Co-sponsored by

ICG Infrastructure Client Group

National Infrastructure & Service Transformation Authority

The Green Construction Board

Delivered by

Built Environment Connective



CReDO

This is one of 15 case studies informing the Infrastructure Systems Review.

System: Cross-sector infrastructure resilience.

Systems contribution and value: Shared data and cascade-risk modelling improved visibility of interdependencies and supported early resilience planning. Modelled potential benefits include better-targeted investment, reduced losses and improved continuity of critical services.

Authors
Tom Burgoyne
Alanna Gluck

Contributors
Tim Chapman
Bruce Elliot
Vic Hurst
Matt Lambert

Summary

Climate change is increasing the frequency and severity of extreme weather events, exposing the interdependent nature of UK infrastructure systems, including energy, water and telecommunications. Historically, these systems have been planned and operated in silos, limiting visibility of cascading risks. This has led to reactive interventions, inefficient investment, and avoidable economic and societal costs.

This case study demonstrates how applying systems approaches across interconnected infrastructure can improve resilience outcomes per pound by targeting investment and operations at critical interdependencies between systems. Rather than optimising assets in isolation, systems approaches enable coordinated decision-making that focuses on whole-system performance.

CReDO (Climate Resilience Decision Optimiser) is a cross-sector digital twin and decision-support platform that enables infrastructure operators to understand how risks and failures can propagate across connected systems. By combining cross-sector modelling of interdependencies, secure data sharing, and scenario-based analysis, it enables infrastructure operators to identify system-critical vulnerabilities, prioritise high-impact interventions, and coordinate actions across organisations. Evidence from its application indicates significant potential value by enabling reductions in cascade failures, more effective targeting of investment, and improved service continuity.

The case study also highlights that realising this value depends not only on technical capability, but on changes to governance, incentives and data sharing arrangements. It demonstrates a pathway from innovation to implementation, showing that the primary constraint on infrastructure resilience is not the scale of investment, but how effectively it is targeted across interconnected systems.

Scope

The CReDO Beta project is a live initiative funded through Ofgem's Strategic Innovation Fund and led by UK Power Networks, focused on improving the climate resilience of the UK's critical infrastructure at a system-of-systems level. It builds on the earlier CReDO demonstrator and has evolved into CReDO+, a scalable decision-support capability for cross-sector planning and operational coordination.

The system of interest is national in scale, spanning interconnected electricity, water, telecommunications and gas networks. It includes physical infrastructure assets and their interdependencies, the operational coordination between infrastructure operators, and the supporting data ecosystem (which is treated as a system in its own right) comprising the data, models and governance arrangements used to understand and manage climate risk.

Climate hazards in scope include flooding, extreme heat and high wind events. Broader regulatory reform and full national deployment are outside scope, though relevant to future scaling.

CReDO applies systems approaches through the development of interdependency models, probabilistic risk analysis, and simulation of cascading failures across sectors. It integrates climate projections, infrastructure topology, and interdependencies with economic and service impact data to support coordinated decision-making.

Key stakeholders include infrastructure operators, regulators (including Ofgem, Ofwat and Ofcom), government departments (Environment, Food and Rural Affairs; Energy Security and Net Zero; Science, Innovation and Technology; Cabinet Office), and delivery and research partners.

At the outset, resilience planning was constrained by limited visibility of interdependencies, weak incentives, and siloed investment decisions, necessitating a systems-based approach to improve whole-system outcomes.

Outcomes

The CReDO platform will enable improved infrastructure resilience outcomes in real-world terms, including reliable provision of essential services, coordinated investment ahead of extreme events, protection of vulnerable users, more efficient use of capital, and reduced long-term economic and societal risk. These outcomes align with national priorities for resilience, productivity and climate adaptation.

Baseline (pre-CReDO outcomes)
Under conventional, siloed approaches, infrastructure operators planned and invested independently within sector boundaries, focusing on asset-level risks rather than system-wide performance. Interdependencies were not systematically identified, and cascading failures were poorly understood.

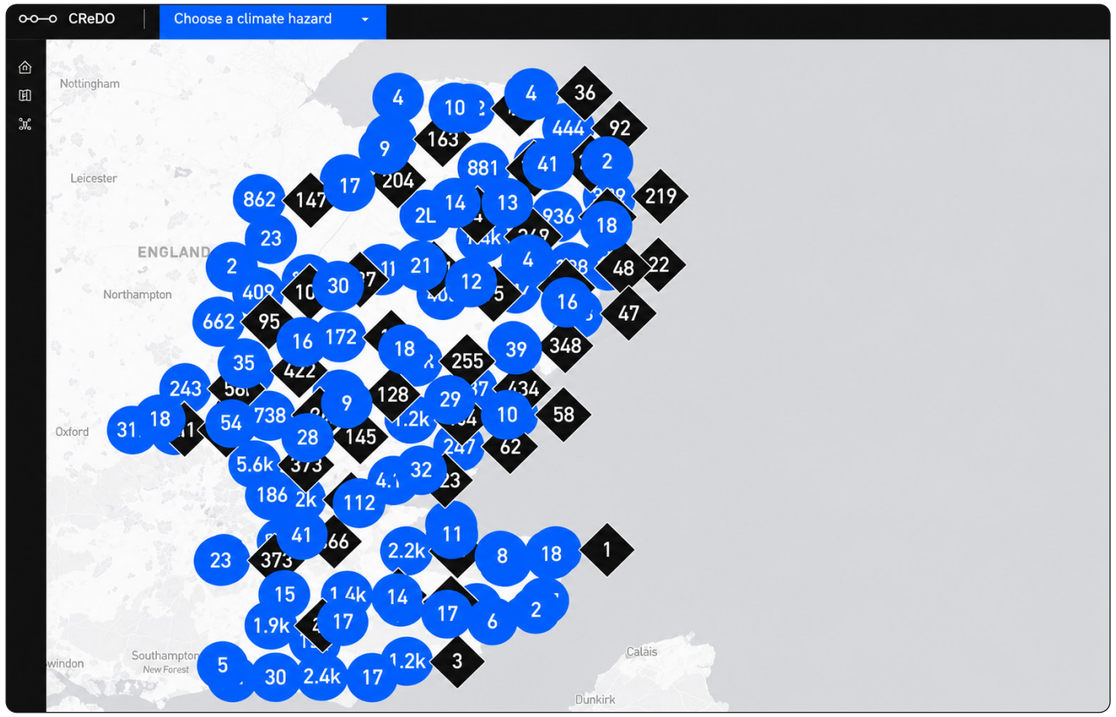
In practice, this led to ineffective targeting of resilience investment, duplication of resources, and prolonged service outages with higher recovery costs.

Storm Arwen (2021) illustrates these limitations. The storm left ~1,000,000 homes and businesses without electricity, with ~40,000 still without power after three days and restoration taking up to ten days. Economic impacts were estimated at >£250 million. Power outages also disrupted telecommunications, highlighting how infrastructure resilience depends on understanding cross-sector interdependencies. The event exposed the gap between asset-level resilience and system-level outcomes, where limited visibility of cascading risks hindered effective coordination and prioritisation of interventions.

Outcomes enabled by CReDO
CReDO improves outcomes by enabling a system-level view of infrastructure performance, leading to:

- **Better-targeted investment:** identification of system-critical assets and prioritisation of interventions with the greatest cross-sector impact
- **Reduced cascade failures:** improved understanding of interdependencies and earlier identification of high-risk failure pathways
- **Improved service performance:** reduced customer interruptions/minutes lost; greater continuity of services
- **Enhanced coordination:** shared situational awareness of upstream and downstream risk, and more effective deployment of resources across organisations

The evidence base for systems change CReDO



CReDO map views. Top: Energy sites (blue circles) and customers and other-sector infrastructure (black diamonds). Bottom: Cascading risk from river and coastal flooding.

CReDO infrastructure interdependencies

Benefit category	Net present value (£ million)
Avoided infrastructure repair and recovery costs	£390
Avoided service disruption impacts on customers and businesses	£622
Environmental benefits	£42
Avoided cascading failures across interconnected infrastructure networks	£3,350
Total benefits	£4,404

Improvements can be achieved as better information and coordination influence planning and operations.

Additional value from systems approaches
Systems approaches deliver additional value beyond conventional interventions by improving how decisions are made, not just what is done. While traditional approaches can strengthen individual assets, they often miss opportunities to address the drivers of system behaviour.

CReDO demonstrates that explicitly analysing interdependencies enables materially better outcomes per pound by targeting high-leverage interventions:

- A coordinated £1.1 million investment in a local flood scenario could avoid £17.2 million in damages, significantly outperforming uncoordinated action[1]
- National-scale analysis indicates potential benefits of around £4.4 billion, largely arising from avoided cross-sector disruption[2]

This additional value arises from improved targeting of investment, shared evidence for decision-making, and coordinated action across organisational boundaries.

Stakeholder outcomes
- **Infrastructure operators:** improved decision-making and reduced outage costs
- **Government and regulators**: stronger evidence base for resilience standards and investment
- **Society:** improved service continuity, particularly for critical and emergency services

Trade-offs and lessons
Early implementation required significant effort to establish trusted data sharing and collaboration frameworks. Benefits accrue across sectors while costs may fall unevenly, highlighting ongoing incentive alignment challenges. Full value depends on embedding systems capability into routine decision-making.

Progress toward realised outcomes
CReDO has progressed from demonstrating capability to influencing planning and early operational decisions through a minimum viable product (MVP) trial within the CReDO+Beta project. While not yet business-as-usual, early applications are already informing asset strategy and investment planning.

Systems

CReDO treats the built environment as a system of systems, recognising that infrastructure performance arises from interactions between physical assets, organisations, digital infrastructure and information flows, rather than individual networks in isolation.

System structure
The system comprises three interconnected layers:

- **Physical systems:** energy, water, telecommunications and gas networks, their assets, and exposure to climate hazards
- **Organisational systems:** infrastructure operators, regulators, emergency responders, and coordination forums
- **Digital systems:** data standards, secure sharing mechanisms and interoperable infrastructure, secure compute environments, models and analytics used to understand and manage risk

The data ecosystem itself is treated as a system, with its own dependencies, governance requirements and failure modes.

System dynamics and root causes
System mapping identified that resilience failures were driven less by individual asset fragility and more by structural factors, including limited visibility of interdependencies, fragmented governance, misaligned incentives, and lack of mechanisms to value cross-sector outcomes. These conditions lead to suboptimal performance despite significant investment.

1 UK Power Networks, Anglian Water, BT Group, Connected Places Catapult and partners. Identifying the Expected Impacts of CReDO. Digital Twin Hub. Available at: Identifying the Expected Impacts of CReDO. https://digitaltwinhub.co.uk/download/identifying-the-expected-impacts-of-credo-report/
2 Energy Networks Association. CReDO Beta (Project 10061361). Smarter Networks Portal. Available at: CReDO Beta Project Page (Accessed: 7 August 2026) https://smarter.energynetworks.org/projects/10061361/

The evidence base for systems change CReDO

Systems approaches and leverage points
CReDO applies connected, cross-sector models to reveal failure modes and leverage points:

- **information flows:** improving visibility of interdependencies and risks
- **system-critical assets:** prioritising based on cross-sector impact
- **investment sequencing:** coordinating interventions across networks
- **decision-making:** aligning operational, regulatory and strategic choices around shared evidence

In practice, the most challenging leverage points to address have been those related to incentive alignment and authorising leadership, where institutional constraints limit the ability to act on system-level insight.

Unlocking value and improving performance
By improving system understanding, CReDO enables comparison of intervention options at whole-system level, more efficient use of existing infrastructure, and a shift from reactive response to targeted long-term resilience investment. This is already influencing strategic discussions across operators and regulators.

Key insight
Improving infrastructure outcomes depends on understanding and managing interdependencies across systems, with digital infrastructure enabling better decisions about where and how to invest in physical resilience.

Interventions

To engage with the CReDO digital infrastructure, organisations securely share relevant infrastructure and operational data, collaborate on modelling interdependencies and climate risks, and use the resulting insights to inform planning, investment and response decisions.

CReDO provides capability and decision-support interventions to influence how infrastructure systems are planned, prioritised and operated. It is currently at MVP stage, with early user trials demonstrating how improved decision-making can be embedded in practice.

Nature of interventions
- Development of a secure, cross-sector digital platform
- Establishment of structured, outcomes-focused data-sharing arrangements
- Implementation of interdependency-based risk modelling across networks
- Integration of economic and service-based cost–benefit analysis at system level

These interventions are designed to improve decision quality and coordination, enabling more effective use of existing infrastructure and better targeting of future investment.

Inputs
- Securely shared asset and network data
- Climate hazard and environmental datasets
- Economic, service performance and customer impact data
- Expert judgement and historical performance information

Outputs
- System-level risk and vulnerability maps
- Simulations of cascading failures
- Prioritised resilience intervention infrastructure targets
- Quantified evidence to inform planning and investment

Impact on the system
These interventions enable a shift from reactive, organisation-specific response to coordinated risk management, supporting shared situational awareness and more effective deployment of resources.

Difference from conventional approaches
Compared to siloed practices, interventions are informed by system-wide interdependencies, prioritised based on whole-system outcomes, and supported by structured, secure data sharing. Success is measured in terms of avoided disruption and improved service continuity rather than asset-level performance alone.

Economic assessment

This assessment considers the economic case for adopting a systems-based approach to climate resilience planning. It examines how improved visibility of infrastructure interdependencies can address market failures and support more effective resilience investment decisions.

Coordination failure and information gaps
Infrastructure operators typically make decisions on investments within organisational and sector boundaries, with limited visibility of interdependencies across networks. As a result, the costs and risks arising from cascading failures are not fully reflected in investment decisions, while limited data sharing and cross-sector coordination can prevent the most effective resilience interventions from being identified and prioritised. CReDO addresses these information and coordination failures by providing a shared understanding of infrastructure interdependencies and climate-related risks.

Theory of change
CReDO combines infrastructure, climate and economic data to identify interdependencies and potential failure cascades across infrastructure networks. This improves understanding of system-wide risks, enabling organisations to share information, coordinate decision-making and target resilience investment towards the most critical assets and interventions. This leads to more effective resilience planning, reduced service disruption and lower economic costs arising from climate-related infrastructure failures.

Quantified and indicative benefits
Evidence from CReDO pilot applications suggests that a systems-based approach to resilience planning can deliver significant economic benefits by improving how resilience investment is targeted. In a local flood resilience scenario, modelling found that £1.1 million of investment could avoid £17.2 million of damages by accounting for infrastructure interdependencies and cascading failures. At a national scale, modelling estimates total benefits of approximately £4.4 billion, with the largest share arising from avoided cascading failures across interconnected infrastructure networks.

The assessment indicates that CReDO improves the targeting of resilience investment, enabling greater economic benefits to be achieved from a given level of expenditure.

Assumptions and limitations
The assessment is based on cost-benefit analysis comparing a CReDO-enabled, system-level approach to resilience planning with conventional sector-based decision-making. Benefit estimates are derived from modelling of flooding impacts and infrastructure interdependencies in the Kings Lynn area, which were subsequently scaled to estimate potential national impacts. The analysis follows established regulatory appraisal approaches and presents results as net present values over the 63-year appraisal period.

As CReDO is currently at MVP stage, the results should be regarded as indicative rather than predictive. Estimates are sensitive to assumptions regarding infrastructure interdependencies, cascading failure effects and the extent to which organisations adopt system-level decision-making in practice. Cross-sector benefits represent the largest component of total benefits and therefore depend on assumptions regarding infrastructure interdependencies and cascading failure effects

Systemic assessment

CReDO highlights a set of persistent system-level barriers that limit infrastructure performance and increase long-term costs. These barriers are structural and interdependent, meaning progress in one area can unlock benefits across the system.

1. Governance and leadership
Infrastructure systems are governed primarily within sector boundaries, limiting the ability to take decisions at a whole-system level. While technical insight can identify optimal interventions, acting on this insight is constrained by fragmented authority and the challenge of coordinating decisions across organisations. However, CReDO has demonstrated that cross-sector governance is achievable, bringing together infrastructure operators, regulators and delivery partners around shared resilience objectives and common evidence.

2. Incentives and appraisal frameworks
Funding and regulatory frameworks are typically aligned to sector-specific outcomes, with limited mechanisms to recognise or reward cross-sector benefits. As a result, high-value interventions that reduce system-wide risk can be under-prioritised. CReDO has helped quantify these previously hidden benefits, providing evidence that whole-system approaches can deliver significantly greater value than siloed decision-making.

3. Data and decision-making capability
Effective system-level coordination depends on trusted data sharing and the ability to translate system insight into operational and investment decisions. While challenges remain, CReDO has demonstrated that secure cross-sector data sharing, interoperable modelling and collaborative analysis can be achieved in practice.

CReDO therefore demonstrates that the principal barriers are no longer technical, but institutional: embedding these proven capabilities into routine governance, investment and regulatory practice.

Recommendations

The recommendations below are presented in order of priority. Together they describe the actions required to translate proven systems-based capabilities into business-as-usual infrastructure resilience planning and investment. The highest priorities focus on enabling organisations to act on system-level insight; subsequent recommendations support the institutional, technical and regulatory conditions required for scaling.

1. Enable system-level decision-making across boundaries
Mechanisms are required to support decision-making at system level, including enabling coordination across organisations and resolving cross-sector trade-offs.

2. Align incentives with system outcomes
Funding and regulatory frameworks should reward whole-system performance, ensuring investment reflects where value is realised across the system rather than within individual organisations.

3. Embed interdependency analysis in regulation
Resilience investment should be assessed using system-level evidence, including cross-sector impacts and avoided cascade failures, ensuring that high-value interventions are not overlooked within siloed appraisal frameworks.

4. Treat shared data as critical infrastructure
Secure, purpose-driven data-sharing capability should be recognised as essential infrastructure to enable coordinated decision-making across sectors.

5. Align resilience standards around outcomes
Resilience standards should shift from asset-based compliance toward service and outcome-based metrics, aligned across sectors to support coherent planning and investment.

6. Enable scaling of systems-based capability
Create the conditions for proven systems-based approaches and decision-support capabilities to transition into business-as-usual adoption and be applied across sectors and geographies where they deliver value.

Taken together, these actions would enable systems approaches to move from isolated applications to standard practice, improving cross-sector coherence, targeting investment more effectively, and reducing long-term fiscal risk.

Success factors
All 15 Infrastructure Systems Review case studies were assessed against a set of seven success factors. The table, right, provides a high-level assessment of CReDO's development and deployment.

The evidence base for systems change CReDO

Systemic assessment

CReDO has been assessed against seven 'success factors' and scored on a four level scale:
0 – Not met | 1 – Partly met | 2 – Mostly met | 3 – Fully met.

Success factor	Level	Description
1. Outcome clarity	**3**	Outcomes stated in real-world terms rather than outputs, and key actors describe them consistently. System scope is clear, including what is in and out of scope, and which external effects matter. Trade-offs between outcomes are explicit, with clear priorities, tolerances, and non-negotiables. Legitimacy is established, with outcomes and trade-off rules agreed through an appropriate process with those most affected. Constancy of purpose is maintained over time, with outcomes changing only deliberately and with clear justification.
2. Systems capability	**3**	Systems capability exists across the endeavour, with people, roles, and routines able to apply systems approaches in practice. System boundaries are actively worked with, including identifying and managing interfaces, dependencies, and external impacts. Shared representations of the system exist, such as maps, models, or causal narratives, and are used by different parties to reason together. Information and sensing are sufficient to maintain shared representations over time, including access to data, feedback and monitoring.
3. Leverage focus	**3**	Interventions are chosen to change underlying system behaviour. Feedback and delays that shape system behaviour are explicitly identified and influence the choice and timing of interventions. Structural drivers such as incentives, information flows, rules and constraints are considered alongside (or instead of) asset-based or capacity-led solutions. Unintended effects and lock-in are considered, including how interventions may reinforce path dependence or create new problems.
4. Authorising leadership	**2**	Authority is clear, with defined decision rights and escalation routes that enable cross-boundary decisions to be made and upheld. Governance facilitates working across system boundaries and supports system-level choices; trade-offs are resolved. Boundary-spanning leadership actively co-ordinates organisations, disciplines and lifecycle stages so that they can act on the system as a whole. Complexity and variety are managed across levels; decisions are taken at appropriate scales. Risks are realistically assessed and managed; resilience is built into the plans and the system.
5. Incentive alignment	**2**	Contracts and funding arrangements encourage behaviour that supports whole-system outcomes. Performance measures reward contribution to system outcomes and interface performance. Accountabilities and risk ownership sit with those able to influence outcomes, so problems are surfaced early. Behavioural and reputational incentives reinforce collaboration and early problem-solving.
6. Decision quality	**3**	Decision processes use clear criteria linked to outcomes, with assumptions, evidence, and trade-offs made explicit. Bias and undue influence are actively mitigated through challenge, independent scrutiny, and consideration of relevant external evidence. Decision roles and escalation are clear, so decisions are taken at the right level and are not avoided, deferred, or endlessly recycled. Timeliness is appropriate to the situation, with decisions taken early enough for systems insight to prevent avoidable cost, delay or lock-in.
7. Adaptive learning	**2**	Learning mechanisms are in place to test assumptions and monitor how the system is actually performing, including the use of evidence and leading indicators. Adaptation occurs in response to learning, with plans, interventions, or decisions changing when evidence shows they should. Experimentation is used where uncertainty is high, including safe-to-fail approaches that allow rapid learning without disproportionate risk. Learning culture supports early issue-raising and honest reflection; bad news travels quickly; experience is not lost across boundaries or phases.

Co-sponsored by

The Infrastructure Client Group brings together UK economic infrastructure clients in partnership with government and industry. The ICG's key purpose is to lead the acceleration of improvement and alignment in the delivery and development of UK infrastructure, for the benefit of society, the economy and the environment. It is sponsored by the Institution of Civil Engineers.
bit.ly/ICG_01

The National Infrastructure and Service Transformation Authority unites long-term strategy with best practice project delivery, to transform the performance of UK major projects and programmes. It gives ministers the levers they need to drive growth. NISTA is a joint unit at the heart of government, reporting to both HM Treasury and Cabinet Office.
bit.ly/NISTA_01

The Green Construction Board is the sustainability arm of the Construction Leadership Council. It brings together government and industry to drive net zero, biodiversity enhancement and resource efficiency across the built environment, helping shape policy and industry practice.
bit.ly/GCB_01

Delivered by

The Built Environment Connective is a public good organisation that brings people together to turn systems thinking into coordinated, lasting change. It connects system thinkers across government, industry, academia and civil society.
be-connective.com

Supported by

The Institution of Civil Engineers (ICE) is the home of infrastructure. It is a professional institution with 95,000 members and over 200 years of history. It qualifies civil and infrastructure engineers, promotes lifelong learning, and provides trusted, impartial, expert advice to decision makers. Its vision is a world where infrastructure enables people and planet to thrive. Its global membership designs, builds, and maintains trustworthy and sustainable infrastructure.
ice.org.uk