Acuity and Agility in Infrastructure Systems Decision-making

IAS Workshop
20-21 July 2022

Project Team

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- Prof. Marios Chryssanthopoulos: Professor of Structural Systems and Head of the Centre for Infrastructure Systems Engineering (CISE).

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- Dr Emma Hellawell: NERC Embedded Digital Research Fellow.

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Synopsis

The broad goal of the event was to explore the concept of 'data as services' in transport networks for two modes of rail and road. The discussions in the workshop were framed around the current challenges and barriers in 'data to decisions and services' workstreams.

The workshop was delivered in hybrid mode (face to face at Surrey, Guildford and via Zoom) in two half-day sessions, from 2 pm to 5 pm (BST). The event was invitation-only, attended by a cohort of national and international participants, from transport asset owners and managers to leading consulting and contracting organisations and research centres worldwide. The event was attended by thirteen in-person and seventeen online attendees. The summary report below reflects the main themes and discussion points. This workshop builds on lessons learnt from our previous Lloyd's Register Foundation-funded event on the future of transport asset management and delves deeper into investigating the value of data in achieving real-time, predictive and adaptive maintenance and management practices.

Main Theme:

The event's main theme was focused on challenges and barriers associated with using data and deriving value from data and information in delivering asset management decisions. As part of the discussions, the gaps in the chain of data to services and decisions were also explored.

The event was organised into two half-day discussions, with Day 1 focusing on asset-level decisions and Day 2 dedicated to network-level decisions. Each session started with a 20-25mins provocation talk by the keynote speaker to build the context for the session. The content of each talk reflects on personal and professional experiences, thoughts and views on general trends in research and industry and recent projects. The recording of these talks will be made available online on the workshop website.

The provocation talks were then followed by two 1hr group discussions and 15mins plenary reflection.

Day 1 – Asset-level decision making:
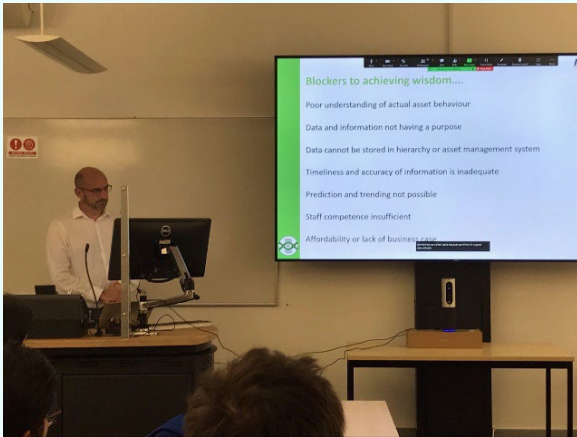
David Castlo CEng FICE MIAM: For the past ten years, David has held senior roles in Network Rail leading improvements in structures asset management and data systems. He is currently Network Technical Head; accountable for the standards, policies, competence, systems and R&D for the national tunnels portfolio. He also coordinates decarbonisation activity across Network Rail's engineering disciplines and is the company's primary contact with the Institution of Civil Engineers for graduate development.

Day 1 provocation talk was delivered by David Castlo, Network Technical Head at Network Rail, focusing on challenges around asset-level decision-making. This talk set the scene and tone for asset-level decision-making, highlighting challenges associated with delivering data and information-driven decisions. In this talk, David provided perspective on key decision-making criteria for Network Rail and how asset availability, safety and reliability are balanced considering the funding available. David highlighted the importance of collecting data that 'adds value to the end-user' and offers 'rich and actionable information and wisdom'.
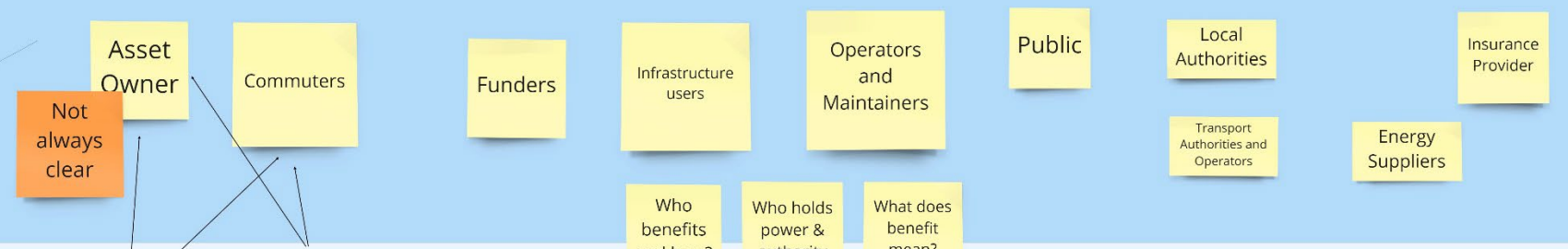
Key themes emerging from the provocation talk and following discussions are:

- *Whilst there is a growing volume and variety of data, data is often collected without clear purpose and offers limited actionable information.*
- *Data collection for the sake of collection should be avoided. Data should be collected if it provides insightful wisdom to improve decision-asking and contributes to managing safety risks and refining interventions or creating opportunities for efficiency in current practice.*
- *The main barriers in driving value from data to delivering decisions are highlighted as:*
  - *poor understanding of actual asset behaviour and inadequate timeliness and accuracy*
  - *poor predictive modelling and trend formulation*
  - *lack of understanding of the relevance and significance of the various data sets and how to model these in such a way to reflect real network performance and, ultimately the wisdom offered in the form of identifying intervention(s) that might achieve a desired effect or outcome*
  - *sparse and insufficient decision analysis to determine which technology to apply to monitor which behaviour and failure mode*
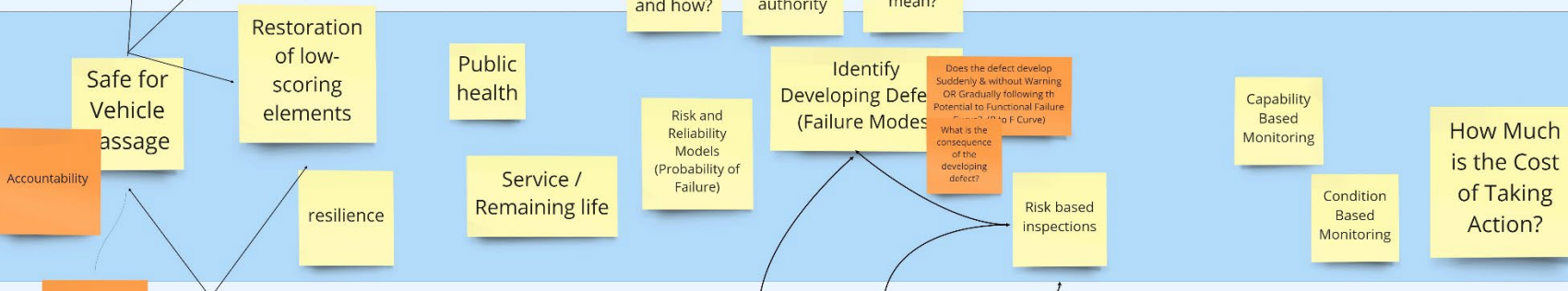
To capture the discussions on Day 1 and engage both in-person and online attendees, a 'data to decision' workstream template was used. A copy of the populated template is provided below.
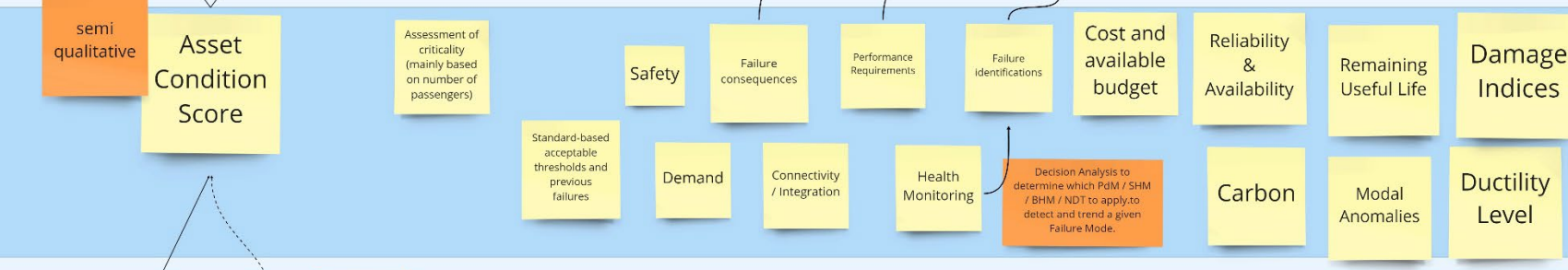
Decision Beneficiaries
direct and indirect stakeholders and end-user

- Asset Owner
- Not always clear
- Commuters
- Funders
- Infrastructure users
- Operators and Maintainers
- Public
- Local Authorities
- Insurance Provider
- Transport Authorities and Operators
- Energy Suppliers
- Who benefits and how?
- Who holds power & authority
- What does benefit mean?

Decision Question
covering any action concerning the asset

- Safe for Vehicle Passage
- Restoration of low-scoring elements
- Public health
- Accountability
- resilience
- Service / Remaining life
- Risk and Reliability Models (Probability of Failure)
- Identify Developing Defe... (Failure Modes)
- Does the defect develop Suddenly & without Warning OR Gradually following th Potential to Functional Failure (.... "P" to F Curve)
- What is the consequence of the developing defect?
- Risk based inspections
- Capability Based Monitoring
- Condition Based Monitoring
- How Much is the Cost of Taking Action?
- Replace track? Adjust geometry of track?

Decision Indictors
proxies, thresholds, scores used to take actions

- semi qualitative
- Asset Condition Score
- Assessment of criticality (mainly based on number of passengers)
- Safety
- Failure consequences
- Performance Requirements
- Failure identifications
- Cost and available budget
- Reliability & Availability
- Remaining Useful Life
- Damage Indices
- Asset life, frequency of trains
- Cascade of track to capitalise on
- Adaptability to aggressive ground environments
- Standard-based acceptable thresholds and previous failures
- Demand
- Connectivity / Integration
- Health Monitoring
- Decision Analysis to determine which PdM / SHM / BHM / NDT to apply.to detect and trend a given Failure Mode.
- Carbon
- Modal Anomalies
- Ductility Level
- Climate resilience

Processes
any form of analysis, calculation, modeling, reporting
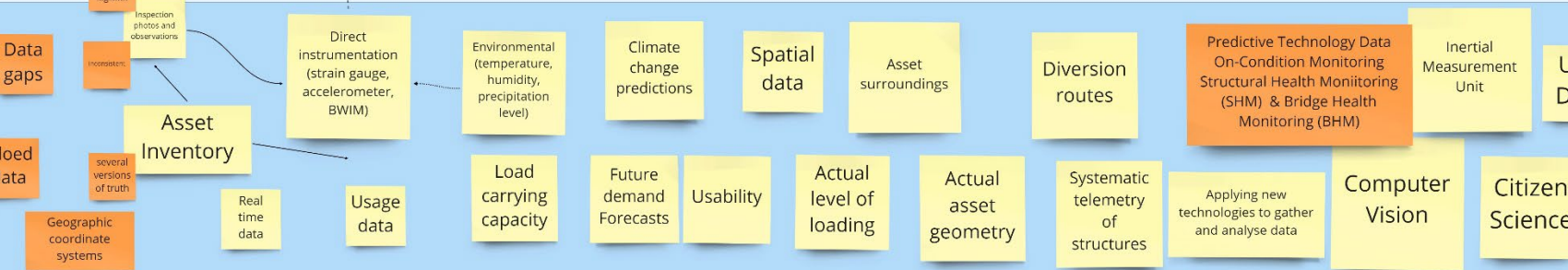
- Data gaps
- Visual Inspection reports
- Category II & III numerical models
- often not calibrated
- Labour intensive
- Identification of structural typology
- Associated Utilities
- Decision Analysis to determine which PdM / SHM / BHM / NDT to apply.to detect and trend a given Failure Mode.
- Reliability Centered Maintenance (RCM)
- Carbon calculator
- Cost benefit analysis
- Climate/weather modelling, e.g. floods, erosion
- Digital twin
- Non-destructive monitoring
- Historical reports
- Asset Criticality Analysis
- Time-dependent risk
- Code-calibration to squeeze more out of our assets
- Whole-life value analysis
- Total Cost of Ownership (TCO) AKA - TOTEX
- Utility Maximization / Loss Minimization
- Data Fusion
- Multi-Criteria Decision-Making
- RACI Responsible Accountable Communicate Inform

Data
visual, written, sensory

- Access issue and logistics
- Inspection photos and observations
- Data gaps
- Direct instrumentation (strain gauge, accelerometer, BWIM)
- Environmental (temperature, humidity, precipitation level)
- Climate change predictions
- Spatial data
- Asset surroundings
- Diversion routes
- Predictive Technology Data On-Condition Monitoring Structural Health Monitoring (SHM) & Bridge Health Monitoring (BHM)
- Inertial Measurement Unit
- UAV Data
- what data for track: per branch line; NMT data
- what data for track: per branch line; NMT data
- Siloed data
- several versions of truth
- Asset Inventory
- Real time data
- Usage data
- Load carrying capacity
- Future demand Forecasts
- Usability
- Actual level of loading
- Actual asset geometry
- Systematic telemetry of structures
- Applying new technologies to gather and analyse data
- Computer Vision
- Citizen Science
- Geographic coordinate systems
- Having data that is 60-70% accurate is probably sufficient

Day 2 – Network-level decision making:

Professor John Beckford PhD MMS FCybS FRSA FIET : John is a partner in Beckford Consulting, Visiting Professor in the Department of Civil, Environmental and Geomatic Engineering at University College London and in the Centre for Information Management at Loughborough University. John is President of the Cybernetics Society and a Board Member of both the World Organisation for Systems and Cybernetics (WOSC) and of the European Union for Systemics (EUS). Through Beckford Consulting, John has been applying his knowledge of stakeholder engaged, information led adaptive organisation design, learning and transformation for over thirty years.

Day 2 of the event was focused on network-level decision-making and started with a provocation talk by Prof. John Beckford, Beckford Consulting. In this talk, John highlighted the importance of striving to achieve a model that leans to 'be more right over time', rather than 'a model that is right at the outset'. This talk provided insights on characteristics of a network-level decision support system which was defined as 'a model of the decisions that it supports', 'a model that is informationally and structurally equivalent with a clear understanding of what is it for and what is it worth'. One of the key messages of the talk was the paradigm shift in moving toward being 'less wrong, more useful but starting with an appreciation of the rationale for the model, the purpose to be fulfilled driven by understanding'.

There were considerable synergies between challenges identified in asset-level and network-level decisions in both Days 1 and 2: as is the case with the asset-level data and decisions, it was highlighted that the diversity and volume of data within the workstream lead to high cost of storage, analysis and information generation. Network-level decisions also are affected by the quality and accuracy of data, lack of reliable understanding of network behaviour and the time lag between changes in the asset and their manifestation data, analysis and decisions.
Some of the highlighted challenges and opportunities emerging from the provocation talks and discussion points include:

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- *lack of stakeholder analysis to account for end-user perspective and balancing & identifying the common interests among disciplines & priorities*
- *lack of real-time data on asset conditions leads to a lack of confidence in analysis methods and simulations. Understanding the relevance and significance of the various data sets and understanding how to model them in such a way to reflect real networks is paramount.*
- *it is not enough to have a model; we should aim to have a model sufficiently quickly to respond to the problems that change with time. The real timeliness needs to correspond to the nature of the problem and the decision being made. Resolution and granularity should also be balanced between possible and desirable.*
- *one of the key shortcomings in network-level decision-making is the lack of consideration of dependencies between assets of a single network (or part thereof), as well as the interdependencies between asset classes inter-dependency-based relationships between different networks. Some of the pathways for generating and collecting such data are identified as:*
    - *building connectivity metrics*
    - *application of learnings from one project-asset-authority to another via Root Cause Analysis*
    - *capitalising on data generated from the accessibility of emergency services*
    - *utilising common strategic priorities - net zero, congestion reduction, safety, resilience*
    - *public policy, regulatory information and specification document*
    - *sentiment analysis and involvement of users*
    - *development of 'reasoning models' for comparison with the experience*
    - *exploiting the value offered by data generated via telemetry systems and crowdsourcing*

Next Steps

The event has led to establishing and consolidation of a network of research, policy and practice stakeholders which will form part of the core Collaboratorium group for future knowledge exchange and research projects. The recording of the provocation talks will be made available online on the workshop website.
The output of the discussions, in particular the conceptual framework focusing on knowledge and practice gaps for achieving value in "data for services", will also be formulated in the form of a technical publication for a civil engineering journal.

Feedback

The event was valued by speakers and attendees and has offered opportunities for further collaborative discussions and research projects – please find below a sample of the feedback received:

"This was a very interesting session. I am still trying to get my head around what the appropriate autonomy for each level would look like in a big infrastructure organisation. It would be a fascinating thing to map out for a real organisation."

"It is very interesting to hear what industrial colleagues think about the recent developments in data-driven decision-making. Academic research tends to come up with fashionable frameworks and industry brings those back to a realistic norm, which is always good to remind ourselves."

"Thank you for a fascinating Session. It's interesting to hear everyone's perspective and SME coming thru."

"Thank you for such interesting discussion!"

Acknowledgement