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
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
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
Olivier Hautefeuille, Chief Underwriting Officer SCOR Business Solutions Construction and Specialties
Infrastructure: to set the scene!
• 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 disturbances 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**

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### Top 10
- **Transport**: Hong Kong, Singapore, Germany, US, Switzerland, Canada, Austria, Luxembourg, Korea, France.
- **ICT**: Germany, Hong Kong, Luxembourg, Switzerland, Singapore, France, Denmark, UK, Sweden, US.
- **Energy**: Norway, Kuwait, Canada, Finland, Qatar, China, Israel, Malaysia, UK, Australia.
- **Finance**: Hong Kong, Singapore, Jordan, Spain, China, Israel, Malaysia, UK, Australia, US.

### Bottom 10
- **Transport**: Madagascar, Congo, DR, Myanmar, Botswana, Zimbabwe, Haiti, Ghana, Argentina, Pakistan.
- **ICT**: El Salvador, Nepal, Papua N.G., Germany, Botswana, Georgia, Ghana.
- **Energy**: Ecuador, Kazakhstan, Namibia, Cambodia, Bolivia, Venezuela, El Salvador, Guatemala, Tunisia.
- **Finance**: Belgium, Sweden, Sweden, Sweden, Sweden, Sweden, Germany, Germany, Germany, Germany.

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
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

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.
& 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 than 100 metro lines in China these last 10 years.
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!

Rainfall during Harvey:
Average 1 m
Peak: 1.32 m

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

- 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
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/
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.”

The role of technologies in building resilience for New & Existing Infrastructure
The Technologies
CSIC strategic themes

Performance based design  Transforming construction  Managing and operating infrastructure  Smart city systems

The use and development of sensor systems

Data-driven decision making

Demonstrating the value of smart solutions
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

- Shape matching & texture matching (on schedule)
- Shape matching but no texture match (in progress)
- No shape matching (behind schedule)
Managing and operating infrastructure

**OPPORTUNITY**

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

Managing and operating infrastructure

**OPPORTUNITY**

- Condition monitoring and predictive maintenance
- Whole-life, value based asset management
- Risk-based maintenance
- Futureproofing
Smart city systems

OPPORTUNITY

• Demand forecasting for future infrastructure needs
• Optimised network management
Examples in operation and management

Masonry Bridge Case Study
Network Rail is responsible for:
- 28,000 bridges
- 22,000 retaining walls
- 21,000 culverts
- 600 tunnels
- 200 miles of coastal defence

Number of assets built each five years:
- 1500 in 1845
- 1300 in 1900
- 800 in 1960

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

1 Alan Hayward, IABSE Henderson Colloq. 2016.
2 Brian Bell, Engineers Ireland Conf, 2014.
These structures are vulnerable

- 40% of the road and rail bridges in the UK are constructed of masonry.
- 3 instances of partial masonry bridge collapse in the UK, in 2015 & 2016 alone.

“Unplanned unavailability of assets has a huge impact on operations”

Senior Network Rail executive

Tenbury Wells Bridge, Worcester
Barrow upon Soar Bridge, Leicester
Tadcaster Bridge, York

Information from Zoltan et al. (2012)
Photos from BBC Online
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
Investigated arch

Longitudinal crack right under track

Longitudinal crack above filled relieving arch between two tracks

Water damaged bricks, no mortar

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.

Transverse crack

Rocking toe damage?
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 3\textsuperscript{rd} Party Assets: Bank Station Capacity Upgrade & St Mary Abchurch
Measure existing damage and new damage

In the chart there are all the sensors of the south façade. Higher strain is obtained due to preexisting cracks.
Instrumenting new structures for whole life management
Giving an asset a ‘health passport’
Self-sensing infrastructure

Bottom Midspan FBG Sensor

West Elevation

Longitudinal View

Real time recorded strains (West Girder)

Distance along girder

Strain (με)

0
10
20
30
40
50

-10
-20
-30
-40
-50

10
20
30
40
50

0
10
20
30
40
50

0
10
20
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40
50

Self-sensing infrastructure
Self-sensing structures → big data
Donuts from Data…
Manage
Analyse
Interpret
Challenges of Data
Data from a variety of sources
Big Data – what is it?

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

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

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

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

• **Veracity**: The challenges posed by poor data quality
Variety

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

Veracity

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

(Variety in) Velocity

- Sub second
- Minute
- Week
- Month
- Year

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”
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.

1. Available
   - The information is available, and stored somewhere.

2. Accessible
   - The information is stored in a place and can be opened.

3. Retrievable
   - The information is searchable.

4. Reusable
   - Once the information is created, it can be used multiple times.

5. Flexible
   - The information can be used for different purposes beyond its creation purpose.

(Source: SCOR, Cambridge Centre for Smart Infrastructure & Construction)
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
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

1. Identify key infrastructure assets
2. Identify key futureproofing criteria
3. Conduct futureproofing assessments (weighted)
4. Conduct futureproofing calculations
5. Conduct futureproofing gap analysis

- Resilience
- Adaptability
- Reusability
- Replace ability
- Information futureproofing
- System stability
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
Results of futureproofing assessment of LWwTW

<table>
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<th>Asset Classification</th>
<th>Infrastructure Classification Comments</th>
<th>Resilient1</th>
<th>Adaptive2</th>
<th>Replaceable3</th>
<th>Reusable4</th>
<th>Operable5</th>
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A – Actual (1-10)
T – Target (1-10)

1 (least futureproof)
10 (most futureproof)

Gap = Target – Actual

Futureproofing Gap Analysis

1 7.00 7.83
Smallest futureproofing gap

Inlet/Preliminary Treatment - Piping
Inlet-Screens
Inlet-Pumps
Inlet-Buildings and Steelworks
Inlet-Grit Removal - Detritor
Primary Settlement - Piping
Primary Settlement - Pumps
Primary Settlement - Tanks
Primary Settlement - Steelworks
Secondary Treatment - ASP Plant (Activated Sludge Plant)
Secondary - Pumps
Secondary - Steelworks
Secondary - Blowers
Secondary - Tanks
Secondary Treatment - Piping
Sludge Treatment - Sludge Dryers
Others/Power Generation - Generators
Gap = Target – Actual

A – Actual (1-10)
T – Target (1-10)
1 (least futureproof)
10 (most futureproof)

Results - total sum of weighted scores against all criteria

One of the biggest futureproofing gaps
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
Results – all assets against a specific criterion

A – Actual (1-10)
T – Target (1-10)

1 (least futureproof)
10 (most futureproof)

Gap = Target – Actual
Key take aways and Q&A
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
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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