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Harmonised Transport Infrastructure Monitoring in Europe for Optimal Maintenance and Safety

IM-SAFE (ref. 958171)

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AFTERNOON SESSION

Moderated by A.J. Bigaj-van Vliet (TNO, the Netherlands)

Data-informed structural performance assessment

Contributors:

P. Darò [1], G. Mancini [1], A. Strauss [2], D.L. Allaix [3], A.J. Bigaj-van Vliet [3]

Risk assessment and risk-based framework

Contributors:

H. van Meerveld [3], B. Cerar [3], A.J. Bigaj-van Vliet [3], A. Strauss [2], L. Ptacek [2]

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Risk-based maintenance management & maintenance strategies

Contributors:

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Speaker:

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- TNO Department of Structural Reliability
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RISK ASSESSMENT AND RISK-BASED FRAMEWORK FOR MAINTENANCE MANAGEMENT

a. **16:00-16:30 |** Risk in maintenance management & methods of assessing risk

Q&A

b. **16:30-17:00 |** Maintenance management & maintenance strategies

Q&A

c. **17:15-17:30 |** Condition state classification and minimum maintenance levels

for transport infrastructure

Q&A

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RISK ASSESSMENT AND RISK-BASED FRAMEWORK FOR MAINTENANCE MANAGEMENT

Risk & methods of assessing risk

Maintenance management & Maintenance strategies

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RISK IN MAINTENANCE MANAGEMENT

Function	An **intended task** of a system that is being performed.
Performance	Efficiency of a system; indicating how well the system works [1] Note: Efficiency of a system with regard to structural behaviour is referred to as structural performance
Structural performance	The **behaviour or a condition** of a structure or a structural component, as a **consequence of actions**, usually **classified by means of a quantitative parameters** (e.g. reliability index, ratio between (local/overall) resistance capacity and action effect).
Maintenance	Combination of all technical, administrative and managerial **actions performed during the service life** of the structure in order **to retain at or restore** its **performance** and future serviceability at/to the level at which it can perform the required function.

- **The purpose of maintenance is to retain or restore performance.**

- **To maintain performance we need to know (and understand) risk.**

RISK IN MAINTENANCE MANAGEMENT

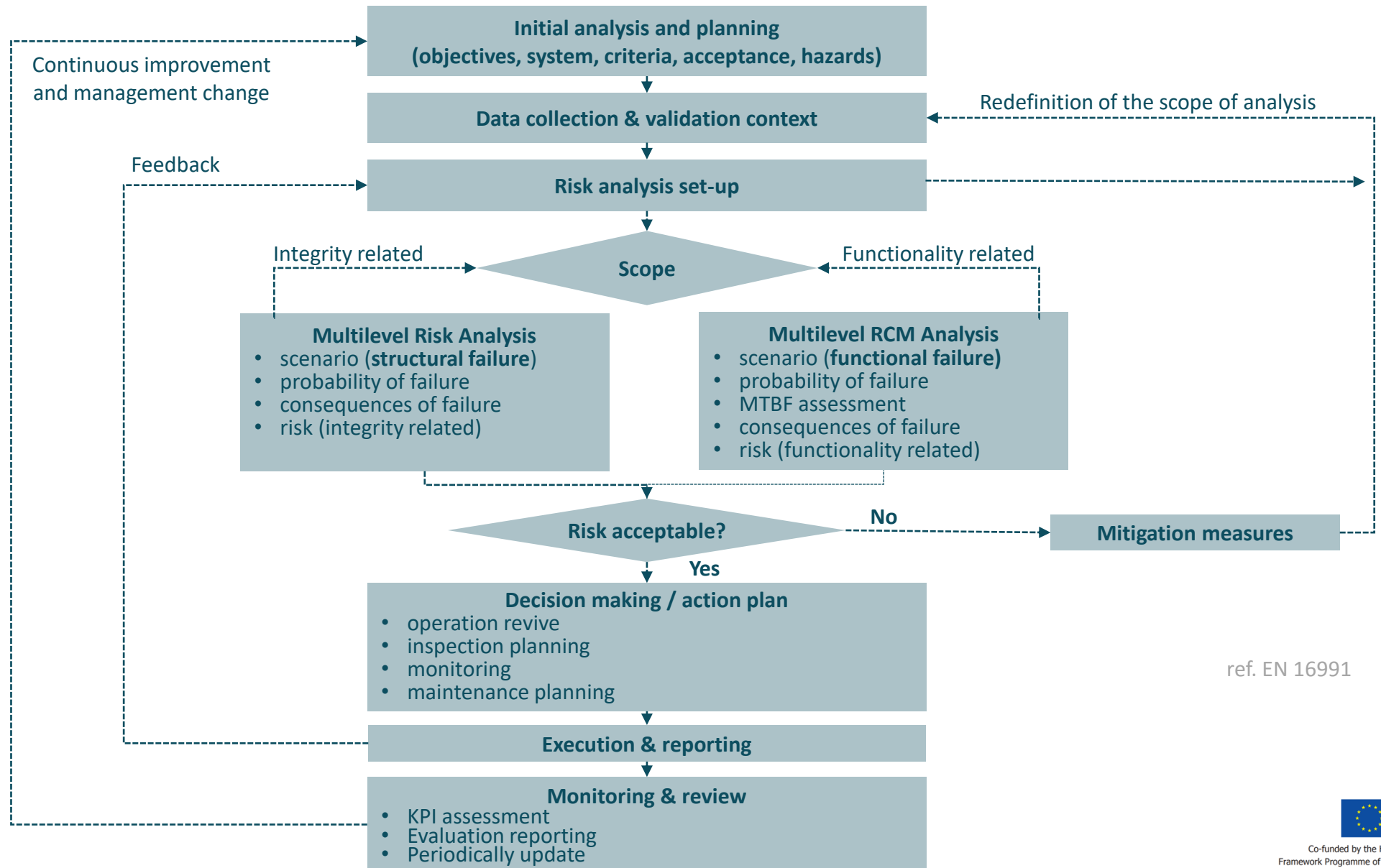|	
Hazard	Potential **source of** undesirable **consequences**.[1] [1] Note: Actions on structures are **source of potential harm** and present hazards to structures.
Event	**Occurrence or change of** a particular set of **circumstances** [1] An event can be one or more occurrences, and can have several causes. [2] An event can be a **source of risk**.
Risk	The effect of uncertainty on objectives, realized as the **expected value of all undesirable consequences**, combining the probability of event and related consequences.

- **As a single event: risk *R* is the probability *P* having potential consequences *C*:**

$$R = P \times C$$

- **As multiple events: expressed as the value of expected consequences *E(C)*:**
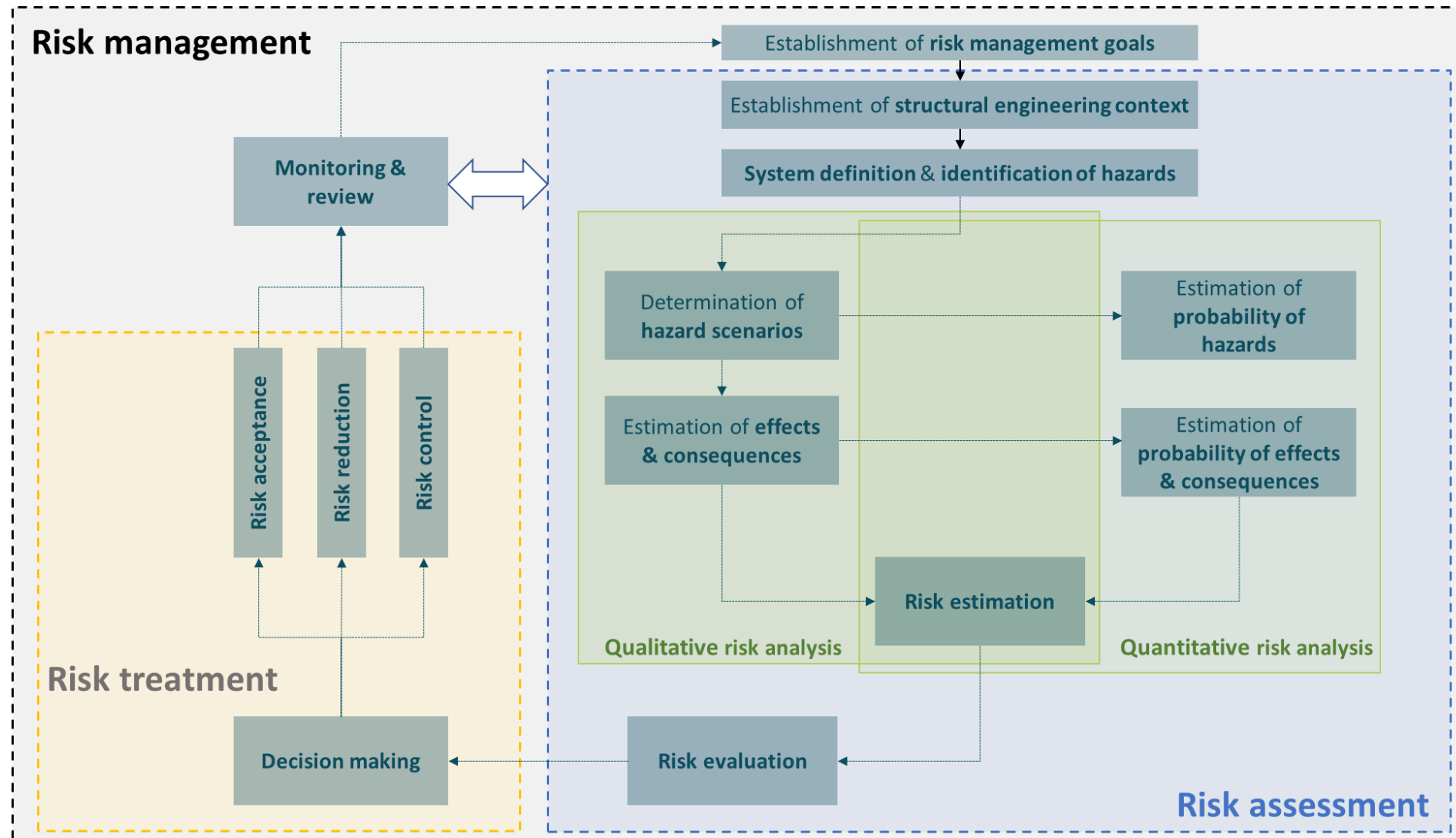
$$R = E(C) = \sum_{i=1}^{n} p_i \times C_i$$

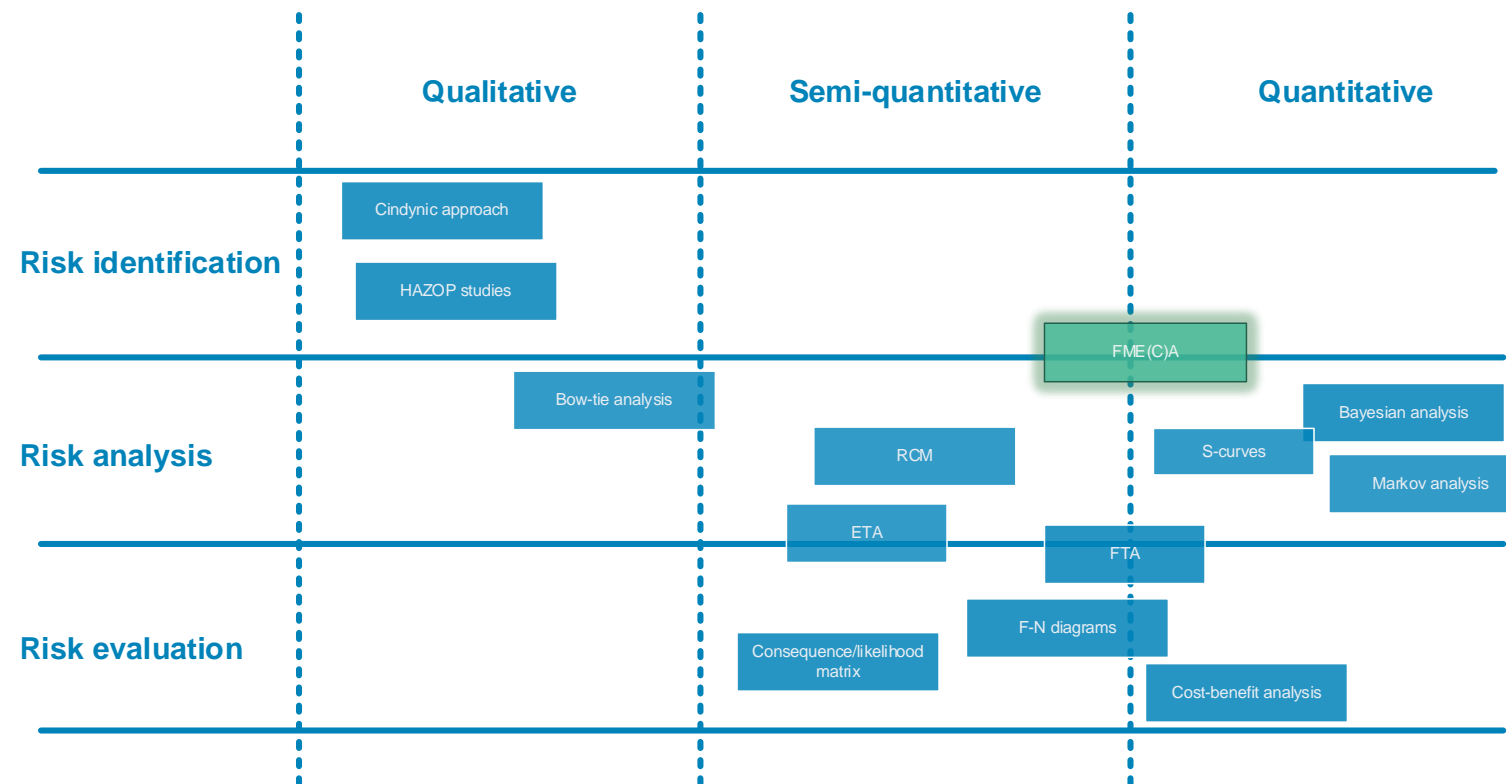**IM-SAFE**

RISK-BASED MAINTENANCE MANAGEMENT FRAMEWORK

Initial analysis and planning
(objectives, system, criteria, acceptance, hazards)

Continuous improvement
and management change

Data collection & validation context

Redefinition of the scope of analysis

Feedback

Risk analysis set-up

Integrity related

Scope

Functionality related

Multilevel Risk Analysis
- scenario (**structural failure**)
- probability of failure
- consequences of failure
- risk (integrity related)

Multilevel RCM Analysis
- scenario (**functional failure**)
- probability of failure
- MTBF assessment
- consequences of failure
- risk (functionality related)

Risk acceptable?

No

Mitigation measures

Yes

Decision making / action plan
- operation revive
- inspection planning
- monitoring
- maintenance planning

ref. EN 16991

Execution & reporting

Monitoring & review
- KPI assessment
- Evaluation reporting
- Periodically update

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METHODS OF ASSESSING RISK

- **Understanding risk means:** (1) identifying risks, (2) identify causes, (3) identify consequences, (4) quantify aforementioned in order to be able to determine an appropriate way to manage risk.

- **There are many risk assessment methods;** a possible typology is shown below

	Qualitative	**Semi-quantitative**	**Quantitative**
Risk identification	Cindynic approach HAZOP studies		
			FME(C)A
Risk analysis		Bow-tie analysis RCM ETA	S-curves Bayesian analysis Markov analysis FTA
Risk evaluation		Consequence/likelihood matrix F-N diagrams	Cost-benefit analysis

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Q&A

- Question (Zoom poll): **Do you use risk assessments methods to identify, analyses and evaluate risks?**
  - **No**
  - **Yes; they are mainly qualitative**
  - **Yes; they are mainly semi-quantitative**
  - **Yes; they are mainly quantitative**

- Question (Zoom poll): **Do you use other (more detailed) risk assessment methods for high-critical assets?**
  - **Yes**
  - **No**

- Discussion: **Would harmonized standardization in risk estimation and/or risk evaluation be desired?**

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RISK ASSESSMENT AND RISK-BASED FRAMEWORK FOR MAINTENANCE MANAGEMENT

Risk & methods of assessing risk

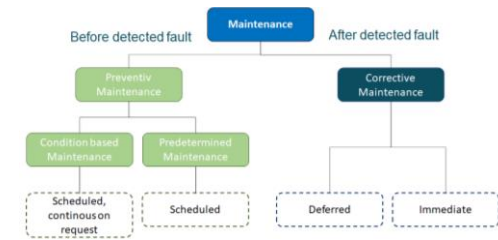**Maintenance management & Maintenance strategies**

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DETERMINING MAINTENANCE STRATEGIES

- **Determining maintenance strategies is a important step in developing and/or improving maintenance plans.**

- **Starting point is a thorough understanding of potential risks.**

- **For each identified risk, an appropriate maintenance strategy is chosen.**

- **The result of the above is a 'first' maintenance plan outlining:**
    - **What information is needed (e.g. via inspection, monitoring, etc.) and what activities are required in this regard.**
    - **What maintenance actions are expected and or planned.**

- **The maintenance plan may then be further optimized (e.g. combining activities).**

DETERMINING MAINTENANCE STRATEGIES

- **For each risk identified, an appropriate maintenance strategy has to be devised.**

Typology of maintenance strategies			Generic motivation for choice (based on risk assessment)			Activities (next to maintenance)
			Risk	**Failure**	**Effectiveness**	
Corrective	Failure-based (e.g. *Run to failure)*		Acceptable	Not relevant	N/A	Observe failure
Preventive	Predetermined	Time-based	Unacceptable	Can be predicted sufficiently accurate based on time.	When above is not (cost)effective	Monitor time
		Use-based		Can be predicted sufficiently accurate based on use.	When above is not (cost)effective	Monitor use
	Condition-based	Non-predictive		Can be determined sufficiently accurate on observed condition.	When above is not (cost)effective	Observe condition and compare to criteria
		Predictive		Can be predicted sufficiently accurate based on observed condition.	When above is not (cost)effective	Observe condition, make prediction, and compared to criteria

Improvement			Unacceptable	Cannot be predicted	When above is not (cost)effective	Redesign and implement improvements

DETERMINING MAINTENANCE STRATEGIES
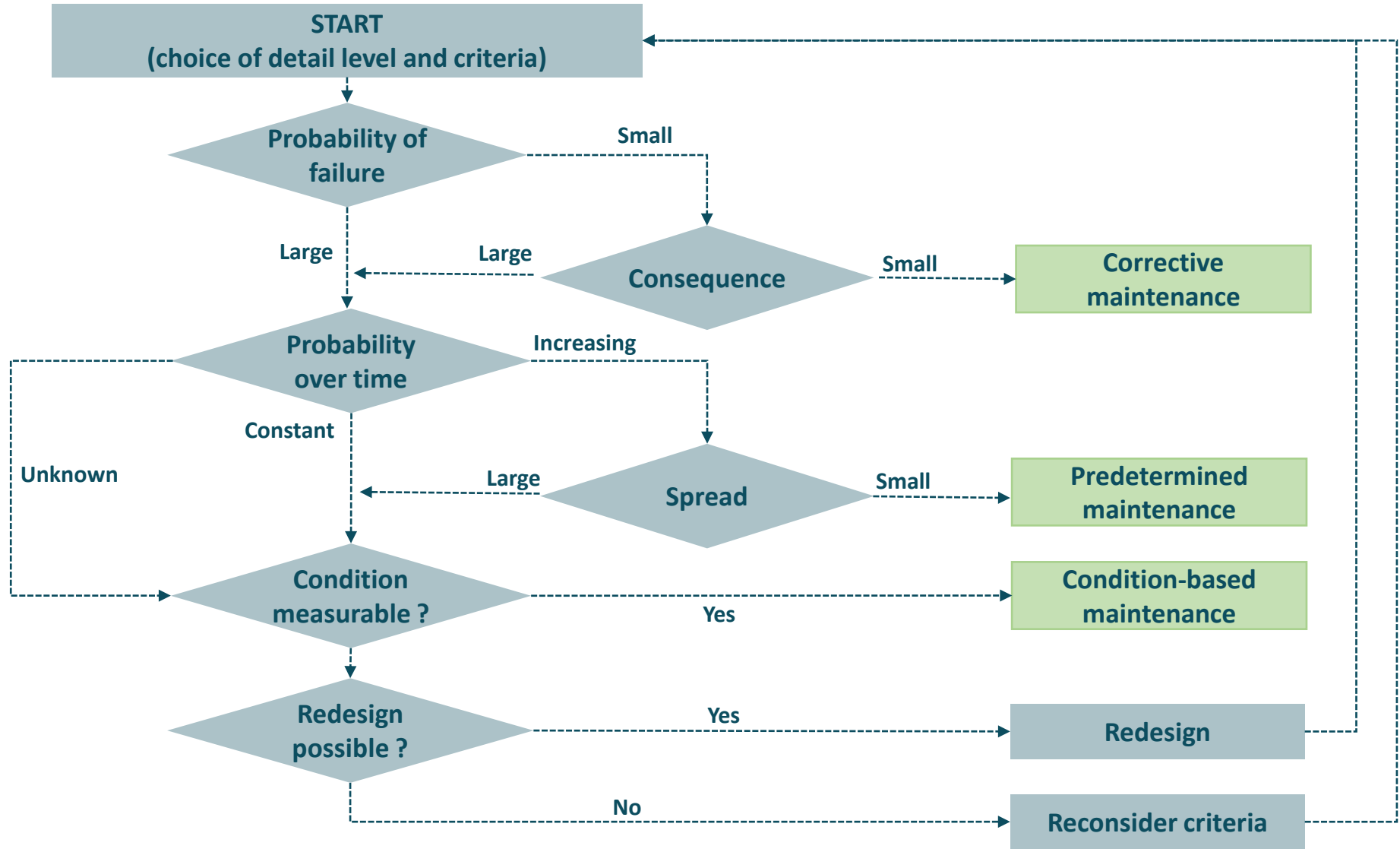
DETERMINING MAINTENANCE STRATEGIES

• Results

- **List of maintenance actions and strategies**

- **Optimization**

    - Clustering of activities

    - Selecting intervals

- **Possible results:**

    - Maintenance concept or plan

    - Update of the maintenance concept or plan

    - Recommendation

DETERMINING MAINTENANCE STRATEGIES

- **Maintenance : ideally predictable and plannable**

	Planned/scheduled	Unplanned/unscheduled
Before failure occurs	Predetermined / Condition based	Opportunistic
After failure occured	Deffered corrective	Immediate corrective

Failures are predictable

Planned Maintenance

Volume of maintenance

Unplanned Maintenance

Failures are unpredictable

Q&A
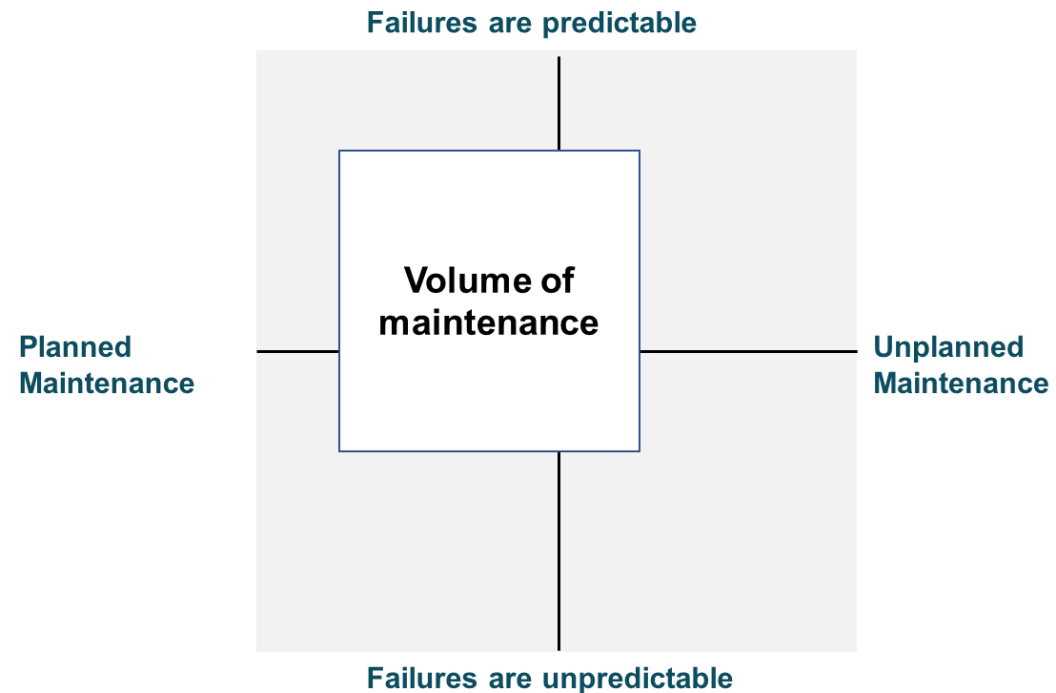
- Question (Zoom poll): **What maintenance strategy is most common with regard to structural performance of bridges and tunnels?**
  - **Corrective**
  - **Time/use-based**
  - **Non-predictive condition-based**
  - **Predictive condition-based**

- Question (Zoom poll): **Do you see a shift towards an different approach in maintenance strategies?**
  - **I don't see any shift in the foreseeable future**
  - **Corrective**
  - **Time/use-based**
  - **Non-predictive condition-based**
  - **Predictive condition-based**

- Discussion: **Which drivers determine the choice of the maintenance strategy in the current practice?**

  To which extend innovation in data analytics & sensor technologies will influence the choice of maintenance strategies in the future?

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

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