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Disused coal tips – a digital twin solution and paradigm shift in addressing risk

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A close up

Storm Dennis Rhondda Valleys, 2020

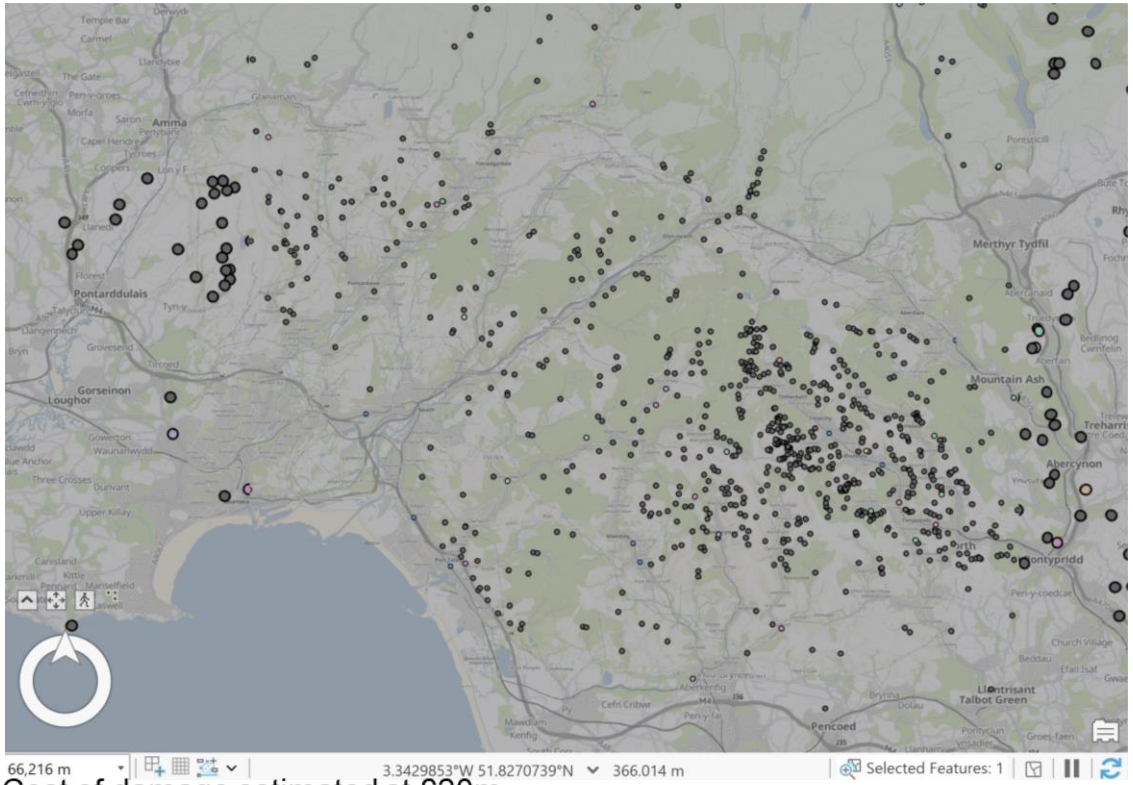
Skewen flood

RCT County Borough Council, Jack Brown

A small failure in a coal waste tip in South Wales. (Clear South Wales's Coal Tips).

A close up

2,456 disused coal tips have been identified with approximately 85% located in the South Wales valleys



Cost of damage estimated at £20m

20,000 non-coal tips in Wales
500.000 people in Wales live and work and £1b of property in the vicinity potentially at risk

The ownership is complex 50% of disused coal tips have more than one owner, sit across more than one local authority

The WG estimated that the cost of mitigating is at least £500m over the next 15y

327 of disused coal tips are characterised as moderate to high risk C or D rating by Coal authority 9Cal authority, 2020)

Category	Criteria
D	Potential to cause risk to life or property known history of movement/signs of instability
C	Potential to cause risk to life or property no known history of movement/instability signs
B	Unlikely to cause risk to life / property
A	Minor tip or tip has been reclaimed / restored
R	Historic tip location – now removed or levelled and often built over

Coal authorities, interim categories

There is no estimation of the probability of failure of some of these coal tips and there many complex failure mechanisms involved

Close up

- Spatially distributed
- Interact / Interrupt other critical systems
- Controlled by different entities

- Cost to maintain and perform inspections is high

- Extremely high cost £600m to mitigate the current system

- What if include climate change

- No standards in terms of the maintenance, receptor, plan etc

Uncertainties

Hazards	Performance	Consequence	Planning	Scenario
Limited hydrological data	Unknown conditions of drainage systems		Effectiveness of evacuation routes	Assumptions in models
No detailed hydraulic or hydrological study	No stability analysis	Public awareness and public behaviour		
Highly heterogeneous material weathering-properties have changed	Drainage interventions			

- Uncertainty of the systems, in the characterising and, understanding of hazards
- Consequences impact our perception of risk the pore water pressure,
  the loading conditions

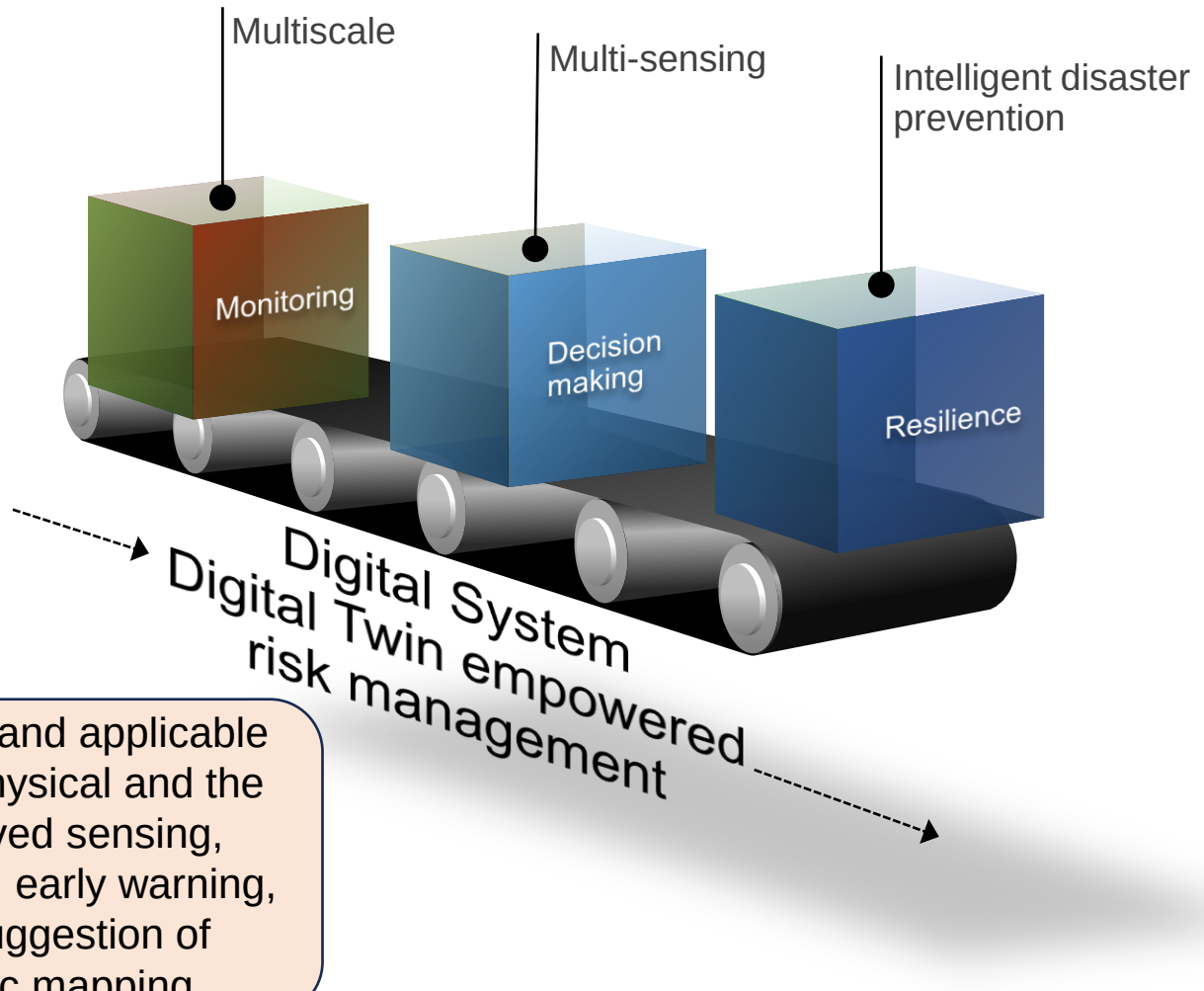
We need to reduce uncertainties!

Need to systematically characterise the surface and subsurface conditions in 4D in time changing systems

Digital Twin empowered risk management system for disused Coal Tips

Challenges

extreme rainfall, storm, a marginal status of stability, vulnerable to reactivation under a climate change regime



Aim

Assist authorities, improve risk assessment, planning, response.

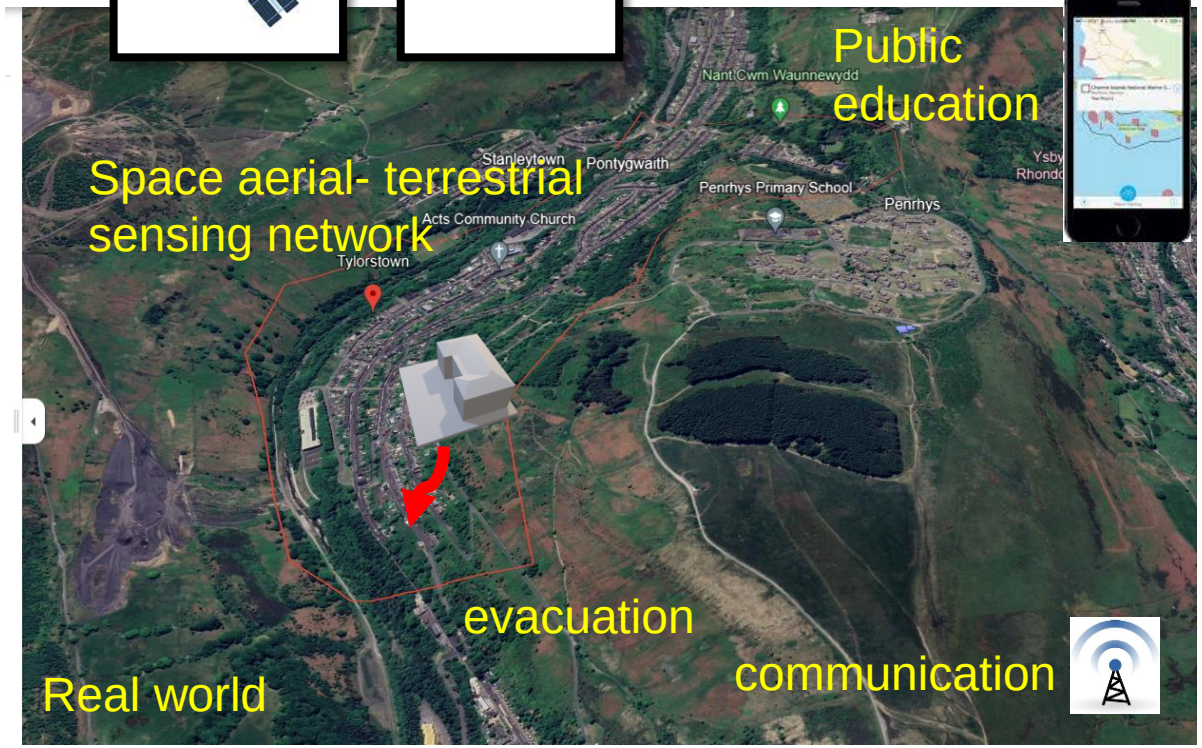
Expected outcomes

Address aspects of hazards including monitoring, forecasting, precursor detection, risk management and decision-making prioritisation.

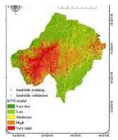
Methodology

Easily implementable and applicable tool connecting the physical and the digital asset. Improved sensing, continuous monitoring, early warning, data integration, suggestion of workflows, dynamic mapping.

Digital Twin Empowered Risk Management



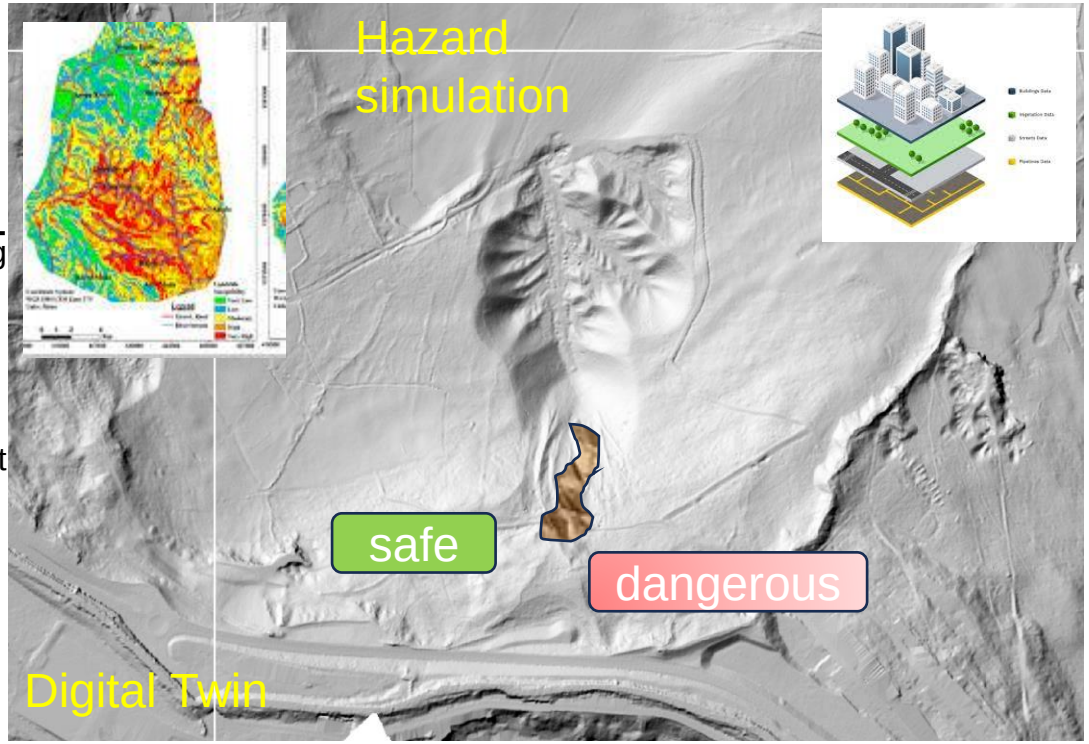
sensing



modelling

Risk assessment

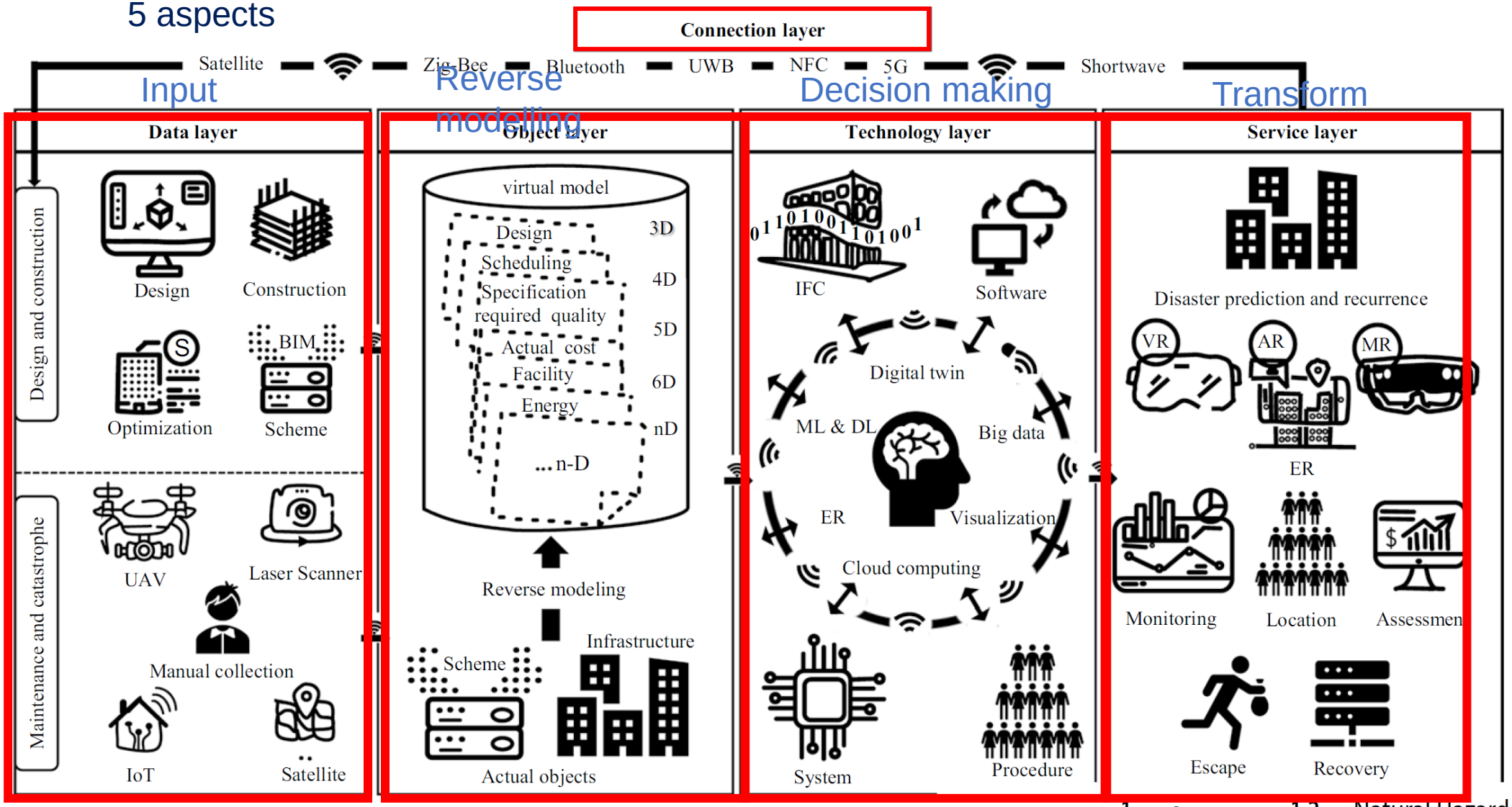
Evacuation



Leverage the technology

Development of a framework of DT-IDPMI

5 aspects



Dianyou Yu[1] · Zheng He[1,2] Natural Hazards (2022) 112:1–36

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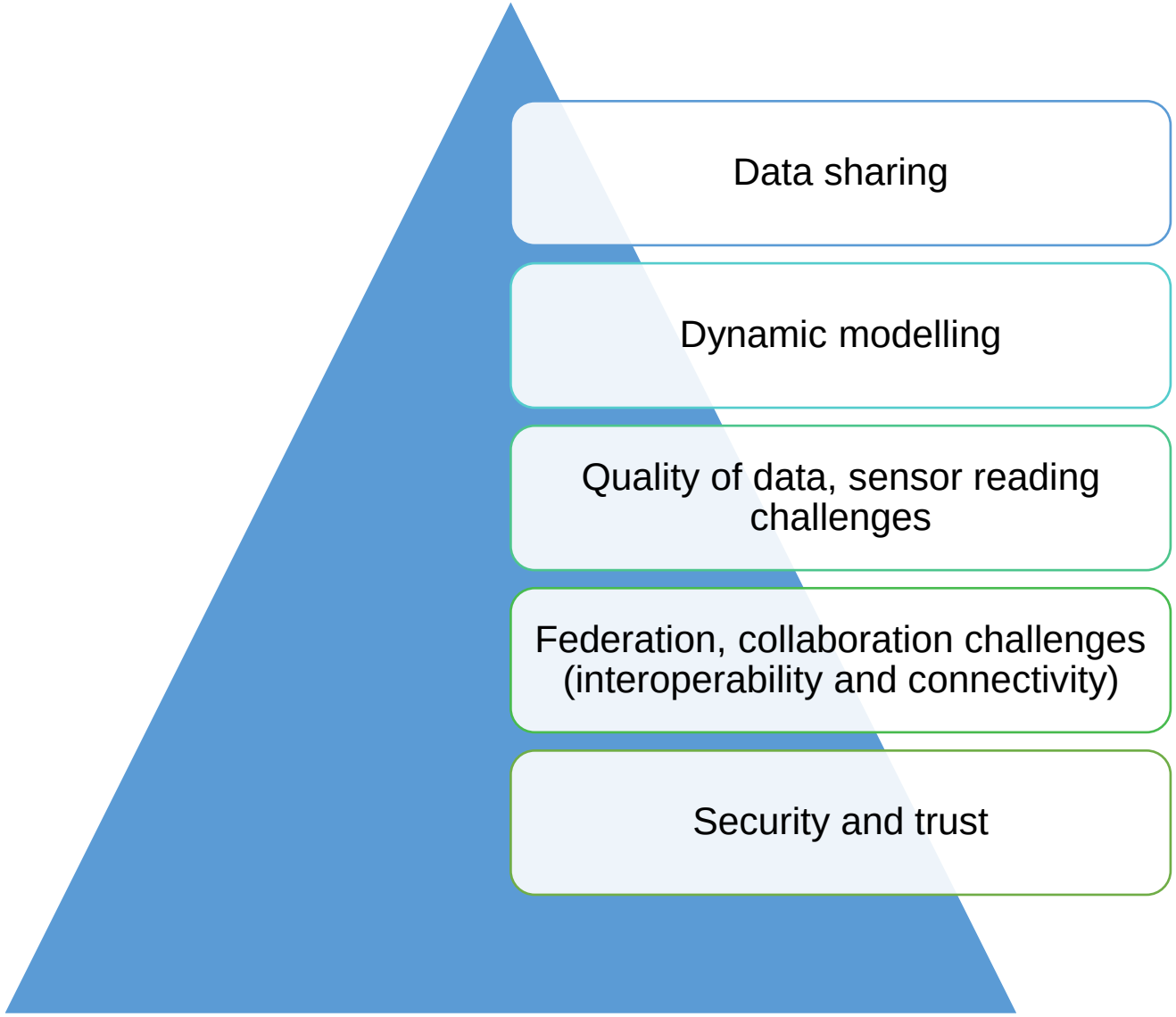
Objectives of DT- enabled management system

- Develop a proof of concept
- Share data, experience and methodology
- Create a cybersecurity asset dataflow system (platform or dashboard)
- DT for disaster prevention
- Enable collaboration between different sectors

Challenges of DT- enabled management system



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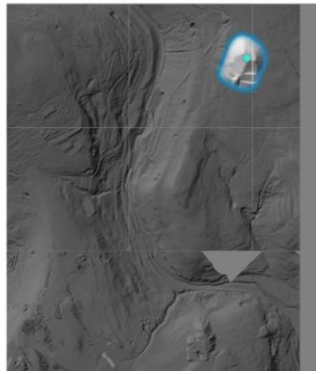
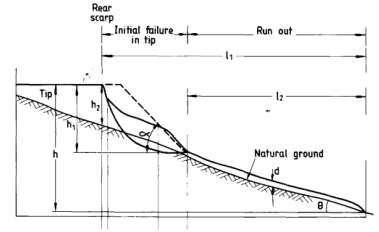
Benefits of DT- enabled management system

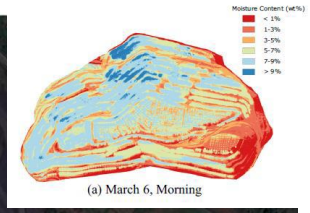
- Enhance the disaster resilience of existing slope systems
- Foreseeing and proactively solving future problems
- Risk assessment, emergency management,
- Novel risk analysis framework, automation, monitor the change
- Monitor surface conditions and social activities
- Increase the resilience of assets
- Improve communication, response time, escape route planning,
- Reduce damage, risk to affected community and infrastructure

Leverage technology





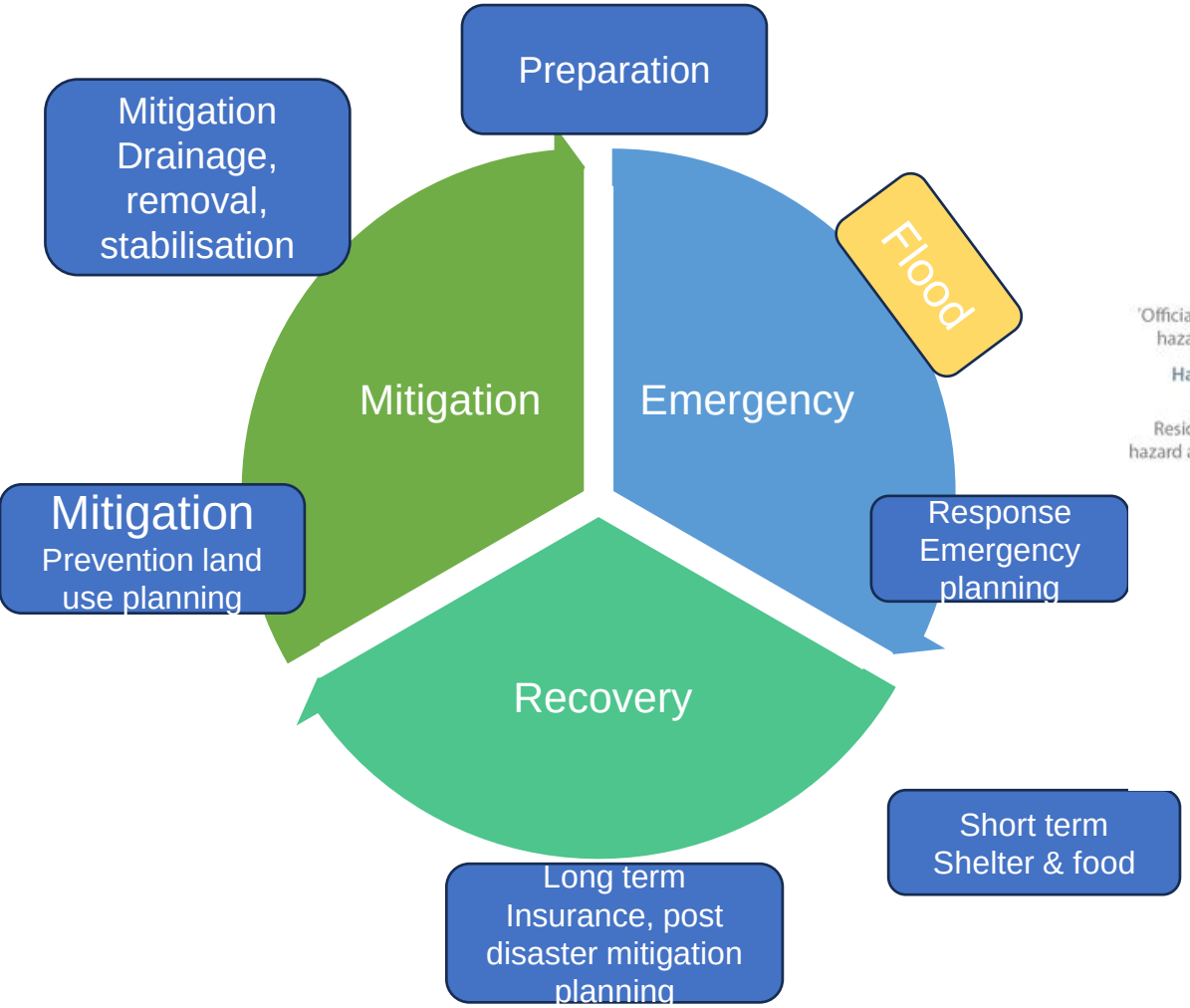
Bentley, S.P. and H.J. Siddle, 1996



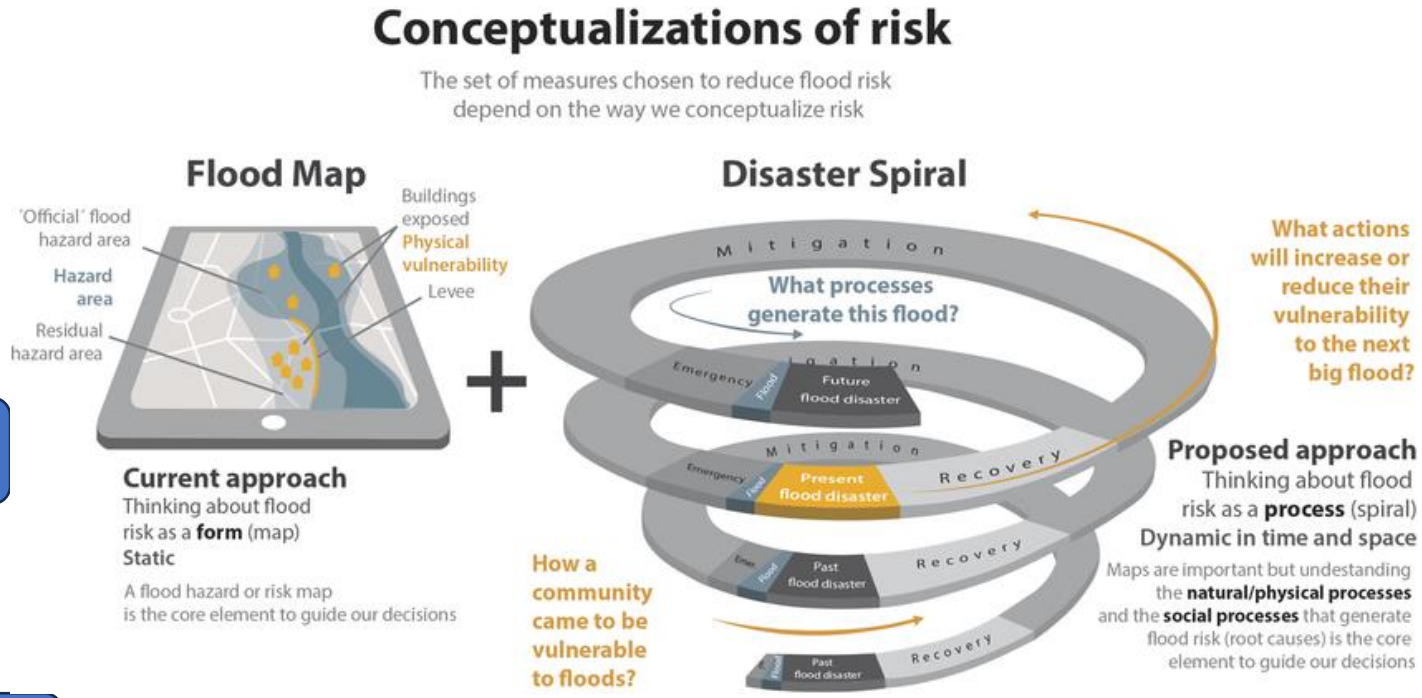
Tang and Esmaeili, 2021

Addressing risk

Risk as a form - current approach



Risk as a process – proposed approach



Anna Serra-Llobet et al. 2023