The Institution of Engineering and Technology

Engineering a more resilient world

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Covid-19 tested the resilience of the global community. In many countries, long-standing protocols and procedures, created to mitigate the interruption or loss of services, proved insufficient or ineffective as the impacts brought by the pandemic created new and extraordinary challenges.

Yet the rapid re-engineering of systems restored vital services with many sectors and service providers accelerating the digital transformation of their operations. Engineers and IET members across the globe were among those who worked quickly within their organisations to help pivot operations, some switching their design and production capabilities to supply vital medical equipment. Global collaboration to design, manufacture, and distribute billions of Covid vaccine doses, enabled and fast-tracked by technology, swung into action.

We live in a world where the probability of global shocks and disruptions, be they environmental, economic, or pandemic, has increased. In light of the pandemic, many governments are reviewing their national infrastructure security, crisis management, and resilience arrangements. These are urgent, substantial challenges and engineers are vital to help secure the solutions and mitigations which will be needed in the future.

This IET thought piece, written with engineers, IET members, supporters, and policymakers in mind, provides an overview of resilience. It includes perspectives of the systems and infrastructures needed to safeguard and maintain the essential services we all take for granted. Together with consideration of the personal and professional competencies, engineers will need to harness an increasingly complex array of interrelated systems, with extensive interdependencies.

Resilience is a huge and complex topic we cannot possibly cover in just a few pages. However, we hope this thought piece will help to stimulate debate around the enabling role which engineers can play in engineering a more resilient world for our increasingly complex and technology dependent society.

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What is resilience?

"Resilience is the ability to anticipate, resist, absorb, recover, and adapt to shocks and stresses in the system with agility, to enable continuity of delivery of critical needs such as safety, food, energy, and healthcare."
Royal Academy of Engineering

"The term 'resilience' refers to an ability to withstand and quickly recover from a difficult situation...we need to understand our vulnerabilities, pre-empt challenges before they arise, ensure we are prepared for them, and mitigate the impacts."
UK Cabinet Office

Reinforcing national resilience

Resilience is usually delivered through a multiplicity of systems, infrastructures, and capabilities with risk assessment, risk management, and response and recovery measures in place to cover a wide range of scenarios. Are the measures in place, adequate? How frequently are they tried and tested?

The measures involve central, regional, and local government interacting with a broad supporting cast of public and private sector stakeholders, including the emergency services and utility companies.

In the UK, The Centre for the Protection of National Infrastructure (CPNI) is the UK Government's National Technical Authority for physical and personnel protective security. There are 13 national infrastructure sectors: chemicals, civil nuclear, communications, defence, emergency services, energy, finance, food, government, health, space, transport and water.

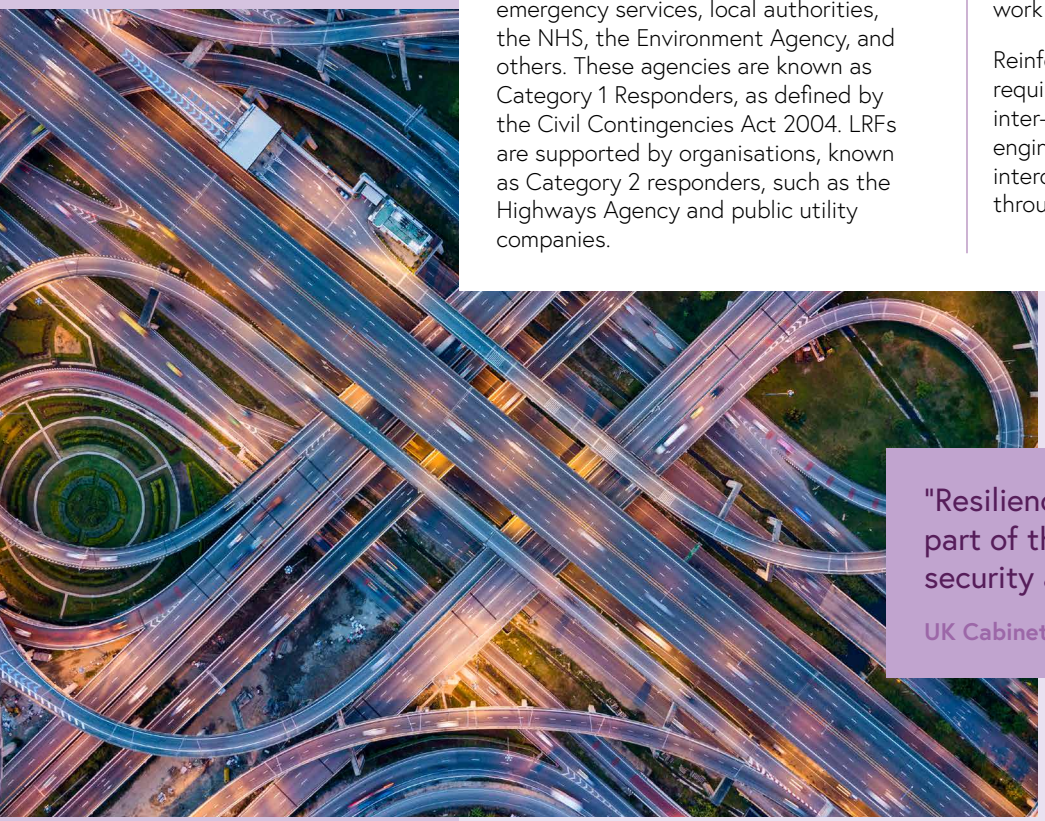
There are Local Resilience Forums (LRFs) across the UK. These are multi-agency partnerships made up of representatives from local public services, including the emergency services, local authorities, the NHS, the Environment Agency, and others. These agencies are known as Category 1 Responders, as defined by the Civil Contingencies Act 2004. LRFs are supported by organisations, known as Category 2 responders, such as the Highways Agency and public utility companies.

The National Risk Register[1] is the public-facing version of the classified cross-government and scientifically rigorous National Security Risk Assessment. Coordinated by the Civil Contingencies Secretariat (CCS) and published most recently in December 2020, it provides an assessment of the impact of a range of risks which may directly affect the UK in the upcoming two years.

The UK Government published its integrated review of security, defence, development, and foreign policy titled Global Britain in a competitive age, in March 2021.[2] A crucial part of the review was an increased focus on building national resilience and developing an agility to respond to unanticipated low probability, high impact events with widespread societal consequences.

A draft National Resilience Strategy[3], issued for consultation by the Cabinet Office in July 2021, set out the overarching vision, to make the UK the most resilient nation, but there remains considerable work to achieve this end goal.

Reinforcing the resilience of all nations will require an unprecedented, integrated, and inter-disciplinary response from the global engineering community given the deep interdependence of systems, from power through digital on international interaction.



"Resilience has long been an integral part of the UK's approach to national security and crisis management."[4]

UK Cabinet Office

1 National risk register 2020 - GOV.UK (www.gov.uk).
2 Global Britain in a competitive age: the integrated review of security, defence, development and foreign policy - GOV.UK (www.gov.uk).
3 National resilience strategy: call for evidence - GOV.UK (www.gov.uk).
4 System approach to management: definition, features and evaluation (yourarticlelibrary.com).

Sector perspectives

Power to the people

Our dependency on electricity has increased massively over the last 100 years, to a point where we would find it extremely difficult to live without power. Basic daily functions - food, water, heat, light, television, mobile phones and so on - all require power to operate. Yet such supply has become reasonably reliable with communities experiencing relatively infrequent outages.

Katherine Jackson,
IET Energy Panel

When interruptions do occur, perhaps because of extreme weather conditions, they are generally well managed, being largely confined to specific localities and communities.

The technical nature of the electricity system is such that a total collapse, nationally, is an extremely low probability event, but one that the system must be developed for. In such exceptional circumstances, the restoration procedure used to restart the grid and restore supplies presents a significant challenge.

The operational characteristics of the electricity system are changing as the proportion of wind and solar generation increases, becomes geographically displaced from load centres, and as energy storage and demand side response are added. New approaches are now being considered to maintain system voltages and frequency stability for this changing system. For system restoration the system operators are investigating contracting with local distributed energy resources to help rebuild the system 'bottom-up' from the distribution networks instead of relying solely on the traditional 'top-down' approach from the transmission system.

BEIS has now introduced a new Electricity System Restoration Standard which will require the Electricity System Operator by no later than the end of 2026 to have sufficient capability and arrangements in place to restore 100% of Great Britain's electricity demand within five days. It should be implemented regionally, with an interim target of 60% of regional demand to be restored within 24 hours.

This new standard, when fully implemented, should improve resilience, because the management of the costs to the economy of total grid failure risk or, indeed, the societal impacts, are not built into current regulatory models. Consequently, cost pressures have made it technically difficult to manage a day-to-day, lowest cost network and achieve the degree of resilience voters expect from government. Impact and time are currently bounded by best effort, with generally untested plans being informed by unproven modelling. As Covid-19 has demonstrated, even the best models do not reflect the reality faced in crisis, with complex technical systems. Infrastructure for instance has been disrupted in other countries by malicious interference with IT systems, demonstrating the interconnectedness of technical sectors.

The interdependencies across commercial and technical systems has created major complexity.[5] These achieve efficiency, but often at the expense of resilience. Failure in any of these systems may have widespread consequences. Most sectors, such as water, gas, electricity or communications, have sectoral plans in place to minimise risk. Yet the interfaces between sectors introduce a level of vulnerability that poses a threat to resilience.

[5] Interdependencies and resilience in digital transformation - report (theiet.org).

Digital transforming lives

The application of digital technologies has transformed the daily lives of billions of people. Digital is part and parcel of most industry sectors too, with high dependency on real time systems from infrastructure control, through commerce in banking, retail and communications.

People increasingly rely on digital technologies. Yet power is needed to operate digital devices. It is also required to provide the connectivity (4G, 5G, 6G) needed to access services.

These assets and infrastructures exist and operate 24/7 as the result of a massive global engineering effort. People place great faith in these trusted systems. They demand and expect the services they use to operate without interruption.

When considering our approach to the resilience of the assets, infrastructures, and systems which enable digital services to run, we need to consider their design, development, and deployment. A whole system approach is required, beyond individual sectors.

Digital networks defy geopolitical boundaries, being global in scale and therefore part of extensive, multi-dimensional, and intricate systems of systems.

In the same way that we deliver digital transformation through assets, infrastructures, and systems, engineers must now apply the same pioneering, problem-solving zeal, to harness the full power of innovation and technology – data analytics, machine learning, artificial intelligence, and other technologies. In this way, engineers can deliver resilient and sustainable digital networks and services for all. As an example, cybersecurity is a critical and integral factor in ensuring the resilience of digital networks and software.

Preetam Heeramun, IET Digital Panel

Making with greater certainty

After decades of relative calm, manufacturers faced up to Covid-19 impacts in 2020 – dislocated supply chains, production lines at a standstill and workers laid off.

Presently, manufacturers are revisiting their assumptions of future risks and threats[6] and how best to manage these. Indeed, impacts and actions for the manufacturing sector provide some important clues for global industrial sectors. Firms looking to create greater certainty for their businesses can strengthen their resilience by:

Foresight - Expect the unexpected in all areas. Identify potential technical threats such as cyberattacks, supply chain or logistics failure, 'just in case' as well as 'just in time' measures. Think and plan for what may occur in the future. Build a robust risk register with detailed tested contingencies and mitigations.

Agility - Move quickly. Build-in flexibility so that you can react to what's happening around you. Pivot your operations, where practical and profitable. Being able to adapt and adopt quickly is probably one of the most important aspects of resilience, and engineers are central to changing, restoring, and providing alternatives to normal business processes.

Reserves - These are the assets and core competencies which distinguish the business in its marketplace, be they in the form of cash, stock, intellectual property, or other value-added.

Security - Think global, go local, where it is viable to do so. Reshoring manufacturing operations, bringing supplies closer to your location, will only work where the price of finished products remains competitive. The UK faces the stark challenge of maintaining sufficient levels of precious metals and natural materials needed to manufacture products or source innovative, sustainable alternatives.

Performance - Maintaining performance in a crisis is crucial. Identify contingency capacity. Deploy digital technologies to maintain your productivity, processes, and profits during major disruption.

Paul Calver, IET Design and Manufacturing Panel

[6] Webinar recap: the future of manufacturing: improve your resilience with digital (theiet.org).

Engineering a systems approach

In the report, *Critical capabilities strengthening UK resilience*[7], the Royal Academy of Engineering explains how a systems approach could be applied to identify the critical capabilities across the public and private sector and strengthen the UK's resilience to emergencies.

What is a systems approach?

In a systems approach, attention is paid towards the overall effectiveness of the system rather than the effectiveness of sub-systems. The interdependencies of the sub-systems are considered.

Whole systems thinking is a method to understand how elements and systems are related, and how they influence one another within a whole.[8]

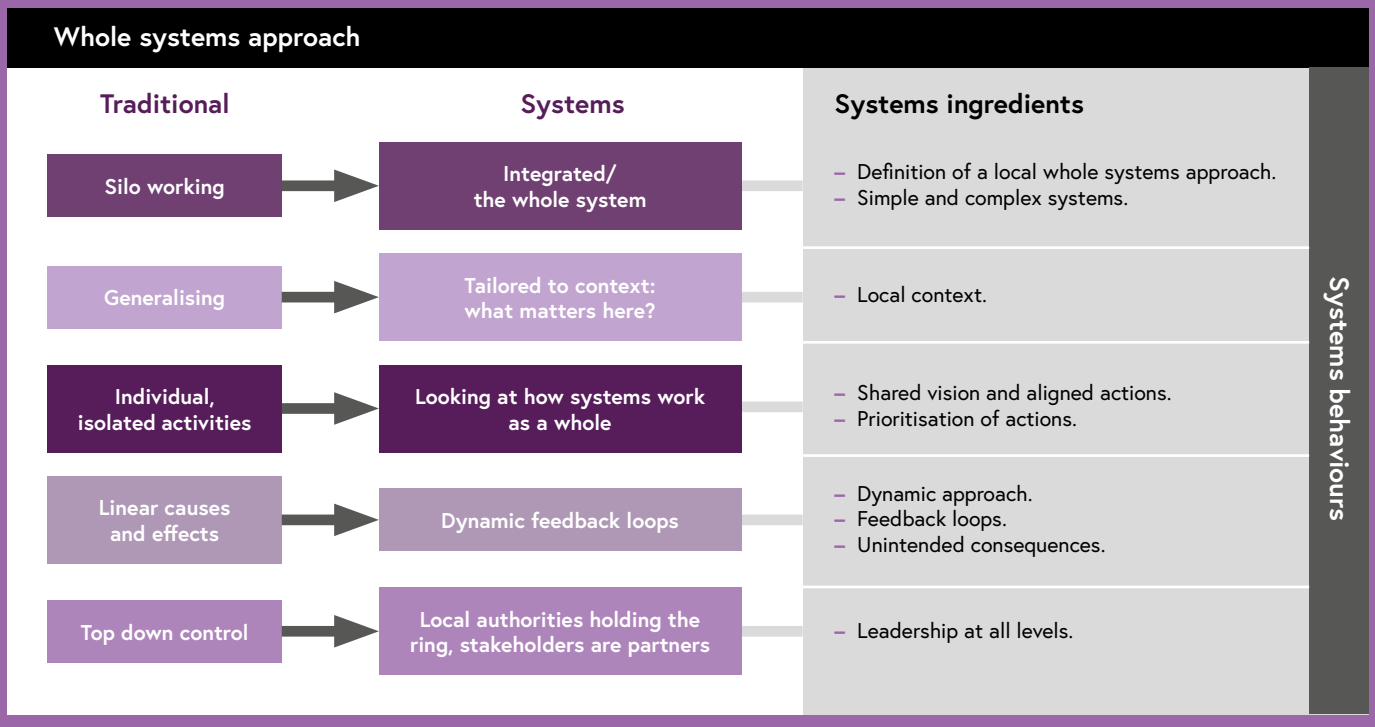
Understanding the wider interdependencies and interconnectedness of multiple sectors critical to life lies at the heart of more effective resilience planning.

Many sectors already have systems in place to respond to predictable events. Where events are less predictable, the challenge will be to improve recovery capabilities to a level where disruption to society is minimised and low probability, but technically foreseeable events, are limited.

Informed by data and analytics, engineers applying systems thinking will improve the visibility of the interconnectivity and interdependencies between sectors, standards, and technologies.

Further research and dissemination are needed if we are to increase understanding of resilience in its many forms and deliver all necessary solutions and mitigations. Engineers will play a vital role. Accordingly, their training and skills will need to provide them with a more in-depth appreciation of self, sector, and systems resilience.

Figure 1: This diagram, from a Public Health England report[9], highlights some of the differences between traditional and systems approaches.



[7] Critical capabilities: strengthening UK resilience - Royal Academy of Engineering.
[8] What is whole systems thinking? (ubc.ca).
[9] Whole systems approach to obesity: a guide to support local approaches (publishing.service.gov.uk).

We say...

These recommendations have been created by the IET's Resilience Working Group to commend additional measures and priorities and champion the vital role which engineers and engineering will play in delivering them.

1 To Government, industry, and local communities

Embedding a whole system approach to resilience and resilience planning will bring into view critical interdependencies between sectors, standards, and systems. Such visibility, enabled by digital technologies, will help to support Government, industry, and communities in their work to anticipate, identify and mitigate future shocks and disruptions.

We welcome the Government's National Resilience Strategy and its work to identify critical capabilities. The UK is world-leading in its use of data, artificial intelligence, and machine learning. Engineers play a vital role in harnessing these technologies to provide powerful modelling systems, capable of predicting the variances within different scenarios and the impact of future shocks.

We will champion the role which a whole system approach can play to further strengthen resilience planning.

2 To Government and the research community

Setting ambitious targets for research to assist resilience and resilience planning will complement and strengthen investment across the UK resilience eco-system (Government, industry, and communities).

Stepping up Government investment in such funded research will help to inform additional resilience measures and extend the interest, influence and understanding of UK resilience issues to a wider audience.

We welcome opportunities to support future research and disseminate outcomes to the engineering community through our multiple communication channels.

3 To the education and engineering communities

Making resilience an integral part of the training engineers receive, including a wider understanding of the interconnectivity and interdependencies between sectors, standards, and systems, is vital.

We understand there are always considerable calls on the education sector, regulators, and others to add further topics to engineering curricular.

We will undertake further work and discussions to pursue this recommendation and work with others who share our ambition.

We are the Institution of Engineering and Technology (The IET), a charitable engineering institution. We bring together expert practitioners from industry, academia, the public and third sectors.

The IET's Resilience Working Group, its Energy, Digital, and Design and Manufacturing panels comprise expert members and subject specialists supported by the IET's Policy and Insight team, part of the IET's Governance and External Engagement directorate.

Your specialist knowledge can inspire others and make a difference. If you would like to support our work, please contact us at **sep@theiet.org**.

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