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SCOR Annual Conference

Pushing the edges of risk awareness and insurance:

The role of the (re)insurance industry to cover risks affecting societies and governments including new applications of artificial intelligence

28 & 29 September 2017

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Risk and resilience of infrastructures: how the smart technologies can improve the risk management

Dr Jennifer Schooling, Director, Centre for Smart Infrastructure and Construction, University of Cambridge

Olivier Hautefeuille, Chief Underwriting Officer, Industrial and Commercial Risk, SCOR Global P&C

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PUSHING THE EDGES OF RISK AWARENESS AND INSURANCE
Risk and resilience of Infrastructures: how the smart technologies can improve the risk management

Jennifer Schooling, Director, Centre for Smart Infrastructure and Construction

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Infrastructure: to set the scene!

Infrastructure

- From various sources, infrastructures are defined as
  - The basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise.
  - The transport links, communications networks, sewage systems, energy plants and other facilities essential for the efficient functioning of a country and its economy. In corporate terms, the essential physical assets necessary to run a business, e.g. the cable laid by a pay-TV company.

- Two classes of Infrastructure:
  - Economics: transportation, energy and power, water, waste
  - Social: Education, Health, defence and security, jails, administration

- The link between country development, growth and infrastructure is quite obvious and therefore infrastructure are considered as the backbone of any country

Infrastructure and Resilience

- The concept of Resilience is also fairly recent and still emerging.
- It is the ability of a system to react, recover from unanticipated distubances and events.
- Two properties associated to the resilience:

  - **Robustness:** **the tendency of a system to remain unchanged or nearly unchanged when exposed to perturbations**

  - **Rapidity:** **system’s ability to recover from an undesired event with respect to the speed of recovery**

Criticality and Resilience

- Despite the evidences of the benefits linked these two concepts, it is not obvious that
  - 1/ Decision makers are including them
  - 2/ The OECD report on Infrastructure
    - Never mentions the word criticality
    - Once Resilience but only to apply on the world economy
  - 3/ Infrastructure rankings are not considering the way the countries are addressing these two concepts
  - 4/ Rating agencies when rating project for financing purposes do not seem to consider the criticality and the resilience of the rated projects

Criticality and Resilience

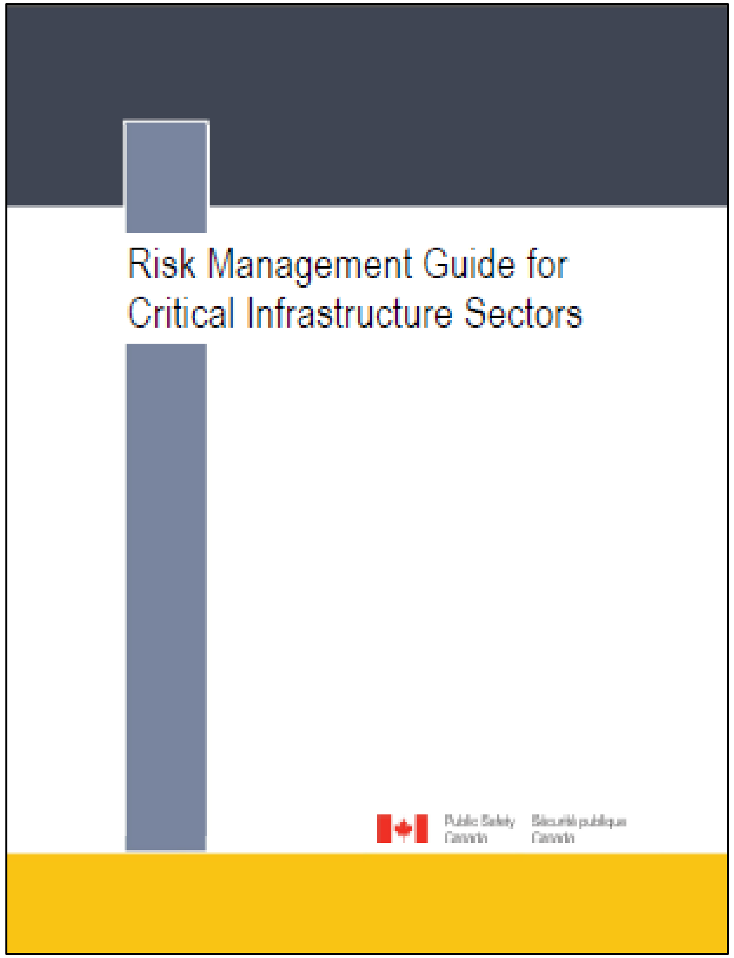
World Economic Forum ranking Overall Quality of Infrastructure

RANK	COUNTRY/ECONOMY	VALUE	1 MEAN 4.3 7
1	Switzerland	6.6	
2	Singapore	6.5	
3	Finland	6.5	
4	Hong Kong SAR	6.5	
5	France	6.4	
6	United Arab Emirates	6.4	
7	Iceland	6.3	
8	Austria	6.3	
9	Germany	6.2	
10	Netherlands	6.2	
11	Portugal	6.2	
12	Luxembourg	6.2	
13	Denmark	6.0	
14	Bahrain	6.0	
15	Canada	6.0	
24	United Kingdom	5.6	
25	United States	5.6	

	Total	Transport	ICT	Energy	Finance
Top 10	Hong Kong	Hong Kong	Germany	Norway	Hong Kong
	Singapore	Singapore	Hong Kong	Kuwait	Singapore
	Germany	US	Luxembourg	Canada	Jordan
	US	Germany	Switzerland	Finland	Spain
	Switzerland	Luxembourg	Korea	Qatar	China
	Canada	India	France	Sweden	Israel
	Norway	Austria	Denmark	US	Malaysia
	Luxembourg	Switzerland	UK	Luxembourg	UK
	Japan	UK	Singapore	UAE	Australia
	UK	Japan	Sweden	Australia	US
Bottom 10	Cameroon	Senegal	Ethiopia	Yemen	Ecuador
	Gabon	Myanmar	Mozambique	Nicaragua	Kazakhstan
	Iraq	Mauritania	Burkina F.	Nambia	Namibia
	Nepal	Chile	Papua N.G.	Cambodia	Bolivia
	Botswana	Bangladesh	Guinea	Dom. Rep.	Venezuela
	Haiti	Brazil	Madagascar	Iraq	El Salvador
	Kyrgyz Rep.	Peru	Congo, DR	Nepal	Papua N.G.
	Namibia	Cameroon	Myanmar	Botswana	Georgia
	Bolivia	Paraguay	Zimbabwe	Haiti	Ghana
	Congo, Rep.	Bolivia	Kyrgyz Rep.	Congo, Rep.	Argentina

The World Economy, a new global index of Infrastructure Construction, Rankings and Application

But some countries are already well advanced: Canada, New Zealand…



Foreword

Managing risk is a shared responsibility among all critical infrastructure stakeholders, including governments, industry partners, first responders and non-government organizations. While partnerships and information sharing represent the building blocks of the Canadian approach to enhancing the resiliency of critical infrastructure, these cannot be undertaken in isolation of risk management and the development of plans and exercises to address these risks.

Recognizing that the impacts of disruptions can cascade across sectors and jurisdictions, the purpose of this document is to provide practical guidance for implementing a coordinated, all-hazards approach to critical infrastructure risk management. Moving forward with this comprehensive risk management process requires federal departments and agencies to collaborate with their critical infrastructure partners, including industry stakeholders and other levels of government. While this guidance document promotes a common approach to critical infrastructure risk management, owners and operators and each jurisdiction are ultimately responsible for implementing a risk management approach appropriate to their situation.

After the Canterbury Earthquake (2010) & the Christchurch one (2011), New Zealand has started a comprehensive review of their Infrastructure Resilience.

Some could certainly do better: the example of UK

24th in the WEF infrastructure ranking, the UK infrastructures have been rated by the ICE (Institution of Civil Engineers): from B to D

THE GRADES

A	B	C	D	E
FIT FOR THE FUTURE Infrastructure is well-maintained and in good condition. There is excess capacity to cope with major incidents. There is clear strategic leadership with good plans to develop the sector to meet the needs of the next five years.	**ADEQUATE FOR NOW** Infrastructure is in acceptable condition with a reasonable maintenance regime. It can meet current demand and deal with minor incidents across the network. However, investment will be needed to meet needs in the next five years.	**REQUIRES ATTENTION** Infrastructure is infrequently maintained and requires attention. There is no excess capacity resulting in deficiencies at peak periods and if there are even minor incidents. Significant investment is required to improve it to meet needs in the next five years.	**AT RISK** Infrastructure condition is below standard and poorly maintained. There is frequently a lack of capacity to meet demand and it is not resilient. In the absence of significant investment there may be an impact on the national economy.	**UNFIT FOR PURPOSE** Infrastructure is in unacceptable condition with little maintenance. There is insufficient capacity and resilience is of serious concern. The state of the infrastructure is impacting on the national economy.

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Some could certainly do better: The USA case

25th in the WEF infrastructure ranking, the US infrastructures have been rated by the ASCE (American Society of Civil Engineers): D+

The last 3 years, SCOR Global P&C has seen an increase in the infrastructure Projects (metro, airports, bridges, …) in USA

D

POOR,
AT RISK

The infrastructure is in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. A large portion of the system exhibits significant deterioration. Condition and capacity are of serious concern with strong risk of failure.

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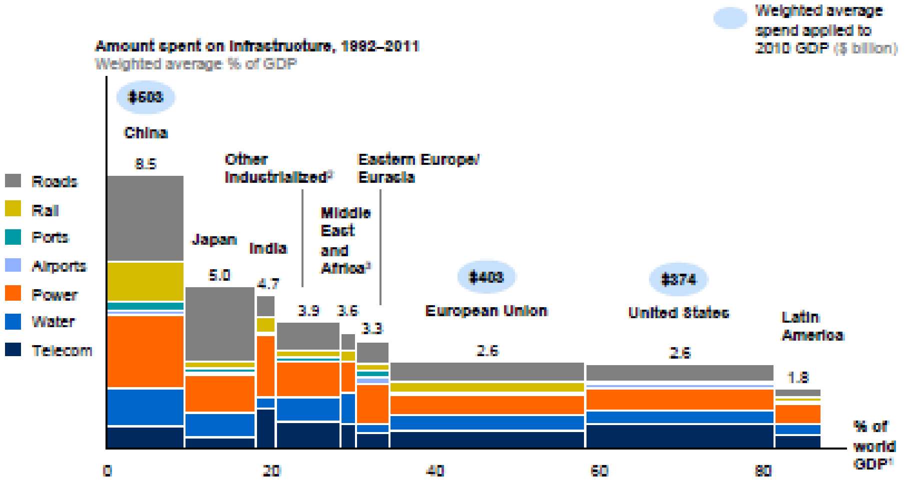
& China, linking infrastructure and economic growth

- Chinese infrastructure have been ranked 69 in the WEF ranking but there is an active government policy to get the best infrastructure

SCOR Global P&C has reinsured more than100 metro lines in China these last 10 years

Exhibit 2

China has overtaken the United States and the European Union to become the world's largest investor in infrastructure



1 Percentage of 2010 world GDP generated by the 86 countries in our analysis.
2 Australia, Canada, Croatia, Iceland, Lichtenstein, New Zealand, Norway, Singapore, South Korea, Switzerland, Taiwan (Chinese Taipei), and the United Arab Emirates.
3 Excludes unusually high port and rail data for Nigeria; including these data brings the total weighted average to 5.7 percent.
SOURCE: IHS Global Insight; GWI; IEA; ITF; McKinsey Global Institute analysis

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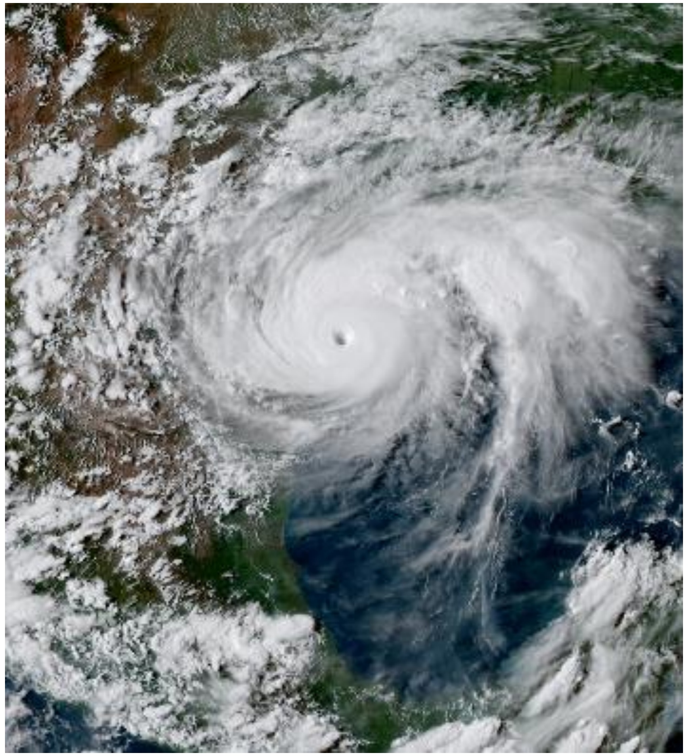
Criticality and Resilience Lessons

Main exposure for Infrastructures likely to affect criticality and / or resilience

- Breakdown & Domino effect on cross-infrastructure inter-connectivity
  - Power black out (power Grid)
  - Cyber risks (Ports, Grids, telecoms, Scada systems)
- Terrorism (all infrastructures)
- Natural Catastrophes (all infrastructures)
  - Windstorm
  - earthquake
  - Flood
- Aging risks (transportation infrastructure mainly)

Hurricane Harvey over Houston: a story of climate change!

“Our infrastructure is aging and deteriorating. That makes situations worse,” says Mark Abkowitz, director of the Vanderbilt University Center for Environmental Management Studies. “It will be difficult to make urban areas more resilient to flooding. In some ways we have our hands tied behind our backs because we’ve allowed development along the coast to occur. We’re going to have to chip away at this problem.” ENR 20 Sept. 2017



More than a week after Hurricane Harvey hit, the Sam Houston Tollway remained underwater from reservoir releases.

Rainfall during Harvey:
Average 1 m
Peak: 1.32 m

Ie in excess of the return period used for the design used in the water management for the urban area

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Local event: UK Floods 2007
Walham Substation & Mythe Water Treatment works

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Last Updated: Thursday, 26 July 2007, 11:39 GMT 12:39 UK

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Army teams to help provide water

The army is to help distribute water across Gloucestershire following complaints that bowsers were not being topped up fast enough.

The army is also helping bring in bottled water

Some 350,000 people could be without mains water for two weeks after a water treatment plant was deluged by the swollen River Severn.

There are up to 900 bowsers across the county, with the army also shipping in bottled water to distribution points.

A Severn Trent Water spokeswoman said the company was addressing the problem.

- 50,000 people without power
- Major operation to restore power over 5 days
- Significant flood defence programme implemented
- 350,000 people without water for 11 days

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Aging infrastructure:
2007 – Minneapolis bridge collapse

1st August 2007
– 8 lane bridge on the I-35W, collapsed into the Mississippi river
– killing 13 people and injuring 145
24 gusset plates-sheets of steel used to connect bridges and columns- were about half the thickness they should have been.

According to the ASCE, 11% of our bridges across the country are rated structurally deficient and another 13% are obsolete
http://www.rmmagazine.com/2014/02/01/a-bridge-too-far-repairing-Americas-aging-infrastructure/

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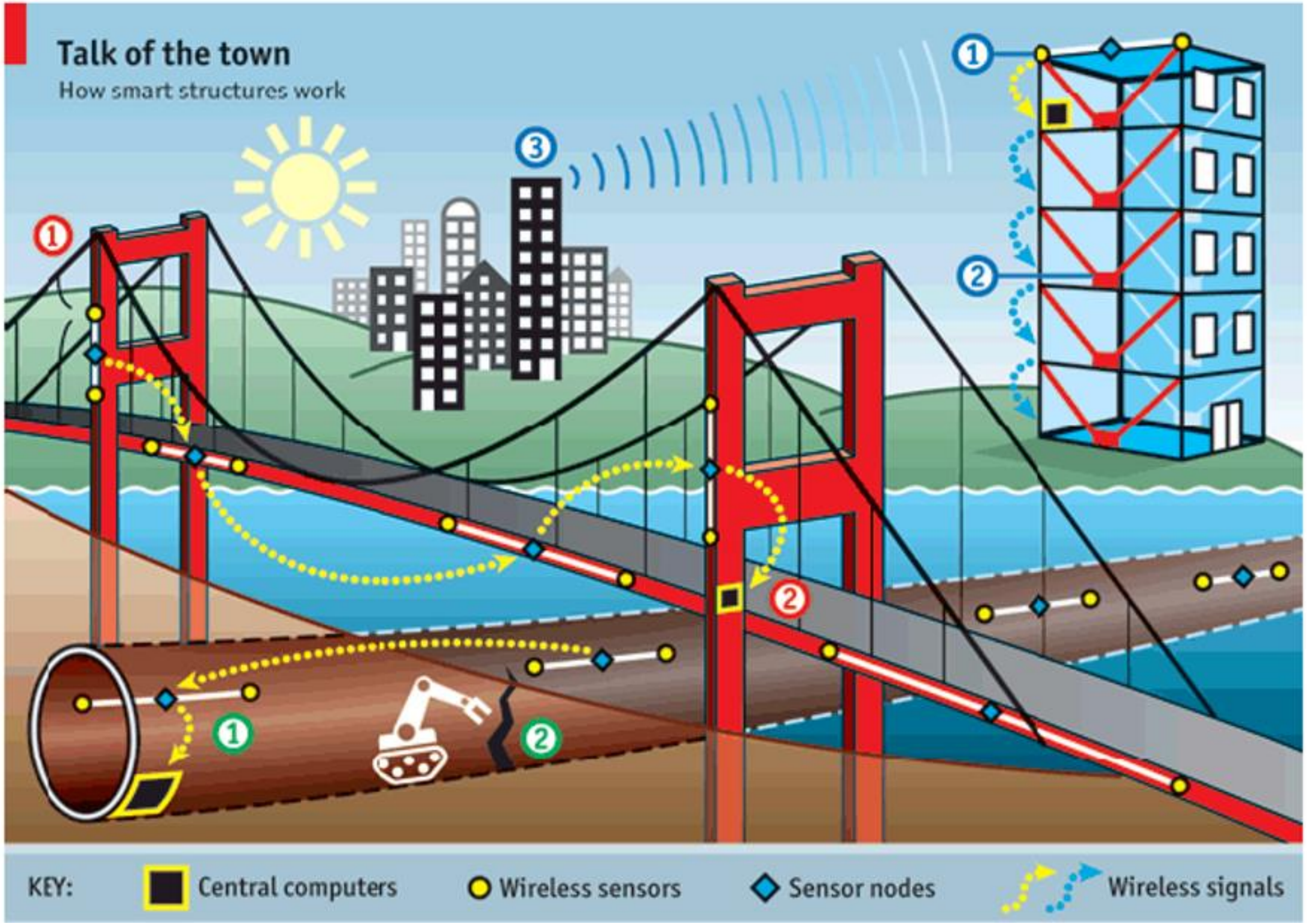
Aging infrastructure:
2016 – Stoke Newington water main burst

11 December 2016
– 3rd incident in South London in a week
– hundreds of homes flooded.
"The bursts are a clear reminder that we need to keep investing in our ageing and sometimes fragile network, with many pipes in London well over 100 years old.”

http://www.telegraph.co.uk/news/2016/12/11/stoke-newington-high-street-submerged-burst-water-main/

The role of technologies in building resilience for New & Existing Infrastructure



Source: The Economist vol 397, iss 8712, Dec2010

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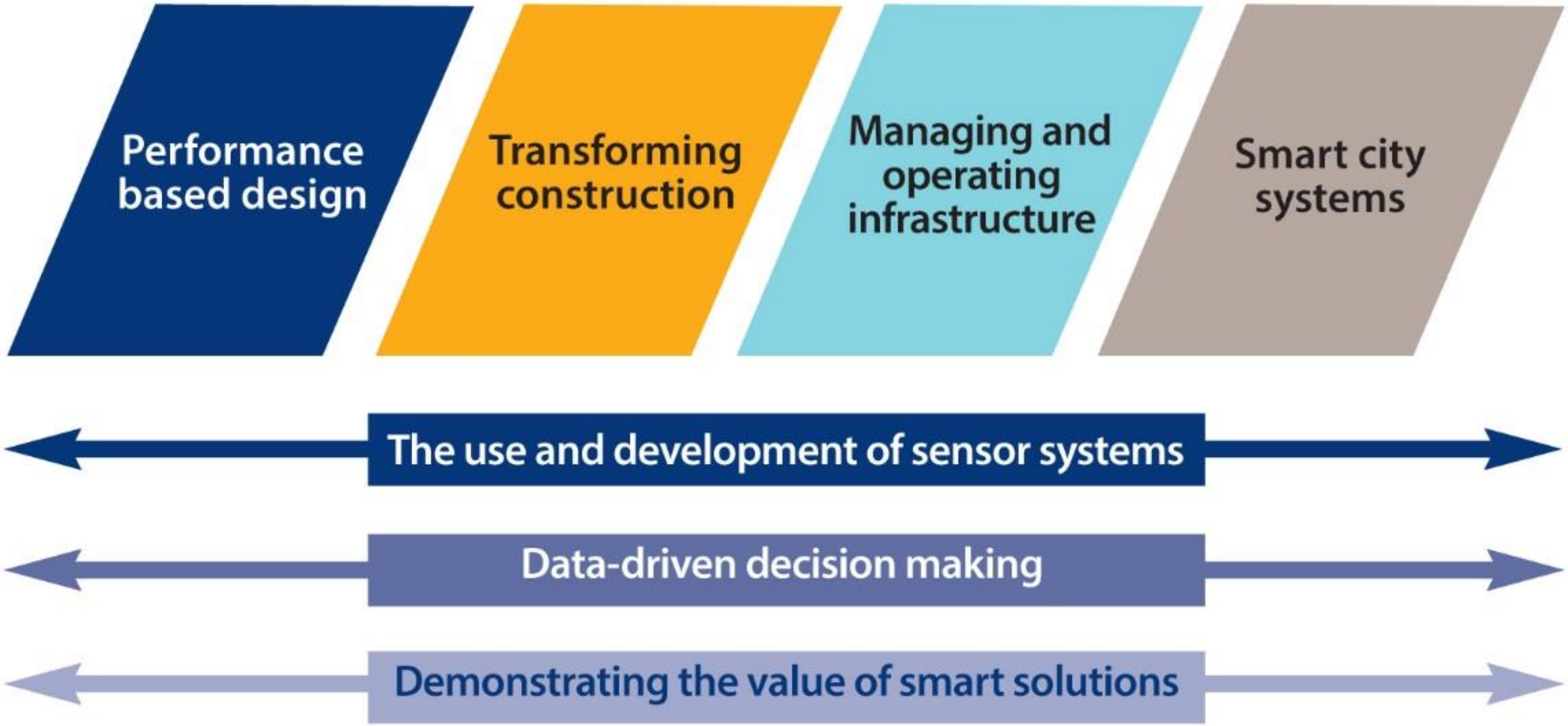
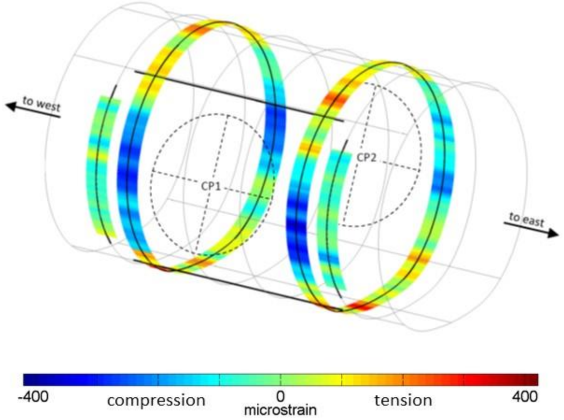
The Technologies

CSIC strategic themes

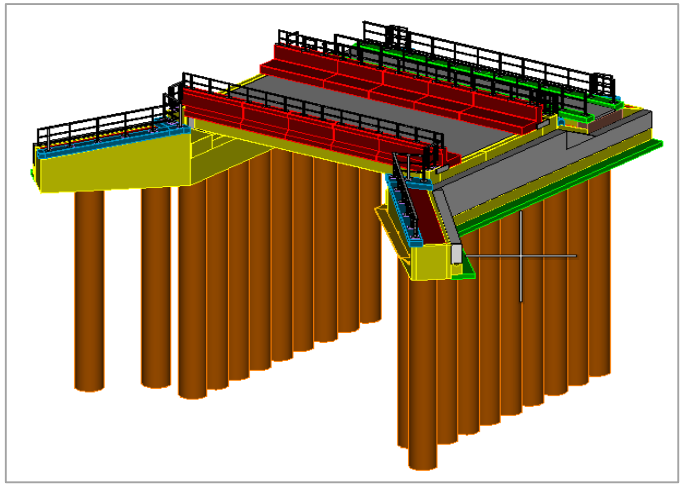


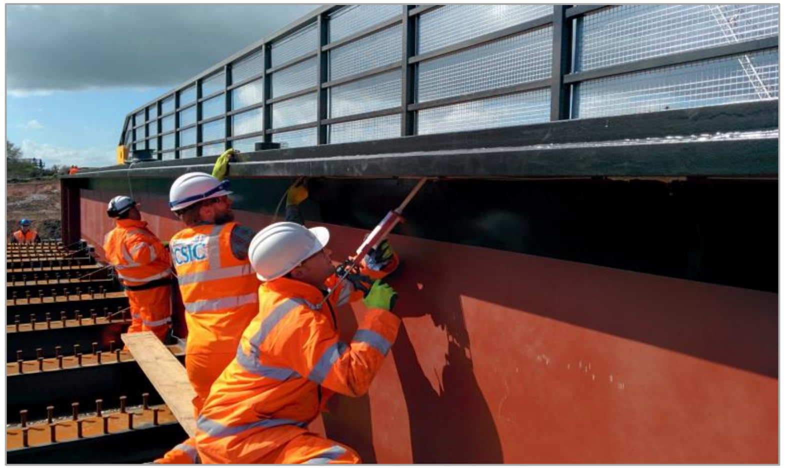
Performance based design



OPPORTUNITY

- Validating models
- Demonstrate cost saving and value
- Design for whole life value

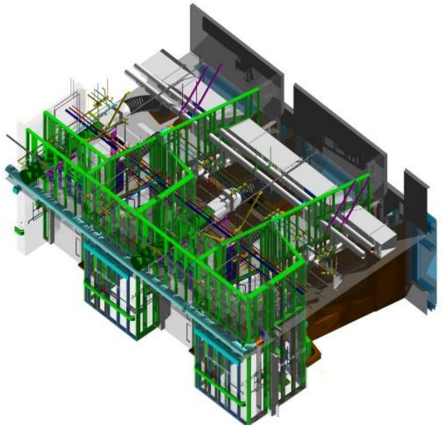


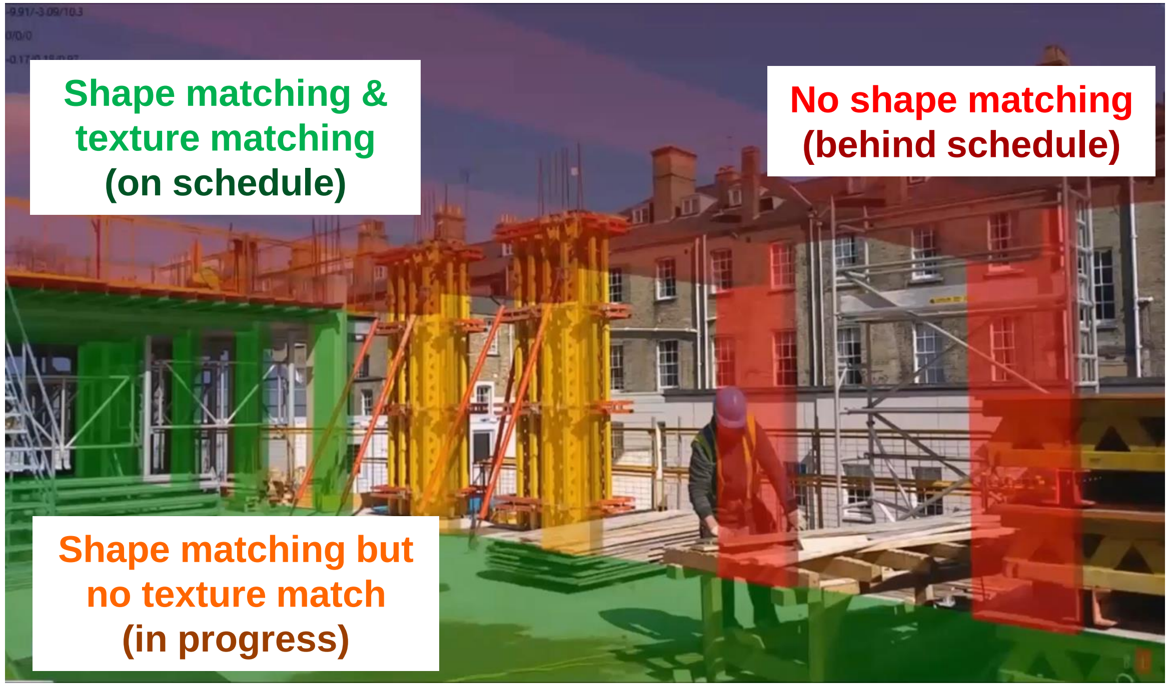


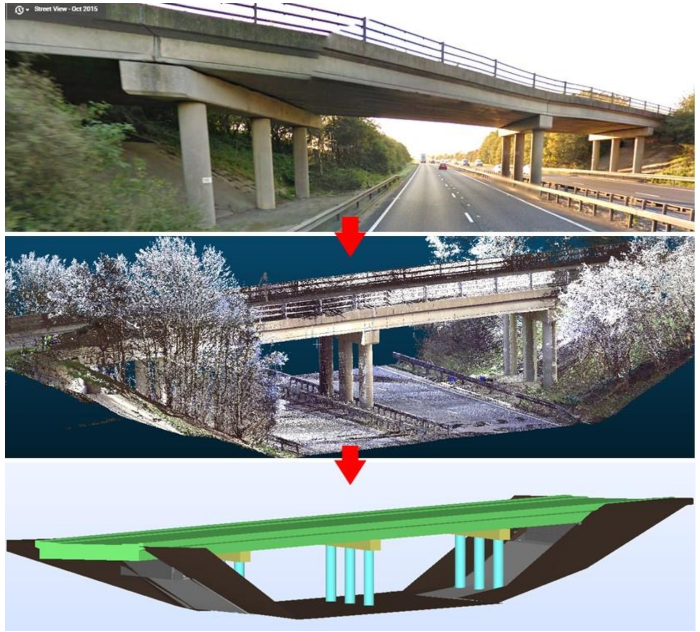
Transforming construction

OPPORTUNITY

- 'As-built' BIM
- Quality assurance
- Construction progress monitoring
- 3rd party asset monitoring







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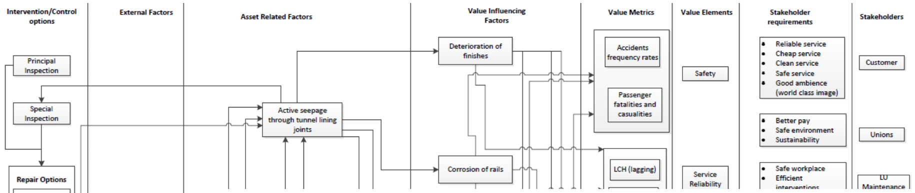
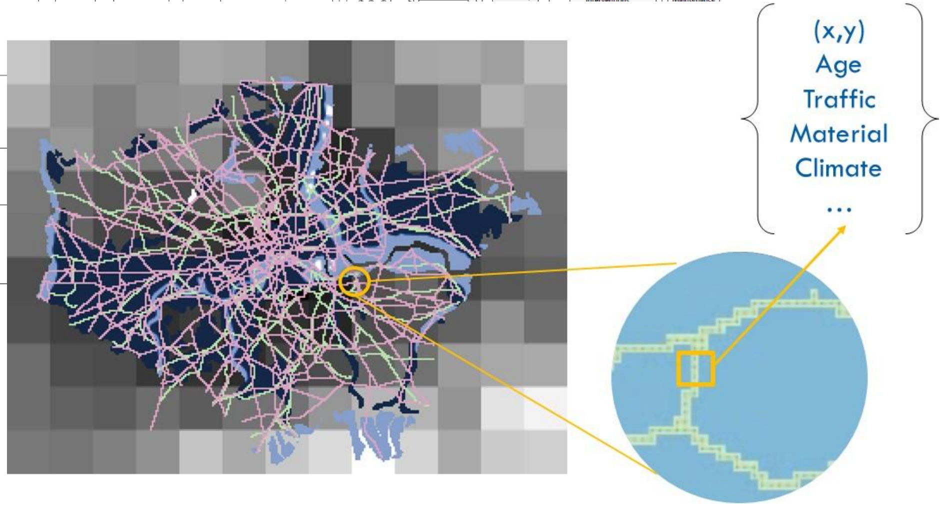
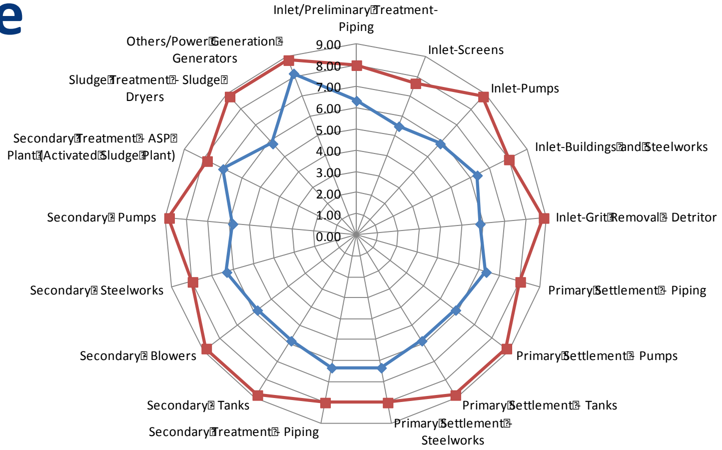
Managing and operating infrastructure

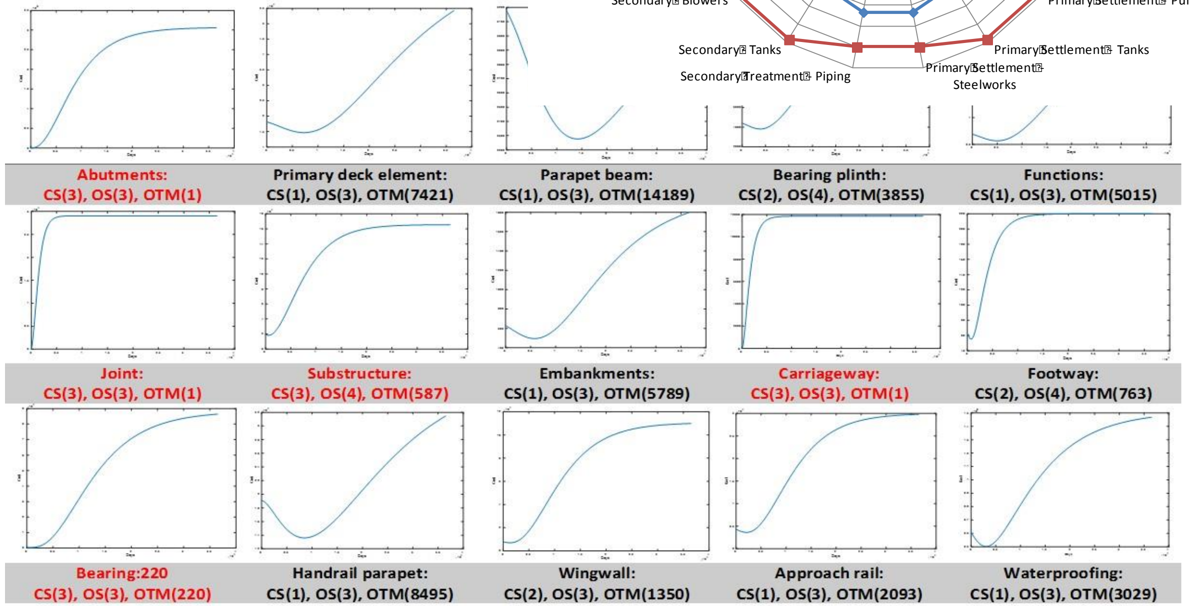
OPPORTUNITY

- **Condition monitoring and predictive maintenance**
- **Whole-life, value based asset management**
- **Risk-based maintenance**
- **Futureproofing**









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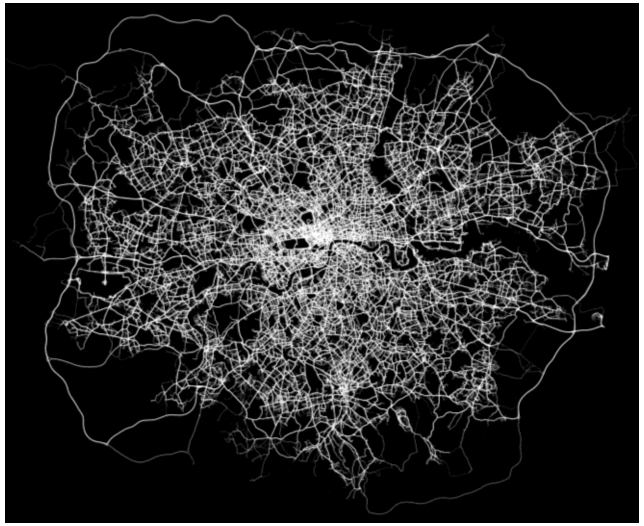
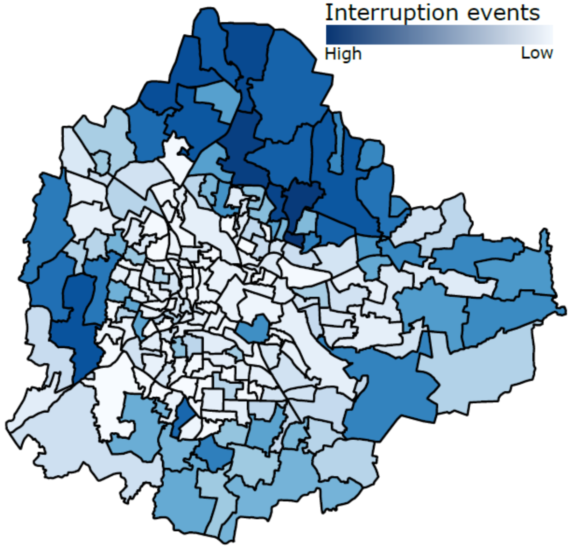
Smart city systems

OPPORTUNITY

- **Demand forecasting for future infrastructure needs**
- **Optimised network management**





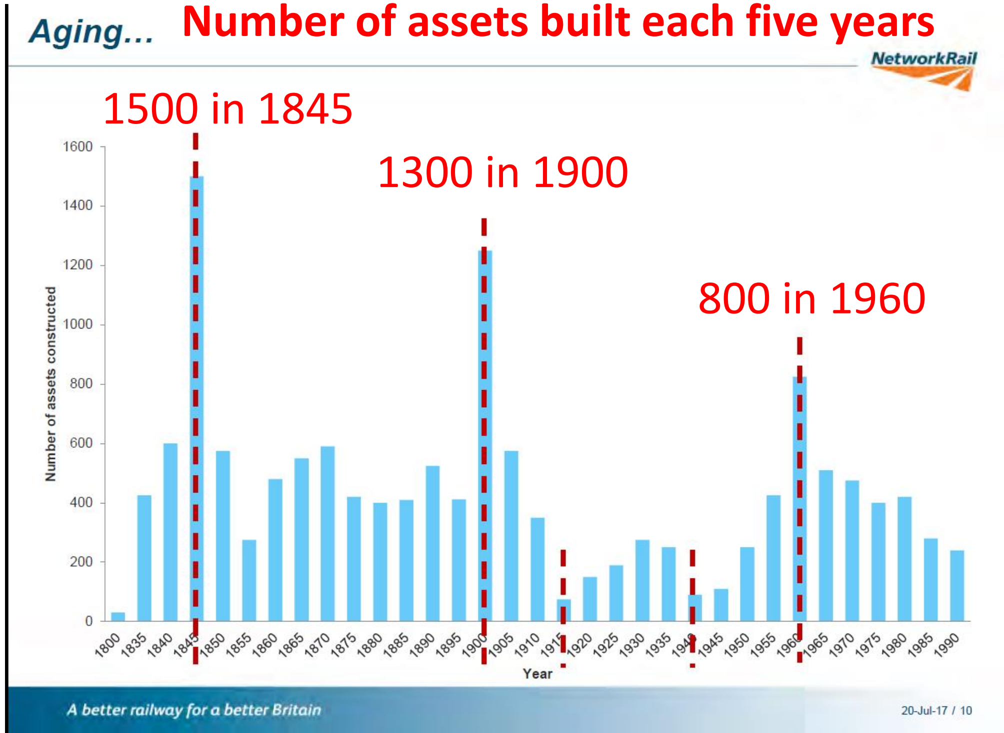
Examples in operation and management

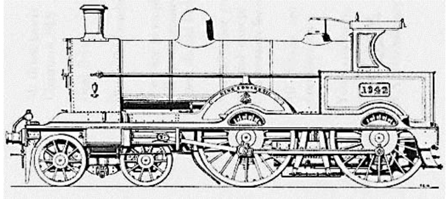
Masonry Bridge Case Study

UK rail network context

Network Rail is responsible for

- 28,000 bridges
- 22,000 retaining walls
- 21,000 culverts
- 600 tunnels
- 200 miles of coastal defence





- Train loads today are 3 times higher than 1860s [1]
- Train cars today are 5 times as long [1]
- Many masonry bridges are noticeably damaged [2]

1 *Alan Hayward, IABSE Henderson Colloq. 2016.*
2 *Brian Bell, Engineers Ireland Conf, 2014.*

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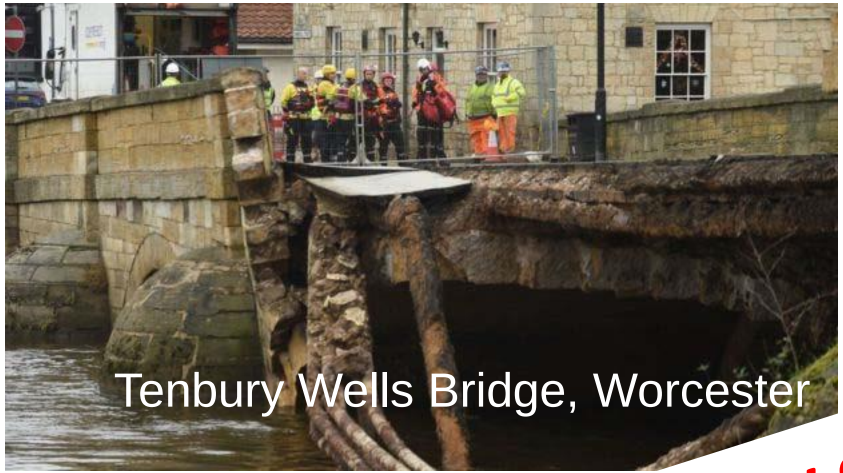
These structures are vulnerable



Tenbury Wells Bridge, Worcester

- 40% of the road and rail bridges in the UK… constructed of masonry [1]
- 3 instances of partial m… …ne UK, in 2015 & 2…

…from Zoltan et al. (2012)

…otos from BBC Online

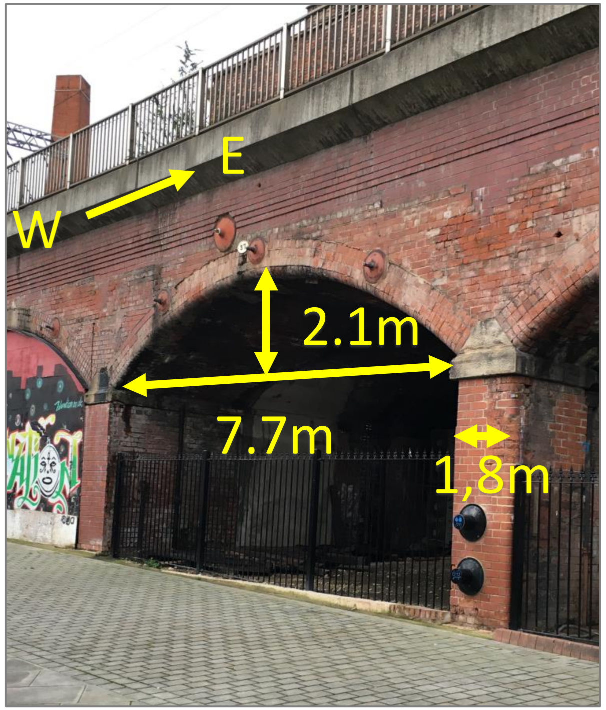
"Unplanned unavailability of assets has a huge impact on operations" Senior Network Rail executive

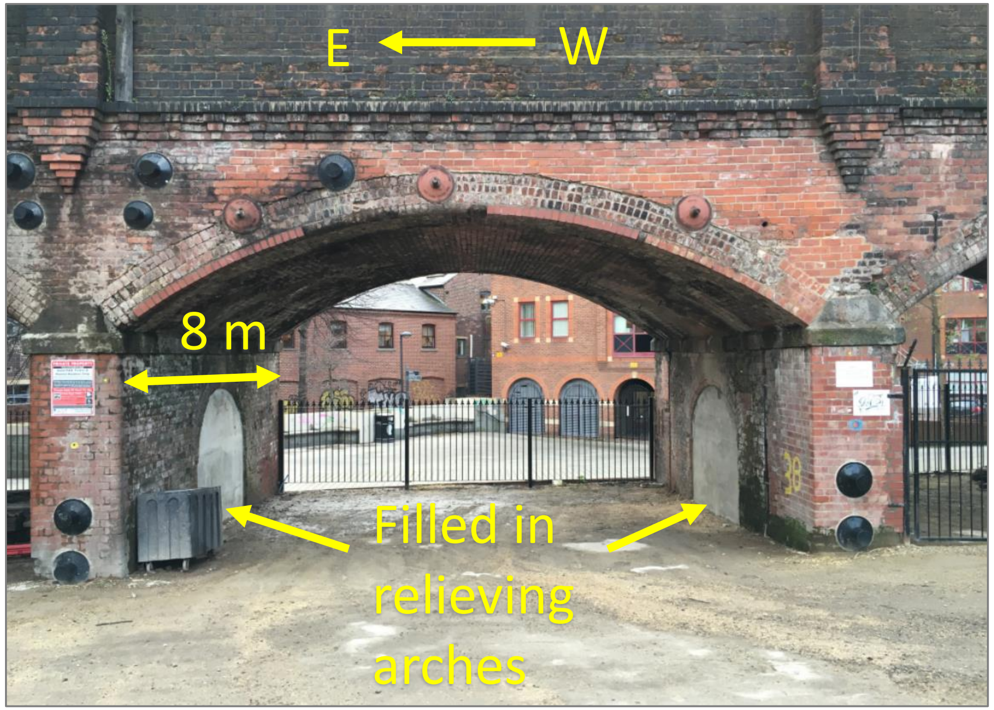
Barrow upon Soar Bridge, Leicester

Tadcaster Bridge, York

Marsh Lane Viaduct, Leeds

- 19th century brick and rubble construction on Leeds main line
- Hundreds of spans of similar dimensions
- Carries passenger trains on two tracks, to and from mainline station
- Speed limit of 25 miles/hour due to condition concerns





Challenges:

- Widespread damage in different places
- Load transfer not well understood

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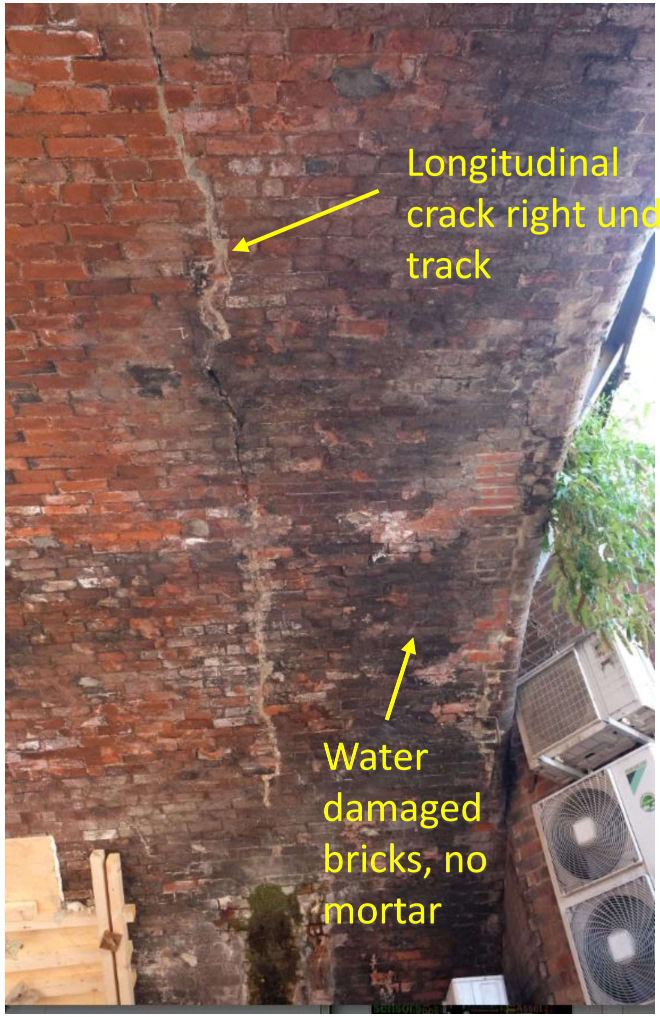
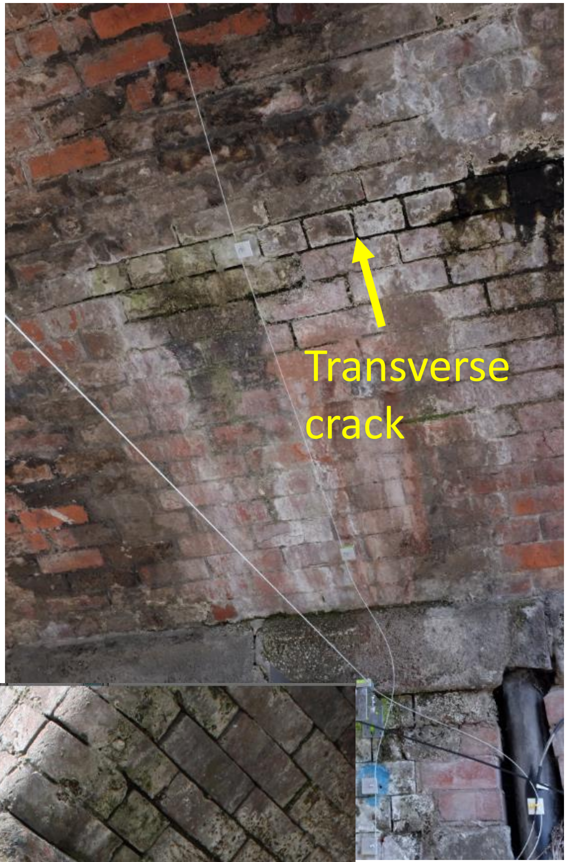
Investigated arch

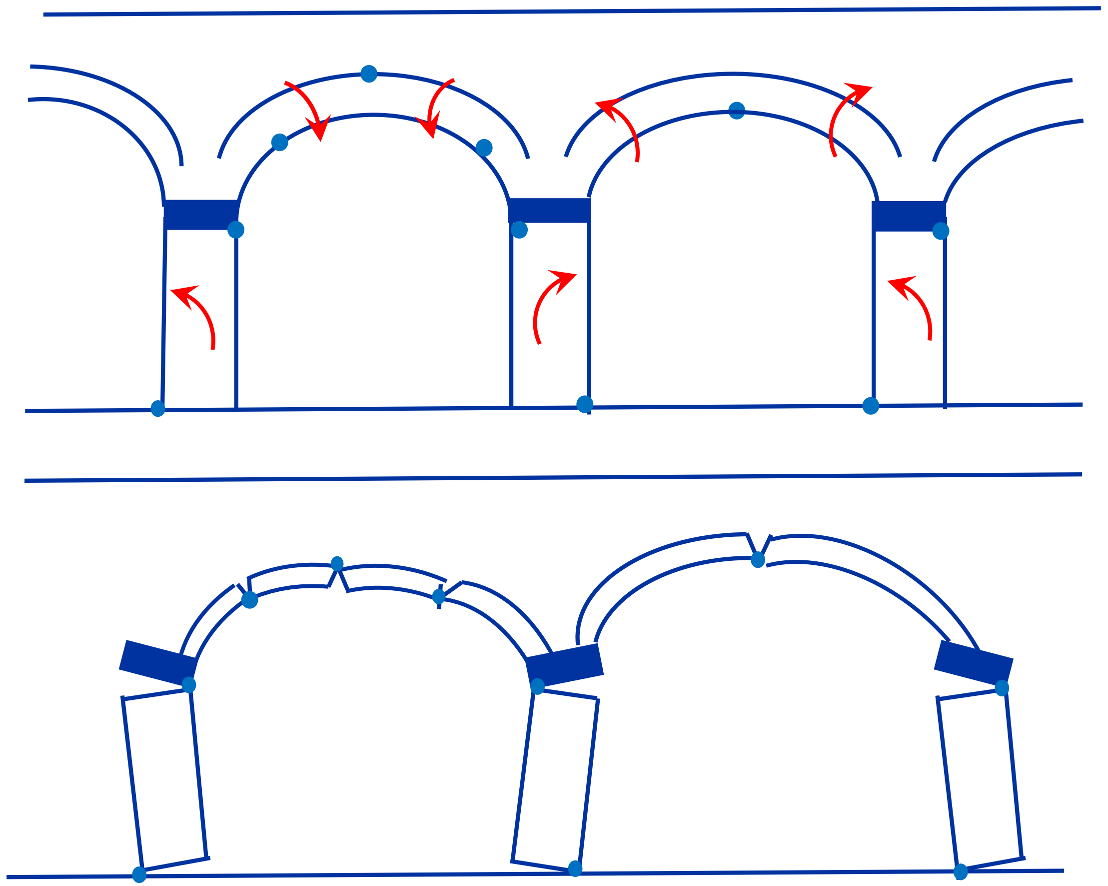


We need extensive monitoring to understand the influence of all these effects on the dynamic response of the arch.

This is made easy by distributed monitoring.

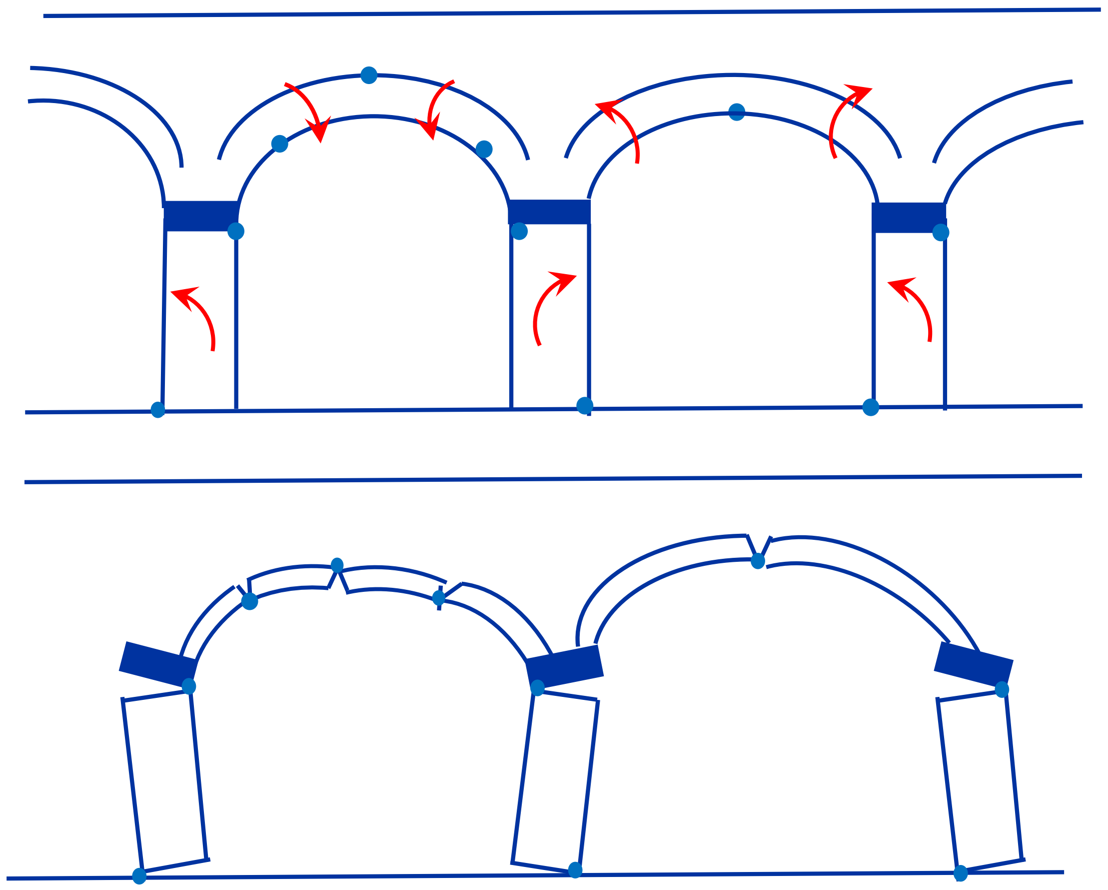


Understanding deformation mechanism



- Span opening and closing induces different mechanisms.
- Different hinge locations allow different crown movements for same span opening/closing.
- A narrow stiff pier top section rotates as a rigid block.

Benefits of understanding

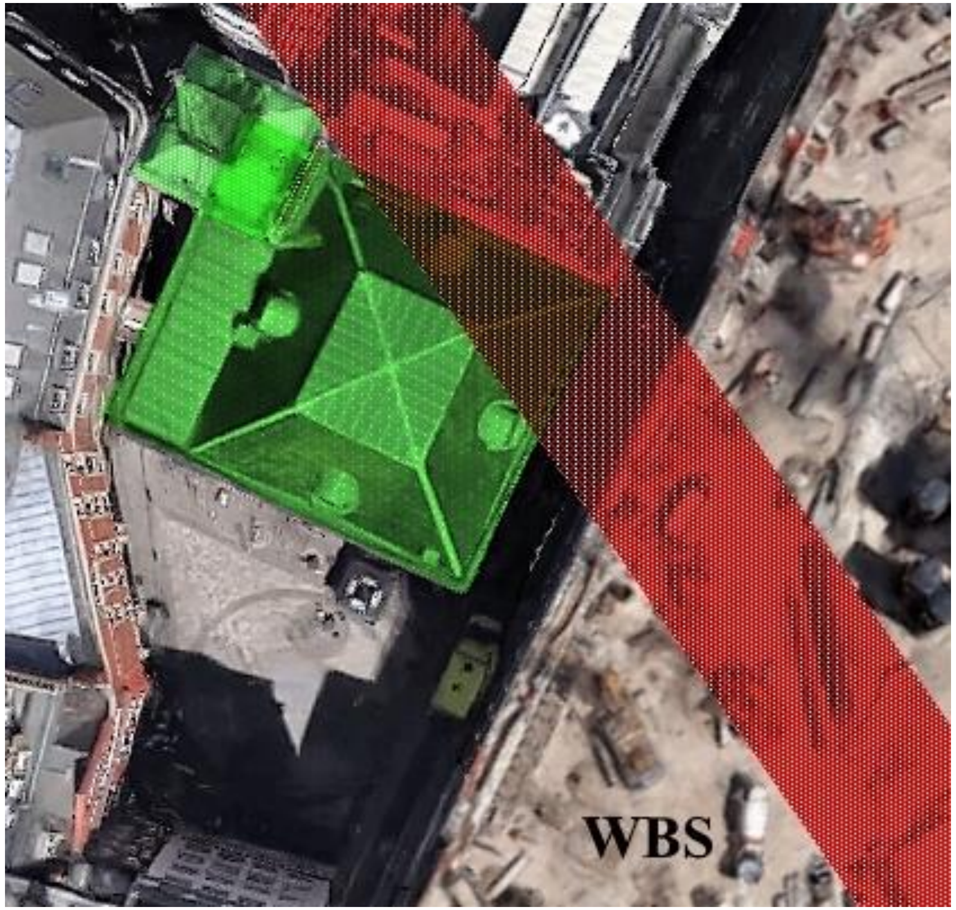


- Speed limit can be lifted, reducing operational disruption
- Appropriate maintenance can be executed
- Ongoing monitoring to assess future maintenance requirements

Next steps

- Long term monitoring
- Further assessment of wider portfolio of bridges – both intensive, and through visual drone surveys
- Project with UK National Infrastructure Commission to assess the 'size of the prize' in reducing unanticipated service interruptions and moving from reactive to proactive maintenance
- Monitoring of other heritage assets

Protecting 3rd Party Assets: Bank Station Capacity Upgrade & St Mary Abchurch



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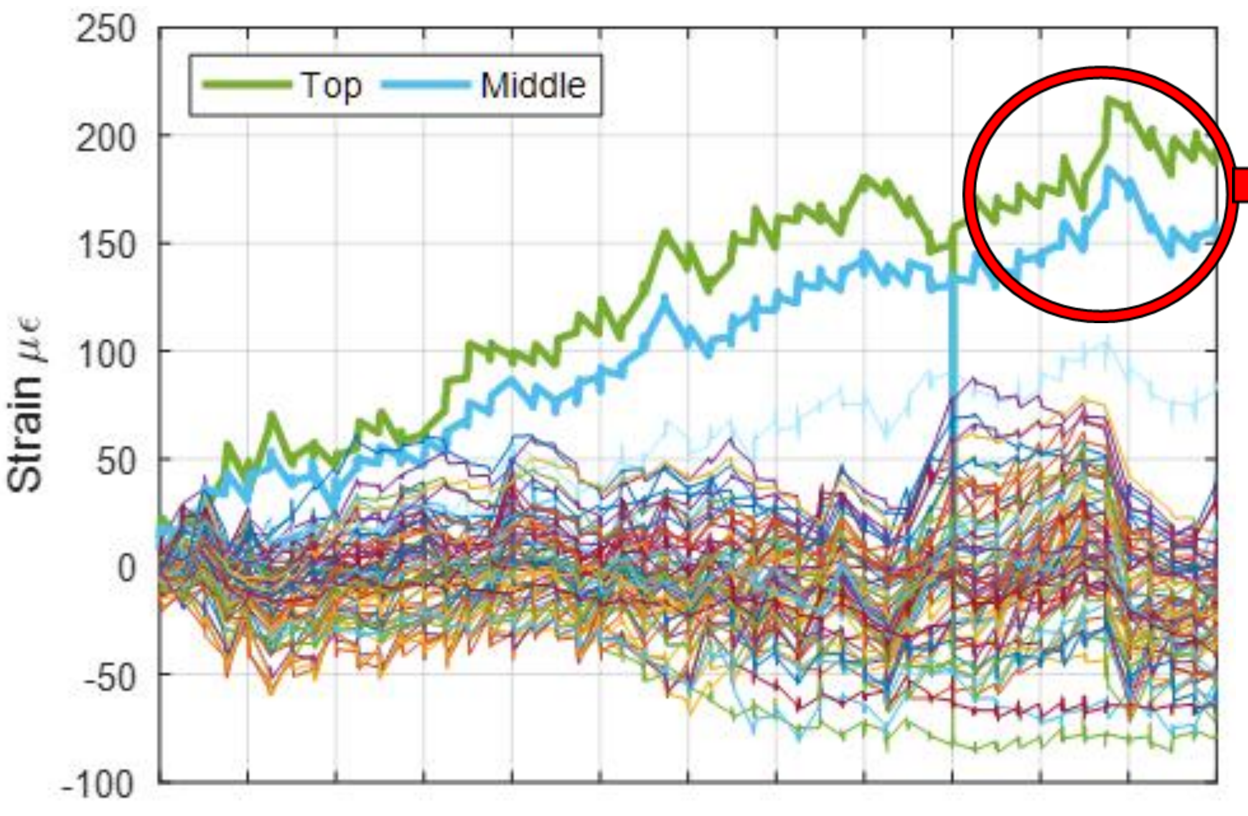
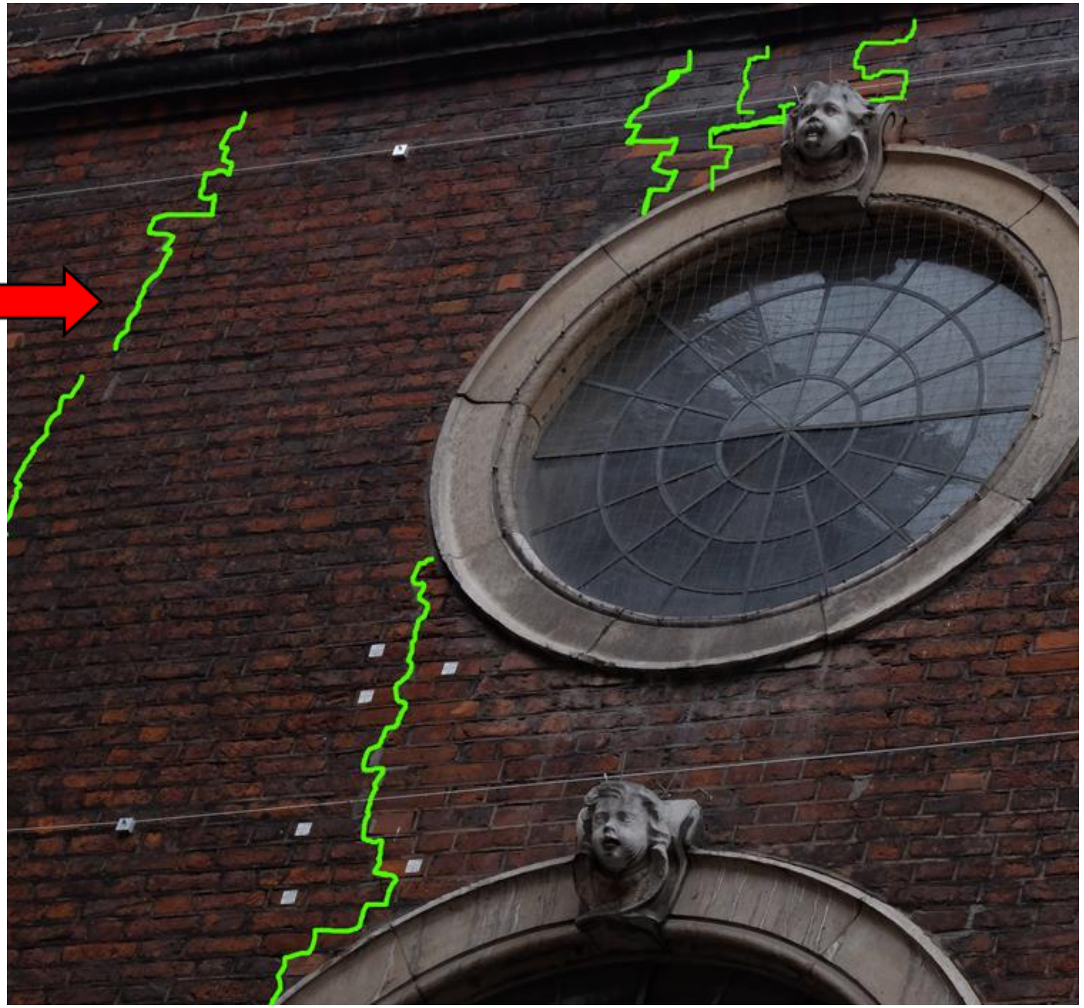
Measure existing damage and new damage

Pre-existing cracks





In the chart there are all the sensors of the south façade. Higher strain is obtained due to preexisting cracks.

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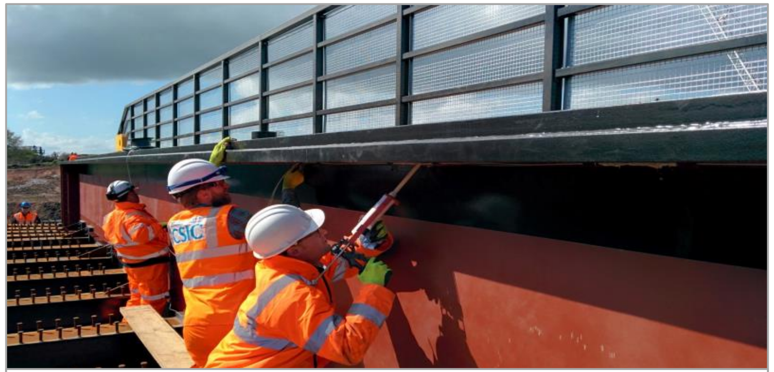
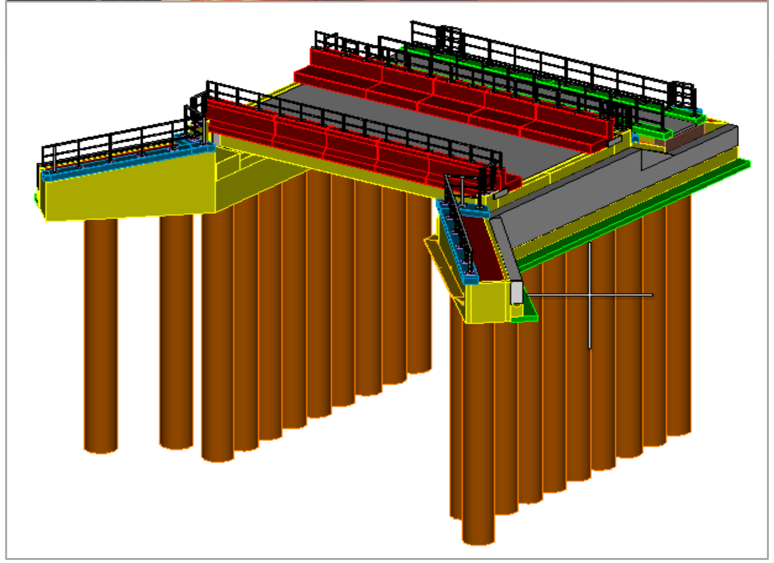
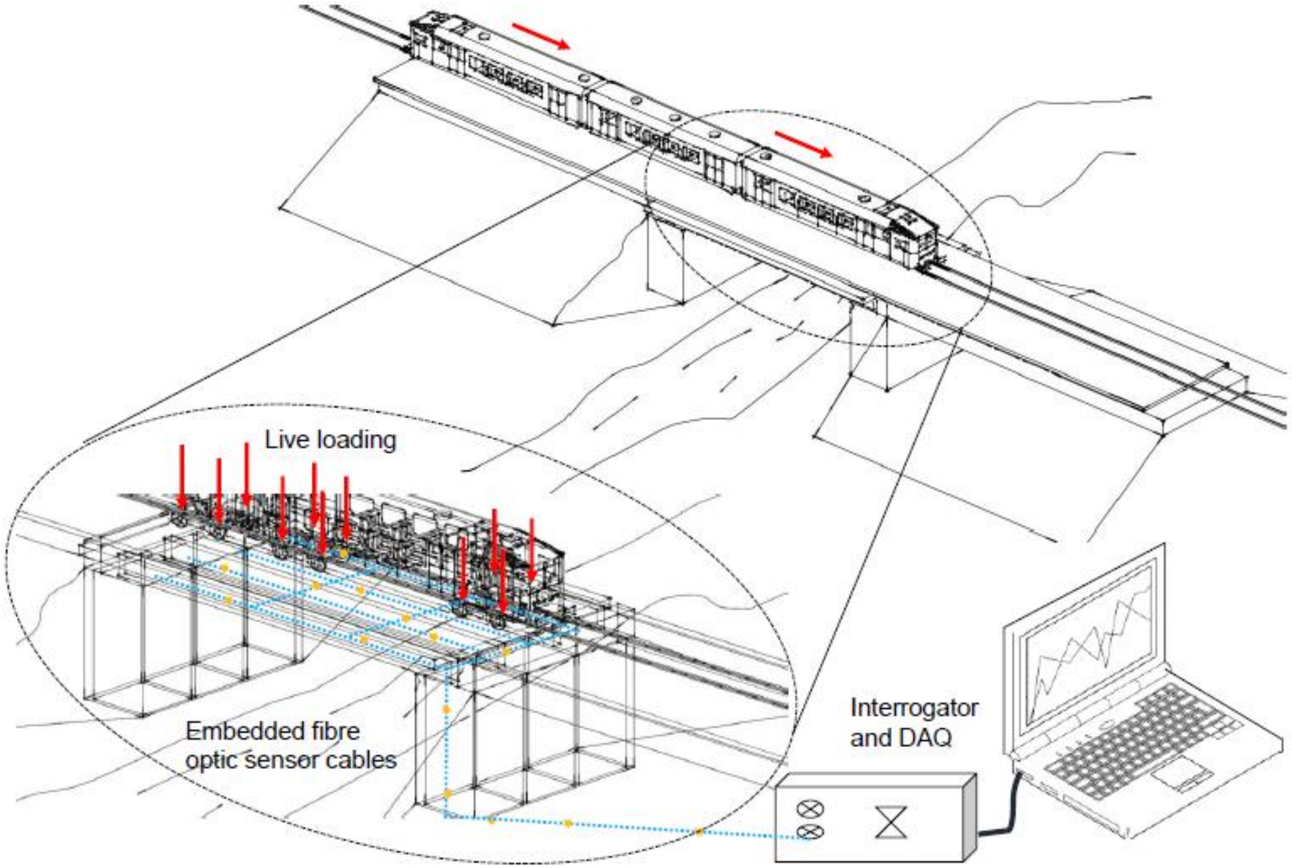
Instrumenting new structures for whole life management

Giving an asset a 'health passport'







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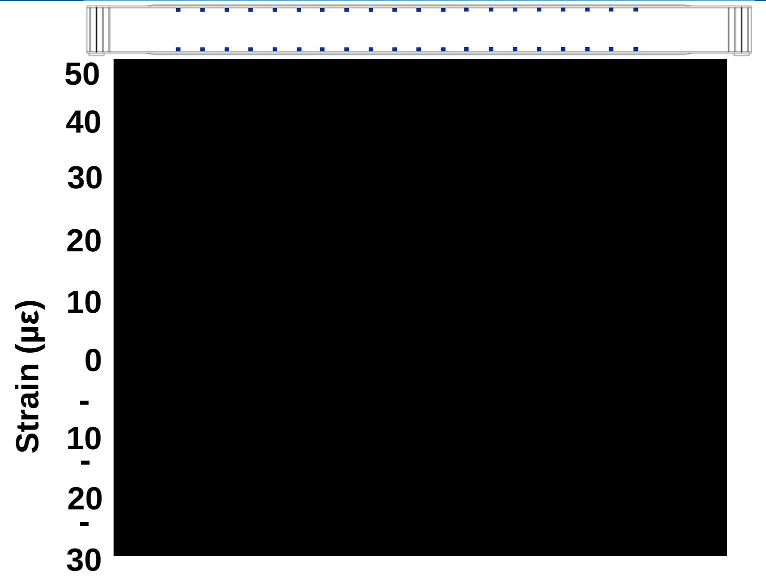
Self-sensing infrastructure

Bottom Midspan FBG Sensor



Real time recorded strains (West Girder)

West Elevation

Longitudinal View

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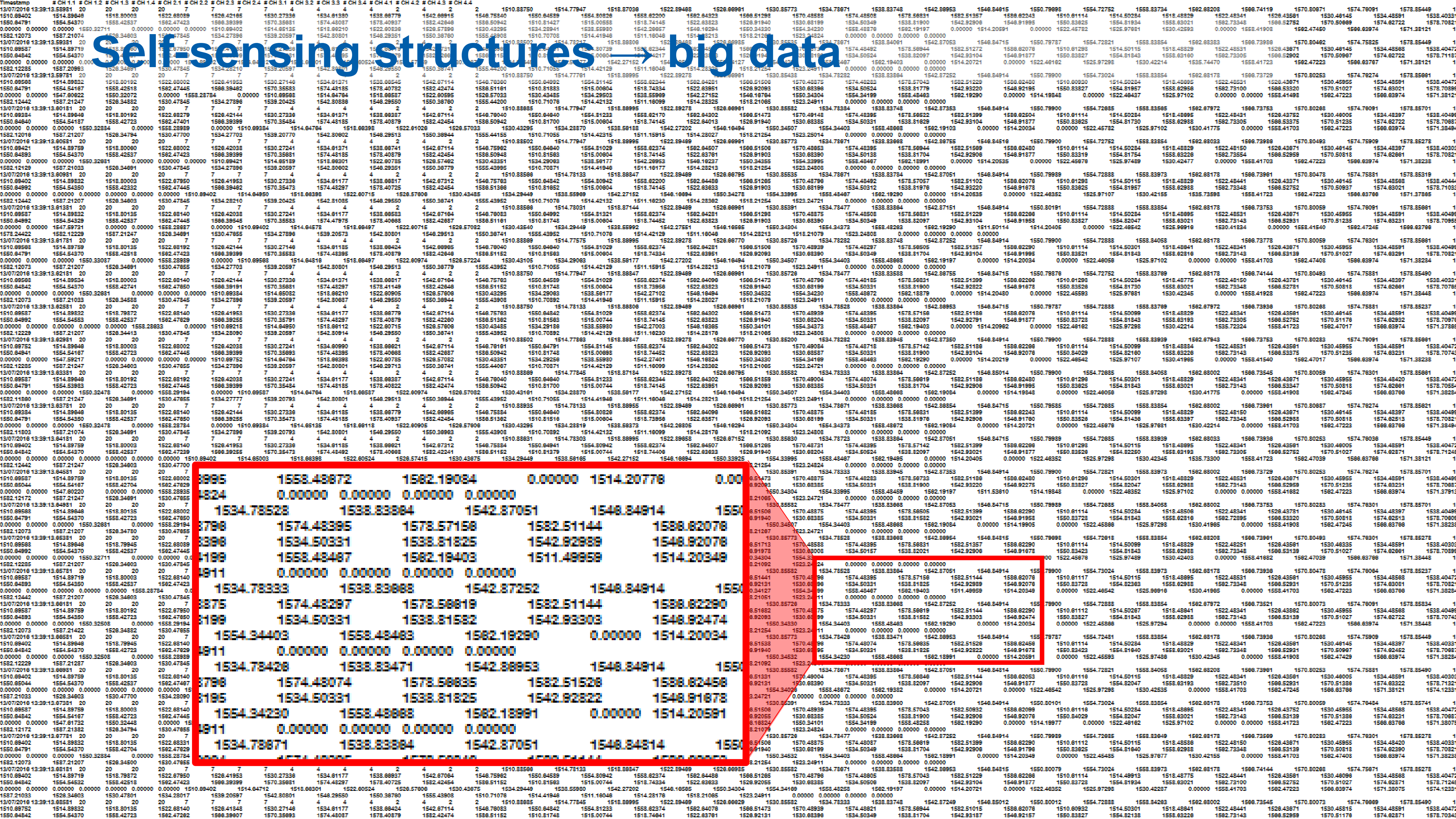
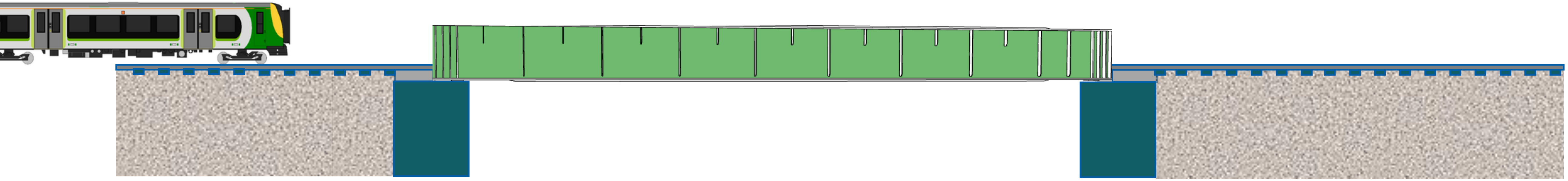
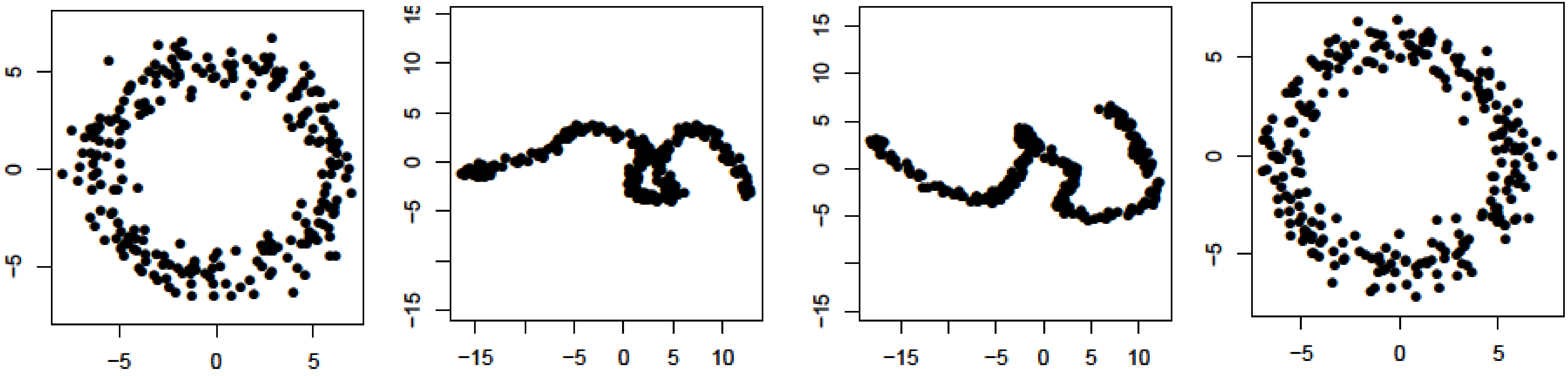
Self-sensing structures → big data



Donuts from Data…





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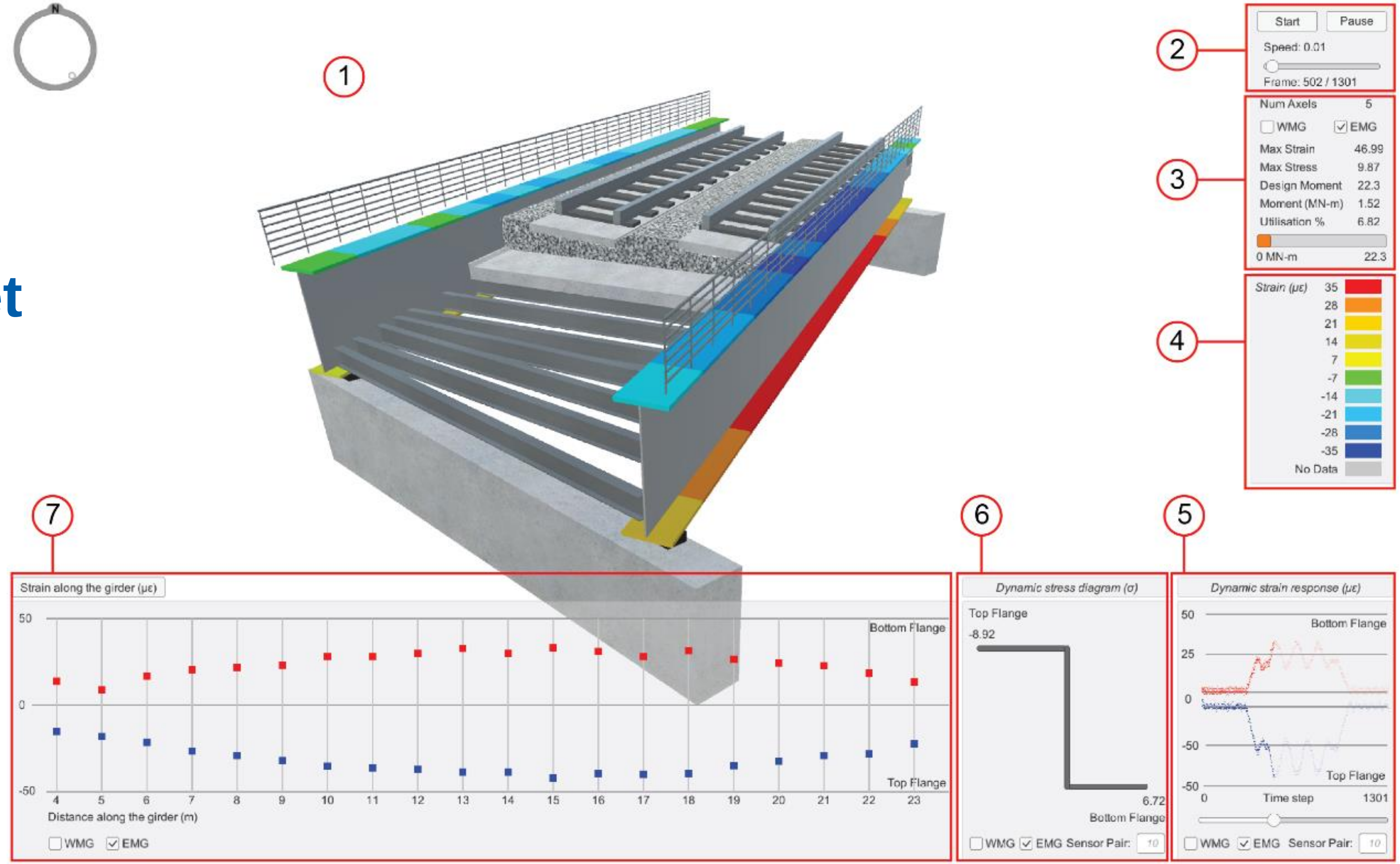
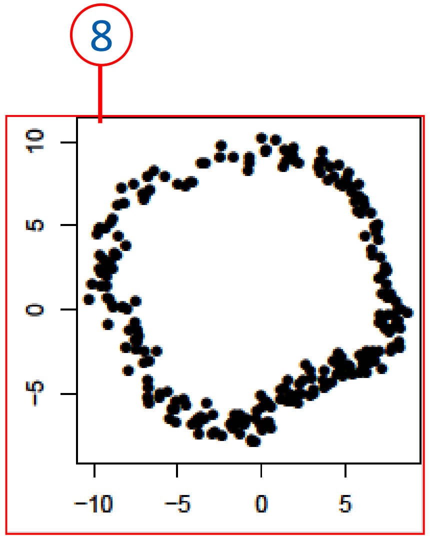
Manage

Analyse

Interpret





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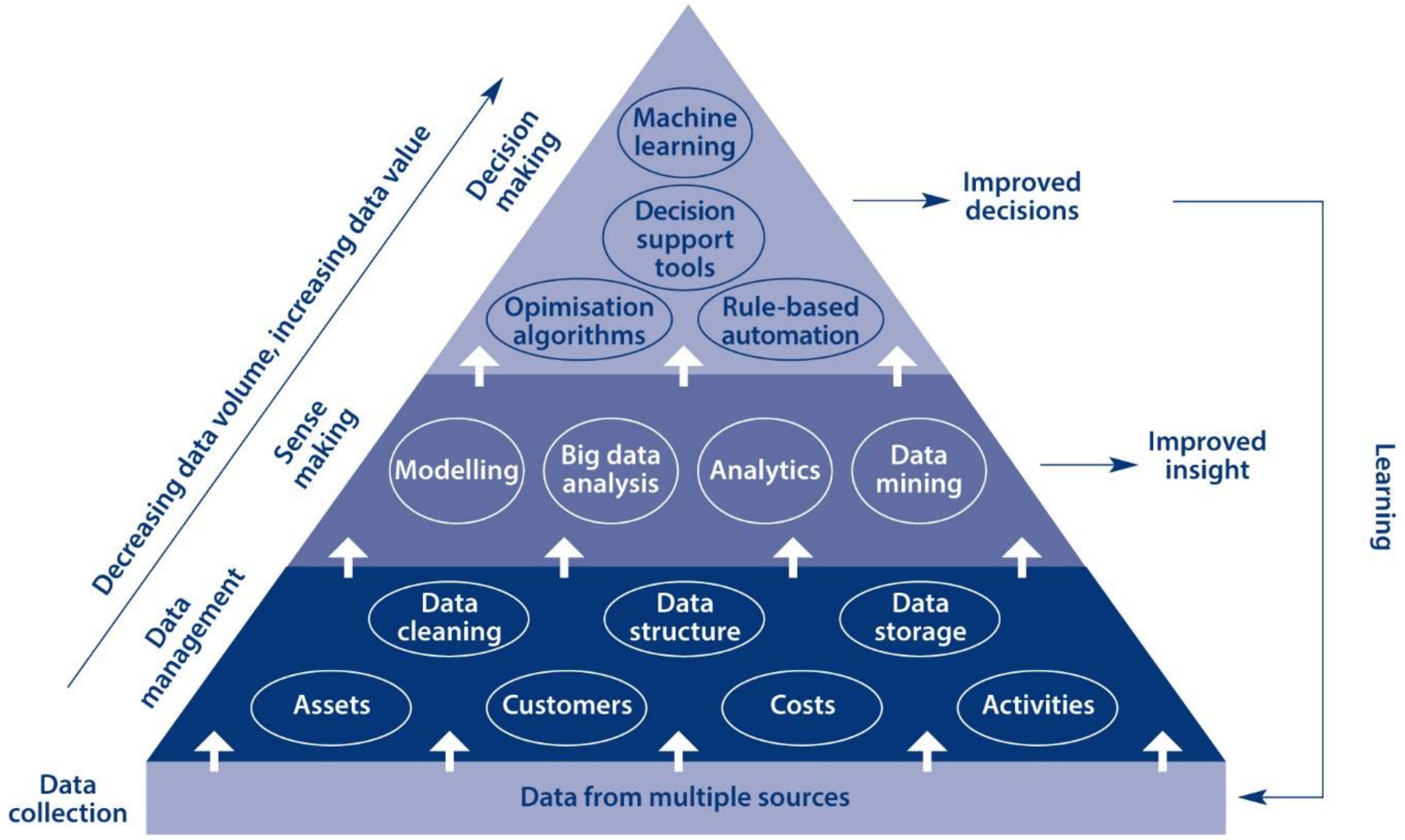
Challenges of Data



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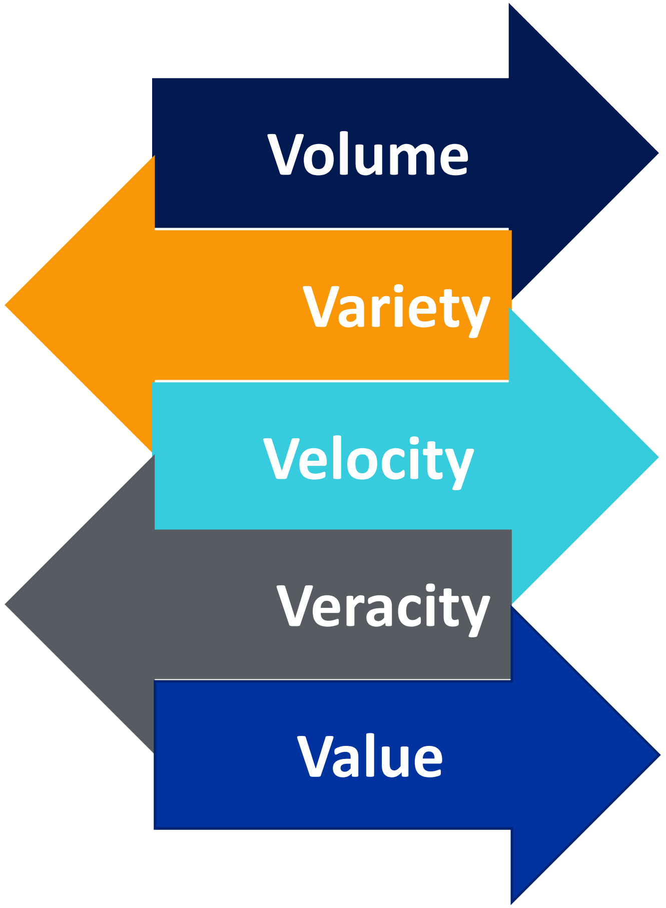
Big Data – what is it?

- ***Volume:*** The increasing size of datasets

- ***Variety:*** The increasing variety of sources from which data originates and is stored



- ***Velocity:*** The speed at which the data is created, changes and needs to be processed

- ***Veracity:*** The challenges posed by poor data quality

- ***Value:*** The value that the data provides for your organisation

Variety

- Position – 1D, 2D, 3D
- Location – m to 10’s km
- Scale – mm to km
- Temperature
- Humidity
- Acceleration
- Images
- ….

(Variety in) Velocity

- Sub second
- Minute
- Week
- Month
- Year

Veracity

- As data generated – e.g. faulty sensors, data tampering
- Over time – confidence in data over decades

Purpose *(Value)*

- Responsive (immediate)
- Reflective (months – years)
- Long term (decades – centuries)

Design > Construction > Operation > Maintenance > Replacement

Future direction

- Applying Machine Learning algorithms such as ‘deep-learning’ techniques to extract features and correlations.
- Real-time prediction of infrastructure behaviour based on statistical correlations and relationships.

“Transform the future of infrastructure through smarter information”

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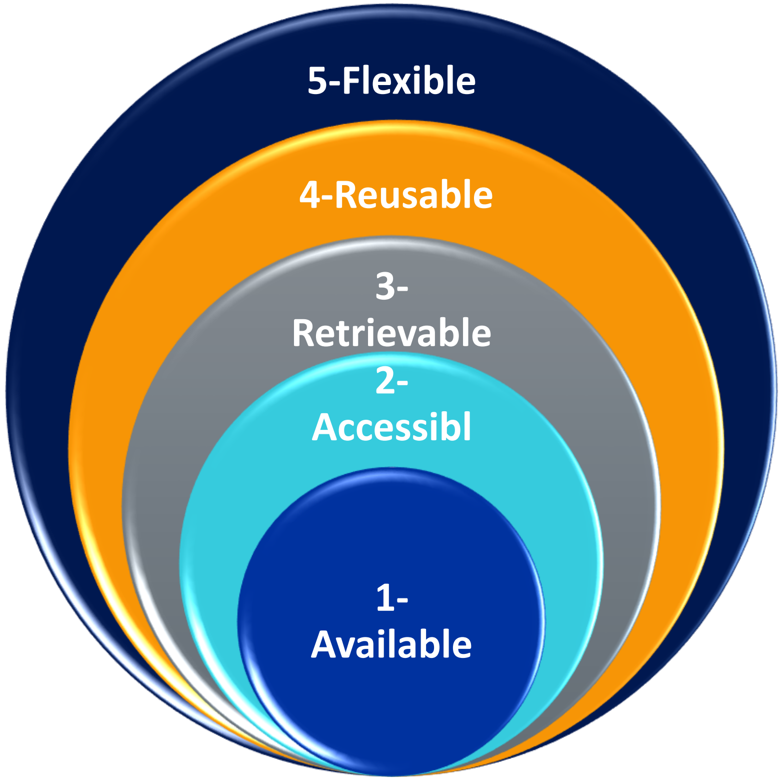
What is Information Futureproofing?

«The process to select or identify technologies and services that would enable long term storage and retrieval of infrastructure information.» *(Masood et al 2013).*

Key characteristics:
To make better decisions for futureproofing infrastructure, information which has ***key characteristics***, should be available in the ***long term***.



5 -The information can be used for different purposes beyond its creation purpose.
4 -Once the information is created, it can be used multiple times.
3 -The information is searchable.
2 -The information is stored in a place and can be opened .
1 -The information is available, and stored somewhere.

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Information Futureproofing Approach

1-Identify information retention requirements for long-term (D-I-T^2 Analysis*)

- *1a-Identify Decisions / Objectives / Tasks*
- *1b-Identify key information produced*
- *1c-Identify Enabling Technology landscape*
- *1d-Identify key information required/used*
- *1e-Identify retention time for each information produced*

2-Assess risk of information loss in long-term

- *2a-Assess severity / impact of information on infrastructure decisions*
- *2b-Identify key hazards leading to information loss*
- *2c-Assess likelihood of hazards of information loss in long term*
- *2d-Calculate preliminary risk rating*

3-Provide guidelines to enable information futureproofing

- *3a-Provide guidelines to enable information futureproofing*

* D-I-T^2 Analysis = Decision – Information – Technology – Time Analysis

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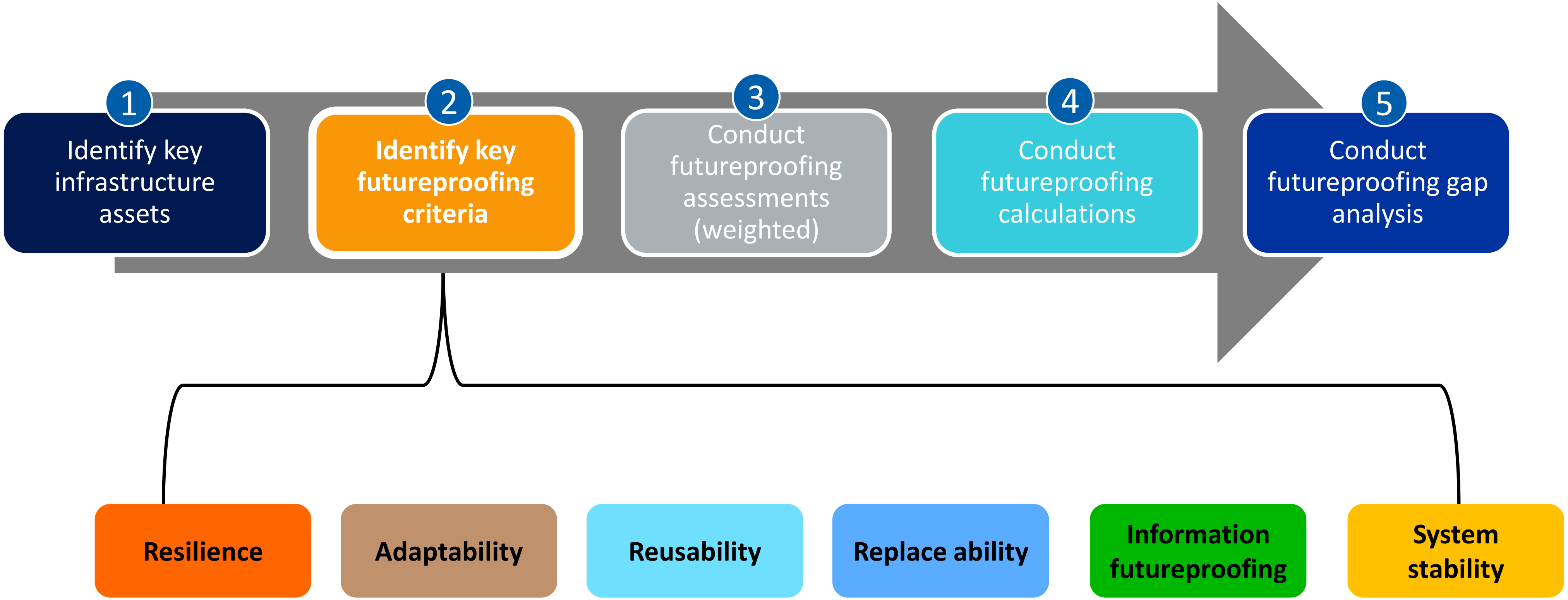
Futureproofing Infrastructure

Testing the futureproofing approach
A case of Liverpool Waste-water Treatment

A tool to provide:

- Futureproofing gap analysis
- Improved risk assessment / management process
- Improved stakeholder management process

Futureproofing Assessment Approach



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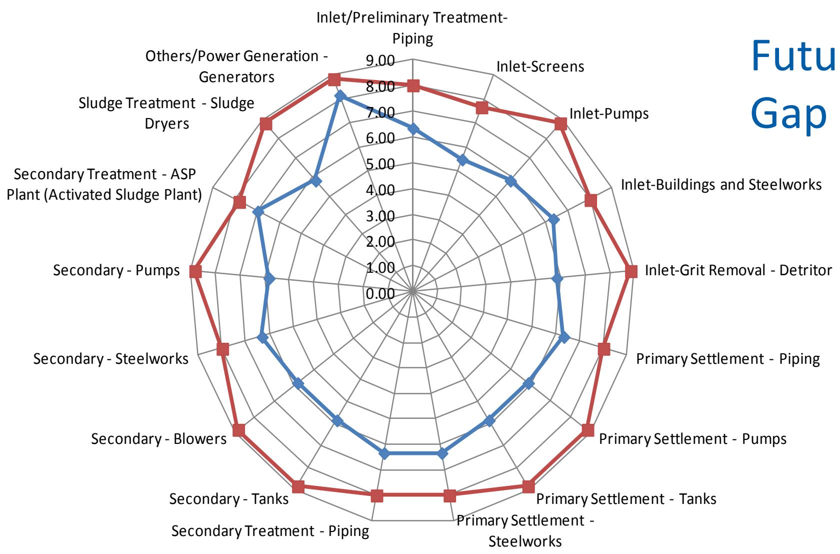
Possible future changes in Liverpool WwTW

- Changes in **regulation** (OFWAT water quality requirements, World heritage regulation, EU directives etc)
- Changes in **budgets & resource allocation** (eg. Cuts in operation budgets, OFWAT cuts or increases in possible charges etc)
- Changes in **sea level**
- Changes in **rainfall**
- Changes in **consumption**
- Changes in **degree of contamination** of water
- Changes in **energy prices**
- Changing **executive values** (e.g. embracing a greener more sustainable agenda)
- Disappearing or new **suppliers** (spare part problems and possibilities for adaption of new technologies)
- **Vandalism and riots**
- **Power cuts**

Changes ?

Results of futureproofing assessment of LWwTW

		Criteria																				
Innfrastructure Classification	Comments	Resilient1			Adaptive2			Replaceable3			Reusable4			Operable5			System-stable6				FPN	
		R1			A			R2			R3			O			S					
Asset Classification		W	A	T	W	A	T	W	A	T	W	A	T	W	A	T	W	A	T	W total	A	T
Inlet/Preliminary Treatment-Piping		0.17	8	10	0.17	5	8	0.17	5	8	0.17	2	2	0.17	8	10	0.17	10	10	1	6.33	8.00
Inlet-Screens		0.17	[illegible]	8	0.17	7	8	0.17	10	10	0.17	2	2	0.17	6	8	0.17	4	10	1	5.50	7.67
Inlet-Pumps		0.17	5	8	0.17	5	8	0.17	7	10	0.17	2	7	0.17	8	10	0.17	8	10	1	5.83	8.83
Inlet-Buildings and Steelworks		0.17	8	10	0.17	5	8	0.17	5	8	0.17	2	2	0.17	8	10	0.17	10	10	1	6.33	8.00
Inlet-Grit Removal - Detritor		0.17																		1	5.83	8.83
Primary Settlement - Piping		0.17																		1	6.33	8.00
Primary Settlement - Pumps		0.17																		1	5.83	8.83
Primary Settlement - Tanks		0.17																		1	5.83	8.83
Primary Settlement - Steelworks		0.17																		1	6.33	8.00
Secondary Treatment - Piping		0.17																		1	6.33	8.00
Secondary - Tanks		0.17																		1	5.83	8.83
Secondary - Blowers		0.17																		1	5.83	8.83
Secondary - Steelworks		0.17																		1	6.33	8.00
Secondary - Pumps		0.17																		1	5.83	8.83
Secondary Treatment - ASP Plant (Activated Sludge Plant)		0.17																		1	7.00	7.83
Sludge Treatment - Sludge Dryers		0.17																		1	5.83	8.83
Others/Power Generation - Generators		0.17																		1	8.17	8.83



Futureproofing Gap Analysis

A – Actual (1-10)
T – Target (1-10)

1 (least futureproof)
10 (most futureproof)

Gap = Target –Actual

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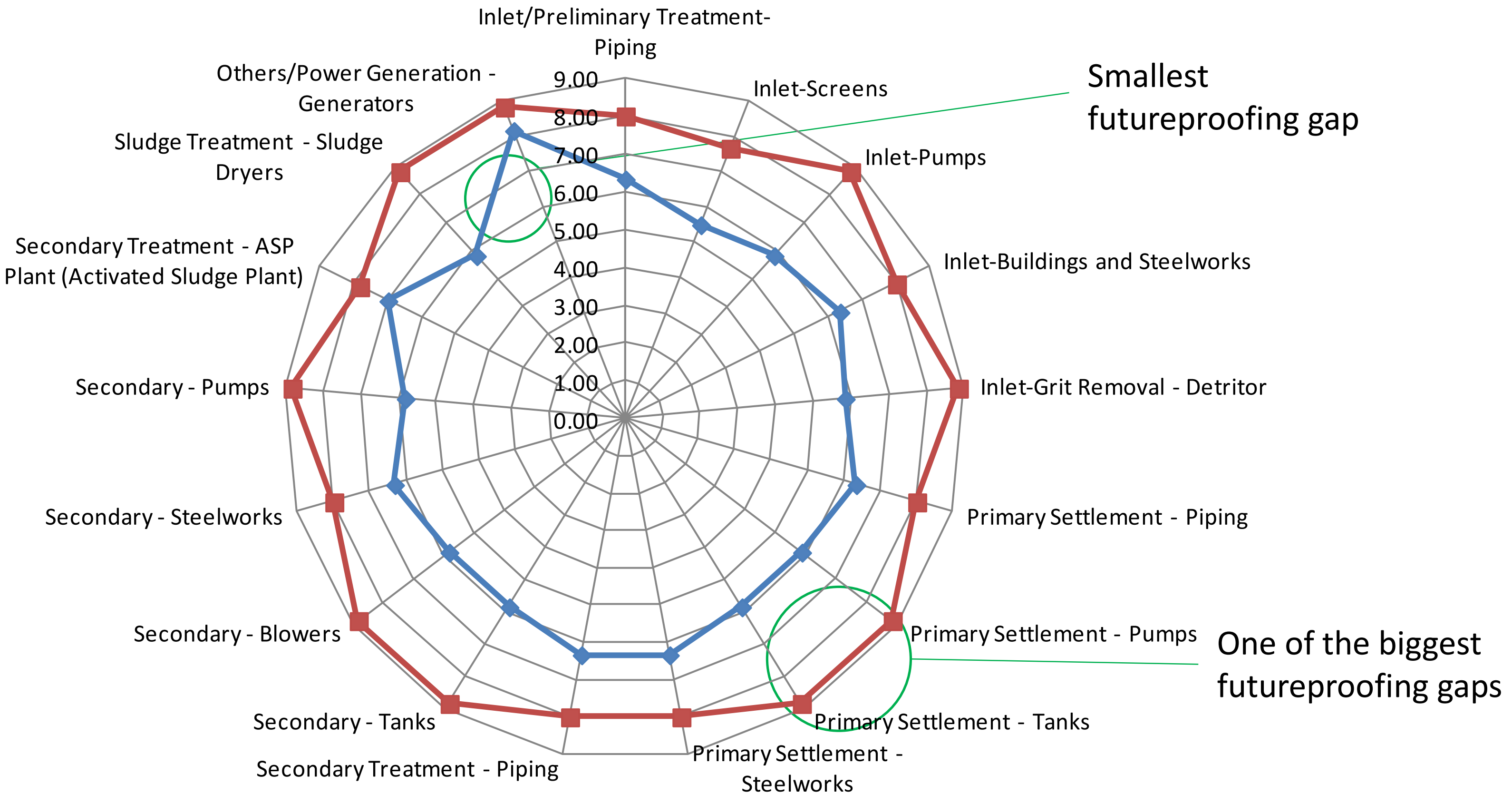
Results - total sum of weighted scores against all criteria

A – Actual (1-10)
T – Target (1-10)

1 (least futureproof)
10 (most futureproof)

Gap = Target – Actual



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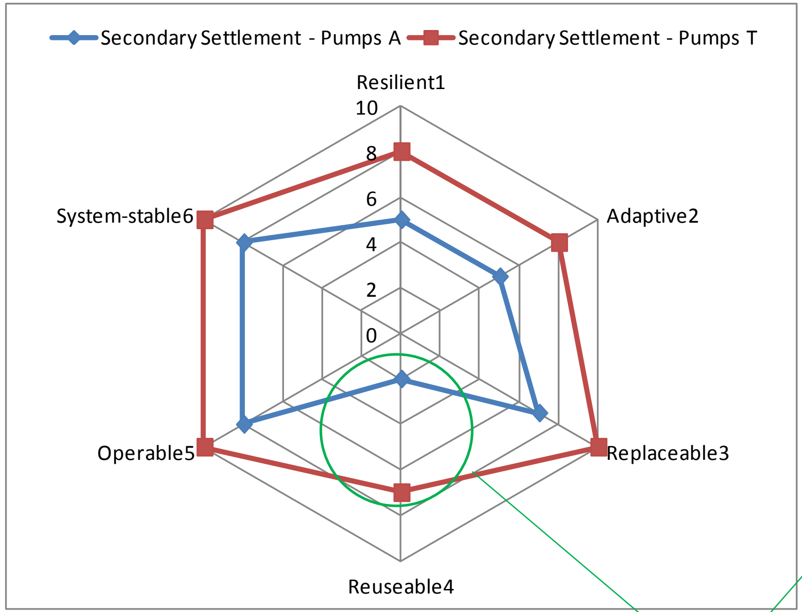
Results – single asset view against all criteria

A – Actual (1-10)
T – Target (1-10)

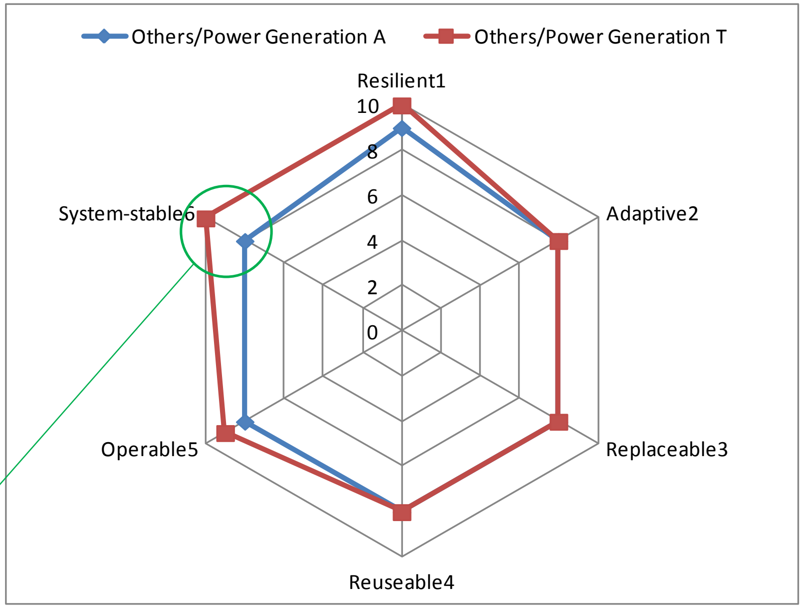
1 (least futureproof)
10 (most futureproof)

Gap = Target – Actual

Primary Settlement Pumps - one of the biggest futureproofing gaps



Others/Power Generation - the smallest futureproofing gap



The biggest futureproofing gap for each asset

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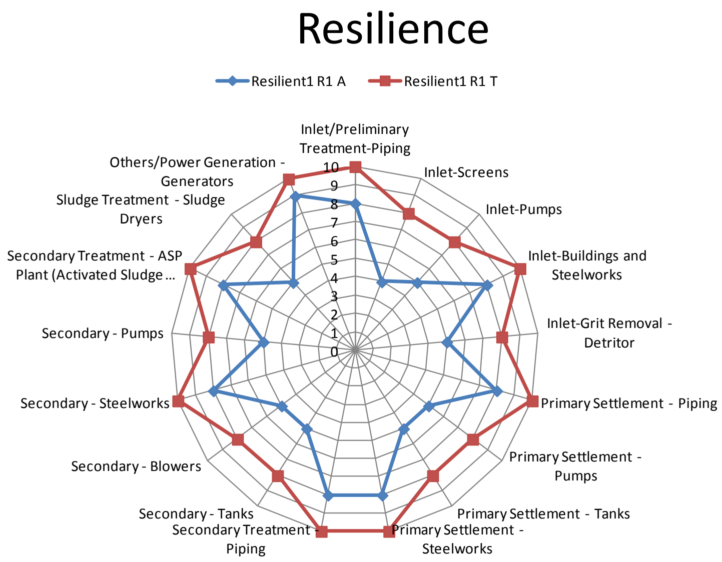
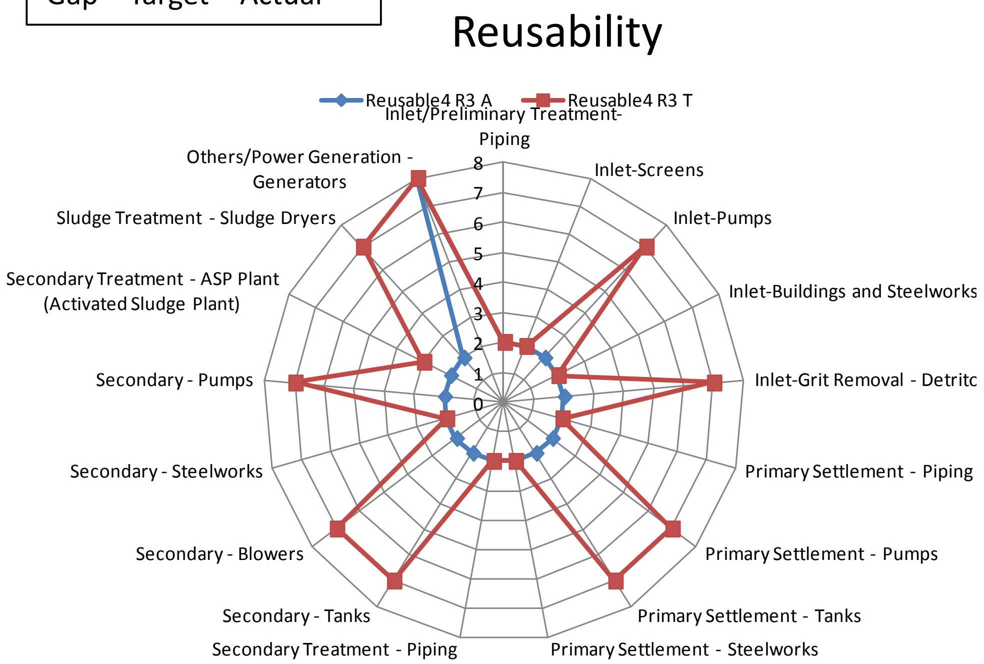
Results – all assets against a specific criterion

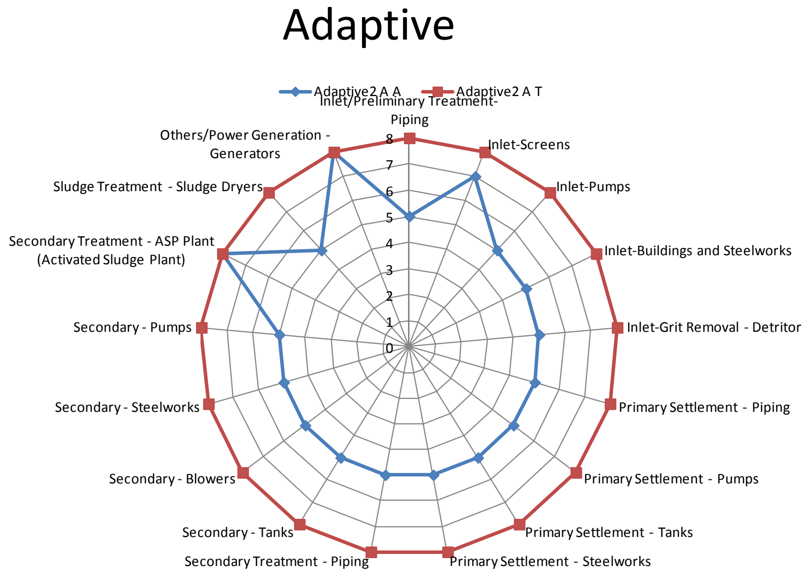
A – Actual (1-10)
T – Target (1-10)

1 (least futureproof)
10 (most futureproof)

Gap = Target – Actual







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Key take aways and Q&A

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Few takeaways for the future

- There is an alignment between the Infrastructure sector and the insurance one to develop further the concept of resilience
  - Development of resilience studies along the environmental studies currently carried out for new projects
- Technology is the way forward to contribute to the resilience and for the management of these assets as:
  - They can be adapted to existing assets
  - This is an effective risk management tool, leading to a substantial reduction of the residual risks, either during the construction or the operation
  - Can optimize the insurance transfer (deductible and price for example) but it should allow then the underwriters to take new risks
- The technology could also assist
  - To improve the risk's robustness to natural catastrophe
  - To give a better assessment of a situation post catastrophe and its management
  - Can also influence the way underwriters are designing their exposure models in nat cat areas

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Few takeaways for the future

- Few challenges
  - Need for regulations or simply guidelines such as « the Risk Management guide for Critical infrastructure sectors » developed by the Canadian government
  - Data complexity
  - Data acquisition and access to data
  - Data ownership:
    - Should the data be the property of the operators or simply associated to the infrastructure with a duty for the operator to ensure adequate maintenance

CSIC mission statement

“Transforming the future of infrastructure and construction, enabling better decision making through smarter information”

CSIC is a multidisciplinary Innovation and Knowledge Centre,
funded by EPSRC and Innovate UK,
translating research into practice in infrastructure and construction

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