- FORESEE -

Future proofing strategies FOr RESilient transport networks against Extreme Events

– Deliverable *6.8*–

Stakeholders Feedback Validation Report

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TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

1 INTRODUCTION

This deliverable aims to describe the evaluation of test results with a validation process from the Stakeholders Group. To maximize the impact, a dedicated workshop and a webinar was organized together with all relevant Stakeholders (Task 6.3).

Moreover, a collection of all relevant feedback gathered during the SRG Webinars and Workshops are included: those feedback came from experts belonging to the Stakeholders Reference Group, that provided an "expert-opinion" point view for the different FORESEE solutions that were developed during the project.

The document summarizes different inputs coming from the work done in Task 6.2 and Task 6.3, and collects all the different feedback, input and opinion from experts gathered during the whole life cycle of the project, thanks to the several webinars and workshops organised by the FORESEE project with the coordination of the SRG chairman.

Namely,

- Chapter 2 provides and overview on the Validation of the FORESEE solution on the infrastructure assets.
- Chapter 3 gives a brief summary of the case studies validation results.
- Chapter 4 describes the main outcomes that came out from all the Stakeholder Reference Group Webinars & Workshops.
- Appendix A to D provides a detailed summary of the output of the FORESEE webinars.
- Appendix E to H gives a complete picture of the outcomes of the FORESEE workshops.

2 VALIDATION OF THE FORESEE SOLUTION ON THE INFRASTRUCTURE ASSETS

In the following paragraphs a general overview is made about the main features of the Case Studies, Hazards and tools that were selected for the validation: please consider that we included only a general summary of the different topic, linking respectively each topic to the full deliverable.

2.1 CASE STUDY #1 - A24 HIGHWAY (TORANO-CARSOLI)

2.1.1 Case Study #1 Overview

The highway A24 or "Strada dei Parchi", is a highway connecting Rome to the Adriatic Sea. First planned in 1973 to connect Tyrrhenian to Adriatic highways, the route currently ends on Teramo and continue by dual-carriageway up to A14 "Teramo-Giulianova" toll road, ending near the Adriatic Sea. The considered section of the A24 highway connects Carsoli and Torano and it is located near the small city of Pietrasecca, in the region of Abruzzo (Italy).

The A24, especially its Apennine section in winter, is particularly prone to bad weather with sudden storms, strong winds, fog and ice. Snow chains on board or snow tyres from 15 November to 15 April are mandatory.

The main characteristics of the Carsoli-Torano section are:

- 21 Km of Highway.
- N. 13 bridge.
- N. 3 tunnels.
- Average Annual Daily Traffic (AADT) 10.705 vehicles.

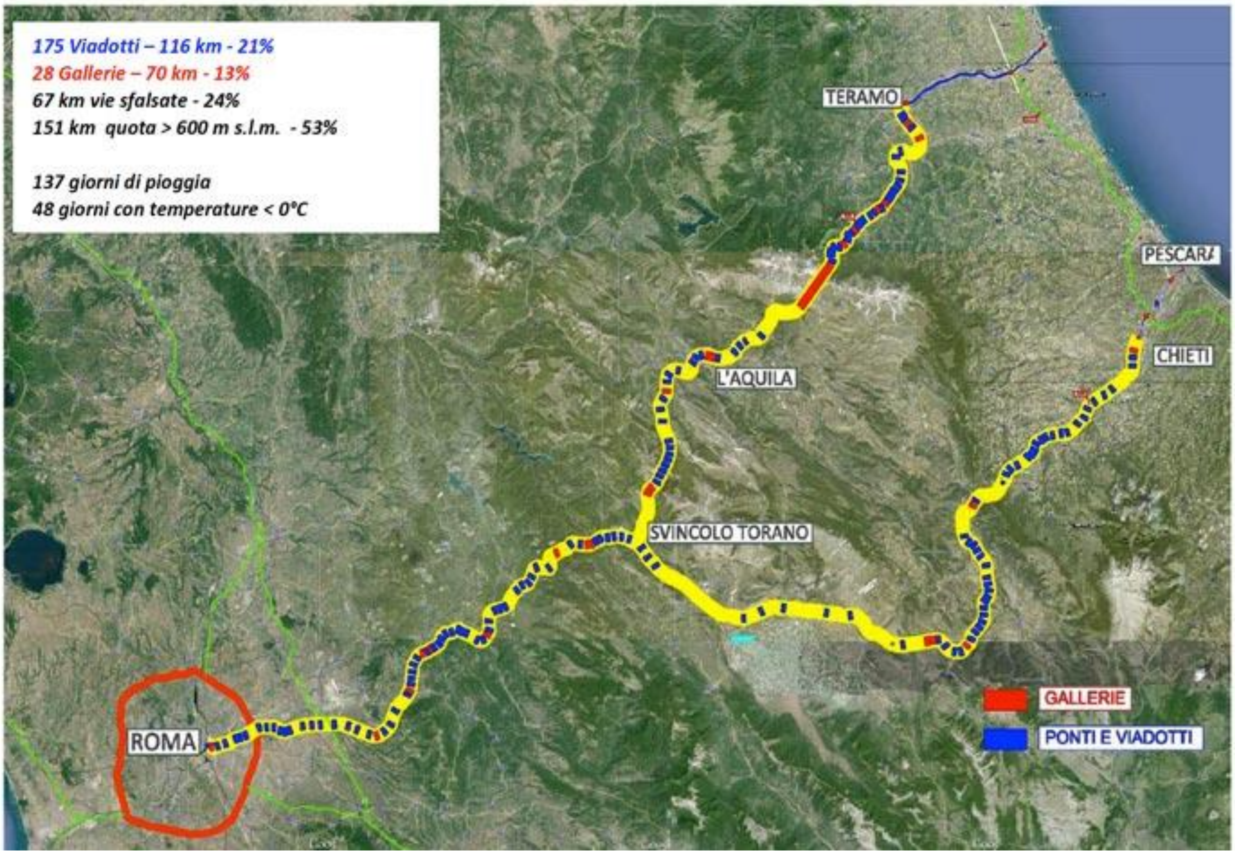


Figure 1: A24 overview within Central Italy

2.1.2 Case Study #1 hazards and tools

The A24 section between Carsoli and Torano has been studied in two different scenarios, taking into account two extreme events, which affects the regular service of the highway traffic:

- Earthquake: risk of moderate of severe events which may bring to partial or total closing of the highway to evaluate, through the Foresee Tools, the enforcement of the contingency plan and the emergency procedures.

- Heavy snow: improve the emergency/contingency procedures, to face Heavy snow/avalanche threats. Using the tools for a comparative analysis with a previous disruptive event.

Due to the localization of the A24 highway, former extreme events of earthquakes and storms (heavy snow) have been analysed and there are data available regarding risks, damages and reduction of service. As a result of the earthquake occurred near L'Aquila city in 6/4/2009, beside the extreme distruction of the L'Aquila city and many villages nearby with more than 300 death, the A24 was completely closed in the section before the one we are analysing (between Valle del Salto and Assergi) in both directions, and the Rome-Tornimparte section (in which the Carsoli-Torano insist) was totally closed to heavy goods vehicles over 7.5 tonnes for several weeks.

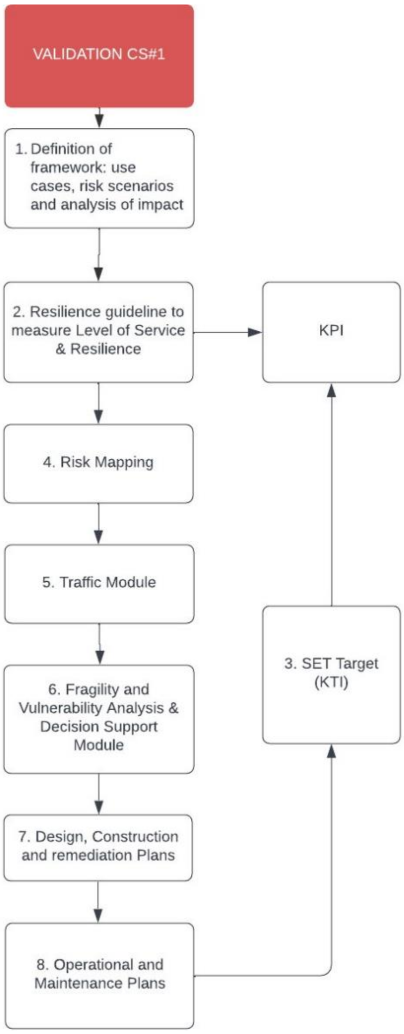
Also the snow hazard generate big slowdown of the viability and closure on the highway, like the storm happened in 4/2/2012, which caused a snow avalanche on the considered highway section, with closure of the highway for several days.

The following main project outcomes has been applied and validated from a theoretical and real point of view:

- Assessment of the Level of service and resilience.
- Risk Mapping.
- Traffic Module
- Fragility and Vulnerability Analysis and Decision Support Mododule.
- Design, construction and remediation plans.
- Operational and maintenance plans.

2.1.3 Case Study #1 validation guidelines

In the following figure the logical validation approach is presented:



The first two action are related to understand the current status:

1. Definition of framework: use cases, risk scenarios and analysis of impact.
2. Resilience guidelines to measure level of Service & Resilience.

Then, the objective in terms of "increased" resilience to be reached after the application of the FORESEE tools:

3. Set of Targets (KRI).

After that, the different tools which were considered strategic and useful to reach the previously identified Key Resilience Targets (KRI) are applied, namely:

4. Risk Mapping.
5. Traffic Module.
6. Fragility and Vulnerability Analysis & Decision Support Module.
7. Design, construction and remediation plans.
8. Operational and maintenance plans.

After this phase, it's been considered if these tools provided a contribution for increasing the level of resilience, in order to calculate again the level of resilience and assess the net benefit analysis (if possible), bringing to the infrastructure a detailed and quantitative analysis of the potential benefit coming from the adoption and use of the FORESEE selected tools.

More detailed information can be taken from Deliverable D6.2 "IT Case Study #2".

2.2 CASE STUDY #2 – ITALY A16 (KM.80-110)

2.2.1 Case Study #1 Overview

The A16 has been built in late 60's and it runs along the TEN-T Corridor n.5 Scandinavian – Mediterranean. The A16 connects Naples, on the Tyrrhenian coast, with Candela, on the Adriatic Sea, close to the port of Bari, playing a strategic role for the connectivity of the country.

Most of the geological formations emerging along the highway in question are characterized by thick layers dominated by the clayey component, with rare inclusions of a lithic nature. The highly clayey nature of these soils strongly influences the stability of the slopes.

Along the infrastructure, we can distinguish morphologies related to surface instability ("slow surface deformations"), but also deep instability phenomena, referring to the slope scale.

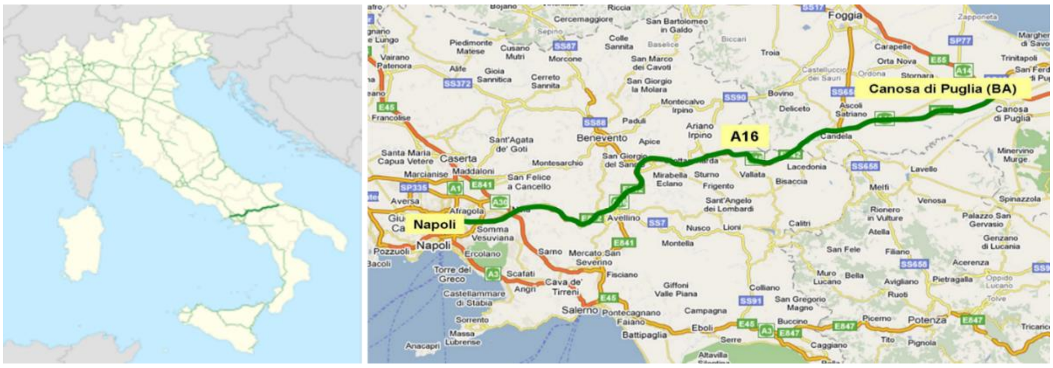


Figure 2: Highway A16 part of the TEN Corridor n.5

2.2.2 Case Study 2 hazards and tools

The highway is subject to extreme weather conditions (i.e. snow) as it crosses a mountainous region and presents a high degree of seismicity.

The highway is also subject to a heavy traffic of goods and passengers all over the year.

A major event took place in 2005 at km.122, causing the immediate closure of the relevant highway section. The structures involved were a 100 m long viaduct and the adjacent embankment. No user was involved in the event. A by-pass was eventually built to restore traffic conditions and the old bridge was abandoned.

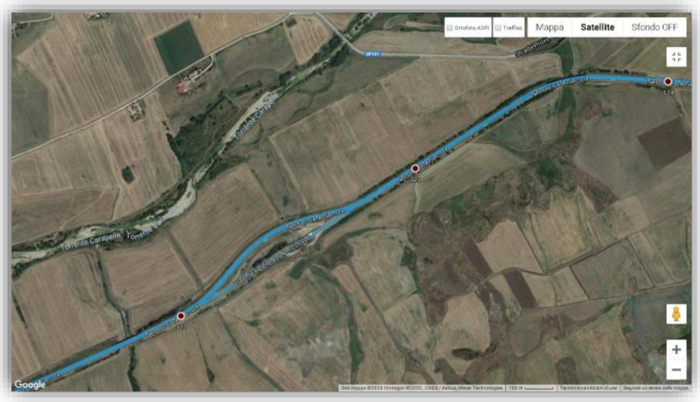


Figure 3: Highway bypass at the km.122

The demonstration is developed using a section of the highway A16 of approximately 30 km, between km. 80-110.

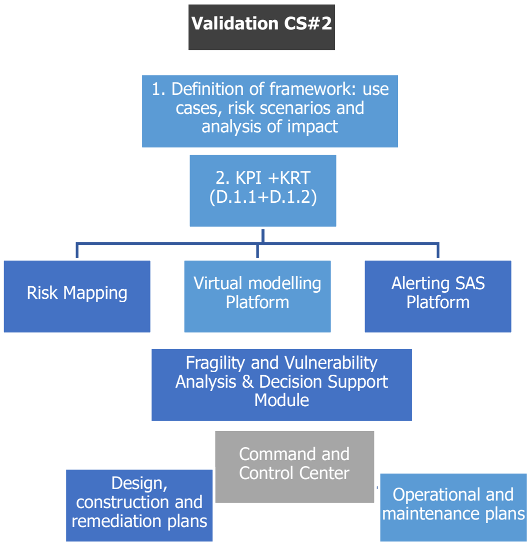
andslides are the specific risk scenario taken into account, as the area around the A16 is subject to hydrogeological risk. The following main project outcomes has been applied and validated from a theoretical and real point of view:

- Assessment of the Level of service and resilience.

- Landslide awareness.
- Fragility and Vulnerability Analysis.
- Design & Construction plans.
- Operational and maintenance plans.

2.2.3 Case Study 2 validation guidelines

In the following figure the logical validation approach is presented:



- The infrastructure is digitized through Indicators, KPI and thresholds KRT.
- The tool Definition of framework: use cases, risk scenarios and analysis of impact, defines the potentials risks.
- The tool Risk Mapping analyzes the real risks graphic.
- The tool Virtual Modeling Platform is expected to predict ground displacements over time.
- The tool SHM BIM based alerting SAS Platform is finalized to operation and management of infrastructure.
- The tool Fragility and Vulnerability Analysis & Decision Support Module assesses the LoS and resilience.
- Design & Construction Plans, along resilient definition.
- Operation & Maintenance Plans, along resilient definition.

More detailed information can be taken from Deliverable D6.3 "IT Case Study #2".

2.3 CASE STUDY #3 - MONTABLIZ VIADUCT & A-67

2.3.1 Case Study #3 Overview

The highway A67 is a dual carriageway land route, which is part of the radial system of motorways of Spain, owned by the Ministry of Development of the Government of Spain, which connects the port of Santander with Madrid capital of Spain, its route runs through the Cantabrian Mountain range with specific risks.

The Montabliz Viaduct is situated in the big valley formed by a river in Cantabria Spain. It has a length of 721m distributed in 5 spans (11 + 155 + 175 + 155 + 126), maximum light 175.00 m, radius of curvature in plant 700 m. Continuous board, formed by a monocellular drawer of prestressed concrete of variable edge between 4.30 and 11.00 m supported on single pile. The maximum height of the pile is 128.60 m, the highest in Spain and among the 6 largest in Europe (year 2008). The board has been built by the voussoirs system concreted "in situ" by cantilevered forward[i].

Figure 4: A67 Highway and particular of Montablitz Viaduct

2.3.2 Case Study #3 hazards and tools

Wind and Snowfall are the main hazards that affect this infrastructure, since they are repeated annually in winter throughout its life cycle.

The fog is a hazard that appears continuously throughout the life cycle, due to the height of the infrastructure. It's impossible to mitigate by design, except to pre-notice its existence.

The Flooding hazard can affect the life cycle of the infrastructure, with different return periods. Also, Landslides occur in some areas of the A-67, already designed for this hazard, but that would be susceptible to improvement.

The following main project outcomes has been applied and validated from a theoretical and real point of view:

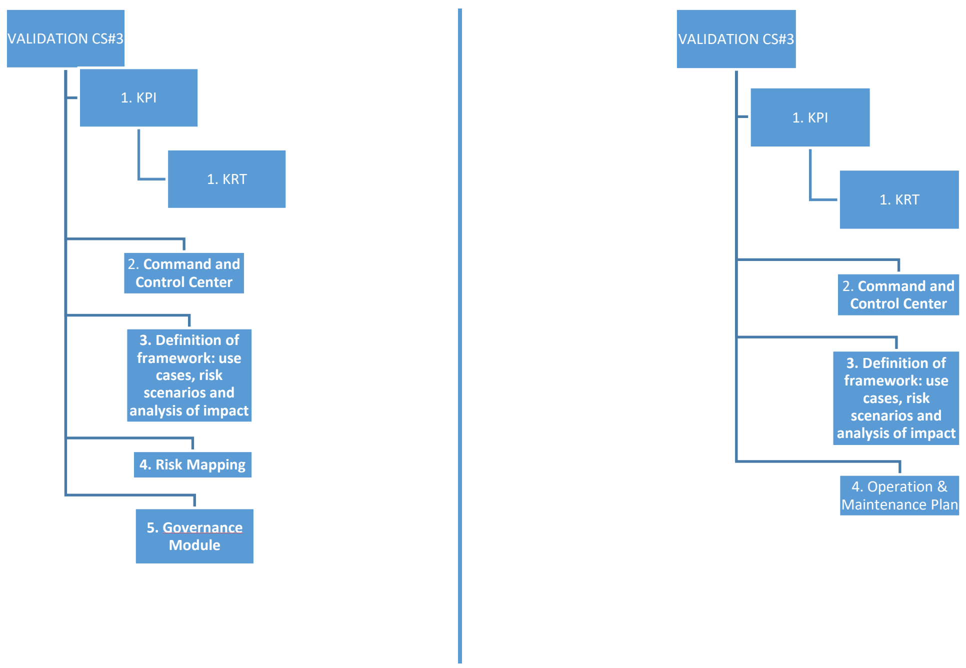
- Assessment of the Level of service and resilience.
- Risk Mapping.
- Governance Module.
- Flooding Methodology.
- Operational and maintenance plans.

2.3.3 Case Study #3 validation guidelines

The case study of Montabliz Viaduct has been studied in two different scenarios, corresponding to two phases of the life cycle:

- **Design & Construction**, **D phase** definition of the design resilient to the specific hazard, wind.
- **Operation & Maintenance**, **M phase** definition of flood zones on the A-67 motorway, for avenues with different return periods.

In the following figure the logical validation approach is presented:



1. The infrastructure is digitized through Indicators, KPI and thresholds KRT. 2. The Tool Command and Control Center represents graphically the indicators and the thresholds. 3. The Tool Definition of framework: use cases, risk scenarios and analysis of impact, defines the potentials risks. 4. The Tool Risk Mapping analyzes the real risks graphic. 5. The Tool Governance Module, select design to mitigate specifics risks.	6. The infrastructure is digitized through Indicators, KPI and thresholds KRT. 7. The Tool Command and Control Center represents graphically the indicators and the thresholds. 8. The Tool Definition of framework: use cases, risk scenarios and analysis of impact, defines the potentials risks. 9. The Operation & Maintenance Plan, along resilient definition.
FORESEE TOOL Flow. Montabliz Design & Construction phase	FORESEE TOOL Flow. Montabliz Operation & Maintenance phase

More detailed information can be taken from Deliverable D6.4 "ES Case Study #3".

2.4 CASE STUDY #4 - RAILWAY TRACK 6185

2.4.1 Case Study #4 Overview

The railway track 6185 corresponds to a section of the Hannover-Berlin high-speed railway line, which include the route Oebisfelde - Berlin-Spandau.

The approx. 150 km long track section between Oebisfelde (km 267,9) and Berlin-Spandau (km 112,7) is built as ballastless track with a maximum speed up to 250 km/h.

Between Oebisfelde and Berlin, the line runs largely parallel to the Lehrte line. The Track is part of the service area of the Deutsche Bahn AG (DB) – the passenger transport is managed by the resort "DB Personenverkehr" and the maintenance is performed by the resort "DB Netze".

In 2011, about 170 traffic and freight trains with approx. 10,000 passengers are on the track per day. The rail infrastructure has many bridges crossing the river Elbe (for example the Haemerten bridge near Schoenhausen) and several smaller rivers.

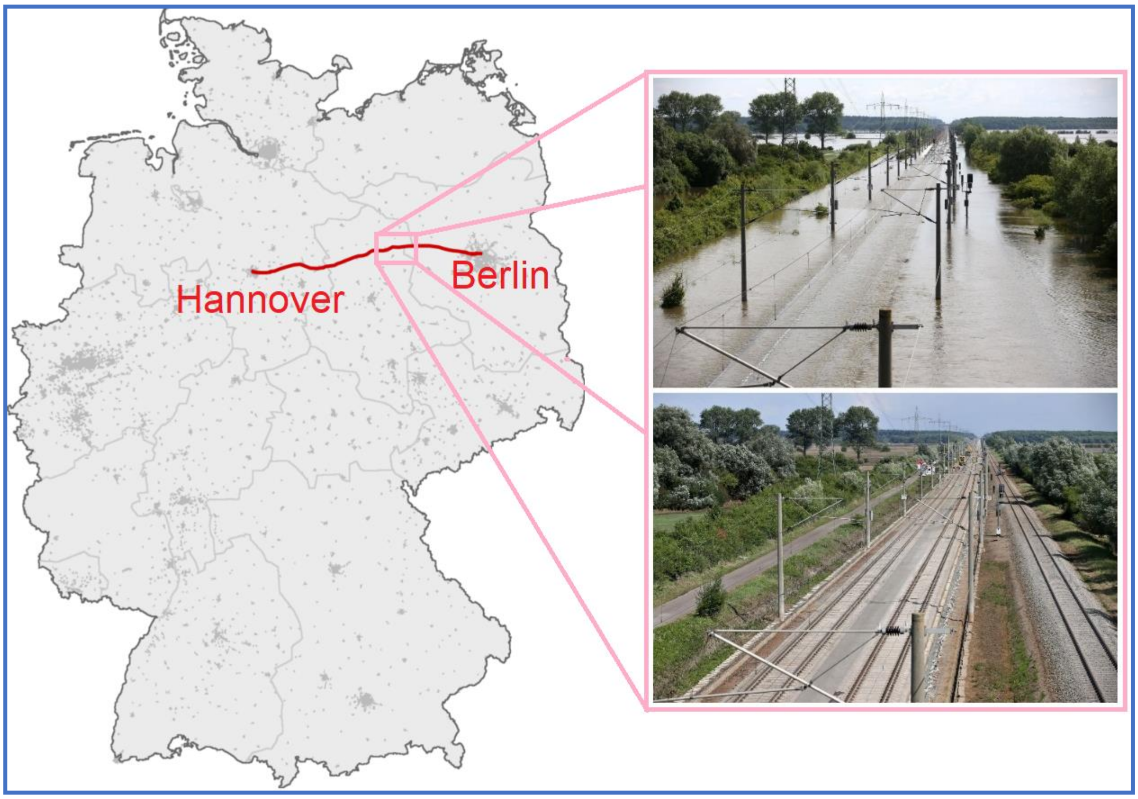


Figure 5: The railway track 6185.

2.4.2 Case Study #4 hazards and tools

The flooding is the main hazard that affect this infrastructure. Due to former flooding events (especially the Elbe Flood in June 2013), there are data available regarding risks and damages caused by flooding. As a result of the Elbe flood in June 2013, the Haemerten bridge and an approximately 5 km long track section near Schoenhausen were closed due to flooding. Due to large-scale deviations, delays of one to two hours occurred. The DB introduced an interim timetable, which was later changed several times. Regular service was not resumed until months later in November 2013.

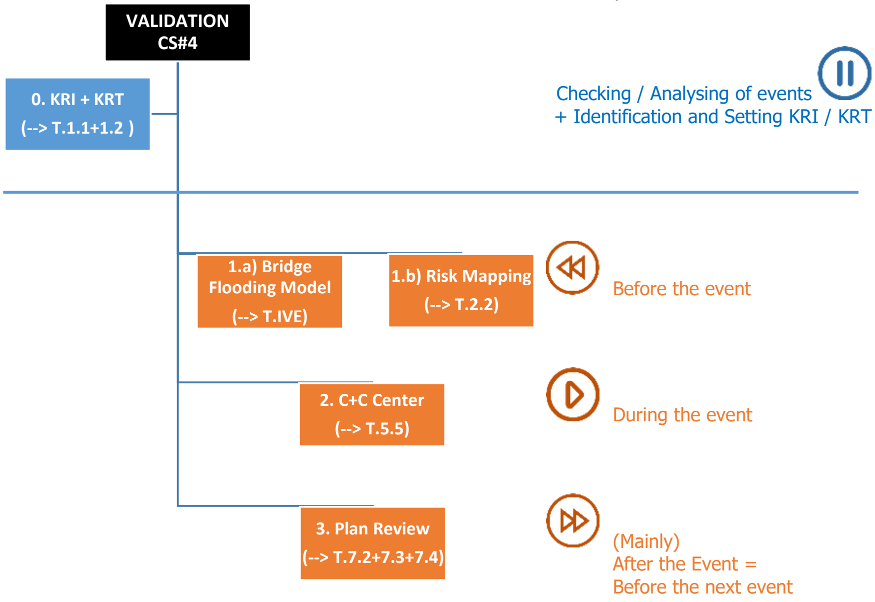
Due to the actuality, the available data and the impact as an extreme event, the Elbe flood 2013 is used in the validation approach and as a benchmark for evaluation the FORESEE tools.

The following main project outcomes has been applied and validated from a theoretical and real point of view:

- Assessment of the Level of service and resilience.
- "Bridge flooding model" (T.IVE)
- Risk Mapping.
- Command and Control Center.
- Operational and maintenance plans.

2.4.3 Case Study #4 validation guidelines

In the following figure the logical validation approach is presented, thematically clustered into the process phases before, during and after a possible flooding hazard:



0. The infrastructure and event are digitized and identificated through Indicators, KRI and thresholds KRT as an evaluation benchmark.

1. a) The Tool "Bridge Flooding Model" analyses the condition of a railway track / -bridge model under the stress of flooding.

1. b) The Tool "Risk Mapping" analyses the flooding hazard risks.

2. The Tool "Command and Control (C+C) Center" represents graphically the indicators and the thresholds.

3. The Tool (or method) "Definition of framework" defines the use cases, risk scenarios and analysis of impact and potentials risks for the Tool (or method) "Plan Review" which analyses, evaluates, updates and improves maintenance and contingency plans.

More detailed information can be taken from Deliverable D6.5 "DE Case Study #4".

2.5 CASE STUDY #5 - MADRID CALLE30 RING ROAD

2.5.1 Case Study #5 Overview

Madrid Calle 30 Ring Road is the most important and the busiest road infrastructure in Spain. More than 1.5 million vehicles per day use (part of) the Calle 30, of which 200,000 vehicles per day make a "full" journey that covers the use of all tunnels (48 km in total).

Tunnel sections mostly have two or more lanes. Heavy vehicles are not allowed, with the exception of buses, and, likewise, dangerous goods traffic is prohibited. During peak hours, the traffic load can exceed 200,000 vehicles per day.

Figure 6: M30 route and tunnel picture

The availability for traffic of Calle 30 is critical, since closure of the road would have a major impact. Not only on Madrid, the capital of Spain, but also on a national level. Such a closure could paralyze and at least collapse road communications "transports of people and goods" and could generate great economic and social damage. So, it is adequate to qualify the road as strategic and of vital importance.

2.5.2 Case Study #5 hazards and tools

The main hazards that affect the M30 Ring Road which have been considered in this case study are the following:

- Man-made events including cyberattack (to the ITS, particularly in the tunnel section), intentional or not intentional - like accidents (average number of 14 interventions/day due to accidents) or fire after accidents.

1. Flooding and other extreme events derived from raining in the valley (in several sections of the open air section of the ring road) and the proximity of the river (tunnels in the west side) interaction with other infrastructures and buildings, and the influence of the water level in the tunnels located at the west side.

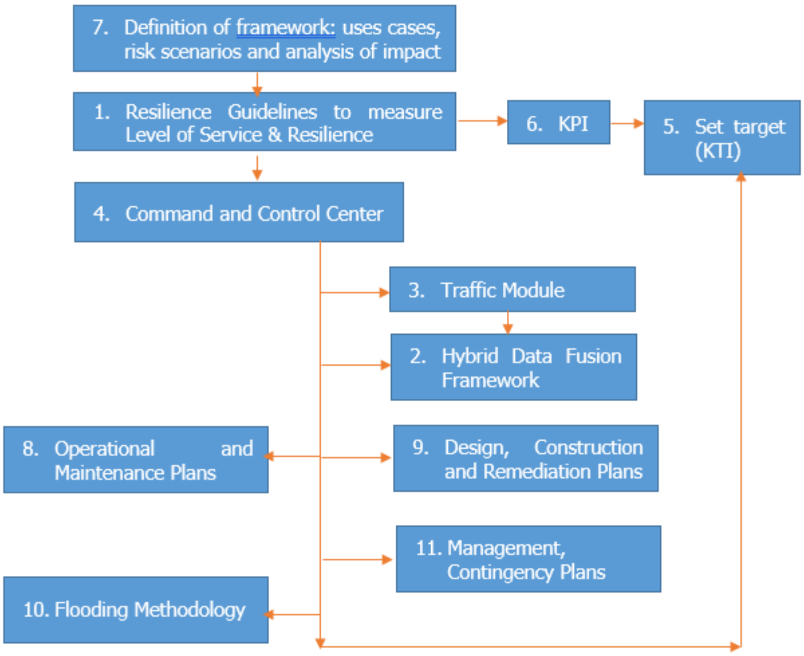
2. Fire inside the tunnels, taking into consideration a dynamic approach for the contingency and emergency plans.

The following main project outcomes has been applied and validated from a theoretical and real point of view:

- Assessment of the Level of service and resilience.
- Traffic module.
- Hybrid data assessment.
- Command and Control Center.
- Framework for the application of foresee resilience plans.
- Design, construction and remediation plans.
- Operational and maintenance plans.
- Contingency plans.
- Flooding methodology.

2.5.3 Case Study #5 validation guidelines

In the following figure the logical validation approach is presented:



- The Tool Definition of framework: use cases, risk scenarios and analysis of impact, defines the potentials risks.
- The infrastructure is digitized through Indicators, KPI and thresholds KRT.
- The Tool Command and Control Center represents graphically the indicators and the thresholds.
- The Flooding methodology define graphically the flood zone, for different Return Periods.

- The Traffic Module is a stochastic algorithm that predict the most probable input data before using it in a traffic simulation software.
- The Hybrid Data Fusion Framework predict the k-ahead traffic volume.

More detailed information can be taken from Deliverable D6.6 "SP Case Study #5".

2.6 CASE STUDY #6 - 25 DE ABRIL BRIDGE (LISBON)

2.6.1 Case Study #6 Overview

The *25 de Abril* Bridge is a suspension bridge connecting the city of Lisbon to the city of Almada and the South of the country, across the Tagus River. It was opened in 1966. The upper deck carries six car lanes, while the lower deck carries a double track railway electrified at 25 kV AC. It is a road and rail bridge used by over 100 million people per year.

The bridge superstructure and rail infrastructure is currently managed by *Infraestruturas de Portugal*, a state-owned company that manages the Portuguese road and rail network infrastructure.

This structure has a socio-economic role at local, regional and national level.

Figure 7: The 25 de Abril Bridge.

2.6.2 Case Study #6 hazards and tools

Earthquake and general train accident can affect regular traffic service (road and railway) of the Bridge, so those hazards have been studied in two different scenarios:

- Earthquake: risk of moderate of severe events which may bring to partial or total closing of the bridge to evaluate, through the Foresee Tools, the enforcement of the operational, maintenance, contingency plan and the emergency procedures.

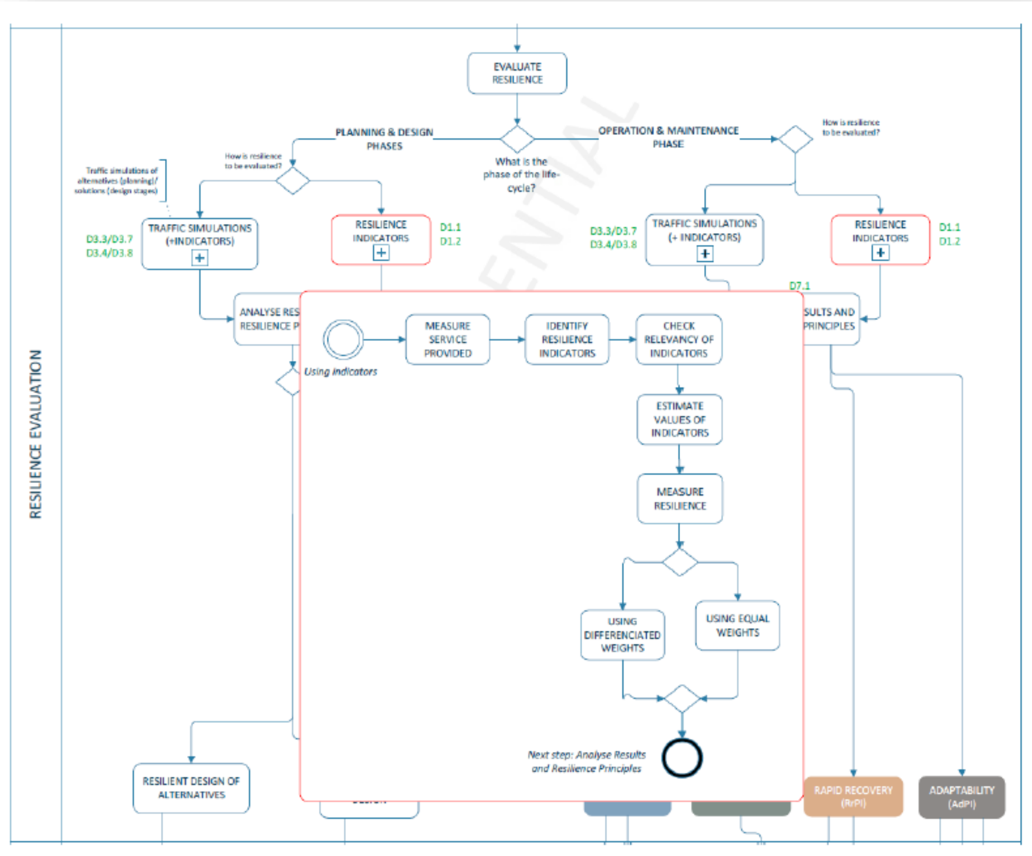
- Simulation of a train accident with a special focus on the management of people (communication, contingency, emergency and evacuation) during and after the event, using the tools for a comparative analysis with actual procedures and a previous disruptive event.

The following main project outcomes has been applied and validated from a theoretical and real point of view:

- Assessment of the Level of service and resilience.
- Risk Mapping.
- Traffic Module.
- Control and Command Centre.
- Design & Construction plans.
- Operational and maintenance plans.
- Contingency and Evacuation plans.

2.6.3 Case Study #6 validation guidelines

In the following figure the logical validation approach is presented:



The approach to the theoretical validation of the tools have been the following:

1 Definition of the main KPIs that each tool uses as an input and gives as an output.
2 Relation between the previously selected KPIs with the ones obtained from the tools.
3 Analysis of the KPIs that will improve the resilience of the infrastructure by using each tool.
4 Executive analysis and conclusions of each tool developed by the infrastructure manager.
5 The infrastructure is digitized through Indicators, KPI and thresholds KRT.
6 The Traffic Module is a stochastic algorithm that predict the most probable input data before using it in a traffic simulation software.
7 The Tool Command and Control Centre represents graphically the indicators and the thresholds.
8 The Tool Definition of framework: use cases, risk scenarios and analysis of impact, defines the potentials risks.

More detailed information can be taken from Deliverable D6.7 "PT Case Study #6".

3 IMPROVEMENTS ON THE RESILIENCE OF TRANSPORT INFRASTRUCTURES WITH THE APPLICATION OF FORESEE SOLUTIONS

In the following paragraphs there are the main results coming from the validation of the FORESEE solutions presented in the final workshop: also in this part we will provide a synthetic summary of the main results, providing the link to the specific deliverables.

3.1 CASE STUDY #1

The application of the FORESEE tools on the A24 highway (case Study #1) was mainly related to address scenario with data from past event, so it was possible to make a theoretical comparison addressing the change in the resilience level before and after the FORESEE tools.

The A24 section between Carsoli and Torano has been studied in two different scenarios, taking into account two extreme events, which affects the regular service of the highway traffic:

- Earthquake: risk of moderate of severe events which may bring to partial or total closing of the highway to evaluate, through the Foresee Tools, the enforcement of the contingency plan and the emergency procedures.
- Heavy snow: improve the emergency/contingency procedures, to face Heavy snow/avalanche threats. Using the tools for a comparative analysis with a previous disruptive event.

The following tools were theoretically validated:

- Risk mapping.
- Traffic module.
- Fragility and vulnerability analysis & decision support module.
- Design, construction and remediation plans.
- Operational and maintenance plans.

The results are included in Deliverable D6.2 "IT Case Study #1": an added value that came out from this activity was also the feedback from the infrastructure manager, that was able to make a theoretical comparison with the current procedures and tools used nowadays, giving concrete feedback for the improvement towards a market adoption for the project's outcomes. Below there is a representative table that depicts the contribution given in the document.

Table 1 - excerpt from D6.2 Overview of FORESEE tools feedback from the infrastructure manager

FORESEE TOOL	***INFRASTRUCTURE MANAGER FEEDBACK – AREA OF IMPROVEMENT***
Risk mapping	The tool seems to be hardly improvable, maybe it can be properly related to specific country-situation, linking national data with European data to make also a comparison in different boundary conditions.
Traffic module	To improve the capability to integrate legacy systems OR to use another commercial tool: at the moment the "traffic module" is not a stand-alone tool but linked to the use of a commercial software, leading to a restricted-usage by users.
Fragility and vulnerability analysis & decision support module	The tool is very promising: it can be improved by adding more infrastructure data typologies, and linking the module to legacy systems, making it interoperable and open for integration by the infrastructure manager.
Design, construction and remediation plans	The tool is useful and can be adopted by the infrastructure manager, however it could be tailored to specific type of infrastructure.
Operational and maintenance plans	The tool is easy to use and can lead to a general improvement in the current procedure: we highly recommend to make it (as the tool above) integrated in a software suite, in order to link with current systems commercially available and used by the infrastructure manager.

More detailed information can be taken from Deliverable D6.2 "IT Case Study #1".

3.2 CASE STUDY #2

The A16 highway was used to test mainly the following FORESEE solutions:

- Assessment of the Level of service and resilience (WP1).
- Landslide awareness (WP2).
- Fragility and Vulnerability Analysis (WP3).
- Design & Construction plans (WP7).
- Operational and maintenance plans (WP7).

As far as it concerns WP1, Level of Service (LOS) and resilience have been computed under two different situations:

1. The first one is based on data from past "extreme" events (a major landslide hit the infrastructure in 2005 at km. 122, even if outside the chosen area of interest) to increase the comprehension of all the relevant elements or factors affecting the specific event and to assess the possible consequences and actions to be undertaken.

Data have been used for the development and further validation of the methodology and guidelines under D.1.1 and D.1.2.

2. In the second one, the expected event is the triggering of a landslide, to hit the infrastructure in presence of normal traffic and/or in case of heavy traffic (works, accidents).

As far as it concerns WP2, CS#2 has been used to develop and test the SHM BIM based alerting SAS Platform, for the purpose of operation and emergency management. Data from the monitoring systems will be used for validation purposes.

At the network level the Fragility and Vulnerability Analysis and Decision Support Toolkit has been used to understand the impact of different hazard scenarios on traffic demand in terms of loss of service and resilience estimation (WP3).

As far as it concerns the validation of WP7, the case study of A16 has been studied under the:

- **Design & Construction**, D phase, definition of the design resilient to the specific risks (landslides).
- **Operation & Maintenance**, M phase, definition of the Operation and Maintenance plan, based on design resilient of the specific risk.

On that respect, the infrastructure manager recognized a general benefit coming from the adoption of some FORESEE tools: for some of them, the benefits are not so evident because similar solutions are already integrated and used by the company. On the other hand, some tools were recognised as promising because they integrated different aspects that are managed separately, so an integration can provide an extensive benefit and can lead to better support the infrastructure manager decisions.

Task	7.1	7.2	7.3	1.1	1.2	2.2	2.4	2.5	T 3.4.2
Deliv.	D.7.1	D.7.5	D.7.6	D.1.1	D.1.2	D.2.7	D.2.8	D.2.9	D3.8
Description	Framework use cases, risk scenarios and analysis of impact	Design, construction & remediation plans	Operational & maintenance plans	Resilience Guidelines to measure Level of Service & Resilience	Set Targets	Risk Mapping	Virtual modelling Platform	Alerting SAS platform	Fragility and Vulnerability Analysis & Decision Support Module
Was this type of analysis made before FORESEE? How it was made?	It complements Risk management carried out in the Company. It integrates current design standards and permissions procedures. It gathers consensus from the different stakeholders. As for operation & maintenance, they could be used to improve the level of service.			It is expected to include measures of service and resilience of elements and infrastructure in the daily and long term management of the assets to comply with national regulation.		An integrated internet tool is not available to manage all the aspects linked to the hydrogeological risk, even if activities are carried out for surveillance, monitoring and assessment			An integrated internet tool is not available to managers. Evaluation of the conditions of the network is/has been carried out and s the basis of actions to undertake
How does FORESEE improve the results/analysis previously made?	The proposed approach could be used to guide the definition of framework resilience plans for design and for operation & maintenance purposes in compliance with the risk strategies, objectives and management procedures of the organization			The resilience target system makes it possible to better correlate the infrastructural condition with the quality of the service. It identifies the areas where provided to concentrate activities		Internet based tools for management of alerts are gaining importance, however the key factor is the rate of acquisition of data on site from permanent monitoring systems.			It gives an overview of the infrastructure condition in terms of risks, possible losses, resilience assessment for different kind of hazards
How does this FORESEE result improve your infrastructure's management	As result of the application of the tools, improved traffic flow and increased mobility are expected.			To have a clear idea of the service that the infrastructure is providing and an understanding of its resilience, if it is affected by natural hazards, and how to counteract the loss of service		The proposed tools integrates the Company's strategy of digitalization and it may be used: o by Company's Command and Control Centres and local branches for surveillance and monitoring of the infrastructure, o to evaluate the performance of the asset over time, o to program and design interventions.			As result of the application of the tools, improved traffic flow and increased mobility are expected.
If it was not made, How does this FORESEE result improve your infrastructure's management	The tools, with their guided" and "objective" approach could complement the actual procedures and allow comparison among different risk scenarios; different territorial needs, different time steps, taking into consideration public socio-economic objectives.			The guideline s and methodology allow to provide : o a unique measure, also toward the other stakeholders also public, o a tool for governance to understand actions to take and where to improve service and reduce negative impact.		The timely warning of potential events has a positive impact on mobility and safety and the identification of warning thresholds, based on the displacements that the infrastructure is able to undergo will be much more reliable, thus increasing resilience of the infrastructure.			The instrument produced could be very helpful in the decision making process that infrastructure managers have to undertake to control infrastructure's safety.
What cost/resource efficiencies you expect these tools/results to have on your day-to-day business?	In general, an optimization of resources (economic, personnel, safety and travel time) is expected. For the operation & maintenance, it can be seen that a clear reduction of costs is possible both for safety ad interventions. As it is a tool that may be used at "high level" to assess a strategy to approach risk and resilience, a positive ROI is expected.			It is expected an optimization of costs meaning there is an improved allocation of resources among the different needs and actions to be undertaken rather than a saving of some sort.		Expected benefits in terms of: o optimised use of economic resources, o increase efficacy of maintenance inventions, o reduced impact of traffic flow due to the reduction in the number of subsequent interventions, reduced impact on mobility for emergency situations			Optimization of costs for operation and reduce maintenance and restoration costs

Figure 8 - excerpt from D6.3 - overview of the FORESEE tools impact.

More detailed information can be taken from Deliverable D6.3 "IT Case Study #2".

3.3 CASE STUDY #3

The case study of Montabliz Viaduct has been studied in two different scenarios, corresponding to different phases of the life cycle.

- **Evaluation & Decision, E phase** definition of main hazards that affect this region.
- **Design & Construction**, **D phase** definition of the design resilient to the specific hazard, wind.
- **Operation & Maintenance**, **M phase** definition of flood zones on the A-67 motorway, for avenues with different return periods.

On that respect, the following tools were validated to address the above-mentioned case Study #3 scenarios:

- Risk mapping.
- Governance module.
- Flooding methodology.

The validation of those tools provided an real added value in terms of resilience, and also cost-benefit ratio, leading to an overall improvement and helping to better consider risks, understand how to properly modify the decisions work-flow and to tackle also flooding events by using updated flood maps.

Table 2 - excerpt from D6.4 - FORESEE tools outputs

	Case Study #3	*OUTPUTS*	*PHASE*
FORESEE TOOL	**RISK MAPPING**	Hazard maps and risk maps of the infrastructure's area to identify the risks prior to the more accurate and local scale quantification, win and snowfall.	Evaluation & Decision, E
	GOVERNANCE MODULE	Making design decisions, to mitigate specific infrastructure hazards, wind	Design & Construction, D
	FLOODING METHODOLOGY	Flood Map different return period.	Operation & Maintenance, M

More detailed information can be taken from Deliverable D6.4 "SP Case Study #3".

3.4 CASE STUDY #4

Case study #4 target is the flooding hazards on railway tracks. This includes rising tides of rivers caused by heavy rainfall in the catchment area. Therefore, the German railway track no. 6185 between Oebisfelde and Berlin-Spandau was chosen, which is part of the high-speed railway (HSR) Hannover-Berlin.

As the railway track 6185 is an existing line, corresponding to the life cycle (LC) only the operating and maintenance phase is considered in the following.

The singular event or risk of flooding is attempted to be divided into the following cascading scenarios due to the different damage and operational effects:

- Heavy rain, risk of moderate flooding.
- Heavy rain + river **flooding**, risk of fast and intense flooding.

The following tools were used and theoretically validated, showing good results in some cases and for some other no substantial improvement in the level of resilience:

- "Bridge flooding model".
- "Risk Mapping" (T.2.2).
- "Command and Control Center" (T.5.5).
- "Plan Review" (T.7.2, T.7.3, T.7.4).

In the table below there is a specific comparison, that give the proper idea about the results that came out after the adoption of the tools, together with their application on the case study identified scenarios.

Table 3 - excerpt from D6.5 CS#4, Improvements via the selected FORESEE Tools

CS#4	***Comparison***		
	ACTUALY / CURRENT TOOLS	**FORESEE TOOL**	
Hazard Assessment	- *Design flood according to guidelines*	T.IVE Bridge Flooding Model	✓ Water level dependent assessment of usability
	- *historically based but possibly outdated design parameters*		✓ Updatable and adaptable simulation model
	- *Use of equipment standards depending on track category*		✓ Track component related improvement measures
Rating	→ *"Improvement!*		
Hazard Assessment	- *Risk and hazard maps freely available and editable online e. g. from LHW or BAFG (→ see annex 4.1)*	T.2.2 Risk Mapping	✓ Risk and hazard maps prepared and predefined by the tool developers (→ see annex 3.1)
	- *National standardised maps according to 2007/60/EC with detailed information only for*		✓ large scale rapid risk analysis based on past real extreme

	Germany or only selected regions within Germany		natural events occurred all over Europe for a general overview
Rating	= *"Equal."*		
Hazard Management	*No comparable tool(s) available!*	T.5.5 C+C Center	✓ Automatized alerts ✓ Predictive risk prevention ✓ AI-based hazard analysis
Rating	→ *"Improvement!"*		
Hazard Planning	- *Subjective, based on Expert knowledge*	T.7.2 T.7.3 T.7.4 Plan Review	✓ Objective, science-based
	- *Static, based on Eu-wide and national regulations*		✓ Dynamic, adapted to more variables and simulations
	- *Incomparable and fixed, no reference or benchmark for possible optimisation available*		✓ Comparable and scalable, monetize resilience / LoS to identify optimal investment decisions
Rating	→ *"Improvement!"*		

More detailed information can be taken from Deliverable D6.5 "DE Case Study #4".

3.5 CASE STUDY #5

As previously described, Madrid Calle 30 Ring Road is the most important and the busiest road infrastructure in Spain. 1.5 million vehicles per day use (part of) the Calle 30, of which 200,000 vehicles per day make a "full" journey that covers the use of all tunnels (48 km in total).

As the M30 ring road is an existing route, corresponding to the life cycle (LC) of the operating and maintenance phase - in relation of the management and contingency plans, is considered in the following.

Three different scenarios for three different hazards have been studied specifically in the section of the tunnels that are located in the southwest part of the M30 ring road.

Criticalities:

3. Man-made events including cyberattack (to the ITS, particularly in the tunnel section), intentional or not intentional - like accidents (average number of 14 interventions/day due to accidents) or fire after accidents.
4. Flooding and other extreme events derived from raining in the valley (in several sections of the open air section of the ring road) and the proximity of the river (tunnels in the west side)

interaction with other infrastructures and buildings, and the influence of the water level in the tunnels located at the west side.

5. Fire inside the tunnels, taking into consideration a dynamic approach for the contingency and emergency plans.

The FORESEE tools selected to improve the resilience of this infrastructure are:

Table 4. Excerpt from D6.6- CS#5, Foresee Tools

Result ID	*Name*	*Developer*	*Case Study 5*	
			SCENARIO	
			Design & Construction, **D**	Operation & Maintenance, **M**
D 1.1	**Resilience Guidelines to measure Level of Service & Resilience**	**ETHZ**	√	√
D 1.2	**Set Targets**	**ETHZ**	√	√
T 4.1	**Flooding Methodology**	**IH**	√	√
T 4.4	**Hybrid Data Fusion Framework**	**ETH**		√
T 5.5	**Command and Control Center**	**FRA**	√	√
T 7.1	**Definition of framework: use cases, risk scenarios and analysis of impact**	**CEM**	√	√
T 7.2	**Design, construction and remediation plans**	**CEM**	√	
T 7.3	**Operational and maintenance plans**	**TEC**		√
T 7.4	**Management and contingency plans**	**ICC**		√

Among the above-mentioned tools, there were a total of 5 tools that used the Madrid Calle 30 data to build a case scenario:

- Hybrid Data Fusion Framework.
- Traffic Module.
- Flooding Methodology.
- Command and Control Centre.
- Fire dynamic simulations.

Table 5. Excerpt from D6.6 - Comparison with current situation regarding Asset Management Plan CS#5

CS#5	Comparison		
	ACTUALY / CURRENT TOOLS	**FORESEE TOOL**	
Traffic Simulation	- Traffic simulations with in-house software adapted to Calle30 needs - Variable input data - Cameras - Sensors – induction loop traffic sensors	**Traffic module**	- Accurate input data as stochastic Montecarlo algorithms are performed
Rating	→ *"Improvement"*		
Traffic Prediction	*No comparable tool(s) available!*	**Hybrid Data Fusion Framework**	- Predictions using Bayesian Networks and Random Forest Algorithms - Heterogeneous data - Travel time, - Traffic volume at a future time (k-hours ahead), - Cost of travel time
Rating	→ *"Innovative & Improvement"*		
Hazard Management Design	- Hourly information on precipitation at the basin's stations - Flooding simulations using HEC RAS and HEC HSM models - Old methodology to calculate the return periods	**Flooding Methodology**	- Synthetic simulation of precipitation events using Copulas - Selection of events to be simulated in the hydrogeological model - Spatial reconstruction of rainfall events at sub basin centroids - Flood elevation reconstruction for all synthetic events - Calculation of the heigh of the water table for different return periods – new and more demanding methodology
Rating	→ *"Improvement"*		
Hazard Management	- Cameras - Flooding and water sensors located on the dewatering pumps - Fire detectors - Control Center - Automatic detection of incidents that is already implemented on the cameras	**C+C Center**	- Automatized alerts considering the existing traffic - Predictive risk prevention - AI-Based hazards analysis
Rating	= *"No improvement."*		
Hazard Planning	- *Subjective,* *based on Expert knowledge* - *Static,* *based on Eu-wide and national regulations* - *Incomparable and fixed,* *no reference or benchmark for possible optimisation available*	**T.7.2** **T.7.3** **T.7.4** **Plan Review**	✓ Objective, science-based ✓ Dynamic, adapted to more variables and simulations ✓ Comparable and scalable, monetize resilience / LoS to identify optimal investment decisions
Rating	→ *"Improvement!*		

More detailed information can be taken from Deliverable D6.6 "SP Case Study #5".

3.6 CASE STUDY #6

As specified in the previous paragraph related to the case study #6, The *25 de Abril* Bridge is a suspension bridge connecting the city of Lisbon to the city of Almada and the South of the country, across the Tagus River. It was opened in 1966. The upper deck carries six car lanes, while the lower deck carries a double track railway electrified at 25 kV AC. It is a road and rail bridge used by over 100 million people per year.

The main investigation topics regarding the considered operating and maintenance phase are earthquake impact on bridge structural behaviour/assessment as well operations in combination with maintenance and contingency plans.

The following main project outcomes will be checked and validated from a theoretical point of view:

- Assessment of the Level of service and resilience (Work Package WP1).
- Risk Mapping (Work Package WP2).
- Traffic Module (Work Package WP3).
- Control and Command Centre (Work Package WP5).
- Design & Construction plans (Work Package WP7).
- Operational and maintenance plans (Work Package WP7).
- Contingency and Evacuation plans (Work Package WP7).

The infrastructure manager (Infraestruturas de Portugal) already had an advanced set of procedures and tools, because the 25thAbril bridge is a critical infrastructure, according to the EU definition, but also a relevant connection of national importance, so the result coming from the adoption and test of tools is in line with the solutions currently used by the company's managers, bringing only an additional value to the standards adopted nowadays.

Below there is a table summarizing the main impact of the FORESEE solutions, in comparison with the current standards adopted by the infrastructure manager.

Table 6. Excerpt from D6.7 - Improvements via the FORESEE Tools in comparison with current situation regarding Asset Management Plan.

CS#6	***Comparison***		
	ACTUALY / CURRENT TOOLS	**FORESEE TOOL**	
Hazard Assessment	- Risk and hazard maps freely available and editable online (databases…)	T2.1 Risk Mapping	✓ Risk and hazard maps <u>prepared and predefined</u> by the tool developers (→ see Annex 2 Section 2.1)

	- National standardised maps with detailed information only for Portugal and online databases		✓ large scale rapid risk analysis based on past real extreme natural events occurred all over Europe for a general overview
Rating	= "Equal"		
Hazard Assessment	- *Traffic simulations using EME software adapted to 25th Abril Bridge needs* - *Variable input data* - *Cameras* - *Sensors – traffic sensors* - *Expert's opinions* - *Lessons learned*	T3.4 Traffic module	✓ Accurate input data as stochastic Montecarlo algorithms are performed
Rating	= "Equal"		
Hazard Management	- *Cameras* - *Structural sensors located on several elements of the bridge* - *Traffic and Railway Control Centre* - *Automatic detection of incidents that is already implemented on the cameras* - *Permanent presence of authorities (police)*	T.5.5 C+C Centre	✓ Automatized alerts ✓ Predictive risk prevention ✓ AI-based hazard analysis
Rating	→ "Slight Improvement!		
Hazard Planning/ Management	- *Subjective,* *based on Expert knowledge/Regulations* - *Static,*	T7.2 T7.3 T7.4	✓ Objective, science-based ✓ Dynamic,

	based on Eu-wide and national regulations/frameworks	Plan Review	adapted to more variables and simulations
	- *<u>Incomparable and fixed,</u>* *no reference or benchmark for possible optimisation available*		✓ <u>Comparable</u> and <u>scalable,</u> monetize resilience / LOS to identify optimal investment decisions
	- *<u>Robustness quality</u>*		
Rating	→ *"Improvement!*		

More detailed information can be taken from Deliverable D6.7 "PT Case Study #6".

4 STAKEHOLDER REFERENCE GROUP WEBINARS & WORKSHOPS: MAIN OUTCOMES

In the following paragraphs we collected and clustered main experts' feedback that were gathered during the Stakeholders Reference Group Webinars Workshops all along the project.

The aim of the Stakeholders Reference Group was to channelize inputs from third parties which could benefit from the results of the project: road and railway infrastructure managers, experts, technical and economical stakeholders provided their valuable feedback for the several FORESEE tools, considering their experience and currently adopted tools and procedures (if any).

4.1 1ST WEBINAR. "GUIDELINE TO MEASURE SERVICE PROVIDED BY, AND RESILIENCE OF, TRANSPORT INFRASTRUCTURES" (D1.1) AND "PRELIMINARY REMARKS ON GUIDELINE TO SET TARGET LEVELS OF SERVIC E PROVIDED BY, AND RESILIENCE OF, TRANSPORT INFRASTRUCTURES" (D1.2)

This was the very first event organized by FORESEE aiming to present the work being carried out about how to measure the service and resilience provided by a transport infrastructure. The online webinar was organized on April 9th 2019 and counted with 13 SRG experts coming from different organizations and 5 experts from the FORESEE project.

Organisation	Contact
Jose Conrado	ADIF (Spanish railways)
Willem Otto Hazelhorst	Rijkswaterstaat
Thierry Pulver	Swiss Federal Railways SBB
Maike Norpoth	German Federal Railway Authority EBA
Johan Jonsson	Trafikverket
Billy O'Keeffe	Transport Infrastructure Ireland
Karl Engelke	ASFINAG
Miguel Caso	PIARC
Fernando Liesa	ALICE
Björn Täljsten	University of Lulea
Björn Paulsson	University of Chalmers
Francisco García	University of Seville

Thanasis Sfetsos	NCSR Demokritos
Iñaqui Beltran	TECNALIA
Bryan Adey	ETH
Clemens Kielhauser	ETH
Sheryl Lynch	FAC

Bryan Adey from ETH and WP1 lead presented WP1 outputs and the main highlights of Deliverable 1.1 on "Guideline to measure levels of service provides by, and resilience of, transport infrastructures" covering items such as:

- Definition of service, definition of resilience, measuring service, measuring resilience.
- Define transport system.
- Measure service: define service, determine how to measure service.
- Measure resilience:

Bryan also presented the preliminary remarks on the "Guideline to set target levels of service provided by, and resilience of, transport infrastructures (D1.2), aimed to set target values for the measures of service".

These guidelines were aimed to be the core of the FORESEE project, implying that all the other FORESEE results would have to be linked on service and resilience following the direction set by the guidelines. As a result of it, it was crucial to receive feedback from external experts. All the feedback gathered in the webinars organized for D1.1 and D1.2 has crystalized in the CWA (pre-standardization procedure) that was reviewed by many experts around the world. CWA 17819:2021 'Guidelines for the assessment of resilience of transport infrastructure to potentially disruptive events

Some of the questions raised to receive feedback were:

1. In order to measure resilience, D1.1 proposes to define the transport system, to define the service to be provided by the transport system and to measure resilience by using the difference between the service provided if no hazard occurs and if a hazard occurs. Do you agree that this is the best way to measure the resilience? Under what circumstances do you see that you would undertake this endeavor?
2. In measuring resilience, it is proposed to measure service in quantifiable units per unit time, e.g. additional amounts of travel time per day. How difficult would it be for you to define the service provided by your transport systems in this way? Are the current methods that you use suitable? If not what new methods would be required?
3. Although deliverable 1.1 acknowledges that simulating the behavior of the transport system without the occurrence of a hazard and with the occurrence of hazards is perhaps the best way to measure resilience, the user of the guideline is only directed to two other articles for more information. Would you like to see more information in deliverable 1.1? If so what?

And other secondary questions forwarded:

4. If resilience is not to be measured using simulations, specific resilience indicators need to be determined. Do you think the guidance given in the document is a sufficient starting point? If not what additional information would you like to have? If you are to develop specific resilience indicators for your transport system, or parts of your transport system, which types of experts would you like to have to help you? Why?
5. When using resilience indicators to measure resilience, one still needs to estimate the maximum possible reductions in service due to the variations in the values of specific resilience indicators. How difficult would it be for you to estimate these values? How would you go about doing it? How exact do you feel that the estimates would have to be?
6. Do you think it is reasonable to have the three ways to measure the resilience, i.e. through simulations, with differentiated weighted resilience indicators, equally weighted resilience indicators? Do you have situations where you would use each? If so please give an example of the situations. If not please explain why.
7. Do you think there are any generic resilience indicators, or indicator categories, missing? If so, please give examples.
8. An indication of resilience can be obtained by looking at the percentage of fulfillment of the resilience indicators. In which situations would this information be helpful to you?
9. Can you imagine developing specific indicators for your transport system? Can you imagine developing specific indicators for specific situations for your transport system? Please give a number of examples of what you think would be useful.
10. Do you think that the measures of resilience could be effectively used in decision making in, and communication of decisions by your organisation? In which situations could you imagine them being used?

The answers to those questions were compiled in one single document that was analysed by the ETHZ in order to take into consideration all the comments received. The Q&A per SRG experts can be reviewed in the Appendix A.

4.2 2ND WEBINAR. GUIDELINE TO SET TARGET LEVELS OF SERVICE AND RESILIENCE FOR INFRASTRUCTURES

This second webinar was organized to continue the work done with the first webinar, to receive the validation of the current advances made in both guidelines. The webinar was organized on November 14th, 2019 and counted with the participation of 15 SRG experts, as follows:

Organisation	Contact

Deutsche Bahn	Michael Below
Eiffage Kier JV:	Marco Bocci
Federal Railways SBB:	Thierry Pulver
Harris County Toll Road Authority HCTRA:	John Tyler
Highways England:	James Codd, Angus Wheeler
IFSTTAR:	Sylvain Chateigner, Andre Orcesi
Kraton Polymers:	Laurent Porot
NCSR Demokritos:	Thanasis Sfetsos
Rijkswaterstaat:	Sander Borghuis
Transport for London:	Mehdi Alhaddad
Transport Infrastructure Ireland	: Billy O'Keeffe
UIC (The World Railway Organization):	Pinar Yilmazer
University of Sevilla:	Francisco García Benítez
University of Zagreb:	Damir Bekic
Virginia Tech. University:	Gerardo Flintsch
ZAG:	Stanislav Lenart
ETHZ:	Bryan Adey, Clemens Kielhauser
TECNALIA:	Iñaki Beltran, Jesús Isoird
FAC:	Sheryl Lynch
FERROVIAL:	David Delgado

Bryan Adey and Clemens Kielhauser from ETHZ leaded the organization of this event. They introduced again the concepts and advances made with the first guideline in order to better focus the introduction and feedback needed for the second guideline "Guideline to set target levels of service and resilience for infrastructures, D1.2".

As mentioned for the previous webinar, all the feedback received enabled the success of achieving a CWA focused on how to integrate resilience in the infrastructure transport asset management. CWA 17819:2021 'Guidelines for the assessment of resilience of transport infrastructure to potentially disruptive events'.

Some questions were also raised in this webinar to receive feedback. They can be consulted next:

- Q1. What type of targets would you set for your transport systems, i.e. targets set through expert opinion or through cost-benefit analysis? Please give an example of each situation in which they would be useful.

- Q2. Do you think it is reasonable to set targets on the resilience curve? The values of indicators? The percentage of fulfilment of the indicators? Please give an example of each situation in which they would be useful.
- Q3. Do you think you would want to set targets for categories of indicators as a block? Please give an example of each situation in which this would be useful.
- Q4. Do you think there are any generic resilience targets missing? If so, please give examples.
- Q5. Which persons would you require to help you set targets? How would you want to defend the targets you set?
- Q6. Do you think targets would need to have their own weights, e.g. a hard target and a soft target, where the hard target has to be met with a high certainty whereas the soft target is a "nice to have" target? If yes, how would you propose assigning these hard and soft weights?
- Q7. In dealing with the resilience of your transport system, what are some examples of hard and soft targets? Why?
- Q8. Do you think that resilience indicators could be effectively used in decision making in, and communication of decisions by your organisation? In which situations could you imagine them being used?
- Q9. What additional information do you find missing from the guideline? How do you see this information being added?

The answers to those questions were compiled in one single document that was analysed by the ETHZ in order to take into consideration all the comments received. The Q&A per SRG experts can be reviewed in the Appendix B.

4.3 3RD WEBINAR. ALGORITHMS TO DETERMINE OPTIMAL RESTORATION AND RISK REDUCTION INTERVENTION PROGRAMS FOR TRANSPORTATION NETWORKS

Following the example of the previous 2 webinars organized by the ETHZ, this one was organized to introduce to the SRG the work being carried out also in the ETHZ regarding algorithms to determine optimal restoration and risk reduction intervention programs for transportation networks.

This webinar was more technical that the 2 previous although more than 29 SRG experts participated, together with 11 experts coming from the FORESEE consortium.

Organisation	Contact
Aecom	Matthew Audley
Aecom	Paul Clarke
Arup	Áine Ní Bhreasail
ASFINAG	Karl Engelke

Deltares	Anoek de Jonge
Deltares	Thomas Bles
Deutsche Bahn	Michael Below
German Center for Rail Traffic Research	Frederick Bott
Highways England	Angus Wheeler
Irish Rail/Iarnród Éireann	Fiona Kelly
NCSR Demokritos	Thanasis Sfetsos
PIARC (World Road Association)	Miguel Caso
Rijkswaterstaat	Léon Schouten
Spanish Road Directorate	Oscar Gutierrez-Bolivar
Trafikverket	Johan Jonsson
Transport for London	Fiona Thompson
Transport for London	Mehdi Alhaddad
Transport Infrastructure Ireland	Billy O'Keeffe
UIC (World Railway Organization)	David Villalmanzo
UIC (World Railway Organization)	Marie Luz Philippe
University College Dublin	Beatriz Martínez-Pastor
University College Dublin	Abdollah Malekjafarian
Université Gustave Eiffel (IFSTTAR)	Franziska Schmidt
University of Bologna	Andrea Benedetti
University of Cantabria	Javier Torres
University of Sevilla	Francisco García Benítez
University of Zagreb	Damir Bekic
ZAG	Darko Kokot
ZAG	Stanislav Lenart
SRG Chairman	Jesús Rodríguez
Tecnalia	Iñaki Beltran
ETHZ	Bryan Adey
ETHZ	Claudio Martini

ETHZ	Saviz Moghtadernejad
ETHZ	Marcel Burkhalter
FAC	Sheryl Lynch
FAC	Anna Yankulova
FAC	William Hynes
Cemosa	Noemí Jiménez
Cemosa	Concepción Toribio

Prof. Brian Adey gave an overview of the objectives and scope of WP1 and WP4, focusing on what a resilient infrastructure represents through developing a guideline and defining metrics to measure the Level of Service and resilience of multi-modal infrastructure. Examples of using Levels of Service and resilience for infrastructures and governance illustrated through the 6 case studies.

Dr. Saviz Moghtadernejad took the floor and focused on the restoration program following a disruptive event should restore services as much, and as fast, as possible, focusing on studied networks and impact through damage/restoration models.

For this event, some questions were also prepared and shared in order to contribute to the validation of the result of this task. For Mrs Moghtadernejad presentation, these questions were forwarded:

1. Assuming you use, or would like to use, simulations to evaluate risk, what parts of the restoration algorithm could be improved to make it useful for you?
2. If you don't use simulations to evaluate risk, how do you evaluate the expected effect on service and restoration intervention costs related to likely natural hazards?
3. How would you prioritize the restoration of objects following the occurrence of a natural hazard? e.g. as a function of the numbers of vehicles that normally use the object.
4. Which measures would you use to evaluate your performance following the occurrence of a natural hazards? e.g. The speed of restoring service? The avoidance of injuries and fatalities? The costs of the restoration interventions?
5. How extensive are your restoration plans to enable you to react quickly following the occurrence of a natural hazard?

After Saviz presentation, Mr. Marcel Burkhalter took the floor to present the algorithm created by the ETHZ. Some more questions were forwarded regarding his presentation

1. Assuming you evaluate possible risk reducing interventions using digital support, do the algorithms you use consider the synergies between objects? If not, why not?
2. If you evaluate, or would like to evaluate, possible risk reducing interventions using digital support, what parts of the algorithm could be improved to make it useful for you?
3. If you do not use digital support, how do you decide on the risk reducing interventions to be executed on your network?

4. How do you make trade-offs between "normal" interventions and risk reducing interventions when you have limited budgets?
5. How do you quantify the effect of postponing a risk reducing intervention one planning period?

The answers to those questions were compiled in one single document that was analysed by the ETHZ in order to take into consideration all the comments received. The Q&A per SRG experts can be reviewed in the Appendix C.

4.4 4TH WEBINAR. MEASURING THE RESILIENCE OF, AND PRIORITIZING INTERVENTIONS FOR, ROAD TRANSPORT SYSTEMS IN PRACTICE

On the 21th January 2021, more than 50 participants joined the 4th webinar of the FORESEE Stakeholders Reference Group with presentations from ETH Zurich, Autostrade per l'Italia and Cemosa.

Organisation	Contact
University Gustave Eiffel	France
Highways England	UK
Bast	Germany
Deutsche Bahn	Germany
National Transport Commission	Australia
Cintra	Spain
Cerema ITM	France
Virginia Tech. University	USA
(PIARC)	Norway
Road Directorate	Spain
Road Directorate	Spain
Trafikverket	Sweden
The Randstat	Netherlands
Transport for London	UK
Rijkswaterstaat	Netherlands
(PIARC)	Australia
Asfinag	Austria
National Roads Authority	Uganda
Irish Rail	Ireland

Madrid Town Council	Spain
DGITM (Directorate General for Infrastructure, Transport and the Sea)	France
Ministry of Infrastructure and Water Management	Netherlands
German Center for Rail Traffic Research	Germany
(PIARC)	New Zeeland
CEMOSA	Spain
UNE	Spain
UNICAN	Spain
Future Analytics	Ireland
ETH Zürich	Switzerland
ETH Zürich	Switzerland
ETH Zürich	Switzerland
CEMOSA	Spain
AISCAT	Italy
SRG chairman	Spain
ERF	Belgium
Autostrade	Italy
Fraunhofer	Germany
Fraunhofer	Germany
CEMOSA	Spain
Future Analytics	Ireland

SRG Chairman Jesús Rodríguez conducted the discussions under the topic "Measuring the resilience of, and prioritizing interventions for, road transport systems in practice". The meeting is following-up the conclusions of the last webinar (18-06-2020) when the algorithms to determine optimal restoration and risk reduction intervention programs were presented.

FORESEE aims at developing a solution to be implemented in real scenarios. In this case, the highway A16 in Italy was the case study where technical presentations focussed. Concretely, participants discussed deployment of the algorithms through two methodologies able to support infrastructure managers in deciding on the prioritization of interventions in real-world practical situations (i.e. with various degrees of accuracy required, time-frames at disposition, expertise, and information available).

The presentations covered the following elements:

Methodology to define the transport system to be investigated, to measure the service provided and the resilience, and to set resilience targets, and Methodology to prioritize resilience enhancing interventions, taking into account current and target values of resilience indicators

For this event, some questions were also prepared and shared in order to contribute to the validation of the result of this task.

Questions on part 1: Measure the resilience of the transport infrastructure.

1. Assuming that correct inputs are used, would you trust using the measures of resilience that this analysis offers to take decisions on the interventions to be executed? Either way, can you explain why?
2. Do you think that the measures of resilience estimated in the case study would be useful in the communication of your decisions? Either way, can you explain why?
3. Assuming you use indicators to measure the resilience of a transport system, would you consider the indicators chosen in the case study as relevant/ complete? If not what is not covered?
4. In measuring resilience in the case study, the service is measured in quantifiable units per unit time, e.g. additional amounts of travel time per day. How difficult would it be for you to define the service provided by your transport systems in this way? Would you define service in a different way?
5. In measuring resilience in the case study, the maximum possible reductions in service due to the variations in the values of specific resilience indicators, is estimated. How difficult would it be for you to estimate these values?
6. Do you see any inputs required in the example analysis that you would have difficulty in providing? Can you specify which ones and how would you prefer these to be different?

Questions on part 2: Prioritize interventions accordingly.

1. In the application of the prioritizing methodology, the definition of system performance (KPI) for each indicator is based on the analysis performed in Part 1; however, target values (KDP) are based on expert opinion, do you see the feasibility of defining these parameters according only to expert opinion?
2. Assuming that indicators, target values (KDP) and system performance (KPI) are correctly defined as input, other prioritizing algorithm needs from several computational time, would you apply the prioritizing methodology as a strategic tool for ranking resilience enhancing interventions?
3. This methodology has been developed in an executable script; do you consider that you are more likely to apply the methodology if it is implemented in an automated tool with a friendly user interface?
4. Currently, this methodology is applied to ranking resilience enhancing interventions, do you see the applicability of adapting this methodology to be applied to other areas of infrastructure management such as maintenance planning? Please, specify which fields (i.e.: prioritization of road segments to be paved).
5. In case of an affirmative answer to the previous question, which data would you use to plan a maintenance program or other infrastructure management task? Please,

6. The results obtained with this methodology are expressed in terms of relative weights (the sum of the weight of all interventions is equal to the unit. This allows to rank interventions in terms of relative importance, but it could happen some interventions scores are quite close (0.2295 vs 0.2187); do you see the results of the A16 Highway application representative enough to take action?

The answers to those questions were compiled in one single document that was analysed by the ETHZ and CEM in order to take into consideration all the comments received. The Q&A per SRG experts can be reviewed in the Appendix D.

WORKSHOPS

4.5 1st WORKSHOP "ROAD AND RAILWAY NETWORKS' RESILIENCE STRENGTHENING THROUGH SATELLITE MONITORING

This face to face workshop took place in London on September 17th, 2019, during the organization of the General Assembly organized in Telespazio's headquarters in London. The aim of this workshop was mainly focused on providing to transport infrastructure owners and operators the latest news and tendencies from the satellite monitoring sector applied to the transport sector.

The attendance to this event almost reached 50 people between external SRG experts and experts from FORESEE's organizations. The composition of the audience can be reviewed next.

Organisation	Contact
Aiscat	Federico Di Gennaro
Arup	Savina Carluccio
Arup	Áine Ní Bhreasail
Atkins	Matt Peck
Austostrade	Livia Pardi
Balfour Beatty	Nick Boyle
Cemosa	Noemí Jiménez
Cemosa	F. Javier Morales
CSIC	Sakthy Selvakumaran
Eiffage Kier JV	Adrian St John
ERF	José Díez
ETH	Claudio Martani
ETS (Basque Railways)	Josu Rodríguez
ETS (Basque Railways)	Cristina López

FAC	Sheryl Lynch
FAC	William Hynes
Ferrovial	Javier Royo
Ferrovial	David Delgado
FORESEE SRG	
chairman	Jesús Rodríguez
Geocisa UK	Diego del Saz
Highways England	James Codd
Highways England	Stuart McRobbie
IFSTTAR	André Dominique Orcesi
Infraestrutura de Portugal	Rodrigo Dourado
Network Rail	Stephen Brooks
NIC	Eleanor Voss
PIARC	Miguel Caso
Rijkswaterstaat	Sander Borghuis
Rina	Marcello Cademartori
Rina	Daniele Pastorelli
Road Directorate	Jerónimo Vicente Dueñas
RWS Spain	Victor Centeno
Tecnalia	Jesús Isoird
Tecnalia	Iñaki Beltran
Telespazio	Michael Lawrence
Telespazio	Maria de Farago
Telespazio	Erlinda Biescas
Telespazio	Michael Williams
Transport for London	Mehdi Alhaddad
Transport Infrastructure Ireland	Billy O'Keeffe
University of Cantabria	Daniel Castro
University of Cantabria	Alejandro Roldan
University of Edinburgh	Boris Gailleton

The FORESEE results presented during this workshop were:

- Hot spot risk mapping and impact ranking from the Univ of Catanbria.
- Virtual modelling and asset failure prediction developed by Univ of Edinburg.
- BIM based alerting SAS platform. S-SHM.

Aiming to receive feedback and validation coming from the external organizations interested in the topics presented during the workshop, several questions were forwarded to the SRG experts. As follows:

1st session. Satellite SAR monitoring

- Have you ever used InSAR direct or indirectly for any of your projects? If not, has any other team or project within your organisation? If so, please discuss with them the questions below.
- If you have not used InSAR or you are not very familiar, please let us know your thoughts about the technology for civilians from the description above.
- How is InSAR data used in your organization?
- Could you associate its use with any of the applications listed below?
- Which of the applications will be relevant to meet your monitoring goals?
- Is InSAR integrated into your systems?
- If not, please explain how InSAR information is used. Please, let us even know if it has been delivered but not used.
- Are InSAR data outputs helpful for the infrastructure management challenges? Explain how.
- Do you think that just surface movement from InSAR direct output data (a point cloud dataset with its metadata), is enough to confront those challenges?
- Is satellite monitoring data reaching industry needs? If not, explain why.
- Please list any limitations you see in the technology.
- What has traditionally been missing in the industry for Instrumentation and Monitoring?
- Which gaps do you think InSAR is covering and not covering?

2nd session. From satellite datasets to “in house” satellite monitoring system.

- Is there a need to develop a digital tool/system fed by satellite monitoring data and other relevant sources to provide efficient and intelligent answers for infrastructure and asset management?
- Is the Earth Observation industry having to adapt to the ways of Transport sector?
- Should the transport sector adopt some of the global digital approach from Earth Observation solutions?

- Which would be the best approach?
- What are the advantages of each approach?
- Are any of the systems described during the workshop (Satellite-SHM, GIS hotspot risk mapping and impact ranking, Landslide Failure Prediction and SUMMIT) meeting the challenges of infrastructure monitoring you face or envisage? If not, what is missing?
- Will you use any of the solutions/systems described above in your project?

3rd session. Resilience Shift initiative

- Do you currently use any assessment frameworks, guidelines, standards or tools for assessing or improving resilience of transport networks? What are they?
- Do you see any gaps where there is currently no available tool for assessing or improving resilience of transport infrastructure but you wish there was?
- Have you ever created a tool for assessing or improving resilience of transport infrastructure for yourself or others to use?
- Where do you see alignment between the RS and FORESEE?
- Where are the differences?
- How can the FORESEE outputs advance implementation of resilience and the knowledge generated by the RS complement FORESEE?

Very valuable feedback was received in how to make the best market approach for the satellite based FORESEE results and the validation on the work that was presented. Partners involved in the organization of this event made the needed adaptations according to the answers received during the event and after it, thanks to Q&A prepared and shared. The feedback received can be reviewed in Appendix F.

4.6 2ND WORKSHOP "ADAPTATION MEASURES FOR RESILIENT TRANSPORT INFRASTRUCTURES NEW MATERIALS AND SYSTEMS"

This online workshop was organized on October 27th, 2020, during the days organized for the General Assembly. The topics introduced by FORESEE partners were related to landslides, flooding, pavements and sustainable drainage systems in transport infrastructures. The topics were aimed for a general audience coming from the transport infrastructure asset management.

The event succeeded in gathering 44 external experts from the SRG and 35 members of the FORESEE consortium, making a total audience of almost 80 experts from the transport sector discussing about new approaches to the issues that the sector faces usually and will face in a more severe way in the future due to the climate change.

The audience was composed by external expert from the SRG, as follows:

Organisation	Contact
Adif	David Villalmanzo

AEGEAN Motorway	Thomai Evangelou
Arup	Aine Nibhreasail
Arup	Oliver Pritchard
ASFINAG	Christophe Antony
ASFINAG	Karl Engelke
Atkins	Adam Daykin
Atkins	Jane Kelsey
Atkins	Robert Sunley
Atkins	Zorica Todorovic
Cintra	Cristobal Martínez
Deutsche Bahn (DB Umwelt)	Michael Below
Federal Railways SBB	Thierry Pulver
German Center for Rail Traffic Research	Sonja Szymczak
Highways England	James Codd
INEA	Sergio Escriba
Irish Rail	Catherine Joyce
Irish Rail	Colin Hedderly
Irish Rail	David Gannon
Irish Rail	Fiona Kelly
Irish Rail	HudaAbbas Yousif
Irish Rail	Padraig Fitzsimons
Irish Rail	Stephen Browne
NCSR Demokritos	Thanasis Sfetsos
Network Rail	Eifion Evans
Network Rail	Mark Langdon
PIARC (World Road Association)	Patrick Boisson
PIARC (World Road Association)	Paul Nowak
PRORAIL	Onno Hazelaar
PRORAIL	Stephan van Eeten
Road Directorate	Alvaro Parrilla

Road Directorate	F.Javier Morales
Road Directorate	Jerónimo Vicente Dueñas
SZI (Sloven Railways)	Tomaž Ramšak
Trafikverket	Johan Jonsson
Transport for London	Mehdi Alhaddad
Transport for London	Michael Tarr
Transport Infrastructure Ireland	Billy O'Keeffe
Université Gustave Eiffel	Andre Orcesi
University College Dublin	Vikram Pakraship
University of Chalmers	Björn Paulsson
University of Conventry	Alireza Fathollahi
University of Zagreb	Damir Bekic
ZAG	Stanislav Lenart

Besides the SRG expert, expert coming from the FORESEE consortium itself also participated in the event.

Organisation	Contact
Aiscat	Federico DiGennaro
Autostrade	Livia Pardi
CEMOSA	Concepción Toribio
CEMOSA	José Solís
CEMOSA	Noemí Jiménez
ERF	José Diez
FAC	Anna Yankulova
FAC	Sheryl Lynch
FAC	William Hynes
Ferrovial	Ana Comas
Ferrovial	David Delgrado Zaldivar
Ferrovial	Elias del Barrio
Ferrovial	Ignacio Jardi
Ferrovial	Jaime Martin Alfageme

Ferrovial	Juan Carlos Guerra Torralbo
Ferrovial	Laura Tordera
Ferrovial	Pablo Sanchez Gomez
Fraunhofer	Manfred Bogen
Fraunhofer	Marvin Richter
IP	Maria Lenor Martins di Nascimento
IVE	Christophe Schuetze

In the same way as in other FORESEE events some oriented questions were forwarded to the SRG experts in order to receive valuable feedback and validation from them and to align, if necessary, the developments being presented, which were:

- New slope stabilization systems from the UC.
- New flooding methodology developed by the EHI.
- Sustainable drainage systems from the CEMOSA.
- Improved porous asphalt mixtures developed by the UC.

The different questions made per session were:

Session1: Slope stabilization-protection systems in roads and railways

1. Are you familiar with potential applications of slope stabilization (flexible systems) and protection systems (rock fall barriers)?
2. How can these systems improve their functions and decrease their costs in the future?
3. Has your organization ever worked with geotechnical groundwater and slope stability software as SLIDE, SLOPE, or others?
4. Can you discuss some geotechnical investigation methods to define the water level and flow conditions in slopes?
5. Has your organization ever worked with geotechnical dynamic simulations? What types?
6. Does your company want to introduce new simulation methods (like SPH) despite the time and cost employed?
7. FORESEE's results (new computer simulation method, improved methodologies for estimation, and materials for porous asphalt) improve slope stabilization. What added value do these results provide you?

Session2: Flooding and sustainable drainage systems SDS

1. In your opinion, how likely is it that your institution adopts a methodology like the one proposed in its flooding assessments? What would motivate such adoption (KPIs, cost reduction, insurance etc.)?
2. Do you believe your institution/organisation would incorporate the methodology into their own practice? Or would they subcontract such an application?
3. What is the added value that you perceive in the proposed methodology?
4. Are you familiar with any of these concepts?
    a. Sustainable Drainage Systems Y/N.
    b. Best Management Practices Y/N.
    c. Green Blue Infrastructure Y/N
5. Do you know or have you used any manual for the design of SDS (Sustainable Drainage Systems)?
6. What are the main barriers to install SDS?
7. Do you consider climate change when designing drainage systems?
8. What are the types of roads in which the porous asphalt mixtures are laid?
9. What are the main parameters which must be considered to design a porous asphalt mixture?

The feedback and validation received was reviewed by the partners directly involved in the organization of this event in order to take it into consideration for their developments in the project. The answers received can be consulted in the appendix C.

4.7 3RD ONLINE WORKSHOP ON "MONITORING-BASED DECISION SUPPORT FOR RESILIENT TRANSPORT INFRASTRUCTURES".

This online workshop was organized on April 28th, 2021 aiming to discuss about the how the monitoring data can support the infrastructure owners and operators in the decision making. In contrast to previous events with a more general topic, this event was focused in technical aspects affecting the transport infrastructures' maintenance and operation.

The attendance was composed from 67 attendees coming from 43 entities participating in the FORESEE SRG, and 35 attendees from 14 FORESEE organizations. In addition to this, the event counted with the participation of Rafal Stanecki from DG, Sergio Escriba from INEA and Helmut Wenzel from Wenzel consult, as external technical invited expert. The total attendance to the event reached 84 experts, mostly all from European countries.

During this event, an introduction to the current tendencies in machine learning techniques applied transport infrastructure asset management was done, different FORESEE results were presented and to conclude a discussion was organized on how to integrate all these tendencies in the operational and maintenance plans.

The FORESEE results presented were:

- The SHM algorithms developed by TECNALIA.
- The satellite SHM techniques developed by Telespazio.
- The landslide models from Univ of Edinburg.
- The decision support model developed between RINA and LB(WSP).
- The data fusion approaches from ETHZ.

All these developments and other topics were discussed with the SRG experts during the event. After it, written feedback was requested from experts by forwarding them some questions related to each different result presented. The questions were grouped as follow.

Session 1: Assessment at the Component, System and Network level

1.1 Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

1.2 Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward.

1.3 Potential for ground motion data from satellites to tune landslide models.

Session 2: Data-Driven Decision Support Tools

2.1 Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

2.2 Using interpretable Machine Learning for Data-Driven Decision Support.

2.3 Integration in operational and maintenance plans.

All the written feedback received was analysed by the FORESEE partners organizing the event, and leter used to adapt the work being carried out in the different tasks linked to the event in order to take into account the very valuable feedback received from external experts.

The minutes of this event, including the written feedback received can be consulted in the appendix G.

4.8 FINAL WORKSHOP

The Final Stakeholders Reference Group (the fourth) was held on the January 27th, 2022, 9:30 – 2:30 (CEST) through an online meeting, involving more than 80 people and different stakeholders (eg. Companies, institutional bodies, road and railway operators, also US representatives). As Annex A, you can find the minutes of the meeting with all the details.

An extensive and detailed overview was done case study by case study, providing useful insights on the main features of the infrastructure, together with the hazard & tools that were considered, and providing useful information about the outcomes coming from the application of the FORESEE tools, together with the collection of experts feedback on different aspects.

Following we structured all the answers in an organised cluster of feedback, in order to give a full perspective on the SRG opinion and main items to be clarified or addressed in the next phase after the end of the project.

General perspective on Resilience tools and its impact on infrastructure	- Need to have an interoperable system, capable to dialogue with legacy systems, without adding extra complexity. - The quality and homogeneity of data will be crucial for the real adoption by the infrastructure manager. - Resilience tools can have an impact if we will consider the resilience of entire "transport system", otherwise we will move a bottleneck from one infrastructure to another, the concept of "mobility" is the key.
Impact in terms of cost and effort to implement new solutions	- The adoption of a "resilient approach" will lead to an additional upfront costs, but it will be wise to consider the positive cost benefit ratio, also when dealing with different investment/climate change scenarios.
Data availability and cybersecurity issues	- One of the critical point is (as stated above) the data quality and availability, that can vary from infrastructure manager to another, leading to additional technical complexity. - Cybersecurity issues are increasing, but due to the risk of "bad-reputation" there is not a clear and transparent communication on cyber accident. - Attacks against Intelligent Transport System (ITS) infrastructure have been few and far between. But as more connected vehicles drive on the road, these threats will increase over time, especially when criminals discover new profiteering models. ITS systems are highly visible and attacks against them will be high impact.

Another set of relevant information can be gathered through the collection of answers to the questionnaire that was circulated among the SRG members.

Integration of the "resilience" concept in the company's processes/procedures	- "resilience" topic is only considered for R&D projects, there are several examples of single application or studies, only few responders considered the topic already integrated in their daily management. The situation looks quite fragmentated.

	- The concept of "resilience" is not fully integrated, but for example in some contracts there are specific KPIs that considers the response time to restore the service. - Social impact is not considered, each infrastructure is a "silo" and there is not a systemic approach.
Infrastructure Resilience assessment: how is made?	- Technical stress test are made, combined also with Failure and delay analysis and root cause analysis. - There is a lot of attention on "technical" tools and engineering topics, instead of a management tools. - Only few cases deal with simulation of hazardous scenarios, that consider the whole set of risks and the cost benefit aspects. - In some cases the data collection is considered a way to assess the level of resilience.
Current Tools & methodologies	- There are a lot of different technical solutions for single risks (e.g.floods, earthquakes) and for specific aspects to be managed (e.g. traffic, asset vulnerabilities). - Only few responders have a widely adopted methodology to properly address in a more comprehensive way the "resilience topic". - One of the example provided reminds to the PIARC methodology. - Few of them also has a specific solution for cyberattacks, which is highly relevant.
Impact on the infrastructure management	- The better awareness on the potential impact on some specific technical issue (e.g. scour, condition of culverts etc) lead to a specific attention and better management. - A general improvement on quality, robustness and objectivity of the analysis carried out. - Results from the resilience analysis are integrated in the design standards or in the infrastructure management processes, in order to improve and take better decisions.
Market Challenges	- Lack of resources from the infrastructure manager. - Integration into regular operations of FORESEE tools is a challenge. - Recognition of the proposed solution by relevant stakeholders. - Integration of the platform with legacy systems and interoperability. - Data availability to properly run the tools. - Fragmentation and lack of standards in this field.

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5 CONCLUSION AND NEXT STEPS

The document provided an extensive overview on the main activities performed by each case study responsible in order test and validate the FORESEE tools on their respective infrastructures.

Moreover, we were able to collect relevant feedback in the several meetings and workshop organised, thanks to the SRG chairman and SRG members, that provided valuable feedback for the different aspects of tools and on the overall project itself.

6 APPENDIX A - 1ST SRG WEBINAR APRIL 9TH, 2019

Comments from SRG

Contributions from SRG members after the 1st webinar.

CEDR (Steve Philips)

My comments are limited to the generalities of the approach to assessment of resilience. I see great value in the approach that you are looking at because it looks promising for inclusion in higher levels KPIs for network governance. For some time, CEDR has been looking at aligning KPIs (much as our railway colleagues have done). Indeed there is great benefit from aligning our KPIs for harmonised assessment.

I see a good connection between your measurement of resilience and more general approaches to network availability and service levels. In principle, the impact of a natural event can be measured in the same way as a road traffic accident, routine maintenance works or congestion.

I would draw your attention to the benchmarking report from PRIME (the EC's railway infrastructure platform) (https://webgate.ec.europa.eu/multisite/primeinfrastructure/sites/primeinfrastructure/files/prime_12_benchmarking_report_for_publication_2.pdf).

This contains some interesting figures such as the average delay on rail (due to infrastructure) is 6.35 minutes per 1000km which equates to 0.4sec/km per train. A 2012 JRC report on congestion showed that the average delay for road traffic is 16.6sec/km for roads below 50km/h, 3.3 sec for >80 and 3.0 for >100. Taking into account the difference between the number of passengers in a car and those in a train, these are actually broadly comparable figures.

Of course these are measured figures and reflect a historical approach, for resilience (and perhaps also for issues such as accident risk) it is also necessary to include estimates of service level impact – an x% chance of a landslides, bridge closure, flooding etc can be included in overall network KPI assessments.

Finally, I would highlight the need for an integrated multimodal approach. The resilience of a rail network will be underestimated if the options to transfer to parallel road corridors is discounted. Unfortunately the European Commission's approach is to treat modes separately but contingency planning for temporary displacement between modes is important.

Spanish Railways Infrastructures ADIF (José Conrado)

D1.1

Q1. We believe that it is a good way to carry out the measurement, since it is objective and, for the purpose of the operation, the travel / displacement time is the main way to expose the productivity of a railway company or manager. We agree therefore with the approach. The liberalization of the passenger rail sector in Spain has become a lever for the transformation of the sector, so that aspects such as resilience will become increasingly important. Currently there is only one railway operator but when there are several this type of approach will become more important due to the implications and deviations in the operation that can occur (logically now, an incidence on the service can always be compensated with simpler actions as there is a only affected, this will change soon). On the other hand and in general terms, the affection of the infrastructure to this more than predictable and contrasted climate change, should be conveniently considered.

Q2. Currently, and particularizing in the case of Adif, the digital transformation has been imposed in the field of operation for several years. It has tools that allow controlling in an exact way and in real time the punctuality of the service and the delays that can be produced. At this moment we are implementing the new SITRA + application that is a tool that improves the existing one and that will be able to integrate all kinds of interfaces with other systems with the common objective of controlling in the most optimal way the punctuality of the service, being able to establish planned improvements and actions to be carried out. Another application that we exploit is ELCANO (Adif's Global Railway Information Platform). At this moment it may seem hasty to establish other methodologies but at this moment we think that we would not have problems to implement the criterion established in the project.

Q3. We see it right.

Q4. In principle as a starting point we see it well. In our case, we have identified that meteorology plays a decisive role in this area (aspects such as lateral wind in high-speed lines and precipitation, mainly in conventional networks, are crucial). It would be interesting for us to have the support of meteorological institutes that allow us to analyze the real incidence of climatic events with rail transport (specifically these two: Precipitation and Wind). Perhaps it would be interesting to define a specific line of work on "human condition" (sabotages in the infrastructure).

Q5. Necessarily, we think that it is necessary to use tools of SW scope that control these indicators according to several parameters. Therefore with this type of tools (that some administrations know that they may be developing) it would be easy to control the evolutionand predict possible incidents. Logically it would be necessary to develop a previous (scientific) work based on which algorithm should be based on those tools.

Q6. We must analyze this question with more time. At this moment we do not see ourselves with the potential to answer in a specific way. We continue analyzing it.

Q7. As mentioned, it would be necessary to incorporate indicators in the meteorological field (temperature, humidity, wind and precipitation in the network). And we think it would be interesting to use a specific indicator of tunnels.

Q8. In the 24 hours of the railway operation.

Q9. For our network, the following areas are strategic from a possible point of view ofresilience:

- Incidents due to rainfall.
- Incidents due to winds.
- Incidents due to snowstorms.
- Incidents due to sabotage (mainly wire theft).
- Incidents due to malfunction of deviations (very influenced by meteorological issues).

D1.2

Q1. In the case of meteorological phenomena, the objectives of the values correspond to numerical values (eg. limit value of the wind speed, in km/h). In the case of sabotage, another type of "more qualitative" variables should be analyzed. We would not know how to express it now.

Q2. Yes we believe that it is reasonable.

Q3. We must analyze this question in more detail.

Q4. We believe that the project specialists themselves could help us select and define the objectives. It would be good to keep planning meetings with them.

Q5. We are sorry. We must analyze it to a greater extent.

Q6. We do not have it clear. We must analyze it to a greater extent. Q7. We are sorry. We must analyze it to a greater extent.

Spanish Road Directorate (Oscar Gutiérrez-Bolivar)

I have read the presentation and I am impressed with the content of the work you have done. I have a point that I am not quite sure if you have addressed it. I do think that we need to stablish a network of sensors or any other tool that allow us to have updated information of the real infrastructure conditions. Then we can be in the best condition for taking decisions, we can foresee in advance disruptive performance, and we can establish a data base for improving the knowledge about the real performance of infrastructure. I think that neural networks and AI tools should be applied. Big data, could also plays a role in the resilient issue.

D1.1

Q1. Yes, I agree that it seems the most feasible scenario. Intermediate stages would be difficult to be considered. I don't know if I have understood the last question, but I think that we need to implement these measurements.

Q2. We have the availability of data, but we have not implemented indicators for the measurement of resilience. In my opinion not a great deal effort would be need for such purpose.

Q3. It is Ok

Q4. I would suggest to introducing user cost as indicator, because give more detailed information about damages.

Q5. We have experiences about those issues; bit not a specific systematic data for such analysis. But again it seems not very difficult to get from a panel of experts the required information.

Q6. I feel happy with the 3 ways…

Q7. The consideration of wayside residents

Q8. ?

Q9. Yes I certainly do. We can envisage the use of such indicators for earth slides, earthquakes, floods, bridge collapse, winter conditions, …

Q10. It is a quite important point. Communication to the public is a crucial issue for any Infrastructure Administration.

Q11. It is a pretty comprehensive document. Further information is always possible, but I do think at this stage is enough

D1.2

Q1. I do think that costs that consider not only personal time but the extra cost for goods delivery delays

Q2. Yes….

Q3. I don't like very much blocks, precious information could be lost.

Q4. N/A

Q5. Not yet in condition to answer…

Q6. No. See the answer to 3.

Q7. …..

Rijkswaterstaat (Willem Otto Hazelhorst)

I have seen in your draft minutes of the webinar and my most important comments are well included, especially page 5/6. Some observations of our role as advisors:

I hope you agree that the most efficient way to collect any comments is the webinar itself. And fortunately you have recorded and analyzed the verbal comments and chats that were made by us. An extra exploration after the webinar session of the presented sheets by the SRG and other followers like me is not necessary then.

Nevertheless: If Bryan or anyone of you has specific questions afterwards on things stated and recorded during the meeting – with an extra conference call we can have a focused talk on it to clarify things that might give a more useful extra and "downdrilling"input on the discussion and it saves time for the participants like me.

Swiss Federal Railways SBB (Thierry Pulver)

D1.1:

Q1. I find it very difficult to match (in figure 1 and 2) the yearly cumulative travel time / injuries and fatalities with intervention costs over time (how can a "yearly cumulative" - line fall back to normal after a hazard, shouldn't it be named as "agreed average service level" or similar, and having the surface between green, red and blue lines as the optimizing value).

Q2. I think the method is suitable to SBB, as we have planned travel capacity (how many people on which route over time) and resulting travel times (how many "Verspätungsminuten" for which train); I see two difficulties here: 1) planning numbers might be available, but effective resulting number of passengers are not as far as I know (I do not know, which data is taken into consideration here; we might get good and even better data by the "Auslastung" - measurement with GSM mobility tracking), 2) granularity of "Zug-/Reisendenverspätungsminuten" should be checked, if applicable on routes or even parts of routes which have a distinct level of service. The alternative way of calculating usage over singledays is also ok…

Q3. Unsure on this one, I think it might be appropriate to have some additional information about the quality of information in case of a hazard event; I think by far not all events have either been tested (by a "Notfall-Übung") or experienced. How do we handle this incertitude?

Q4. is sufficient, maybe examples would help; experts would be business continuity managers and risk managers at first hand, then technical experts. To be honest, I do not completely understand the mecano how the indicators work together; we have - like I mentioned in the call- developed a way of identifying "critical resources" affecting business service (see BCM- presentation, confidential!).

Q5. To be able to answer this question, I'd need to discuss the topic with colleagues responsiblefor BCM and RM… I did not have the time to do so.

Q6. It seems reasonable to have three ways to measure resilience, in my opinion I'd prefer trying to build a simulation tool with known methodologies like "integrated logistic support" (ILS in short, see MIL-standards for that, or EN-50126 about RAMS for rail). Weighted indicators make more sense than unweighted to me, therefore I'm interested in understanding the way the weighting itself will take place (c.f. chapter 5.5.5); is there a way to utilize AHP (analytic hierarchy process, Saaty 2001) or a similar method to ensure consistency of the weighting over the whole indicator-hierarchy?

Q7. One aspect that I miss a bit is the planned service-/workload of the infrastructure due to the agreed timetable (say "Auslastung durch den vereinbarten Fahrplan"); I see this indicator in table 48 under "traffic", but I'm not sure if this get's enough weight… otherwise the list of indicators is quite remarkable and fits the main thoughts of BCM-concept as far I can see.

Q8. The information might come handy in the financial planning (short and mid-term I think), in the design phase of infrastructure (where studies are conducted) and also in the timetable- planning processes. I like the idea of marking the resilience indicators as a function of the abilityto change them. I think this has to be taken into consideration (see chapter 5.6.3).

Q9. In chapter 8.3.1 and table 24 you label comfort and noise related to the road user, all three aspects impacting on society and not directly the road user itself; I think it might come handy to have a label on lv 2 of "comfort" that considers the possibility for the user to use the travel time productively (e.g. having work done), this would differentiate roads from tracks, or roads that do not provide possibility for self-driving cars to run vs. a road that does etc.; this may lead toan interesting discussion about services provided by carriers (for now we have the passenger, freight customer and carriers on the same stakeholder-level, see table 29). In rail we arehandling noise as an emission as well (same group), and do additionally take the impact of electronic/electric smog into consideration (see NISV-regulation, which applies to telecom,catenary and high voltage power transmission), see table 35. There are even more (impact on biological habitats due to usage of herbicides etc.), but this would lead to far I think…

Q10: Yes, measuring resilience has to be part of the decision making processes for investments (see "Ausbau, Erweiterung, Nutzungsänderung von Assets", not only physical assets!) as well as for scenario-based decisions concerning the control periods (e.g. "Verhandlung der Umsetzungs-/Leistungsvereinbarung mit dem Bund") by asset management responsibles.

Q11: I'd like to emphasize the need of graphical modeling of the indicators and their way of working together/their interdependencies. Most of my difficulties understanding the concept comes from missing graphical overview(s), I'm not good at interpreting the many provided tables, sorry!

D1.2

Q1. I think both target value - types must be used (and already are used at SBB, see BCM-concept with required service levels and logic about cost-benefit analysis of measures).

Q2. Targets on the resilience curve must include time-component (e.g. time to get back to normal/agreed service level) and level of services (say minimal service level in case of an event has to be over X%). These will be cornerstones for the ILS-approach I'd like to take at SBB Infrastruktur (which brings up KPI like MTTR, MDBF, etc.).

Q3. Not sure if this helps…

Q4. We need responsible persons for service-levels at route and node level of the network; what we have so far is responsible persons for asset types, and that does not help today!

Q5. It would be helpful to get some support about how to systematically learn from previous events, say the tools, methods, criteria etc. that are recognised to be state of the art.

Q6. I do not have a clear opinion about soft- and hard-targets so far…

Q7. -

German Federal Railway Authority EBA (Maike Norpoth)

Note: As the EBA does not operate the infrastructure, the Deutsche Bahn will be able to answer a number of the questions more precisely.

D1.1

Q1. Yes, we see this as a good approach to measure resilience. In our (research) department, we would investigate this approach to see if it allows a prioritization of our entire German railway system and to get an idea e.g. about rerouting in case of interruptions (of any kind).

Q2. As the Federal Railway Authority we do not have any data regarding "service". It is possible to obtain some data, for instance, the number of trains or passengers per time unit to quantify the transport of goods and persons within a specific amount of time. We do not hold data on damaged goods or injuries/fatalities. That kind of data lies with the Deutsche Bahn.

Q3. As simulation is the most time/cost intensive approach, it would be good to obtain more information regarding the measure of resilience using resilience indicators with differentiated weights and using resilience indicators with equal weights. D 1.1 already contains some information in the appendix 10. However, maybe an example (show case) would be very helpful to understand how the indicators can be used to obtain the information wanted.

Q4. See answer to question 2. We would work closely with the Deutsche Bahn in order to develop the required resilience indicators.

Q5. We would work closely with the Deutsche Bahn in order to estimate these values and also discuss with them how exact the values would need to be in order to obtain valid results.

Q6. See answer to number 3. As also discussed during the webinar, it is useful to start with the least cost/time consuming approach and go more into detail if further details are required. It also depends on the availability of data required and the area that needs to be covered.

Q7. -

Q8. When conducting a resilience measure using resilience indicators with differentiated weights or resilience indicators with equal weights it is very useful to know that the percentage of fulfillment of the resilience indicators is a good starting point.

Q9. -

Q10. They would certainly be useful, however, the approach and the indicators used need to be clearly described and comprehensible. As the EBA is not an operator, the information would be used to provide a necessary basis for other decision making organisations.

Q11. Include show-cases to make the application easier.

D1.2:

Q1. Also as discussed in the webinar, we agree that asking the infrastructure users, i.e. railway companies, freight operators, etc., will be helpful to determine target values. As the EBA we are responsible for a safe and functioning infrastructure. However, we do not operate the infrastructure. Therefore we would set target values i.e.

Exposed or vulnerable sections of the German railway structure to certain hazards (we currently analyse storms, flood events and landslides in connection with climate change)need to be protected before extreme events occur.

The restoration period should be kept as short as possible.

Get no-regret or low-regret measures in places, especially if cost of these measures is lower than estimated cost of restoration after an extreme event occurred.

Q2. As we are no operator of the infrastructure, the Deutsche Bahn will be able to answer this question more precisely.

Q3 As we are no operator of the infrastructure, the Deutsche Bahn will be able to answer this question more precisely.

Q4. As we are no operator of the infrastructure, the Deutsche Bahn will be able to answer this question more precisely. But see also question 1: Identify stakeholders, in our case users of the railway infrastructure in Germany[1].

Q5. Get an overview what aspects should be considered when setting target values.

Q6. Yes, targets with weights make sense as some aspects are more critical than others and to take in the entire system is too complex. However, as we are no operator of the infrastructure, the Deutsche Bahn will be able to answer this question more precisely.

Q7. –

Deutsche Bahn DB Umwelt (Michael Below)

I am sorry, that we could not join the meeting and we do not have much time to check the document. Actually, the focus of my working group is on some other topics. Hope the information/comments will help you at least a little bit.

Comments

Foresee objectives (slide No.13): we can go with these statements, we have had problems mentioned in 1, but this is often combined with landslides; # 2 and 3 are less important for us at the moment.

What does Foresee propose? (slide No.15): this sounds good, because we need information on the expected costs due to the fact that the probability of some natural hazards is very low hence nobody of the management would spend money for measures to increase the resilience...

Foresee Toolkit. A Situation Awareness System for prediction and alert of extreme events (slide 17): the idea of an awareness system is good and not new; the main problem wehave, that the geographical and time resolution is too low to get the information needed...

Foresee Toolkit (slide 18): see my comment in slide No.17, because a good GIS/ BIM system or other tools needs a reliable database to work properly... this is the main problem wehave - I guess there are already lots of evaluation tools existing, but no reliable data to feed them.

[1] https://www.eba.bund.de/DE/Themen/Eisenbahnunternehmen/eisenbahnunternehmen_node.html (list ofall registered railway companies in Germany)

The guideline: Service (slide No.29): both points makes sense for me

The guideline: Resilience (slide No.30): maybe we should differentiate into existing infrastructure and new build ones, because it could be much cheaper if a new build infrastructure is already planned with respect to resilience aspects...

Define Transport System (slide No.33): one point for the German conditions is the funding, because a new construction of a railway line/ road is funded by the state while the reconstruction has to be funded by the company itself for some part; in general the frame conditions for funding have to be checked as well

Measure Service (slide No.34): Why not defining a ratio additional travel time to the regular travel time as a base?

Answer to D1.1 questions

Q1. In general I agree on this, I see the main problem, in defining the right parameters.

Q2. We use "lost units" or minutes for the whole system, therefore it seems to be suitable

Q3. --

Q4. We use "lost units" or minutes for the whole system, therefore it seems to be suitable

Q5. I guess it is very difficult, because very often we have to deal with single events and this is not representative. Actually we work on so called risk maps, we would like use for the sensitivity of our network concerning different hazards. At least it should give us indicators for tracks or section of tracks, where we have to look for measures to make it more resilient.

Q6. --

Q7. --

Q8. --

Q9. Actually, we are lost units or minutes of delay in passenger transport.

Q10. The main point is, that this are theoretical approaches and getting the real number linked to a hazard will be difficult.

Q11. --

Highways England (James Codd)

I am afraid I have not had an opportunity to answer the questions and had not realised how many there were. I'd be very happy to put an appointment in my calendar to talk to you about these. We would be interested to be involved with FORESEE work, subject to fitting it in with our own highway projects and research, which it seems to align with very well.

To keep informed on our own work on resilience – we have a research programme developing a framework for the resilience of geotechnical assets and this is includes topics such as developing knowledge through enhanced hazard products (e.g. maps), the whole life assessment of special geotechnical measures, improved geotechnical data, proactive monitoring of geotechnical asset performance etc. I attach a copy of a briefing note which outlines the programme, some of the associated tasks and their objectives **(ANNEX I)**.

We currently define resilience as "the ability of assets, networks and systems to anticipate, absorb, adapt to and/or rapidly recover from a disruptive event". This definition is based on Cabinet Office (2010) Keeping the Country Running: Natural Hazards & Infrastructure. A guide to improving the resilience of critical infrastructure and essential services. We have developed a resilience framework which builds on a traditional risk assessment type framework to consider various hazards and help the company and its suppliers prepare for risks and respond to issues. We have a number of tools that measure different resilience related variables some of which are quantifiable and some of which are not. There are a number of variables that need to be considered with regards to service and time/delay is just one. Others might include, for example, annual average daily traffic (AADT), lane availability, and the impact of these factors will vary depending on the importance and/or criticality of the route and the type of highway asset affected.

Transport for London (Fiona Thompson)

D1.1

Q1. I agree that this is a sensible approach. As to what is required of the infrastructure, London Underground has targets for reliability of its network, but also service commitments e.g. number of trains per hour or 24-hour train running at weekends on given routes. In terms of scope of resilience, I think there is potential to look at resilience to permanent change, e.g. climate change resulting in a new operating environment, or increasing demands and expectations of customers. I am not sure whether this should be classed as a hazard, or a permanent change. Either way, resilience is required as not usually physically feasible or affordable to completely rebuild.

Q2. London Underground uses Lost Customer Hours (LCH) as a measure of reliability. This is a calculation of how the customer experiences loss of service or delays, using notionally accumulated Customer Hours. This is a set of values representing how many people are predicted to be using the service at a given clock time and location, and thus affected by the disruption. More LCH would be incurred during peak times, and/or at busy locations. We can also multiply LCH by a Value of Time in order to monetise the impacts.

Q3. Apologies - I do not feel I have a sufficiently developed response.

Q4. I am relatively new to considering resilience. I generally seek advice from within my wider organisation of Transport for London (TfL), and from industry peers. TfL are a member of CIRIA

– the Construction Industry Research and Information Association, which also provides contactsand access to shared information.

Q5. For Civil Engineering assets such as embankments, cuttings, bridges, tunnels etc, we have assigned notional disruption times based on type of asset and behaviour experienced. For example, an immediate complete collapse of an embankment has an assumed loss of service of 2 weeks. We assess risk using pre-set definitions of physical behaviour for each asset type, with impacts for service loss and safety. I am reasonably content with our risk assessment methodology, but ease of implementation could improve.

Q6. Apologies - I do not feel I have a sufficiently developed response.

Q7. Apologies - I do not feel I have a sufficiently developed response.

Q8. Apologies - I do not feel I have a sufficiently developed response.

Q9. Apologies - I do not feel I have a sufficiently developed response.

Q10. Being able to project required resilience with time would support long term investment and maintenance plans, business case development for interventions, and scenario planning.

Q11. I do not think I can answer this at this stage in the guideline's development.

<u>D1.2</u>

Q1. I would be interested in exploring both methods. I feel the first type is more practical to start with.

Q2. I am not fully comfortable with my understanding of the curves as shown.

Q3. I am unclear as to what is meant by a "block" in this context. Does it mean all values combined in common currency to one?

Q4. I would initially go for a similar situation to what I currently have in London Underground, which is essentially LCH targets not to be exceeded. This is on the basis of line (route) and asset type. However, LCH targets are of limited use for Civil Engineering assets where events tend towards low likelihood and high consequence, which means one such event could exceed an entire year's LCH target allocation, but is not sufficiently predictable to pre-mitigate.

Q5. Peer and expert guidance welcomed.

Q6. Rather than Hard and Soft, I would consider as in terms of thresholds with scaled operational consequences associated, e.g. restricted operation if resilience indicated at or below a set threshold,

Q7. The closest example is Safety and Maintenance Level Standards for Track. This is where changes in condition prompt immediate restrictions, e.g. of speed, if values representing allowable safety are breached. Maintenance Levels prompt intervention before values have deteriorated to the Safety Level.

National Infrastructure Commission NIC (Matt Crossman)

We haven't had time to go through the papers in detail but were interested in the approach set out in the documents and will be keen to continue to follow the work. In the meantime we would offer the following comments and questions:

The indicators approach is interesting, but it would be good to understand whether / how would it could be applied to unforeseen hazards or threats

How is the system defined and does the approach take account of potential substitution(for example between different transport modes or communications instead of transport). We weren't clear how the approach would be applied to a whole system (transport or otherwise) rather than individual assets. (although we appreciate theexample was illustrative)

How might dependencies and interdependencies between different infrastructure sectors feature in this approach?

Transport Infrastructure Ireland (Billy O'Keeffe)

D1.1

Comments: Our (Transport Infrastructure Ireland) main experience in this area relates to assessing the road network from the perspective of flooding which is the most important issue facing us from the Climate Change perspective. I am not in a position to comment on resilience in relation to accidents but it also plays a huge role in determining the functionality of the network.

Flooding and simulating behaviour: In order to determine the resilience of the network to flooding TII needed to essential elements:

A detailed Digital Terrain Map (DTM) of the entire network.

An accurate and reliable software package that could take account of fluvial, pluvial andcoastal flooding in Ireland.

It would not be possible to carry out a risk assessment or test the resilience without both of these crucial elements. In order to get a suitable DTM we had to commission an expensive LIDAR survey. TII did not have an accurate map of the network – I am not sure if this is commonacross other member states.

To carry out the hydrological modelling we employed consultants. As a result, we now have a very good understanding of flooding on our network and can test it for various climate change scenarios – a very useful resilience tool. *(I have attached a document explaining the outcomes and the process).* **ANNEX II.**

My essential point is that in order to establish resilience we needed to invest in considerable resources and expertise. I imagine that it will be similar for other resilience parameters – landslides, subsidence (Ireland has considerable amount of Karst areas prone to subsidence), storms, prolonged dry spells (rutting) etc. Without high levels of detail, it is difficult to quantify these risks and therefore difficult to determine resilience.

Units: The units we adopted fort flooding were related mainly to:

Depth of road flooded

Velocity of water flow on the road

Numbers of people at risk

Traffic volumes on the road

This resulted in an overall ranking of the entire network and the identification of high risk areas

– a very useful outcome. These units could be translated into travel times or periods of road closure. Will it be possible to translate all hazards to travel time – e.g. a landslide could result in a prolonged road closure for weeks. It may be that each hazard will have its own units but possibly with some mechanism of translating these units to and overall score related to a 'Priority Action' maintenance score. If the event occurs then it will rank in and overall **resilience plan**. Something along the lines of the cost and travel time graphs but with an overall ranking score. These are just some thoughts on assessing each hazard in an overall resilience plan.

Critical Infrastructure: As well as identifying high risk areas, an area that we have insufficient knowledge of relates to ***critical infrastructure*** – just what parts of the network are critical from a strategic point of view. With this knowledge, we could prioritise these parts of the network and increase the ranking for these sections. This element requires a stakeholder engagement with several other agencies e.g. Electricity Supply, Surface water installations and supplies, Key hospitals, communications facilities etc. This is lacking in our database and I would be very interested in how other states are coping ***with Critical Infrastructure.*** This approach couldconsiderable lessen the cost of increasing resilience of the network – i.e. if we initially focus on the critical sections only.

D1.2

Target Values: Some sections of the networks just cannot be impacted without major disruption. The target values for these sections, again, are related to identifying areas of critical infrastructure.

We have had a major road flooding event. Detailed hydrological investigations using modelling and simulation actually demonstrated that the event was related to fluvial flooding (not pluvial as suspected) and culvert sizing – this was by no means obvious and did require a detailed assessment. Mitigation will be very costly.

It would be useful to represent such an event on a resilience curve but with a detailed understanding of the event it cannot be costed but it could be represented on a travel time curve.

The block concept is useful as it could be used as an overall assessment and comparisons of various hazards. E.G. How does a flood event compare with a major accident?

Cascading Effects: I think the project would benefit by considering cascading effects in the context of resilience. Again, this may help to prioritise certain sections of the network for targeting increased resilience mitigation.

Harris County Toll Road Authority HCTRA (John Tyler)

The group have put together a very complete document. The theory used to develop a system to identify potential breakdowns in the network of roadways seems logical. Our experience with events is that the impacts are quite different for each one. How we resolve this issue is similar. Thanks for the extra few days. After reading the comments made during the phonecall, it appears initially that my thoughts will align with several of those comments.

Just a couple as I try to catch up to the understanding of where the committee is. We have also experienced industrial accidents that have impacted our roadways, specifically petrochemical plants. Another oddity is a solution to provide access to a water treatment plant during a flood recovery. The solution required closing several ramps to place an on ground pipe to an adjacent facility so services could continue. Not sure I would have ever thought of that as part of this exercise. Anyway, I do not have any further comments.

ASFINAG (Karl Engelke)

Resilience indicators in the point of view of ASFINAG as Austrian highway operator.

A resilience indicator could be a function or combination of impacts with its effects (measured in time and/or costs) and time and/or costs for recovery. Therefor this indicator should be a weighted combination of these parameters. The impacts should additionally be weighted with the probability of occurrence.

Starting with impacts we recognised that our main problem for availability is "traffic accidents". But this is an indicator hard to control. So we implemented a strategy (program) for road safety with focus on prevention measures (not only constructive measures, also campaigning and so on).

The next class of impacts is "road works". These are mostly plannable and therefor management of our road work has central priority. Due to technical failures it also can happen that sudden road works are necessary. So this is our main approach to resilience. But so far we haven't defined any resilience indicator or target value except that "availability" must not decrease under 95% due to road works. But we don't see this as a resilience indicator.

The least problems we have with natural hazards. So we actually just gather data of hot spots including the type of hazard (snow/avalanche, water/flood, mudslides and rock fall) the risk (probability) and intensity/probability of incidents and the functionality of protection structures (if existing). This combined gives us an indicator for the urgency of further measures. As you can see, we don't have earthquakes in our focus. That is because all you can control here is the structural resistance of engineering structures which is defined in standards like Eurocode 8. If the risk of hazards is too high (means the risk of deaths is over 10^{-5} or the damage costs are over the costs of protection structures) we act, mainly by building protections.

A resilience indicator of natural hazards seems to be a proper indicator to find the optimal line for a new infrastructure. On the existing infrastructure resilience indicators can support Asset Management by prioritising necessary maintenance projects, but for any type of impact not only for natural hazards. Such indicator can certainly be used in public discussions.

D1.1

Q1. I don´t know if this is the best way, but it certainly is a good way. The key-question seems to be, how you measure the "service" provided by a transport system. ASFINAG as the Austrian highway operator defines a main target in "availability" of the road network, but ASFINAG do not have a target value for decreased availability because of natural hazards. We do have a value only for planned roadworks (the availability must stay above 95% over the year)

Q2. ASFINAG can provide indicators for traffic in vehicles per day or per hour. Also we can give a theoretical maximum traffic depending on the number of lanes available. That means it is a very high effort to get an idea for additional travel time. We don´t calculate or simulate the additional travel time in any case, including natural hazards, especially if the detour is not on our highways, though we are working on providing estimated actual travel time (for trucks only) through our toll gantries.

Q3. No

Q4. I think that resilience cannot only be measured for natural hazards.

Q5. Any indicators should always be easy to get, so estimations are a common way to go. But they have the disadvantage of not being very transparent. They also are not good to handle in a digital process.

Q6. Simulations seem to be a working method but are very costly and the question is, is there no more simple method to achieve the same result? Differentiated weighted indicators are certainly useful and easier to obtain. Equally weighted indicators should be avoided because I don't think that all indicators are of the same importance or priority.

Q7. Probability of occurrence.

Q8. A resilience indicator of natural hazards seems to be a proper indicator to find the optimal line for a new infrastructure. On the existing infrastructure resilience indicators can support Asset Management by prioritising necessary maintenance projects, but for any type of impact not only for natural hazards. Such indicator can certainly be used in public discussions.

Q9. See chapter "resilience in the point of view of ASFINAG".

Q10. Yes, to prioritise and to give reasons for decisions.

Q11. I don´t know.

D1.2

It seems not necessary to have specific target values because the common use of resilience indicators is to compare between different possibilities.

ARUP (Savina Carluccio)

D1.1

Q1. I agree with the premises of defining the transport system and the need to maintain service and functionality in the face of shocks and stresses. The resilience measures that can be implemented increase the resilience of the system and may be used to give an indication of how resilient the system is likely to be. However, there are other aspects to be considered in proposed framework:

Interdependencies within and between systems (e.g. the transport system may beresilient but there is no electricity to power trains)

Hazard vs multi-hazards

Consideration of cascading impacts

Uncertainty (we can't rely on the past to predict the future, what ifs analyses, HILFevents)

Q2. This recently published report reviewing LoS of UK critical infrastructure may be useful https://www.nic.org.uk/wp-content/uploads/Review-of-UK-levels-of-infrastructure-service.pdf There is significant variability within and across infrastructure sectors in terms of levels of service. Safety and availability of service are predominant focus of levels of service across sectors, but there is no consistent definition or thresholds of either. Levels of service are predominantly set in the UK through:

Customer engagement – to understand the expected levels of service (e.g. water and highways sectors)

Safety – with understanding that some risks are unacceptable (e.g. Health and Safety Executives ALARP approach)

Legislation – where operators are required by law to deliver a specified standard of service that includes safety. (e.g. obligation of telecoms providers to ensure uninterrupted access to emergency services).

Levels of service typically focus on 'everyday' or 'business-as-usual' activities (e.g. train punctuality or leakage from water pipes).

Lack of consideration of long-term levels of service.

Lack of consideration of cascading impacts between and within infrastructure sectors.

Q3. I am not clear on the question being asked.

Q4. Defining a harmonised set of resilience indicators is very ambitious. Indicators will likely need to be tailored for different across sectors and even across organisations from the same sectors. Resilience indicators should be done at different scales as you aspire to increasing resilience of the whole transport system. I would suggest starting from a holistic high level resilience assessment framework to inform decision on a generic set of indicators to monitor/focus on (e.g. CRI https://www.cityresilienceindex.org/#/resources particularly the infrastructure quadrant, https://cati.unops.org/) and then define more granular indicators for individual sectors/organisations around the prepare/respond/recover/adapt resilience phases. Please note the 'adapt' phase is missing from your framework at the moment. An understanding and appreciation of resilience and its aims and value is needed across the value chain of critical infrastructure policy/decision makers, planners and engineers, contractors, investors and financiers, insurers, infra owners and operators, emergency responders, the end users (customers) etc. Experts with domain knowledge able to undertake analyses and design interventions should also be engaged with from early stages through to O&M.

Q5. (See Q6) I think an interdependencies mapping and analyses of critical nodes should be undertaken before deciding which indicators.

Q6. My view is that a framework such as the one being developed is useful as a guideline but it is always going to be an over simplification. Limitations should be highlighted so that infra owners and operators are not given a false sense of security that they have the resilience fully covered. Assigning weighting to different indicators can help with prioritisation of investments but there is no certainty on whether the aspect where less investment has been allocated will eventually turn out to be the weak link leading to cascading failures. Therefore, there should be health warnings on any indicator and particularly on quantified indicators.

Q7. See Q4

Other considerations:

Cost of interventions: it would be very helpful to distinguish btw before the event (upfront costs) or after the event (repair costs)

Efficiency and resilience interventions need to add this into consideration (does the intervention deliver efficiencies? Does the intervention address more than one hazard?)

Prioritisation of interventions, how would this be done?

Digital system resilience https://www.nic.org.uk/supporting-documents/infrastructure- and-digital-systems-resilience/, this underpins a lot of the tools in your proposed the toolkit

University of Chalmers (Björn Paulsson)

First of all I think the objectives of FORESEE are excellent;

Provide cost effective and reliable tools to improve resilience of road, rail and multimodal infrastructures and transportation hubs.

Address the effectiveness of resilient measures to improve the ability to anticipate, absorb, adapt and recover from a potentially disruptive event.

They address resilience which is an area that has become important since a modern society is so dependent on infrastructure. There are too many examples where the society is unable to act when undesired serious occurrence happens.

FORESEE propose to develop a harmonized resilience assessment methodology and a Toolkit able to reduce the impact and the consequences for short, medium and long-term events with a systemic perspective.

Update of best available methodologies from a performance based approach.

Situational Awareness System based on best available data acquisition system supported by GIS/BIM mapping technologies.

Innovative technologies: permeable pavements, slope stabilization systems, innovative drainage and culvert designs and engineering of links.

Guidelines for the adaptation to extreme events.

These ambitions are very high! Are they really reachable? My question is if a more narrow approach would be better in order to deliver some implementable result?

Looking more careful at FORESEE TOOLKIT I find them good but are they realistic? For example the two below:

New slope stabilization-protection system combining, flexible membranes and geosynthetics.

Innovative Drainage Systems.

During my time as head of Track and structures at Banverket we had problems with slope stability and drainage. The problem was not that it was anything wrong with the system. The problem was that the used system was not properly maintained and that that it was a new situation caused by e.g. large asphalted areas or total felling of wood. For this reason I think that Case Studies are important for the success of FORESEE.

D1.1

Q1. In order to measure resilience, D1.1 proposes to define the transport system, to define the service to be provided by the transport system and to measure resilience by using the difference between the service provided if no hazard occurs and if a hazard occurs. Do you agree that this is the best way to measure the resilience? Under what circumstances do you see that you would undertake this endeavour? In some cases yes if the transport system is simple. For example is most rail system not very redundant which makes this model not so easy to use.

Q2. In measuring resilience, it is proposed to measure service in quantifiable units per unit time, e.g. additional amounts of travel time per day. How difficult would it be for you to define the service provided by your transport systems in this way? Are the current methods that you use suitable? If not what new methods would be required? See answer question 1 and also remember that today way of working is mainly based on experience from earlier events.

Q3. Although deliverable 1.1 acknowledges that simulating the behaviour of the transport system without the occurrence of a hazard and with the occurrence of hazards is perhaps the best way to measure resilience, the user of the guideline is only directed to two other articles for more information. Would you like to see more information in deliverable 1.1? If so what? This is probably a way to simplify a complex situation which is positive if it can handle the situation. I think it is good to look at this.

Q4. If resilience is not to be measured using simulations, specific resilience indicators need to be determined. Do you think the guidance given in the document is a sufficient starting point? If not what additional information would you like to have? If you are to develop specific resilience indicators for your transport system, or parts of your transport system, which types of experts would you like to have to help you? Why? I cannot answer this without a more deep study. I was involved in key performance indicators when I worked for UIC I Paris. It was a good way to understand what was important and what is not so important.

Q5. When using resilience indicators to measure resilience, one still needs to estimate the maximum possible reductions in service due to the variations in the values of specific resilience indicators. How difficult would it be for you to estimate these values? How would you go about doing it? How exact do you feel that the estimates would have to be? See answer on Q4.

Q6. Do you think it is reasonable to have the three ways to measure the resilience, i.e. through simulations, with differentiated weighted resilience indicators, equally weighted resilience indicators? Do you have situations where you would use each? If so please give an example of the situations. If not please explain why. I need more time to really understand the better. Answering on woolly I would say that test one first and evaluate before you go to the others.

Q7. Do you think there are any generic resilience indicators, or indicator categories, missing? If so please give examples. No since it is very complex and every situation is unique.

Q8. An indication of resilience can be obtained by looking at the percentage of fulfilment of the resilience indicators. In which situations would this information be helpful to you? It applies especially to when you plan and prioritise preventive measures. See also final comment.

Q9. Can you imagine developing specific indicators for your transport system? Yes. Can you imagine developing specific indicators for specific situations for your transport system? Yes. Please give a number of examples of what you think would be useful. See final comment.

Q10. Do you think that the measures of resilience could be effectively used in decision making in, and communication of decisions by your organisation? In which situations could you imagine them being used? See final comment.

Q11. What additional information do you find missing from the guideline? How do you see this information being added? First of all I must confess that I have not had time to read it in depth.

Final comment: I think a risk analyse approach is important. By using a risk analyse you separate the different stages "preventive measures" and "consequence reducing measures". By doing this you will make a structured analyse and see which are the most effective measures during the event chain.

University of Seville (Francisco Benítez)

D1.1

Q1. Most infrastructures are not single elements but items of a related set of elements, such it is the case of a network. The loss-of service (partial or full) of a specific item/element will affect the availability of the whole network in a more or less severe level. Therefore the resilience of a particular infrastructure item/element/unit has to be ensured taken into account the sensitivity of the infrastructure system it serves for. This assessment will vary according to the system the item belongs to (the same item, e.g. an specific bridge type, will have many different resilience levels, depending on whether it is part of network N1 or network N2). Thus, the "loss of service" has to be assessed taking into account the full system the infrastructure element belongs to. There are other many factors that might be implied by the concept " Resilience", aside of "service", such as "safety to users" (e.g. situations may arise where, for the same infrastructure, the service provided are the same (or similar) but some differences exist regarding safety to non-users (or for other sufferers: environment, populations…).

Q2. --

Q3. It would be advisable to include a section analysing the pros-cons of different methodologies (reported in the literature) regarding the explanatory variables used for estimating/assessing resilience (e.g. Serulle at al., 2011), and a concluding summary supporting the chosen approach. I see this point rather limited.

- Serulle, N. U., Heaslip, K., Brady, B., Louisell, W. C., Collura, J., 2011. Resiliency of transportation network of Santo Domingo, Dominican Republic case study. *Transport. Res. Rec.*, 22-30.

Regarding simulation methods, the literature contains a multiplicity of them. But this is not addressed in D1.1. I envisage, it will be properly tackled in a later Deliverable.

Q4. I refer to comment to Q7.

Q5. ---

Q6. –

Q7. From the literature on Resilience, many indicators have been conceptualised. Some of them have been taken as first level from an explanatory point of view:

Redundancy: Capacity of the system to provide high levels of functionality based on alternate options

Maintainability: Capacity of the (managerial) system to restore their funcionality.

Availability gradient: The speed a loss of functionality can be recovered.

Robustness: The endogenous capacity of the system to resist a level of stress without an appreciable loss of availability and functionality.

In order to choose the final set of indicators, a prior a) review of used indicators is a must, and a founded reasoning of the final relevant indicators to be used along FORESEE is needed.

Q8. Agree, as long as the number of indicators frames the explanatory measurable variables which map Resilience.

Q9. Of course, for instance, in maritime infrastructures, tide levels and water temperature and salt contents are explanatory variables affecting the Resilience of docks (e.g. affecting concrete life).

Q10. --

Q11. A specific section on methodologies and approaches on:

Relevant (pre-explanatory) variables data collection.

Data analytics.

Resilience data-driven inference.

D 1.2:

Q1. They have to be related to those resilience explanatory variables. This refers back to previous comment to Q7 from last section.

Q2. Well…it is hard to know; mainly because lack of data regarding past cases. But sooner or later this is also a must. For instance, railway and road infrastructures (among other infrastructures) quality are driven by standards limits. Similar approach will follow to define resilience standard limits. The only drawback is that this stage is not enough developed.

Q3. This can be done. It is a common tool in statistics; one can always define composed variables, which can be taken as explanatory variables of the dependent one.

Q4. –

Q5. --

Q6. Yes, I agree. To assign the propose weights is another question…in order to fir the adequate weight, enough data should be available (dependent and independent variables)…otherwise everything is limited to an "academic case".

Q7. Hard targets are related to users time and cost (generalised cost) and safety, soft targets to repair cost (up to a limit). There are other externalities (related to environment variables, socioeconomic factors) that should be properly weighed.

NCSR Demokritos (Thanasis Steftsos)

D1.1

Q1. In principle is a very interesting metric provided that you sort out details like:

If transport operator invest in resilience and build defence barriers which result in no impact from hazards and no service lost, how do you differentiate against baseline?

In case of a single transport asset impacted, the city/urban/highway system will work but at a reduced capacity. How resilience is defined then? For asset level, or operator level, *or city/region/administrative level?*

If hazard time scale is well beyond a year does the yearly

Q2. Very interesting approach. In EU-CIRCLE we use a new metric to quantify the 5 resilience dimensions: anticipate, absorb, cope, restore and adapt.

Q3. More clarification, please. Question not clear. A state of the art review would be the profound and right answer, critique on existing indicators.

Q4. See previous. Simulation is not always the obvious choice and there is also the element of accuracy and validation that needs to be accounted for.

Q5. As previous, resilience is not only about loss/reductions, is how "well" and "fast" you bring services back.

Q6. –

Q7. --

Q8. Nice one, but you need to provide a weight recommendation.

Q9. A generic solution is my preferred option more elegant. Only Correct solution as common indicators should be able to compare different solution/situations/hazards.

Q10. Resilience ISO. Very hard to communicate resilience yet.

Q11. --

D1.2

Q1. Those that quantify risk. Risk and resilience should be aligned. In the report the difference/similarity between the two terms is not clear.

Q2. --

Q3. Operator policy should define the target values. Nothing more nothing less

Q4. Company BoD.

Q5. –

Q6. –

Q7. –

7 APPENDIX B - 2ND SRG WEBINAR NOVEMBER 14TH, 2019

Comments from SRG

Contributions from SRG members after the 2nd webinar

ASFINAG (Karl Engelke)

Q1. As a highway operator ASFINAGs main-target is availability, which we measure indirectly by the duration of traffic jams (in hours) on our road network. We do not consider evasion traffic on low-ranking roads. Which makes our approach not very useful to the foresee project. We actually do not have a target for traffic jam hours, we just try to keep it on a low level. But if we would set a target it would be by expert opinion. We use cost-benefit analysis only in specific projects to make decisions between different variants (including the variant "do nothing")

Q2. No, because the measures to be taken to control this indicator could be costly, so a hard target will not be accepted. Presumably there must be different targets for different road sections. For monitoring the percentage of fulfilment will be a good method to prioritize projects.

Q3. No

Q4. No

Q5. It depends on the targets, we cannot say this now

Q6. Yes, we would try to balance the weights on past events

Q7. A hard target for us is the death probability by natural hazards. It must be less than 10^{-5} (personal risk of an individual traveling a section 4 times daily for a year) otherwise we have to build protection structures, regardless the costs. A soft target is availability. We badly want it, but we have no actual target level for it.

Q8. No, this resilience indicators should be defined / monitored by governmental organisations. ASFINAG cannot decide measures on low ranked road networks.

Deutsche Bahn DB Umwelt (Michael Below)

Q1. In our company the most important target is punctuality based on monitored data (Unit: delays in minutes), beside this is based on both expert opinion and cost-benefit analysis. This general monitoring parameter is not mandatory linked to natural hazards (could be due to failure of trains/ electrical infrastructure installations/ … and it is due to the public and political awareness. We started with the expert opinion in the vegetation management first. Then a first approach for cost-benefit-analysis in the vegetation management was made. It was related to delays – so fare it is not really successful due to the high local variability of storm events. Therefore, we try a new approach looking at certain technical installations/ components related to its failure and link them to certain weather conditions (hope to have some more results at the end of 2020).

Q2. It could be very helpful, if the targets/ parameters are linked to concrete disturbances/ failures of technical installation/ components of the network (but I guess, this has to be done by every company itself - identifying critical installations/ components). Because in this case, you are able to control/ avoid such kind of disturbances by changing/ using the identified and critical components. Hence the higher the percentage of usage resistant components the higher the resilience will be – best case: 100% usage of resistant components = 100% resilience. Starting from this each company will be able to define their targets e.g. 90% resilience for component X and so on.

Q3. It could be helpful to have cluster of indicators/parameters (like for electrical components, mechanical component, constructional parts and vegetation) as information for the management board, but therefore one should know, in which amount every indicator/parameter is contributing to the whole cluster – otherwise it makes no sense due to the fact that you are not able to control it resp. to identify the most important ones.

Q4. I would say no, because so far, the guidelines are on a generic level, and we, in our company are already trying to find detailed parameters, having an important impact of our main target (punctuality/ reliability) and in follow, which of those having the most impact. I think, we are one step further…

Q5. Actually we are talking with the different stuff in our infrastructure group meaning, people from the vegetation management, signaling, track construction, catenary,… And in combination with climatic/ weather experts we try to identify the natural/ climatic conditions affecting the infrastructure and link them to the technical experts (for what is technically possible resp. the economic effects…). This process we would like to start next year.

Q6. Of course, you need such differentiation due to the economic effects/ efforts. As I already mentioned in question 1. For me, it is a weighting between the importance of a parameter (like the (economic) effect on the whole network), the economic efforts to avoid it and the probability of occurrence. I guess a company would focus first able on "quick wins" (relative low costs and high benefits, if possible) and then proceed stepwise with parameter having high effects on the network but with increasing economic effort to avoid them.

Q7. This question is hard to answer, and it is more or less my personal perspective due to the fact, that we haven't defined hard or soft targets in our company yet, except the punctuality (as a more general (overall) target). Therefore, for me hard targets are indicators which occur very frequently, having an (high) impact on the network and which are well located. Hence you have the chance to deal with it. Soft targets could even have a huge impact as well but are very seldom and they could not be avoided by the company alone e. g. flooding, where third parties must be involved.

Q8. Of course, they might be very helpful in discussion with customers, NGOs, politicians and other stakeholders. If a company is showing, what are the important parameters/ indicators to increase resilience and what the company is doing to increase it, it will help in discussions about supporting the company with money, within the planning process, if constructive measures are needed and last but least to increase the tolerance of the customers, if an unavoidable event occurs…

Q9. For me the guidelines of such generic level cannot provide detailed procedures (as mentioned by me above), this has to be done by each company itself. It might be helpful to provide some detailed information as examples – even it is theoretically – to underline the importance and give hints for the management, how to proceed.

Federal Railways SBB (Thierry Pulver)

Q1.

Targets through expert opinion for…

- Non-constructive prevention measures (e.g. patrols for suicide prevention)
- Shape of decrease in service (e.g. definition of minimal service level and minimal restauration time, requirements for contract with carrier for "Bahnersatz" as maximum setup-time for alternative service)
- Maximum allowed restoration time (e.g. linked to adaptability of clients to shift to othertransport systems)

Targets through benefit analysis for …

- Constructive prevention measures (e.g. variants of assets for alternative routing)
- Constructive measures to alter the shape of service curve during restoration (e.g.variants of "Spurwechsel" on routes)
- In short: wherever there are design-principles that apply.

Q2 Yes, I think it is reasonable to set targets on the resilience curve (e.g. MTTR on route level); preferably leading indicators (as time, not cost); how long after hazard event alternative transport is at service, or how long after hazard event alternative routing is available (see Rastatt-hazard as example), how long additional travel time per client is acceptable during service restauration,…

Q3 If this means being able to define interdependent targets (e.g. assuring that reduced service level is shorter than X hours and intervention costs is less than Y, then yes, otherwise I do not see the application of it; or I do not understand correctly the meaning of setting "targets for categories of indicators as a block".

Q4 As stated in an example above I've been missing the view on preventive aspects, but this might be completely out of scope.

Q5 Operations, maintenance and intervention teams, timetabling, route as well as technical asset managers; over crossfunctional commitment as well as service levels with owner.

Q6. Committed hard over imposed soft targets.

Q7. e.g. condition state of assets as a soft target (relates to performance/availability of assets), delayed minutes of single trains/passengers as a hard target per route including rolling stock, not single asset types (relates directly to expected service level by customer).

Q8. Yes, decision making for capex and opex must be linked to resilience.

Q9. Deterioration of assets over time (thus impact on performance) and interdependencies between assets (e.g. complexity-factor) are important aspects that are taken as static in the guideline; resilience model should be linked to usage and deterioration models.

FERROVIAL (David Delgado)

Q1. I think it depends a lot on the data you can gather, and even more in how real is that data or, on the other hand, what is the level of estimation of the data. When you are capable of quantifying both benefit and cost in a very real manner, this is obviously the best way to do it. However, if you do know the cost of certain prevention measure, but you do not know how to measure the real impact of a hazard occurring and therefore, you have to estimate it, you might be comparing a cost which is real against a benefit that is based on estimations and assumptions that might be realistic or not, so at the end of day there is always a level of reliance in experts opinion. When both of them requires a high level of estimation, at the endof the day we are in situation number one, i.e: experts' opinion, assumptions might be wrong and the quantification of benefit and cost completely unrealistic.

Q2. Yes, I think it is reasonable. Values of indicators and percentage of occasions in which these parameters remain in the set values are a good combination so we allow infrastructure managers to have some room/ flexibility and make compliance requirements realistic. Sometimes keeping the same level of service as a constant value with no drops may be impossible. We must accept decrease in level of service may happen no matter how prepared you are, and there is always a budget constraint which involves certain risks are accepted. Traffic related matters are a good example of this. The rating of the state of a bridge for example is a value of an indicator that could be considered like a constant value you can and must maintain.

Q3. I think target values are always better to be considered individually unless a couple of indicators are very directly related. Categories are definitely too broad to be considered as a block because you might be performing very well in one specific indicator and poorly up to an unacceptable level in other one.

Q4.

Q5. The people responsible for the design of the infrastructure, because they know what the infrastructure was design to withstand under what maintenance conditions; The people responsible to set the maintenance budget, because they must accept the level of service the infrastructure can provide depending on this budget; The people responsible for actually carrying out maintenance tasks, because they can put a price to maintaining a certain level of service.

Q6. It can be useful in some occasions, particularly when there are no penalties involved in not compliance, or when some incompliances might involve penalty but others are completely unacceptable and therefore must involve termination of the contract.

Q7.

Q8. I think they would be useful for our clients definitely. They could be useful for us as well if it helped us to make them understand the risks they undertake when they do not carry out certain refurbishment or improvement/maintenance works.

Q9. Recommendations on which groups of experts would be necessary or recommended to provide with their input to set for the target values (similar to question number 5). References to what to do when budget is a constraint (which is most of the cases): how to accept the level of service has to be maximised in the BC analysis within the limited budget by undertaking the actions that provide with maximum B-C.

HCTRA (John Tyler)

Q1. Each situation that we have experienced has been a bit different, impacting a different location of our system. Mainly from hurricane impacts or flooding. Setting targets by experts would be good goals to obtain, but a cost-benefit analysis would be important for improvement planning. An agency may not be able to implement all that is required at one time due to costs.

Q2. It would be the goal of every system to be in compliance with the targets, but what if the targets are surpassed by the event. Does that shift the targets? This is similar to code issues. The importance of a certain element to a system should be a factor in determining the indicator.

Q3.

Q4.

Q5. Setting targets will be done by the responsible organization. The target goals defense will be determined by the organizations need. Setting parameters to allow an organization to determine their goals is the purpose of the document.

Q6. Yes. The weights should be based upon the impact to the system if the portion of road is not available. Each system would need to do its own self-assessment to determine the type of target.

Q7. Hard targets could be bridges, connections to other highways. Soft targets would be elements that could provide a minimum level of service during or after an event, while waiting for a repair.

Q8. Yes. Data is always helpful in determining a direction to go. If multiple projects all currently fall in one category, the indicator could provide a separation for how to move forward.

Highways England (James Codd)

Q1. Targets should be based on levels of service, rather than based on intervention costs, as the service delivered by transport network is to provide safe and time-efficient customer journeys between A and B. Costs need to be understood to deliver this service but are not used to measure it. Relevant targets that we currently use are based around a safe network (i.e. no. of users killed or seriously injured), user satisfaction, network availability and network condition.

Q2. Targets will need to be set by the organisations responsible for the transport networks and their stakeholders.

Q3.

Q4. The reference to the condition state of bridge is confusing – is this framework intended to be used on all infrastructure or just bridges? Similarly, the reference to seismicity seems biased and in significant areas of Europe, largely irrelevant – what about other more universal environmental conditions?

Q5. Stakeholders to include user groups/customers, the regulator, national government and asset specialists/subject matter experts.

Q6. Would it be more realistic to have different targets over a defined period of time, to measure or track progress over e.g. a year, rather than hard/soft?

Q7.

Q8. Yes, resilience indicators could be used to measure the performance of a service provider and to measure improvement over a period of time i.e. as a performance indicator.

IFSTTAR (Sylvain Chateigner)

Q1. The chosen target may depend upon the stakeholder or the concerned service. As raised Example:

- the target "minimum travel time" (expert opinion) may be useful for a service dedicated to traffic management.
- The target through cost-benefit analysis will be useful for a service dedicated to budget allocation decisions to priorize investments.

The WG2 report of COST action TU1406 (available here: https://www.tu1406.eu/wp-content/uploads/2017/11/tu1406_wg2.pdf) details targets at strategic, tactical and operational levels, with description of objectives in each case.

Q2. The resilience is not associated with a single indicator. It may thus be difficult to set a target on this, especially if it is needed to associate weights on indicators. To put targets on the resilience curve, it should be known in practice which are the values generally encountered so that one can identify realistic targets afterwards.

Q3. If there exists some recommendations (guidelines) with given sets of indicators. This may be useful. From past experience, one can indeed group categories of indicators covering similar aspects. Again, see the WG2 COST report (link provided above) that identifies the five following performance aspects: Reliability - Availability- Economy - Environment- Traffic Safety.

Q4. I was wondering whether there could be some indicators related to redundancy. This may exist at the scale of a structure (robustness) but also at the scale of one transport network, or at the scale of several transport networks. There could be perhaps some proposal for a redundancy indicator that would take into account the different ways to access from point A to point B in a certain amount of duration.

Q5. This seems to be the key point of the approach. First, a clear view of the boundaries of the system will be needed to identify the stakeholders: a) Infrastructure managers (technical services, but also traffic services and budget services); b) Users; c) Main companies that may be entitled for emergency interventions.

The different types of actors (operational, tactical and strategic) levels need to be around the table to deal with the various aspects of this problem (short-medium-long term perspective, from component to system then network levels).

Q6. A similar question is raised when talking about LCA (life cycle assessment). Yet, I am not sure that the ponderation will be easy to settle, therefore I do not think that it should be carried out. However, there may be hard targets and soft targets with no ponderation. See the WG2 COST TU1406 to see how some tools have been implemented (in particular the MCDA namely Multi-Attribute Utility Theory (MAUT) by using the R Utility package) on some case studies.

Q7. A hard target may be a maximum duration of travel time. A soft target may be themaximum duration of network recovery.

Q8. Some of the proposed indicators are already used in decision making even if it is not called like this. Most of the time, these indicators are referred to in a qualitative way. The concept of resilience may propose a framework to gather all the considered parameters during decision making processes (in a quantitative way).

Q9. An introduction dedicated to the help with the boundary's description may be added. This will ease to clarify the applicability domain of the guide, and will help the stakeholders to do this methodology on their own network.

KRATON POLYMERS (Laurent Porot)

Q1. Time to release the traffic; Speed limit reduction; Passenger / goods time value, I mean on secondary road with 10 travelers by hour should not be ranked as intercity highway with 10000 travelers/h.

Q2. Yes.

Q3. Not necessary.

Q4. Not as far as I can see now.

Q5. Traffic manager, PMS.

Q6. Definitively and maybe working with risk matrix analysis combining occurrence and severity, I mean high severity which will occur once every 1000 years should be weighted lower than medium severity with high occurrence.

Q7. Sorry I don't have.

Q8. Yes.

Q9. So far good approach.

NCSR (Thanasis Sfetsos)

Q1. Firstly one has to fame the problem is working with (= resilience of the transport network) . some questions to define this could be:

- Resilience of what – the context which is critical infrastructure, their networks and interdependencies – could be a bridge, a highway, a city, an urban network, interconnected transportation networks
- Resilience for what – the disturbance which is the hazards – both manmade and natural and compound events
- Risks and Impacts - which includes the consequences of a hazard and the likelihood of the occurrence – linked to service level & cost of the interventions

Q2. Yes, in my view linked to accepted levels of risk (e.g. 100 flood); My perception on a resilience transport network:

- if hazard below design hazard level (or acceptable level of hazard) then service level should be 100%
- if hazard over then it should be at defined level

Q3. Question not clear, but based on above comment then yes.

Q4. Also, a very critical indicator is "recovery time". = how fast the network will return to normality. This shifts resilience curve ends more left if the operator manages to efficiently respond to the hazard. Timely response

Q5. In the following order: Government through national law; Operator; Other infrastructures through service level agreements; Customers

Q6. Yes, but is not mandatory.

Q7.

Q8. In certain decisions it is already used but not in the coherent way that the foresee projects has defined it.; Resilience for investment

Q9. Once final version is made can respond to this question

TECNALIA (David García Sánchez)

After reviewing D1.2 and D1.3, I would like to share some comments:

- D1.2 is for operational issues. Is technically well done. My only concern is that, according toDoA, is totally focused on the last phase of the life cycle: the service, operation and the maintenance. That's why they exclude, for example, environment indicators as target indicators "because they are outside the sphere of influence of the infrastructure operator" (pag 15).
- D1.3 is for strategic issues. It has to cover the whole life cycle.
- And that's the problem. The parameters, measures, indicators proposed in D1.2 are totally focused on the operation and maintenance.

From my point of view, and after reviewing the shared docs, I think D1.2 should include a point explaining the approach to the different life-cycle phases although it is focused on the operation one. The real challenge is to stress the consortium to think globally.

Trafikverket (Johan Jonsson)

The questions in the document are very detailed and almost impossible to answer. I would put it in another way and give a more general answer. As an Infra Manager (IM) I would propose to discuss this from a capability point of view, where the capabilities are connected to the role of the transport system in society. In many ways the capabilities are technical, so they describe "what should the future technology-enabled infrastructure be able to do?" A capability is independent as concept, but inter-dependent in terms of real-world outcome. Furthermore, a capability does not define a precise technology. The choice of capabilities is also very much a political decision as they set the tone in which direction society should develop. Once capabilities have been defined, guiding objectives could be formulated to include the whole infrastructure lifecycle, affordability and of course resilience to natural and man-made hazards, including adaptation to climate change. For an IM the "how" in infrastructure governance,balancing benefits for the economy, society and environment are central. For each capability a strategic context can also be formulated and then developed into a challenge.

Targets cannot be set until an IM has an understanding of end user needs (i.e. mobility and logistics) and the possibilities to influence in order to provide satisfactory services and access to the infrastructure. Cleary, targets used today are limited, and should take into consideration the needs and requirements of the end users. Regardless of e.g. digital layers, transport infrastructure has to offer the necessary availability and service for end user in a reliable and a safe way. To cope with e.g. increasing traffic volumes a better ability to plan and organise construction and maintenance work with minimum interruptions at critical nodes i.e. bridges, tunnels, intersections and locks. In terms of management of accidents and incidents as well as for interruptions due to man-made or natural events, emergency plans need to be further explored to keep transport interference to a minimum. Different infrastructure users may have different needs, but the bottom line is that the IM cannot define these priorities, end users have to do this.

UIC (John Dora on behalf of UIC)

Q1. Currently main line railway organisations tend to measure the performance of the railway by recording the times that trains pass set points on a route and measuring whether the individual train is 'on time' or 'delayed' against a timetable[1]. Delays against the timetable can be aggregated along a rail route to show the overall performance. Public Performance Measure (PPM); Cancellations and Significant Lateness (CaSL) and Delay minutes were identified as key quantitative metrics with the National Rail Passenger Survey (NRPS) identified as a key metric of customer satisfaction for the GB railway network. However, these measures have limitations when resilience of a network or a route is considered, as recording delays against a timetable has little meaningful use when a timetable is changed owing to e.g. flooding causing a line closure. In my expert opinion and being informed by the TRaCCA report referenced, I consider that transport systems should have targets based upon a) the normal 'timetable' and b) the purpose of the system i.e. moving passengers and freight, rather than being related to trains v. timetable (what if the train is empty?). Ideally some form of cost-benefit analyses would be used; in the absence of CBA, expert opinion informed by stakeholder discussions would be 'permissible'.

Q2. *Do you think it is reasonable to set targets on the resilience curve*? Yes, bearing in mind what has been noted above. *The values of indicators*? Yes, but the expectation/ use of a reasonable timetable needs considered. *The percentage of fulfilment of the indicators*? Yes. *Please, give an example of each situation in which they would be useful*. I consider these would be good to use to start the process of discussion in order to initiate analyses, but do recognise these are subjective and a change process to improve indicators as practise and learning evolve. Indeed, my experience in Standards' development suggests that indicators and weighting thereof should be set in an Annex to the guidelines, allowing more frequent updating than for the guidelines.

Q3. Not sure I understand the question.

Q4. There is fairly comprehensive coverage however the target setting process ought to recognise how there can be a 'political' bias (how would this be dealt with?) and that 'traditional' economics theories are poor at justifying long-term resilience building ('future generations can afford more than current generations') and this can cause problems where e.g. resilience investment for climate change adaptation is required.

Q5. *Which persons would you require to help you set targets?* Interested parties including a range of experts in rail performance [those that understand both the immediate (day-to-day) and long-term (10+ years, out to the future – think 'asset lifecycle which can be more than design life) operational and asset management pressures and standards, customers (passenger and freight or representatives thereof). *How would you want to defend the targets you set?*We would want to discuss these with the interested parties and would consider the need to inform and brief these people so they understand the issues well.

Q6. I can foresee a range of hard and soft targets and assigning weights would necessarily be agreed with the interested parties mentioned in 5

Q7. Difficult to relate – extreme disruption requires a bespoke response and mobilisation of repair teams. 'Nice to have' ideas might not be thought of in the 'heat' of emergency response except maybe in terms of passenger comfort – offering water on delayed trains on a hot day

Q8. *Do you think that resilience indicators could be effectively used in decision making in, and communication of decisions by your organisation*? I can certainly see them being used toanalyse rail route or network resilience current and future (with climate change) so as to justify climate change adaptation investments. See UIC's RailAdapt[2] report and ISO 14090 Adaptation to climate change – Principles, requirements and guidelines[3]. *In which situations could you imagine them being used?* As part of a strategic planning process in rail organisations for long- term resilience planning, maybe with key customers or on critical passenger or freight routes (e.g. deep sea ports; city-scale passenger networks; key high-speed and inter-city routes).

Q9. My only comment is that this kind of information can be identified in actual, 'real life' practise of the guideline.

UNIVERSITY OF SEVILLA (Francisco García Benítez)

Q1. Pros & Cons of Expert opinion versus cost-benefit analysis:

	Pros	Cons

Expert opinion	Easy to get	Difficult to quantify the level of reliability of the opinions. Different experts may provide different target values. An envelope value for each target has to be agreed. The outcome can be easily questionable as affected by expert's subjectivity and degree of experience.
Cost-benefit	Is an objective/quantifiable measure.	It needs a sufficient dataset of similar cases to derive a reliable cost-benefit function. This is a task that might take enough resources (time and effort).

My opinion: Cost-benefit always, but supervised by experts. This a procedure long implemented in transport infrastructure projects.

Both cases (cost-benefit and experience) should be taken in consideration simultaneously.

Q2. Yes, targets on resilience curves should be specified. Improving the resilience of infrastructures is the main objective of the project. So, setting target and indices are a must. In road and railways, for instance, there are a multiplicity of normalised indexes which pursue the riding and safety quality are preserved. The same guidelines should be followed.

Q3. Sometimes using compendium indexes is also convenient, this is the case of Overall Quality Index in roads/railtracks, which aggregate a set of single indices in order to facilitate a fast evaluation of the infrastructure; but this is a first step that do not eliminate the further task of analysing single indices one by one.

Q4. It is hard to give a response to this question. There are many different type of infrastructures. Terminals, for instance, work in a different manner that airways, roads or signal/communication systems. Each of those systems, even when exploited by different entities use their own targets (on top of those compulsorily/normalised stated); this is the case of specific/proprietary Quality Indices.

Q5. Specialist in maintenance, rehabilitating and major refitting of transport infrastructures.

Q6. For sure. Any target could have a severity ranking associated to the infrastructure maintenance/administrator. In some infrastructures, as railways there is a three-level rank associated to maintenance alarms (Alert Limit AL, Intervention Limit IL, Immediate Action Limit IAL). A similar methodology should be followed for resilience targets. The rankings would reflect the affection of the resilience loss to the user/society, therefore they should be assigned taken into account this aspect.

Q7. For railway tracks, for instance, a hard target would be to surpass a specific level of a geometric measurement: level 1 for AL, level 2 for IL, level 3 for IAL.

Q8. For sure, this has been the way followed by transport linear infrastructure administrations (i.e. roads and railways) for long time. This also includes probability prediction analysis of further scenarios.

Q9. The guideline is too much generic. In order to be more specific, I would suggest to stick closer to the objective of the project and start working with real data sets as soon as possible. By working with real data, new challenges will bring up and clarify the path to follow.

ZAG (Stanislav Lenart)

Q1. It seems to me that a combination of two approaches would perform best. Thus, targets set by expert's opinion would be combined with cost-benefit analysis. For instance, design risk levels with perfect resilience (eg. level of earthquake that should cause no damage) should be defined. Above that level, costs and benefits of achieving the targets (eg. intervention costs needed to allow a certain level of service) should be estimated.

Q2. Yes, I do think so. Target could be understood as a value of indicator. When target is achieved, certain action has to be taken to provide the required level of service of infrastructure. If a condition state of an asset is an indicator, it should be defined at which condition state an intervention is needed and what kind of intervention.

Q3. It could be helpful to define for every indicator several targets with required actions (eg. what is the lowest level of condition state of an asset that can be reached, at what level a certain intervention is needed etc.).

Q4.

Q5. Targets could be set by infrastructure managers (those who maintain the assets) and users of infrastructure. Everyone knows best what level of infrastructure service requires actions.

Q6. If I understand correct, there are rather indicators that would need to have their own weights (not the target). Targets are just characteristic values of indicators. Indicator weights would be nice to have, but difficult to define. They could be used in cost-benefit analysis (not allindicators have the same importance). Probably, they should be defined in the agreement between infrastructure maintainer and infrastructure user.

Q7. Not sure.

Q8. As a research institute, we do not use directly resilience indicators for infrastructure. But some parallels could be found to the other types of services (testing of material, quality assessments etc.)

Q9. It is a little bit difficult to understand, but in general, I like the idea of service level indicators and setting targets as a kind of threshold service levels.

8 APPENDIX C - 3RD SRG WEBINAR JUNE 18TH, 2020

Comments from SRG

Contributions from SRG after the 3rd webinar

***The contributions included in this chapter reflect the opinion of the experts and do not necessarily represent the position of the entities they are working for*.**

ASFINAG (Karl Engelke)

Q1. This algorithm is very detailed und focus highly on costs. The probability and the effect of hazards on the other hand is a very rough estimation – so this algorithm seems to be quite elaborate compared to the accuracy of the result.

Q2. We use simulations (3D models) on the impact (rockfall simulations, avalanche simulations)to know which part of our network is actually involved. The costs are usually estimated with benchmarks

Q3. Our main target is a high availability of our Infrastructure, so the highest priority is to open the lanes as quickly as possible. If necessary, we build provisional structures (dams, bridges).

Q4. First the avoidance of injuries and fatalities and second the speed of restoring service.

Q5. There are detailed emergency plans and periodical trainings for our operating stuff in combination with emergency forces (rescue service, fire department and police) and the crisis management team. For restoration we have standard processes.

Q6. Presumably yes.

Q7. Cost are not our primary focus. First is always availability, then we optimise the costs.

Q8. We are following our strategy for natural hazards and so we are mapping all hazard points und danger zones. These are prioritized by experts from 1 (low risk) to 5 (high risk). All these points are regularly monitored. For zones with risks 4 and 5 we are doing simulations and if the risk of fatality is more then 10^{-5} we do erect protecting structures. When the fatality risk is lower the decision for protecting structures is maid by the economic efficiency (benefit/costs ratio).

Q9. We are just working on a risk-based approach, but the idea is to prioritise by the overall risk for our customers our staff and our infrastructure.

Q10. If we have to postpone a measure and we need a temporary solution, we calculate the costs for this.

Deutsche Bahn DB Umwelt (Michael Below)

Q1. The algorithm is adequate – the problem right now is, that we are not able to provide the right or better the needed numbers /data base to feed the algorithm. Hence it is difficult to calculate, what might be an optimal restoration program. We are working to improve the situation.

Q2. Actually, all the costs arsing within a natural hazard are summarized on different cost centers and companies, therefore we are not able to get a detailed picture of the costs linkedto the hazard itself so far. In general, the expected effect depends on the kind of hazard and theimportance of the railway line affected. Hence the measures implemented mainly follow the importance of the railway line. For example, the adaptation of our vegetation management focus on those lines, which are the most important once and may have a massive influence on the minutes of delay at the same time e.g. After this, the effect will be verified by measuringthe reduction in minutes of delay (due to this individual consideration it might even not be the direct effect or the right measure…).

Q3. In general, it follows the importance of the railway line (see also answer 2 before). This is mainly based on the number of passengers or the volume of freight transported.

Q4. In general, the most important issue is to avoid any injuries and fatalities for our company. After that, in case of a high priority railway line the most important measures implemented will be the speed of restoring the service. Due to the fact that our company is owned by the state with a strong legal obligation and even we are organized under private law the costs of restoration may not play such an important role as for a private owned company.

Q5. Due to the legal requirements we have to concentrate on that part of the lines with highest priority (a plan is hardly to develop for natural hazards, if their occurrence is uncertain and at the same time it depends on the type of hazard, the kind of disruption (falling trees are removed by our own local service providers immediately after the occurrence, while a damagedcatenary needed to be restored by an external company taking more time – up to several days),the importance of the railway line, the availability of construction companies/ service providers on the market if not bounded by contract).

Q6. We are working on it, but so far we do not have a fully complete picture on this – every single issue is evaluated on its own like temperature effects in winter for planning the deployment of the staff of our own regional service providers. Constructive measures of course have to be combined with other issues to reduce the time of closure for the traffic.

Q7. As mentioned within the webinar, it would be very helpful to take at least one more issue into account: The catenary system of the railway line, because this is one of the most sensitive and most often affected construction part of the high priority lines – especially due to disturbances from (thunder)storms. At the same time this part of a railway line is limited factor for the duration of interruption (a tree falling on a catenary block the line for a much longer time than on a line without catenary). And the most important railways lines in Germany are equipped with catenaries.

Q8. Actually, we are working on so called "hazards maps" to identify the lines /sections of the lines, where there it is likely that identified natural hazards may occur like landslides in mountain /hilly regions or a typical temperature regime in certain regions to plan heaters for switches /winter service. This information will be used for risk analysis beside working on betterforecasts due to the fact that wind as one aspect within this issue is almost not predictable. Thefocus is laid on railway lines with high priority.

Q9. The Deutsche Bahn must fulfill the legal obligations for a safe and function track for a save operation. Hence all measures within the maintenance having a positive effect on a more resilience infrastructure are already implemented (within the vegetation management e.g. as one task of the maintenance, all trees, which may disturb the traffic operation due to age and diseases must be removed). On the other hand, all measures outside the regularly maintenanceworks like constructive measures are separated from this, because they are financed by our owner, the state.

Q10. This seems a more theoretical view, because as long as we have no secure forecasts concerning the frequency of the occurrence for different natural hazards it is hard to make any statement.

German Center for Rail Traffic Research (Frederick Bott)

Q1

Network-related functions regarding the importance of the (railway or road) section (e.g. alternative routes, life cycle management of singular objects…) High flexibility and selectable parameter

Ecological aspects (e.g. noise/ air pollution).

Q2 ……

Q3. One way to prioritize the rail or road sections and objects is by the above mentioned: The function of numbers of vehicles that use the object. Another way to prioritize would be the division of vehicles in different types of vehicles and the related importance (e.g. heavy traffic share, special transports route, importance..). Consideration should also be given to integrating the network-related importance of objects and sections.

Q4. Maybe measurable in four different aspects of resilience: Prevent, protect, respond, recover If possible: Comparison to previous events without "intervention"

Q5 ……

Q6. Yes, synergies and object to objects relationships should be considered

Q7 ……

Comparison to previous events without digital support

Are indirect costs included in this algorithm (e.g. maintenance, integration of life cycle management of singular objects, network vs object, noise/ air pollution...)

Are chains of effects regarded (Event – Object – Network)

Early integration in existing procedures

High flexibility and selectable parameter

Clarity and simplicity of the algorithm

Q8. For example:

Manual field inspections or observations by e.g. drivers, track commissioners

Analog information (e.g. maps or zones of potential danger) as general information of potential risk areas

"Analog" life cycle management (e.g. age and exposition of objects)

Q9 ......

Q10 -----

Highways England (Angus Wheeler)

Q1. As the algorithm develops it would be useful if real world cost data could be incorporated into it.

Q2. Highways England use a proactive inspection regime which categorises defects based on the risk of an event occurring and the proximity to infrastructure. This grading, and the criticality of the route, is then used to prioritise maintenance activities over a 5-year programme. Highways England's asset is within a geotechnically relatively benign environment, which means that most defects can be treated before the effect serviceability. Those defects which are unexpected are therefore relatively low in number and can be treated rapidly without having to resort to prioritisation.

Our geotechnical data management system also includes hazard layers identifying areas of potential geotechnical risk from sources such as the British Geological Survey and the Coal Authority.

To further enable proactive maintenance Highways England are currently undertaking studies of the deterioration of earthworks and related geotechnical features with the ultimate aim of producing a Decision Support Tool for prioritising repairs, including our drainage assets.

Q3. A number of factors would be considered including proximity to critical assets, likelihood of further failures occurring, criticality of route etc.

Q4. In Road Investment Strategy period 2 Highways England have a KPI "Geotechnical Asset Condition Performance Indicator". This indicator reports the proportion of the asset designated as 'Good' condition, based on its Condition Grade

Q5. As stated above Highways England has a relatively benign network in terms of geotechnical hazards, however we do have an extensive knowledge of the areas of geotechnical risk so can reactive quickly if required.

Q6. The Decision Support Tool that we will ultimately develop will consider both geotechnical deterioration and the condition of the drainage network.

Q7. Presentation not seen due to meeting clash.

Q8. As stated in response to D4.2 Part 1 we use a combination of proactive inspections and data hazard layers to determine areas of our network most at risk, enabling us to prioritise interventions.

Q9. The risk reducing interventions are programmed over a five-year period enabling the"event" interventions to be minimised.

Q10. The costs of planned interventions are built into our forward programme. High risk sites are treated as a priority; however, a detailed analysis of the effect of postponing any interventions is not currently carried out.

Irish Rail/Iarnród Éireann (Fiona Kelly)

It is difficult to fully answer these questions in terms of cost of remediation subsequent to failure as IÉ's priority is to prevent the failure from occurring in the first instance and thereby preventing injury or fatality to their passengers. As such IÉ operate their maintenance works primarily on a preventative basis my implementing mitigation measures to reduce the risk. Works following the occurrence of failures is purely reactive to the individual evolving situation. However, as a result of the imitation measures and current risk management processes, the occurrences of such failures occur infrequently. Therefore, the Indirect cost of failure is generally not considered when analysing the risk of failure occurring.

Q1. Iarnród Éireann/Irish Rail currently use simulations to manage risk and implement mitigation measures to ensure the safety of the network. As such all interventions are undertaken as a consequence of risk. Restoration time and cost do not directly impact on this as the priority is to prevent derailment and subsequent injury and/or fatality to passengers. Where a potential risk is imminent, Irish rail do impose the necessary line speed reductions or closures as deemed necessary to ensure the safety of passengers. The cost of these reductions in speed or closures are far less than the cost of derailment.

Q2. IÉ manage all earthworks employing a Decision Support Tool (DST). All earthworks on the network are inspected for condition and defects on a cyclical basis. The data base for earthworks is updated following these inspections and inputted into the DST twice annually to determine the risk of each individual structure. The DST analysis the earthworks geometry, geotechnical characteristics and degradation factors to determine the hazard which might be imposed. The risk is then calculated based on the likelyhood of material fouling the railway line for various Met Éireann Rainfall conditions ie. Normal conditions and Yellow, Orange and Red Rainfall alerts. This DST further employs a Cost Benefit Analysis Tool capable of analysing each earthwork for the associated risk reduction obtainable by using various mitigation measures and/or remediation.

Q3. All occurrences of natural hazards which pose a risk to the railway and the safety of passengers are remediated without delay.

Q4. The avoidance of injury and fatality is top of IÉ's agenda at all times.

Q5. As mentioned in point 1 above, IÉ have a budget in place for emergency works at all times. IÉ's cyclical inspections of all structures and implementation of a DST enable maintenance works and mitigation measures to be undertaken in order to prevent such occurrences. All plans are preventive at present.

Q6. The algorithms do not consider synergies between components, all structures are analysed on an individual basis based on the structure type. The failure of any structure will result in a line closure. Such a line closure (as a result of failure) will occur based on the weakest link i.e. the structure in the poorest condition.

Q7. IÉ currently analyses risk reduction interventions using a Cost Benefit Analysis (CBA) tool which is part of the DST for Earthworks. The CBA analyses the risk reduction of failure of the earthwork based on various mitigation measures eg. Drainage works, regrading works etc. All works are prioritised based on the Risk Ranking output of the DST, which as mentioned previously, analyses the Hazard (probability of Failure) imposed by the structure and the consequence of failure (likelyhood of failure affecting operations). IÉ intend to employ a similar type of DST in the future for their bridge structures.

Q8. IÉ currently do not use digital support for the management of their bridge structures. All bridge structures undergo cyclical inspections to assess their condition. The structural inspector dictates any required works which may be necessary and assign priority ratings for these works. Bridge over water further undergo a cyclical scour inspection programme with a Scour Vulnerability Rating (SVR) system applied. The budget is then assigned to the highest priority or highest risk structures, mitigation measures will be implemented where possible so as to achieve the maximum risk reduction of all these structures across the network.

Q9. Due to budgetary constraints, risk reducing interventions are the primary method employed except where the structure has significant issues and is deemed to be at the end of its life span.

Q10. If the work must be postponed and the risk is imminent the asset will be assessed a temporary speed restriction may be implemented. If a temporary speed restriction is insufficient to prevent the consequence from occurring, the section of railway will be closed, and alternative modes of transport will be introduced. Please note the safety of the railway is paramount and postponement of works for imminent risk rarely occurs due to the frequent inspections and mitigation procedures IÉ currently have in place.

NCSR (Thanasis Sfetsos)

General remark: Figure 1 of D4.2 may not be accurate in all types of disasters. First the situation needs to stabilise before engaging / allowing restoration team to move into an event (incident) scene.

Q1. Present solution is adequate to reflect risk with simulations.

Q2. Must be some sort of simulation or pattern matching against historic conditions. No other way possible.

Q3. 1) Flow diversion to ensure max continuity level at network level; 2) existence or material and spare parts; 3) time to full restoration

Q4. Safety of personnel, restoration of service (service flow), economic cost, environmental hazards

Q5 ......

The approach in Part 2 with the three organizational levels is very good

Q6. Yes, fully interconnected approach between different objects

Q7. Algorithm is very promising

Q8 ……

Q9. Add different cost function / objective and also consider the effects of time.

Q10 ----

PIARC (Miguel Caso)

Q1. The algorithm is designed to assess any linear transport infrastructure (e.g. roads, railways, waterways…) which is a positive approach, however, some specific aspects should be customize for each transport mode. From the road perspective it would be essential to include injuries and fatalities during the disaster, but also road safety during recovery phase, for instance if the deviation itinerary has lower road safety standards. Currently, road sector is very careful with GHG emissions so a part looking into the consequences of GHG emissions during the disaster but also during recovery phase would be much appreciated.

Q2. Several road administrations from PIARC membership have a limited approach, and they just evaluate risk in on single objects, without integrating the effects and resilience of the whole road network.

Q3. In the road sector fatalities and injures have come the top preoccupation, followed by impact on economy and mitigation of climate change by reduction of GHG. Therefore, the prioritization could be something close to:

Avoiding fatalities and injured during the disaster.

Avoiding fatalities and injured during the recovery phase, including deviation itineraries.

Minimizing costs for road users and local/regional/national economy (this includes a combination of traffic volumes, deviation itineraries, accessibility, etc.).

Minimizing costs for road administration (from a global perspective this aspect could have lower prioritization but from practical aspects and budget restrictions this is probably where it is, maybe even upper).

GHG emission during disaster and recovery phase.

Road user expectations (reputation of road administration and local/regional/national governments).

Q4. I would use indicators adapted to measure the priorities on point 3.

Q5. Within PIARC membership the reality is very different. Countries subject to regular natural hazards, such as earthquakes in particularly, have more extensive and reactive procedures. Most of these countries are outside Europe, such as Japan, Chile or Mexico. Japan bases its plans in high technological preparedness and reaction, with permanent monitoring, countermeasures during construction and large use of UAS (drones) to monitor impact quickly after the natural disaster. Chile's strategy on top of countermeasures during construction, it includes a task force for reconstruction right after the disaster which is integrated in the Ministry, being one of the few HIC to build with Ministry employees and equipment road work under normal operation, when this task force is not mobilize for a natural hazard (it represents around 10% of the annual roads works of the Ministry).

Q6. I do not know these details used inside PIARC member countries.

Q7. Comments are similar to the first algorithm, if we adapted to road sector, on top of economic costs and benefices, plus budget availability, we would also need to take into account road safety and environmental considerations aspects of different risks.

Q8. I do not know these details used inside PIARC member countries.

Q9. Through cross assessment budget allocations. Budget constraints are a common reality within road sector since at least 2008, so road administrations are used to cross assessment among different assets, interventions and risks.

Q10. I do not know these details used inside PIARC member countries.

Rijkswatersaat (Léon Schouten)

Q1. As far as I know Rijkswaterstaat does not really use simulations to evaluate risks that are due to natural hazards. We do look at the scenarios that have been built by our MetOffice (KNMI) that portray possible outcomes of climate change and how these scenarios will impact our road network. But climate change is a different kind of natural hazard than the ones that you look at. In my opinion we deem the chance these kinds of natural hazards occur too small to assess their possible impact on our network. That is not to say that will remain this way. I think a study like yours can influence our way of thinking. But we need to know what kind of natural hazards we are talking about. In general, we tend to look more and more at the network function of our roads: even though one road sections may be out of order, is it still possible for our 'customers' to travel from A to B? The direct connection may have a drop of service level, but if cars use a different route, they are still able to reach B?

Q2. Again, as far as I know we distinguish between time that the road is available to the public (to traffic) and time that the road is not available to traffic. The latter is then further divided into planned non-availability (e.g. to maintenance) and non-planned non-availability (e.g. to incidents and other unforeseen events). The cause of the non-planned non-availability is not really important; the ambition is however to minimise this at much as possible. Furthermore, we have classified our roads in 4 categories. These classes range from crucial (like ring roads around our most important cities) to major roads that connect provincial areas to our network. For the crucial roads (called network category D) non-planned non-availability must be prevented by all means and hence we look at the possible risks that can be identified and take precautionary actions. Natural hazards rank low as source of these risks.

Q3. Normally I would expect that RWS prioritises according to the network categories. Road sections with category D have the highest priority and road sections with category A the lowest priority. Bu if multiple road sections would fail at the same moment, I think it is likely that politicians will intervene and that they determine the ultimate priority sequence of the objects that need to be restored.

Q4. The speed in which the services are restored is definitely an important parameter, but safety guidelines will always define the preconditions under which restoration activities willtake place. At the same time, I think it is very likely that we (RWS and policy makers) will assess if we can confine ourselves to a restoration of the old service or whether we need to restore according to an updated service level.

Q5. I do not believe we have meticulously elaborated plans that will help us if we were to be confronted with a dramatic drop in service levels. We do have regional teams that can provide technical assistance in case of a severe incident or calamity on one of our three networks:

Q6. I am not quite sure if we have indeed algorithms at hand for such scenarios. However, I think I made it clear earlier that RWS looks at the network function of our road's sections and objects. And hence we do look at the context in which objects operate and how they arerelated to one another.

Q7. I haven't had the time to read D4.2 part 2 in its entirety (partly because the case deals with a rail network) and therefore I am not quite sure what "risk reducing interventions using digital support" is supposed to mean. If it covers simulation models that e.g. model the degradation of roads (or rail networks), then we are interested. We support various initiatives to develop such models. If one (or more) of these initiatives is successful we have the means to explore the factors that impact the degradation and hence come to recommendations that will help reducing this impact. More than in railway infrastructure (I guess) we are confronted with a variety in the as-built quality of our roads. If the variation in quality of the newly built pavements is not captured by a model, then we, or at least I will treat the model with the necessary reservations.

Q8. At this moment empirical business rules play a dominant part in these decisions. These rules are written out in internal documents in order to ensure that they can be passed on to new employers.

Q9. Sorry, I am not comfortable answering this question. To some extent – I think – we shall look at the network categories. But I also think that "normal" interventions are to a certain extent covered by regular contracts that we have to ensure that the service level remains in tact. And in that case, they do not compete in the way that you seem to think.

Q10. To the best of my knowledge risks are quantified by guestimation: experts give weight to identified risks. But postponing an intervention one planning period (5 years) is in road maintenance extremely unlikely. I do not know if that is imaginable in the maintenance of our railway network. That is a question for ProRail to answer.

Transport for London (Fiona Thompson)

Q1. TfL are not at a sufficiently mature point to comment on improvements to the algorithm. We need to look at how we could begin to use such simulations.

Q2. For London Underground, effects to service are modelled using Lost Customer Hours, which are evaluated as a function of the numbers of people expected at each location on the network and time of day in 15 minute intervals. This total lost time is multiplied by a Value of Time (e.g. £9.81/hour) to assign a monetary cost. In practice, for Civil Engineering assets such as embankments or bridges the duration of disruption is likely to be in days or weeks, so the total cost per day is used rather than considering the disruption at a particular time.

Restoration intervention costs are not included in the risk assessment at this point.

Q3. Availability of assets to offer full or at least partial service, ramping up to full. For example, following a partial collapse of an embankment, temporary works could allow a resumption of train service at low speed, so less Trains Per Hour.

Q4. The first priority is the avoidance of injuries and fatalities, followed by speed of restoring service, and then the cost of restoration interventions.

Q5. Our reactive plans, e.g. Emergency Preparedness Plans for specific assets and Business Continuity plans are relatively extensive.

Q6. We do not yet have risk reducing interventions evaluated to that level of sophistication.

Q7. TfL are not at a sufficiently mature point to comment on improvements to the algorithm.

Q8. Risk reducing interventions take the form of standardised inspection and maintenance regimes. When capital interventions are planned these are evaluated prior to selection, and amount of risk reduction is part of this.

Q9. With highly limited budgets, the standardised inspection and maintenance regimes form the minimum requirement. This is with a view to keeping the safety risk As Low As Reasonably Practicable. If these interventions are not going to be sufficient to meet this requirement then additional measures will be identified and implemented, e.g. remote monitoring, temporary speed restriction, temporary works etc.

If a partial service is re-established it is then desirable to restore full service by permanent works. For the whole life cycle benefit this should be at the optimum time as regards cost to mobilise etc, but generally is the shortest time possible. However, the customers and stakeholders may expect the full service back as soon as feasible and this can outweigh whole life cost consideration.

If a full service can be provided while keeping the asset safety risk ALARP through additional measures then we consider the annual cost of doing so as opposed to the capital intervention required and build the business case in this way.

Q10. At present we would have to predict how much the risk could grow over the given time, e.g. if an asset is going to be subject to natural attrition, or if the external risk could increase. As a minimum we would be holding the same risk for a longer duration, which may or may not be within risk appetite.

Transport Infrastructure Ireland (Billy O'Keeffe)

Q1. It is not clear just exactly how the algorithm will be populated. It is essential that it is user friendly and easy to input the parameters.

Q2. A basic cost benefit analysis is used.

Q3. We identify priorities mainly by AADT – there is little collaboration with other infrastructural stakeholders.

Q4. The speed of restoration and the time that the network section was not fully functioning appears to be the main driver.

Q5. That is a function of the damage – for flooding it is very quick but for bigger events such as bridge damage it can be a lot longer depending on the priorities.

Q6. Any interventions will have to consider synergies and cascade effects.

Q7. There is an assumption in the project that a certain knowledge of the asset database is available to all NRAs. This is not the case and it would be useful to define what level of knowledge of the various assets is required before using the various algorithms. For example we have a very good database on bridges and their current condition but not the same level of detail for culverts.

Q8. It is mainly reactive based on surveys. We are carrying out an extensive bridge maintenance program at the moment based on national scale surveys.

Q9. Simple priority procedure

Q10. Not aware that this process if this is carried out.

University of Cantabria (Javier Torres, David García-Sánchez)

Additional comments for future researches: Is there a way to evaluate Without Simulation, using the consequence of the simulation already made?

All activities have a Shape like «Function V».

In this «V Shaped Function», the objective to be optimized, the risk and the network are contained.

«V Shaped Function» for any Activity has four or five variants that should be determined based on the position of the Peak and the Amplitude.

Identify what type of «V Shaped Function» each KPI has.

Identify what type of «V Shaped Function» each Alternative has.

Q1. Cascade effects are also a risk to bear in mind. How to proceed using this algorithm? How do you consider the correlation/concatenation of different risks?

Q2. By experience and KPI evaluation. Data Analytics.

Q3. It has to be as holistic as possible and multivariant.

Q4. Also, periodicity.

Q5 ......

Q6. It is mandatory from my perspective to consider synergies (as mentioned before).

Q7. It looks quite static. Obviously, this algorithm provides intelligence for the decision making but in a digital platform it doesn't see clear the integration of weather information or other services.

Q8. Based on experience and the repetition and periodicity of events.

Q9. Bearing in mind KPIs.

Q10. Based on KPI evolution.

University Gustave Eiffel (André Orcesi, Franziska Schmidt)

Comments on the report « 1st version of the algorithms to determine optimal restoration and risk reduction intervention programs for transportation networks »

The deliverable is well written, and quite easy to understand. The use cases are interesting, the work is well explained and the results nicely explained. At some times, the work would benefit from a review and/or comments of an infrastructure manager/owner. For example, it is quite difficult

(I do not want to say « impossible ») to choose a fixed number for state 1 or 2, percentage of LOS for all roads/bridges/…Therefore, I would propose a sensitivity analysis for these numerical values (some of them), or at least some expert knowledge discussion on that.

Comment on the 3rd foresee webinar

The webinar has been well organized, for example in terms of introduction and explanations. The presentations gave an adapted depth of information, even if there is a redundancy in what is written in the deliverable (of course). During the first presentation, there has been discussion about given bridges and/or roads when talking about the results and the optimization program. I would have been happy to see some images or have more info on these bridges and/or road. The second presentation has been very interesting, with numerous and explicit links to the considered infrastructure. The constant indexes and prices used here are believable as the use case is a railway (one infrastructure owner/manager) with consideration of tracks/switches which are industrially built elements.

Answer to the questions

Q1. The simulations are quite easy to understand, and I assume that your method to determine the optimal restoration programme is a « good » solution. I think it could be interesting to have the users decide on the numbers of damages states for the various parts of the road infrastructure, and the other parameters that are used.

Q2. Lists of possible consequences are made, with precise plans and steps for repairs/strengthening leading to recovery.

Q3. The level of the consequences is indeed a primary factor. But often, the impacted infrastructure elements are on the same stretch of road, with the same consequences. Then the prioritization is a combination of budget and easiness of repair.

Q4. The answer to this question depends on the road you are considering. First, the avoidance of injuries and fatalities is always first. But then, on primary roads the speed of recovery is the most important point. For secondary roads (or roads with alternatives), the budget might be the leading factor.

Q5. That, again, depends on the structure you are considering. For simple and reproductible structures (pavements, equipment, even simple bridges like integral bridges), the restoration plans can be quite detailed. But for difficult structures (like big bridges) with often high consequences, the restoration plans are only engaged when a problem happens (because of lengthy and difficult simulations/calculations/discussions).

Q6. No, the tools do not consider synergies. I assume this is not the case because these synergies may be quite difficult to model.

Q7. The algorithm seems quite optimized for me. Maybe (but this is not an algorithm issue), there is the need to explain which steps have to be performed before getting in the algorithms (like identifying the issues and the various elements to be studied).

Q8. Generally, there are digital supports available, but when not (secondary roads) the possibilities are considered « manually ».

Q9. This would depend from the person making the decisions. Generally, there is not even enough budget to making all the repairs that should be made.

Q10. We do not quantify that.

UIC (Pinar Yilmazer, Marie Luz Philippe, David Villalmanzo)

Q1. Our railways sector members would use the algorithm, if there was more complexity of the technical subsystems involved, with elements such overhead catenary lines (as main lines useto be electrified), from the energy subsystem or signalling elements for the Control, Command and Signalling (CCS), as both elements have also have important contributions to functionality of the whole system, capacity for railway traffic and therefore, on direct costs and indirect for disruption time. It'd be good also to have an estimation of expected structural damage for the standard cross-section of railway track sections within a certain range of height and the resulting repair costs. As well, we consider of high interest both the identification of risk hot spots in the railway sections and the relation on how to proceed and communicate operational warnings for those classified as critical infrastructures, due to their condition of either being strategical connection points for transport or having the risk to become bottlenecks or increase the disturbances if they were already bottlenecks.

Q2. By now our railway sector members, especially infrastructure managers or vertical integrated companies, are more doing either quantitative (see RAILADAPT project final report done in the frame of UIC, https://uic.org/IMG/pdf/railadapt_final_report.pdf) or qualitative riskassessment, in the last case more related to safety than financial costs regarding the resilience of the system. In the case of EU there's a general regulation on risk assessment (402/2013) which is mandatory and includes also natural hazards in this qualitative way for the infrastructure subsystems. It also includes a quantitative risk probability calculation for electrical or electronic systems, such as energy or signalling elements. However, some projects have still considered and favored the quantitative approach such as the EU funded project ENHANCE: Building railway transport resilience to alpine hazards in Austria (referenced both in EU research databases https://cordis.europa.eu/project/id/644000 and by the technical coordination http://euaffairs.brussels/enhance/files/building-railway.pdf). As part of this project, a series of 10 case studies were undertaken including one with ÖBB Infra, the Austrian Railway Infrastructure company. To protect their railway infrastructure from Alpine hazards,the ÖBB engages partners to jointly plan and implement resilience measures.

Q3. Affections to number of trains, but also a more precise approach to passenger and load considerations in terms passenger/train.km or tonnes/train-km should be assessed for railway objects.

Q4. In our case, restoration speed is a factor but also maximum load per axle allowable forthese first moments. Also, capacity of the line which is provided only by a holistic approach of technical and operation subsystems. Avoidance of fatalities and accidents (as defined per the recast Directive (EU) 2016/798) is also needed. Finally, of course, costs of first restoration and full restoration.

Q5. Our railways members have very extensive plans for these cases. Normally try to re-route traffic when a natural hazard occurs, however, this has less possibilities than the road traffic. First responses can be easy to implement, normally if only earthworks are affected. However, bridge affections or tunnel affections can take sometimes months to be solved with total interruptions of traffic during the period (e.g. see case of Rastatt tunnel collapse in Germany).

Q6. Our members will consider these synergies between elements as completely necessary au our railway system requires a holistic view and there’s a huge interdependency.

Q7. As per the corrective algorithm, our railways sector members would use the preventive algorithm, if there was more complexity of the technical subsystems involved, with elements such overhead catenary lines (as main lines use to be electrified), from the energy subsystem or signalling elements for the Control, Command and Signalling (CCS), as both elements have also have important contributions to the renewal cost and durability of the system.

Q8. Normally, there are KPI’s already in force in the Railway Infrastructure Managers to decide on these subjects, some initiatives such as the PRIME platform is currently trying to harmonise these KPI’s along the different companies in the EU member states.

Q9. Same answer than the question before, based on the KPI’s assessment.

Q10. Some of our members make a risk assessment, but this is sometimes qualitative in terms of safety and traffic capacity, and only quantitative in terms of economics. In any case, it’s difficult to find holistic quantitative approaches- However, not all of them make such as what could be considered public explicit assessments for the moment, and in most of the cases these are for internal use only.

9 APPENDIX D - 4TH SRG WEBINAR JANUARY 21ST, 2021

Comments from SRG

ASFINAG (Mario Krmek)

Part 1

Q1. From our point of view, resilience can't be used as a separate value for decision making. In our company (→ Motorway operator), we use several indicators to prioritize and furthermore to decide about the severity of a measure. We can very well imagine a resilience indicator as an additional indicator for prioritizing measures. It gives us the opportunity for an objectification according to defined points of view. You have to validate it in practice. If it is validated, it would support decision-making.

Q2. See 1.

Q3. Currently, no indicators are defined or in use. The case study presented in the workshop gives a first overview. We have to validate the methodology with our data and processes to give you an answer concerning completeness.

Q4. The approaches presented seem to be reasonable. For our company whose revenues base exclusively on tolling there is one very important performance indicator: cross-sectional availability. This means, if no lane is available in a certain motorway section and the traffic is diverted via secondary (or local) network our company loses the opportunity to charge the customers what reduces the revenues. So, a main objective is to provide our network.

Q5. The presented system may be too detailed and sophisticated for practical use and feigns a false accuracy. On the other hand, there are adjusting screws which influence the final result (change of one value changes the overall assessment).

Q6. Yes, we have. Some of the parameters are not available "out of the wrist". It is questionable, what is the impact of every parameter on the overall result (→ a sensitivity analysis has to be done). We should follow the KISS-principle.

Part 2

Q1. Yes, the definition should be carried out by experts to receive reliable values.

Q2. Yes. I assume that this is the objective of this project. Is computational time a relevant factor?

Q3. Of course, we do! If it supports the daily business to define the right measure in the right time and to prioritize measures in the context of construction programme, definitely!

Q4. This goes hand in hand. For our company and our daily business, this ist he (only) added value.

Q5. Our wish would have been to define one resilience indicator as an additional input for an optimised ranking of measures in our construction programme. This resilience indicator canonly be an additional indicator for our construction programme planning. Other indicators (e.g. budget, condition, inventory) are more relevant to meet the basic requirements of our corporate planning (→ e.g. compliance with the concession contract and legal framework).

Q6. The level of detail is to be questioned here. In the case of "tight" decisions, the decision must be made on the basis of the overall context. Question to be answered: Are we able to capture the reality in an adequate accuracy? Question to be answered: What are the consequences of a small difference in the 3rd decimal place? For a decision between "which of2 measures in a section with the same condition has to be carried out first?" it may well be a decision criterion.

Cintra (Cristobal Martínez)

Part 1

Q1. As a first approach, the existence of a methodology to measure the infrastructure resilienceand the actions to be adopted in case of occurrence of an event are essential to guarantee a minimum level of service.

Q2. Probably to much simplified, but a good starting point to face the challenge of measuringthe infrastructure resilience.

Q3. At this point in time, it seems the set of chosen indicators is not complete. The use in specific cases will give additional information to progress in this analysis.

Q4. In the common ITS systems already installed in most of highways, it does not seem to be a complex task.

Q5. It seems to be acceptable.

Q6. Travel timed could be complemented with level of service data that are automatically collected with usual ITS equipment.

Part 2

Q1. The opinion of operator in charge, with a more detailed knowledge of the infrastructureand environmental conditions, should be taken into account.

Q2. The principle is correct, but I presume that the algorithm should be adapted to theconditions of specific projects.

Q3. The interface should not be an issue.

Q4. Drivers for maintenance management do not completely fit with the analysis of resilienceand, in that sense, this methodology could be partially used.

Q5. Whatever data related to infrastructure quality KPIs.

Q6. Although some ratios are pretty similar, at least, they provide you a first reference of relevant parameters.

DB (Michael Below, Benjamin Schmitz) & DZSF (Sonja Szymczak)

Part 1

Q1. Yes, the measures presented offer decision-makers a comprehensible way to balance the opportunities and risks of necessary interventions.

Q2. Yes, either way the outcome is suitable to communicate it to managers (return of investment, reduction of maintenance costs, breakdown reductions, increase in productivity) and/or customers (downtime reduction, overall safety and satisfaction).

Q3. We agree that the named indicators are relevant and covers all important aspects to measure resilience. Nevertheless, factors like "average condition of the infrastructure" appear partly subjective and risk poor comparability. Additionally, we would suggest adding supplementary traffic-specific indicators depending on the type of transport system to be analysed. For instance, for rail traffic the proper functioning of the overhead line is of great importance.

Q4. Deutsche Bahn already measures its performance in terms of minutes of delay and is also rated by customers on this basis. We would therefore think, it is a suitable and easy way to define the service provided.

Q5. Nowadays, we already determine performance losses due to disruptions in "lost units". Therefore, we do have some experience in estimating certain total losses in reductions in service which we could use for estimation. However, dividing this up into individual indicators would entail additional work. In general, indicators from the level "Environment" are difficult to estimate. Currently, several research projects and initiatives (i.e. BMVI Network of Experts) deal with this topic and help to improve the data basis for these indicators.

Q6.

Part 2

Q1. Yes.

Q2. Yes.

Q3. Yes, user-friendliness is essential for implementation in the application.

Q4. We see a great potential in adapting the methodology to other areas of infrastructure management, for instance prioritization of vegetation management measures and structural safety measures or in the identification of capacity bottlenecks. Deutsche Bahn already carries out risk assessments to prioritize maintenance measures (e.g. storm risk for planning vegetation measures).

Q5. Tree height, geometrical factors (distance to track), data on: weather extremes, soil, type of tree, single tree vs. group of trees, tree vitality indicators, etc.

Q6. In the case mentioned, we believe that the uncertainties exceed the very close scores, which leads to problems in prioritization. We would suggest validating the results in other case studies, for instance on different transport systems.

Highway England (Agnus Wheeler)

Part 1

Q1. At this stage, we would not be able to "trust" the analysis without more background and a detailed review.

Q2. Highways England already has standards for carrying out various levels of inspections for our various assets. The findings and reporting of these are used to prioritise maintenance and intervention activities on a 5 year cycle.

Q3. This is unlikely as we have key Performance indicators set by the UK Government Office of Rail and Road. These are set every 5 years and we have just started one 5 year investment period.

Q4. If required, this should be relatively easy task to calculate as we know traffic flows and have set diversion routes for different parts of our network. Additional items that could be considered are such items as the criticality of the route, e.g. is this the only route that certain commodity can be transported over; is this the only abnormal load route etc.

Q5. This all depends on what the indicators are. Presumably only indicators that could easily be determined for particular pieces of infrastructure would be used? Time for tendering/demolition/construction would be variable dependant on the activity so would be hard to estimate as part of overall transport system.

Q6, Only Sheet 2 of 2 of the Resilience Indicators can be clearly seen on the pdf. Of those that can be seen the input data can probably be obtained from the wider Highways England, though note the caveat above regarding time for tendering/demolition/construction.

Part 2

Q1. I think they will have to be defined by an "expert" familiar with that type of infrastructure.

Q2. Probably not at this stage as Highways England are developing their own decision Support Tools.

Q3. It would be easier for non specialists to use, especially if the inputs are correctly defined.

Q4. This is unlikely as Highways England already have tools for maintenance activities.

Q5.

Q6. If it is known that results are likely to be close that is fine to rank the results but to me this means that the values put on the inputs and the weighting are very critical and they do appear to be subjective.

National Transport Commission (Caroline Evans)

Part 1

Q1. Yes, the Foresee project provides a detailed analysis to measure the service provided and enables the setting of resilience targets. This methodology also outlines an effective process to prioritise interventions according to limited time and resources, which aligns with the challenges faced by road administrations globally.

Q2. Yes, these resilience measures would greatly assist in the integration of these findings into decision-making processes, and could assist in the areas of further education, awareness, and training, as well as business case development and future planning.

Q3. As noted in the webinar, there is an opportunity to assess the aggregate savings of alternative resilience measures under different reoccurrence scenarios. For example, estimation of different resilience strategies in the short- and longer-term. There is also an opportunity to include a wide range of other road user cost savings, such as vehicle operating costs, freight delay savings, and reduced environmental externality costs.

In the PIARC cycle (2016-2019) a report was published entitled PIARC Adaptation Methodologies and Strategies to Increase the Resilience of Roads to Climate Change – Case Study Approach. In particular, this document sets out approaches to selecting and monitoring adaptation measures and responses provides a range international case studies which identify types of adaptation measures relating to infrastructure, traffic hazard management, maintenance measures and planning). Additionally, the document outlines some approaches to prioritising adaptation measures in appraisal and evaluation. This sets out a range of economic methodologies and wider economic issues that can result from climate change impacts on road infrastructure and network operations. This may be useful context for the Foresee project.

Q4. There is a considerable amount of practitioner guidance available in Australia (at the Local, State and Commonwealth Government levels) to assist in the estimation of road user costs. Further information can be provided if necessary.

Q5. As per response to Question 4.

Q6. No additional comment.

Part 2

Q1. This is a useful approach; however, the sources of the expert opinion would need to be documented and updated regularly.

Q2. No additional comment.

Q3. Yes, an automated tool would be beneficial to enable it to be easily applied by a broad spectrum of users with different requirements. The use of automated tools is being applied at an increasing rate globally. The use of the methodology via a user-friendly interface would encourage a larger number of users.

Q4. This methodology aligns with work being undertaken by the World Road Association (PIARC) through the development of the PIARC International Climate Change Adaptation Framework for Road Infrastructure. The Framework guides road authorities through the process of increasing the resilience of their networks and assets through four stages:

Stage 1: Identifying scope, variables, risks and data. This stage guides road authorities through a series of steps to allow for establishing the assessment scope and activities and to identify the assets, locations, risks and changes in climate to be considered. Early engagement of stakeholders in the process will ensure that the knowledge and interests of different specialists and groups (including road designers, hydrologists, environmental experts, risk modellers, business and investment managers, operational staff, policy makers and the supply chain)

Stage 2: Assessing and prioritising risks. Based on the findings from stage 1, guidance on assessing the probability and severity of climate change risks on road infrastructure is provided. Furthermore, road authorities are enabled to understand and quantify the risks posed to their assets in an effective, robust and holistic way.

Stage 3: Developing and selecting adaptation responses and strategies. The process for the identification, assessment, selection and prioritisation of adaptation responses is outlined.

Stage 4: Integrating findings into decision-making processes. Findings from the assessment are integrated into road infrastructure programmes, processes, investments, strategies and systems.

The Foresee tool is relevant to Stage 3, where there are opportunities to apply the methodology to a suite of adaptation measures which are infrastructure related e.g. bridge retrofits, retaining structure, tunnels; or applications for traffic hazard management e.g. early warning systems; or application for maintenance measures (periodic, routine service restoration); and planning adaptation measures.

Additionally, this methodology can be applied across a range of climate change and other hazards in assessing the increased resilience for infrastructure and also network operations

e.g. increases in road height, increased pavement maintenance frequency and more resilient material technology use.

Q5. As a minimum, the following data requirements would include information on the network condition, rehabilitation works, categorisation of the network based on vulnerability and condition, Average Annual Daily Traffic, vehicle composition, reoccurrence intervals of events and estimated future projections of events, reconstruction cost and rehabilitation works (current and projected), road user costs (travel time, vehicle operating costs, accident costs and externalities), freight delay costs, and costs of variations in reseal and surface deterioration.

Q6. No additional comment.

NPRA (Gordana Petkovic)

Part 1

Q1. In principle – yes. However, ensuring the correct /reliable input could be a problem, which would require many test trials.

Q2 Yes, and I think this is helped by the good explanation and (graphical) description of all the elements or compounds of resilience. It is difficult to argue against it. The knowledge about resilience approach in our company is limited to a smaller number of people, mostly working on societal safety and security. However, they are increasingly interested in implementing the resilience approach.

Q3. The indicators seem definitely relevant. I can not suggest what else to include.

Q4. I think this is feasible for us. It should be possible to assess the data needed. However, I wonder if there are some absolute boundaries for when such a measure of service is applicable and when not. Norway has a large range of ADT the road network. In some areas, the traffic load is low and redundancy poor, but it is the only road.

Q5. Probably difficult because of large variations. Q6. Sorry.

Part 2.

Q1. I would say this is the best way to do it.

Q2. As in the first question, we would have to have some experience and concrete output from analyses performed on our own networks. But it does look very promising and feasible.

Q3. No. Ready-to-use automated tools are usually very difficult to implement. Automated tools need to be "local".

Q4. It does seem possible to adapt the methodology for adjustments in any of the elements that are put in relation. It would be interesting to know if this analysis could also be adjusted for exploring the effects of an increase in frequency of some disruptions, such as more frequent flooding episodes due to climate change. This would i.e. lead to an estimate of maintenance needs.

Q5. Sorry, do not know now.

Q6. This is really difficult to answer without having one's own experience in application. I suppose we would investigate the scores given and see if any stronger differentiating could be done. I don not know.

Spanish Road Directorate (Jerónimo Vicente)

Part 1

Q1. I´m not sure. Considering what I think I have understood, the exposed methodology is applicable for one or various specific and predefined hazards, and there will always be unexpected ones. This can be a limitation for the methodology.

Q2. Definitively yes. Although the measure of resilience will be always dependant on the identification of correct hazards and indicators, the result can be considered impartial and unbiased.

Q3. I think I´m not really prepared to answer this question. The indicators seem to be correct but for assuring that they are complete, I think it would be necessary to do a thorough and deep research. A subsequent calibration of the results will be also necessary before a general application of the methodology.

Q4. I think the approach for the assessment of service seems to be appropriate. The figures considered for each parameter can be debatable, but the approach is correct for me.

Q5. Extremely difficult.

Q6. In fact, most of them. I find especially difficult to asses figures for parameters detailed in Table 5 "Assumed values of variables used to measure service". For a correct estimation I consider that these values should be agreed between all stakeholders involved in the transport system operation.

Part 2

Q1. I think it is completely feasible, but the definition of the target values will be completely biased. I would prefer a cost-benefit approach if possible.

Q2. For me it would be necessary to make some tests before applying it. I haven´t understood completely the matrix procedure to assign priorities.

Q3. Both. Executable script to understand and validate the algorithm and an automated tool to apply the methodology.

Q4. I think this methodology is applicable to any maintenance operation, taking into account as input values KPIs (state indicators) and KDPs (target values) and the deviation between them. This is especially useful for predictive maintenance.

Q5. I cannot answer this question, as I am not a specialist in infrastructure maintenance. Q6. I don´t have an opinion about this.

Spanish Road Directorate (F.Javier Morales)

Part 1

Q1. Yes, I think if the resilience indicators are well proved in a number of case studies and results are coherent, the results of this type of analysis could be a good tool at the time of taking decisions, particularly from the point of view of a infrastructure manager.

Q2. Yes, from my point of view the case study cover different approaches that must be take into account in any resilience analysis. Thus, these measures can be included in a summary or report of any infrastructure action.

Q3. As far as I know, the chosen indicators describe in a proper way the resilience of the infrastructure. Perhaps, for others case studies additional indicators should be included in the analysis in a way, that a most range of infrastructure cases can be analysed following the same methodology.

Q4. Terms of capacity are the most reliable and useful way of measure the LoS, however other ways of defining resilience should be considered such as delays, time of recovery after an incident or societal cost (in terms of money or similar).

Q5. I guess the main problem of estimating these values is the lack of objectivity or in other words, the high level of subjectivity in some parameters. In some way, it is needed to determine a procedure or mechanism to obtain the values in the most possible objective way.

Q6. Some of the inputs are pretty difficult to determine in a proper way. For instance, socio-economic activities imply a number of data that vary from one source to another.

Part 2

Q1. Is a very difficult question. Firstly, it is needed a number of experts big enough to reduce the subjectivity of the different approaches. On the other hand, the expert opinion differs too enough depending on many factors such as the infrastructure manager policy, financial or political orientations which are highly difficult to take into account in the analysis.

Q2. Yes, of course. I see this methodology as a helping tool at the time of taking decisions. However, I do not consider that the prioritizing policy of interventions can be based exclusively on this type of analysis in a short or medium-term.

Q3. Friendly user interface always helps to implement this type of analysis, particularly in public administrations.

Q4. As I said above, I see this methodology as a helping tool at the time of taking decisions of any type. However, I do not consider this type of methodology can be based exclusively at the time of planning. Other factors cannot be 'parametrized', which should be included in the decision process.

Q5. Infrastructure policy, economical restrictions, electoral programs…

Q6. Following the same reasoning, from my point of view these methodologies can help to take decisions, however, such a close result show that is very difficult and maybe, bold, based the decisions exclusively in a parameter, particularly if consider that little variations of the KPI can lead to high differences in the results. From an ambitious vision, perhaps in the future, technologies such as machine learning, I.A., can improve these processes, resulting in better and accurate results.

10 APPENDIX E - 1ST SRG WORKSHOP SEPTEMBER 17TH, 2019

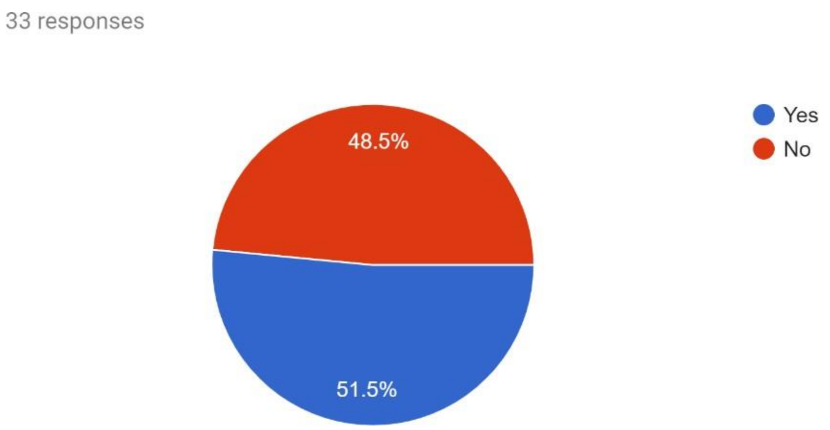
Comments from SRG

This report just collects the received answers that will be taken into consideration by FORESEE partners involved in WP2 on Data acquisition, collection, integration and management system.

1st session

Satellite SAR monitoring

Have you ever used InSAR direct or indirectly for any of your projects? If not, has any other team or project within your organisation? If so, please discuss with them the questions below.



If you have not used InSAR or you are not very familiar, please let us know your thoughtsabout the technology for civilians from the description above

- It would be interesting
- Look like it has great potential
- It could be extremely helpful in relation to monitorize unstable slopes, to measure construction settlements and to foresee potential risks in transport infrastructures.
- We have reviewed InSAR but not yet found it suitable for our challenge
- Yes I did.

- There is no "description above" but my understanding is that this technique can be very interesting for precise monitoring of infrastructures.
- Our company used it this technic one time, to check movements before the tunnelling construction.
- It should be implemented as a tool to better monitor and plan intervention
- Technology via satellite to measure movements
- I think it could be very useful to obtain precise and broad data about civil infrastructure
- Not sure
- InSAR seems a promising technology for long term structural monitoring.
- I don´t know, we used laser scans. But InSAR sounds as an alternative
- I think this technology is interesting but not suitable for accurate monitoring activities

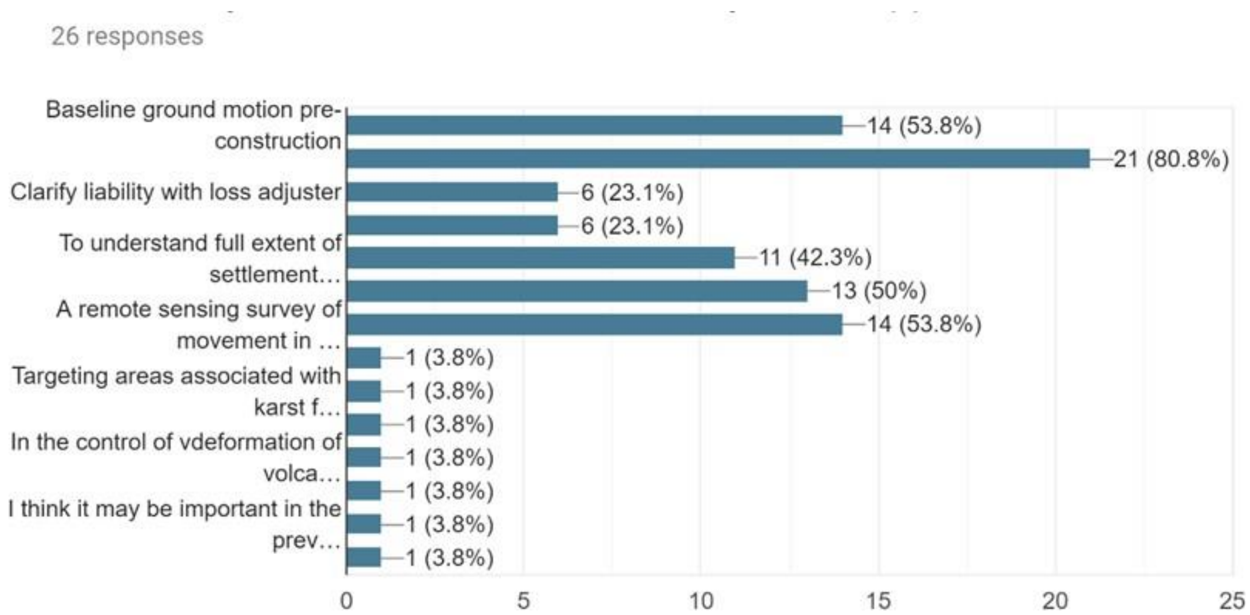
How is InSAR data used in your organization?

- InSAR data are used for the identification and monitoring of the areas in which the infrastructure is located. InSAR data are used for designing interventions and new constructions
- We worked with satellite data from Telespazio for FORESEE project
- As part of a research project on the national road network, InSAR was used to examine subsidence in areas of karst limestone.
- InSAR has been used in a number of research projects and site trials relating to the remote inspection of geotechnical assets to develop a better understanding of conditionand potential for deterioration, specifically focusing on ground movement and ground saturation.
- It is not
- It is not currently used.
- It is currently technology we see on the horizon at the moment.
- Our company have used it twice. The first to check the extent of the subsidence o a plot over a tunnel; and se second we used as a baseline ground motion preconstrution.
- Mostly we are carrying out R&D projects to try and use INSAR technology tocomplement tradition surveying activities
- Not used
- Research purposes
- No use so far
- In an attachment of Risks
- It has been employed only occasionally
- It has been looked at in research work to ascertain its capabilities for monitoringcondition of infrastructure assets (bridges, roads, other associated assets)
- Mainly for monitoring purposes, (de-)selection of points for in-situ measurement
- Currently it is not used, it is still under evaluation
- No used
- For detecting ground movement caused by civil engineering works (tunnelling,excavation, etc)
- Not used yet.
- InSAR has been used to validate and assess movements cause by Crossrail work on nearby assets. The use of InSAR has generally been reactive within TfL (when there hasbeen a need to validate/confirm movements and their extent and magnitude) .
- Not currently routinely used

- SBB started to use InSAR for Natural Hazards. We are now currently starting to use the technology in other use-cases (earthworks, bridges, tunnels, etc.)
- R&I activities in Connection to large infrastructure projects
- Not used

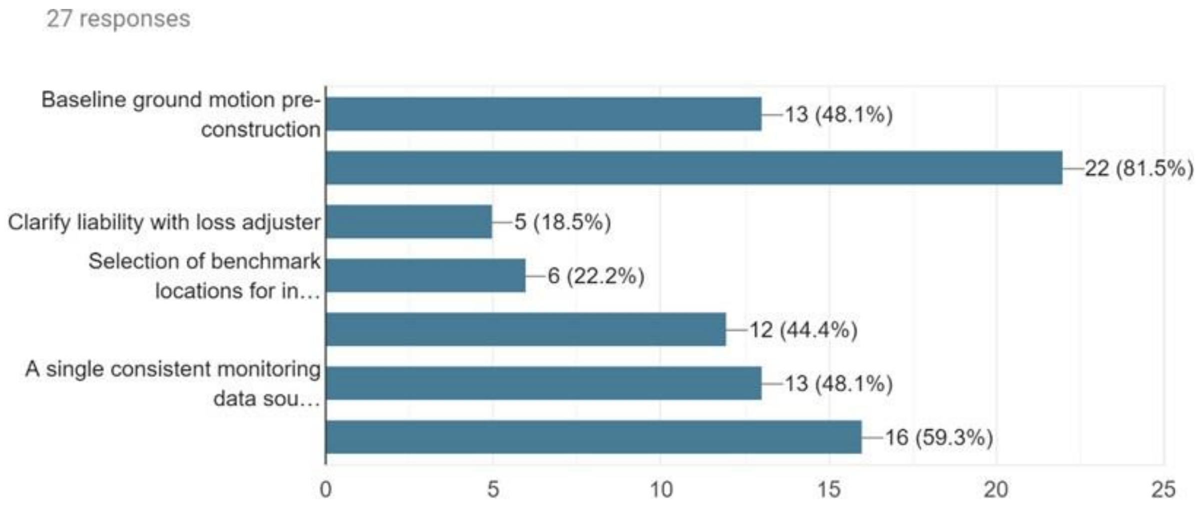
Could you associate its use with any of the applications listed below?

- Baseline ground motion pre-construction
- Long term monitoring after construction
- Clarify liability with loss adjuster
- Selection of benchmark locations for in-situ
- To understand full extent of settlement trough
- A single consistent monitoring data source for the entire extent of the infrastructure
- A remote sensing survey of movement in difficult or inaccessible areas
- Other

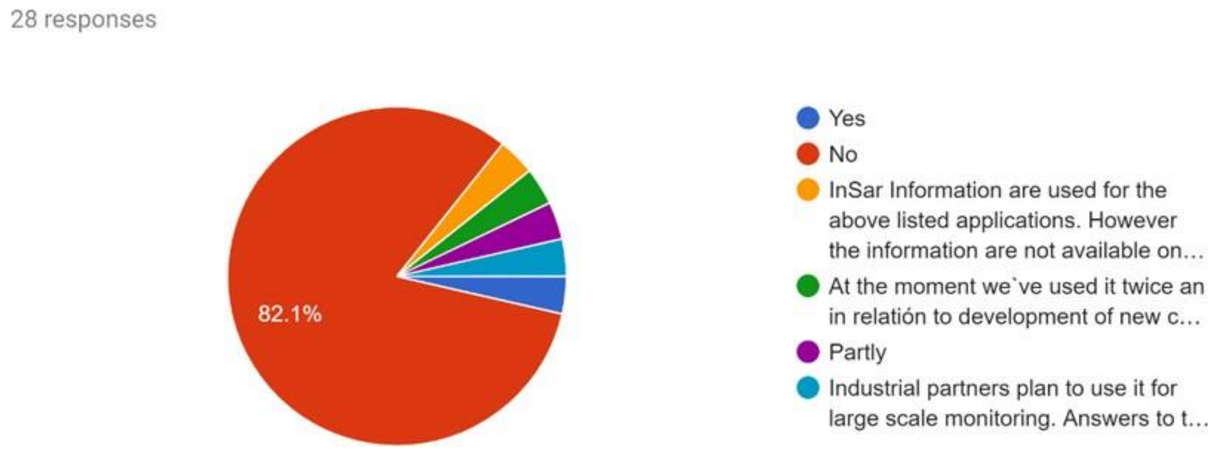


Which of the applications will be relevant to meet your monitoring goals?

- Baseline ground motion pre-construction
- Long term monitoring after construction
- Clarify liability with loss adjuster
- Selection of benchmark locations for in-situ
- To understand full extent of settlement trough
- A single consistent monitoring data source for the entire extent of the infrastructure
- A remote sensing survey of movement in difficult or inaccessible areas



Is InSAR integrated into your systems?



If not, please explain how InSAR information is used. Please, let us even know if it has beendelivered but not used

- None of us work with this technology
- Not used
- Research only
- InSAR data has been used on isolated sites and projects. We are aiming to integrate an InSAR ground motion layer into our geotechnical asset information system but need to determine which InSAR sensors and satellites are most appropriate for our purposes, and also how to display that data in a GIS type environment.
- It is not
- As far as I know, InSAR information is not used nor delivered in our organization.

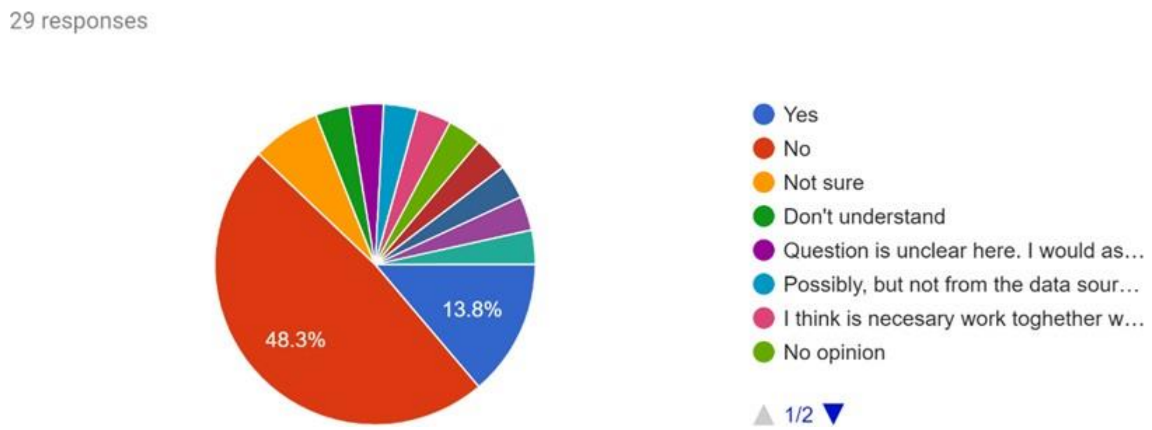
- Sentinel InSAR does not have the necessary spatial resolution we require.
- Currently we are studying different uses in the construction industry
- Not used
- As a database
- By the moment it's only used to set de baseline before the construction
- Has been looked at in research work, but not used operationally
- Moving from innovation / pilot phase to implementation phase
- At the moment InSAR information are not used
- Not used
- On a case by case bases and commissioned through supply chain
- Not currently used
- We do not use InSAR in a systematic way. The technology is not yet known in our company.
- In our case it is not integrated. This is not something that is done on a regular basis, but in our case only as a pilot R&I
- Since we do not use InSAR, we also do not use InSAR Information. Our elevation model was generated from laser scans
- Not used

Are InSAR data outputs helpful for the infrastructure management challenges? Explain how

- Yes. In particular for an improved characterization of the infrastructure and its surroundings (i.e. identification of risk prone areas)
- The InSAR data can provide significant information to determine risk zones.
- Yes, not sure how yet
- Predicting embankment failure and areas of the network at risk from subsidence
- Early indications are that InSAR has a lot of potential with regards to long term remote asset monitoring, subject to selection of the correct sensors and satellites and them being cost effective.
- I assume it can be but I've never worked with InSAR.
- I really think so. It can be extremely helpful for the monitorization of unstable slopes, the measure of construction settlements and also the management of the whole infrastructure including risk assessment.
- We've only found Sentinel derived InSAR to be mildly useful for our mining teams.
- I actually don't know. We are studying the possibility to use this technics in the railway network maintenance.
- Still under assessment but we think it will help to identify critical areas and focus the efforts on them
- I do not know, never tried it
- We have used it to develop a risk attachment.
- Yes I think may be useful in the early warming of slope slide
- I hope so. i am interested in road condition monitoring to look for changes in surface shape and texture.
- Yes, the data serves as an information source that supports decision making
- The use of InSAR can potentially provide greater knowledge of extent of subsidence boundaries and provide indicators to potential catastrophic collapse by analysing SAR data

against periods of known rapid collapse of ground. InSAR data can be used as source of additional info for a better comprehensive monitoring strategy
- To measure movements, settlements or any failures in different infrastructures
- Yes. Quasi-continuous precise monitoring and prediction (after data analysis)
- As per 2.1 above
- InSAR data outputs are helpful for history of deformation or large scale, mostly surroundings or landscape monitoring of a structure. Can be relevant for a city wide construction project.
- In principle they are. The industry needs to do more to understand capabilities and limitations
- Useful for understanding long term ground movement trends for regional rural areas and to remotely monitor earthworks assets provided a sufficient number of reflectors is available
- Yes, Satellite InSAR provides a synoptic view and allows us to look at the past. Ground-based InSAR provide us high spatial resolution at a smaller scale for Dams, slope monitoring, etc. We may test car-borne or UAV-borne InSAR systems.
- It certainly is. This technology should be standard and integrated not only into construction projects, but also into asset management systems.
- We use elevation models in the planning phase of infrastructure projects
- No, in my opinion not suitable for accurate monitoring activities and costly to implement when compared with traditional methods.

Do you think that just surface movement from InSAR direct output data (a point cloud dataset with its metadata), is enough to confront those challenges?



Is satellite monitoring data reaching industry needs? If not, explain why

- Not for our industry yet as it seems too focused on urban areas.
- Yes I do. But it is necessary to improve
- We think it will meet the needs once traditional surveying is not necessary
- I think so
- Yes
- I am not sure.
- It is getting there
- Yes
- Cost is a key deciding factor for stakeholder uptake of this technology
- Yes
- Not yet although maybe in certain applications such as in landslides
- Don't know
- At this date, it is still complicated to sell InSAR technology because accuracy of final data is complicated to predict.
- InSAR cannot provide a full answer but it certainly provide additional information which can potentially be valuable and irreplaceable
- Too expensive, laborious data processing and specialist skills needed to interpret results
- Satellites are one component of a monitoring system. It provides the hotspots at a large scale. Further details of the hotspots should be measured in-situ or with UAVs.
- Just using raw InSAR data limits its use. Advanced algorithms for data interpretation and image processing should be developed further and connected to traditional engineering disciplines.
- Data and processing costs

Please list any limitations you see in the technology

- The rate of acquisition of data which hinders the use of InSar for alerts
- Cost
- Processing
- Cost. Orientation of infrastructure relative to satellite orbit. Vegetation. Data collection frequency.
- Filtering relevant information
- The necessity of managing a huge amount of data. Efficient filters and data selection applications will be necessary.
- Relies on reflectors, there are insufficient reflectors on rural sections of railway and adjacent hillsides.
- It is not utile for instant rock movement, or in vertical climbs in narrow trenches
- Frequency of data collection, price and accuracy
- I am not sure of it is usefulness in very wooded areas and very narrow trenches
- I require sub-millimetre shape information on the shape and texture of roads which is hard to achieve from satellites.
- Uncertainty in what is the exact source of the persistent scatters. Dependency on the RS data provider...

- Quality of measures
- Geotechnical and geomorphology data but I think the aim would be to merge both technologies
- Cost and speed of data acquisition
- Sampling rate; Deformation in line of sight of satellites vs. 3D displacements; Unpredictable loss of correlation of some points ; Hard to predict accuracy.
- Monitoring of earthworks, frequency of monitoring, ampleness of 3D movements, complication in understanding the fundamentals, etc
- Limited use in rural areas
- No displacement measurements North-South. Loss of coherence with vegetation. Costs of high resolution satellites.

What has traditionally been missing in the industry for Instrumentation and Monitoring?

- Budget for example
- A holistic approach. The integration of different techniques and models for managing infrastructures
- Inter-operability
- Large scale monitoring of embankments
- Reliable automated remote monitoring.
- Automatic filtering of relevant information from a mass of data
- The availability of data during the long term. The acquisition of monitoring data does not usually last in the long term and it is difficult to compare with "old" or preconstruction data.
- We use in-situ monitoring and no form of remote sensing can provide an equal view of our infrastructure at sufficient intervals, cost effectively.
- The control without invasive techniques
- In many occasions there is no allowance for I&M in construction projects.
- The possibility of analysing a very wide area without having to Access the property
- Unknown
- Thorough mutual understanding of producer and customer? What are limits in instrumentation and monitoring and what are the requirements of the customer...match or no match? In the end maybe a lack of cooperation?
- A enough number of measures
- Robust, reliable, remote, low cost monitoring with the appropriate level of accuracy
- Fast and reliable novelty detection approach based on dense monitoring with fast and reliable extraction of the effects due to environmental conditions"
- Best practice guides on selecting the optimum instrumentation
- A way to proactively and remotely monitor assets
- Integration of satellite imagery
- The Construction industry is very conservative. Although benefits exist, profit margins are low and that has a direct impact on introducing new ideas / technology.

Which gaps do you think InSAR is covering and not covering?

- Long historic records - wide areas monitoring
- Not sure
- Research
- Unsure at this stage, due to not having undertaken complete trials on all available InSAR datasets; this can be cost prohibitive
- It can provide extensive and constant infrastructure monitoring
- Covering> Availability of comparable data trough extended periods of time. Notcovering> This technology is not currently broadly used.
- InSAR doesn't work everywhere across the UK. The industry needs to be more open andhonest as to where it works well and where it doesn't.
- I think it's very helpful for the hillsides control near of railways, but I have doubts abouttheir utility in vertical slopes or in leafy areas
- Covers a general overview and qualitative assessment. Accuracy and availability of realtime data are not covered.
- The possibility of covering large areas of study
- Unknown
- InSAR closes the gap of a nationwide overview of deformations.
- Frequency of records
- Not sure
- Large scale dense monitoring : covered by InSAR; Long term monitoring and Historicaldata : covered by InSAR (only lower resolution free services); Absolute displacement data : not covered by InSAR; Daily phenomenon : not covered by InSAR"
- It is covering the areas that cannot be accessed otherwise. It can go back in time. It cancover a larger area. However, it is limited to what already reflects unless reflectors are installed for future monitoring
- Good data frequency, good resolution for commercial satellite, availability of historical data. For gaps pls see above. It provides spatially and temporally continuous monitoring. It still has some limitations (see above).

2nd session

From satellite datasets to "in house" satellite monitoring system

Is there a need to develop a digital tool/system fed by satellite monitoring data and other relevant sources to provide efficient and intelligent answers for infrastructure and asset management?

- There is but perhaps the priority is to provide robust solutions first
- Yes I do. I think that this kind of tool improve the usefulnes
- There is a need to develop digital systems/tools for asset monitoring, whether it is fedby satellite data or on site devices is a matter of cost an accuracy of the data
- Yes it is. It is the only tool that can analyze so many parameters throughout the space.
- Yes

- Yes
- Yes
- Yes
- If satellite monitoring can provide additional and reliable information in addition to traditional ground monitoring, there is an interest to develop such techniques.
- There is actually a need for state assessment of infrastructure networks. Personally speaking I consider that satellite monitoring should be complementary to other type of inspections/monitoring.
- Yes, sure, and I believe the need and complexity can range from a simple viewer or portal to intelligent decision support systems
- Yes
- Yes
- No, in my opinion.
- Yes, a map layer that can share across platforms would be useful. It must be capable of being integrated into existing asset management systems.

Is the Earth Observation industry having to adapt to the ways of Transport sector?

- Certainly
- I think they have to do
- The data gathered nowadays provides a rather qualitative assessment to a very high cost. For these technologies to be useful they should be more accurate so they can better help traditional surveys, and cheaper so the value added/cost ratio is attractive.
- Of course, it is necessary that the data adapt to the idiosyncrasy of the sector such as the frequency of availability or the immediacy of the data.
- Yes
- Yes, monitoring linear infrastructure is not the same as using InSAR for construction monitoring in urban sites.
- Yes
- Yes
- Transportation sector needs to be able to make decisions fast, which is maybe still not feasible with current earth observation industry.
- I think it definitely is. It would be necessary to have access to a continue stack of historical images/data. Data collection only on demand is not very useful.
- No, not necessarily, I believe that through cooperation we can design and launch instruments that can be used for infrastructure monitoring
- Yes
- YES, to develop specific solutions
- I think so
- It needs to - its pricing systems cover large areas and are not effective for linear infrastructure.

Should the transport sector adopt some of the global digital approach from Earth Observation solutions?

- Not sure if this is practical at this stage due to the limitations in the platforms of the transport clients
- If they know our need they improve the work
- Maybe in the future when the cost decreases, at the time we do not think that is an option.
- In my opinion it would be interesting.
- Yes
- Not clear about the question
- Yes
- Yes
- Not enough knowledge in this field to provide an answer.
- I think so. Earth Observation solutions are (or could be) a very useful tool.
- See my answer above
- Definitely
- Yes
- Maybe, if suitable to accuracy requirements
- Question not understood - not sure what the global digital approach is.

- Which would be the best approach?

- A 3rd party provide consultancy services
- The one described in 2.1
- The acquisition of real-time data outputs to anticipate different natural (meteorological and geological) and anthropogenic risks
- Centralised processing offering deliverables
- Best approach would be a shared database of processed InSAR data available to infrastructure owners and operators to manage their asset.
- Satellite InSAR is certainly the number one technology. Then, it comes multispectral satellite imagery. SAR backscatter could also provide useful information. The spatial resolution of free satellites imagery is still limited.
- Dialogue
- Not enough knowledge in this field to provide an answer.
- Integrate Earth Observation data with the rest of monitoring results into an assessment tool.
- Cooperation
- Pooling of resources among different stakeholders to build a comprehensive database to manage assets
- Cooperation between sectors is the best option
- I do not know
- Question not understood - what approaches?

What are the advantages of each approach?

- We do not think there is an option for transport sector to adapt at the time, due to budget constrains
- A quick and efficient response would improve the resilience of infrastructures.

- Most of the client would not have required computer infrastructure to process theamount of data
- There is only one way, talk and meet.
- Not enough knowledge in this field to provide an answer.
- Control costs
- Both have to adapt
- Question not understood - which approach?

Are any of the systems described during the workshop (Satellite-SHM, GIS hotspot riskmapping and impact ranking, Landslide Failure Prediction and SUMMIT) meeting the challenges of infrastructure monitoring you face or envisage? If not, what is missing?

- They are in the right direction, but the impression was that these are yet in researchstages
- I think that it is not possible only one tool. I think it's necessary a GIS tool that canintegrate some of them
- all of them are useful to a certain extent, but we consider most of them provide withlimited information with a very high cost
- These tools are really useful but I would add others such as the implementation of allthis in the same software that also includes other tools such as synchronization with real-time meteorological models or with traffic data.
- Not Applicable
- Clear guidance on how to use Sentinel-1 and commercial satellite outputs for infrastructure asset management applications with use cases would be a very usefuloutput.
- Satellite-SHM coupled with GNSS based monitoring seems an interesting solution.
- It is missing a multi-technology approach that may be able to integrant all the monitoring or test data. The technologies described are extremely focused on satellitemonitoring, lacking of a more general approach.
- Yes
- Yes
- Implementation strategy
- Satellite-SHM and Landslide Failure Prediction are the most interesting solutions
- GIS hotspot risk mapping, for sure
- Not really - there is a need for a network-wide survey approach so that defects can be identified and prioritised before they become an issue. It needs to take into account thefact that most transport infrastructure is linear.

Will you use any of the solutions/systems described above in your project?

- Yes, if they could demonstrate that they are more economical and can improve thesafety and efficiency of operation
- If they became economically competitive and once the features are proven interestingto our needs, yes, we would.
- It is possible

- Not applicable
- They look useful, however these solutions need to be interoperable with existing asset management systems already in place in the organisation
- Maybe
- Introducing these ideas on a broader scale at in Infra Manager is a challenge
- GNSS bridge monitoring is investigated currently.
- Only to obtain complementary information
- more likely not
- Yes
- Yes
- Possibly
- No
- Not yet

3rd session

Resilience Shift initiative

Do you currently use any assessment frameworks, guidelines, standards or tools for assessing or improving resilience of transport networks? What are they?

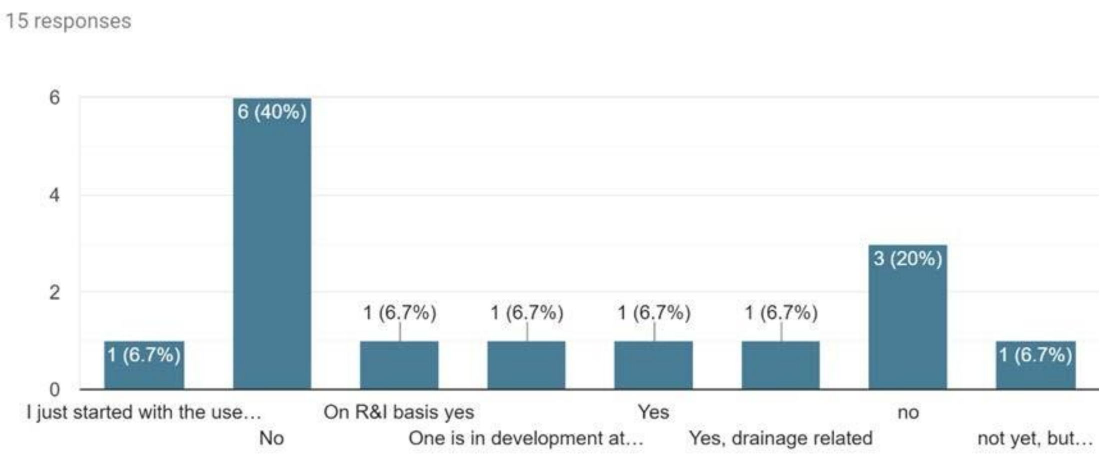
- Not personally
- No, we don´t
- No, we are only carrying out R&D related projects related to resilience
- Yes, the GIS hotspot risk mapping and impact ranking
- Internal inspection guidelines
- No
- Some references: M. Bruneau et al., "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities," Earthq. Spectra, vol. 19, no. 4, pp. 733–752, 2003. N. J. Mansfield, "European Directives," 2018. C. Of, T. H. E. European, G. Paper, O. N. A. European, P. For, and C. Infrastructure, "No Title," 2005. RESILIENS consortium, "Methods for Resilience Assessment," p. 138, 2016.
- No
- Not yet, but we are working on it
- Yes, we use earthquake proof construction standards, flood risk and climate change resilience frameworks and guidelines in The Netherlands
- Yes - flood modelling, landslide susceptibility maps, Extreme weather response strategy, Embedding climate factors into designs (increase rainfall), Shift to SUDS systems for quality and quantity controls.
- No
- We are developing our own Resilience Assessment Framework Tool (RAFT) for use in determining inspection and maintenance programmes for geotechnical assets. This comprises

two parts i) understanding risk ii) improving resilience, including an online tool that can be accessed both internally and externally, by our supply chain.

Do you see any gaps where there is currently no available tool for assessing or improving resilience of transport infrastructure but you wish there was?

- More awareness is a first step - tools can follow after
- Mainly drainage systems, but resilience is generally a new topic that should be further studied
- Yes, software that implements in real time all the risks that may affect the transport network
- Definition of resilience itself often leads to different interpretations
- Yes, a common and approved method/toll would be nice
- Maybe in extreme weather events (storm, rainfall), but also for long droughts
- Subsidence, impacts of karst.
- Tools could help in assessing resilience and improve operation of networks
- Yes - a cross asset, network-wide tool would be useful. A challenge for us is understanding and scoring network criticality, which is an essential part of a resilience framework.

Have you ever created a tool for assessing or improving resilience of transport infrastructure for yourself or others to use?



Where do you see alignment between the RS and FORESEE?

- FORESEE provides an additional tool for assessing resilience
- Very similar project in general
- Data collection through RS is one of the tools to assess the resilience of transport networks.
- RS seems to work on general concepts which could be used to better highlight the needs associated with resilience.

- Deformation monitoring, climate modelling based on RS data, extreme weather prediction through satellite information...land use change, plenty!
- The approach is similar

Where are the differences?

- RS is a process while FORESEE provides a tool
- Very similar project in general
- How to make the communication infrastructure more resistant to extreme events is not limited only to data collection. Also the creation of methodology, actions or structures that are able to hold the functionality of the infrastructure after an extreme event.
- As mentioned before, RS is more on general concepts and FORESEE on the development of technological solutions.
- Possibly in the choice of the indicators to measure resilience
- Not sure.

How can the FORESEE outputs advance implementation of resilience and the knowledge generated by the RS complement FORESEE?

- As above
- The tools we create may help contrast outputs where they overlap or can be complementary
- Creating a database robust enough to be able to base decision making. It would also serve to classify by priority the different measures to be taken.
- The problem is not the results as they are. The results are great. The problem can be found at the InfraManager, and it is a way of thinking that needs to be changed.
- The RS should identify some real situations on which the FORESEE solutions could be applied.
- When the lessons learned are shared and implemented by the FORESEE members (>60 people from >14 countries?). 2. The RS solutions that prove valuable to resilience must lead to new guidelines and practice
- FS outputs could be used to valid

11 APPENDIX F - 2ND SRG WORKSHOP ON OCTOBER 27TH, 2020

Comments from SRG

ADIF (David Villalmanzo)

Session 1

Q1. Yes, we know both and make use of them in part of the reinforcement and stabilization slope works carried out both in maintenance and new designs.

Q2. According to our experience the use of the above-mentioned items is improving exponentially functionality in rail works:

More specialized companies offer these systems to the geotechnical market.

New projects (both for maintenance and investments for classical lines and those focused on design and construction for new lines) consider these systems more than before and are based on improved geotechnical studies.

Extensive use of these systems reduces their prices.

Good results in their use favour the constant consideration on new designs and installations.

The combination in the use of different systems is being improved (i.e. geomembrane and wire mesh)

Also helps the application of risk assessment approaches for the whole Life-Cycle, beginning pre-design with design phases.

Q3. Yes, we know them, and their use is quite intensive and frequent in our projects, not only with the above-mentioned applications and commercial brands, but also with others.

Q4. We use them in all the geotechnical works carried out in the first steps of the design process and later in maintenance works. Piezometric control, foronomic control, numerical modelling of aquifers, hydrological methods to measure surface runoff and/or infiltration, pumping tests and hydrogeochemical analysis, also permeability testing on-site using Lefranc or Lugeon methods, respectively for soils and rocks, and some lab testing to determine coefficient of permeability.

Q5. It's a somewhat fuzzy question. If the reference is about impulse calculations, seismic actions or instantaneous actions on the ground in general, as well as strains and stresses of elements of the support of ground and soils, the answer is yes, but those are traditionally based on FEM with Lagrangian solving methods. If it's referred to high mess distortion in combination with high dynamic forces, as seen in the workshop, the answer is not quite often.

Q6. In this case, it will be on the side of consultants in geological/geotechnical engineering providing our company the service in the frame of projects or maintenance remedial actions. Probably, before tendering and contracting, we would perform a Cost/Benefit, time of calculation, accuracy and general performance and strategical analysis of use to assess it before the introduction of any of these new simulation methods, Smooth Particle Hydrodynamics (SPH) or others.

Q7. Probably, porous asphalt mixes will show high value ensuring quality and durability of earthworks against flooding, caused by intense rain fall/precipitations with high periods of return, or in the case of very high embankments with somehow unstable geotechnical conditions for natural ground. In our case, snow, or ice, due to local conditions, or salt application to dissolve them do not represent such a big problem. Also, similar things can be said regarding new simulation methods and improved methodologies for estimation, which would help in those cases prediction of behaviour, especially in extreme events with heavy rain fall. Also, when higher than usual dynamic forces or other actions that may destabilise the ground happen, such as seismic events. Those will be the most considered applications.

Session 2

Q1. Nowadays, due to more aggressive and intense effect of floods in railway infrastructures, is more likely and necessary the use of new and more accurate flood assessment methodologies like the one presented in this workshop. Probably all the above motivations will justify its adoption, KPI's regarding quality and durability, cost reduction and reliability of results.

Q2. State owned/public companies like ours will most likely subcontract the application when needed.

Q3. Essentially, the added value is that it will give more accuracy of prediction, when high periods of return are to be evaluated depending on local conditions and criticality of the sections to be assessed in design or for post-assessment if catastrophic events related to this may happen in historical sections.

Q4. Are you familiarized with any of these concepts?

Sustainable Drainage Systems N

Best Management Practices Y

Green Blue Infrastructure N

Our company is mostly familiar with Best Management Practices, not so much regarding drainage or ground design and construction with SDS or GBI.

Q5. Not yet a specific one regarding SDS. Of course, we have our practical internal codes and nationwide regulations for drainage systems.

Q6. The limited knowledge of the concept right now, and the actions thereby included, as well as the lack or specific regulation may be crucial to this subject. Apart from that, later it will depend on an assessment of use.

Q7. Sometimes, depending on technical needs or strategic approaches. For example, it's mandatory to assess climate change for drainage systems when projects are EU co-financed one.

Q8. This question is not applicable, for the case of railways, except for some bituminous sub- ballast layers applications, but those sections in our network are not numerous and more prototype ones than a standard for the moment.

Q9. Not so applicable for railways, except for the above-mentioned case, in which drainage, permeability and necessary thickness of the bituminous layer, to comply with mechanical behaviour design specifically against vertical forces due to railway loads, and overall durability are considered.

Q10. The answer here is quite like the one we give hereby for the first question in Section 2, extending the topic from resilience to flooding to SDS. Due to more aggressive and intense effect of floods in railway infrastructures, is more likely and necessary the use of new and more accurate flood assessment methodologies and drainage systems like the one presented in this workshop. The added value will justify its adoption, will linked to KPI's regarding quality and durability, cost reduction and reliability of results.

ASFINAG (Karl Engelke)

Session 1

Q1. Yes, they are common in Austria

Q2. The durability of anchors and nails has to improve or at least methods to assess their condition. The most sustainable slope stabilisation is the one which does not have to be built. This should be taken into account in the planning of new infrastructure.

Q3. No, usually our contractors do those simulations.

Q4. First step usually is a geotechnical mapping including the water (for example soil wetness, water outlet at the surface). If necessary and possible we build boreholes including piezometer tubes. Groundwater, layer groundwater, pore water pressure and surface water is monitored(in best case automatically and permanent). Chemical and physical parameters are measured.

Q5. Not by ourselves. Usually our contractors do those simulations. We often ordered rock fall or flood simulations

Q6. Basically yes, but as we use contractors, they would have to get used to those methods. Wecan order those methods, but if there is no market for it we will have difficulties to get them.

Q7. We cannot answer this now. We will have to compare those methods we the common methods used by our contractors.

Session 2

Q1. If there is a benefit in lower risks and or lower costs, we will adopt this method.

Q2. We would in any case subcontract it.

Q3. No overdimensioning, lower costs.

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems Y.

Best Management Practices Y.

Green Blue Infrastructure N

Q5. No, not yet

Q6. Contractors will have to adopt it and create a market for SDS

Q7. No, not yet

Q8. ASFINAG used porous asphalts in the 1990ies on a large scale to reduce noise. The experience showed that porous asphalts didn't keep any promise. The short-term advantages (noise reduction and drainage) are outweighed by the disadvantages (e. g. significant higher costs during complete life-cycle – construction, operation/winter service, maintenance – in compare to standard asphalt). Porous asphalts are not in use in ASFINAG's network since the 2000s.

Q9. It is allowed to install porous asphalts, but these types of asphalts are not in use in Austria since the 2000s. There are European standards and Austrian regulations which have to be followed. In addition to asphalt properties (Type of bitumen, grain size distribution of the aggregates, polishing values, LA-values, etc.) it is important to seal the surface of the underneath layer. State of the art is to install a SAMI-Layer (Stress Absorbing Membrane Interlayer) or a mastic asphalt to ensure that water from surface will not penetrate the asphalt construction. Furthermore, a systematic drainage (including road gullies which are able to absorb water from porous asphalt layer) has to be installed.

Q10. Availability improvement

ATKINS/PIARC (Paul Nowak)

Session 1

Q1. Yes

Q2. Use of more sustainable materials and vegetation

Q3. Yes, SLOPE-W and TALREN

Q4. Using normal ground investigation techniques with real monitoring from installed piezometers

Q5. No

Q6. Potentially, if they can be of benefit

Q7. They are worth considering in future design

Session 2

Q1. Already using

Q2. Already incorporate into our own practice

Q3. Reduction in drainage systems and discharge into existing systems that are close to design capacity

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems Y.

Best Management Practices Y.

Green Blue Infrastructure Y

Q5. Yes, CIRIA Guide in the UK

Q6. Potentially, permeability of the ground and groundwater table

Q7. Yes

Q8. Not used extensively in the UK

Q9. N/A

Q10. Useful additional case studies

ATKINS (Jane Kelsey)

Session 1

Q1. Yes

Q2. Ensuring the client understands the factors of why you have chosen the material and typeof rock fall barriers will enable more expensive solutions to be used where they are more appropriate.

Q3. Yes, but I have limited knowledge of the software.

Q4. Groundwater monitoring wells, pumping tests and tracer tests. Monitoring wells to locate ground water level, pumping tests to understand the rate of recharge and tracer tests to identify the flow direction and rate between boreholes.

Q5. Unsure.

Q6. Possibly, if the client was on board.

Q7. I have passed on information of the porous asphalt to a pavement team, I am unsure what knowledge the team already have on porous asphalt.

Session 2

Q1. If there was a strong enough business case, or the client had an emphasis on innovation within a particular project.

Q2. Depending on the length of learning process, most likely incorporate the methodology intotheir own practice.

Q3. More accurate risk modelling and risk registers.

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems Y.

Best Management Practices N.

Green Blue Infrastructure N

Q5. No. Q6. N/A. Q7. N/A.

Q8. Mostly motorways.

Q9. The length of time that the material retains its porosity.

Q10. More accurate risk modelling and risk registers.

ATKINS (Zorica Todorovic)

Session 2

Q1. As a consultant, we could see the value of adapting this type of approach especially related to KPIs and insurance.

Q2. We have similar methodologies developed in house.

Q3.

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems Y

Best Management Practices Y

Green Blue Infrastructure Y

Q5. I was involved in developing UK CIRIA SuDS Manual.

Q6. Adoption and perception of practitioners that it is more costly and more challenging to install.

Q7. Yes always

Q8. Usually side roads; we installed one as a trial in the very centre of London in a residential area 5 years ago. It is still working well, however, there were challenges with clogging and with potential replacement if there is a need to emergency digging for utilities replacement or repair.

Q9. Its prospect use, structural stability, climate, installation time

Q10. Better understanding of complex interaction in the catchment, better estimation of critical design events and assessment of other multicriteria factors and benefits in design.

CINTRA (Cristobal Martínez)

Session 1

Q1. It is common to implement these types of solutions in non-mature soils and weathered rocky slopes.

Q2. I am not pretty sure, but economies of scale based on a relevant use of these solutionscould bring more opportunities to refine current designs and reduce cost of material.

Q3. Our sister company Ferrovial Construcción usually runs this type of software.

Q4. It is not my expertise

Q5 Probably, our sister company has hired some specialized consultant to develop this type of analysis.

Q6. No, as far as I know

Q7 To have access to last techniques in this area that can procure a better risk management.

Session 2

Q1. Reducing uncertainty is the best way to decrease direct costs and improve assetperformance.

Q2. Such specialisation seems to recommend counting on expert consultants.

Q3. Better risk control

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems N.

Best Management Practices N.

Green Blue Infrastructure N

Q5. No

Q6. Probably applicable standards and prizing

Q7. Not yet

Q8. In general terms, in roads located in areas with highly rainy conditions and limited freezing risk. Also, in specific sections where noise reduction is needed (sensitive urban areas or environmental protected zones).

Q9. Limitations for being exposed to extreme weather conditions and to heavy traffic turning and stopping.

Q10. To be updated on the last state of the art of techniques related to road maintenance and operation.

DEUTSCHE BAHN (Michael Below, Josefine Dogs, Benjamin Schmitz, Sonja Szymczak, Ralph Fischer)

Session 1

Q1. Deutsche Bahn AG already has such systems in operational use. These are anchored or defined in the set of rules 4102 Appendix 02 (Safety measures for embankments and rock slopes). DB also works together with market leaders such as Geobrugg (Switzerland, https://www.geobrugg.com), Truma (Austria, https://trumer.ca), Maccaferi (Italy, https://www.maccaferri.com). Maccaferi has currently approved a new protective net.

Q2. Deutsche Bahn AG sees potential savings in terms of indirect costs (operating time and maintenance-friendly). At the same time, the question arises as to how the systems can be monitored efficiently. In most cases, an assessment is required every three years, for which engineering firms are commissioned with stability investigations. In individual cases, Deutsche Bahn AG already uses drones. For us, in some cases, the difficult access to the areas for inspection and maintenance represents a challenge. In this respect, the accessibility of structures would be a criterion for maintenance-friendly systems. It is also useful to combine technical and biological measures, as with adapted vegetation management, the positive characteristics of vegetation can be used more effectively for slope stability. Further we know other technical solutions but do not use them, e.g.

Automated notification in case of damage (by voltage sensors in the safety net)

Automatically triggered closure of infrastructure routes (where rocks with risk of falling are monitored by laser and when registering a movement, automatically switches a traffic light to red on the road below) (Austria)

It is also known from Switzerland in relation to mudslides (preventive closure of road sections, if the occurrence of a mudslide is very likely).

Q3. As the operator of assets and infrastructure Deutsche Bahn AG is the problem owner and requester but does not carry out any investigations in this area itself. This is done together with planning and engineering offices, which in turn use their own software solutions for calculation. Calculations of slope stability and dimensions, with a view to an expected event, are thus awarded exclusively as external services. The same applies to the DZSF, as no research has been carried out on groundwater and slope stability.

Q4. Geotechnical inspections take place, among other things, within the building ground exploration/ building ground assessment and are also the subject of external service contracts. Reliabilities and partial reliabilities for all influences (e.g. rating water level) are measured with surcharges in accordance with Eurocode 7.

Q5. Until now, the DZSF only works with geotechnical dynamic simulations within the framework of external research projects. For example, the RAMMS (Rapid Mass Movement Simulation) software is being used in the project "Analysis of rapid water-containing mass movements: nationwide studies on the exposure of the German rail network and modelling of spatial propagation" which was launched this month.

Q6. No own simulation methods in the application (possibly within the framework of university activities/ cooperation)

Q7. For Deutsche Bahn AG, the focus is on a better risk assessment of slope or slope instability based on the actual situation. So far, there are rather rough assessments of the risk for large areas. Within the framework of the BMVI Expert Network, case studies are planned on a regional/local basis in which, depending on the contractor, the methods of the FORSEE project can be applied. The methods can also be used in detailed analyses for the validation and further development of the reference maps on gravitational mass movements.

https://www.bmvi-expertennetzwerk.de/EN/Projects/TF1/SP-105.html

In the case of porous asphalt, we might see the advantage of "diffuse" water permeability. In the case of cementation, drainage systems must otherwise be installed in order to reduce the pressure of the water flowing in. It would be interesting to know if this makes such a big difference so that safety constructions could be smaller (due to a lower water pressure).

Session 2

Q1. In Germany, the regional authorities are responsible for the designation of risk areas. We are not aware on what methods the evaluations/simulations are based on in detail.

Q2. Deutsche Bahn is only a user of the risk cards and does not carry out its own calculations in this regard. In the first phase of the BMVI Expert Network, nationwide flood warning maps were created. These are now validated and further developed in the 2nd phase, analogous to the note cards on gravitational mass movements, whereby the presented methods could be applied.

https://www.bmvi-expertennetzwerk.de/EN/Projects/TF1/SP-103.html

Q3. So far there is no DB position available

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems: Y.

Best Management Practices: Y

Green Blue Infrastructure: Y

DB refers to DWA rules and worksheets available. These in turn refer in particular to regulations of DIN. But as you may know, aspects of climate change have so far been insufficiently taken into account in relevant documents. Nevertheless, it should be noted that the fact sheets already take into account the methods and designs outlined in the presentation. DB is therefore already using sustainable drainage systems. Source: https://de.dwa.de/de/

Worksheet DWA-A 138 "Planning, construction and operation of precipitation water infiltration plants"

Worksheet DWA- A102 "Principles for the management and treatment of rainy weather drains for discharge into surface waters"

Q5. see DWA regulations

Q6. From an operational safety perspective for track systems and with regard to additional costs for maintenance (as there is "more green on the railway"), measures may be viewed more critically.

Q7. If it concerns the dimension approaches, then this is taken into account via the safety margins. As far as we know, however, the associated regulations do not yet have a climate- adapted method (e.B. rain frequency not 10 years but e.g. 50 years, or HQ extrem vs. HQ 50). If a so-called environmental impact assessment is required for new construction or maintenance of infrastructure systems, aspects of climate change must also be taken into account. But there is also a lack of uniform standards and methods/data for a systematic and spatially differentiated assessment. A project on this topic has already been carried out within the framework of the BMVI expert network (EBA Research Report 2019-05: "Assessment of the dimensioning of track drainage systems and culverts of flowing waters. Evaluation of the basis of assessment against the background of changed precipitation events due to climate change"). A further project is planned to examine and evaluate the guidelines, regulations and measurement values with regard to climate change.

Q8.

Q9:

Q10. Methods were presented that allow more detailed information about the potential floodplains. The added value of these results is that protection measures can be planned and implemented in a more targeted manner, saving costs, and ensuring more reliable operation.

HIGHWAY ENGLAND (James Codd)

Session 1

Q1. Yes

Q2. Make them open source

Q3. Not directly but both are used within our supply chain.

Q4. There are many methods for investigating groundwater regimes, e.g. observation wells, piezometers (incl. standpipes, vibrating wire) and electrical resistivity surveys, multispectral imaging, L-Band InSAR.

Q5. Not directly but probably within the supply chain.

Q6. Only if a need is identified. At the moment, existing simulation and other techniques seem to suffice.

Q7.

IRISH RAIL (Colin Hedderly)

Session 1

Q1. Yes, but my experience of rockfall barriers is limited to the one installation shown below at Bray Head (This is the cliff railway shown in the last page of my presentation).



Q2. This is very difficult. The high costs in my experience are always associated with the difficultto access location, not so much the cost of materials themselves. For example, see above where we had to bring materials in with helicopter. Perhaps if they were more lightweight?

Q3. No, we have not worked with any of this software.

Q4. The investigation methods we use is either visual or with piezometers.

Q5. No.

Q6. No. If the situation required a simulation study, we would likely engage a specialist consultant to undertake the simulation study and provide us with a report and recommendations.

Q7. If the results bring improved methodologies for estimation, then this is good for theindustry.

Session 2

Q1. Certainly, there are limitations in the traditional methods and Irish Rail is aware of this problem. We have been a key stakeholder over the last few years involved with the Office of Public Works (OPW) who has responsibility in Ireland for leading and co-ordinating the implementation of the National Flood Policy which involves the development of a planned programme of feasible works, with a greater emphasis on non-structural flood risk management measures The OPW undertook the National Catchment Flood Risk Assessment and Management (CFRAM) Programme to give a clear and comprehensive picture of flood risk in areas of potentially significant flood risk and to set out how to manage the flood riskeffectively and sustainably. Irish Rail has benefitted from the flood modelling studies that have been done.

Q2. We would subcontract this practice.

Q3. It is more accurate. We have experienced flooding as the result of a combination of multiple events which on their own are not exceptional, but when combined have caused serious flooding (point 2 in conclusion of presentation 1)

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems: Y

Best Management Practices: N

Green Blue Infrastructure: N

Q5. No

Q6. Our lack of understanding and our Procurement Policy (Our Procurement process is designed to be a competition on cost grounds only. It does not consider the wider benefits of sustainable options. It needs to change in my opinion).

Q7. We make a nominal allowance (typically +25%) but there is no science behind it.

Q8. We do not lay roads. Not applicable.

Q9. Not applicable

Q10. If the results bring improved methodologies for estimation which allow for improveddesign for resilience, then this is good for the industry.

IVE (Christophe Schuetze)

Session 1

Q1. Not before the workshop and FORESEE-Meeting

Q2. Maybe industrial mass production and standardization could help.

Q3. No.

Q4. No.

Q5. No.

Q6. No.

Q7. Nothing.

Q8. Other comments: We do not work in this specific field.

Session 2

Q1. In my opinion, there are a lot of motivations to adopt such a methodology, but – as always there needs to be a failure to implement something new.

Q2. In my opinion for Deutsche Bahn: They would incorporate it into their practice.

Q3. Better model for prediction.

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems: N

Best Management Practices: Y

Green Blue Infrastructure: N

Q5. No

Q6.

Q7. In my opinion and as far as I know from the guidelines by Deutsche Bahn: It is not yet considered but they are planning to do so.

Q8.

Q9. We do not work in this specific field.

Q10. We do not work in this specific field.

NCSR Demokritos (Thanasis Sfetsos)

Session 1

Q1. Yes, but not in great details as it is not the domain of my expertise

Q2. Protection of slope instability / could be used to support NBS

Q3. No

Q4. No.

Q5. No

Q6. It is a possibility but will need a considerable investment in human resources and related expertise

Q7. Significant and important elements in a comprehensive risk / resilience assessment andinput to adaptation pathways

Session 2

Q1. Highly likely

Q2. Yes, it is a strong possibility

Q3. Detailed inputs to risk assessment

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems Y

Best Management Practices Y

Green Blue Infrastructure Y

Q5. Colleagues

Q6. Complex topography of Demokritos, hazardous materials

Q7. Yes

Q8. Urban

Q9. Soils / rainfall / snow/ ice

Q10. As before

NETWORK RAIL (Mark Langdon and Eifion Evans)

Session 1

Q1. Network Rail have a programme of slope repair including installation of rock netting (after scaling rock slope), regrading soil slopes with gabion retaining wall and soil nailing soil slopes.

Q2. Network Rail work with their supply chain to bring in efficiencies in slope repair design and methods. Cost benefits are realised by tendering work.

Q3. Slope stability assessment is carried out using SLOPE (or similar programe) following ground investigation, instrumentation, and monitoring at selected soil slopes. Slope stability calculation is done by Network Rail design group or consultants.

Q4. Typically, piezometers are installed (as part of a ground investigation) and monitored in soilslopes to gain data on seasonal ground water levels.

Q5. No.

Session 2Q1. N/A Q2. N/A Q3. N/A

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems Y/N. Yes - some Network Rail designs use CIRIA guide onSustainable Urban Drainage.

Best Management Practices Y/N. Yes - Network Rail every 5 years write an Earthwork Policy document based on identified good practice.

Green Blue Infrastructure Y/N No.

Q5. CIRIA guides on Sustainable Urban Drainage are used.

Q6.

Q7. Yes - drainage design incorporates increased rainfall in Winter due to climate change prediction.

Q8. N/A

Q9. N/A

Q10. FORESEE could produce a report giving guidance on methods of estimation of return periods which would be useful.

Q11. In response to the question at the workshop about the CAT tool accuracy: The CAT tool is the development of a near real time heavy rainfall / convective rainfall monitoring system. It will use the precipitation radar at its highest resolution currently available in the UK engaging a spatial 'grid size' of 500x500 meters, updated every 5 minutes of the day. It is a new feature within the Network Rail Weather Service web environment and provides a 'rationalised' overview of both National and Route alerts with the ability to 'drill down' to look at the 500m detail.

PRORAIL (Stephan van Eeten)

Session 1

Q1. ProRail is familiar flexible systems. We have used this method when constructing new embankments. The rock fall barriers are not necessary in the almost flat country that The Netherlands are.

Q2. For now, we cannot answer this question. Main purpose is in our opinion to strengthen the slope and to prevent the outflow of soil particles on to the track.

Q3. In The Netherlands we normally use the software made by Deltares (2D models) or Plaxis (FEM models)

Q4. In slopes normally we want to investigate determine the different soil layers by using CPT's and for extra detail boreholes. For the water table there is an nationwide network of long-term monitoring wells. We combine the data of this network with local monitoring points. By linking this data, we can calculate for example the 1:10 years water levels.

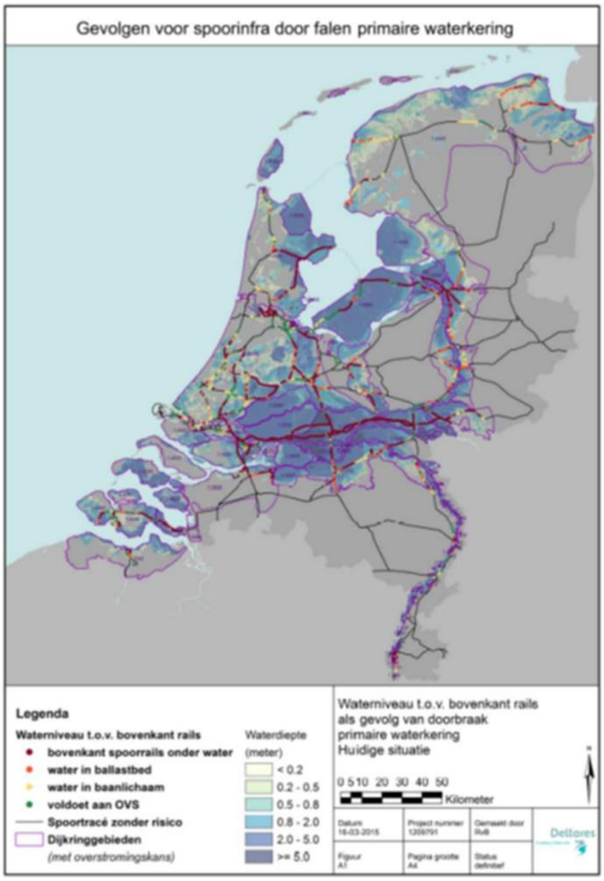
Q5. ProRail has experience with some dynamic calculations in order to predict vibration levels, when greenfield constructions are being engineered. We are also working on fundamental research program in order to have better understanding of the dynamic train embankment interactions, especially on soft soils.

Q6. For now, we are less interested in slopes adjacent to the track but are mainly focusing on the embankment stability assessments. There for the post-failure slope analyses is not applicable

Q7. For the moment this is not clear. Partially because we are just starting to assess the impact of climate change and extreme weather on our assets, including the inflow of water and soils.

Session 2

Q1. In the Netherlands flooding by sea or rivers is management by specialized waterboards. The safety against flooding is embedded in Dutch Law, therefore ProRail does not have to protect against this treat. For example, these is our current state of defence against flooding (see figure):



Q2. See response on question 1.

Q3. In The Netherlands the safety against flooding is mainly based on the group risk and economical value. Rail represents a certain economical value. The result is an flooding with a certain recurrence, for the river Rhine it is a flow rate with an occurrence of 1:1250 years. For the river Meuse 1:250 years. For every location this will result in high water levels the flood protection has to withstand. So for the Netherlands this methodology is already implemented, maybe based on a different method to calculate the occurrence and water leaves and velocities. The added value is high because it is now possible to determine the acceptable level of safety and the money to spent to reach or maintain this level.

Q4.

Q5. The waterboards are mainly responsible for SDS. In total 21 waterboards are responsible to manage extreme weather, flood defences, quality of the surface water, the salination of deep groundwater, the extraction of groundwater, etc.

Q6. It is already completely embedded in the Netherlands. It is the oldest democratic governing body of the Netherlands.

Q7. Our National Climate Research Institute determines the extreme weather for different scenarios. These are adopted by ProRail and used to design new systems. In future this will probably also result in redesign of existing systems, but this is still under debate.

Q8. As we only manage assets for trains, we do not have porous asphalt. However, for our highways. RWS has a lot of ZOAB (Dutch version of porous asphalt).

Q9. If you specify the requirements you need, maybe I can look them up.

Q10. None; see answers on the questions. I do believe that Deltares as our National knowledge institute can help Foresee in this field. See www.deltares.nl

SPANISH ROAD DIRECTORATE (Álvaro Padilla, Jerónimo Vicente

Session 1

Q1. Yes.

Q2. Better material optimization. Standardization of similar solutions provided from different manufacturers.

Q3. Yes.

Q4. Water level: Piezometers; Flow conditions: Permeability essays on soil and rock samples, Lefranc and Lugeon essays in boreholes. Pumping essays in wells.

Q5. Yes. Transient hydrogeological flow

Q6. No opinion.

Q7. Better computer simulation methods and improved methodologies for estimation: They will provide more accurate input data that will lead to better project design / correction measures.

Session 2

Q1. Quite likely if the estimated results are accurate compared to real observations. Cost, better design, more effectiveness of protection measures against flooding, less maintenance.

Q2. Subcontract

Q3. Improved methodologies for estimation will lead to more accurate input data and, consequently, better project design / correction measures.

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems: Y

Best Management Practices: Y

Green Blue Infrastructure: N

Q5. No

Q6. Lack of standards and regulations compared to conventional drainage systems.

Q7. Indirectly. It is considered in the precipitation input data.

Q8. Highways (smooth bends), in rainy areas (function: avoid water spills and better horizontal signalling visibility) and warm climatic areas (better durability if the road is no affected by ice). Q9. Traffic load, road layout (smooth bends) and weather (rainy and warm, desirable no ice inwinter).

Q10. Improved methodologies for estimation: More accurate input data will lead to betterproject design / correction measures. Best practice for SDS: Optimal use of these solutions.

SPANISH ROAD DIRECTORATE (F. Javier Morales)

Session 1

Q1. Yes, I am, from my current job position, slope stabilization is one of the main task carried out in the maintenance tasks of roads, particularly relevant in rainy season. Protection systems are mandatory in many of these cases.

Q2. I am a little bit sceptical about the application these systems for several reasons. However, during the presentation, speakers explained very well the benefits of the systems. In my opinion these systems need more experience to be applied in real environments.

Q3. Yes, we have. They are extremely useful to study the problem of landslides.

Q4. The main cause of landslides is water. I have read a lot about different methods to determine the water level. However, in real problems, traditional methods have shown thebest results.

Q5. No, really.

Q6. Yes of course. I think these methods can provide best result at management level.

Q7. A best management of maintenance of roads which can result in a safe cost and a better level of service (reduction of traffic disruptions).

Session 2

Q1. Flooding assessment is mandatory according the main prescriptions in the road project. The current European Directive for flooding assessment collects all these techniques in order to evaluate the impact of flooding not only for the adequate management of the infrastructurebut also for the cost reduction, human lives and so on.

Q2. As infrastructure owner we are extremely interested in this type of methodology. We would like to incorporate these processes to our workflow, so an application to help us will be really interested.

Q3. In my opinion this methodology does not added any special added value over the current methods. However, the integrated characteristic of the process is interested to analyse.

Q4, Are you familiar with any of these concepts?

Sustainable Drainage Systems Yes.

Best Management Practices Yes

Green Blue Infrastructure Yes

Q5. Yes, CIRIA has published really interested documents.

Q6. The lack of experience and the costs can be the main barriers.

Q7. Until some years ago, climate change had not been considered in the design of drainage systems. However, nowadays, precipitation models and drainage calculations include the effectof increase the rainfall in this hypothesis.

Q8. Porous asphalt is usually laid in roads where the climate is extremely wet or where safety problems related to water are expected. Pavement roads guidance includes the cases of study where these types of pavement are mandatory or recommended.

Q9. Durability, costs, permeability, and capacity of drainage.

Q10. The estimation of a new return periods draws my attention. This methodology sounds extremely useful to adapt the current drainage systems to a new paradigm of climate change. However, it is difficult to evaluate the results due to the lack of experience of this technique.

TRAFIKVERKET (Johan Jonsson)

Session 1

Q1. Yes

Q2. Due to rock quality the application of these kinds of systems are not as common in Swedenas in central Europe. For that reason, the relation function – cost is limited.

Q3. Yes

Q4. Not an expert in this area.

Q5. Not as described in FORSEE

Q6. Yes

Q7. It is line with the long-term strategy to work towards performance-based design and move further towards virtual tools for prediction in early stages.

Session 2

Q1. Not highly likely

Q2. It is not likely that something like the proposed methodology will be incorporated into everyday design. It may however be used in large and complex projects for critical infrastructure where a second opinion is required.

Q3. Here and now, it would be second opinion

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems: Y.

Best Management Practices: N.

Green Blue Infrastructure: Y

Q5. Local ones

Q6. There are no barriers as they are commonly used

Q7. To some extent, yes, especially in large complex projects

Q8. N/A

Q9. N/A

Q10. As mentioned earlier it would be of great value for an inframanager to use methodologies as described in both sessions of the workshop. Virtual validation of any system allows for optimisation using a general objective function, but also a possibility to scenario analysis during a concept selection phase. In addition, for existing infrastructure, it allows a possibility, what investments that would be required for the future, to deliver infrastructure services to society.

Other comment: In addition, I have to say that the FORSEE results are fantastic and would mostlikely do wonders. Sadly, the engineering community is not ready for full implementation. One thing that should be taken into account is the fact that modelling in the Civil Engineering sector is different of other sectors. In e.g. Aerospace/ automotive you rely heavily on testing before you can validate a model and a later product. Civil Engineers however get only one chance – it has to work the first time, hence the use of slightly more blunt instruments and codes and standards that captures experience from the past.

TRANSPORT FOR LONDON (Mehdi Alhaddad)

Session 1

Q1. Rock fall is not a typical issue that we are faced with in TfL. However, we do employ 'flexible systems' for stabilisation works across the network for either existing slopes that sufferfrom face loss (due to erosion, shoulder instability etc) or for new designs where we are limited in space and need to add an extra layer of stability where the slope angles are deemed to be steep

Q2. Design life is a key concern for us especially when using these systems for new designs. Thisis addressed by adding protection coatings that can last for 120 years design life. Flexibility of installation is another concern, where ease of installation can enhance the health and safety and reduce costs, especially at locations where there is limited space to operate. Aesthetic has been also mentioned where it is favourable that the flexible systems can blend with the environment that they are installed in (green mesh/coat for example).

Q3. We very often use SLOPE/W

Q4. We typically use standpipe open piezometers, vibrating wire piezometers and hydraulic flushable piezometers that can also measure negative pressure.

Q5. Not internally – However, there are situations where external consultants carryout design or assessment for us. The external consultants can use conventional or new analytical/design methods if they are rigorously critiqued and professionally approved, such a FE modelling or dynamic simulations. I have not come across dynamic simulations for any TfL projects myself.

Q6. We have an open mind for applying this and any other new methods, if they can improve the way we do things.

Q7. We have not used these methods extensively (at least within Earth Structures and Geotechnical Team) and not in a position to evaluate the added values.

TRANSPORT INFRASTRUCTURES IRELAND (Billy O'Keeffe)

Session 2

Q1. TII has developed its own risk assessment methodology and its own protocols in relation to flooding, therefore unlikely.

Q2. No. This type of work is contracted out.

Q3. See above.

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems: Y

Best Management Practices: Y

Green Blue Infrastructure: Y

Q5. Yes

Q6. Design standards for construction

Q7. Yes, a factor is applied to rainfall intensities.

Q8. Rarely used in Ireland – perceived to require excessive maintenance.

Q9. Maintenance

Q10. Yes, this is interesting and clearly is a far better methodology than the existing approach.

UNIVERSITY OF CANTABRIA (Laura Castañón, Pedro Lastra)

Session 1

Q1. A flexible system is a superficial slope stabilization technique that has the aim of minimizing damages provoked in roads due to a rockfall or landslide. They consist of membranes of cable nets or wire meshes fixed to the ground through anchorages and bolts, and they can have high or low resistance. This technique started in Europe in the 70s and it has widely extended due to its lower visual impact and the scarce traffic inference during its installation. The working range of these systems are limited to superficial instabilities, acting mostly in slope thicknesses under 3 meters. Rockfall barriers are also used to protect roads or railways, but there are focused on stopping rocks and their configuration is different. These barriers are metallic structures that retain rocks and have an impact area that somehow transmits the energy to the ground. By definition, the system is light and slender; the most common materials are cable nets or wire meshes with different grid configurations.

Q2. Their functions can be improved by exploring new materials and/or geometries for the components, as well as the connections among them. For example, rockfall barriers are constantly evolving by creating new geometries for the brakes, which is a component that absorbs a high amount of energy of the total generated by the rock impact. As for flexible membranes, the use of improved anchorage plates helps to the fixation of the membranes to the ground. The decrease of the costs is mainly related to two facts: the cost of materials and the installation costs. The first item may be reduced by the material optimization of the system. The selection of each component of flexible membranes and rockfall barriers must be done from an estimation of the maximum loads that could be applied to the system. If not, it could be oversized, and then, the cost would potentially increase. The reduction of the installation costs is achieved by developing an installation plan able to consume less resources trying at the same time to keep installation time the same. Another strategy to reduce their cost is by substituting the steel cable nets or wire meshes by polymeric geomembranes. These membranes, generally fabricated with polyester or polyamide, show a higher ratio of strength/cost in relation to steel cables and wires while also presenting a lower weight. Therefore, they could reduce the overall cost, because of the savings in material and installation time. Geomembranes are well known products among the geosynthetic family, although they are not used to date with the slope stabilisation purposes. Further investigation of connections between rolls is still needed together with improving their fire resistance. Nevertheless, there could be a potential market to develop these products for this specific application.

Session 2

Q8. Porous Asphalt are basically used in two types of road:

Mainly, highways or national roads with high traffic level and high speed, when properties as skid resistance, spray or even noise (if the road is closer to urban areas) are critical.

Secondarily, in much lesser extent, in some parking or urban areas, when they are used as part of a Sustainable Urban Drainage System or it is imperative to drain the water run-off.

Besides, there are important parameters to consider:

The weather is one of the main parameters. The area should be rainy in general, if it rains a lot but only once or twice per year, it is probably the pavement will be clogged. If the layeris used in snowy areas, the low temperatures make this mixture stiffer, and therefore more prone to suffer ravelling. Besides, if snowplough is used to maintain open the road, the blade will damage very severely this pavement, applying a shear stress which is the worst effort for this type of mixture.

Heavy vehicles at low speed can damage the porous asphalt. The acceleration, deceleration, or the moving of the tyres at low speed, generate shear stresses on the surface of the layer, which is the main damage of this type of mixture. For example, a bus stop or a crossroad with high traffic of trucks, are areas which probably will have ravelling problems.

If the layer is going to be used in urban areas, it is important to check if there are threes or green areas very close to the road, because they could clog the surface layer with leaves, seeds, etc.

Q9. The percentage of voids (or the density) controls its properties, mechanical and functional, therefore this parameter should be the first to be controlled. Besides, the main problem is its useful life because the ravelling damage, in our opinion the ratio filler / bitumen is the key pointto reach a good behaviour. This mortar material links the coarse aggregates, and ravelling happens because mainly two reasons: because mortar is aged and fissures appears (it is like a fatigue problem but a small scale), or because there is a stripping problem between mortar and aggregates.

UNIVERSITY CHALMERS (Björn Paulsson)

Session 1

Q8. The train accident in Getå, Sweden, October 1, 1918, was the most serious in Swedish railway history. At least 42 people died. It was a landslide that went out in the see. My other concern is that I am skeptical of geotechnical calculation programs. The reason is that input data often is too often insecure. Which often can lead to conservative input data, which in turn leads to unnecessary high costs.

UNIVERSITY COLLEGE DUBLIN (Vikram Pakrashi)

Session 1

Q1. Yes

Q2. Better models -> better designs, less uncertainties

Q3. Yes

Q4. Not an expert

Q5. Yes (linear/nonlinear fundamental models, including constitutive models)

Q6. N/A – we use SPH

Q7. Collaborative opportunities

Session 2

Q1. For us – collaboration

Q2. N/A

Q3. Joining future funding calls

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems N.

Best Management Practices Y.

Green Blue Infrastructure Y

Q5. No

Q6. Do not know

Q7. Climate variability – but not change since the lifetime is smaller. Yes, for designs with large lifetime.

Q8. Not an expert but parking lots is a good idea for example, also people have used it in SuDs/SDS, driveways, sidewalks, bike paths, playgrounds, and tennis courts.

Q9. Not an expert but maybe runoff volumes, loads, pollution type and extent, climate,longevity needed, degradation (salt deposits, freeze-thaw?) etc.

Q10. Resilience computation

UNIVERSITY GUSTAVÉ EIFFEL (André Orcesi, Franziska Schmidt, Sylvain

Session 1

Q1. Not with flexible systems for stabilization of slopes (only rigid systems, like anchors). Yeswith rock fall barriers.

Q2. Proposal for easy design of systems, choice on shelf, and easy installation.

Q3. Another department at Université Gustave Eiffel is in charge of these topics.

Q4. No

Q5. Finite elements

Q6. Not concerned.

Q7. Our department is not directly involved in such developments.

Session 2

Q1. CPU reduction (we are a research institute)

Q2. Not concerned.

Q3. Better assessment.

Q4. Are you familiar with any of these concepts?

Sustainable Drainage Systems Y

Best Management Practices Y

Green Blue Infrastructure N

Q5. No

Q6. Q7. No.

Q8. When there are water issues, but no freeze issues.

Q9. Water level, temperature, traffic loads.

12 APPENDIX G - 3RD SRG WORKSHOP ON MARCH 18TH

Comments from SRG, 28th of April 2021

1. Scope of this document

On March 18th, 2021, the 3rd SRG workshop of FORESEE project was organized to deal with "Monitoring-based Decision Support for Resilient Transport Infrastructures".

67 attendees from 43 SRG's entities (see the table) and 35 attendees from 14 FORESEE's partners participated in this workshop plus three invited attendees: Rafal Stanecki from DG Move, Sergio Escriba from INEA and Helmut Wenzel from Wenzel consult. Jesús Rodríguez, SRG chairman, coordinated the workshop.

SRG attendees participated and contributed with comments and the content of this workshopis summarised in another document. After this workshop, written contributions were asked to the SRG's attendees to answer some of the questions.

Entit y	Typ e	Country	Nam e
ADIF	1	Spain	David Villalmanzo, Pedro Martín Pérez
Aecom	2	UK	Mathew Audley
Aegean Motorway	1	Greece	Dimitris Poulitsis; Dimitris Nikolaides
Asfinag	1	Austria	Karl Engelke
Atkins	2	UK	Jane Kelsey
Bast	4	Germany	Martin Klose
CEDEX	4	Spain	Laura Parra
CE.R.T.H.	4	Greece	Ioannis Benekos
CEREMA	4	France	Andre Orcesi
Cintra	1	Spain	Cristobal Martínez
CSIC Univ. Cambridge	1	UK	Campbell Middleton; Simom Ye
Deutsche Bahn	1	Germany	Michael Below
Eiffage Kier Ferrovial BAM JV	2	UK	Marco Bocci
ETS	1	Spain	Josu Rodríguez
Geocisa	2	Spain	Ana Belén Menéndez; Alejandro Rodríguez
DZSF	4	Germany	Fabia Backendorf
Ines	2	Spain	Gonzalo Arias
Highways England	1	UK	Angus Wheeler
Irish Rail	1	Ireland	Fiona Kelly; HudaAbbas Yousif, Shane Creaven, Stephen Browne
LNEC	4	Portugal	Tiago Coelho, Pedro Oliveira; Helena Cruz; Catarina Miranda Oliveira
			Fabiana Navia Miranda; Manuel Pipa; Ana Sofía Louro, Juan

			Mata
Madrid Town Council	1	Spain	Pedro Jose Rodríguez
Main Roads Western	1	Australia	Flori Mihai
Mott MacDonald	2	UK	Christopher Power
National Roads Authority UNRA	1	Uganda	Mark Rubarenzya
National Transport Commission	1	Australia	Caroline Evans
NCSR	4	Greece	Thanasis Sfetsos
Network Rail	1	UK	Mark Langdon; Julian Harms
Norwegian Public Roads	1	Norway	Gordana Petkovic; Tommy Bjerkvik Steinnes; Christian Røkke
Politecnico di Milano	4	Italy	Dario Coronelli
ReCAP	4	------	Nkululeko Leta
Rijkswaterstaat	1	Netherlands	Leon Schouten; Sonja Fennis, Sander Borghuis
Road Directorate	1	Spain	Jerónimo Vicente Dueñas; F.Javier Morales
SINA (ASTM S.p.a. Group)	2	Italy	Giulia Guzzini
Swiss Federal Roads Office FEDRO	1	Switzerland	Dimitrios Papastergiou
TII	1	Ireland	Vincent O'Malley
Trafikverket	1	Sweden	Johan Jonsson
Transport for London	1	UK	Fiona Tomson; Nicola Head; Duro Basic
UIC	3	-----	Mercedes Gutiérrez
University of Bologna	4	Italy	Andrea Benedetti
University College Dublin	4	Ireland	Vikram Pakraship; Abdollah Malekjafarian
University Parma	4	Italy	Lorenzo Franceschini
University Porto	4	Portugal	Filipe Magalhaes
ZAG	4	Slovenia	Stanislav Lenart, Rok Vezocnik
1. Transport Authorities, Infrastructure Owners and Transport Operators; 2. Engineering, material and construction companies; 3. Associations; 4. Research entities			

This document collects the 33 contributions that were received (see the list below). It complements the comments made during the webinar and it will allow FORESEE members to be considered for the documents under preparation.

SRG	Page
ADIF (Spain): Jose Conrado Martínez, Pedro Martín Pérez	6
Aecom (UK): Mathew Audley	11
Aegean Motorway (Greece): Dimitris Poulitsis; Dimitris Nikolaides	12
Asfinag (Austria): Karl Engelke	15
Atkins (UK): Jane Kelsey	18
CEDEX (Spain): Laura Parra	19

2. Questions addressed to SRG members.

SESSION 1: ASSESSMENT AT THE COMPONENT, SYSTEM AND NETWORK LEVEL

1.1 STRUCTURAL HEALTH MONITORING FUNDAMENTALS: SURFACING IN AN OCEAN OF SHM ALGORITHMS.

- Do you think you can implement any of these algorithms in your organisation for SHM purposes?
- Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?
- Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

1.2 SATELLITES DELIVER ADVANCES IN REMOTE MONITORING FOR ROAD, RAIL & OTHER CNI: STEPS TOWARD FULLY INTEGRATED STRUCTURAL HEALTH INSIGHTS IN DIGITAL TWINS.

- The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?
- Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?
- How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

1.3 POTENTIAL FOR GROUND MOTION DATA FROM SATELLITES TO TUNE LANDSLIDE MODELS.

Landslides or ground motion can damage infrastructure. The aim of this subcomponent of FORESEE is to use satellite ground motion data to tune predictions of future slope failure or ground motion. Our questions relate to how this information could be made useful to an infrastructure owner.

- Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?
- If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

SESSION 2: DATA-DRIVEN DECISION SUPPORT TOOLS

2.1 DECISION SUPPORT MODULE: FROM DISRUPTION EVENTS TO DECISION MAKING USING TRAFFIC DATA AND VULNERABILITY OF THE NETWORK.

- Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?
- If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?
- Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

2.2 USING INTERPRETABLE MACHINE LEARNING FOR DATA-DRIVEN DECISION SUPPORT

- Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?
- Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?
- Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

2.3 INTEGRATION IN OPERATIONAL AND MAINTENANCE PLANS.

- Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?
- Do you follow ISO 55000 as general framework?
- What do you value the most: precision or promptness?
- Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Answers that were received from SRG

The contributions included in this chapter reflect the opinion of the experts and do not necessarily represent the position of the entities they are working for.

ADIF (Jose Conrado Martínez, Pedro Martín Pérez)

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes? Yes, we do. From ADIF we are interested in the implementation of algorithms to monitor infrastructures such as bridges, embankments, switches, track circuits and rails in real time.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms? Yes, of course. We can improve the railway maintenance using algorithms related to predictive maintenance.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms? Yes, we do. Indeed, we are working to monitor infrastructures, such as bridges, switches, rails, track circuits, where the main goal is the acquisition the data in order to know in real time their state and make optimum decision based on analysis of these data.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

In the Pilot BIM Project, we have carried out the first phase of the project, a 3D survey with laser scanner technology of the Malaga - María Zambrano station.

A topographic campaign has been carried out with laser scanner technology that has made it possible to obtain a complete geo-positioned point cloud with a high degree of precision from the entire existing infrastructure of the station. This information is helping us to feed the Smart Station and Smart cities platforms currently under development with reliable data.

In SENTINEL Project the main objective was the development of an intelligent management system integrated by a georeferenced data capture device that has been installed on board railway vehicles. These georeferenced data have allowed us to carry out an automatic inventory of railway assets and to interpret and characterize the elements of the track, optimizing their maintenance.

In addition, Adif is currently implementing the Building Information Modeling (BIM) methodology and defining the railway BIM classification, thus promoting innovation throughout the life cycle of an asset through the implementation of a new BIM methodology based on the digital transformation and process automation with the use of new technologies.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

We are starting some projects whose purpose is to develop prototypes that will help us to validate the technology can use in the future (such as DAS Technology, Lidar, Drones, IoT, Digital Twin, Machine learning, Big Data, BIM, vibration sensors, etc). For example, We know that DAS technology can be very interesting for us, because is a system that uses fiber optic like a vibration sensor but first we need to know how it works, know that the main problem is the number of false alarms it generates and work on defining the best solution

One of the most difficult issues we are going to face is the integration of this huge amount of data into our maintenance process. The change of model must be progressive, during several years and both models must live together. For the moment, we are developing individual dashboard where we can check in real time the state of the element we are studying.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Proving that you can avoid maintaining false positives, i.e. maintenance on assets that don't need it. Improving scheduled periodic maintenance plans or a predictive maintenance plan based on previous data analysis from the digital twin.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

The threshold will depend on the type of movement of the hillside and according to the geological material affected, the mechanism and type of breakage, the speed of the processes, etc. and the risk of the affected infrastructure.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

It would be necessary in real time or as soon as possible to anticipate the necessary works and prevent accidents.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation? Yes, of course.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Determination of the impact of extreme weather events on infrastructure:

Identification of the different scenarios and risks associated with extreme weather events.

Application of risk estimation algorithms and creation of vulnerability maps to determine points of high risk or intervention.

Evaluation of measures or options to reduce the impact of these events

Mitigation and management of the reduction of the impact of extreme meteorological phenomena on the infrastructure:

Development of a control platform in the face of extreme events: high and very low temperatures, strong winds, heavy rainfall, strong waves, etc. Integration of meteorological data and predictive models.

Increase and integrate data from the infrastructure and events and historical monitoring of meteorological data (temperature, wind speed and direction, and rainfall) by geographic segments corresponding to the official processing of the lines to optimize maintenance and create predictive models.

Provide sensors and basic analytics in real time for the monitoring of the infrastructure to improve the detection and prediction of possible impacts of extreme meteorological phenomena.

- *Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?*

New tools through (IoT, drones, AI, etc.) or methodologies for infrastructure maintenance, especially for hillside movements, rocky block falls and floods

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

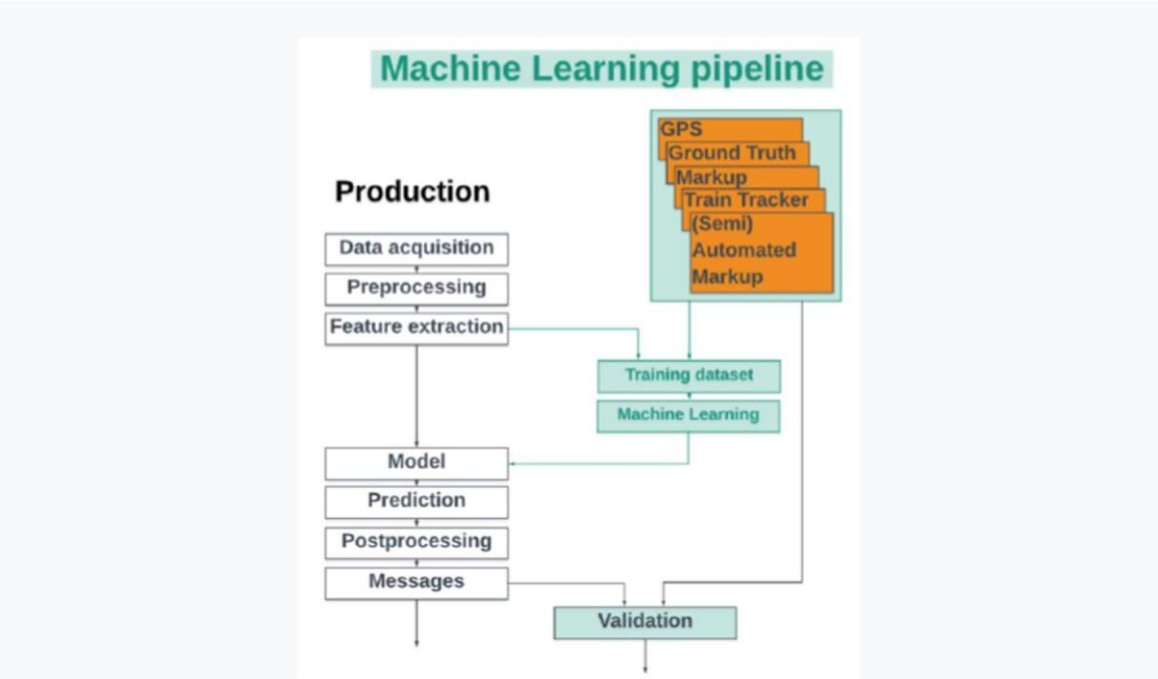
Yes, we are interested and the way I would prefer to have diagnostic metric is through a Dashboard with alarms and mail.

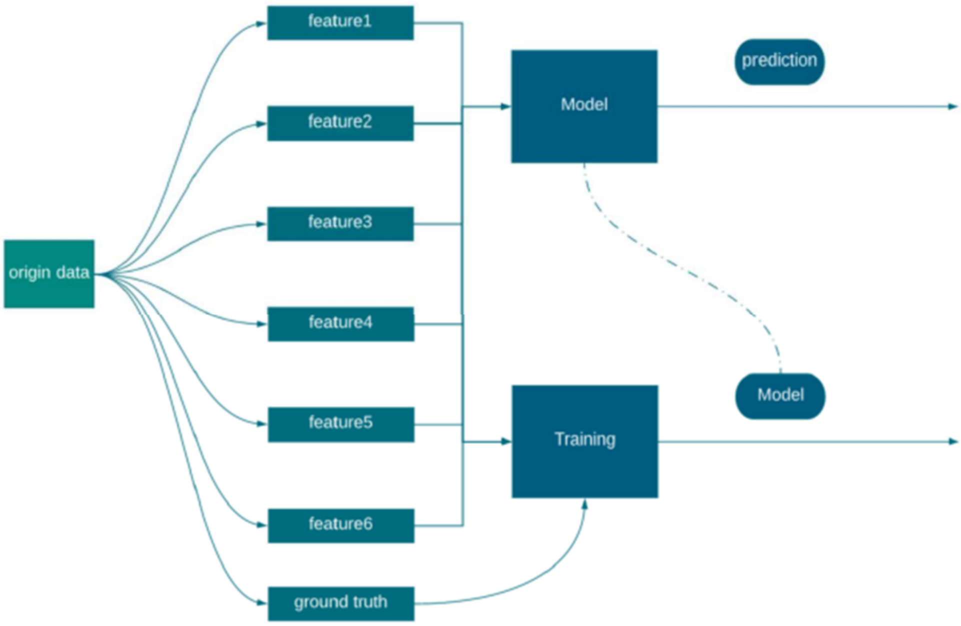
Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

We are working on different projects where the idea is moving from an empirical decision – making to a analytical one, especially in terms of predictive maintenance.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

We are developing algorithms in different projects related to predictive maintenance in which we use machine learning. For example, in a prototype to detect break rail using DAS (Distributed Acoustic Sensing) technology, we developed an algorithm called Train Tracking where we extracted a set of unique parameters (“features”), which identify a train. Based on these features we set up and trained a model.


Machine Learning pipeline
Production
GPS
Ground Truth
Markup
Train Tracker
(Semi)
Automated
Markup
Data acquisition
Preprocessing
Feature extraction
Training dataset
Machine Learning
Model
Prediction
Postprocessing
Messages
Validation



Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

From Innovation Department we are not able to offer a solid answer to this question, because at this moment we are starting a project which goal is to monitor bridges.

Do you follow ISO 55000 as general framework?

Adif is currently implementing an Asset Management System based on ISO 55000.

What do you value the most: precision or promptness?

Both are necessary to carry out optimal maintenance and we cannot renounce either of them

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

For the moment, we are subcontract it as a service.

AECOM (Mathew Audley)

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes? No

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms? Yes

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms? Yes

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management? Not Known

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management? Not Known

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin? Not Known

Using interpretable Machine Learning for Data-Driven Decision Support

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)? No

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)? No

AEGEAN Motorway

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

The implementation of the proposed algorithms in SHS require a significant number of inputs towards the structural integrity verification. Probabilistic approaches require more sophisticate data as well as ad hoc analyses for a large amount of assets in Aegean Motorway's network, in order to provide a probabilistic estimation regarding damages or structural redundancies. The types of bridges included in our network are not suitable for such analyses related to long term SHM or any implementation of stochastic algorithms.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms? No

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms? No

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?.

We are not using any BIM or Digital Twin

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

ADVITAM Scanprint IMS

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

We have already established a monitoring system with threshold values and time reaction. A Risk Analysis Study has been established and it is updated in certain periods or when the situation parameters change (e.g. significant traffic volume increase or change ingeomorphology condition)

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

We already using on site investigation for any ground movements. For any evidence of ground motion we implement a detailed inspection.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organization?. Yes

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future? Positive

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

We are interested only on specific cases that demand further examination (i.e superloads).

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

We have already carried out probabilistic deterioration models for bridges , regarding to Aegean Motorway's maintenance plan as well as detailed structural analyses (FEM-based) .

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?. *No*

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?. *No*

What do you value the most: precision or promptness?. *Promptness*

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?.

It can be done either as internal procedure by our structural experts or as a subcontract.

ASFINAG (Austria): Karl Engelke

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Yes, for large objects this is an option, in few special cases (large objects in bad condition) we actually use such monitoring systems with external contractors

Do you think you can improve any process in your organization (e.g, inspections) using any of these algorithms?

Probably yes, this would have to be tested in detail.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Probably yes, this would have to be tested in detail.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

We are currently using BIM in the planning of objects in pilot-projects and and we have also started using BIM in inspections of bridges and tunnels. We want to develop our inspection process in a fully digital process beginning with mapping of damages, monitoring those damages, compare changes and so on up to defining maintenance measures for larger objects.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Mostly we use geodetic deformation measurements an in few cases measurements of frequencies.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

First, the technical component of recording and storing the data must be ensured, then the interfaces for data exchange must be harmonized so that they can ultimately be made available to external contractors who then carry out the inspections.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

This is decided very individually and depends on the current situation.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

At least a couple of days in advance to have enough time for deciding correct decisions.

Session 2: Data-Driven Decision Support Tools

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

These parameters would be of subordinate importance.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

I´m sorry, no

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Probably yes, Data delivery should be automated directly into the Asset Managemtn system, any arlamations should be routed to our monitoring centers

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Yes, we use several models, both analytical and empirical.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

We have some pilot projects with AI supported damage detection, but these results are not further developed in models for decision making.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

The damage index alone is not meaningful enough to make a (correct) decision, it is important to know the specific damage. A KPI derived from damage index should be used very carefully.

Do you follow ISO 55000 as general framework?

Yes we do, this or next year ASFINAG will be audited first time.

What do you value the most: precision or promptness?

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We are currently developing the necessary structures for this

ATKINS (UK): Jane Kelsey

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

This would be a decision for the client and would be project specific. However, clients are open to innovation suggestions.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Digital twins are currently being developed on a project by project basis, generally larger projects have plans to produce digital twins.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Asset management contracts use specific monitoring systems, such as periodical instrument monitoring, in some cases this monitoring is remote. A risk-based approach has been developed for some asset management contracts.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

For certain asset management contracts this may be useful, where a risk-based approach is not already in place.

CEDEX (Spain): Laura Parra

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

CEDEX doesn´t perform routine bridge inspections. But, CEDEX has to take decisions based on the variation of the structural response over time. We find difficulty in deciding thresholds, due to the complexity of the deterioration mechanisms and also to the fact that the response signal is affected also by climate conditions (e.g.T variations). CEDEX is very interested in this issue.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

It is something that should be explored. As previously said, CEDEX is very interested in SHM algorithms.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

CEDEX has performed several remote inspections in bridges. These datasets could be useful to test the algorithms.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

At this moment, Digital Twins in CEDEX are widely applied in the field of railways operations (ERTMS tests). CEDEX is also in the process of implementing digital twins in existing infrastructures.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

The monitoring system for asset management are visual inspection (using drones when needed) and sensoring (accelerometers, LVDT, strain gauges, humidity) that can be remotely operated. However, CEDEX is not responsible of asset management systems so we don´t integrate these information.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

CEDEX is no responsible of procurement of monitoring systems.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

So far CEDEX has not established precipitation thresholds, or the other parameters, that are general and that have as a consequence an increase in geotechnical surveillance or the implementation of corrective measures. We study case by case and depending on the level of damage that the sliding may cause, the triggering cause and the failure mechanism (brittle or ductile), more or less strict thresholds of movement or speed of movement are established.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Roughly, you could say that one or two months. The sooner the better.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

CEDEX is not a road operator but we are very interested in all these parameters. We are also doing research in this field.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

It should help to have better action protocols and emergency plans. Therefore, helping to restore the service asap and minimizing the losses.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

CEDEX is not a road owner/operator but we think that this kind of data driven decision support are needed.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

CEDEX is not a road owner/operator but we are interested in compiling data that will help a better informed decision making.

Integration in operational and maintenance plans.

Do you follow ISO 55000 as general framework?

CEDEX doesn´t perform asset management

What do you value the most: precision or promptness?

I would value a combination of both. I consider that both parameters should be informed.

CEREMA (France): André Orcesi

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

This is the objective indeed, although some of the advanced aspects are still at a research level.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Some of these algorithms are already investigated with the objective of improving surveillance strategies.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Datasets are generally property of bridge owner. Difficult to answer this question.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Not being in charge of this topic in my organization, difficult to answer this question.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

The reference system used in France on the roads of the National Network (ITSEOA) distinguishes the monitoring of a structure from its assessment (which consists of giving a rating). The objective of monitoring systems consists not only in damage detection but also in structural health prediction to perform maintenance strategies. In France, it is part of "enhanced surveillance" and only implemented when the structural state justifies it (in case of doubt on the origin, the nature, the cause or the evolution of defects) or on innovative structures. Monitoring systems, when considered, are included in the set information used by asset managers to help them make decisions.

In link with the presentation in this session, there is some research effort currently in Cerema, in collaboration with other partners, to investigate the use of S-SHM.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

There are currently some research effort to encourage the development of digital twin concepts.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Not in charge of this topic at Cerema.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Not in charge of this topic at Cerema.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes, indeed. Similar concepts have been recently investigated in some EU research projects (PANOPTIS EU project).

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Better preparation to disruptive events to be more resilient (from absorption to adaptation).

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

The proposed parameters already represent an advanced level of analysis of resilience. As mentioned previously, you can check the indicators proposed in other EU projects such as PANOPTIS.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Indeed, this is a key interest, all the more to send alarms linked to sudden failures in hidden areas of a structure.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

There is not a unique type of model used in decision-making. There is an increasing complexity level of models, depending on the consequences, the type of degradation, and if the structure is under usual surveillance, or enhanced surveillance.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

At this time, this is mostly investigated in research projects (in collaboration with other institutes at a national or international level).

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?. *Yes.*

Do you follow ISO 55000 as general framework?

Not enough information to answer this question. In link with this presentation, it is indeed important to be in line with standards when talking about strategy, tactic and operational issues.

What do you value the most: precision or promptness?

Good question. Both are very important. Precision is key aspect.

CINTRA (Spain): Cristóbal Martínez

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Cintra is permanently analyzing solutions in the market to improve our Asset Management System that includes, among others, an early detection of defects in our structures portfolio. Inthat sense, this type of developments could be implemented in our AMS.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Any development in this area following the latest state of the art could be tested in ourconcessions to check the improvement of our existing AMS.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

We use different database structures depending on the geographical market, but all of them are compatible with most common standards.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

We are evolving to include these digital twins in our assets under operation but, at present, just a few pilots are using this satellite information. Once we check the reliability of this info and its cost feasibility, it is expected to expand the solution in the critical assets of our portfolio.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Static information from periodical pictures taken with drones or CCTV systems and dynamic information from other Roadside equipment (extensometers in structures, embedded sensors in pavements, DAS based on available fiber optic,…)

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

We are continuously open to new solutions, although in some occasions we are conditioned to the BIM creation during construction that usually follows Administration rules and these BIM models can provide enough information for our future operation.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Conflictive slopes are usually monitored using inclinometers and periodic topographical surveys. Depending on the geological information and the age of the infrastructure after substantial completion, different thresholds for acceptable movements and periodicity are set.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

It will vary depending on you risk analysis (combination of vulnerability and exposure) and final impact in your asset (from a financial point of view, but also considering possible impact on user safe or thir parties). Summarizing, enough time to correct defects that can involve penalties in your contract (especially relevant in availability models), affect notably to your revenues or put at risk your users or third parties. In the last hypothesis, the minimum required time to receive an alert will be that one that guarantees that the evacuation or traffic warning is achieved and the correction works can be put in place.

Session 2: Data-Driven Decision Support Tools

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

As explained above, it is one of the most valuable data that should be collected.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Acting in advance, cheaper restoration solutions can be launched or simple routine maintenance can be reinforced to avoid non planned capital expenditures.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

As a preliminary approach and before testing this solution during a pilot during a minimum period of time, it seems to be enough the proposed parameters.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

If info in advance is desirable, real-time diagnostic capabilities could be really appreciated. But this real-time information could be useless if generates too many false alarms. Depending onthe installed AMS and type of info (pictures vs alphanumeric data), the way the information is provided can vary a lot.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

We usually combine both solutions: analytical models duly calibrated using real data

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

At this time, we are in a preliminary stage using different commercial solutions that are based in AI. At the end of these pilots, we could be in a better position to give an opinion.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?.

Yes, I do

Do you follow ISO 55000 as general framework?

Yes. Our AMSs follow the guidelines of this standard

What do you value the most: precision or promptness?

Both terms must be analyzed in a wider concept of risk, as I've roughly indicated above.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

In the holding we have both, data analysts and structural engineers, but we need permanent support of external specialist to be updated at the latest trends.

Deutsche Bahn/DZSF (Germany): Michael Below, Fabia Backendorf

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

In theory, implementing any of those algorithms for SHM purposes seems to be a great and sensible measure. Therefore, a more detailed and intensive knowledge and information exchange with experts from different departments of Deutsche Bahn and German Centre for Rail Traffic Research (DZSF) in combination with the Federal Railway Authority (EBA) is needed. In addition, it would be very helpful to have an additionally presentation in the future with those experts.

Do you think you can improve any process in your organisation (e.g. inspections) using any of these algorithms?

see answer above

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes, but there is need to discuss in detail with the experts of the different involved parties as already mentioned above.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

DZSF and EBA, both are dealing with Building Information Modeling (BIM). Topics such as BIM in operational rail traffic or BIM and data management are part of DZSF´s research.

Actually, at DB the BIM and especially the use of digital twins are tested in different processes like in maintenance shops, infrastructure and operations in a pilot region, analyze customer flows. The knowledge gained in this way forms the basis for increasing quality and reducing costs through process optimization.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

This depends on the site.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

This depends on the site.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes, the mentioned parameters are an important base to estimate possible hazards /downtime and thus an important basis for estimating the costs of possible countermeasures.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

see answer above

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Duration of the failure although it should be included in operating losses already; Restoration costs (without loss of income), possibly level of resilience before and after the restoration.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

In general, such support is most welcome, especially for security reasons. It might be helpful, if a graduation is implemented due to different alarm levels concerning the various systems or system parts.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

Yes, because the structural damage index has an immediate impact on the KPIs.

Do you follow ISO 55000 as general framework?

Due to the responsibility of the different business units within DB this is organized in different ways. In general, the ISO-rules are followed in many cases within DB, but it is not mandatory to be certified.

What do you value the most: precision or promptness? Depending on

operation and maintenance plans: precision,

security: promptness.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Due to the responsibility of the different business units within DB this is organized in different ways, beside internal staff, the service is provided by external service providers

Eiffage Kier Ferrovial Bam JV (UK): Marco Bocci

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Interesting but I don't think we will use them on our project.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms? Possibly, yes.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms? Possibly, yes.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Not sure, but HS2 is driving forward this implementation.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Not sure, I am not dealing regularly with asset managers.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

I don't think I am in a position to influence such internal conditions.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Not sure, EKFB are not managing infrastructure assets, we are contracted to construct them.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

I would expect to be able to intervene within days.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

I guess so, from a design perspective.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Better predictions could indicate areas where the design needs to be improved.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

I am not sure.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Yes, possible alerts of advance trigger breaches following current trend.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

I don't directly but our designers are.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

EKFB is trialing the use of a platform using machine learning algorithms to optimize geotechnical models using monitoring data.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly? Yes.

Do you follow ISO 55000 as general framework?

No, we are not a company dealing with asset management.

What do you value the most: precision or promptness? Promptness.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We prefer to subcontract to a SHM specialist.

ETHZ (Switzerland): Claudio Martani

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes? Not in practice. We are a research institution.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

As a research institution we don't execute any Structural Health Monitoring in our organization. We though investigate the implication of their use in our research.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Within the ETHZ yes, but not in our group specifically.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

At the ETHZ there is a Chair in Innovative and Industrial Construction that makes a particular research focus on the use of BIM and Digital Twins in asset management but not in my chair specifically. We work mainly on processes and methods to improve decision making with respect to infrastructure management.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

We optimize asset management processes considering any type of monitoring system. We though don't operate any directly.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

We don't procure any monitoring system directly.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

We do are interested in real-time diagnostic capabilities for optimizing decision making on interventions. Though as a research institution we don't use diagnostic metrics ourselves.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

We develop several analytical models for decision-making (i.e. both pre-event and post-event decision-making), that though don't use in practice.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

As a research institution we don't take any decision on infrastructure. For research purpose though we are interested in the development of these.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

Yes, I believe so.

Do you follow ISO 55000 as general framework?

We follow the general framework and terminology for asset management as from the ISO 55000 both in our research and in teaching.

What do you value the most: precision or promptness?

We tend to favorite risk minimization, i.e. minimization of the potential consequences. So we prioritize precision, when consequences of incorrect interventions are more disruptive, and promptness when timing is more impacting.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Within the ETHZ yes, but not in our group specifically.

Geocisa (Spain): Ana Belén Menéndez, Alejandro Rodríguez

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

All these algorithms are well suited to dynamic issues related to the structures we are working on (high-speed railway structures). Perhaps this is a great opportunity to start conversations between GEOCISA and some of the project members.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Of course. In fact, we are now dealing in a project to improve the dynamic part of load tests, which is our main activity, including regulations.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes. We are currently working on a load testing contract for Adif, as we have done many times in the past. This allows us to acquire a large amount of both dynamic and static data from real high-speed rail structures. We understand that something very interesting would be obtained by using data-driven algorithms.

Highways England (UK): Angus Wheeler

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

The algorithms presented are aimed at structural situations.

Unfortunately, they are unlikely to be of help in an earthwork context.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Not for earthworks.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

My structural colleagues maybe interested.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

At the moment BIM is not used by our Operational teams however I can see that changing in the future as more projects are constructed using BIM Level 2.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Our earthwork assets are primarily monitored using inspections. However, we also use AVIS, and I, network wide house system incorporating LIDAR and video. Some assets are monitored by bespoke systems such as remote accessed inclinometers etc. We are also carrying out research projects into using remote sensing.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

We carry out research projects to determine their viability and cost effectiveness.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

We do not have generic thresholds/uncertainties as these triggers are very much site specific.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Again, this is very much dependant on the site. If it was a high risk site we would know the issues that cause the elevated risk and so would have procedures in place, such as Matrix signs, warning that closures may occur at short notice. It would then be easy to implement those closures onto established diversion routes should the trigger level be reached.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

These maybe of use however at the moment the development of our Decision Support Tools are more aimed at strategic funding rather than at a tactical level.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

As our DSTs are planned to be used at a Strategic level any remedial works will be programmed in and constructed during low levels of traffic flow, using established diversion routes.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Again, this is very much site specific, as is the form of delivery. Higher risk sites could potentially have telephone alerts with lower risk sites having data delivered by email with remedial measures installed in advance.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

We are developing deterioration curves for earthwork deterioration.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

These have not been developed for Highways England geotechnics.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

We do have a performance measure relating to our earthworks condition but at the moment this is not a Key Performance indicator. KPIs are at a higher level, concerning a well maintained and resilient network; customer experience; safety and the environment etc.

Do you follow ISO 55000 as general framework?

Our Asset Management Development Plan for Road Investment Strategy Period 2 will be mapped against ISO55000.

What do you value the most: precision or promptness?

This very much depends on the circumstances but generally precision within an agreed programme.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We do have a small number of specialists but generally we subcontract our earthwork inspections.

IP (Portugal): Rui Coutinho

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organization for SHM purposes?

No, at least in short-term.

Do you think you can improve any process in your organization (e.g, inspections) using any of these algorithms?

Yes, but it would take time to be implemented.

Do you think there are datasets in your organization that can be exploded using data-driven algorithms? Yes.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilization of Digital Twins in your organization? Alternatively, what is the roadmap that your organization has for the utilization of Digital Twins in asset management?

At this time, it is not considered in terms of project and design nor construction, and there's no plans for a near future delivery.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

The use of SHM is restricted to a small percentage of Bridges (cable-stayed, suspended and some big bridges). The system used is based in a traditional approach, with data stored on data- loggers or collected remotely and analysed later as well decision making.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

As mentioned above, it is not a priority and it's not foreseen in the short-term. Beforehand, it's necessary to include it in our company's digital strategy.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

For most cases, unstable ground associated with structures is signaled from visual inspections and might be flagged an alert for specific weather conditions. Anyway, in more complex situations, containing structures might be instrumented as monitored remotely or locally. Any thresholds are designed specifically to each structure. From a generic point of view, there isn't a static threshold of ground motion that triggers site investigation of potentially unstable locations, since there isn't a tool that allows for a macroscale (and progressively microscale) analysis of the total infrastructure. This kind of action usually begins with visual inspection insitu.

Regarding a degree of uncertainty about the magnitude of ground motion, naturally it depends on each case specific circumstances. Probably, points near the infrastructure, between a few millimeters (in railways) to a centimeter or a bit more (in roads). Points farther away from the infrastructure could assume a larger magnitude.

On timing of ground motion, it's certainly hard to guess, but always dependent of response capability from the infrastructure manager.

Also, ground motion, in some cases, is not directly related to rainfall occurrence, depending on the depth and geometry of the displacement and soil's geotechnical and hydraulic proprieties.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

The sooner the better but should depend on the probable severity of the damage and velocity of the displacement. Minimum, 1 year, to arrange the project and necessary contractor. Can be less in case of an emergency intervention. Of course, short term information might be very useful to ensure users safety.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organization?. *Yes.*

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Those parameters would rank the priority and infrastructure's assessment level subjected to those topics.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Condition and Traffic Level.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Yes. The alarm approach would be the best option, if well supported with the real-structure.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

It is our intention, in short/mid-term, to develop an approach based on empirical decisions (deterioration models).

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?.
No

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

From our experience, we use our structural damage index based on our (specific) asset management system to determine global infrastructure condition and quality.

Do you follow ISO 55000 as general framework?

Yes. Infraestruturas de Portugal´s asset management system is compliant with ISO 55001 and certified since 2019.

What do you value the most: precision or promptness?

Precision and promptness should "walk" together.

Do you have any specialist in SHM or data analytics in your organization or do you prefer to subcontract it as a service?

Regarding SHM, we have a partnership with LNEC (National Laboratory for Civil Engineering).

Irish Rail (Ireland): Shane Creaven

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Irish Rail have many suitable bridges of varying ages and construction types that could be used.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

To achieve for example a reduction in inspection frequencies would require a change in the bridge inspection standards within Irish Rail. This could only be achieved after a prolonged length of trials but for decision support regarding maintenance interventions the algorithms could be used as one element of the decision making.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

It is possible that Irish Rail have a comprehensive set of data available. Further investigation into the quantity and quality of information would need to be examined.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Currently Irish Rail do not use BIM or Digital Twin in operational asset management. I am not familiar with any current plans for using Digital Twins for our current programme of remote monitoring of assets.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Currently there is a programme of remote monitoring of safety critical assets in Irish Rail under review. A cutting and embankment risk model is actively used throughout the network.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Internal conditions are reliant on the business requirements and needs of the organization.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Irish Rail have a cutting and embankment risk model and decision support tool for predictive failures and risk associated with rainfall intensities. There are no thresholds based on actual ground movement that trigger site investigations of potentially unstable locations. The threshold for site investigations is based on rainfall intensity. The problem with using the magnitude of ground motion is that the embankments were primarily constructed in the mid 1800’s with different materials used throughout the network therefore different tolerances would need to be established.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

To mobilise staff to carry out a site investigation would require a minimum of 12 hours.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

This would be extremely useful particularly in a railway environment where network resilience is of the upmost importance.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Using the information to prioritize inspections following events or prioritize preventive maintenance based on the indications to increase resilience and level of service based on potential economic losses.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Historic information such embankment slips, previous repairs, railway tamping data.

Using interpretable Machine Learning for Data-Driven Decision Support

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Irish Rail do not currently use machine learning for data driven decision support. Maintenance intervention is carried out based on results from General Engineering Inspections carried out every 2 years or Principal Inspections carried out on a 6-yearly interval.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

It is clear to see the connection between key performance indicators and structural damage index.

Do you follow ISO 55000 as general framework?

Irish Rail follow ISO 55000 as general framework.

What do you value the most: precision or promptness?

There is an argument for both. Precision is important but if precision is late then the information may not be useful to the infrastructure manager whereas if inaccurate information is promptly supplied then confidence in the tool with reduce so a balance is required.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We have no specialist in SHM within Irish Rail at present. If and when a requirement for SHM is required a specialist is subcontracted at present.

Main Roads Western (Australia): Flori Mihai

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes? Potentially, pending on the commitment to install sensors and collect data over the required period 9+ months.

Currently sensor collection on structures in its infancy.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

MRWA has more experience in using AI and neural network approach for pavement inspection.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes, e.g. road pave and surface condition, real time traffic data.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Towards Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Currently not utilized. The organisation is currently considering the development of a road map for digital engineering.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

We use maintenance management information system based on GPS enabled tablets to record maintenance inspections and treatments, issue work orders i; Piezo systems to collect traffic information by vehicle class; Lidar and video data and AI to analyze road side clearance.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

We just started this journey.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

WA does not have Landslide events, not a common type of event here.

Session 2: Data-Driven Decision Support Tools

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes. We have over 10 yrs of road closure data by event type, with duration in hrs and extent, as km of road closed, and by type of vehicles the closure applied. We can quantify travel time delays and calculate a resilience score and Resilience risk at what we call strategic link (homogeneous section of road re usage, AADT and/or tonnage). We do have records of disaster recovery expenditure and treatment types.

We created an ArcGIS tool to view this information. We are a year in this project, yet to complete. Adding the historical treatments will allow for the evaluation of their effectiveness and efficiency in improving resilience or reducing risk.

We do also calculated LOS based on road closure.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

We had used for a while some sensor devices to alert on river flooding, with some degree of success. Due to the remoteness of the area where flooding occurs regularly it was difficult to maintain.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Yes, for pavement deterioration, for replicating the visual inspections and identifying treatments. For collecting asset information such as line marking based on video data.

Integration in operational and maintenance plans.

Do you follow ISO 55000 as general framework?

Yes.

What do you value the most: precision or promptness?

I would argue both are important.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We have in house few data scientists and contract AI modelling skills.

Mott MacDonald (UK): Christopher Power

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

I concur that usage is mostly for design/construction at the moment, but in our organisation we are moving towards bringing digital twins into the realm of asset management. But ultimately, we are driven by our client's needs, and few are advancing into these areas year.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

No my area of expertise

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Convincing clients of the benefits of things that will only reward them in the future is a challenge. All we can do is relentless keep making the case and try to influence decisions whenever we can

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

It is usually the other way around. We have trigger levels for rainfall that result in mitigations being put in place. Realtime or regular monitoring of slopes is not commonplace. And until the cost of satellite data (and processing) is low enough and enough case studies available toconvince clients, that will continue to be the case.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Most asset management and intervention in the UK is on 5 year cycles.

Decision Support Module: from disruption events to decision making using traffic dataand vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Very useful to the client organisations I work for

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

The point was made several times in the workshop about converting our engineering expertise into language that decision makers can understand. Showing the links between decreasing resilience and level of service is exactly the type of thing that is needed.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Not sure I understand this question I am afraid

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Yes. But just as interested in how such a wealth of data can be analysed and converted into usable information in a short enough timescale to make a difference

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Yes, we work a lot on the development of deterioration models/curves for civils assets

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Yes, we are working in this area, investigating several advanced analytical techniques, but all the time ensuring they are based on sound engineering principles.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

Not my area of expertise

Do you follow ISO 55000 as general framework?

Yes, absolutely.

What do you value the most: precision or promptness?

Promptness. A precise decision delivered too late is no decision at all.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We have expertise within Mott MacDonald.

National Roads Authority UNRA (Uganda): Mark Rubarenzya

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

We are yet to implement SHM. However we recognize the need and potential benefits, hence our keen participation in the SRG

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms? *Yes*

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms? *No*

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

We are yet to begin using Digital Twins. The organisation's research team (which I lead) has been looking into the case for operationalization of Digital Twins, but no timeline is available.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Annual monitoring is undertaken manually, and information entered into Asset Management Systems This information is then used to guide the Investment Planning.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Increased awareness on current best practices in Asset Management, which should also include capacity building to offer skills to the team that is responsible ofr data collection and analysis.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes, they should be, and the research team have been developing the requisite basic datacollection tools upon which the DSS tools would build.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

A first step in this direction will be to install the monitoring systems. Before this is done it is not useful to discuss technological options for real time information systems.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Yes, we do. They are based on deterioration curves (however this applies to pavements, not structures).

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly? Yes

Do you follow ISO 55000 as general framework? No

What do you value the most: precision or promptness? Promptness

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service? No, we have neither.

NCSR (Greece): Thanasis Sfetsos

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Partially

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Needs heavy revision and customization

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes multiple data sets

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Not applicable

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Linked to performance, security, and safety levels.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Not easily implemented.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Not established

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you? *Yes*

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Empirical / FEM for design & upgrade purposes

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

No

Network Rail (UK): Mark Langdon, Julian Harms

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Yes. There is potential application to our major structures where monitoring regimes, algorithms could provide earlier warning of defect. It is less easy to see a cost-efficient application to e.g. assets such as masonry arch structures (which form the majority of our structures asset base).

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Potential reductions in detailed physical inspection frequency on a limited number of larger and more complex structures

Do you think there are datasets in your organisation that can be exploited using data-driven algorithms?

Yes. There is always room for such applications but we would need a more detailed understanding of the potential outputs to evaluate across the whole asset type range.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

This is becoming a prominent feature of major but localized enhancement projects on Network Rail. The digital twin model is considered to be of value, with elements in use (NR has a lidar model for the surface terrain in a GIS Platform for example). However the scale of a network- wide application currently precludes use across the network as a whole. We need to understand what the opportunities and benefits could be across the organization.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Multiple approaches to monitoring are adopted as appropriate to the distinct asset groups (e.g. Civil or Mechanical and Electrical Engineering applications). These range from simple switch

operation monitoring to three dimensional movement linked via 'smart' network with radio data transfer.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Internal conditions support development due to benefits in worker safety and greater operational efficiency. Cost benefit modelling would also be required to build the case for a Digital Twin. NR runs discipline-specific and cross-discipline groups to consider options and opportunities for the application and procurement of monitoring and other systems.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

This is a very complex problem when applied to a very diverse and heterogeneous earthworks assets across the whole network. NR has multiple active monitoring and R&D applications underway to work towards systems which are fit for purpose to achieve meaningful threshold 'trigger' values.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Any advance notice of ground movements could have application, for a variety of interventions including:

Rapid intervention (< I hour) to stop traffic in advance of incident

Short-term intervention (<28 days) to permit timely emergency remedial works

Medium term intervention (<6 months) to facilitate ground investigation and monitoring

Long term intervention (1 to 3 years) to plan physical remediation (including monitoring)

Very long-term intervention (>3 years) to permit work bank prioritisation and intervention planning.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes, although data of this sort are currently available in NR drawn from a number of data sources within the business. Enhanced and 'packaged' modelling to predict impacts would aid in intervention planning and work-bank prioritisation.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

A variety of model attributes can be envisaged which could bring benefits in a complex operating environment, primarily in risk assessment and targeting of interventions (e.g. monitoring, maintenance and renewal of assets)

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Multiple

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

NR is interested in any diagnostic monitoring system which can reliably predict intervention levels to set time thresholds. NR currently receives monitoring outputs in a wide variety of ways. Preferred options are those which are easily transferable, and which minimize the work-load for those actively engaged in an operational environment.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

NR uses a wide range of decision support tools across all asset groups and operational environments, and which include the range of methods suggested.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?)?

Machine learning / artificial intelligence applications are being trialed by NR in a limited number of areas of the industry (Air operations route monitoring for example). No further information is available at present.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

NR sets a wide range of KPI's against its asset management activities as required to satisfy the requirements of those activities and to conform to its' license to operate.

Do you follow ISO 55000 as general framework?

Yes, as a general framework.

What do you value the most: precision or promptness?

It depends on the application and activity.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

NR builds specialist capability within its own work-force but also uses sub-contracted resource for a range of specialist applications and activities.

Politecnico di Milano (Italy): Dario Coronelli

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

At Politecnico studies have focused on Digital Twins within industrial processes; other areas are under study as well. My research group at DICA has focused on FE models for use in Digital Twins of existing structures

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Carrying out consultancy state of the art procedures are used

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Research in this field at DICA is carried out by Prof. Barzaghi and his research group.

Potential for ground motion data from satellites to tune landslide models.

Research at Politecnico, DICA is carried out by the research group led by Prof. Claudio di Prisco.

Experience @DICA concerns pipes for gas distributions and transport infrastructures, the landslide monitoring is activated after detecting infrastructure damages. Subsequently, the landslide monitoring is tailored on the specific cases and prevision models are implemented.

Recent event @DICA

https://www.dica.polimi.it/event/il-programma-completo-del-seminario-remote-sensing-data- for-environmental-monitoring-e-ora-online/

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times,

Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Research on these topics, and consultancy is carried out. The items listed are all important outputs for this

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Yes

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Please refer to publications at DICA by prof. Biondini and coworkers

Messore, M.M., Capacci, L., Biondini, F. (2021). Life-cycle cost-based risk assessment of aging bridge networks, Structure and Infrastructure Engineering, Taylor & Francis, Published online.

Capacci, L., Biondini, F., Probabilistic life-cycle seismic resilience assessment of aging bridge networks considering infrastructure upgrading, Structure and Infrastructure Engineering, Taylor & Francis, 16(4), 2020, 659–675

Capacci, L., Titi, A., Biondini, F., Lifetime seismic resilience of aging bridges and road networks, Structure and Infrastructure Engineering, Taylor & Francis, 16(2), 2020, 266–286.

Biondini, F., Frangopol, D.M., (Eds.), Life-Cycle Design, Assessment and Maintenance of Structures and Infrastructure Systems, American Society of Civil Engineers (ASCE), Reston, VA, USA, 2019, 188 pages.

Biondini, F., Frangopol, D.M., Life-cycle performance of civil structure and infrastructure systems: Survey, Journal of Structural Engineering, ASCE, 144(1), 06017008, 2018, 1-7.

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Biondini, F., Camnasio, E., Titi, A., Seismic resilience of concrete structures under corrosion, Earthquake Engineering and Structural Dynamics, Wiley, 44(14), 2015, 2445–2466.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

These are still object of ongoing research.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Yes, in my research group we use FEM models

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

These are still object of research

Integration in operational and maintenance plans.

Do you follow ISO 55000 as general framework?

Not in my group, we are focused on structural safety (ISO2394)

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Politecnico di Milano has specialists in the field

Road Directorate (Spain): Jerónimo Vicente Dueñas

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

I think it would be desirable to have this kind of tools to accurately assess the condition of the structures in the network.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Taking into account the information provided by these algorithms, the inspection efforts could be focused where the problems are beginning to arise, so maintenance operations would be more productive and effective.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Some datasets from the monitoring currently implemented in some structures in the network could be exploded by these algorithms.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

The level of utilization of BIM in the Spanish Ministry of Transports is compiled in

https://cbim.mitma.es/.

The specific implementation on the Spanish road network is compiled in

https://cbim.mitma.es/experiencias/hacia-una-gestion-digital-de-la-red-de-carreteras

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

In the Geotechnical Area we generally use topographic control of terrain movements, laser scanner, inclinometers, piezometers, …

Creating relations between monitoring data and the asset where they are acquire based on specific reports. Creating files with all the historical registered data for every single asset under monitoring.

We use monitoring data to compare them to thresholds for different scenarios in a specific asset.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

In practice, site investigations are triggered when evidence of movements have been already observed (e.g. cracks on paved roads, cracks on a natural slope, etc.). This observed thresholds may correspond to movements of a few centimetres.

Unfortunately, deep and thorough site investigations including boreholes, seismic refraction, piezometers and inclinometers comprises several months. If the failure is going to happen in a shorter period, the only option is to protect the infrastructure and their users and to design repair works. It is difficult to define a degree of uncertainty as it can vary depending on the case considered.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

It would depend on the speed of the movement and it can be very variable. To carry out an appropriate site investigation I think it would be advisable to have information of the movements with about a year in advance.

Session 2: Data-Driven Decision Support Tools

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

I think that all the aforementioned indicators are extremely useful to determine resilience of a network, and the subsequent intervention prioritization.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

The aforementioned indicators can give a quantitative measure of the resilience of the system and subsequently select which intervention can have a bigger impact on increasing resilience.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Yes. Values over/under predefined thresholds for assets, level of service for the infrastructure network.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Not in my area (Geotechnical).

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

No.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

Yes.

What do you value the most: precision or promptness?

It depends on every case. In general, a balance between them is the most valuable (accurate enough to be valuable data and prompt enough to make decisions on time).

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

In general, it is outsourced in our organization, but the results are supervised by our technical staff.

Road Directorate (Spain): F.Javier Morales

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Yes, I do. From the Spanish Directorate-General for Roads we have a specific asset management systems for bridges and we are involving in a new one for tunnels in which these type of algorithms can be implemented in order to obtain more information from recorded data.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Of course. The use of these algorithms can help to take better decisions due to a better information about the behaviour of systems, particularly structural behaviour of bridges.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes, the main problem I can see it the quality of data and the needs for a better implementation.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Nowadays we are working in the definition of IFC standards and a BIM model for the different elements which compounds the Spanish Road Network at maintenance and operational level. This digital model will be based in the future IFC road standards consequently adapted to our needs in order to maintenance and operation actions.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

It depends on the type of asset that we consider. Monitoring as a set of different devices are only used in relevant bridges and in the most cases of tunnels. Several tools use these data to determine the structural state of these elements.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

This is a really good question. In my opinion the best way it to probe that the use of these systems can be useful to improve the LoS of infrastructure and in a reduction of operational and maintenance costs in a long-term.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Usually, site investigations start when visible signs of failure in a slope appear. The timing for this type of operation is not well-defined, and normally landscapes occur in short periods of time under certain conditions (severe rainfall, earthquakes, …).

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

It depends on the severity of the ground motion and the potential risk. In normal conditions, information should be transmitted to infrastructure manager as short as possible (hours).

Session 2: Data-Driven Decision Support Tools

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Definitely yes. Particularly some of these as restoration times are extremely useful at the time of take decisions.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

These parameters can help to a better management of maintenance actions and the development of new auxiliary infrastructures.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

All about costs for losses are interesting.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Both are interesting, it depends of the level of management in your organization in which you are working.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

No in this moment. We are working in the use of this model in a short-time.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Only for some operations (e.g. snow management)

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

It will depend in the way of defining the KPI, but from my point of view is not a easy-question.

Do you follow ISO 55000 as general framework?

All our systems are based on this regulation.

What do you value the most: precision or promptness?

It depends on the event that we consider. For instance, in case of an event that can lead to a severe restriction in traffic promptness is vital. In other cases, precision are more relevant.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Yes, we have some specialists working with some external consultancy firms.

Swiss Federal Roads Office FEDRO (Switzerland): Dimitrios Papastergiou

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

The supervised learning approaches could be interesting for our bridge asset.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Inspections, as mentioned and the rehabilitation project generation for bridges which actually is done rather empirically.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes, data from inspections (photos).

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

For the time being this is performed rarely to objects that present a risk and have a central importance for the redundancy of the network. A more widely application could only be established if the win to costs relation is justified.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Monitoring in a wide scale applies only to ground anchors. All anchored structures must be equipped with measureable anchors. The minimum number of measurable anchors is 5% of all anchors. For each anchored structure, structural deformation monitoring devices must be installed, which provide useful information on the behaviour of the structure.

For the time being, the information is treated by the responsible for the maintenance of each one of the five operative branches. In the future, a centralized data bank is likely to be created so as to guarantee a uniform way of analysing data and proposing intervention measures.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Too early to answer. A project about monitoring of all types of assets of the road network has just be launched. This question can be answered only when the global concept for monitoring will be established. The economic criterion under accepted risk will be predominant for such a decision.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Unable to mobilise the expert of natural risks so to provide this answer in the deadline.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Unable to mobilise the expert of natural risks so to provide this answer in the deadline.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes, to define the accepted risk we need to quantify expected losses. The level of service especially for lifelines and the resilience of the network are also essential for the intervention plan in case of the hazard.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Defining the resilience estimation and the level of service can help the asset owner to prioritize assets to be reinforced.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

No.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Yes, for the assets for which a monitoring will be applied and for which real-time diagnostic is essential. Expected diagnostic metrics are of two kinds: a) alerts and b) general behaviour (for instance fundamental frequency by time or evolution of monthly maximum span displacement)

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Empirical deterioration curves are used. A call has been announced recently together with the German authorities and the Austrian ASFINAG so as to provide up to date deterioration curves that apply to different type of static systems and bridge types.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Not yet but it is expected for the future.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

Not for all cases, for instance not possible if damage is undetected.

What do you value the most: precision or promptness?

Both

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

The department of Maintenance (Erhaltungsplannung) has engaged recently a specialist in Data Analysis, yet an expert in SHM is not foreseen. FEDRO will subcontract it as a service to private consulting.

TII (Ireland): Vincent O'Malley

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Yes

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

It would have to improve on existing practices and this could be established in a pilot study at TII.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes, we have a 'Bridge Management System" database that could be assessed.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

TII have appointed a BIM Manager to assess the use of Digital Twins and other technologies – appointed about 2 years ago.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Use dTIMS Pavement Management System (PMS)

Annual Pavement Condition Data stored in Pavement Database and utilised as part of PMS analysis

SCRIM, IRI

LCMS (Cracking)

FWD/GPR

Retroreflectivity

3D Spatial Coordinates

Spatial Video

Survey results stored in

Pavements Database

Approx. 3,200 bridges: Mix of structures across the network

eirspan – Bridge Management System: 500+ Principal Inspections per annum

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Service requirement are specified in a tender document.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? No but investigating the use of Insar data to set triggers. What degree of uncertainty about the magnitude and timing of ground motion can you tolerate? Not established

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Emergency response could be hours – but days for any meaningful assessment.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation? Yes

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

This requires a buildup of knowledge base and experience of using the systems.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Areas of Critical Infrastructure (road network leading to hospitals, power systems, water supplies).

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? Yes. In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you? Text

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

This information is specified in our Standards – all of the above are used in various forms.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions?

Not aware of its direct application

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly? Yes

Do you follow ISO 55000 as general framework? Not familiar with its application

What do you value the most: precision or promptness? Can't have one without the other – need both.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We have both – internal expertise and access to consultants.

Trafikverket (Sweden): Johan Jonsson

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Although the results presented by the FORSEE team are very impressive, it is difficult to say atthis stage

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

At least challenge them.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

All infrastructure managers that monitor their infrastructure in any way have this data.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: StepsToward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

The idea of Digital Twin usage is under development. This work is carried out through a number of national and European projects, e.g. Shift2Rail JU.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Measurements of infrastructure assets are continuously carried out and evaluated. Since there is no overall umbrella system, monitoring takes place for individual objects.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Procurement activities at a public body has to follow rules and regulations, there are no exemptions for monitoring systems.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

It is difficult to answer, however we see great benefits with InSAR to follow ground motions

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Cannot answer this question.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

The results presented by FORSEE would be valuable for any infrastructure owner.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

They do not necessarily have to support existing systems, in many cases there are no existing systems. For a broader usage of indicator, a fresh start would be benefitial.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Cannot answer this question.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

This is a far to detailed question to answer. To be successful in the future, one of the more important issues include transparent data flow.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Both.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Machine learning and AI are two very popular expression. I would characterise them as buzzwords. For data driven analysis, it would be better to talk about methods to analyse the data. In many applications it all comes down to standard multi-varaiate and principal component analysis, but it doesn't sound that flashy.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

No

Do you follow ISO 55000 as general framework?

The standards have been considered in developing the Trafikverket asset Management strategy

What do you value the most: precision or promptness?

In what respect?

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Like any other infrastructure owner, we have a combination of both.

Transport for London (UK): Fiona Tomson (LU), Nicola Head (TfL surface)

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

These could be worth implementing for monitoring any concerns with some of TfL's largest or most complex structures. It would depend on the individual situation.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Monitoring of highly trafficked structures with condition or loading concerns may benefit.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes, but may not be fully accessible to such tools yet.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

We have a developing BIM capability as part of the Digital Engineering Team. They are looking at applications across all TfL assets. I quote the strategy below:

'Our approach is to align our internal standards and processes to the BS EN ISO19650 Framework with an initial focus on CapEx. By working with programmes and projects to establish a minimum of BIM Level 1 maturity, we will ensure consistent ways of working and delivery of complete and assured quality asset information requirements. We will then work with the operational and maintenance areas within the business to develop approaches to further embed and enable benefits from BIM across the wider asset lifecycle. We will consolidate and increase capability with Digital Engineering tools to harness opportunities from technology to improve decisions about our assets'.

Digital Twin is also a developing concept, again quoting our Digital Strategy: 'The generation of TfL's digital twin will support our business objectives, enabling us to become a leaner, more efficient organisation.'

Currently the Digital Engineering team are engaged with industry Digital Twin groups to understand how our peers are developing their Digital Transformation Strategy's to enable Digital Twins. This is pan-TfL rather than Civil Engineering-specific.

We can get more details and/or a contact person from Digital Engineering if needed.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

We use visual monitoring, some remote sensor monitoring e.g. for bearing movements or checking performance of post tensioned strands. We use monitoring mostly as an Interim Measure to enable continued safe operation of structures which have an identified concern. Also to inform capital intervention schemes.

London Underground has some Earth Structures subject monitoring of inclinometers and piezometers – this is needed to keep Safety Risk As Low As Reasonably Practicable – this is equivalent to an Interim Measure but can be over longer term when remedial works not affordable. Monitoring data from these is reviewed by the Engineering team and Maintainers advised. Separate to safety concerns, such monitoring can also be used to inform an Observational Approach to managing an asset – i.e. improve understanding over several years and plan interventions appropriately.

LU has other monitoring for structures, similar to TtfL Highways. We also have some underbridges with instrumented protection beams for bridge strikes by tall vehicles.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin

Don't know

We are still developing our understanding of how Digitial Twins can realistically work for us and what our requirements should be. So far, models might be created as part of new works projects and aid design and construction, but we don't have an operational asset Digital Twin for existing Civils assets.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Don't use in TfL highways. On LU Earth Structures, those under instrumented monitoring have individual trigger levels for the inclinometers and piezometers.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Many months, due to problems securing network access. For LU, accessibility varies, so if particularly constrained would also take months but some sites would be easier as less 3rd Parties to deal with than on Highways.

Session 2: Data-Driven Decision Support Tools

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes, these would be of interest to the railway side of the business us.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

In LU, we currently have a spreadsheet-based Risk Assessment tool (STRATA). We are looking at options to improve it's usability and maintainability. Part of the tool deals with expectations for how long an asset would be out of service so would be good to inform this. We also want to project degradation and changes in consequence with time, e.g. show if consequences or likelihood experience a rate of change.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

We are lacking in reinstatement cost integration, so this would be of interest to us.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Potentially, for future problems on major structures. Would expect deliverables to be via electronic means (email alert with info, or prompt to log into a site containing the remote monitoring info.

Plus, in further future it depends how far we go with Digital Twins, e.g. can interaction with them create change / instruction in real time?

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Use both analytical (e.g. FEM to model load effects) and empirical (e.g. deterioration curves in whole life cost modelling scenarios). Deterioration curves not well-incorporated on LU yet.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Yes, in BridgeStation, our structures asset management system (Duro Basic will be able toprovide more detailed info if you require it)

We don't have BridgeStation in LU, but currently learning more about its capability.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

Structures State of Good Repair is used as a KPI, which is a direct correlation of condition. In LU we have an Asset Condition Report that contains a similar framework, and currently looking to more closely align.

Do you follow ISO 55000 as general framework?

Yes

What do you value the most: precision or promptness?

Life is not as black and white as that, however generally it is promptness, as long as it is precise enough for the purposes it is required for. It would depend on the situation being presented.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Sub-contract on TfL Surface side of business.

In LU we effectively have a mix of sub-contracting and in-house, depending on the asset.

UIC: Mercedes Gutiérrez

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Although UIC is not an operational organization, it is indeed useful the knowledge of all the algorithms, processes and datasets studied, to provide a better advise to the working groups that are currently dealing with these topics: artificial intelligence, predictive maintenance, automation, new supervision methods, asset management.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

Although UIC is not an operational organization, DT are present in the working groups in which testing is one of the typical phases of the projects. There is still improvement needs in those projects related with dynamical behaviour (specially train – track interaction or high-speed technologies) and during operations.

Potential for ground motion data from satellites to tune landslide models.

We are starting to go deep in this topic through a new project focused in flooding with operation, infrastructure and environmental approach.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

UIC is launching a new project focused in flooding for railways. All the parameters/indicators described in this presentation are applicable to the railway sector.

Using interpretable Machine Learning for Data-Driven Decision Support

UIC is truly interested in this topic. UIC is launching a new project for Artificial Intelligence for Predictive Maintenance. Railway sector is still to further develop these technologies that we are convinced will dramatically change the way of working of our members.

Integration in operational and maintenance plans.

UIC has a specific sector which deals with topics, the Asset Management sector. We believe asset management is transversal and crucial for the performance of the whole rail system.

University of Bologna (Italy): Andrea Benedetti

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes
We are currently using most of the presented algorithms in obtaining frequency data

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

The question is about obtaining damage classification with the identified data. Only this step can improve the decision processes.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

I do not understand what is exploding data….

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Digital twins are used in the FE modeling phase to obtain quantitative assessment of safety

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

No, we don't do asset management. We simply check structures.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

We use monitoring systems to trigger the models we create

Potential for ground motion data from satellites to tune landslide models.

We do not deal with landslides and do not do interventions

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

The probability of damage levels given some recorded data is far to enter in a decision procedure for bridge owners. So, these parameters are purely theoretical

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Yes, I am interested in diagnostic. I think that the degradation process of structures needs further studies in order to have a well behaving alarm system.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Only FE models of every structure under study

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

At this moment we don't use machine learning. Only traditional structural analysis.

Integration in operational and maintenance plans.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We are SHM specialists, but we apply mostly on academic research.

University College Dublin (Ireland): Vikram Pakraship

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

I have implemented some as a commercial engineer in Ireland.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

Inspection; Demonstration of repair efficacy

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

You mean explored? Right? Yes there are for bridges and floating platforms.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

None. But some county councils in Ireland and City Councils in Ireland has some initiatives.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Case specific-not uniform. For the ones I have done commercially all inventory and inspection data was considered for instrumentation and sensor selection. And then we used it to monitor repair of an impact damaged bridge. The same for before and after repair of a scour repaired bridge.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

No experience

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

No – in fact for a collapsed bridge, even before a day of collapse due to scour, there was insignificant ground movement despite presence of sensors.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

No experience.

Session 2: Data-Driven Decision Support Tools

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes – operativity losses. Expected losses. Restoration times.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

I think resilience is not well understood in industry and academia both. LoS is also defined a bit differently each time.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Value of Information

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Yes. Alarms, Green-Yellow-Red. Characterizations/early indications.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

Yes. All three.

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

Yes. Real-time monitoring systems. Will be publishing a book on real-time SHM this year with CRC press. Also – feature engineering for time series based and statistical learning based models. All – using demonstration of real bridges.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

No

Do you follow ISO 55000 as general framework?

No

What do you value the most: precision or promptness?

Depends on the need.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

Usually people subcontract.

University of Parma (Italy): Lorenzo Franceschini

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

I think that the use of SHM Algorithms could be an interesting and powerful tool during experimental test or for the monitoring of infrastructures and structures. Maybe a possible implementation of SHM Algorithms could be in the "project for the Protezione Civile" for the monitoring of existing corroded bridges.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

At this moment, I think that our organization (University of Parma – especially our research group) is focused on others research topics.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Probably, the research group concerning the infrastructure field could have more interesting data that might be exploded using data-driven algorithms.

Potential for ground motion data from satellites to tune landslide models.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

I think that more or less 2/3 days (in case of emergency) can be considered as a reasonable period of time (prediction) in order to have the possibility to make a useful intervention to the infrastructure.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

I think that Key Performance Indicators (KPI) can be clearly considered as a powerful tool for the assessment and monitoring of new and existing structures or infrastructures. However, generally, the use of Performance Indicators only cannot be considered as a faithful representation of the real behaviour of a structure or infrastructure.

Do you follow ISO 55000 as general framework?

No, we don't.

What do you value the most: precision or promptness?

In case of emergency situation, I think that promptness is the most important feature. On theother hand, referring to daily activity and monitoring phase, precision and accuracy must be pursued.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

At this moment. We don't have any specialist in SHM in our research group.

University of Porto (Portugal): Filipe Magalhaes

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Similar algorithms are being used in my organization in the scope of research projects and consultancy works

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

We may consider it in the context of consultancy works.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes, we have several dataset collected in the context of monitoring projects that can be used to explore the presented algorithms

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

I'm not aware of relevant use and future plans.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

We as a faculty do not do asset management, we provide support with the design, installation and operation of monitoring systems.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

It is a topic we may explore in a near future.

ZAG (Slovenia): Stanislav Lenart, Rok Vezocnik

Structural Health Monitoring Fundamentals: Surfacing in an ocean of SHM Algorithms.

Do you think you can implement any of these algorithms in your organisation for SHM purposes?

Bridge SHM is the area where these algorithms could be implemented in our organization. With some limitations they could be implemented also in other kind of infrastructure monitoring, particularly more sensitive infrastructure, e.g. energy infrastructure.

Do you think you can improve any process in your organisation (e.g, inspections) using any of these algorithms?

The simulation of structural response and linked algorithms could enable better forecasting of structural behavior and thus improve the prognosis of asset's conditions as well as optimize assets management.

Do you think there are datasets in your organisation that can be exploded using data-driven algorithms?

Yes. We do have a long tradition of asset monitoring (particularly road and rail infrastructure – bridges and tunnels, river dams and other energy infrastructure assets) with large datasets.

Satellites Deliver Advances in Remote Monitoring for Road, Rail & other CNI: Steps Toward Fully Integrated Structural Health Insights in Digital Twins.

The BIM or Digital Twin has been widely adopted in infrastructure design and construction phases but less used in operational asset management. What is the current level of utilisation of Digital Twins in your organisation? Alternatively, what is the roadmap that your organisation has for the utilisation of Digital Twins in asset management?

Currently we use BIM mostly in research projects and in some recent commercial projects for important parts of infrastructure where the construction is in progress. The integration of monitoring data within the BIM models has been adapted already.

Digital Twins are used for the research purpose only.

Roadmap:

The implementation of selected assessment algorithms into the BIM platform via various APIs.

Participation in H2020 research projects where we could upgrade our work.

Promotion of research results among our clients.

Which monitoring systems do you use in your operational asset management? How, if at all, do you integrate monitoring data with assets information? Alternatively, how do asset managers use monitoring data in asset management?

Various remote sensing technologies e.g. accelerometers, inclinometers, strain gauges, pressure cells etc, combined with scanning data (GPR, thermo camera etc.) and manual inspection. In commercial projects asset management platforms are not adapted to being able to process monitoring data.

How do you go about creating internal conditions to support the procurement of monitoring systems and services that could be built upon a Digital Twin?

Internal education on information modeling and its potential for assets management, the upgrades of monitoring systems by using modern monitoring technologies, participation in recent research projects with related content etc.

Potential for ground motion data from satellites to tune landslide models.

Our models make predictions of ground motion using rainfall forecasts. Do you have established thresholds of ground motion that trigger site investigations of potentially unstable locations? What degree of uncertainty about the magnitude and timing of ground motion can you tolerate?

Depends on the case. 1 cm per day.

If you had a prediction of ground motion (with uncertainty), how far in advance would you need that information to make a useful intervention to your infrastructure (e.g. site investigations)?

Again, it depends on the case. One hour is enough if the intervention means a possibility to avoid casualties. If site investigation and rehabilitation measures are needed, several months might not be enough.

Decision Support Module: from disruption events to decision making using traffic data and vulnerability of the network.

Some of the Decision Support Module outputs are: Indication about operativity losses after natural events, probability to have different damage levels and correspondent restoration times, Expected losses, Resilience and Level of Service assessment before and after natural events. May these parameters be useful and an added value for your organisation?

Yes, all of these aspects are of great value to us.

If so, how can these indications improve existing systems (increasing Resilience and Level of Service performance) and decrease losses in the future?

Make more accurate and objective predictions as well as the reduction of costs.

Do you suggest other important parameters/indicators that may improve the proposed methodology and be useful for your organization?

Our work is not so much related to taking decisions regarding asset management as we are a research organization.

Using interpretable Machine Learning for Data-Driven Decision Support

Are you interested in real-time diagnostic capabilities from monitoring systems? In what form would you prefer to have diagnostic metrics (e.g. alarms) delivered to you?

Short text messages.

Do you use models in decision-making? Are these analytical, numerical (e.g. FEM-based) or empirical (e.g. deterioration curves)?

We rarely make decisions, but we help asset managers in this process by our own evaluations based on analytical, numerical and also empirical models (depends on the case).

Have you adopted Machine-learning based tools and modules as predictive models, or in support of decisions? If so, can you offer a description of such tools (format, inputs, outputs, purpose)?

We have used tools like WEKA and Matlab machine learning tools in the research work, but not in the asset management process.

Integration in operational and maintenance plans.

Do you see the connection between Key Performance Indicators KPI and structural damage index clearly?

The connection depends on the structure being monitored.

Do you follow ISO 55000 as general framework? No.

What do you value the most: precision or promptness? Depends on the case.

Do you have any specialist in SHM or data analytics in your organisation or do you prefer to subcontract it as a service?

We do it alone.

13 APPENDIX H - STAKEHOLDERS REFERENCE GROUP MINUTES 4TH SRG WORKSHOP

Date: January 27th, 2022, 9:30 – 2:30 (CEST)

Venue: Teleconference via Zoom

Organisation	Country	Name
ADIF	Spain	María García
ADIF	Spain	PEDRO MARTIN PEREZ MARTINEZ
Arup	UK	Oliver Pritchard
ASFINAG	Austria	Clemens Klass
Atkins Consultants	United Kingdom	Chris Hendy
Atkins Consultants	United Kingdom	Jane Kelsey
Atkins Consultants	United Kingdom	Matt Peck
Atkins Consultants	United Kingdom	Paul Nowak
Atkins Consultants	UK	Andrew Hart
Atkins Consultants Limited - EPSOM, Surrey	United Kingdom	Anurag Kushwaha
Bluewin	Switzerland	Walter Waldis
BUNG Ingenieure AG	Germany	Anna Diehl
CEDEX	Spain	Laura Parra
CINTRA	Spain	JESUS ALVAREZ
CINTRA	Spain	María Chaves López
CINTRA	Spain	Cristobal Martinez Alvaro
Conference of European Directors of Roads	Belgium	Steve Phillips
DB Netz AG	Germany	Benjamin Schmitz
Deltares	Netherlands	Mike Woning
Deutsche Bahn AG	Germany	Michael Below
Deutsches Zentrum für Schienenverkehrsforschung	Germany	Sonja Szymczak
Deutsches Zentrum für Schienenverkehrsforschung	Germany	Vigile Marie Fabella
DG-MOVE	European Commission	Rafal Stanecki (Rafa Stanecki)
ETS	Spain	Josu Rodriguez Duque

Federal Highway Research Institute (BASt)	Germany	Lennart Meine (Marvin Stell)
Federal Roads Office (FEDRO)	Switzerland	Dimitrios Papastergiou (FEDRO/ASTRA CH) (Dimitrios Papastergiou)
Finnish Transport Infra Agency FTIA	Finland	Marketta Hyvärinen
Finnish Transport Infrastructure Agency	Finland	L090175
Fraunhofer IAIS	Germany	Lina Krisztian
Fraunhofer IAIS	Germany	Lorenz Wickert
German Centre for Rail Traffic Research	Germany	Frederick Bott
Harris County Toll Road Authority	United States	Brian Alcott
Highways England	United Kingdom	James Codd
Iarnród Éireann (Irish Rail)	Ireland	Huda Yousif
IMC GmbH	Switzerland	Rade Hajdin
INES Ingenieros	Spain	DAVID LÓPEZ OLIVER
Infra Plan consulting	Croatia	Irina Stipanovic
Irish Rail	Ireland	Colin Hedderly - Irish Rail (Colin Hedderly)
Irish Rail	Ireland	Padraig Fitzsimons
Main Roads WA	Australia	Eric Cheung
Main Roads Western Australia	Australia	Louis Bettini
Ministerio de Transportes, Movilidad y Agenda Urbana	Spain	Francisco Javier Morales-Gámiz (MITMA) (Francisco Javier Morales-Gámiz)
MRWA	Australia	Jan Karpinski
National Highways	United Kingdom	Angus Wheeler
National road network support unit of DGITM	France	Radoine Dik
NCSR Demokritos	Greece	Thanasis Sfetsos
Network Rail	UK	Julian Harms
Network Rail	UK	Mark Langdon
Network Rail	United Kingdom	Neil Esslemont
NZ Transport Agency	New Zealand	Stuart Woods
PIARC World Road Association	France	Miguel Caso Florez
Politecnico di Milano	Italy	dario angelo maria coronelli
ProrRail	Netherlands	Onno Hazelaar
PTV Planung Transport Verkehr AG	Germany	Alexander Dahl
Research Driven Solutions	Ireland	Lorcan Connolly
Rijkswaterstaat	Netherlands	Kees van Muiswinkel

Rijkswaterstaat	Netherlands	Léon Schouten
Rijkswaterstaat	Netherlands	Hidde Boonstra
RINA Consulting	Italy	Ruben Valsecchi
SBB Infrastruktur	Switzerland	Thierry Pulver
Sina S.p.A.	Italy	Giulia Guzzini
SNCF Voyageurs	France	Philippe CLEMENT (SNCF) (Philippe CLEENT)
Strada dei Parchi S.p.A.	Italy	Luca Bartoccini (SdP)
Strada dei Parchi SpA	Italy	Francesco Marchetti
Swiss Confederation - Federal Roads Office FEDRO	Switzerland	Charles-Henri Demory
Telespazio UK Ltd	United Kingdom	Frauke Diehl
TfL	United Kingdom	joanne parkes
Trafikverket	Sweden	Johan Jonsson
Transport Infrastructure Ireland	Ireland	Billy O'Keeffe
Transport Infrastructure Ireland	Ireland	Sarah-Jane Phelan
Transport Infrastructure Ireland	Ireland	Stephen Smyth
UIC	France	Mercedes Gutierrez Ferrandiz UIC (Mercedes Gutierrez Ferrandiz)
Universidad de Cantabria	Spain	Laura Castañón Jano
Universidad de Sevilla	Spain	Francisco Garcia-Benitez
Universidade do Minho	Portugal	José António Silva de Carvalho Campos Matos
Università di Parma	Italy	Lorenzo Franceschini
University College Dublin	Ireland	Abdollah Malekjafarian
University of Minho	Portugal	Sérgio Fernandes
University of Zagreb	Croatia	Damir Bekic
Virginia Tech	United States	Gerardo Flintsch
WSP	#N/A	Gonzalo Antolin
ZAG	Slovenia	Darko Kokot (Darko Kokot)

Consortium Member:

Organisation	Country	Name
AISCAT (Italian Association of Toll Motorways)	Italy	Federico DI GENNARO [AISCAT] (Federico Di Gennaro)

AISCAT (Italian Association of Toll Motorways)	Italy	Fabrizio Federici
Autostrade per l'Italia	Italy	Livia Pardi
CEMOSA	Spain	Concepción Toribio
CEMOSA	Spain	Jose Solis Hernandez
CEMOSA	Spain	Noemi Jiménez Redondo
CINEA (European Commission)	Belgium	Sergio Escriba
ETHZ	Switzerland	Bryan Adey
European Union Road Federation	Belgium	Jose Diez
FERROVIAL	Spain	Tobias Hanel
FORESEE SRG	Spain	Jesús Rodriguez
Fraunhofer IAIS	Germany	Marvin Richter (Fraunhofer IAIS) (Marvin Richter)
Fundación Tecnalia & Research	Spain	Iñaki Beltran
IP	Portugal	André Martinez Gonzalez de Costa
IVE mbH	Germany	Sebastian Kantorski
KPMG FA	Ireland	Cailean Keaveney
KPMG FA	Ireland	Anna Yankulova
KPMG FA	Ireland	John Sheils
KPMG FA	Ireland	KPMG Webinars
KPMG FA	Ireland	Mallika Singh
RINA Consulting	United Kingdom	Jane Hunt
RINA Consulting	United States	Saimir Osmani
RINA Consulting	United Kingdom	Alexandra Brown
RINA Consulting	Italy	Fabio Bolletta
RINA Consulting	United Kingdom	Po Man Liu
Spanish Association for Standardisation, UNE	Spain	Aitor Aragón
TECNALIA	Spain	David Garcia Sanchez
TECNALIA	Spain	Laura Barriuso

Telespazio UK Ltd	United Kingdom	Erlinda Biescas
Telespazio UK Ltd	United Kingdom	Krupa Kumar
UNIVERSIDAD DE CANTABRIA	Spain	ignacio robles
UNIVERSIDAD DE CANTABRIA	Spain	Irune Indacoechea
UNIVERSIDAD DE CANTABRIA	Spain	ANTONIA PEREZ HERNANDO

Agenda

9:00 (CET) Opening of the platform for connection of the attendees.

Opening Session

9:30 Opening and scope of the workshop

Jesús Rodríguez, SRG chairman

9:45 Main results of the FORESEE project

Iñaki Beltrán, Tecnalia

First Session (10:00 – 11:15)

Introduction to the validation of FORESEE results

Chair: Erlinda Biescas. Telespazio UK Ltd

10:15 Scope of the work, short description of the infrastructure assets, hazards that have been considered and how FORESEE results tools are linked to improved resilience. Federico Di Gennaro, AISCAT and David García- Sánchez, Tecnalia

10:45 Guidelines to measure level of service and resilience and to set target values. Bryan Adey, ETH Zürich

11:00 Transport Infrastructure Resilience (Design, Operation and Contingency plans). Concepción Toribio, Cemosa

11:15 Break

Session 2 (11:30 – 1:00)

Improvements on the resilience of transport infrastructures by means of the application of FORESEE results

Chair: Federico di Gennaro. AISCAT

11:30. A24 highway in Italy. Fabrizio Federici, AISCAT

- Traffic Module
- Fragility Functions, Vulnerability Functions, Decision Support Interpreter Module

11:50. A16 highway in Italy. Livia Pardi, Autostrade per l'Italia S.p.A.

- Virtual Modelling platform and asset failure prediction
- SHM BIM based alerting SAS platform

12:10. Montabliz viaduct in Spain, Mª Antonia Pérez, University of Cantabria, and David García-Sanchez, Tecnalia

- Governance module
- Risk mapping tool

12:30. Railway track 6185 in Germany, Sebastian Kantorski, IVE

- Flooding assessment. The effects of flooding to different railway track components in dependency of the water level
- Command and Control Center

12:50. Tunnels at M-30 ring-road Madrid (Spain), Tobías Hanel, Ferrovial

- Flooding assessment. Novel methodology
- Hybrid data assessment package
- Cybersecurity assessment

Final session Chair: Jesús Rodríguez, SRG chairman **13:15 Open discussion** Some exchange with transport infrastructure stakeholders (roads, highways, and railways) on the advantages/disadvantages when applying FORESEE results in their infrastructure networks **14:00 Closing** Rafal Stanecki, DG Move Sergio Escriba, CINEA

9:45 Main results of the FORESEE project

Iñaki Beltrán, Tecnalia

Question	Answer
Thierry Pulver: Concerning the traffic module, is it focused solely on roads or is it possible to integrate also other type of traffic (e.g., rail)?	Yes, the module can be applied to railway traffic. FORESEE has been applied to railway traffic but a meeting with the developer can be arranged to explain more detail.
Philippe Clement: Does the traffic module take into account the evolution of the climate in the future? If yes, which IPCC scenario?	Risk mapping evolution of the climate. I am not sure of all the data layers used. It used historical data and current open data, this if there is GIS data of the evolution of the climate it could be integrated as another layer of data to generate the risks maps. I will try give a better answer as soon as possible.

Alexander Dahl: Does the traffic module take changes in terms of route choice or even transport mode in case of incidents into account?	-

First Session

10:15 Scope of the work, short description of the infrastructure assets, hazards that have been considered and how FORESEE results tools are linked to improved resilience.

Federico Di Gennaro, AISCAT and David García- Sánchez, Tecnalia

Question	Answer
Cristobal Martinez Alvaro: How many people apart from the usual operating teams do you think it will be necessary to manage this FORESEE toolkit? What are the estimated implementation costs considering the operators have an asset management system in place? Traffic module: What is the difference from typical traffic modelling that are fed from a variety of inputs? Is the automatic integration with a Montecarlo cases generator?	**Federico di Gennaro:** The deployment will be a challenge. The difficult part was the homogeneity of the data. Every company has their own legacy system which are interconnected. We should find something neutral which is interoperable with the company' current system. This will be the next challenge for the exploitation phase. We need to make these tools available to companies.

10:45 Guidelines to measure level of service and resilience and to set target values.

Bryan Adey, ETH Zürich

Question	Answer
Steve Phillips: The resilience chart shows restoration immediately after the end of the event, but I assume this could equally consider future restoration long after the event? Follow up comment to Rafal in relation to Sergio's second question: We need to be very clear if we are talking about resilience of the transport system of the resilience of the transport infrastructure. Resilience of the system may come at the expense of the 'resilience' of a specific infrastructure.	**Bryan Adey:** You are right. The resilience graphs show one illustrative possible situation. There are many others, and one of them would be one where restoration starts later than immediately following the event. Your point is a very good one. It is of utmost importance when conducting an assessment of resilience of a transport system. A transport system is really composed of the infrastructure itself, the environment in which it is located and the organisation which is maintaining it. An incorrect definition seriously skews the analysis. To take an absurd example, the only way a road itself can be resilient is for it to be built to resist a hazard as it cannot fix itself. If one was interested in how quickly service could be restored following a hazard event one has to consider both the ability of the road to not be damaged and how quickly the responsible organisation is able to repair any damages that do occur. As you are aware it is certainly not the case that all orgs are equally prepared to react to identical situations.
Sergio Escriba: What do intervention costs mean? Cost to restore the service or cost to repair the infrastructure? And how is that it decreases over time after the event? What happens if the infrastructure is not repaired immediately?	-
Sergio Escriba: Previous studies show benefit/cost ratios of 4:1 for investments around 3% in increasing resilience. The figures in the last slides are quite lower. Any reason?	**Rafal Stanecki:** The EU adaptation strategy talks about new investments: ''Investing in resilience, climate proof infrastructure pays off. Infrastructure often lasts for many decades but much of the existing stock is not coping well with the climate change. To minimize the risk of disasters and be cost effective over its lifetime,

	infrastructure investments should be climate resilient. This may require an additional upfront cost of 3% of a project but resilience investments have a cost benefit ratio of about 1:44". Interesting if this ratio is possible and for what type of investment/climate change scenario. **Bryan Adey:** The numbers shown are completely illustrative. The work was only focused on the steps. If one was interested in calculating specific benefit/cost ratios of an investment it would be necessary to focus on a specific situation. That said, the numbers do draw out the fact that not every investment is worthwhile in improving resilience, and decision makers need to decide on the best ones. I assume the ratio of 4/1 to which you refer are for very good investments. Additionally, we have only illustratively used one event. Where a complete cost benefit analysis would need to cover multiple events over a specific time period.
Michael Below: Have you validated the figures/euros you gave for the indicators or do they represent theoretical considerations?	**Bryan Adey:** Within Foresee some realistic numbers were generated in the case studies. I am sure Federico can give you more insight. Within the documents, the numbers are presented are only illustrative. Following on this work though, we are currently conducting work focused on detailed cost benefit analysis of resilience enhancing interventions in specific situations and hoping to conduct more in the future. I would be happy to follow up with you if you are interested. **Federico Di Gennaro:** Each case study applied the guideline developed by ETH< by including also real numbers in terms of traffic, cost related to intervention, delays and so on. Each case study will produce and release a specific deliverable for its activity, which will be public.

	On these documents you will find more information with specific numbers.

11:00 Transport Infrastructure Resilience (Design, Operation and Contingency plans).

Concepción Toribio, Cemosa

Question	Answer
Steve Phillips: Will we hear more about the 'resourcefulness' phase mentioned? This is an interesting area to develop	**Concepcion Toribio:** There is a specific task on FORESEE, led by a different partner, that is focused on developing new and more effective contingency and communication strategies to increase the resourcefulness. However, it is still under development and results will not be shown in this workshop. You could leave us your contact details and we can keep you updated and informed of upcoming events.

11:30. A24 highway in Italy. Fabrizio Federici, AISCAT

- Traffic Module
- Fragility Functions, Vulnerability Functions, Decision Support Interpreter Module

No questions asked during presentation.

11:50. A16 highway in Italy. Livia Pardi, Autostrade per l'Italia S.p.A.

- Virtual Modelling platform and asset failure prediction

SHM BIM based alerting SAS platform

No questions asked during presentation.

12:10. Montabliz viaduct in Spain, Mª Antonia Pérez, University of Cantabria and David García-Sanchez, Tecnalia

- Governance module
- Risk mapping tool

No questions asked during presentation.

12:30. Railway track 6185 in Germany, Sebastian Kantorski, IVE

- Flooding assessment. The effects of flooding to different railway track components in dependency of the water level
- Command and Control Center

Question	Answer
Irina Stipanovic: How does the bridge model evaluate the scour of the bridge foundation and the softening of the embankment?	**Sebastian Kantorski:** The Bridge flooding model primarily determines the overloading of the culverts. Further assumptions are derived from this.
Thierry Pulver: Do you know if Deutsche Bahn will try to reapply the tools for other bridges?	**Sebastian Kantorski:** Currently the Bridge Flooding Model is applied exclusively to the Haemerten Bridge, but it can and should be applied to other examples.
Benjamin Schmitz: Is the tool also able to take flooding damage on "traditional" tracks into account? Many important cargo routes (e.g., along the Rhine river) are not built as ballastless tracks and therefore much more vulnerable to washouts.	**Sebastian Kantorski:** In the study work of TU Braunschweig on which the BFM is based, assumptions were also made for "normal" ballasted track (the basic model described ballasted track and was extended for slab track).
Benjamin Schmitz (Follow up to first question): The tool follows an asset-based approach in the case study. For the large length of Deutsche Bahn's tracks, it would be important in a first step to identify those assets which, compared to weather/climate projects, have the smallest margin to the determined critical water heights for the whole of Germany. Is a further development	**Sebastian Kantorski:** Currently there is no link between the Riskmaps and our Flooding Model - this would be a very useful extension.

of the tool for such an application possible/planned in order to further develop existing risk maps?	

12:50. Tunnels at M-30 ring-road Madrid (Spain), Tobías Hanel, Ferrovial

- Flooding assessment. Novel methodology
- Hybrid data assessment package
- Cybersecurity assessment

Question	Answer
Sergio Escriba: How often do cyberattacks happen in current infrastructures? If so, is there a growing trend? (Asked again in the open discussion and addressed by Federico then).	**Federico di Genarro:** The number of attacks and frequency is difficult to assess due to company confidentiality in attempting avoiding bad reputation. However, it is wort highlighting that the number of IT critical devices system is increasing especially those that monitoring activity and management. Think about bridges and tunnels or think about critical safety devices that are managed remotely to ensure safety in a tunnel to avoid incidents like fires etc. The number of cyberattacks are growing everywhere. However, we only know the cases known by the public and detected by journalists or the media. The work done within case study five by Ferrovial is crucial because in the past few months our members have prepared a cybersecurity plan and procedures for these different kind IT devices. So, my answer is yes cyber-attacks are growing and the trends is increasing exponentially.

Final Discussion & Closing Questions

Question	Answer
Steve Phillips: How do you recognise the difference between the resilience of the infrastructure with the overall issues of the overall issues of the transport system?	**Bryan Adey:** It is a very important point and is one of the reasons that I believe that you can't leave out how the organisation is prepared and react in certain situations which is left out in the literature. There is a lot on strengthening but a much smaller literature on restoration but the part in the middle on how to react is missing. It is a wonderful topic for future research. **Inaki Beltran:** During an event situation the best thing we can do is training and preparation. We have presented today different tools which helps and identify situations and I think this is the approach that should be followed. A lot of research still needs to be done but through FORESEE and other projects we are working on this.
Gerardo Flintsch: Which tools/info will be made available in each case?	**Inaki Beltran:** In the following days we will be updating the website to provide the results and materials which are public.
Dimitrious Papastergiou: Can the principal methodology (risk maps, fragility maps for example) be used for other type of risks on infrastructures such as overloading of bridges and pavements?	**Inaki Beltran:** Yes, the results have been developed thinking of the hazard, data etc. and interest within the project. These hazards mentioned by you have not been considered. However, for the risk maps that can be another layer of information that will be considered in the future. **Federico di Gennaro:** The tool that was designed by RENA was originally made for case studies within the FORESEE with specific attention to the hazards. I agree with Inaki, the tool can be adapted consider other hazards such as impact, heavy loads etc. The flexibility of the tool can be addressed after the project. We will take this into account for the optimisation of the foresee toolkit.

	David: You are suggesting a change from the natural to manmade hazard, but the methodology will remain the same so yes, these situations can be applied.
Michael Below: Was it a problem for the participants to get all the data you need to feed all the models?	**Bryan Adey:** This is one of the biggest issues of trying to measure resilience for transport organisations. It has to be recognised that you cannot always have the most advanced models as there isn't always the data available and if that is your standpoint, you'll never measure resilience because you'll never have enough data to make it possible. This is one of the reasons is why the guidelines are the way they are. There is a wide range of data and situations and a means to combine those. The example by Livia Pardi is a great example of how to combine both of those things.
Colin Hedderly: Can the model be adapted to consider coastal flooding and the risk of coastal erosion which is a problem for the east coast of Ireland?	: In flooding we have the same issue in Germany and risk flooding maps must be considered when planning new railway tracks. **Michael:** Coming back to the Elbe flood, as we have seen in Sebastian's presentation, he has shown that a 100-year high flooding didn't reach the bridge at the top. This made it a special case as the flooding was a result of a dam break which is not in the responsibility of Deutsche Bahn. If the dam didn't break, we wouldn't have had such a problem. This means we must look at what we can do within our responsibility and flooding is an area where we are not the only player for dealing with resilience.
Cristobal Alvaro Martinez: Is there a plan to establish a common framework for the tools created by FORESEE to remain competitive in the market?	**Federico di Gennaro:** The deployment part will be a challenge. During the project the difficult part was homogeneity of the data and requirements because every company in Italy have their own legacy system that are

	interconnected. In regard to the deployment of the tools to the market we are required to create/find something neutral which is capable and operable with the current system. This will be the next challenge for the exploitation stage.
Kees van Muiswinkel: What is the ambition for climate change adaption and how does this feed into procurement for a level playing fields with governments and national road authorities involved in CI?	**Steve Phillips:** There is a challenge to start looking at procurement chains overall. We have had intervention from the OECD which have talked around how public authorities embed the risk in their procurement processes. We need to have some thinking about these processes and improve them. We also need to widen the discussion because now you're talking about the activities between different operators but there is also the question between the modes. Are we talking about the resilience of the transport system or are we talking about a rigid resilience within the modes. So, for example what decisions will be made regarding how modes back each other up has not been addressed and needs to be looked at it. **Rafal:** From the point of view from the EU, where tenders and public procurement is concerned, the EU can intervene in situations where it has competence and money. This is for example in the Trans European Network (TEN-T) and I will give a presentation in how climate resilience will be included into the revised TEN-T. Transport infrastructure otherwise is a national competence and EU regulation is focused on competition rules and guaranteeing a level playing field and climate resilience (as far as I know) is not included so it still has to be resolved on the national level.

Survey Results:

We have received 33 responses to the survey that has been issued to the SRG members after the event on January 27th, 2022.

The survey was divided into two parts: A) Questions linked to the event and the presentations of the day, and B) Overall event satisfaction.

This is the table of the respondents to the questions shown below:

Respondents
Frederick Bott
Alexander Dahl
Brian Alcott
Onno Hazelaar
Andrew Hart
Vigile Marie Fabella
Luca Bartoccini
Colin Hedderly
Dr. Michael Below
Marketta Hyvärinen
María García Santiago
James Codd & Angus Wheeler
Anna Diehl
Laura Parra
Jesus Alvarez Arcos
Mike Woning
Josu Rodríguez Duque
Lorenzo
Cristóbal Martínez Álvaro
Francisco Garcia Benitez
Jane Kelsey
Clemens Klass

Billy O'Keeffe
Benjamin Schmitz
Thierry Pulver
Mercedes Gutierrez Ferrandiz
Stuart Woods
Darko Kokot
Julian Harms
Kees van Muiswinkel
Francisco Javier Morales-Gamiz
Johan Jonsson
Rade Hajdin

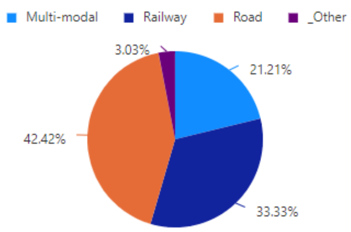
Results' highlights can be found below:

PART A

— Transport sector (Q4)

Transport Sector

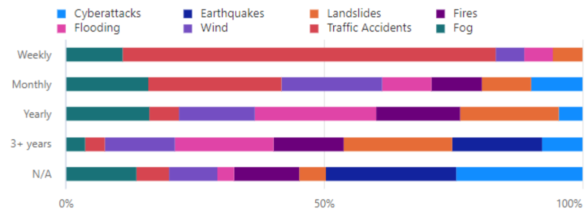
Option	Responses
Multi-modal	7
Railway	11
Road	14
_Other	1



— Type of organisation (Q5)

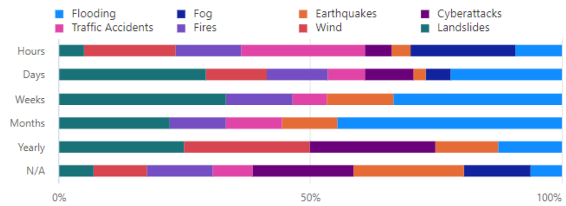
6. Which are the main hazard currently affecting your region/transport infrastructure and how often does your infrastructure suffer disruptions due to these types events? (choose "N/A" if not applicable to your organisation)

Option	Responses
Cyberattacks	33
Earthquakes	33
Landslides	33
Fires	33
Flooding	33
Wind	33
Traffic Accidents	33
Fog	33



7. Following on from the previous question, please outline the applicable hazards to your organisation/infrastructure AND the duration they last. (choose "N/A" if not applicable to your organisation)

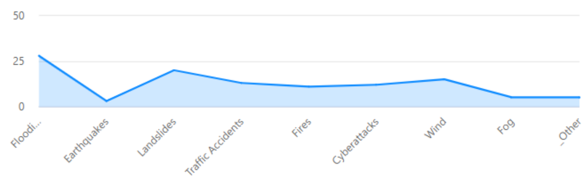
Option	Responses
Flooding	33
Fog	33
Earthquakes	33
Cyberattacks	33
Traffic Accidents	33
Fires	33
Wind	33
Landslides	33



— Q9: How is your organisation/region measuring the costs associated to these

8. In the future, which are the hazards that you expect to have most relevance to your organisation/infrastructure? (multiple options allowed)

Option	Responses
Flooding	28
Earthquakes	3
Landslides	20
Traffic Accidents	13
Fires	11
Cyberattacks	12
Wind	15
Fog	5
_Other	5



events? Is the social impact being considered?

(Reference to DB answer)
We apply transport models to quantify detours and resulting socio economic costs (due to additional travel time, additional emissions of greenhouse gases and air pollutants as well as accident costs).
I am not aware of direct costs being measure for previous flooding events. More of the emphasis is on improving region wide design criteria.
That are now the direct costs. The social impact is not included in the costs.
N/A
We are still at the beginning of trying to estimate the cost to the railway system of these disruptions. Our primary focus at the moment is to measure the extent of lost operations, which will allow us to quantify the economic losses in monetary terms, including time costs of detours and lost business.
Toll loss and restoration/repair costs. Unconsidered social impact.
Alternative road transport is provided when there is disruption to rail services.
We do not monitor the costs of hazards in detail, but we measure downtimes and lost units (availability time); compensation payment for customers
No exact measuring of costs
With maintenance plans
They will be measured by a different part of the business
Increased travel costs and costs for repairs are considered. social impact can be considered with the aversion factor which takes into account that people have a higher acceptance for more smaller events with few fatalities than for few bigger events with lots of fatalities even if the total fatalities over time are equal.
We are in the process of defining some recommendations for performing cost benefit analysis
Cintra is developing a tool to measure (in terms of cost) the impacts of the climate change in our infrastructure. The social impact has not been taken into account in the development of that tool
Costs considered as Expected Annual Damages and Expected Annual Losses (= social impact)
N/A
We are not dealing with this aspect, since we have structural engineers

Quantifying refurbishing/rehabilitation measures, assessing impact on revenues and adapting affected infrastructures to make them more resilient. Social impact is not accounted directly, but as lost of time for affected people.
Economical losses due to infrastructure impact.
Social cost is estimated, but costs are measured in predicted or actual cost of repair.
Due to my position as a geotechnical engineer at ASFINAG is it difficult for me to say how costs were measured. In the field of natural hazard risk management, we use the risk analysis (a systematic procedure which contains a hazard analysis, an exposure assessment, a consequence evaluation, and a risk calculation). The goal of the risk analysis is to quantify a potential damage due to a natural event and assign the damage to a monetary assessment. A distinction is made between personal-, material and availability-risks. At this, person related risks are transferred in mortality charges (a dimensionless parameter) whereas material and availability-risks are indicated in monetary values (EUR/year).
Yes - Social impact is considered. Costs are monitored
Costs are approximated by the amount of caused delay. Social impact is not considered.
Costs are measured per incident; social impact is considered as (monetizable) train and passenger delay minutes
N/A
Emergency repair costs; days disruption; # disruptions
ZAG is not an infrastructure owner, but a national public research institute. Thus, we rather deal with the research perspective of hazards.
Capital and operational costs of recovery together with compensation payments to train operating companies. Social Impact is not considered.
In repair costs as well as in vehicle loss hours. Social impact is measured too
Financial costs, maintenance costs and loss of human lives costs
This answer to this question is of sensitive nature.
It depends on the authorities. Communal authorities don't consider social impact, whereas on high volume network they do,

— 10. How does your organisation integrate transport resilience in day-to-day processes?

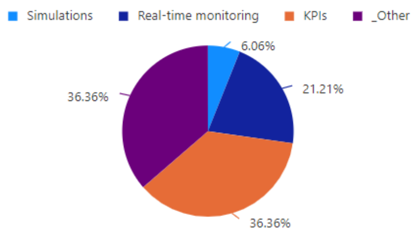
(Reference to DB answer)

We are working on several research projects for federal ministries in Germany to set up a resilience management concept. Within these projects we also apply the concepts to use cases.
This is something that the US is developing and working toward implementing. Based on the presentations during the last meeting I would say that Europe is ahead of the US in working towards implementing resilience into organizational processes.
ProRail measures the overall performance (RAMSHEEC) of our infrastructure. With our Government we have special targets on safety and availability.
N/A
Not applicable since we are a research institute. However, resilience is an area of research that is gaining popularity within the institute.
None
We keep performance records of failures and delays so that we can analyse trends to identify a course of action that will bring improved performance.
The idea of resilience is integrated in our vegetation management as well as maintenance measures.
Resilience is taken into account on daily maintenance of roads, on developing drainage of roads, in guidelines of design and construction, in cooperation with other authorities/institutions (meteorological institute, traffic management company for example)
Resilience studies of the rail network are being carried out
By emergency management planning, e.g. our GEOmaps and Geotechnical Resilience Framework and by public information campaigns.
"human-caused" events are taken into account as referred to in guidelines. nature events are not considered
It is one of our research priorities
As part of the above-mentioned tool, adaptation measures will be proposed. Those measures will be considered as actions included in the climate strategy and the implemented in the day-to-day processes.
N/A
We are working in this way.
-

Most of contracts include different KPIs, including response time to restore the service, maintaining the quality of the service, ... If not, the concessionaire must afford related penalties.
N/A
Impact on travel time, cost and repair schedule forecasting, monitoring and routine inspections, lessons learned
At first by adaption of the existing buildings and structures to the changing conditions and natural hazards. Second, by preparation of the operational units on a fast response for the various eventualities and temporary repair measures.
Embedded into standards
-
BCM; risk-based approach for designing and maintaining assets; route development plans and strategies; route & asset criticality assessments; asset failure prognostics (especially for track and catenary)
Resilience is in our vision, our strategy, and our multi-annual work programmes. We have launched a new project RERA-RAIN Resilient Railways facing climate change. Heavy Rains
Standard maintenance and operations procedures for small-medium events; capital projects objectives for higher risks
Only through research projects.
Company design and construction standards required consideration and inclusion of weather and climate change resilience measures. Delays from all causes are recorded.
Stress testing infrastructure, we have started to integrate resilience by taking into account in performance management, by adjusting guidelines, starting to monitor, integrate in planning
We are in the process of incorporating resilience costs in the decision process.
This answer to this question is of sensitive nature.
Resilience is still regarded as research topic. Clearly, aspects of resilience are considered within the well-developed risk assessment and mitigation process, but there is still no focus on resilience.

11. How is transport resilience measured?

Option	Responses
Simulations	2
Real-time monitoring	7
KPIs	12
_Other	12



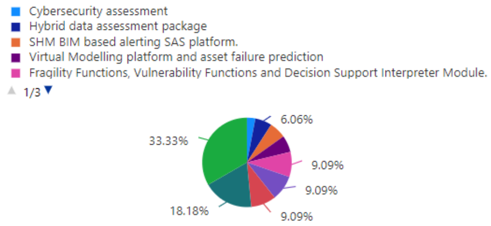
— 12. What type of assessments do you perform to improve infrastructures' resilience?

(Reference to DB answer)
See answers to 9. and 10.
Although not referred to resilience, we perform system wide assessments on a regular basis to identify needs.
We have done some stress tests and will be conducting them every 5 years.
I focus on assessing the impacts of natural hazards on assets
N/A
None
Failure and delay analysis and root cause analysis.
There is need to apply national regulations and the environment assessment in early planning process of infrastructure and assets.
Collecting data about the condition of road network, data about flooding road sections
R&D Projects of infrastructure monitoring
Planned annual earthwork inspections carried out on a risk basis leading to improvement and renewals of infrastructure at risk.
As written in guidelines; a concept to improve resilience against nature events is examined in a research project
Vulnerability and risk assessments
Climate risks assessments in different climate scenarios and terms (short, medium and long terms)
Stress tests, C/B analyses,

We are working in inventory of slopes, tunnels and continuous monitoring
-
If the event has had a direct impact on the infrastructure, different simulated scenarios are developed to check its response.
N/A
Routine inspections, calculating a comparable asset condition score.
In the field of natural hazard risk management, we use risk analysis combined with cost-benefit analysis.
Review engineering designs
Storm risk maps that identify the possibly affected vegetation. Unhealthy trees are removed on this section first.
Cyber security assessment, impact analysis for failing assets
N/A
Risk assessments at several levels of granularity; strategic annual reporting
Structural health monitoring upgraded with simulations/numerical analysis
Physical condition-based inspection of Civil Engineering assets, to establish a Risk score based on Asset location criticality and an algorithm established hazard score.
stress test of our roads, waterways and water systems
Life cycle costs
This answer to this question is of sensitive nature.
Again, the risk assessment is an established procedure and therefore resilience is improved by risk reduction.

13. Would any of the results presented applicable to your needs? (please consult the interactive pdf shared if not sure)

Option	Responses
Cybersecurity assessment	1
Hybrid data assessment pac...	2
SHM BIM based alerting SA...	2
Virtual Modelling platform ...	2
Fragility Functions, Vulnera...	3
Fully Stochastic Flooding M...	3
Governance module	3
Traffic Module	6
Risk mapping tool	11



— 14. What type of analysis/tools/methodologies do you use to address the challenges that you're currently facing in the domain of critical infrastructure?

(Reference to DB answer regarding operative infrastructure managing) In terms of research: remote sensing, simulations, GIS-analysis.
Traffic models, flood models, statistical data from other authorities concerning vulnerability and exposure.
This organization is very proactive to protect against cyber-attacks. Given that we are a toll authority.
Risk analyses, Stress test, expert meetings, simulations, big data analyses etc.
Geohazard risk assessment, geospatial data analysis, use of remote sensing data
We are developing tools to monitor trees along the rails in real time. Hazard indication maps have been developed for the planning of new infrastructure.
-
Decision Support Tools. Asset Management System
Quality scenario analysis, expert interview, case studies of the Ministry of Traffic, GIS-System, locally Sensor and LIDAR systems for real time monitoring
Asset management tools
Jaspers Guidance
CS 641 Manging the Maintenance of Highway Geotechnical Assets.
Mixture of risk maps that are available from the government

PIARC methodology; adaptecca; clarity project; Spanish flooding maps (SNZI)
Methodology developed internally with the support of stakeholders
In house developed risk assessment and resiliency tools.
Risk mapping tools.
-
Traffic assignment models, duly calibrated, to assess impact on revenues due to business interruption compared to necessary investments to make more resilient the highway
N/A
Inspections via a risk-based approach which is reviewed yearly, forecasting of frequency remediation works based on past data.
In the field of natural hazard risk management, alongside the high-quality road network, the hazard potential analysis (hazard maps) was carried out. The hazard maps get evaluated in a period of ten years. These hazard maps provide the information about the vulnerable zones in which area a risk analysis must be realized. When the hazard potential analysis and the risk analysis are completed, we use a special cost-benefit analysis which rates the financial benefit of a respective measure.
Risk assessments - review of standards
Satellite remote sensing
Various
N/A
Risk assessments; event recording and monitoring; operational procedures
Analysis of infrastructure capacity based on response measurements of assets (eg. bridges, etc)
Physical inspection, Video camera (CCTV) survey, Aerial survey, LIDAR Survey (aerial and ground level), condition monitoring, failure detection monitoring (xyz movement, deformations sensors, lidar change detection monitoring)
There are more options possible in question 13, but not possible to select. Not applicable are: virtual modelling platform; alerting SAS platform, bridge flooding model tool;
Risk and costs analysis
This answer to this question is of a sensitive nature.

Full-fledged probabilistic assessment is one of the major tools. This assessment also allows us to identify critical infrastructure.

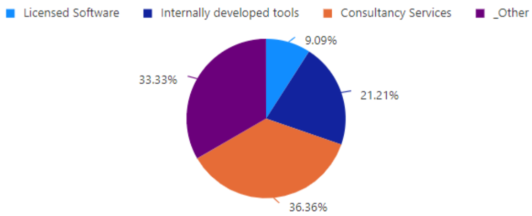
15. Please describe how specific results are affecting/improving your infrastructure management?

(Reference to DB answer regarding operative infrastructure managing)
As described above we are currently working on a resilience management system on behalf of the federal German ministry. We hope, that on the long run, this system will be applied by German infrastructure Operator.
Unfortunately, I am not aware of any.
In progress.
Better awareness of the key issues.
Not applicable, as our institute does not handle specific infrastructure. But for research purposes, the traffic module would be useful for us to simulate detour routes, the risk mapping tool will allow us to provide informed recommendations to the ministry regarding critical areas to focus on.
-
We have a scour management programme for bridges which we have recently refined by developing a below water scour vulnerability rating. This has improved our scour management programme.
./.
For example, the data about the condition of culverts and bridges are used to target the reparations
Through the implementation of adaptation plans
Our renewals programme is based on the findings of the Principal Inspections carried out as part of CS 641. We are carrying out a deterioration modelling research project looking at the deterioration of assets with time and how that can be used to predict future performance.
-
Specific results will allow us to improve the quality, robustness and objectivity of the results obtained.
Under development.
Providing advice to national road agency and railway agency
We are working to improve the areas that the inventory analysis shows are vulnerable areas.

-
Not directly, but some FORESEE methodology could provide the management with some tools anticipating the infrastructure behaviour in case of special climate events
N/A
Due to climate change and extreme weather, past data trends may not be applicable for the future. Proactive management manages and potentially prevents earthwork failures on the network.
Some of the tools could be used in profitability analysis or socio-economic analysis in the course of maintenance and reconstruction projects.
Results are integrated into design standards
Results highlight potentially endangered areas. A complete clearance of vegetation will never be achieved.
most of the presented results will be shortly discussed in peer-groups at SBB, then we will see where and how we can learn from the case studies (see below)
N/A
Targeting capital works programmes and improving maintenance and operational procedures
Infrastructure management is not part of our professional focus
Physical inspection programme provides a condition-based prioritisation approach to capital investment planning resulting in fewer service-affecting failures. Real-time monitoring provides advanced warning for interventions on a reactive basis leading to failure impact risk-reduction.
Tools etc. that have been developed in FORESEE, are already partly in use at Rijkswaterstaat, we will investigate how we can use FORESEE to improve our methods
Tools for analysis of pavements state and structural health monitoring in bridges and cuttings & embankments
This answer to this question is of sensitive nature.
The proper inclusion of consequences is clearly the key issue if one wants to improve decisions in infrastructure management.

16. Could you specify how these solutions are being paid for by your organisation?

Option	Responses
Licensed Software	3
Internally developed tools	7
Consultancy Services	12
_Other	11



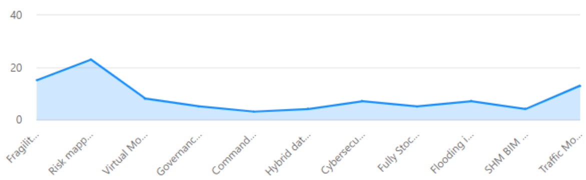
— 17. What market challenges do you expect these solutions to encounter in the future?

(Reference to DB answer regarding operative infrastructure managing)
We are not sure whether infrastructure operators will have sufficient resources to deal with this topic (beside their "normal" business).
None that I can think of.
All infrastructure managers have their own vision off their way of working. A one to one integration of the FORESEE results is difficult and will require flexibility to make it work.
Continually developing technology, budgets
Integration into regular operations. The question of whether the value added to the infrastructure managers is higher than the cost of the tool and the cost of migrating to a new system
-
Competition
No idea so far
N/A
Tools for predictive maintenance
Limited geotechnical resources.
-
Implementation
Recognition of the proposed solutions by key stakeholders
?

I think the climate change is important
-
XXXXXXX
It would be of great interest once the development of the solutions reaches a higher level. At present it is not fully operational from a practical/professional point of view.
Increasing cost of materials, more frequent earthwork failures.
N/A
Cost will escalate and sustainable solutions must be managed.
No challenges but great potential of live earth observation services.
Platform-integration will be the greatest challenge in my opinion
N/A
Applicability across a range of contexts; amount of client data required as inputs.
No specific idea
Resourcing challenges in suitably qualified and experienced personnel.
To implement tools in working procedures
Simulations and decision support tools to avoid risk and improve resilience of infrastructures
This answer to this question is of sensitive nature.
Data availability and clear legal framework to get data from vehicles.

18. Would you consider implementing any of the FORESEE results in your organisational processes?

Option	Responses
Fragility Functions, Vulnera...	15
Risk mapping tool	23
Virtual Modelling platform ...	8
Governance module	5
Command and Control Cen...	3
Hybrid data assessment pac...	4
Cybersecurity assessment	7
Fully Stochastic Flooding M...	5
Flooding impacts on railway...	7
SHM BIM based alerting SA...	4
Traffic Module	13



19. If implemented, what cost/resource efficiencies you expect these tools/results to have on your day-to-day business? (e.g., 10%-20% decrease in working hours over the first year; reduction of maintenance costs (20%-25%), Return on Investment (ROI) – 10-15%, increase in productivity 25-30%)

(Reference to DB answer regarding operative infrastructure managing)
The question does not fit to our role.
I do not see us implementing these items as of yet. But I do see us working towards resiliency policies to establish a clearer path in this direction.
Unknown
Not sure at this stage
Not applicable
Increase in productivity 10%-15%
ROI 10-15%
No idea so far as we don't know the total costs of climate-related risk
Do not know.
N/A
Unlikely to be implemented in the near future.
As it would be an expansion of the so far done examination it would also cause an increase in working time; just the safety would be higher
Not enough knowledge of the tools to answer this question

Reduction of maintenance cost and improvement in the operation of the infrastructure
Unknown
N/A
I think that the correct implementation of these tools can lead to money saving. Unfortunately, I'm not an expert on this field
This is highly dependent on the specific asset. Not feasible to provide a figure without a deeper analysis of different highways.
N/A
Very hard to determine due to multiple factors.
Hard to tell since the tool hasn't been released so far and the quality of the analysis is not known.
Significant Reduction of maintenance costs - not possible to give an accurate figure. More resilience in the road network with less closures.
?
better investment decisions and higher overall resilience (5-10% decrease of passenger delays)
N/A
Have not considered the business case, so do not know
No specific idea. ZAG is a research institute
Reductions in incident delays (say a 10 - 15% reduction because of more rapid deployment of staff and more rapid hand back to full operations). 5 - 10% reduction in cost due to better targeting of responses and interventions
That is hard to answer currently. I would say 5% maximum.
Mainly in the reduction of maintenance costs and an increase of the serviceability of the infrastructure
This answer to this question is of sensitive nature.
This assessment is not possible at the moment.

20. Would you consider contacting any of the FORESEE developers?

(reference to DB answer regarding operative infrastructure managing) In terms of research: We would love to implement some of the tools in our research and development activities
Perhaps we will contact those FORESEE experts dealing with the transport module.
We are not prepared to at this time.
Yes, but I have to investigate it more.
Yes
Yes
Yes
Yes
Due to procurement regulation we have to tender such services
Currently no
Yes
Unlikely.
Maybe
Yes
yes
Yes
N/A but is probably
Not at this moment, we are facing other topic in our research activities.
Those ones that have managed the modules: risk mapping, traffic module and governance
N/A
Potentially with the Client's buy-in
Yes, a colleague of mine is interested in the Traffic Module, Fragility Functions tool and Cybersecurity assessment tool.
Unlikely.
Possible but at this stage unlikely since applicability could not be tested so far.
To be discussed.
Yes. For our new RERA-Rain.

Possibly, but mostly would use local suppliers for development and support purposes.
Yes.
Yes.
For specific questions
Yes, particularly ETH.
No.
We have already established such contacts.

21. Do you have any additional feedback or comments?

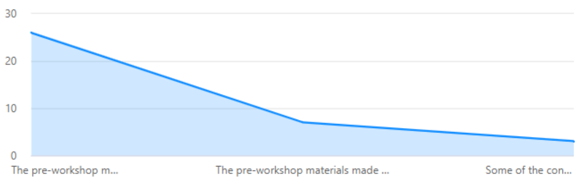
I would suggest reaching out to the Transportation Research Board to make sure they are aware of this effort.
The results off Foresee are promising. I miss however a view of the structure and way off working off the modules.
None at present.
More tools on intermodal analyses.
No.
Well done on the presentations on 27 January.
N/A
Our resilience is based more on proactive prediction, assessment, preparation, and mitigating for events whereas we feel the FORESEE project accepts events happen and puts in place retrospective mitigation to manage those events.
Just one organisational thing for the next online event: as there are speakers from several countries with different accents it would be great if every speaker would use a microphone to improve the sound quality. From time to time, it was hard to understand because speakers used their laptop microphone which is far away from their mouth and catches a lot of background noise.
I would like to have more information of several of the developments of the FORESEE project.

no
Great workshop with very interesting developments but the duration was too long. I suggest either a lunch break or dividing into 2 sessions.
N/A
-
No more comments
NO
None
No
IT systems of our (and hopefully all infrastructure operators) are protected extremely well. Integration of external tools/software is facing high hurdles.
Thank you for the development of this project. It is quite useful for the railway community
We are interested in future research collaboration
Not yet, we need to investigate actual applicability
Thank you for your work
No

PART B

22. How well did the pre-workshop materials prepare you to understand the content of the workshop? (Select all that apply)

Option	Responses
The pre-workshop material...	26
The pre-workshop materials...	7
Some of the concepts prese...	3



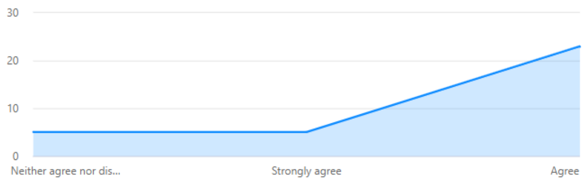
23. What were the three most important areas/topics you have learned about during the workshop?

Resilience, Risk Mapping, Bridge Flooding Model
It was great to see that you did in-depth research on almost all the topics related to transport infrastructure resilience.
The guidelines to setting up how to measure resilience might be most helpful since we are just beginning this pursuit.
The overview, and the case study based in Germany. Bryan Adey,
different approaches to similar problems
Case studies on the railway network, FORESEE's the resilience framework, virtual modelling platform
-
SHM, Flooding and hazard mapping
availability and quality of data needed (for modelling)
Resilience is about infra, service levels and management.
Landslides, flooding
Insight of resilience studies in Europe and current management of infrastructure.
-
SHM, resilience indicators, flooding, and risk mapping
The way to assess and classify an infrastructure, the KPIs to measure the resilience of an infra and the selection of measures
how to measure resilience, vulnerability on an asset level, cyber attacks
N/A
Health-Monitoring in general, Cyberattack
Traffic, flooding, landslides
The different methodologies used for cases. The level of the knowledge in different fields.
Resilience scoring, cyber security, severe impacts of flooding
Resilience measurements with uncertain input parameters. Cyberattacks and the impact on traffic.
Risk assessment - governance - modelling tools

It is very hard to create a tool/method which can be used across different transport infrastructure types. Compromises make them less useful for specific needs of single types.
applicability of the framework, intervention classification, vulnerability function
Ways to focus the issue. New tools. Use cases.
stochastic flood modelling, risk modelling, fragility functions
risk mapping, infrastructure resilience evaluation
Integration of EO and ground monitoring systems, Integration of control systems using traffic and flood modelling,
The areas addressed by the tools I mentioned to be of interest for Rijkswaterstaat
Development in the field of risk analysis and risk maps
Modelling data analytics measurements
None in the particular area, but rather the holistic approach.

24. The terminology during the workshop was understandable.

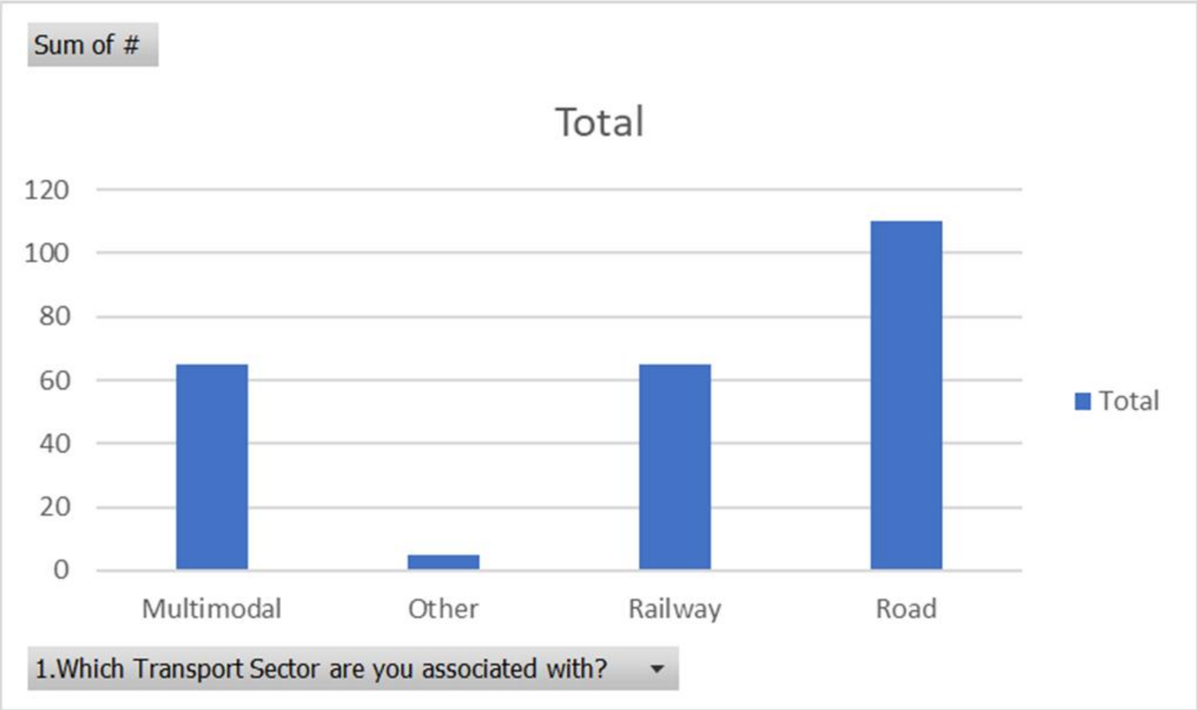
Option	Responses
Neither agree nor disagree	5
Strongly agree	5
Agree	23



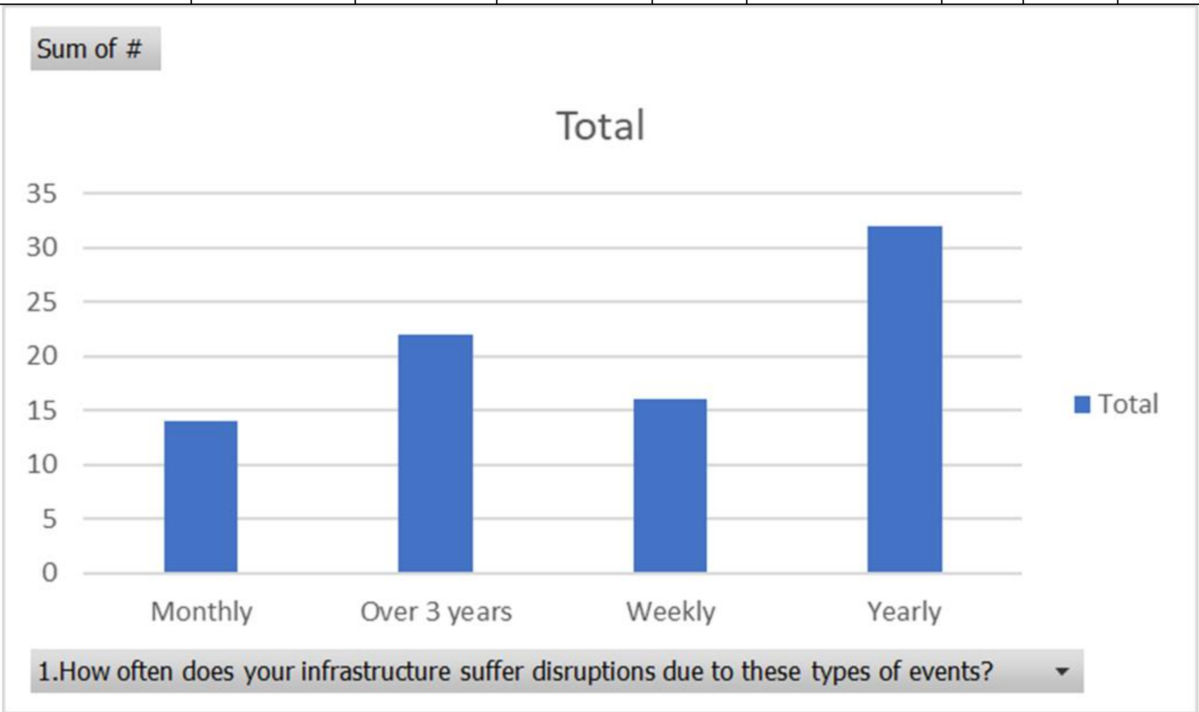
25. Overall, I was satisfied with this workshop.

Option	Responses
Disagree	1
Neither agree nor disagree	3
Strongly agree	3
Agree	27

POLL Questions



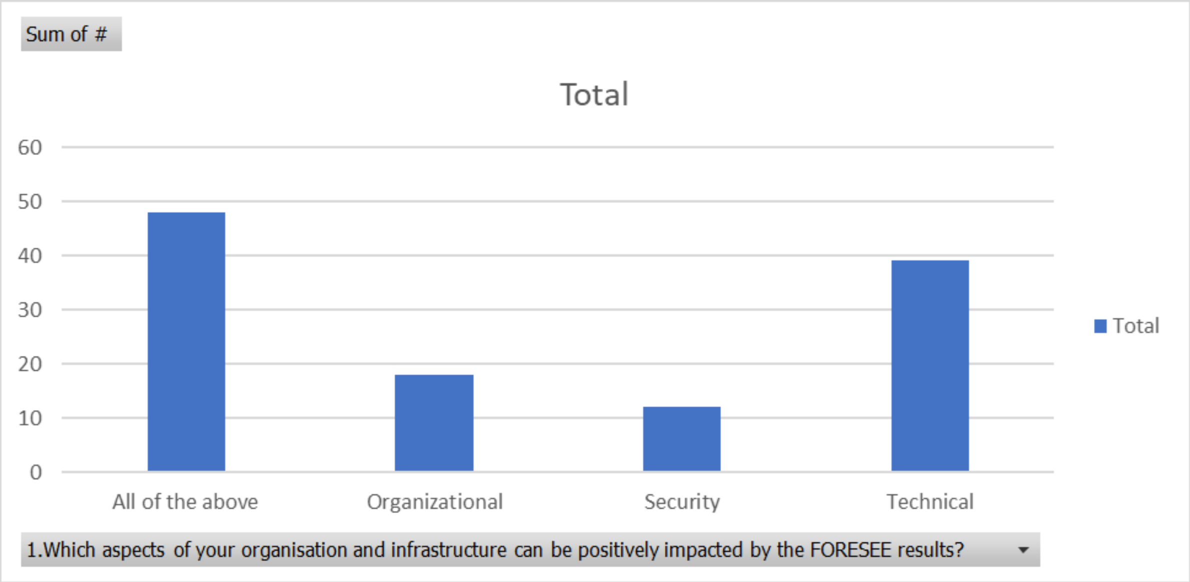
Earthquakes;	Landslides;	Flooding;	Traffic Accidents;	Fires;	Cyberattacks;	Fog;	Wind	Other
13	**29**	**34**	**29**	**17**	**7**	**14**	**22**	**9**



Which are the main hazard/s currently affecting your region/transport infrastructure?

Would any of the results be applicable to your needs?

Traffic Module	Frag. & Vuln. Function, Decision Support	Virtual Modelling & asset failure prediction	SHM BIM based alerting SAS platform	Governance Module	Flooding assessment	Risk Mapping Tool	Cybersecurity Assessment	Hybrid Data Assessment Package	Command & Control Centre
18	**23**	**22**	**18**	**9**	**25**	**29**	**8**	**11**	**14**



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[i] The Montabliz viaduct. (2006). Villegas, Roberto; Pantaleón, Marcos J.; Revilla, Roberto. Consejo Superior de Investigaciones Científicas (España)