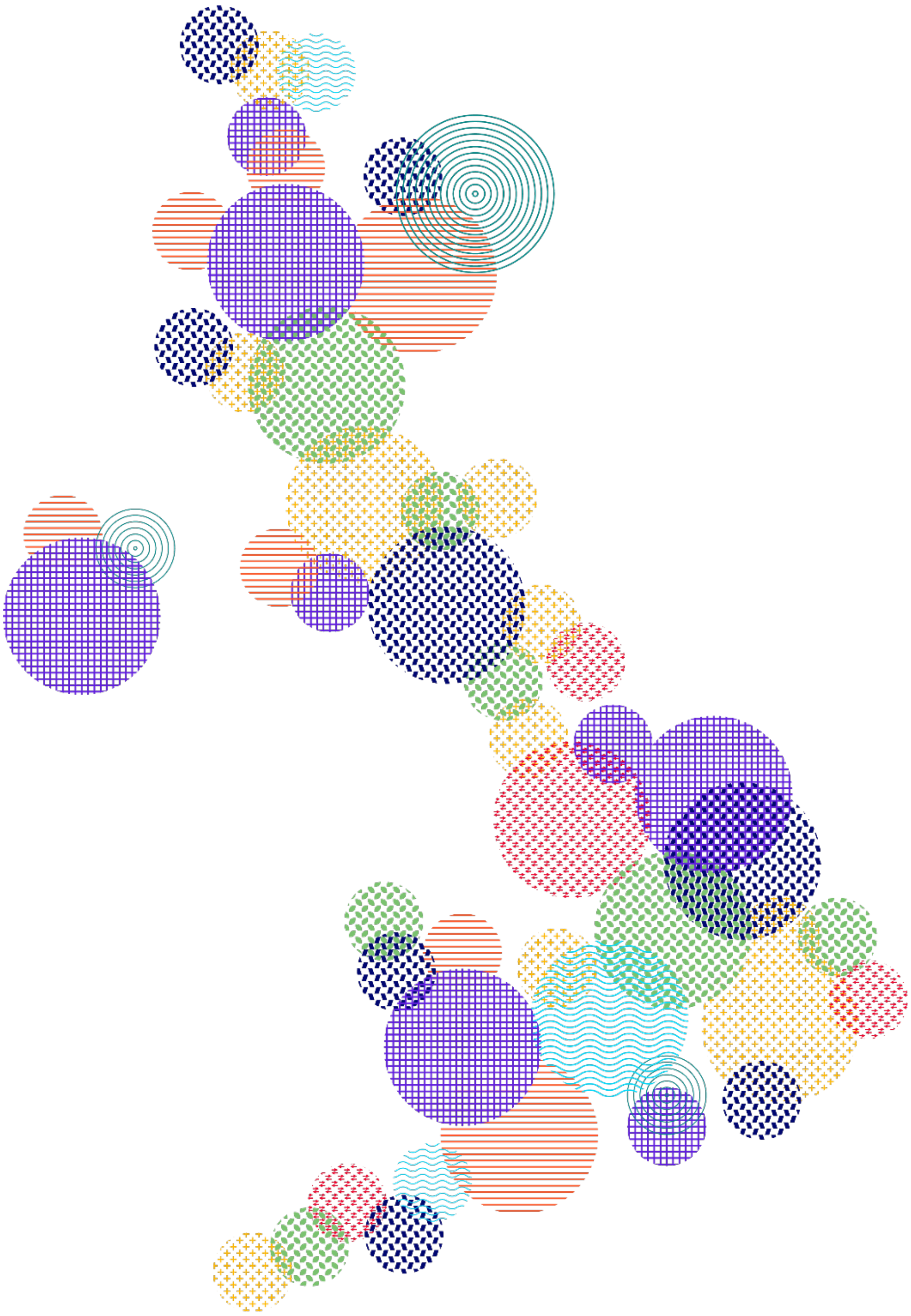
NATIONAL DIGITAL TWIN PROGRAMME

CReDo
Climate Resilience Demonstrator

Credo: an overview

Executive summary

March 2022



Executive summary

Project vision and objectives

The National Digital Twin's Climate Resilience Demonstrator (CReDo) is the UK's first climate adaptation digital twin that adopts a novel approach to resilience planning at a systems level, building on the principles of connected digital twins across organisations and sectors. CReDo uses asset information from different infrastructure sectors, as well as climate data, to show how connected digital twins at the systems level can support better long term resilience planning. The use case involves three infrastructure asset owner organisations from the water, power and telecommunication sectors sharing data in a common data environment with the aim to understand the cascading failures across the system under a range of flooding scenarios. This helps to understand asset criticality beyond the boundary of individual sector-level networks and shows the most vulnerable points in the system, which require priority interventions to maintain existing levels of service in the face of climate change. The purpose has been to demonstrate how an Information Management Framework approach to connecting datasets and digital twins can enable connections between digital twins to scale and how connected digital twins can help to tackle climate change. Starting with a specific use case demonstrates how the National Digital Twin can be developed into an ecosystem of connected digital twins, on a case-by-case basis.

Approach and outputs from the first phase of CReDo

Building on the principles of the National Digital Twin programme's Information Management Framework, asset data from multiple organisations has been integrated within one system model and equipped with a visual interface. This has allowed for a clear representation of the connectivity between assets and an analysis of the resulting interdependencies between sectors as shown in Figure 1.

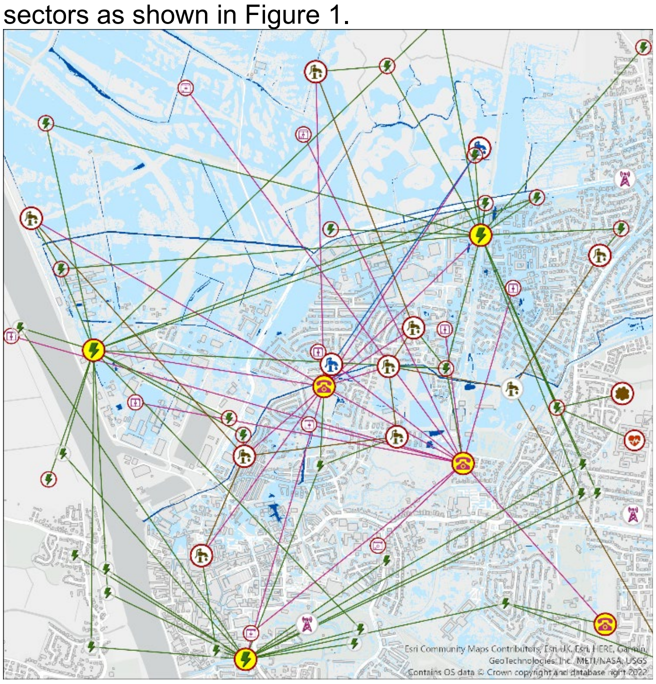


Figure 1 Data about assets is brought together with a flooding scenario (Note this diagram shows synthetic asset data)

Additional flood hazard information was processed, integrated and interrogated within the system model to represent the extent and depth of flooding across the studied area under various future flooding scenarios. This climatic data was used alongside asset information to investigate direct failures resulting from local flooding conditions, and to test the ability of the system to cope under a range of future flood scenarios. In order to build a picture of the wider system impacts, two processes were run in parallel;

- First, information about assets was gathered along with information concerning the likelihood of failure in various flooding scenarios. This was conducted using expert elicitation techniques and Bayesian modelling, assessing the probability of failure of a given asset as a result of local flooding conditions.
- Second, operational research techniques have been employed to better understand the infrastructure interdependencies and to propagate failures resulting from flood conditions across single networks, and further across the entire infrastructure system.

Learnings and recommendations for future work

While the work in this first phase of CReDo allows for the visualisation of system impacts resulting from direct and cascading failures across the networks, it is based on a contained part of a wider system. Further system complexities and increased granularity at the asset level should be further explored to obtain a richer picture of single asset failures and how these propagate across the wider system considering actual operating conditions. This involves the consideration of existing asset redundancies (e.g. dual power supply in a pumping station) and other resilience measures (e.g. water storage, back-up generation capacity) that would prevent the failure of an asset. Future iterations of CReDo would also benefit from the development of dynamic models as opposed to the current static modelling. This would allow for a representation of asset and system failure and recovery over time, as the flood event propagates and while mitigation measures are put in place over time. More comprehensive modelling would provide a more accurate picture of vulnerabilities and impacts at the system level and would help to prioritise more targeted investment decisions for building resilience.
Understanding the impact of climate change hazards that cause flooding requires a predictive estimation of extreme weather changes as well as modelling the impact of those changes on the total magnitude of flooding. In this first phase of CReDo, this was achieved by adding a climate change allowance to uplift the selected pluvial and fluvial flooding extremes. The UKCP18 local projections for the high carbon emission scenario were used, and this enabled an understanding of changes in the intensity of convective storms. The probabilistic projections of extremes, based on UK Climate Projections (UKCP), also examined the full range of uncertainty in emissions and climate models. Although, in this first phase of development, the impact of climate change on a single extreme flood event has been used to demonstrate the asset failure risk, the long-term objective of CReDo is to expand the hazard information to include a greater number of events and additional hazards (e.g. heat waves) and test the ability of the system to cope under a range of future climate conditions. In addition, future modelling could consider how multiple hazards, such as high winds and lightning alongside flooding and heat, could lead to further cascading failures and could examine different types of failure mechanisms.
It is important for future phases of CReDo to consider how the lessons learnt from this initial phase can be scaled up to bigger and more complex infrastructure systems. The methods used in the first phase should evolve to allow for greater scaling, repeatability and consistency across wider networks of assets. Whilst a level of reproducibility and automation is necessary, future modelling at the systems level should consider how the necessary detail at the asset level (e.g. asset performance characteristics) affect asset failure, and in turn cascading failures. Furthermore, criticality, vulnerability and resilience metrics need to be defined and quantified at the asset and system level. Future phases of CReDo could consider integrating asset information from the transportation sector since site accessibility for all water, power and

telecommunication parts of the system was found to be critical to how quickly recovery procedures could begin during a flooding incident.

Data quality is another area of improvement for future work phases. Improving quality will require systematic and robust data cleansing processes to accelerate data formatting, structuring and suitability for modelling. The Information Management Framework principles allow for single digital twins and datasets to be connected in a scalable way. The design of the data model in the current CReDo digital twin should evolve towards full compatibility with the Information Management Framework to enhance its interoperability, repeatability and scalability. Furthermore, integrating the connected digital twin with asset owner data IT systems would allow for futureproofing technology applicability, ensuring that the most up to date data is fed into the digital twin, whilst retaining the ability for asset owners to control the data they share.

Due to time constraints, the IMF team were able to work only with Anglian Water to identify patterns in the data to improve the quality of select datasets by cleaning data, enriching and refactoring the semantics in order to raise the level of interoperability in the future. Continuation and expansion of this approach will facilitate data sharing at scale.

The Benefits report includes an illustrative quantification of the potential benefits of CReDo. The Frontier Economics team found that the benefits from CReDo looking at the impact of future surface water flooding scenarios could range from £6m to £13m across East Anglia and from £81m to £186m across the UK over the period to 2050 (in constant prices from 2022-2050). The analysis used synthetic data and does not cover the benefits of other use cases such as extreme heat. Limitations from using synthetic data rather than real data mean that at this stage, it has not been possible to provide robust estimates of the potential benefits that CReDo can generate. The methodology underpinning the results can be adapted and refined to form the basis of a more detailed evaluation of a future version of CReDo. A refined version of this cost-benefit analysis methodology could be integrated in CReDo and would help the users of CReDo to understand the costs and benefits of different strategies to increase resilience of the infrastructure networks. An indicative public return on investment of 23:1 implies that connected digital twins like CReDo help to address a coordination problem. While the benefits accrue across multiple parties, individual actors may lack the incentive to invest alone in systems-based solutions such as CReDo. Therefore, work is required to demonstrate the benefits and to kickstart the coordination of effort to achieve those benefits.

Conclusion

The ambition of CReDo is to allow for better and more cost-effective climate resilience planning for infrastructure assets at the systems level using a connected digital twin approach. Providing a systems level approach to understanding asset vulnerabilities, criticality and service failure when exposed to climatic hazards is a powerful tool that allows different asset owner organisations to plan for resilience in a more dynamic way. Collaboration across sectors is essential to a systems level approach. Translating this data into a visual picture of the system as illustrated in Figure 2 also aids understanding of the system level view. This enables asset owners to better communicate their respective investment plans to regulators, funders and other stakeholders involved in resilience planning transparently. Future work on CReDo should build on the current digital twin demonstrator outputs to provide more dynamic modelling of the system vulnerabilities, facilitate important data sharing and expand to include more climate hazards and other cascading failures, as well as explore how different climate adaptation interventions could be tested and supported by built-in cost-benefit analyses.

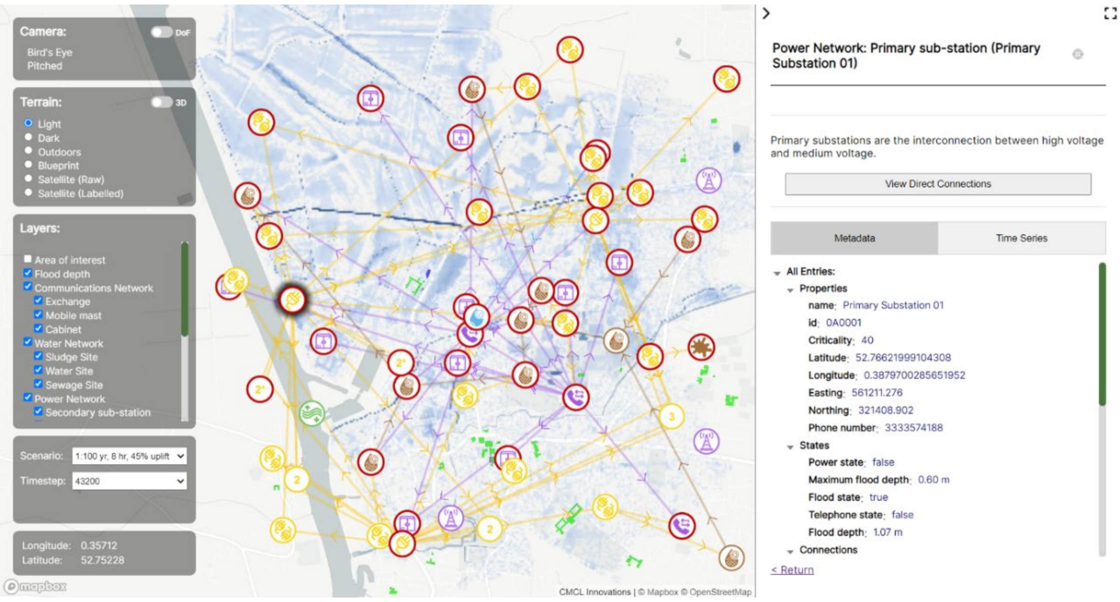


Figure 2 CReDo visual dashboard

For the complete CReDo: an overview report please visit the [Digital Twin Hub](#).

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