COST ACTION TU1406

QUALITY SPECIFICATIONS FOR ROADWAY BRIDGES,
STANDARDIZATION AT A EUROPEAN LEVEL

COST TU1406 WG4 Final report Appendix A4

Bridge Case study

Girder bridge over the Channel of the Prague Port in Warsaw, Poland

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1. General data of the bridge

1.1. Basic information

The investigated bridge is a 104,60 meters three-spans combined steel-concrete bridge structure built in 2001. The bridge carries road no. 801 (Wybrzeże Szczecińskie Street) across the Channel of the Prague Port in Warsaw. Localization and photos of the bridge are presented below.

Fig. 1 Localization of the bridge (bridge marked with red circle).

Fig. 2 East side view of the bridge.

Fig. 3 View along the road over the bridge.

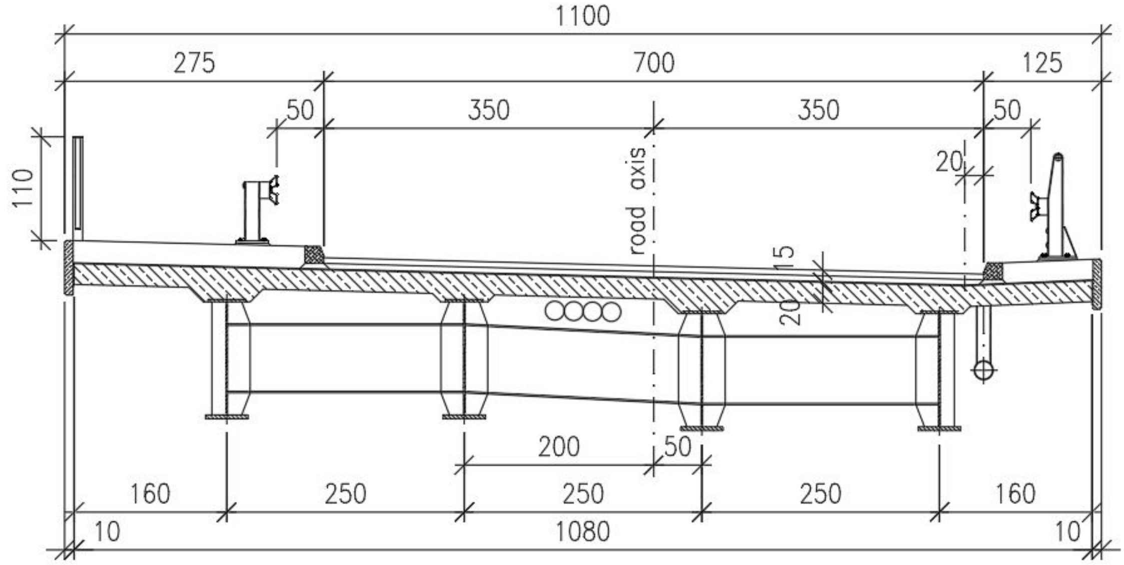


Fig. 4 Cross section of the bridge.

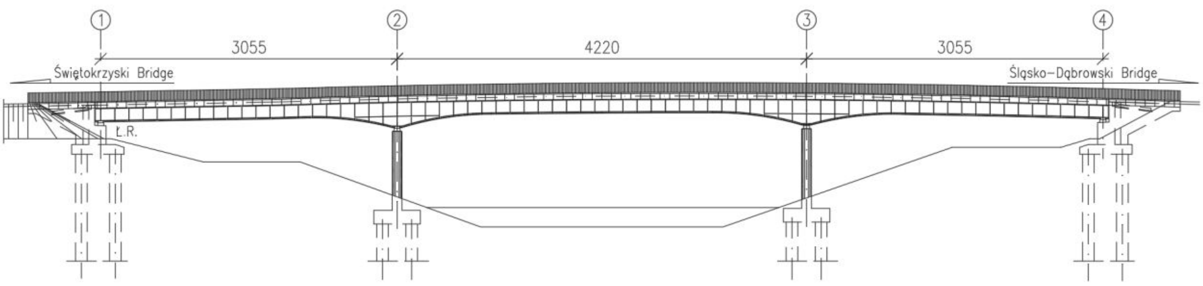


Fig. 5 Elevation of the bridge.

1.2. Traffic information

No information.

1.3. Foundation

The bridge is based on the bored pile foundations. The diameter of the piles is 1200 mm.

1.4. Substructure

Substructure is formed by two abutments and two wall piers made from reinforced concrete. The angle between deck axis and support axis is 60 degrees.

1.5. Superstructure

The superstructure is 104,60 meters long composed of 3 spans: 30,55 + 42,00 + 30,55, designed as combined steel-concrete structure. Main load bearing members are 4 plate girders placed in 2,52 m spacing. Two girders on the east side of the bridge are placed 126 mm higher than the western pair. Webs of the girders are 1200 mm high in the span section and it rise to 2400 mm in the sections above supports. The steel girders are connected with reinforced concrete slab, which is 22 cm high (increased above girders' top flanges). The slab's cantilevers are 1,47 m long (from the external girders axis) on both sides of the bridge. Total width of slab is 10.5 m. The slab under the road and pavement is formed with inclination of 2,5% in direction of western carb and 4% of counter inclination under the service sidewalk. The intersection of the both inclination is located under the road in a distance of 20 cm from the wester carb.

1.6. Accessories

The deck slab is paved with modified asphalt concrete road surface layer. The pedestrian sidewalk is made of reinforced concrete, covered by bituminous surface and surrounded by stone carbs.

Road barriers located on two sides of bridge and also pedestrian safety rail are made of steel.

Pot bearings are pined on each pier and movable bearings are on the north side abutment. Expansion joints are located on 1 and 4 pier.

The drainage is provided by several bridge gullies which collect water and then drained it out by horizontal tubes to the back of abutments.

Fig. 6 Accessories on the bridge.

Fig. 7 Accessories on the bridge.

1.7. Load capacity

The load capacity of the bridge was calculated according to Polish standards (PN-85/S-10030). The bridge was designed to bear “class A” loads, which are equally distributed load of 4,0 kN/m^2 and “K vehicle” load of 800 kN divided to 4 axles of 200 kN. The scheme of these loads is presented below.

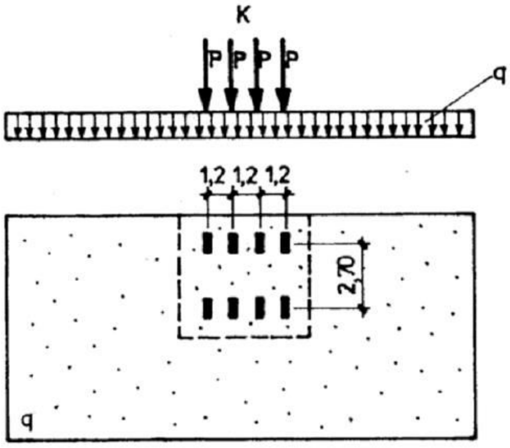


Fig. 8 The load’s scheme according to Polish standards.

1.8. Condition rating

According to technical review made in 2017 by Municipal Road Authority in Warsaw, the rating of the bridge is 3.0. It means that condition of the bridge is disturbing and in case of not repairing damages, the period of safe exploitation will be shortened.

2. Technical Condition

2.1. Collection of defects

The main defects discovered during bridge review are:

- corrosion of structural elements such as steel girders and steel transoms,
- reinforcement corrosion, spalling and cracks on reinforcement structure,
- efflorescence on reinforcement elements,
- contamination and vegetation on substructures,
- contamination and corrosion of accessories,

- lack of soil on abutment slope,
- cracks, deformation and leak of pavement,
- trees reducing the clearance.

2.2. Defects of the main structural elements

2.2.1. Steel beams

Fig. 9 Corrosion of steel girders and damage of anticorrosion.

Fig. 10 Corrosion of steel girders and damage of anticorrosion.

2.2.2. Transoms

Fig. 11 Corrosion of transoms.

2.2.3. Piers

Fig. 12 Horizontal crack, reinforcement corrosion and efflorescence on pier in axis 2.

2.2.4. Abutment

Fig. 13 Reinforcement corrosion, contamination and vegetation on abutments.

2.2.5. Expansion joints

Fig. 14 Contamination of expansion joint.

2.2.6. Pedestrian deck slab

Fig. 15 Reinforcement corrosion, spalling and efflorescence on pedestrain deck slab.

2.2.7. Abutment slope

Fig. 16 Pavement movement caused by lack of soil.

2.2.8. Bearings

Fig. 17 Corrosion of casts.

2.2.9. Safety barrier

Fig. 18 Corrosion of safety barriers (connection with deck).

2.2.10. Road pavement

Fig. 19 Deformation of road pavements, cracks.

2.2.11. Pedestrian pavement

Fig. 20 Cracks and deformation of pedestrian pavement.

Fig. 21 Cracks and deformation of pedestrian pavement.

2.2.12. Cover of expansion joints

Fig. 22 Deformation and corrosion of cover of expansion joints.

2.2.13. Drainage installation

Fig. 23 Corrosion of connectors.

2.2.14. Waterproofing

Fig. 24 Leak on road pavement.

2.2.15. Pedestrian traffic clearance

Fig. 25 Trees reducing the clearance of pedestrian pavement.

3. Vulnerability assessment

3.1. Vulnerable zones

The vulnerable zones are presented in the pictures below.

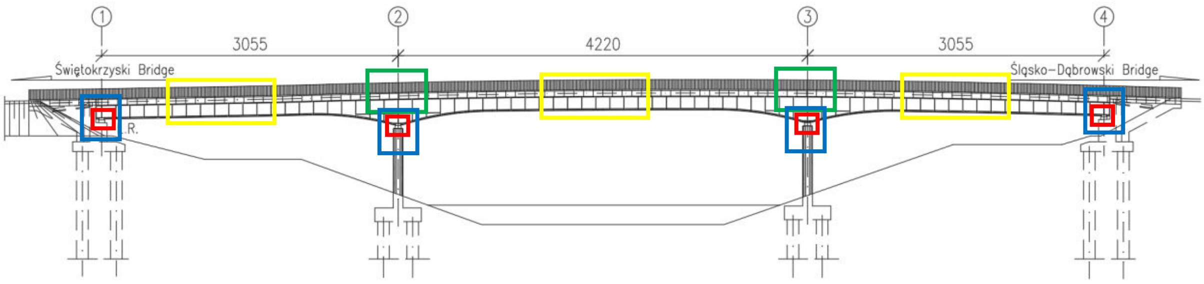


Fig. 26 Vulnerable zones - High moment regions: [] Sagging (label HMS region), [] Hogging (label HMH region); [] High shear regions; [] Bearing area.

3.2. Potential failure mode of the bridge

According to current state of the bridge following failure modes are considered:

Failure modes related with reliability of the structure:

- Beam failure – loss of stability under live loads due to the significant reduction of cross-section caused by increased corrosion of steel beams.
- Piers and abutment failure – stability loss due to cracking and overloading.
- Deck failure – loss of stability under live loads due to the significant reduction of cross-section caused by increased corrosion of reinforced concrete slab.
- Bearing failure – loss of functioning of the bearings due to corrosion and accumulation of debris.
- Expansion joints failure – loss of functioning of the expansion joints due to accumulation of debris.
- Drainage failure – loss of functioning of the drainage system due to clogging of drainage pipes.
- Waterproofing failure – loss of functioning of the waterproofing system due to perforations and discontinuities caused by incidental impact, execution defects or material aging.

Failure modes related with safety of the structure:

- Disturbance to pedestrians or drivers – due to sudden changes in pavement, such as cracks or deformations etc.
- Falling of the deck – due to damaged barriers, as a result of, for example, corrosion of connectors, impacts etc.
- Falling concrete chunks – threat to the people under the bridge caused by falling chunks of concrete as a result of corrosion.

4. Key performance indicators

Key performance indicators are provided in accordance with best practice knowledge of the team and the experience with bridge inspection in Poland. The indicators are evaluated and failure modes of the bridge are estimated. Two life time cycle approaches are shown to evaluate the life time costs, reliability, availability and safety of considered truss bridge in following 100 years.

First referenced approach considers a lack of any repairs of the bridge except of very basic ones on the pavement. The bridge defects are developed until component or system failure and a comprehensive intervention is performed for the relevant component or system only while others are continuing to deteriorate.

A second Preventative approach consider first major rehabilitation of the bridge and a later periodical set of timely interventions during the life time cycle to prevent further defect development and overall damage to the structure.

4.1. Current state evaluation

According to current condition of the described bridge structure following KPIs are considered:

Structure type	Group	Component	Material	Design & Construction	Failure mode	Location/ Position	Damage /Observation	Damage process	KPI	Performance Indicator component level		Performance value		Estimated failure time [years]
												R	S	
SC3	Structural elements	Steel beams	Steel	2001	Beam bending failure mode	Bottom flanges (HMS region)	Corroded flanges	Corrosion	Reliability	3	3	4	3	40
							Damage of anticorrosion	Impact		2				10
						Top flanges (HMH region)	Corroded flanges (connection with deck)	Corrosion		3				40
					Beam shear failure mode	Beams' webs	Corroded webs	Corrosion		2				40
		Transoms	Steel	2001	Beam shear failure mode	Bearing area	Corroded webs	Corrosion	Reliability	2	2			40
		Piers	Reinforced concrete	2001	Pier failure	Pier 2	Horizontal crack	Corrosion	Reliability	3	3			80
					Pier failure	Pier 2	Reinforcement corrosion	Corrosion	Reliability	2				80
					Pier failure	Pier 2	Efflorescence	Water penetrability	(Symptom)	(2)				80
		Abutment	Reinforced concrete	2001	Abutment failure	Abutment 1 (north) and abutment 2 (south)	Reinforcement corrosion	Corrosion	Reliability	2	2			80
						Abutment 1 (north)	Contamination and vegetation	Debris and biological growth	(Symptom)	(2)				80
		Expansion joints	Steel	2001	Locking of expansion joint	EJ 1 (north) and EJ 2 (south)	Contamination of expansion joint	Debris	Reliability	4	4			10
		Pedestrian deck slab	Reinforced concrete	2001	Deck bending failure	Bottom	Reinforcement corrosion	Corrosion	Reliability	3	3			30
					Deck bending	Bottom	Spalling	Corrosion	Reliability	3				30

					failure									
					Deck bending failure	Bottom	Efflorescence	Water penetrability	(Symptom)	(3)				30
		Pedestrian deck slab	Reinforced concrete	2001	Falling chunks	Bottom	Spalling	Corrosion	Safety	3	3			30
		Abutment slope	Soil	2001	Disturbance to pedestrians	Abutment 2 (south)	Lack of soil	Soil failure	Safety	3	3			80
		Bearings	Elastomer and steel cast	2001	Bearing failure	Bearings	Corrosion of casts	Corrosion	Reliability	2	2			15
		Safety barrier	Steel	2001	Falling of the deck	Safety barrier	Corrosion (connection with deck)	Corrosion	Safety	2	2			10
		Road pavement	Asphalt	2001	Disturbance to driver	Expansion joints surroundings	Deformation of pavements, cracks	Locking of expansion joints	Safety	2	2			15
	Equipment	Pedestrian pavement	Bitumen	2001	Disturbance to pedestrians	Expansion joints and safety barriers surroundings	Cracks and deformation	Corrosion and locking of expansion joints	Safety	2	2	4	4	15
		Pedestrian pavement (approach)	Concrete paving blocks	2001	Disturbance to pedestrians	Approach	Deformation	Soil failure	Safety	3	3			15
		Cover of expansion joints	Steel	2001	Disturbance to pedestrians	Expansion joints	Deformation	Corrosion	Safety	4	4			10
		Drainage installation	PCV	2001	Failure of drainage	Connectors	Corrosion	Corrosion	Reliability	2	2			15
		Waterproofing	Asphalt felt	2001	Failure of waterproofing	Deck bottom	Leaks	Discontinuity, perforations	Reliability	4	4			15
		Pedestrian traffic clearance	-	2001	Disturbance to pedestrians	Pedestrian sidewalk	Trees reducing the clearance	Biological growth	Safety	4	4			0

The estimated failure time is assumed according to state of the bridge and the team experience with steel and concrete structures in Poland.

4.2. Referenced approach

In the referenced approach to the maintenance of the bridge it is assumed that there is lack of any repairs of the bridge structure and accessories except removing the trees disturbance to pedestrians clearance. This approach leads to the defects escalation which ends with the bridge failure. The existing structure defects development and estimated failure times are assumed below.

In 10 years:

- expansion joints failure – due to corrosion and contamination,
- safety barriers failure – due to corrosion of connectors or accidental impact.

In 15 years:

- bearing failure – due to corrosion and accumulation of debris,
- pedestrian and road pavement failure – due to cracks and deformation,
- drainage failure – due to clogging of drainage pipes,
- waterproofing failure – due to perforations and discontinuities.

In 30 years:

- pedestrian deck slab – due to reinforcement corrosion, spalling and efflorescence.

In 40 years:

- expansion joints failure – due to corrosion and contamination,
- safety barriers failure – due to corrosion of connectors or accidental impact,
- steel beam failure – due to increasing corrosion,
- transoms failure – due to increasing corrosion.

In 50 years:

- bearing failure – due to corrosion and accumulation of debris.

In 70 years:

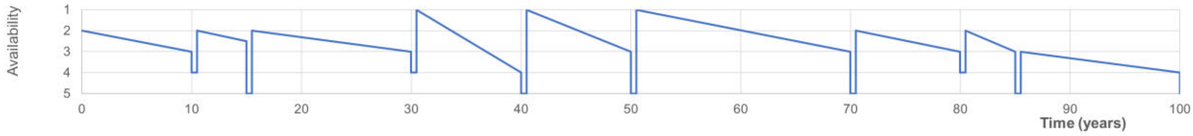
- expansion joints failure – due to corrosion and contamination,
- safety barriers failure – due to corrosion of connectors or accidental impact,
- drainage failure – due to clogging of drainage pipes,
- waterproofing failure – due to perforations and discontinuities.

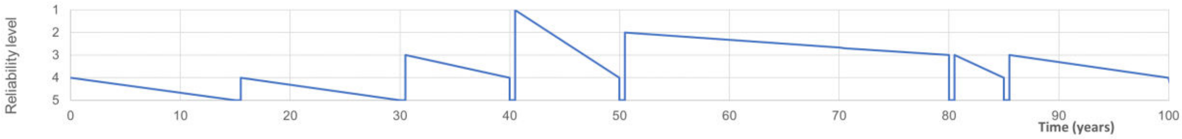
In 80 years:

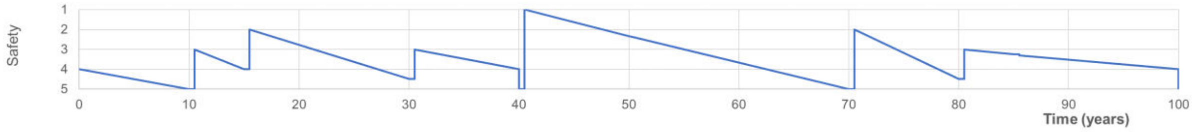
- abutment failure – due to reinforcement corrosion, contamination and vegetation,
- piers and abutment failure – due to reinforcement corrosion and cracks.

In 85 years:

- bearing failure – due to corrosion and accumulation of debris.





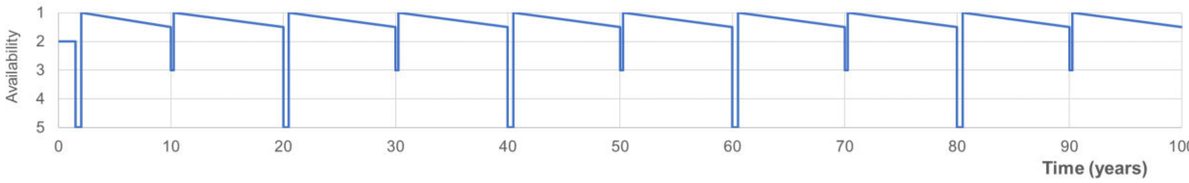


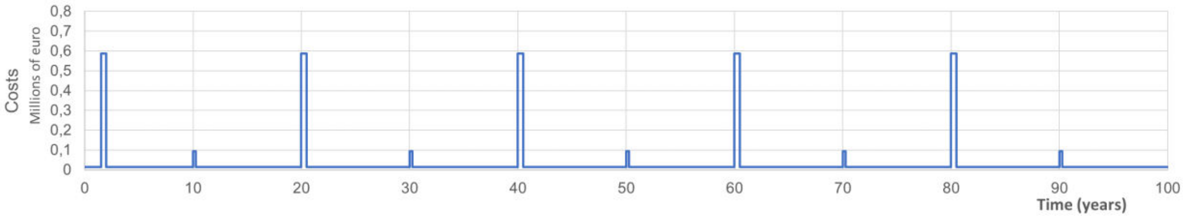
4.3. Preventive approach

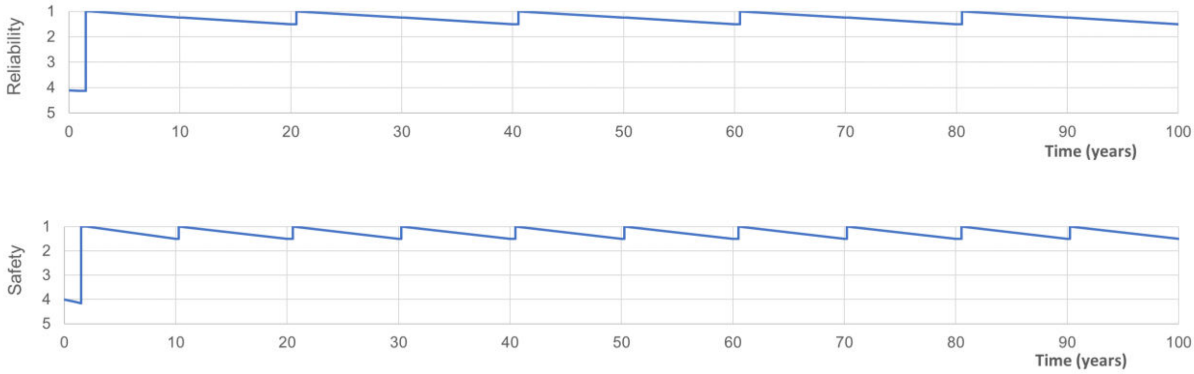
In the preventive approach to the maintenance of the bridge it is assumed that the object will be completely rehabilitated in following two years. Most of the damages that could be observed on the object are related to the natural deterioration after 20 years of exploitation, exaggerated by lack of regular maintenance. Therefore, the cost and range of immediate actions will be similar to the actions that will be performed every 40 year from now (according to preventive approach).

The planned interventions are as follows:

- Every 10 years intervention, incudes: cleaning and repainting steel and concrete structures. The costs includes the temporary traffic arrangements.
- Every 40 years interventions, includes 10 years interventions plus: change of bearings, change of infill of expansion joints, change and repairs of waterproofing and pavements, repairs of drainage system, repairs of handrails and barriers. The costs includes the temporary traffic arrangements. During this intervention the bridge will be completely out of service (traffic will be redirected to the Western Bridge).



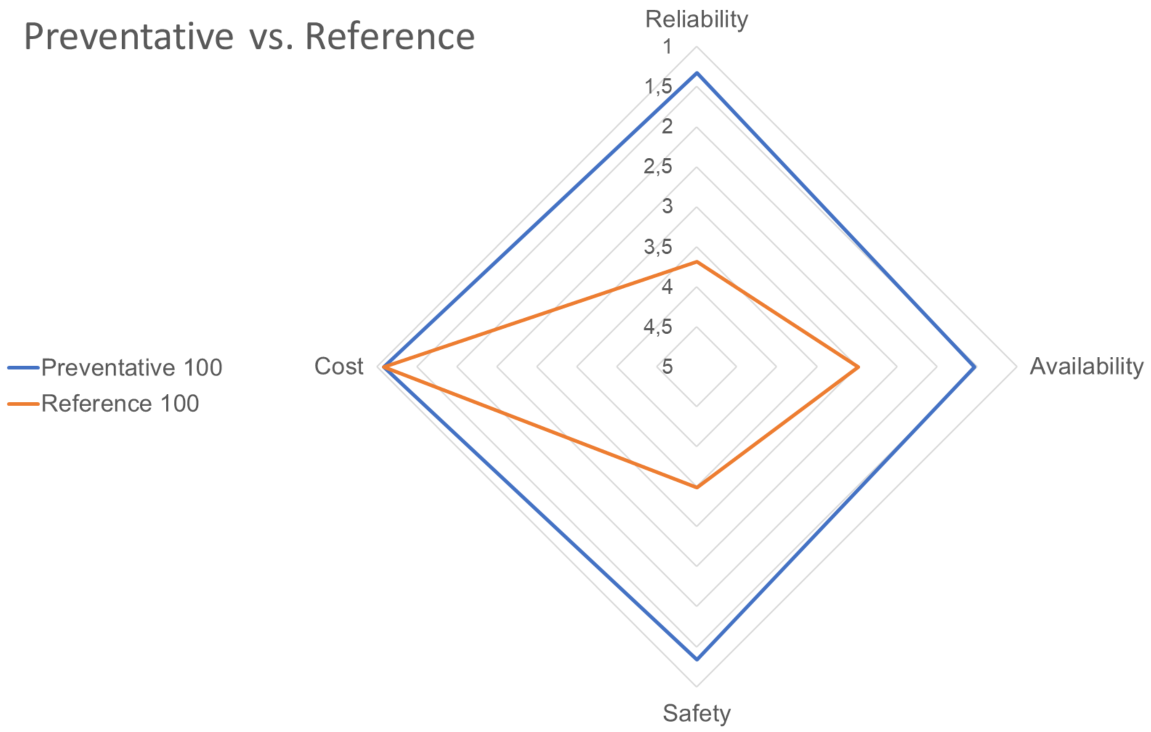




4.4. Comparison of the approaches

A comparison of the two considered approaches is shown in “spider” diagram below.

Comparing two approaches, the is preventive approach is more appropriate for this bridge. The costs in both approaches are at the similar lever but other indicators are more favourable. The availability, reliability and safety are kept in higher levels all over the period.



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