, the carriage way was constructed and the fence was assembled. The kiosks on the west side of the bridge are assembled of precast elements.

1.6. ACCESSORIES

The bridge is illuminated with 126 neutron lamps below the extrados, while the pavement is particularly illuminated by candelabras.

1.7. CONCLUSION

Despite all the problems as well as the complex security environment, the bridge was constructed before the agreed deadline (43 days). The construction period was set for 15 months, of which the effective construction time was only 8 months.
This is an excellent example of the use of modern technology in the reconstruction of the old bridge. This was the first built bridge after the 1992-1996 period in Mostar. This is as well the first application of the lowering pre-cast arches with full pre-fabrication of all elements.

1.8. LOAD CAPACITY

The load capacity of the bridge was calculated according the British standards (BS 5400) while design procedure was done according to DIN 1045.

1.9. RATING OF THE BRIDGE

The overall rating of the bridge is 2 indicating that specialized works are needed in a long term.

1.10. TRAFFIC INFORMATION

The last information about the traffic are from the last counting done in 2010 (Figure *1-*).
Number of cars / 24h: 14198

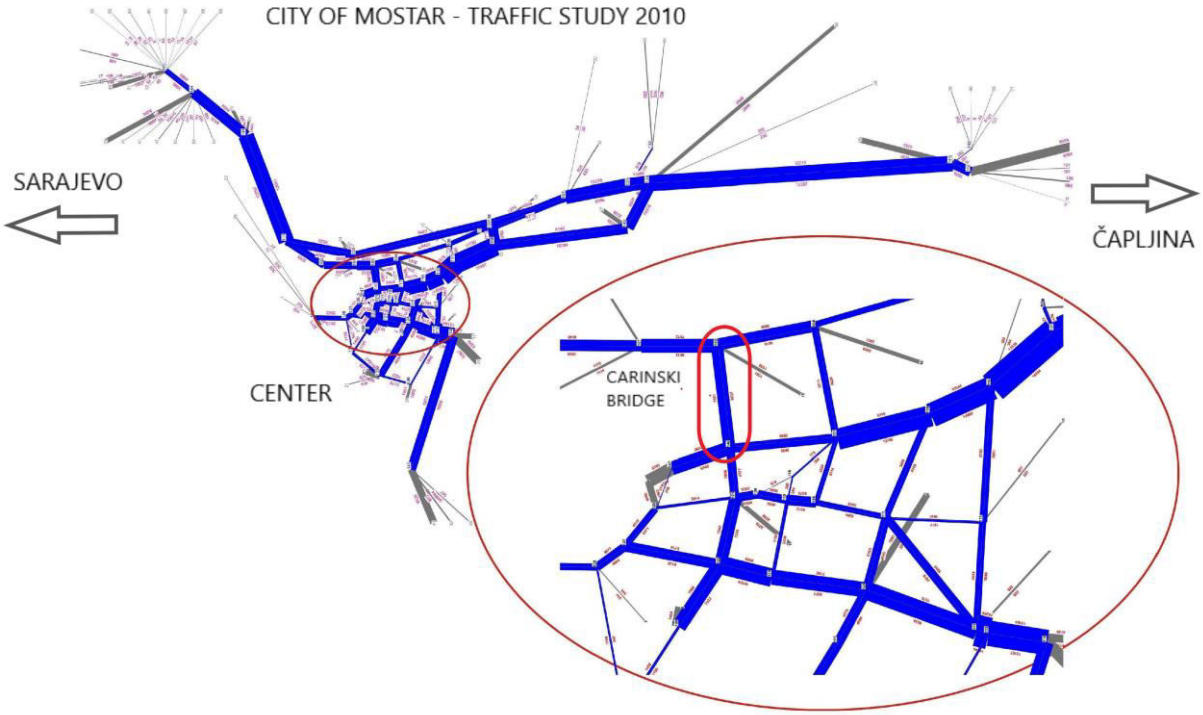


Figure 1-11 Location of the bridge on the map of traffic intensity

1.11. VUNERABLE ZONES

The vulnerable zones are marked on the following Figures:

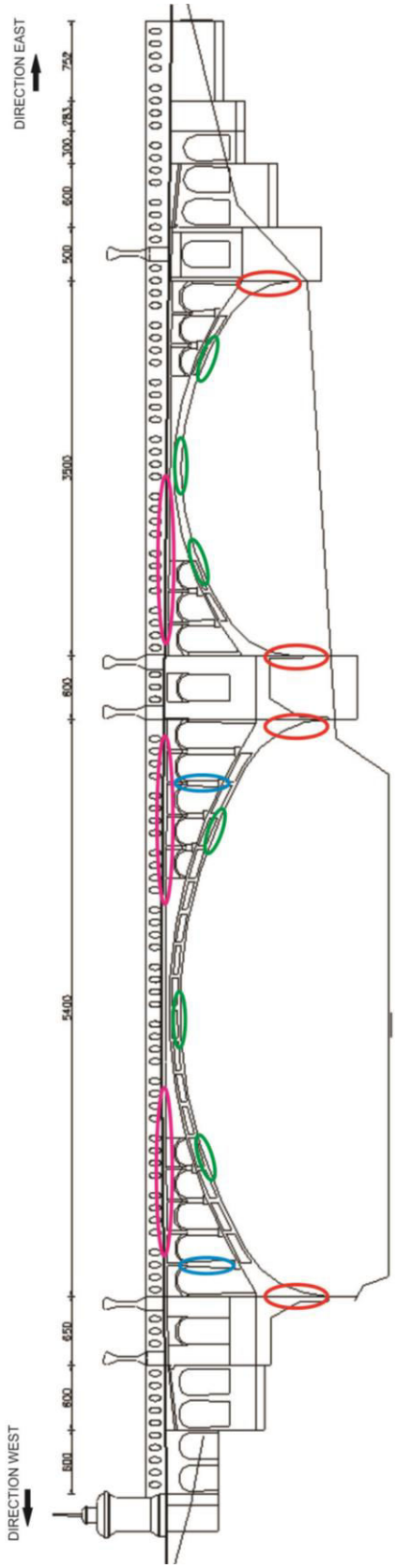


Figure 1-12 Vunerable zones: damage of the arch (green), damage of pylons (cyan), damage of the abutment (red), possible slab failure (pink)

2. TECHNICAL CONDITION

2.1. COLLECTION OF DEFECTS

All the defects are presented on the pictures below.

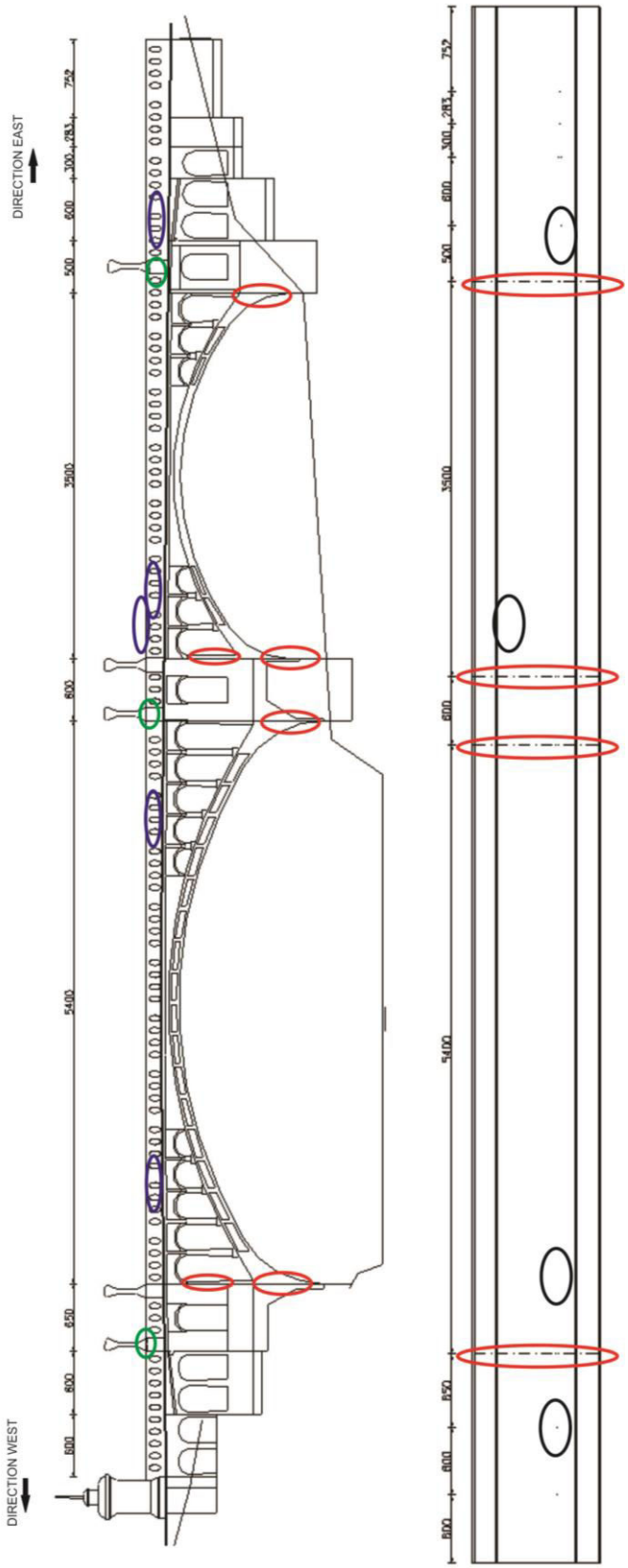


Figure 2-1 Types of defects: waterproofing and damage of elastomeric dilatation (red), damage of lighting pylons (gren), bridge fence damage (purple), defects of pavement ( )

The types of defects discovered on the analyzed bridge are:

1. waterproofing,
2. damage of elastomeric dilatations,

3. damage of lighting pylons,
4. bridge fence damage,
5. problems with drain pipes,
6. defects of pavement

2.2. WATERPROOFING DAMAGE

The most significant defect on the bridge is water flow through virtually all existing asphalt expansion joints. Traces of high humidity are visible on the wall of the strut but also on the middle column of the bridge (Figure *2-2*). There are visible deformations of asphalt expansion joints on the roadway as well. It is necessary to replace all the existing expansion devices with new ones. The life expectancy of well-designed, well-built and well-maintained asphalt devices of small displacements is around 15 years. All dilatations are older than 20 years, and in that respect that should be replaced.

Figure 2-2 Visible traces of water through dilation

2.3. DAMAGE OF ELASTOMERIC DILATATION

Figure *2-3* shows the damage of the elastomeric dilatations.

Figure 2-3 Damaged elastomeric dilatation

2.4. DAMAGE OF LIGHTING PYLONS

Most electric lighting pylons have unprotected access to electrical installations (Figure *2-4*) and the lower metal parts are corroded. It is necessary to protect the electrical installations and paint all posts up to 200 cm high.

Figure 2-4 Unprotected installations on lighting pylons

2.5. DAMAGE OF THE BRIDGE FENCE

The concrete layers used for monolitization of the prefabricated elements of the bridge are in good condition.
Most of the joints of the bridge fence, which were made of cement mortar, have been frozen due to thermal deformation but the usability of the bridge is not compromised. Figure *2-5* shows a damaged fence. This part of the fence has only a negative aesthetic effect. No interventions are needed regarding these defects at this time.

Figure 2-5 Damaged fence

There is a visible crack on the bridge due to corrosion of the embedded reinforcement (Figure *2-6*). A small protective layer of concrete was used because of the small thicknesses of concrete elements causing corrosion of reinforcements and the appearance of longitudinal cracks.

Figure 2-6 Damaged fence Damage to the fence due to corrosion of the reinforcement

2.6. DRAIN PIPES PROBLEM

The outlet drain pipes are not placed in a correct manner- not sufficiently lower in respect to the intrados of the concrete arch, so both arches are drained by this water. It is necessary to regularly congregate all drains and extend it for 75 cm of outlet drainage pipes under intrados of bridge arches (Figure *2-7*).

Figure 2-7 Drain pipes on the bridge

2.7. DEFECTS OF PAVEMENT

Draining the water from the bridge is not the good because all gullies (Figure *2-8*) are clogged with dirt.

Figure 2-8 Gullies on the bridge

3. KEY PERFORMANCE INDICATORS

Key performance indicators are provided in accordance with best practice knowledge of the research team and experiences with bridge inspection in Bosnia and Hezegovina. The indicators are evaluated and failure modes of the bridge were estimated.

Furthermore, two life time cycle approaches are shown to evaluate the life time costs, reliability, availability and safety of the considered arch bridge in the following 100 years.

The life time costs consider annual maintenance costs, pavement replacement, bridge repair and other costs described in following sections depending on the considered approach.

4. CURRENT STATE EVALUATION

In accordance with the current state of the described structure the following KPIs are considered:

Structure	Component	Material	Design and construction	Failure mode	Vulnerable zone	Symptoms
Arch concrete bridge	Wall	Reinforce concrete	1996	Global failure	Connection	Reinforcement corrosion, leakage
	Arch	Reinforce concrete	1996	Global failure	Arch	Reinforcement corrosion, leakage
	Tops slab	Reinforce concrete	1996	Local slab failure	Slab	Reinforcement corrosion, leakage
	Abutment	Reinforce concrete	1996	Loss of stability	Abutment at foundation	Undermined abutment
	Fence	Reinforce concrete	1996	Fence collapse	Fence	Reinforcement corrosion
	Pavement	Reinforce concrete	1996	Skid resistance	Top surface	Crack, deformation

KPI	Performance indicator		Estimated failure time
Reliability (Structure safety)	2	2	20
	2		35
	2		35
	2		40
Safety	2	2	10
	2		5

The estimated failure time is assumed according to experience of the engineers dealing with concrete structures in Bosnia and Herzegovina and estimated progress of the defects.

4.1. REFERENCED APPROACH – VERSION 1.

In this approach it is foreseen to conduct the repair of the bridge, which will be previously designed and conducted in the 5 years. Minor repairs are foreseen.

The following activities are going to be undertaken in the reference approach:

1. Minor repairs

- Cleaning the drainage
- Partial repair of expansion joints
- Correction of visible corrosion of the fence reinforcement
- Protection of open electrical installation (closure of openings)
- Filling the cracks in the asphalt
- Cleaning the surface of concrete (washing under pressure water)

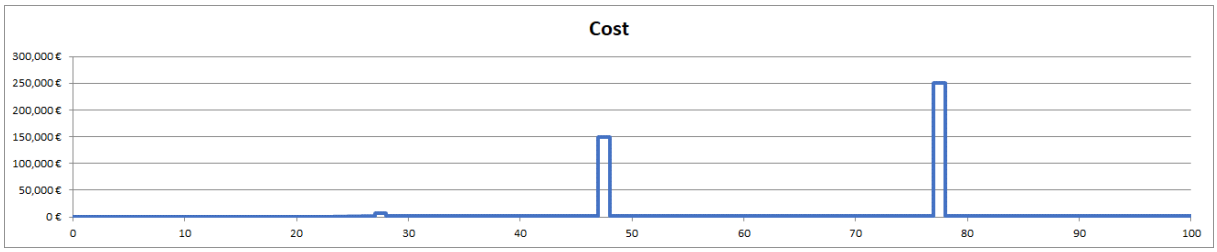
2. Significant repairs

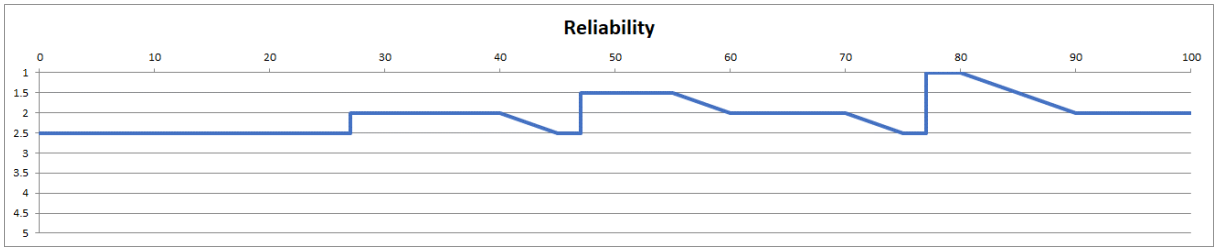
- Replacement of first layer asphalt
- Repair of concrete (fences and other parts)
- Replacement of drain pipes
- Replacement of the expansion joints and repair of the road
- Repair of light columns
- Cleaning of concrete surfaces (washing and eventually sandblasting)
- Creating an inspection opening for the interior arch control

3. Reconstruction

- Full replacement of the asphalt and watreproofing
- Concrete repairs
- Drainage repairs (or replacement)
- Replacement of existing expansion joints
- Protection of surface of concrete with protective coatings after repairs


Availability
0 10 20 30 40 50 60 70 80 90 100
1 1.5 2 2.5 3 3.5 4 4.5 5


Cost
300,000 € 250,000 € 200,000 € 150,000 € 100,000 € 50,000 € 0 €
0 10 20 30 40 50 60 70 80 90 100


Reliability
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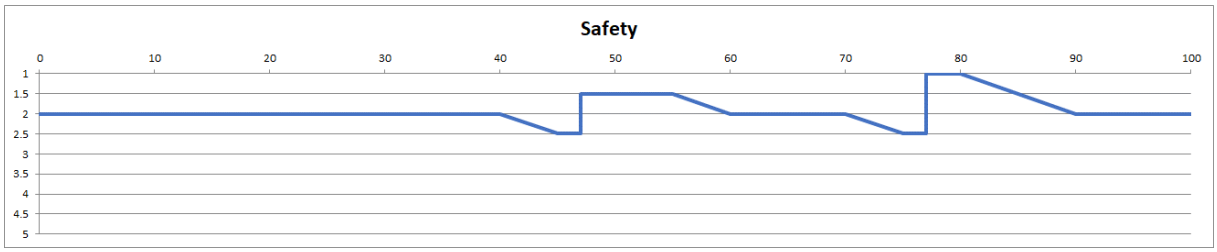
Safety
0 10 20 30 40 50 60 70 80 90 100
1 1.5 2 2.5 3 3.5 4 4.5 5

4.2. PREVENTATIVE APPROACH – VERSION 1.

This approach considers repair of the bridge as the first step. The design for the repair will be done and the repair will be conducted in 5-year time.

Reference approach includes the following activities.

1. Complete repairs

- Cleaning the drains and replacing drainage drain pipes
- Replacement of first layer of asphalt
- Repair of concrete (fences and other parts)
- Replacement of the expansion joints
- Repair of light columns
- Cleaning of concrete surfaces (washing and eventually sandblasting)
- Creating an inspection opening for the interior arch control

2. Reconstruction

- Full replacement of the asphalt and waterproofing
- Concrete repair and protection
- Drainage repairs (or replacement)
- Replacement of expansion joints

3. Complete repairs

- Replacement of first layer of asphalt
- Repair of concrete (fences and other parts)
- Replacement of drainage drain pipes
- - Replacement of the expansion joints
- Repair of light columns
- Cleaning of concrete surfaces (washing and eventually sandblasting)
- Creating an inspection opening for the interior arch control


Availability
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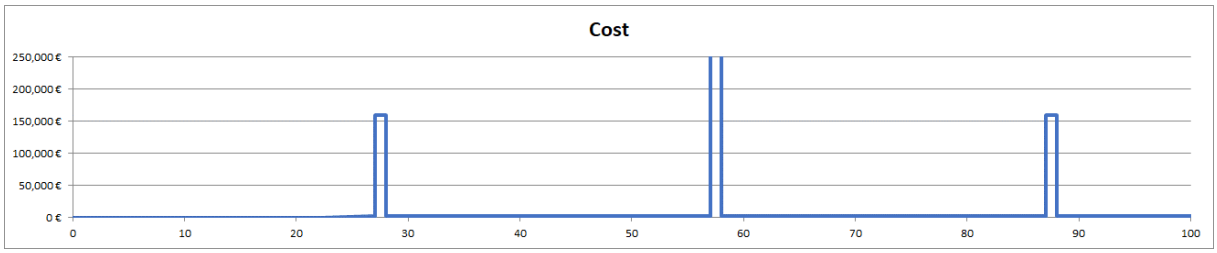
Cost
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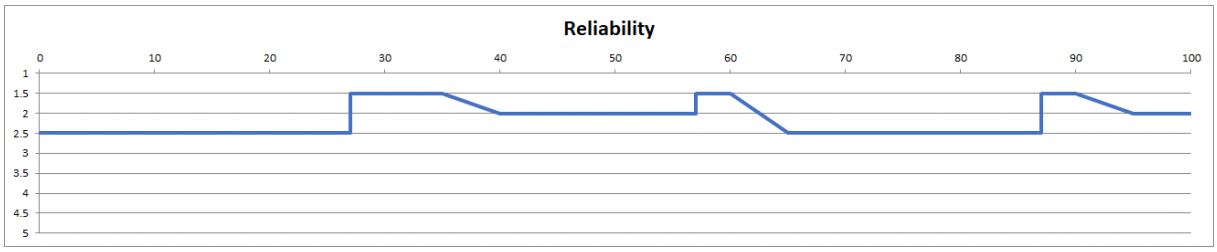
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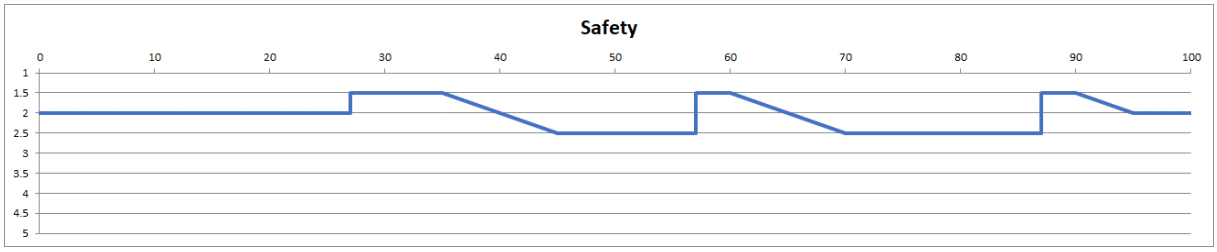
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4.3. REFERENCED APPROACH – VERSION 2.

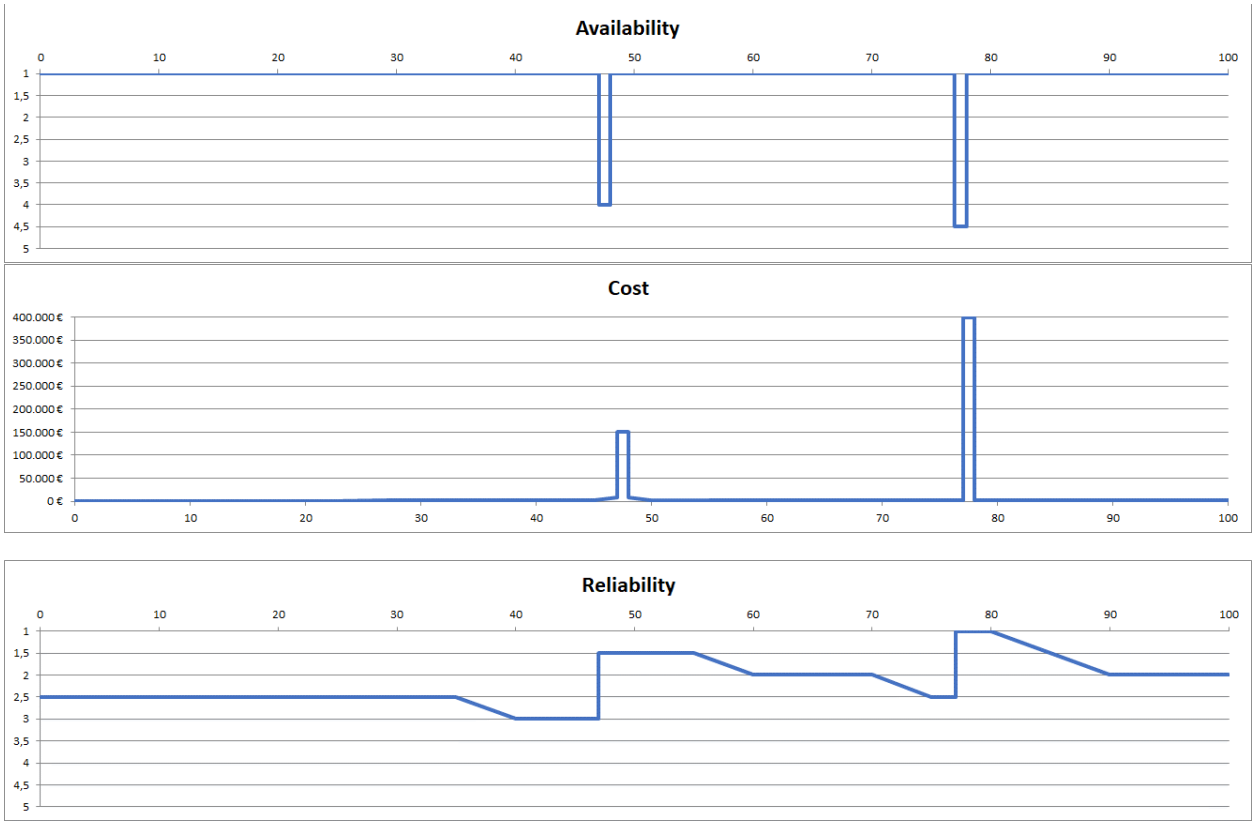
The following activities are going to be undertaken in the reference approach, version 2. :

1. Significant repairs

- Replacement of first layer asphalt
- Repair of concrete (fences and other parts)
- Replacement of drain pipes
- Replacement of the expansion joints and repair of the road
- Repair of light columns
- Cleaning of concrete surfaces (washing and eventually sandblasting)
- Creating an inspection opening for the interior arch control

2. Reconstruction

- Full replacement of the asphalt and watreproofing
- Concrete repairs
- Drainage repairs (or replacement)
- Replacement of existing expansion joints
- Protection of surface of concrete with protective coatings after repairs



4.4. PREVENTATIVE APPROACH – VERSION 2.

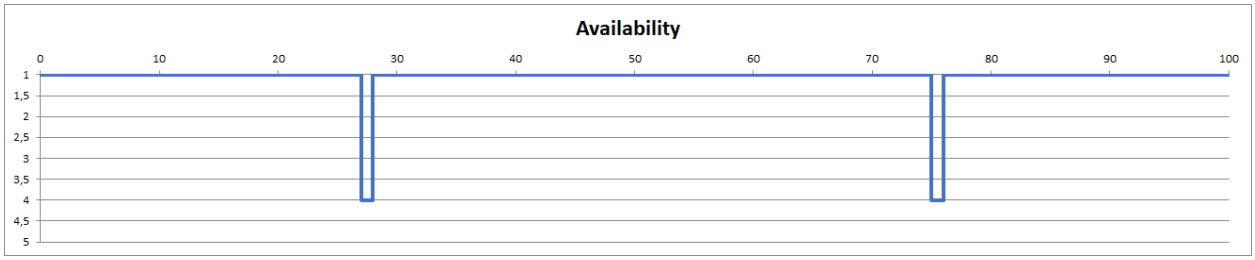
The following activities are going to be undertaken in the preventive approach, version 2. :

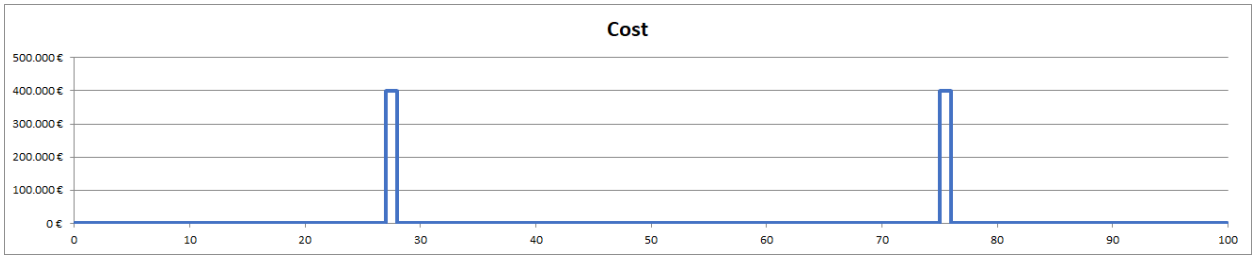
1. Reconstruction

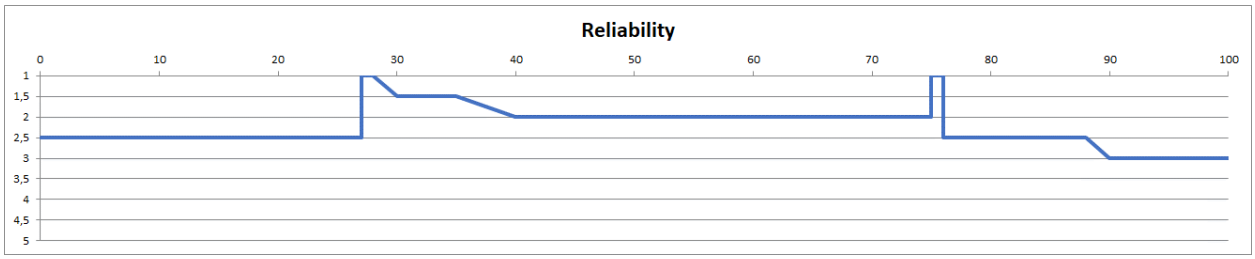
- Full replacement of the asphalt and waterproofing
- Concrete repair and protection
- Drainage repairs (or replacement)
- Replacement of expansion joints

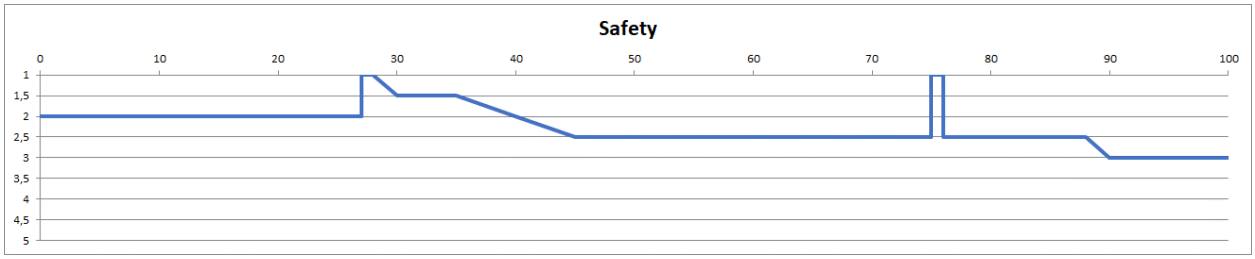
2. Reconstruction

- Full replacement of the asphalt and waterproofing
- Concrete repair and protection
- Drainage repairs (or replacement)
- Replacement of expansion joints





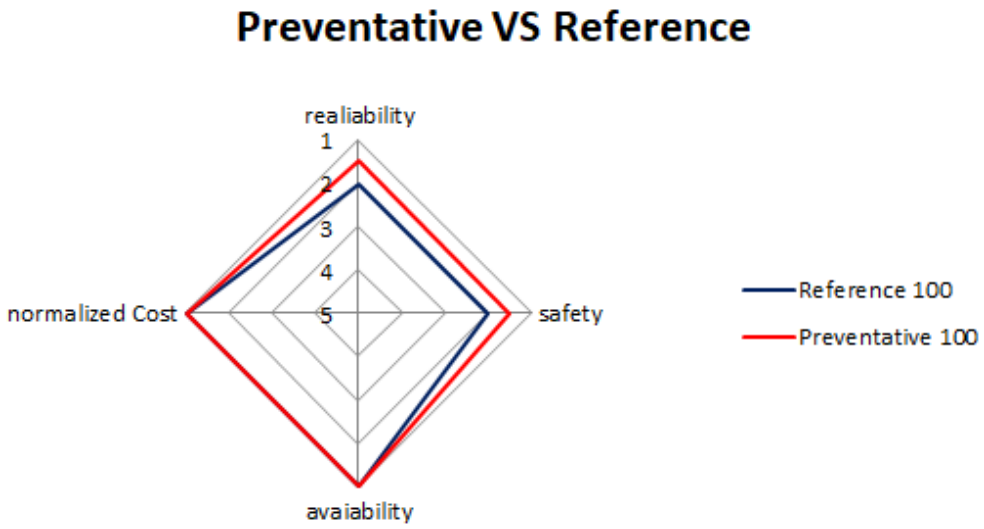




5. COMPARISON OF THE APPROACHES

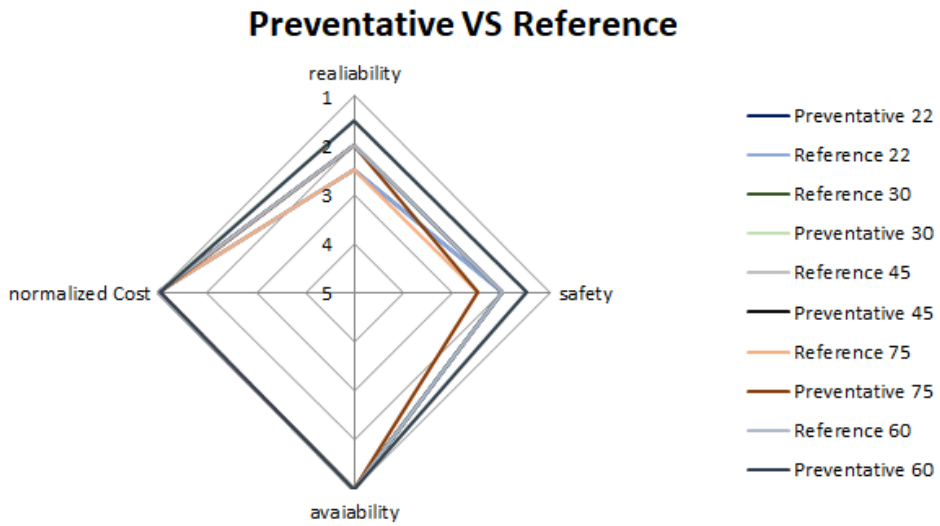
5.1. COMPARISON OF THE APPROACHES – VERSION 1.

A comparison of the two considered approaches is shown in following “spider” diagram:



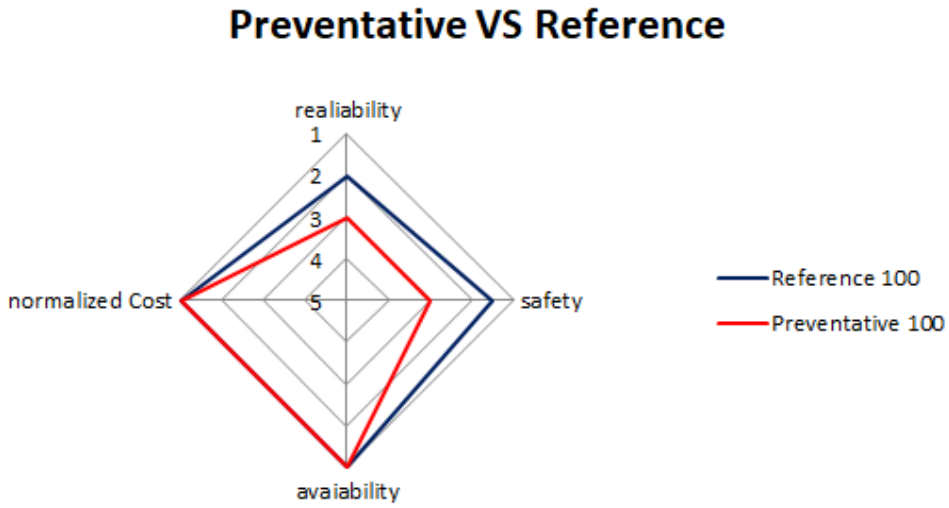
According to the carried out analysis the preventative approach is more appropriate for the arch bridge - the indicators shows more favorable results for all aspects – safety, reliability, availability. Only the costs are almost comparable.

Also, a comparison of the two considered approaches is shown in following “spider” diagram is also presented for 22, 30, 45, 60and 75 year time:



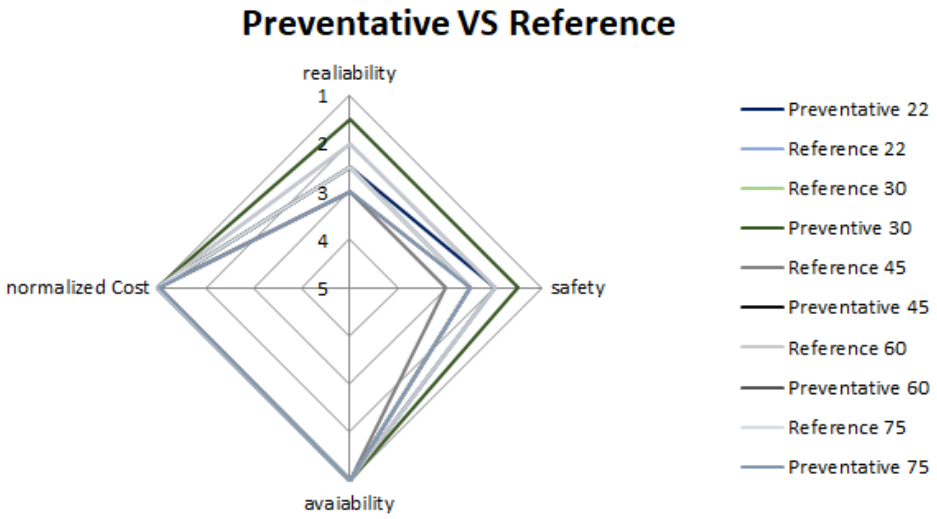
5.2. COMPARISON OF THE APPROACHES – VERSION 2.

A comparison of the two considered approaches is shown in following “spider” diagram:



According to the carried out analysis the reference approach is more appropriate for the arch bridge - the indicators shows more favorable results for all aspects – safety, reliability, availability. Only the costs are almost comparable.

Also, a comparison of the two considered approaches is shown in following “spider” diagram is also presented for 22, 30, 45, 60 and 75 year time:


Preventative VS Reference
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normalized Cost
safety
avaiability
Preventative 22
Reference 22
Reference 30
Preventive 30
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Preventative 45
Reference 60
Preventative 60
Reference 75
Preventative 75