



IM-SAFE^{.EU}

**Harmonised Transport Infrastructure Monitoring
in Europe for Optimal Maintenance and Safety**

IM-SAFE (ref. 958171)

www.IM-safe-project.eu

<https://www.linkedin.com/company/im-safe-project/>

<https://cordis.europa.eu/project/id/958171>



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Framework Programme of the European Union



MORNING SESSION

Moderated by P. Darò (SACERTIS Ingegneria S.r.l., Turin, Italy)

Surveying technologies

Contributors:

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Damage indicators & vulnerable elements

Contributors:

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Performance indicators for bridges and tunnels

Contributors:

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Condition state classification & minimum maintenance levels

Contributors:

A. Strauss, L. Ptacek

Speaker:

A. Strauss (University of Natural Resources and Life Sciences, Vienna, Austria)



Prof. Dipl.-Ing. Dr. Alfred Strauss

- University of Natural Resources and Life Sciences, Vienna, Austria
- Scientist in Structural Engineering
- Life-Cycle Engineering.

PERFORMANCE INDICATORS

a.

11:50-12:10 | Concept of performance indicators

b.

12:10-12:25 | Use of performance concepts in asset management

Q&A

c.

12:40-12:45 | Performance indicators for the community of practice

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Definition of Structural Performance Indicators

IM-SAFE definition A measurable and/or testable parameter (i.e. characteristic of materials and structures) that quantitatively describes property of the structure and/or of the aspect of its performance and are used to qualify fitness of the structure for its purpose during service life.

<i>fib Model Code 2010:2013</i>	<i>COST TU1402</i>	<i>COST TU1406</i>	<i>ISO 13824:2020</i>	<i>ISO 13824:2009</i>	<i>ISO 2394:2015</i>
A measurable/testable parameter (i.e. characteristic of materials and structures) that quantitatively describes a performance aspect i.e. an aspect of the behaviour of a structure or a structural element for a specific action to which it is subjected or which it generates. .	Parameter describing a certain property of the structure or a certain characteristic of the structural behaviour	The term performance indicator stems from economics and measures the success of an organization or of a particular activity (such as projects, programs and other initiatives) in which it engages. The application of this term to physical objects is coupled to their fitness for purpose. The performance indicator measures fitness for purpose of a physical object such as bridge or its element. ...	Qualitative or quantitative representation of the behaviour of a structure (e.g. load bearing capacity, stiffness) in terms of its safety and serviceability.	-	Parameter describing a certain property of the structure or a certain characteristic of the structural behaviour.

Performance Indicators PIs

Concept

Observations / Data

Performance Indicators

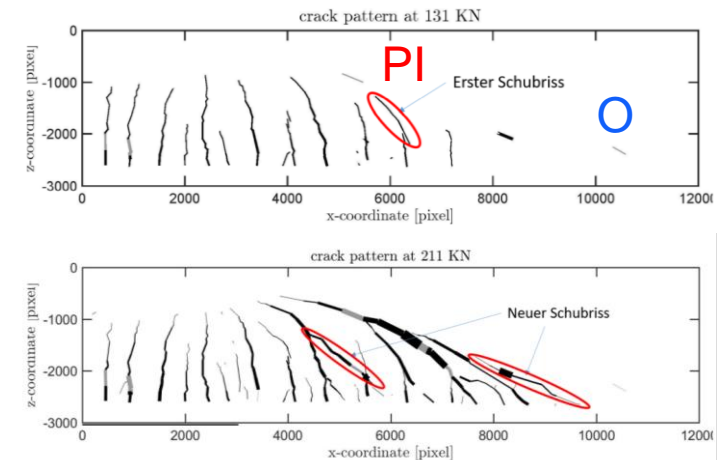
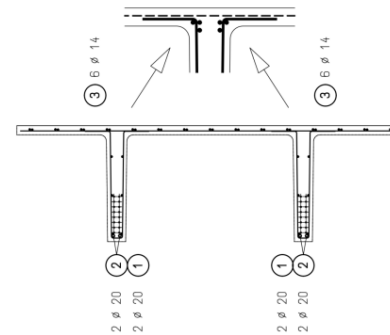
Key Performance Indicators

Need of differentiation between observations and PIs.

Successive inspections ...whether it is

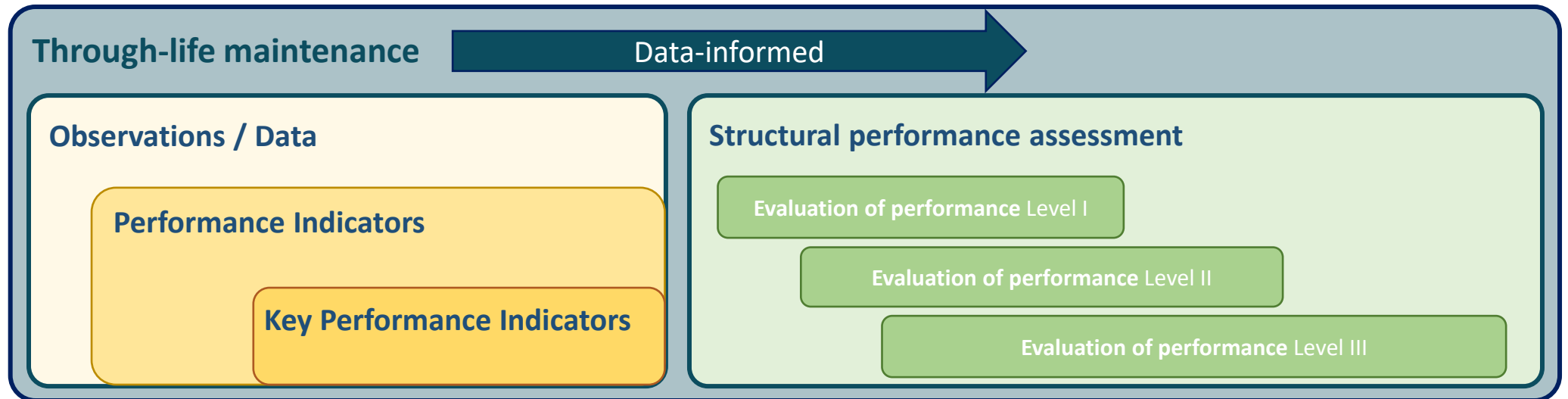
- a pure observation **O** (e.g. stable crack) or
- a possible **PI** (e.g. growing crack).

- **O** Observations indicates the fact
- **PIs** interpretation of Observations on the structural performance



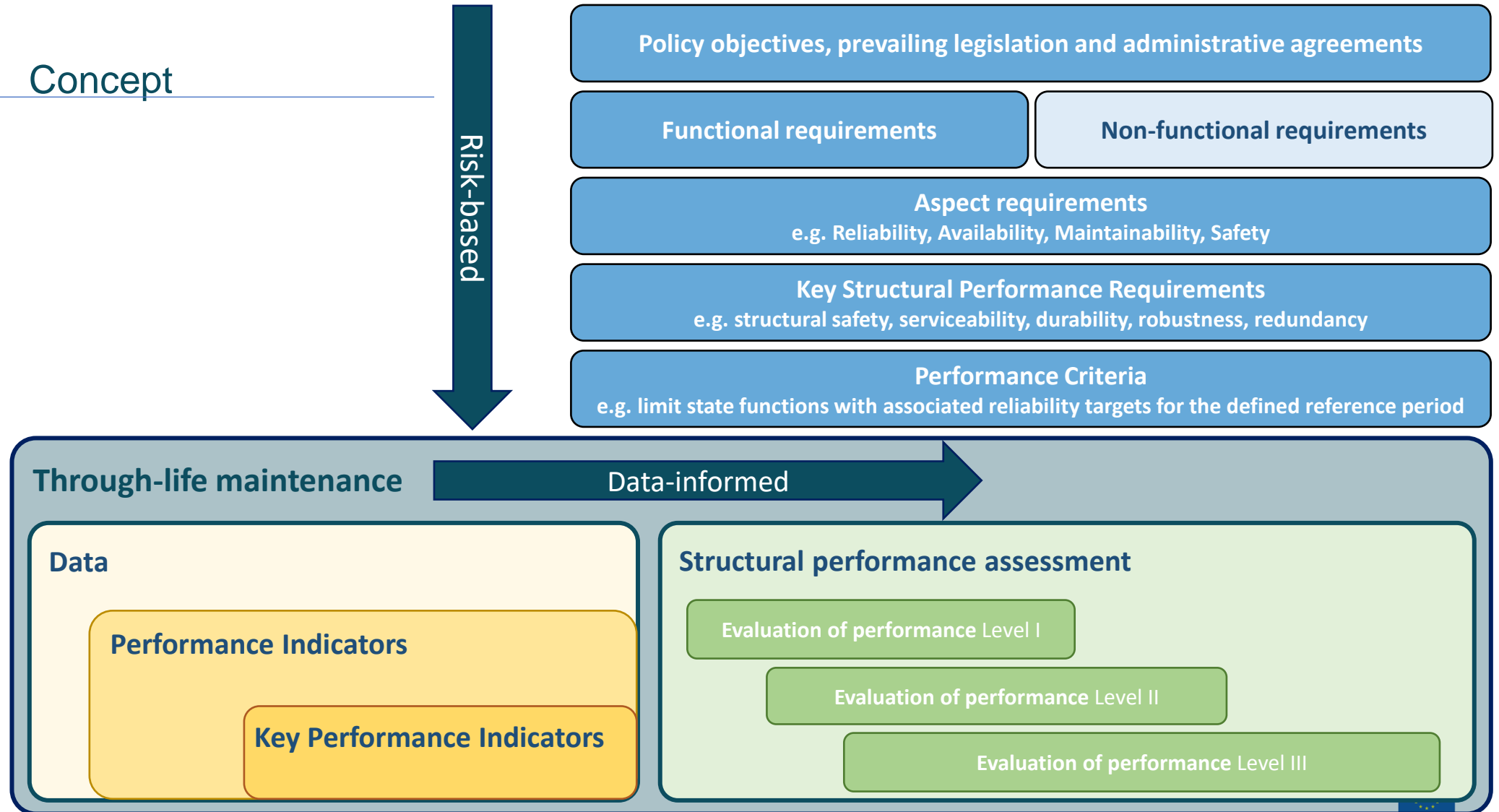
Performance Indicators PIs

Concept



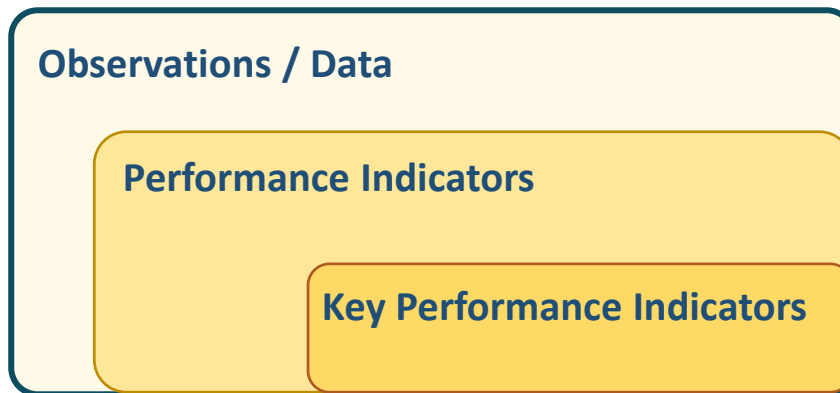
Performance Indicators PIs

Concept



Performance Indicators PIs

at the component level



Categorisation of **damage** as a **primary performance indicator**, requires taking into account

- related detection methods,
- performance thresholds and
- evaluation methods.

Categorisation level - **bridge component**

- e.g. Crack assessed differently depending on where it is found, what is its width, its orientation, and origin.

Damage identification includes

- ascertaining the cause of damage and its consequences
- damage evaluation comprises the degree or/and extend with respect thresholds.
- duration of damage phase (low, moderate or high).

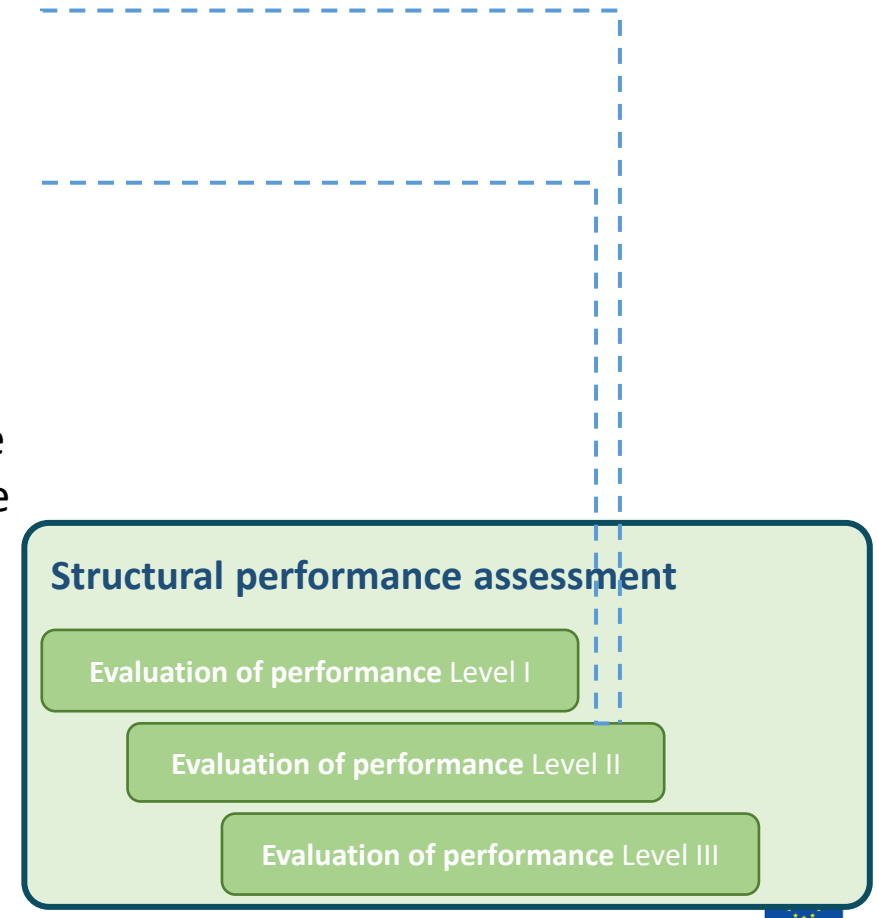
Performance Indicators PIs

at the system level

A qualitative scale of values may show how the **collapse of a particular element** would affect **each criteria**.

Indicators, for example, testing and monitoring, dynamic behaviour and reliability of structures, should be included at this level, as well.

Research-based performance indicators: Structural reliability assessment will require an adequate knowledge level on particular related properties such are for example stiffness changes and local traffic loading which requires investment in **additional inspection, testing or monitoring method, advanced modelling techniques** and updating data on resistance and loads.



Performance Indicators PIs

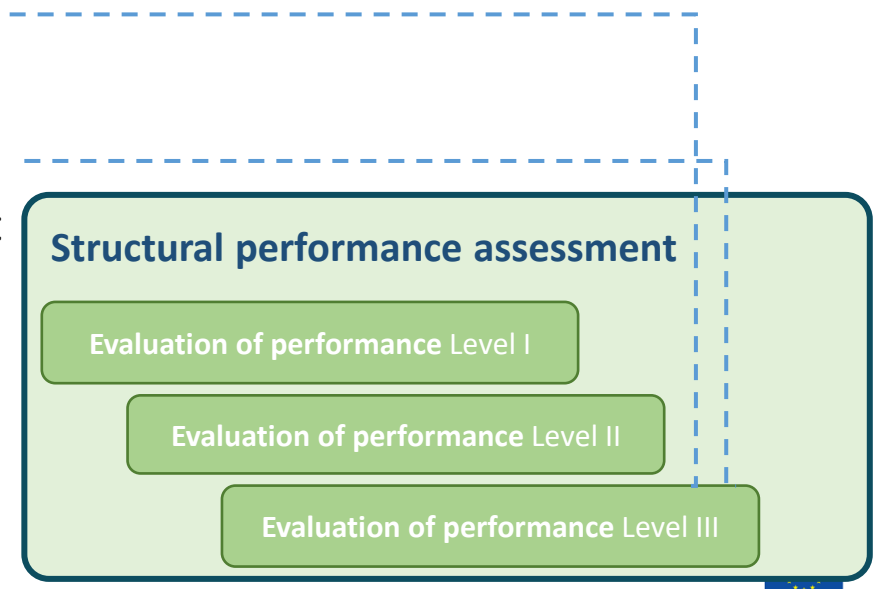
at the network level

Primary goal - priority repair ranking.

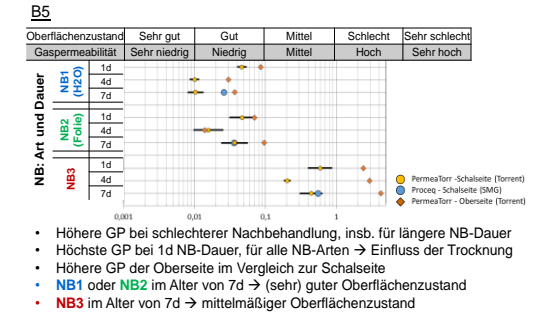
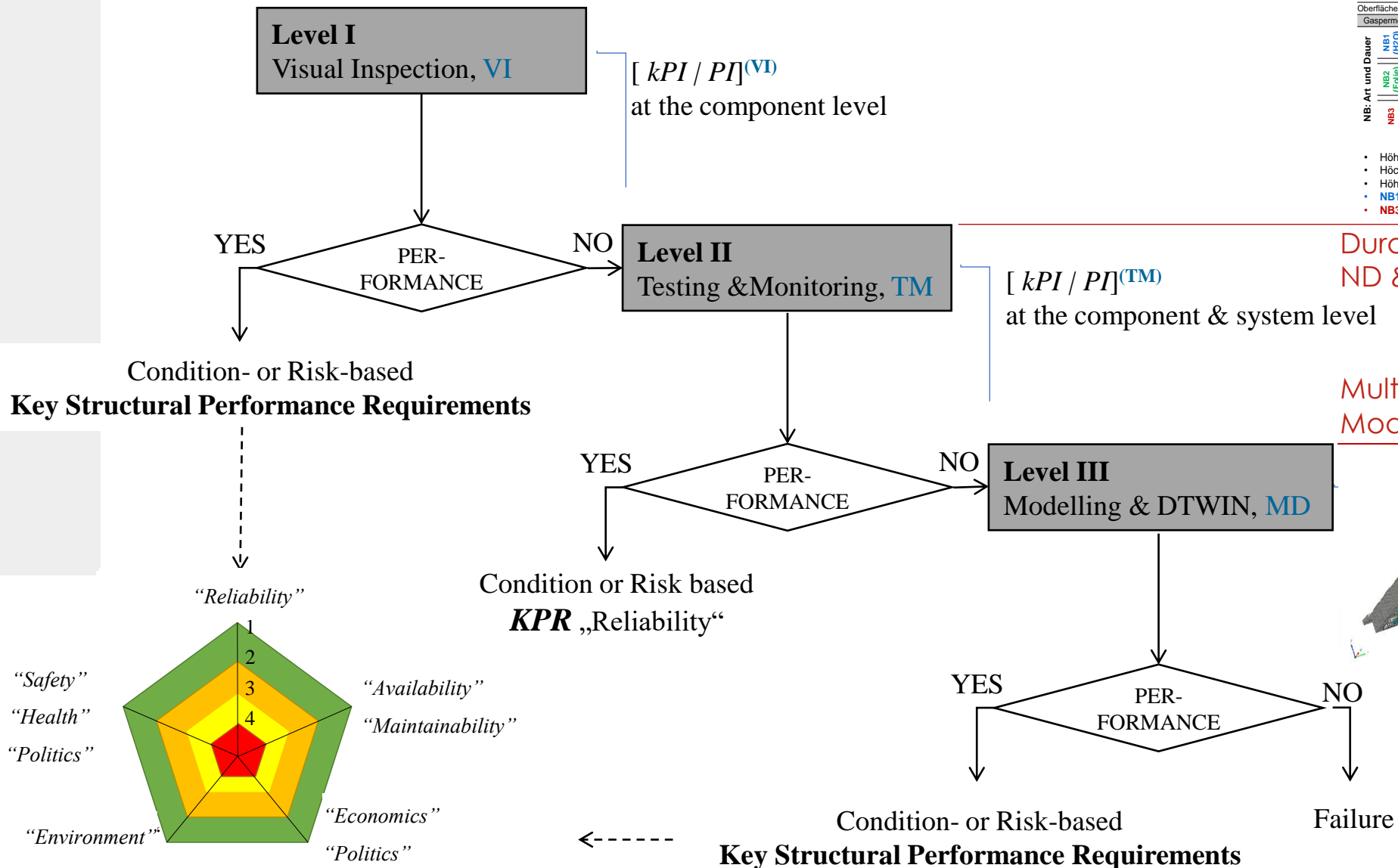
Bridge condition assessment - four criteria: structural safety and serviceability, durability, traffic safety and general bridge condition.

Bridge importance in the network - five criteria: road category, annual average daily traffic, detour distance, largest span, total length.

The transfer of performance indicators at the component level via the PI at the system level to the performance indicators on the network level or the **key performance requirement indicators** should be processes via a **quality control plan**.

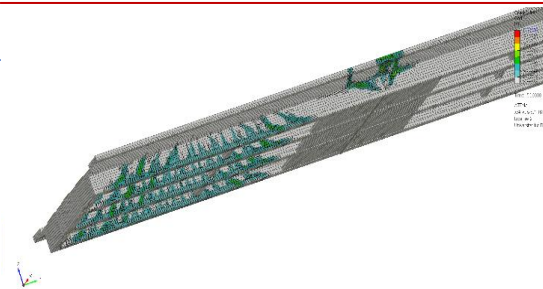


Transfer of PIs to Key Performance Requirements & Aspect Requirements

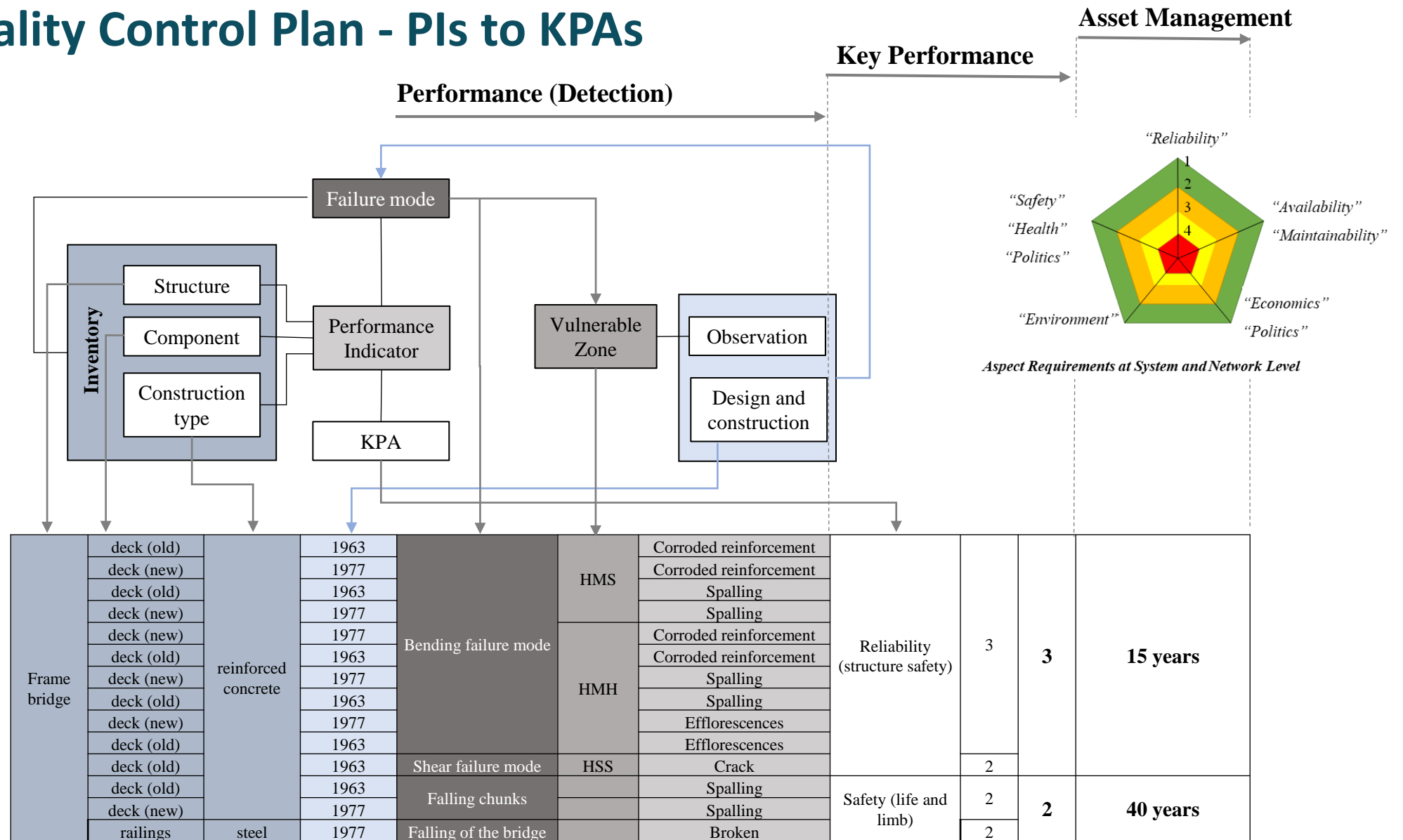
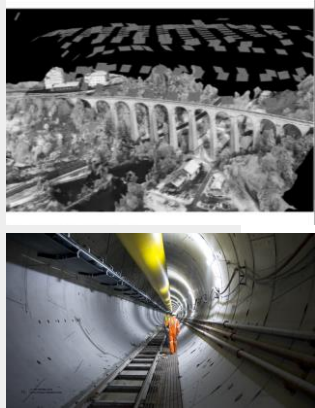


Durability
ND & SD Testing and Monitoring

Multi Level Performance Modelling



Quality Control Plan - PIs to KPAs



PERFORMANCE INDICATORS

a.

11:50-12:10 | Concept of performance indicators | **CoP feedback**

b.

12:10-12:25 | Use of performance concepts in asset management

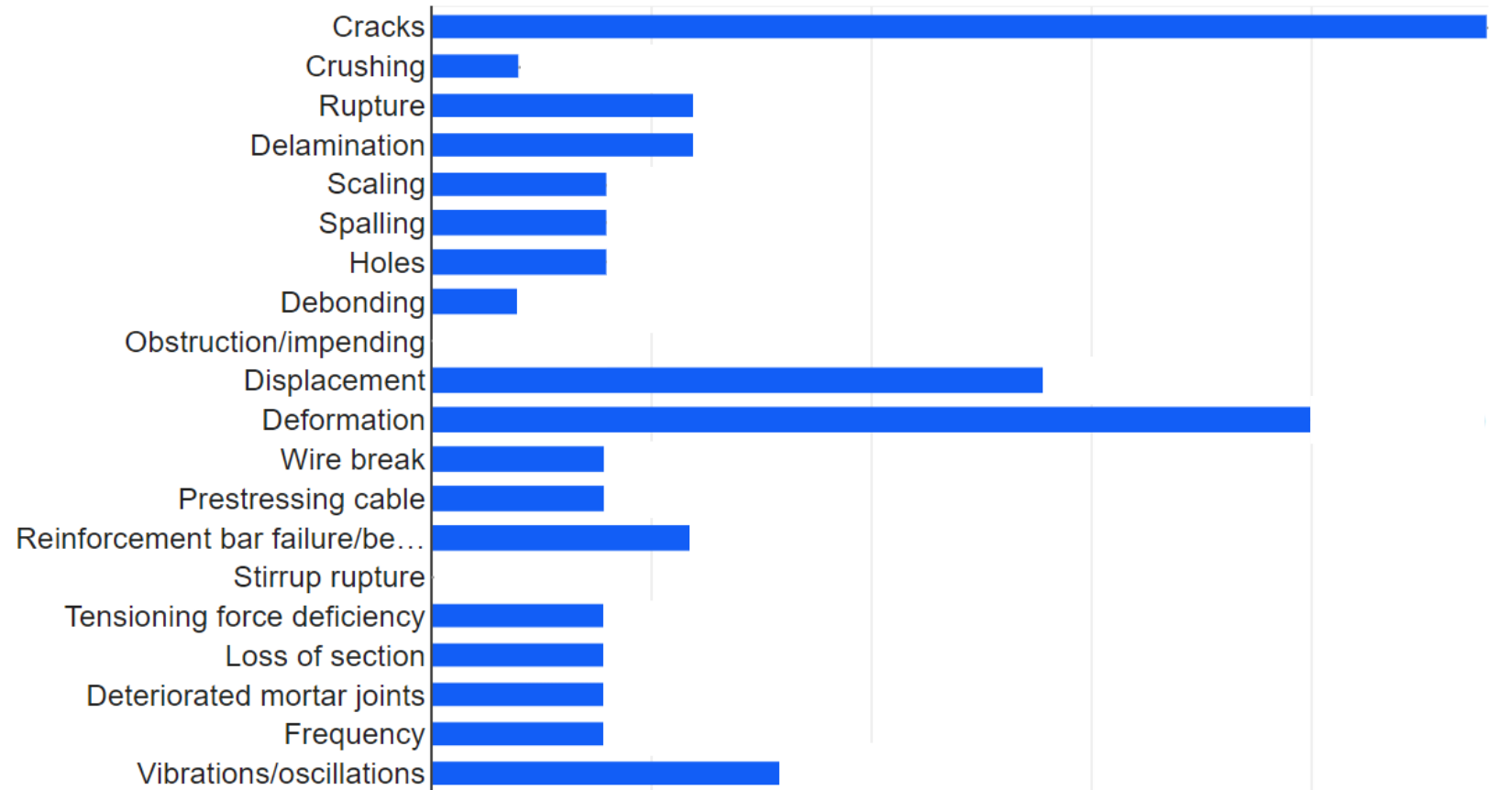
Q&A

c.

12:40-12:45 | Performance indicators for the community of practice

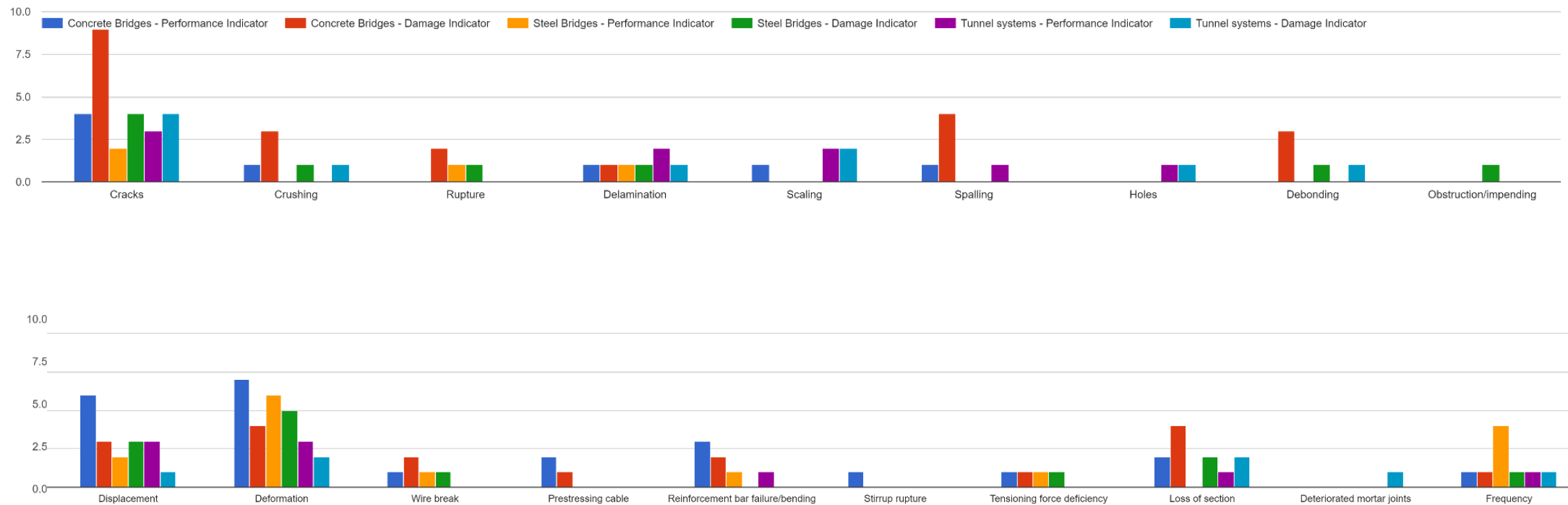
Performance Indicators - CoP feedback

Which Performance Indicators are usually monitored in your current practice?



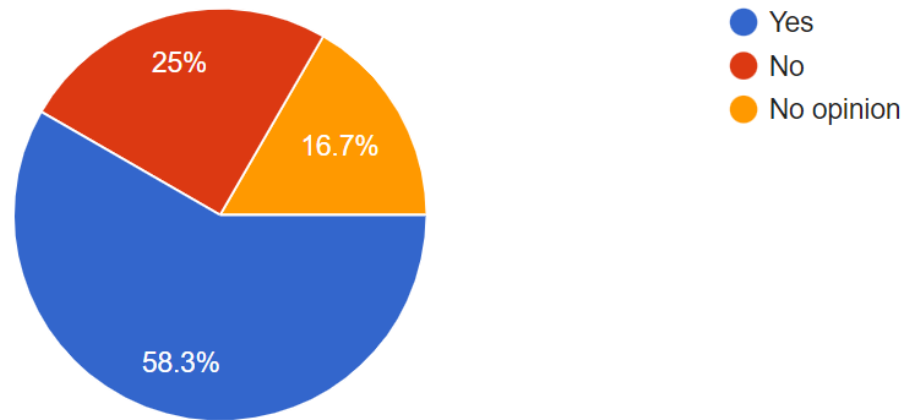
Performance Indicators - CoP feedback

Which are the five most important indicators that are used for condition pre-assessm.?



Performance Indicators – CoP feedback

Do Pis play a role in your decision making process with regard to interventions?



PERFORMANCE INDICATORS

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b.

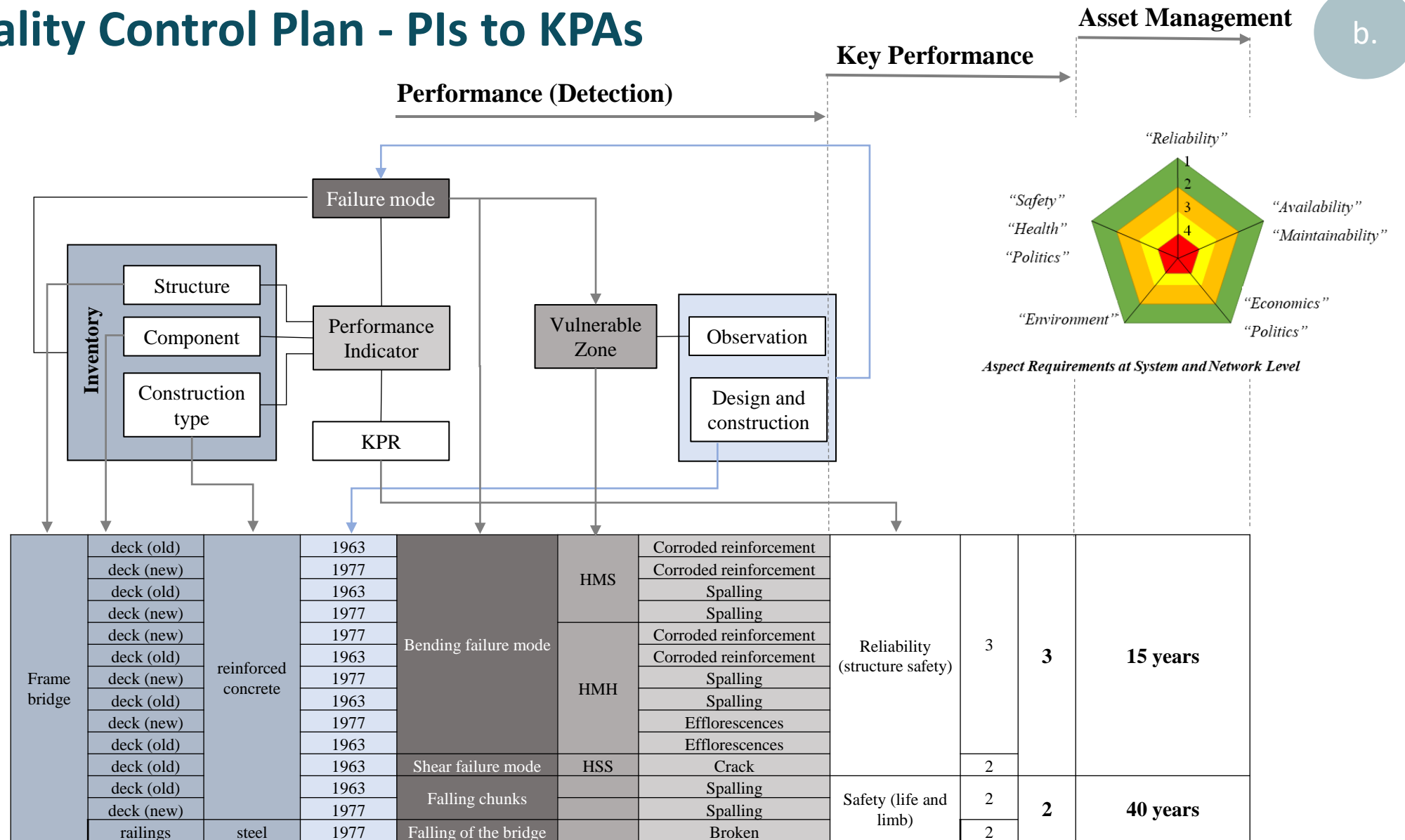
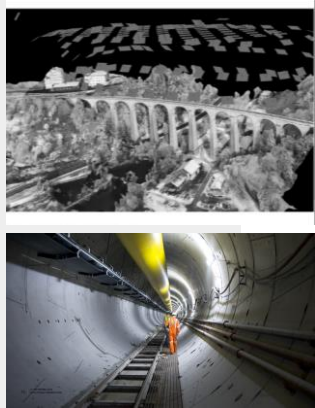
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Q&A

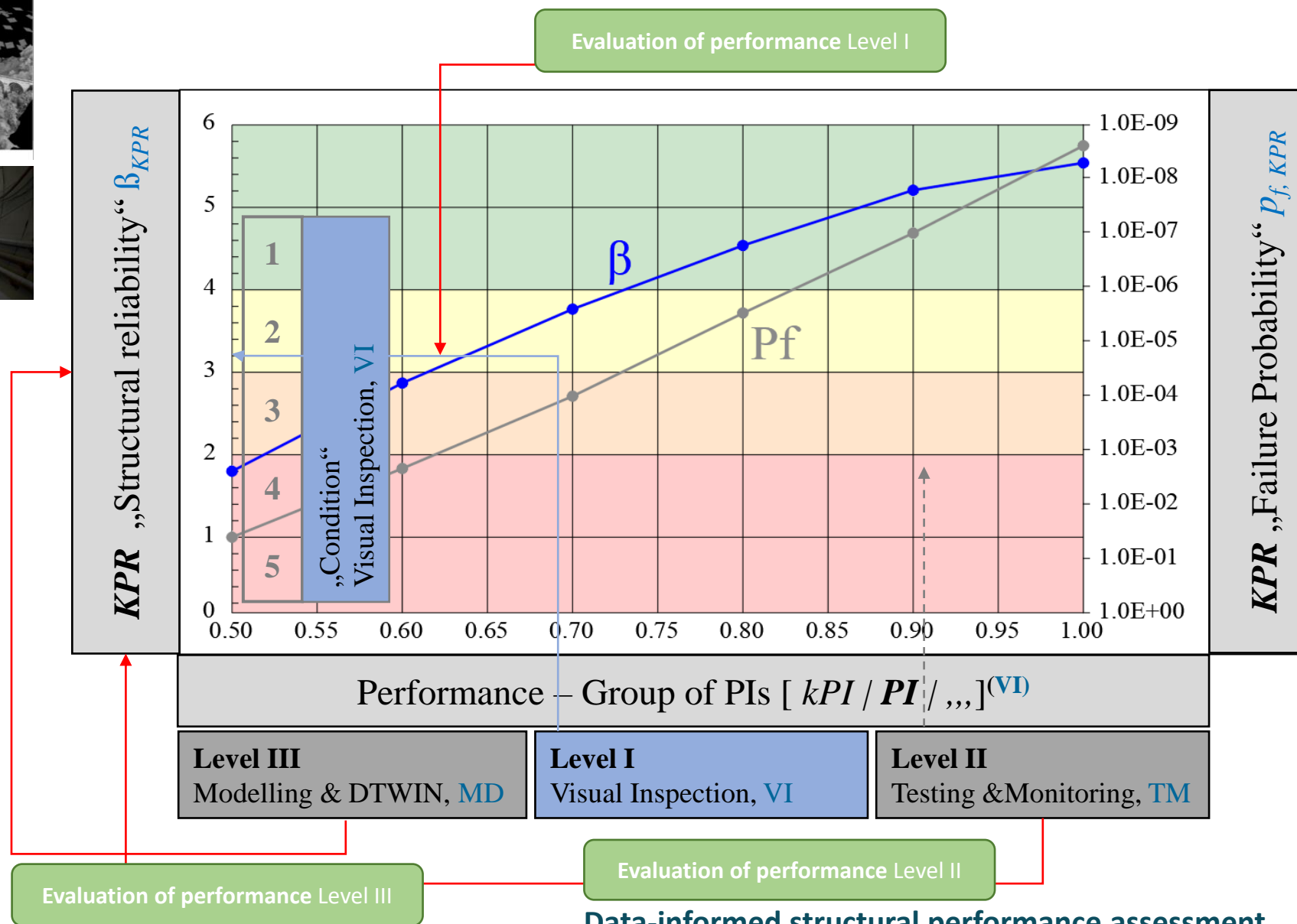
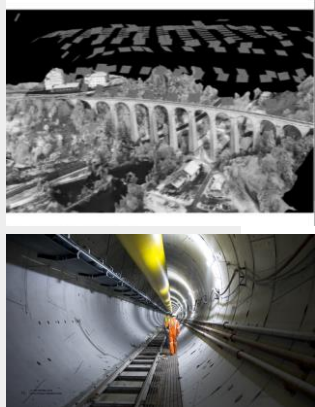
c.

12:40-12:45 | Performance indicators for the community of practice

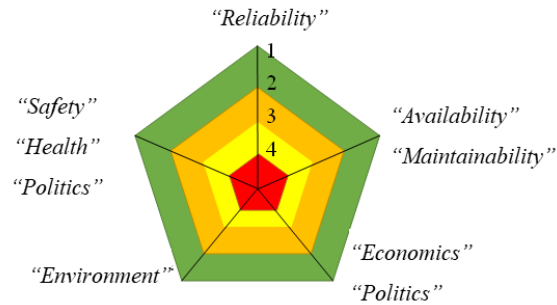
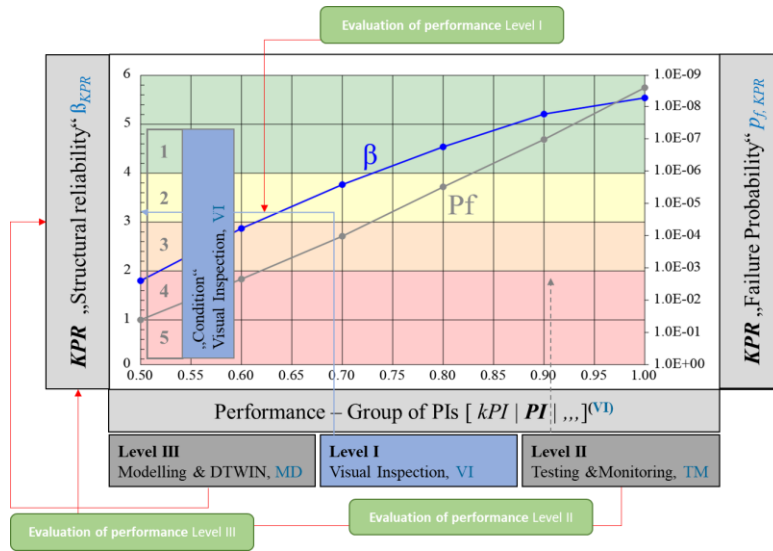
Quality Control Plan - PIs to KPAs



Transfer of PIs to KPRs



KPRs to ASSET MANAGEMENT



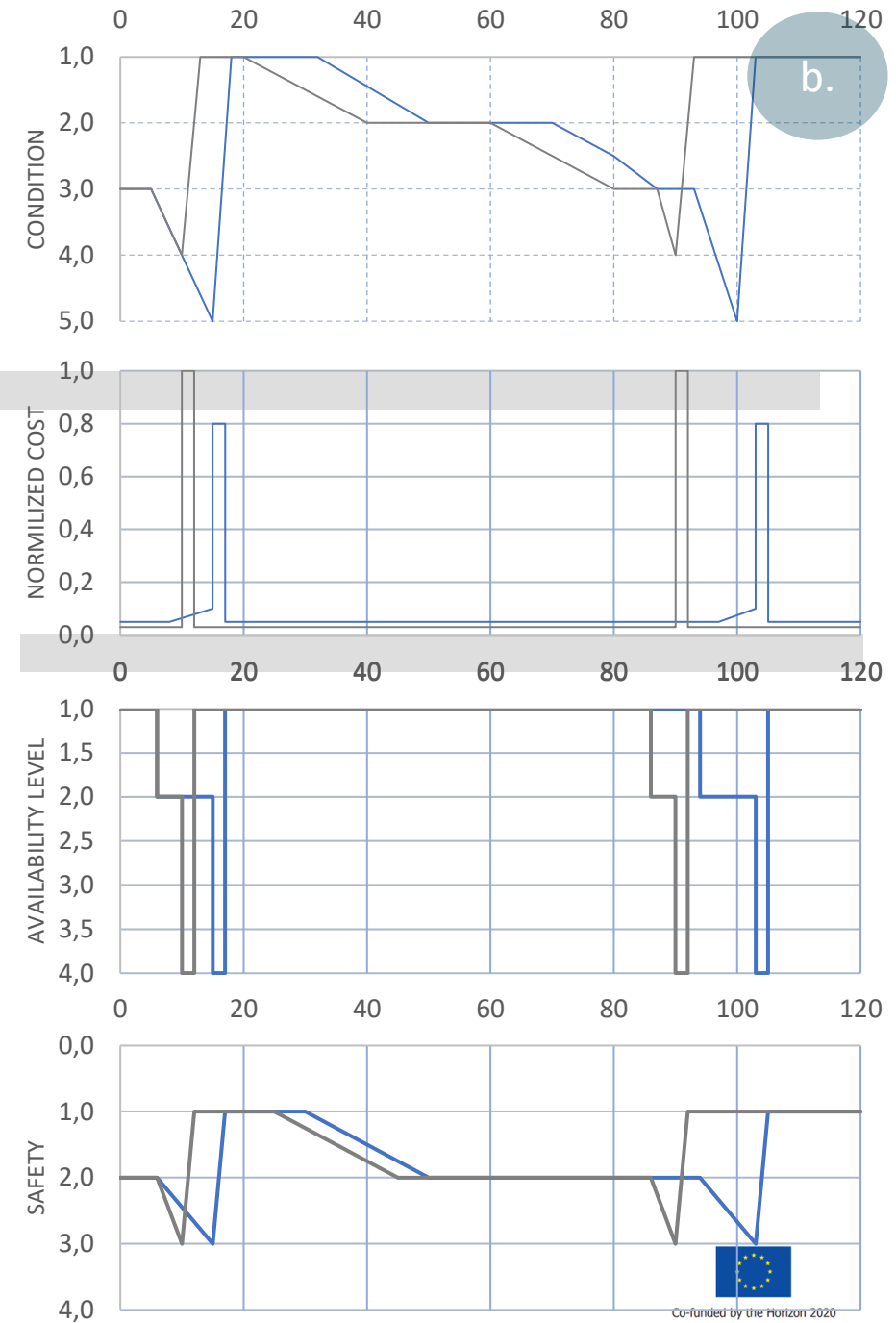
Aspect Requirements at System and Network Level

Reliability

Availability

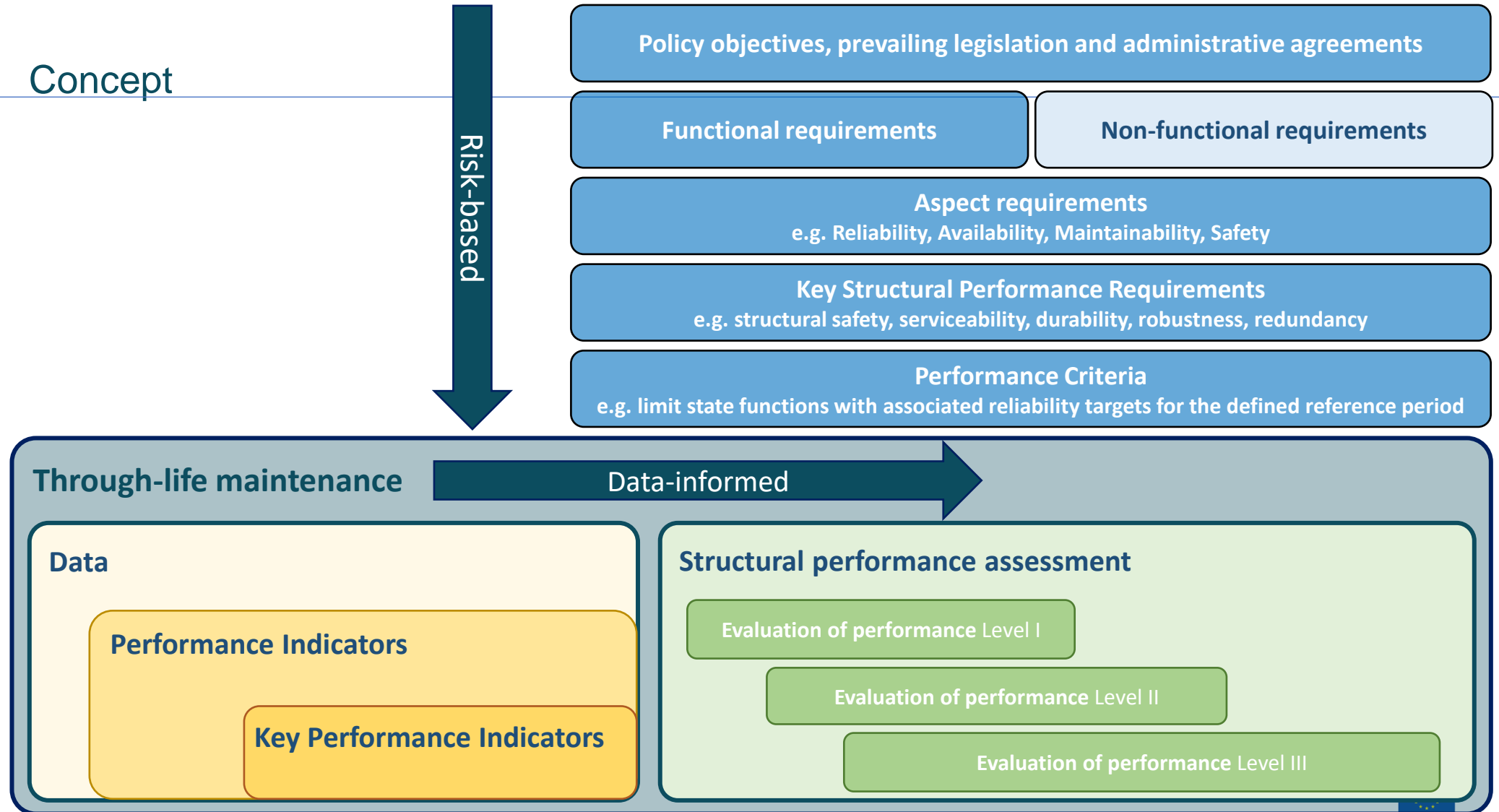
Economy

Safety



Performance Indicators PIs

Concept



Questions and Answers

Questions

- Is a systematized performance indicator system already in use in your country?
- ...used solely for visual inspection?
- Is there an established system for the transfer of PIs to KPAs in use?
- ...based solely on visual inspection?

Questions for discussion:

- Is it reasonable and practicable to build up a systematized performance indicator system for vulnerable areas (pros and cons)?
- In your opinion, is it possible to use a performance indicator system for an objective performance evaluation?
- Is it appropriate to use monitoring or modeling to characterize performance indicators (pros and cons)?
- Is it reasonable and practicable to use monitoring systems for supporting in the transfer from PIs to KPRs
- Is it appropriate to use monitoring and modeling to process KPRs and ASSET Management

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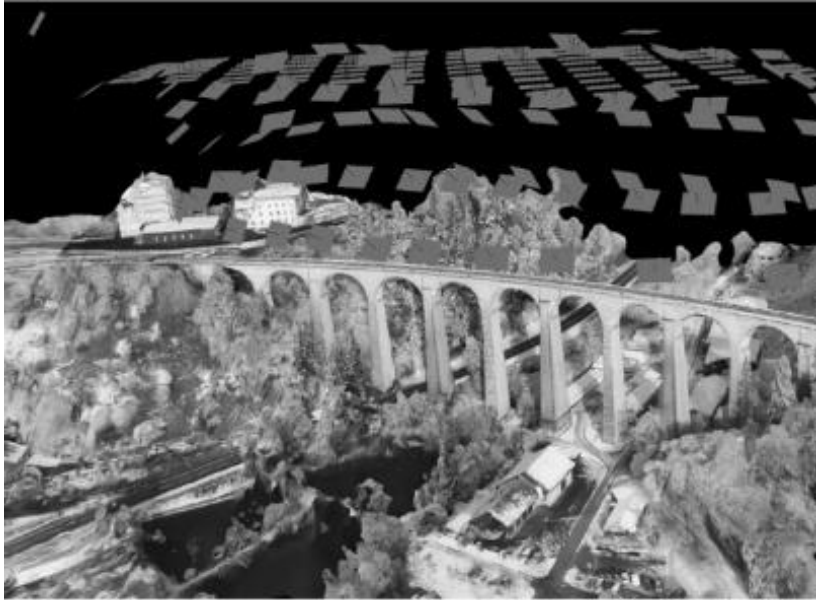
Q&A

c.

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Performance Indicators Pls

Bridges



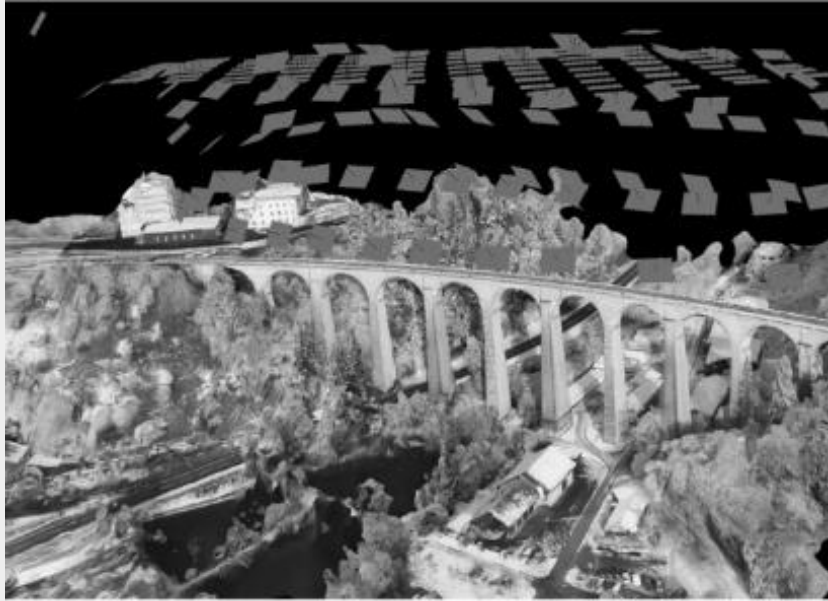
Concrete Bridges

Steel Bridges

Composite Bridges

Performance Indicators PIs

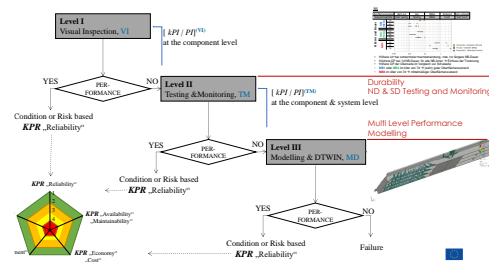
Bridges



Visual Inspection (Level I)

Testing and Monitoring (Level II)

Modelling and DTWIN (Level III)



	Performance Indicators	Cracks	Crushing	Rupture	Delamination	Scaling	Spalling	Holes	Debonding	Obstruction/impending	Displacement	Deformation	Wire break	Prestressing cable	Reinforcement bar failure/bending	Stirrup rupture	Tensioning force deficiency	Loss of section	Deteriorated mortar joints	Frequency	Vibrations/oscillations			
1	Abrasion			o				o				o	o					o	o	o	o	●		
2	Aggradation (alluviation)									o	o	o										●	●	●
3	Erosion	o		o		o		o			o	o	o		o	o		o	o	o	o	●		
4	Changing geotechnical properties	o	o	o				o			o	o	o	o	o	o	o			o	o	●	●	●
5	Aging of material	o							o		o	o					o	o	o	o	o	●	●	●
6	Alkali aggregate reaction (alkali-silica reaction)	o			o						o	o			o	o	o			o	o	●		
7	Sulphate reaction	o			o	o	o	o			o	o			o	o	o			o	o	●		
8	Chemical attack				o	o						o	o	o	o	o		o	o			●		
9	Fatigue	o		o				o				o	o	o	o	o			o	o	o	●	●	●
10	Pitting corrosion	o				o							o	o	o	o		o		o		●		
11	Corrosion related to prestressing steel	o	o	o										o				o		o	o	●	●	
12	Corrosion related to structural steel	o		o		o												o		o	o	●	●	
13	Corrosion related to reinforcement steel	o		o	o	o	o	o	o						o	o		o		o	o	●	●	
14	Corrosion related to equipment made of steel	o		o		o												o		o	o	●	●	
15	Corrosion related to fixings, connectors	o		o		o			o									o		o	o	●	●	

Performance Indicators PIs

Tunnels



Bored Tunnels

Cut and Cover Tunnels

Submerged Floating Tunnels

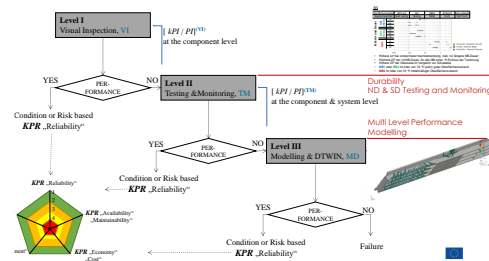
Performance Indicators PIs Tunnels



Visual Inspection (Level I)

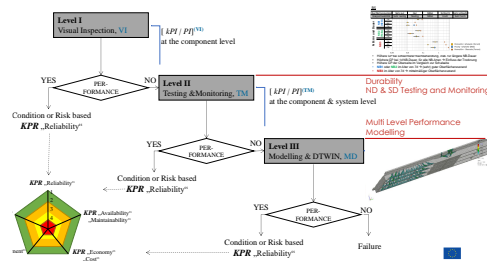
Testing and Monitoring (Level II)

Modelling and DTWIN (Level III)



ID associated with Table 5-5	Performance Indicators Damage Process																		ULS(U)	Functionality/operational safety(F)
		Cracks	Crushing	Rupture	Delamination	Scaling	Spalling	Holes	Debonding	Obstruction/impending	Displacement	Deformation	Wire break	Prestressing cable	Reinforcement bar failure/bending	Stirrup rupture	Tensioning force deficiency	Loss of section		
1	Continuous vertical rock movement	○	○	○														●	5	7
1	Bending stress	○	○	○														●	5	7
2	Local rock movement (punching)	○	○	○							○	○						●	9	10
3	Higher horizontal actions (underestimation of lateral action)	○	○	○											D			D	9	5
3	Missing reinforcement	○	○	○											D			D	9	5
4	Deformation due to shrinkage, temperature within the shell-blocks	○									○	○						●	4	4
4	Missing reinforcement	○									○	○						●	4	4
5	Corrosion of reinforcement	○					○		○					○				●	6	2
5	debonding	○					○		○					○				●	6	2
5	Partial spalling of concrete cover	○					○		○					○				●	6	2
6	Different casting times	○									○	○						●	4	2
6	Different concrete qualities	○			○						○	○						●	4	2
6	Delaminations of concrete layers (e.g. spreaded concrete)	○			○						○	○						●	4	2
7	Overloading (rock movement) of prestressing	○	○	○						○	○							●	9	10
	Anchor failure	○	○	○						○	○							●	9	10

Modelling and DTWIN (Level III)



ID associated with Table 5-5	Damage Process	Performance Indicator																				ULS(U)	Functionality/operational safety(F)
		Cracks	Crushing	Rupture	Delamination	Scaling	Spalling	Holes	Debonding	Obstruction/impending	Displacement	Deformation	Wire break	Prestressing cable	Reinforcement bar failure/bending	Stirrup rupture	Tensioning force deficiency	Loss of section					
8	Soil liquefaction			○					○	○									●			6	4
9	Thermal reaction	○			○			○	○	○									●	●	●	3	2
9	Lack of concrete curing	○			○			○	○	○									●			3	2
9	Plastic shrinkage	○			○			○	○	○									●	●	●	3	2
10	Different (partial) shrinkage between layers of concrete	○			○			○	○	○									●	●	●	3	2
11	Higher freeze-thaw cycles (exposure class)	○			○			○	○	○									●			3	5
11	Insufficient concrete quality	○			○			○	○	○									●			3	5
11	Freeze-thaw cycles in the first 100 m of a tunnel	○			○			○	○	○									●			3	5
12	Electrochemical reaction lowers the alkalinity, rebar corrosion													○					●	●	●	3	4
13	Chemical (salt) attack													○					●			3	5
13	Rebar corrosion (chloride penetration distributed)													○					●	●		3	5
14	Lack in the drainage system																		●	●		2	4
14	Lack in the waterproofing system																		●	●		2	4
15	Lime efflorescence																		●	●		1	2
16	Low quality curing		○	○								○							●	●		3	3
16	Settlement of the fresh concrete		○	○								○							●	●		3	3

Solicitation

We will make available tables treated in c. and ask you to provide us with your comments

**Thank you all for
attending, questions,
input, etc.**



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