ice
Institution of Civil Engineers

In plain sight:

assuring the whole-life safety of infrastructure

Contents

Foreword from the President

The world of infrastructure in Britain in the 21st Century is a safe one. However, recent tragedies at home and abroad have shown that no system, process, project or structure is 100 per cent free from risk during its life.

All of us at ICE were as shocked as the rest of the nation by the fire at Grenfell Tower in June last year. In the aftermath of the fire, we commissioned a report from the Government's former Chief Construction Adviser, Professor Peter Hansford, leading a panel of industry experts, to examine the whole-of-life risks to infrastructure. Crucially, we also asked that Professor Hansford make recommendations on how the industry can reduce the prospect of future failures.

ICE enthusiastically welcomed the Panel's interim report findings in November 2017. This final report offers recommendations that, when implemented, will further reduce the risk of failure in economic infrastructure. Some of the key actions it identifies are for ICE to implement; others require collaboration with our friends across the built environment; and others require Government to decisively lead.

This report seeks to take a candid and wide-ranging look at the profession of civil engineering and we believe that it can play a significant role in stopping these kinds of events from happening again.

We know that while change does not always happen immediately, it is required for processes, practices, training and work cultures to improve. We are proud to have been at the forefront of driving forward changes and improvements in our industry for 200 years, and greatly welcome the honest and challenging investigations and insights that have contributed to this final report.

Finally, I would like to thank my predecessor, Professor Tim Broyd for commissioning this important report during his tenure as ICE President. I also thank Professor Hansford and the entire panel for their diligence, expertise and hard work in bringing us all to this point. Safety will always be our number-one priority, and we will continue to lead all efforts to keep our society safe.

Professor Lord Robert Mair,
CBE FREng FICE FRS

October 2018

Review Panel members

- Peter Hansford FREng FICE, University College London (Chair)
- Liz Baker MICE, The Nichols Group
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- Tim Chapman FREng FICE, Arup
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- Margaret Sackey MICE, ICE Health and Safety Expert Panel
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Foreword from the Review Chair

Society rightly expects buildings and infrastructure to be planned, designed, constructed, operated and maintained in such a manner as to present an extremely low risk of failure, and to cause negligible hazard to occupiers, users and the public.

No designer or constructor carries out their work with the deliberate intent of endangering others. However, failures do occur – albeit infrequently, and thankfully very rarely with significant safety consequences.

That said, we have recently seen the catastrophic failure of a motorway bridge in Genoa, Italy resulting in multiple fatalities. Concerns are being expressed regarding alleged construction malpractices in Hong Kong. And, of course, last year we witnessed the tragic fire at Grenfell Tower in West London.

This report does not focus on high-rise buildings, does not feature cladding, and does not consider the specific risk of fire. Rather, it encompasses all the risks of catastrophic failure in infrastructure and considers measures to reduce the level of risk to society.

The review was conducted in two stages. An interim report, published in November 2017, set out preliminary findings; this final report draws the review to a close. It concludes on matters raised in the interim report, setting out recommendations for the Institution, policy makers and others which, if implemented, should result in still greater confidence in the integrity and safety of our infrastructure.

As Review Chair, I am grateful to the Panel for their advice and guidance throughout, and to all contributors to working groups and the various aspects of this review. My thanks also go to the ICE in-house team for their support in producing this final report.

We, the profession and its members, already know many of the factors that can contribute to failure of infrastructure assets. They are among us as we undertake our work as engineers, day in and day out; and yet they can be hiding in plain sight because of their very familiarity. It is for us, as professionally qualified civil engineers, to be ever diligent and always critical so that they do not stay hidden. Rather, we must ensure they are actively highlighted, managed and mitigated, to better secure the whole-life safety of our existing and future infrastructure. And it is for the Institution to provide assurance to society that we have done so to the best of our professional ability.

Professor Peter Hansford
FREng FICE

October 2018

Summary

This report is the culmination of a thoughtful, challenging and honest look at the profession of civil engineering. The review's remit is wide: to consider the risks of catastrophic failures in economic infrastructure assets on a general basis.

This report makes recommendations that, when implemented, will further reduce the risk of failure in economic infrastructure. Several actions lie directly within the Institution's remit. Others require collaboration with fellow professional institutions before they can become effective, while some will necessitate engagement with and action by Government.

The Panel's Interim Report, published in November 2017, presented the conclusions and recommendations drawn from interviews, workshops and literature reviews. ICE task and finish groups then challenged and further developed three particular topics identified in the interim report: lesson sharing, competence and governance. At the same time, Loughborough University undertook an academic validation exercise on the methodology and conclusions reached.

In parallel, other work streams within the ICE have been moving forward. These include a review of learning approaches and future skills needs, as well as Project 13's pioneering work in transforming the transactional model for delivering major infrastructure projects. Over that same period, the Ministry of Housing, Communities and Local Government published Dame Judith Hackitt's *Independent Review of Building Regulations and Fire Safety*. This report takes all of those many drivers and moving parts in this manifold landscape into account, distilling matters down to a few key recommendations.

The main challenges

The Panel concludes that, while the risk of catastrophic infrastructure failure is low, crucially, the threat is rising. Over recent decades, gradually and sometimes imperceptibly, risks have weakened long-established mitigations or lines of defence.

The Panel's first concern is that the infrastructure sector lacks both a sufficiently consistent public safety culture and a systematic approach to learning from incidents and near misses, both in the construction and operation phases. Other sectors that have public safety at their core, by contrast, do.

Another concern is that maintaining an enduring, coherent, system-wide, whole-life asset-centric risk-management approach is difficult in a fragmented world informed by specialists who inevitably may not see the integrated picture.

In addition, the current industry structure and modern procurement methods can spawn numerous organisational interfaces throughout design, construction and whole-life stewardship which can interrupt asset knowledge and create data continuity risks.

Furthermore, economic pressures, prioritisation of capital cost savings over whole life value, and narrowly-designed contract incentives can create unintended outcomes that increase risks.

New infrastructure represents the minority of assets. Most assets in daily use are old, some a century or more so, designed for fewer users and for environments that were more predictable. As time passes and the demands placed on these assets increases, a lack of clear accountability for whole-life asset safety mutes responsiveness.

Some owners – not all – may not know enough about their assets' conditions, nor take seriously enough the capture and maintenance of asset data throughout the life of the asset. This may be challenging for assets that are very old, but it is inexcusable for newly created infrastructure.

Chartered accountants must audit the accounts of medium - or large-sized companies each year. Similar statutory requirements do not exist, however, for chartered engineers to affirm infrastructure safety.

The exception is the ICE Reservoirs Committee with its panel of named experts, established by the Reservoirs Act 1975. No such whole-life statutory obligation or role exists for other infrastructure assets, such as buildings, roads, bridges or tunnels.

Some engineers note with regret the decline of the 'client checking' role during construction under the Clerk of Works and Resident Engineer models. Those roles have faded away due to changes in contractual and delivery arrangements, and there seems little appetite to replicate them. But something comparably robust needs to be in their place. Self-certification provides a weak line of defence against issues such as team 'groupthink', the fragmentation of knowledge, poor incentives or mistakes.

This combination of factors leads the Panel to conclude that today's society is facing growing challenges with the safety of its infrastructure that previous generations did not, prompting the need for action.

To regulate or not to regulate?

In her report of May 2018, Dame Judith Hackitt recommended creating a regulatory regime for residential tower blocks higher than ten storeys. The intention is that a Joint Competent Authority (JCA) with statutory approval powers will regulate the work undertaken over the lifecycle of an asset.

Several infrastructure sectors already lie within regulatory regimes. With the support of the Health and Safety Executive (HSE) and other regulators, health and safety risk management during construction has vastly improved over the past two decades. The challenge now lies in ensuring that this progress is fully considered, extended and rooted within the operational life of infrastructure assets. The Panel acknowledges the recommendation of the Hackitt Review to form a new JCA for higher-risk residential buildings, but is not persuaded of the need to create a new regulatory framework for wider infrastructure and asset owners generally.

Instead, these improvements can be made by working with existing regulatory bodies in strengthening, deepening and embedding the multiple lines of defence which should, and in most cases do, exist to reduce the likelihood of infrastructure failure.

Strengthening defences against failure

The Panel strongly supports the risk-reduction philosophy first proposed by James Reason in the colloquially termed 'Swiss Cheese Model', in which each slice of cheese represents a line of defence against risks and the holes represent inherent weaknesses. When two holes align the risk increases. When all holes align, catastrophe is possible. The aim is to shrink the weaknesses – in this case the holes in the Swiss cheese – and to erect or maintain multiple lines of defence, reducing the chances of failure.

This report identifies 13 lines of defence against failure, grouped into three broad areas of lesson sharing, competence and governance. Engineers have a role to play in the effectiveness of all of these. These areas, in turn, translate into the recommendations shown overleaf.

At its heart, this is a full transformation. The Institution's thought leadership and commitment are essential enablers, as are its persuasive skills in enlisting support from other professional institutions and government. This is the time to strengthen the lines of defence, taking measured and thoughtful steps to improve accountabilities, roles and responsibilities, mitigating the risk of infrastructure failure and enhancing public safety.

Summary of recommendations

To mitigate the risk of infrastructure failure the Institution of Civil Engineers and the wider infrastructure sector should:

1. Strongly promote the Swiss Cheese Model concept of risk management, emphasising that all engineers have roles to play in mitigating and managing infrastructure risk.

2. Work with professional bodies to scope, sponsor and find funding for a sector-wide organisation to review, comment on and disseminate lessons from concerns, near misses and catastrophic incidents, building on the work of Structural-Safety.[1]

3. Run an annual event with HSE on infrastructure near misses, incidents or forensic reports, to promote understanding and identify sector-wide responses.

4. Encourage engineers to highlight unaddressed infrastructure concerns, risks and near misses to their management and provide guidance via the ICE website on suitable confidential reporting channels should these become necessary.

5. Establish an electronic system that captures ICE members' CPD activities, increasing tenfold the CPD returns audited annually; and work with the Engineering Council to explore introducing periodic mid-career peer reviews.

6. Identify and communicate mandatory risk-related topics, themes and reading lists for members to include in their annual CPD learning.

7. Strengthen awareness of ICE's Code of Professional Conduct through guidance, education, disciplinary processes, sanctions and publicity.

8. Work with Government to identify any new safety-critical asset classes requiring lifecycle statutory certification.

9. Set out the responsibilities of a competent infrastructure owner and work with Government to promote a voluntary charter.

10. Work with other professional institutions to promote a whole-systems multi-disciplinary approach for the lifetime safety of infrastructure assets.

11. The chief officers of ICE and relevant professional institutions to maintain a co-ordinated disaster response capability and triage decision-taking process, to help Government and the authorities respond to an infrastructure incident.

1 Structural-Safety is a not-for-profit group dedicated to disseminating learning from concerns, near misses and incidents in structural safety. It comprises of two entities; the Standing Committee on Structural Safety (SCOSS), a committee established to maintain a continuing review of building and civil engineering matters affecting the safety of structures; and Confidential Reporting on Structural Safety (CROSS), a confidential safety reporting scheme established to capture and share lessons learned which might not otherwise have had formal recognition.

Section 1: Introduction

Scope of the report

This report primarily considers the risks to economic infrastructure (i.e. physical built assets within sectors such as transport, power, water, waste, communications and flood defences) and their design, construction and whole-life operation. The Panel recognises, however, that the delivery and ongoing operation of infrastructure involves numerous engineering elements, including mechanical and thermodynamic processes, electronic control systems, the use of vehicles or rolling stock, and more besides.

The multiple processes and disciplines that underlie our infrastructure reinforce the importance of a collaborative approach to delivering and operating infrastructure safely, requiring a wide pool of expertise and stakeholder participation, both from inside and outside of engineering disciplines.

The Panel considers that the audience of this particular report is primarily practising civil engineers, both members and non-members of ICE; the construction workforce more widely; ICE itself, and other professions allied to the built environment sector, for example the infrastructure advisory, academic and legal services sectors. This should not preclude the importance of this report to other stakeholders and responsible persons engaged in the delivery or operation of infrastructure. Indeed, their support is vital to assure the whole-life safety of complete infrastructure systems on which society depends.

The fire at Grenfell Tower on 14 June 2017 shocked the entire country, prompting a vast outpouring of sympathy and grief, together with professional dismay and a resolution that a similar event must never happen again.

Since the fire, businesses and professionals up and down the country have been reassessing their processes and practices, while reviewing the assets they own and the projects they operate.

In the aftermath of the fire, cladding and other elements from some residential tower blocks and other high-rise buildings across the UK failed safety tests and it became apparent that failings were systemic and not site specific. In these circumstances, it is vital that a responsible professional body, and its members, reflect on current practice to examine the actions that are needed to deliver safer and more effective whole-life stewardship of assets.

The Morandi Bridge collapse that took place on 14 August 2018 in Genoa, Italy, is closer to the heartland of this report. Whatever the causes of that disaster, and time will tell, the chances are that several factors aligned and weakened the usual multiple lines of defence against failure. At a generic level, those risks – ones that hide for a long time in plain sight – form the focus of this report.

This report is, therefore, not about high-rise buildings or cladding, nor does it specifically consider fire. Instead, it examines what the infrastructure sector, its institutions, companies and governments can do to mitigate the risk of catastrophic failure and, if an incident does occur, deploy the most effective post-incident response.

In July 2017, ICE responded in its duty to act for the benefit of society with then-President, Professor Tim Broyd, asking former Government Chief Construction Adviser and ICE Past President, Professor Peter Hansford, to lead an independent review of the lessons for civil engineers and other professionals working on the UK's infrastructure in response to the Grenfell Tower disaster. An interim report, *In Plain Sight: reducing the risk of infrastructure failure*, was published in November 2017 concluding that, while the risk of a major failure of UK infrastructure is relatively low, it is still not low enough.[2]

2 ICE (2017), In Plain Sight: Reducing the risk of infrastructure failure

The interim report drew on contributions from practitioners and experts, while also considering reports and inquiries into prior incidents, both in the field of civil engineering and other sectors. A full literature review is available in the interim report. A pattern of vulnerabilities and blind spots emerged, including:

- a failure to identify all risks within the system
- incomplete or inadequate information
- older assets being used by more people than their original design intent
- poor quality supervision and assurance, with an overreliance on visual inspection;
- design flaws
- operations not in harmony with design intent, including the disabling of safety controls
- inadequate governance and poor organisational culture, including a failure to follow up on concerns
- a failure to share lessons from past incidents and near misses.

These vulnerabilities should not be considered in isolation. Rarely does a failure occur due to a single weakness; a combination of multiple flaws in the system, some obvious and others not immediately apparent, are often the cause.

The Panel used the 'Swiss Cheese Model' of risk analysis, pioneered by Professor James Reason, to help understand the systemic nature of risk and evaluate the lines of defence against infrastructure failure. The Panel considered the lines of defence in three groups: 'knowing', 'applying' and 'ensuring'.

The interim report's four primary recommendations were:

- **Validation:** ICE should commission a study to analyse and validate the lines of defence against infrastructure failure.
- **Lesson sharing:** ICE should work with other infrastructure organisations to further consider how the sector shares information from safety reviews, accidents, failures and near misses.
- **Competence:** ICE should review the robustness of its Continuing Professional Development (CPD) regime and Code of Professional Conduct, and should also review the effectiveness of arrangements for professional oversight of assets in different sub-sectors of infrastructure.
- **Governance:** ICE should work with other infrastructure organisations to identify whether improvements can be made to the role played by governance in the development and management of assets. This should include the competence of boards, scrutiny systems and the presence of a technically competent engineering voice in safety-critical decisions.

In response to this, ICE established three task and finish groups covering lesson sharing, competence and governance to provide a fuller examination of how to reduce risk further in those areas. ICE also commissioned a validation study of the lines of defence by experts in built environment resilience at Loughborough University. This report builds on the findings of these exercises and reflects other developments that have occurred in the fast-paced debate on competence, resilience and accountability.

Changes to the landscape

Various events have occurred since ICE published the interim report in November 2017.

Notably, the Grenfell Tower public inquiry, chaired by Sir Martin Moore-Bick, began on 21 May 2018. While the inquiry into the disaster is ongoing, evidence taken from expert witnesses will continue to shed light on further details about the building, its refurbishment and its management.

Building a safer future

In May 2018, the Government released the final report prepared by Dame Judith Hackitt's Independent Review of Building Regulations and Fire Safety panel, in response to the Grenfell disaster. Issues highlighted include industry culture, unclear responsibilities and accountabilities, and a need to strengthen the competence of professionals.[3]

Dame Judith's final report sets out several recommendations around the design, construction, operation and maintenance of higher-risk residential buildings. It concludes that the building regulation system in England is "broken" and calls for a complete overhaul of the regulations, guidance and compliance processes, alongside an outcomes-based approach to encourage real ownership of risk and accountability. While the report is aimed directly at higher-risk residential buildings in the context of fire safety, its conclusions and the direction of travel that policy makers may take have much broader implications for the construction and infrastructure sectors. This is a position taken by the House of Commons Housing, Communities and Local Government Committee's report into the independent review, which suggests that many of the proposed reforms should apply to a wider range of buildings and to the construction industry as a whole.[4] The *In Plain Sight* Review Panel has met with Dame Judith Hackitt to ensure that its work is aligned to hers, as far as is appropriate.

The Steering Group on Competences for Building a Safer Future, a sub-group of the Industry Response Group established in the wake of the Grenfell fire, is developing a pan-industry competence framework for higher-risk residential buildings. The group's aim is to develop a comprehensive, coherent and robust framework for assessing and accrediting the competence of all those creating, maintaining and managing such buildings. ICE and other professional bodies are involved in the initiative.[5]

England's building regulation system is not the only one within the UK to come under scrutiny. In July 2018, the Scottish Government published a report on building standards compliance and enforcement in Scotland, and another on building standards associated with fire safety.[6,7]

These were published in the context of the fire at Grenfell Tower and in the wake of the multiple failures found on schools and other buildings across Scotland following the collapse of a wall at Oxgangs Primary School in Edinburgh in 2016. These reports concluded that the Scottish building regulation system requires reshaping to address weaknesses, particularly with regards to the inspection regime, but should not fundamentally change. Additional recommendations focused on a need for better communication and information sharing between all parties and strengthening enforcement of and compliance with building regulations. The Scottish Government's proposals based on these reports have since gone out for consultation.

3 Dame Judith Hackitt (2018), Building a Safer Future
4 House of Commons Housing, Communities and Local Government Committee (2018), Independent review of building regulations and fire safety: next steps
5 Construction Industry Council (2018), Steering Group on Competences for Building a Safer Future
6 Scottish Government (2018), Report of the Review Panel on Building Standards (Fire Safety) in Scotland
7 Scottish Government (2018), Report of the Review Panel on Building Standards Compliance and Enforcement

BIM and digital

Dame Judith's final report emphasises the need for a single repository of information – a 'golden thread' – detailing work from design through construction and all subsequent changes to a building during occupation, to ensure a digital record exists for the benefit of owners and end users of higher-risk residential buildings. There is a suggestion that expanding this to all buildings and infrastructure, or at least to those at higher risk of failure, would ensure improved transparency and accountability while disincentivising corner-cutting.

The 'golden thread' has strong associations with Building Information Modelling (BIM), digital technologies and the Government Soft Landings (GSL) programme. The first Government Construction Strategy in 2011 mandated central government's six major capital-spending departments to deliver BIM level 2 by 2016 across their projects, with GSL mandated on all Government projects from the same time.[8] BIM take-up in the private sector has also increased since the mandate, with the latest NBS National BIM Report stating it has "gone from a niche platform to the norm."[9]

BIM and digital techniques, if implemented correctly, provide traceability, accountability, information sharing and greater supply chain engagement, demonstrating a clear link with improving resilience and mitigating risk. GSL has manifest benefits to asset owners and users on the smooth operation of that asset, including performance, maintenance and a proactive approach to lessons learned.

ICE initiatives

Several complementary ICE initiatives have also come to the fore since the Panel's interim report was published in November 2017.

Firstly, ICE asked Vice President Ed McCann to lead a review into whether ICE members have the necessary skills to practise in an industry in which procurement techniques, technology and commercial constructs constantly change. ICE published that report in July 2018, which concluded that ICE's qualification process is broadly fit for purpose, but the notion that a qualification is for life, once achieved, is untenable and has a number of implications on competence.[10]

Secondly, ICE and the Infrastructure Client Group industry-led initiative, Project 13, was launched in May 2018.[11] Project 13 improves infrastructure delivery and management by promoting true delivery integration rather than perpetuating transactional waste and inappropriate risk transfer. It also addresses issues of governance, the 'golden thread', handover management and asset stewardship, all of which are complementary to the findings of Dame Judith Hackitt's review and this report, and calls for a fundamental shift in leadership and behaviour.

In the context of Project 13, it is important to consider the collapse in January 2018 of contractor and outsourcing firm Carillion, which highlighted the vulnerability of the industry's supply chain, large parts of an industry focused on short-term financial gains, as well as the potential to expose weaknesses through inappropriate apportion of risk. The House of Commons Public Administration and Constitutional Affairs Committee (PACAC) report into Carillion's collapse from July 2018 identifies poor procurement choices as a contributor to Carillion's demise. The Committee accuses the Government of placing cost-cutting above all else, forcing firms to take on excessive risk and "driving prices down to below the cost of the services they were asking firms to provide". It concludes that lessons must be learned about risk management, as well as the strengths and weaknesses of the sector.[12]

8 BIM level 2 is fully collaborative 3D BIM with all project and asset information, documentation and data being electronic.
9 NBS (2018), The National BIM Report 2018
10 ICE Skills Review Group (2018), ICE Professional Skills
11 www.p13.org.uk
12 House of Commons Public Administration and Constitutional Affairs Committee (2018), After Carillion: Public sector outsourcing and contracting

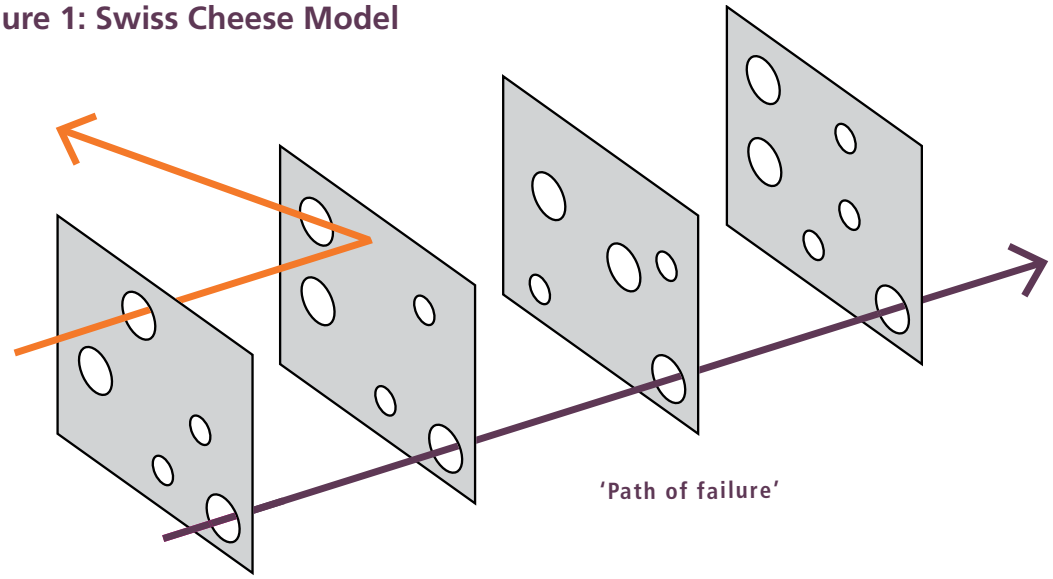
Section 2: Lines of defence

Infrastructure makes modern civilisation possible, but is far from being sufficient by itself in supporting all that society requires. Society also relies on many other essential activities, facilities, sources of expertise and resources. Each and every one of these constituent parts requires constant improvement in their capability to withstand not just extreme strains and unexpected events, but also to deliver their day-to-day functions. Companies implement risk-management processes to ensure service continuity. Governments pursue their aim of delivering economic growth and public safety in the face of rising challenges. Even households protect themselves against the risk of an uncertain future by putting money aside for an inevitable rainy day.

Catastrophic failure in a complex system such as economic infrastructure is difficult to predict, but asset owners must assess, understand, mitigate and manage their risks. Major hazard scenarios in high-risk industries, such as chemical, oil and gas, nuclear and rail, help to pinpoint vulnerabilities. Preparedness measures help ensure there is an effective response in place if an incident does arise.

In recent years, researchers have developed models and methods that explain the causes of incidents and that help understand and manage risk, including The Egg Aggregated Model (TEAM) and the Bowtie method.[13] One of the most recognised and established models, seen in numerous sectors, is the 'Swiss Cheese Model of Accident Causation', developed by Professor James T. Reason in 1990.[14] The Swiss Cheese Model allows analysis of the causes of failure, identifies how to reduce that risk and, more generally, provides a useful way of illustrating how apparently unrelated and often small errors in different parts of a complex system can combine to create catastrophic failure.

Figure 1: Swiss Cheese Model



The model **(Figure 1)** depicts different lines of defence against an incident occurring as slices of Swiss cheese with their vulnerabilities presented as holes. An error, oversight or an event may allow a threat to pass through a hole in one line of defence – no human system is perfect, after all – but if no holes align after that, the risk of failure falls to zero. A clear pathway needs to open through aligned holes in every line of defence for a catastrophic failure to occur.

13 Vierendeels, G et al. (2017) An Integrative Conceptual Framework for Safety Culture: The Egg Aggregated Model (TEAM) of Safety Culture, Safety Science, 103. 10.1016/j.ssci.2017.12.021].
14 Reason J (2000), Human error: models and management, BMJ. 2000; Mar 18; 320(7237): 768–770 https://dspace.lboro.ac.uk/2134/34858

Knowing + Applying + Ensuring = Assurance

The Panel has used the Swiss Cheese Model to consider the systemic nature of risk to infrastructure, with individual lines of defence grouped under the headings of 'knowing', 'applying' and 'ensuring'. These three areas form the basis of the report and its recommendations, distilled into Sharing Lessons, Competence, and Governance.

'Knowing' covers three lines of defence: knowledge of the asset's condition, including the availability of high-quality data; knowledge gleaned via learning from previous failures; and the rigour of the regime used by professional engineers for their continuous learning – that is, their CPD.

'Applying' concerns the processes used. These consist of five lines of defence: standards and regulations; attention to quality in both the design and construction phases; the deployment of suitably qualified, current and experienced persons (SQEP); adherence of individuals and corporate bodies to professional institutions' Codes of Professional Conduct; and the accountability and responsibilities of asset-owning organisations.

'Ensuring' focuses on the processes put in place to guarantee application of that knowledge. This covers five lines of defence: governance processes and corporate decision-making; incorporating lessons from prior incidents into investment cases and the Health and Safety File; external scrutiny and assurance; the concept of asset stewardship; and cyber security.

Following the publication of the interim report, ICE commissioned experts in built environment resilience at Loughborough University's School of Architecture, Building and Civil Engineering to perform an academic evaluation of the applicability and validity of the lines of defence model.[15]

Loughborough University carried out interviews, desk research and workshops, confirming that the Swiss Cheese Model is an appropriate conceptual model in this instance. They identified potential enhancements including: consideration of crosscutting influencers that could affect every line of defence, such as changes in the political landscape; effective communication with stakeholders; a corporate culture that makes risk assessment a value-based decision rather than a compliance exercise; and the understanding and perception of risk itself.

Loughborough also noted that post-incident considerations then follow, once the lines of defence are clear. Post-incident preparedness can cover the immediate response and its handling, the longer-term response (including mitigating strategies), and future preventative measures.

The Panel believes it is important for the Swiss Cheese Model to be promulgated to the ICE membership and the wider civil engineering community in order to highlight the role engineers play in the knowing, applying and ensuring processes that, together, assure the whole-life safety of infrastructure.

15 Chmutina, K et al., 2018. Academic analysis of the ICE Report 'In Plain Sight: reducing the risk of infrastructure failure', Loughborough University, 19pp.

Cyber security

The Panel considers it imperative that cyber security, both in terms of infrastructure development and asset management, forms part of the lines of defence, particularly in an age of ever-increasing connectivity.

Recent years have seen ransomware attacks on NHS trusts and German rail networks, supervisory control and data acquisition (SCADA) systems breached at US water utilities in Illinois and Texas, and targeted cyber-attacks in Ukraine that resulted in the loss of power to almost a quarter of a million people. In some of these cases, taking measures as simple as applying the latest security updates to computer systems could have prevented a serious incident from developing. Last year in the UK, 590 significant incidents were reported to the National Cyber Security Centre (NCSC).[16] This included foreign-state attacks on UK telecommunication and energy infrastructure.[17]

A successful attack on critical national infrastructure in the UK could cost the economy tens of billions of pounds, with the estimate for the most severe attack increasing to hundreds of billions of pounds.[18] Many infrastructure asset owners are confident of the cyber security measures they have in place, but there is little evidence of a strong security culture extending into operational and engineering functions, or across the supply chain and other vital partners.

Within the EU, the stringent penalties that apply for breaches of the General Data Protection Regulations (GDPR) incentivise firms to embed cyber security into everyday business processes and to better mitigate security threats against their computer systems. The incoming EU-wide Networks and Information Systems Directive also provides legal measures to boost the security and resilience of network and information systems in core sectors of the economy such as energy, transport and water.[19] As highlighted in ICE's 2017 *State of the Nation: Digital Transformation* report, clients have a role to play in enforcing cyber security awareness as part of the contract, giving it increased weighting during procurement and mandating it throughout the supply chain.[20]

1. KNOWING

1.1 **Asset condition data** – collating and sharing accurate and up-to-date data on asset condition and performance allows professionals to make better judgements across the whole lifecycle of an asset.

1.2 **Incident reporting and dissemination of learnings** – collecting and communicating information on incidents and near misses to a wide audience helps to prevent similar events from reoccurring.

1.3 **Continuous Professional Development (CPD)** – a robust CPD regime helps maintain and improve an individual's competence and capability over their career.

2. APPLYING

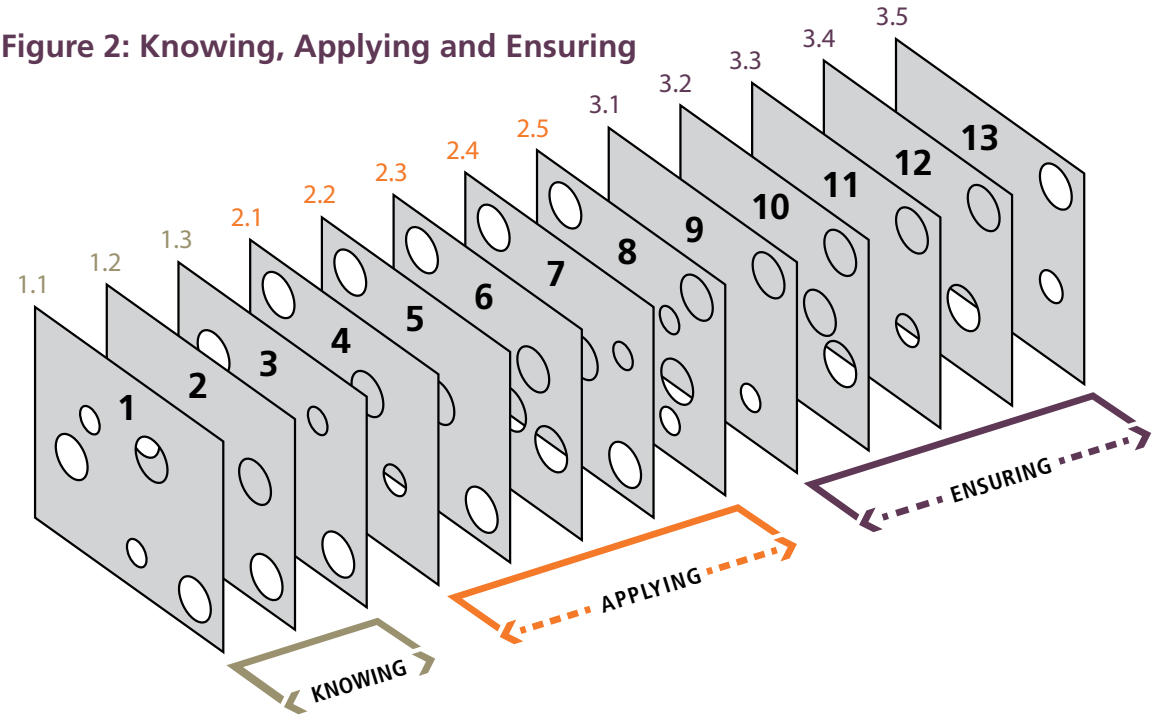
2.1 **Standards and regulations** – these exist to ensure safety, consistency and efficiency across a range of processes and products. Policy makers, experts and practitioners should review and update them regularly.

2.2 **Attention to quality in design and construction** – a high-quality design process can reduce or remove risk in both the construction and operational phase of an asset. In the construction phase, clear communication of design intent and a focus on quality can remove defects and latent risks.

2.3 **Suitably qualified and experienced persons (SQEP)** – SQEP provide assurance to asset owners and regulators in their ability to undertake critical responsibilities. They are professionally qualified in their discipline with several years of experience and keep up-to-date on current practice.

16 National Cyber Security Centre, 2017 Annual Review
17 *The Independent*, 15 November 2017, Russian cyber attacks have targeted UK energy, communication and media networks, says top security chief
18 University of Cambridge (2016), Integrated Infrastructure: Cyber Resiliency in Society
19 National Cyber Security Centre (2018), Introduction to the NIS Directive
20 ICE, State of the Nation 2017: Digital Transformation

Figure 2: Knowing, Applying and Ensuring



2.4 **Code of Professional Conduct** – members of a professional body must adhere to a Code of Professional Conduct, which establishes the professional and ethical behaviour required of them. This includes only undertaking work they are competent to do.

2.5 **Client organisations and interfaces** – client organisations are responsible for the development, construction, operation and maintenance of an infrastructure asset. They manage multiple interfaces across various phases of asset ownership and must have appropriate processes in place to reduce the risk of failure.

3. ENSURING

3.1 **Governance** – at the head of all client organisations is a board or committee with ultimate accountability for an asset. This governance group must have a range of expertise and skills that enable them to make the best decisions over the lifecycle of an asset.

3.2 **Investment cases and the Health and Safety File** – an investment case sets out the need, cost, risk and delivery plan for creating a new asset or making major changes to an existing one. The Health and Safety File, a statutory requirement in projects involving more than one contractor, is a live document containing health and safety information that must be kept up-to-date and passed on for use during subsequent work on an asset.

3.3 **Independent scrutiny and assurance** – this subjects decisions and sign-off procedures to appropriate checks, guarding against errors and groupthink.

3.4 **Asset stewardship of infrastructure** – a senior technical 'voice' running through asset creation and management, for example a SQEP engineer, helps ensure critical decisions about an asset throughout its lifecycle are better informed.

3.5 **Cyber security** – asset owners and their supply chains have increasingly turned paper processes into digital ones, handling vast amounts of data in the operation of critical infrastructure. Protecting these systems and data against malicious actions is vital as a line of defence against failure.

Recommendation 1:

Strongly promote the Swiss Cheese Model concept of risk management, emphasising that all engineers have roles to play in mitigating and managing infrastructure risk.

"The fact is bad news is good news, because it shows that information channels are working. The corollary is that no news is bad news." [26]

Professor Andrew Hopkins
Author of *Lessons from Longford: The Esso Gas Plant Explosion*

Section 3: Sharing lessons

Infrastructure failures, whether small or catastrophic, are always avoidable. When the holes in the Swiss Cheese Model align, breaching the lines of defence, failure is an inevitability. Yet these incidents can repeat multiple times, sometimes with tragic consequences.

This happens when there is a failure to share and learn lessons, a failure to eliminate known risks, and a failure to identify and act on early warning signs.

Too often information is held back due to legal or insurance issues, or is sometimes not thought worth sharing wider than internal learning processes. An underlying fear of tacit admission of liability on the part of individuals and companies can make it difficult for the cause of an accident to be found swiftly. There is a need to develop and foster a more open culture, albeit with consideration of security implications, sharing information with the wider industry at the earliest possible stage.

While not possible every time, learning from failure and disseminating the findings quickly is substantially preferable to a lengthy process where facts take time to emerge. The Hatfield rail crash in 2000, in which four people died and 102 were injured, is a case in point. It took until the final report into the disaster, released in 2006, to determine that deficiencies in the track inspection and maintenance regime, under a 'find and fix' approach, was the primary cause of the disaster – information that went hidden from the industry for six years.[21]

A number of sectors with major public-safety interests have well-established mechanisms for reporting and learning from failures and near misses. It is right to ask the question, then, of how effective the infrastructure sector is at learning from past mistakes and empowering professionals to speak out when they spot risks. Within this context, it is important to include learning not just from incidents of failure, but also from near misses.

1. Management and processing of learning

Sectors with robust lines of defence against failure typically use a combination of a database for collating information on failures and near misses, together with mandatory or voluntary confidential reporting mechanisms to ensure they are acted upon.[22]

Databases and reporting mechanisms are necessary as it may be difficult on the basis of one incident or near miss to determine that there is a public safety issue. Statistical handling of the data enables the frequency and magnitude of contributory factors and trends to be determined, while wider issues can become apparent following a pattern of similar incidents.

From this it may be possible to make the case for wider communication and, where necessary, intervention. Alternatively, where more information is required, it may be possible to initiate research. Databases are therefore an important resource for the monitoring of accidents, incidents and near misses, improving safety and helping to define areas of further examination. However, due to the sensitive nature of the information in some of these databases, access is frequently – and correctly – restricted to authorised users and submissions are often anonymised to encourage reporting.

Data from the mandatory reporting of occurrences or confidential reporting systems can be subject to bias, even with safeguards put in place. Confidential reporting suffers from the fact that reports can be from a disaffected subset of the workforce.

In the UK, there are several incident databases and reporting mechanisms. The Civil Aviation Authority's Mandatory Occurrences Reporting programme (MOR) is in use across Europe, while the Confidential Human Factors Incident Reporting Programme (CHIRP), initially used for the aviation industry but since extended to maritime incidents, has been in place since the 1970s.[23, 24] In the transport infrastructure sector, the Confidential Incident Reporting and Analysis System (CIRAS) programme has built up a substantial database and resulted in tangible safety improvements.[25]

21 Office of Rail Regulation (2006), Train Derailment at Hatfield: A Final Report by the Independent Investigation Board
22 NASA Aviation Safety Reporting System (2001), ASRS: The Case for Confidential Incident Reporting Systems
23 Civil Aviation Authority, Mandatory occurrence reporting
24 CHIRP, Aviation and Maritime Confidential Incident Reporting
25 University of Strathclyde (2014), Improved railway safety through the implementation of a confidential incident reporting and analysis system
26 The Chemical Engineer (2018), The Long View on Longford

Within the field of infrastructure, the Panel learned much from the genesis, development and work of Structural-Safety, a not-for-profit group founded in 1976 that is dedicated to disseminating learning from concerns, near misses and incidents in structural safety.

Structural-Safety operates through two entities: the Standing Committee on Structural Safety (SCOSS), an expert panel established to maintain a continuing review of building and civil engineering matters affecting the safety of structures; and Confidential Reporting on Structural Safety (CROSS), which operates a common shared database in a number of countries and regions. CROSS collects anonymised reports from engineers on structural safety concerns, subjects them to peer review, and publishes them with comments as learning documents on its website, in newsletters and through alerts.

Structural-Safety is funded by the Institution of Structural Engineers (IStructE) (who also provide all administrative support), ICE and HSE, and is supported by several government bodies and the wider industry.

Despite the institutional endorsement and funding, knowledge and use of CROSS's reports is rightly limited both by its focus on structural safety and by whom it can reach. In order to strengthen the lines of defence, there must be processes in place for sharing information with as wide a pool of professionals and practitioners as possible, and it is clear that there is an enabling role for ICE and other professional institutions to play.

CROSS's approach is mature and deliberately focuses on the remit of structures. In contrast, the wider infrastructure sector is singled out as one where near misses are rarely acknowledged and there exist considerable cultural, legal and financial disincentives to share information.[27] There is, then, an opportunity to learn from CROSS and other systems, extending the confidential reporting mechanism beyond structural safety to the whole design, construction and life-long use of infrastructure.

The panel believes this would be a good model for reporting safety-related incidents throughout the infrastructure sector.

Recommendation 2:

Work with professional bodies to scope, sponsor and find funding for a sector-wide organisation to review, comment on and disseminate lessons from concerns, near misses and catastrophic incidents, building on the work of Structural-Safety.

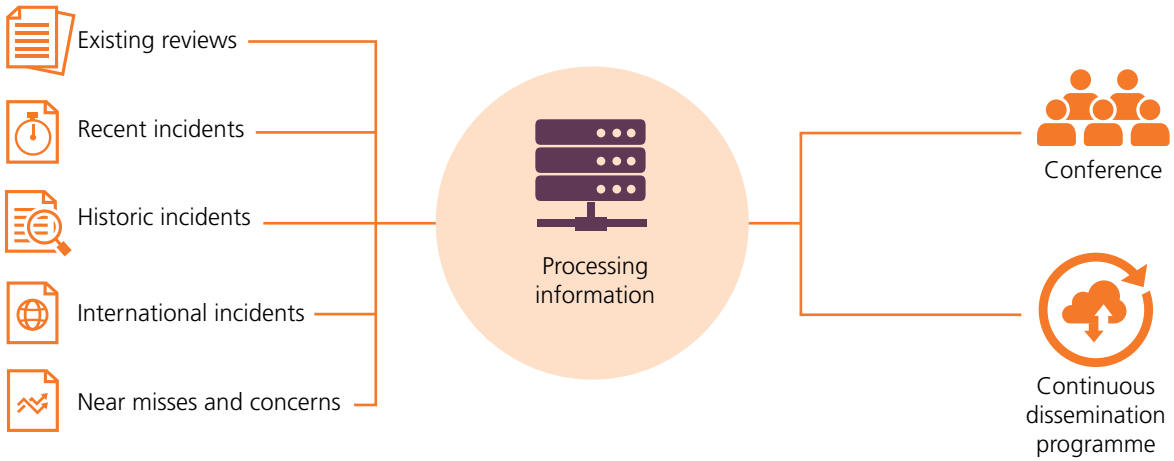
Many of those working within an engineering environment are neither chartered nor necessarily even associated with a professional institution. Sharing lessons from within a wider catchment than just the professional institutions and their members is important in order to improve knowledge and reach as large and relevant an audience as possible. HSE provides a level of authority and influence, as well as learning from other sectors that can be shared and applied, and appears a natural fit for collaboration. The Panel believes that convening an event, either physical or virtual, to share findings and identify opportunities for co-ordinated action to prevent failures and near misses will foster a wide-ranging reach. This event should be informed by ICE's Health and Safety Register and other relevant forums where appropriate. The event should provide attendees with engaging presentations on the strategic lessons learned from more historic incidents as well as trends identified from the reporting system and international examples.

Recommendation 3:

Run an annual event with HSE on infrastructure near misses, incidents or forensic reports, to promote understanding and identify sector-wide responses.

27 ICE (2017), In Plain Sight: Reducing the risk of infrastructure failure

Figure 3: Flow of lesson sharing and information processing



2. Empowering professionals

A confidential reporting system is one vital cog in the machine to embed lesson sharing within the industry. Learning processes, however, may take a long time due to security considerations and potential resourcing issues, while unavoidable considerations of confidentiality could dilute a report's usefulness. It is important, therefore, to consider additional measures to quickly identify problems, potentially rectify them, and ensure dissemination of learning.

The UK Public Interest Disclosure Act (PIDA) 1998 is designed "to protect individuals who make certain disclosures of information in the public interest".[28] Put simply, any worker who believes that they would suffer from damaging consequences if they disclosed certain types of information is protected in the eyes of the law, providing the individual follows the process correctly. While the Act does not require organisations to provide whistleblowing arrangements, a company that does not put in place adequate measures is exposing itself to the risk that, when its employees have concerns, they will voice these first outside the organisation. The UK Government also provides whistleblowing guidance for employers.[29]

Business leaders expose themselves to risk when their directors, employees and contractors act illegally, unethically or unsafely, creating holes in the lines of defence. It is expected that all organisations involved with the creation and operation of infrastructure will actively promote and support professional competence with their staff, especially with regard to whole-life asset stewardship. If organisations fashion the appropriate culture, people will feel able to speak up when they suspect there has been a breach of ethics or values, or where they have identified a problem. Whistleblowing is just one part of a strategy to encourage this culture of transparency and open communication within organisationss.

It is a duty of the civil engineer to understand why failures happen, learn from them, and share those lessons. Indeed, it is explicit in ICE's Code of Professional Conduct that all members "give full regard for the public interest, particularly in relation to matters of health and safety" and give "all reasonable assistance to further the education, training and continuing professional development of others".

Organisations should therefore rely on the knowledge and resolve of professional engineers who are prepared to speak up and notify them of a concern or issue before it reaches the public domain.

In high-risk sectors, prescribed bodies exist for individuals to whistleblow with a greater degree of security.[30] Protection for the whistleblower only applies if a disclosure is made to the right prescribed entity. Dame Judith Hackitt's recent proposal for a new prescribed body to deal with whistleblowers' fire and structural safety concerns in higher-risk residential buildings is welcome, given the clear deficiencies in the current system identified in her report.

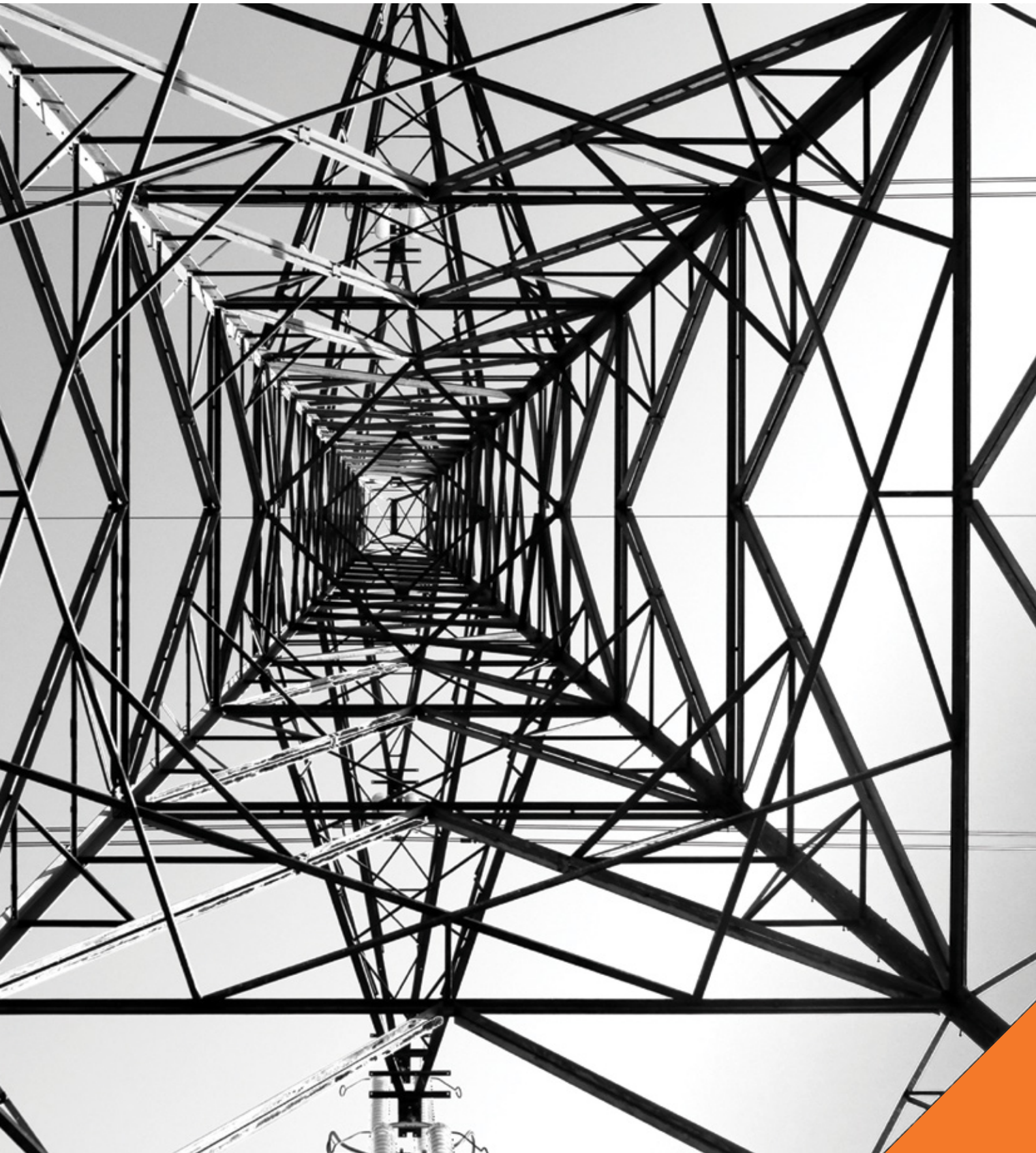
ICE's current whistleblowing guidance to members makes clear that the Institution itself cannot act as a trade union or representative.[31] Furthermore, members would not acquire the whistleblowing protection that they would through other paths. ICE's investigatory and enforcement powers are limited, suggesting that a signposting and information service is the best route to take.

Whilst members may not always feel empowered to raise concerns about construction or whole-life operational safety of an asset to their employer, the Institution should do more to inform members about escalating their concerns properly, transparently and supported by evidence, within their own organisations in the first instance and to a relevant prescribed body if not acted upon. Advising on the appropriate wording used to raise a concern in the right way or signposting to an organisation such as HSE or Public Concern at Work are methods to achieve this. ICE could do more to highlight existing information and make clear to members that routes to raise concerns exist, empowering their ability to interrogate quality and act ethically to assure the whole-life safety of infrastructure.

Recommendation 4:

Encourage engineers to highlight unaddressed infrastructure concerns, risks and near misses to their management and provide guidance via the ICE website on suitable confidential reporting channels should these become necessary.

28 Public Interest Disclosure Act 1998
29 BIS (now BEIS) (2015), Whistleblowing: Guidance for Employers and Code of Practice
30 BEIS (2018), Whistleblowing: list of prescribed people and bodies
31 ICE, Whistleblowing – Guidance to ICE members



Section 4: Competence

Competence can be defined as the combination of training, skills, experience and knowledge that a person has and their ability to apply them in performing a task effectively. Factors such as attitude and physical ability can also affect someone's competence.[32]

Ensuring and delivering competence for the benefit of society is a fundamental raison d'être of ICE. ICE was created to share knowledge to develop and maintain competence, while its Royal Charter requires the Institution to deliver competent civil engineering as a societal value.

Competence in civil engineering is delivered at both a personal and corporate level. Education, training and experience deliver personal competence, while the ICE Professional Review validates it. Corporate governance protocols deliver and validate corporate competence. The prevalence of self-certification, the ever-evolving digital agenda and the advent of new ways of working make it even more important to ensure today's engineers remain competent.

Human nature, however, means that errors occur. Effective measures must be in place to reduce the risk of failure, be it by mistake, incompetence or malicious act. The profession and industry must be the provider and validator of those measures, checks and procedures.

The Hackitt Review identifies competence as a core area for change. It notes that, while there are many competent people working within the system, the lack of a coherent and comprehensive approach to competence can seriously compromise safety. This is particularly so when decisions are taken or materials installed by people who do not fully understand the implications of how to achieve good-quality work, as well as the implications of getting it wrong.

Competence is not about a single event in time in personal or corporate life; it is a continuous improvement requirement – a lifelong learning – always updated with the latest knowledge and thinking, and incorporating lessons learned. In that sense, it is a whole-life activity.

Within that whole-life activity inevitably comes change, for example working in differing fields, specialising in a core area, and promotion into management and, potentially, director roles. Additionally, civil engineers can have a significant influence on high-level infrastructure development policy – this requires expertise across a broad range, building upon experience of the main discipline.

1. Continuing Professional Development (CPD)

Our world is changing rapidly, and our profession must similarly evolve. All members will therefore need to continue learning – and at increasing pace – throughout their careers. As professionals, members also need to demonstrate this to employers and to clients. ICE can adapt its existing system, making it more robust, and therefore of greater benefit to members.

ICE has in place a process to develop professional Incorporated and Chartered Engineers through Initial Professional Development (IPD), taking them through formal training, individual examination and an interview by their peers to confirm their competence as civil engineers. Individuals' training and CPD is reviewed at the Professional Review stage.

As a member's career develops they agree, in line with the Code of Professional Conduct, to develop their professional knowledge, skills and competence on a continuing basis and only undertake work they are competent to do. There is also a requirement to give reasonable assistance to further the education, training and professional development of others.[33]

ICE encourages members to anticipate what they may need to know in future, by drawing up a Development Action Plan (DAP), maintaining a Professional Development Record (PDR) and subsequently recording CPD. For those in the early stage of their career, this requires them to decide on their ambitions and career plans – what they need to learn for the next stage of their advancement, as well as keeping up to date with developments in their current role. Members confirm they have satisfied these requirements when they renew their annual membership.

32 Health and Safety Executive (HSE), What is competence?
33 ICE (2017), ICE Code of Professional Conduct

Mindful of developments in technology, materials, equipment, processes and delivery models, in 2017 the ICE Council asked Vice President Ed McCann to lead a review to ensure ICE members have the necessary skills to practise in an industry that is changing rapidly.[34]

McCann found that a culture of continuous learning needs embedding more deeply into the Institution and its members. His report also recognises that civil engineers who fail to keep abreast of changes affecting their areas of activity are unfit to practise. The report calls for ICE's CPD requirements to be reviewed swiftly, to establish a more robust system which ensures that a member's qualification remains relevant and up-to-date throughout their career. The report went further by saying that CPD must be much more than the 'tick in the box' which has frequently been seen in the past. CPD should be compulsory, related closely to the individual's required job skills, and appropriately audited.

This report echoes these findings, alongside the need to raise awareness of the importance of continuous learning and to ensure that appropriate learning resources are available.

Put simply, the current CPD model is no longer an adequate means of assurance. Developing a more robust approach to CPD is an essential measure in strengthening the lines of defence against infrastructure failure.

The Engineering Council requires all PEIs to introduce compulsory recording of CPD from January 2019.[35] This requirement was endorsed by a ballot of ICE's membership in July 2018. The requirement to *undertake* CPD has always been mandatory; however, ICE members are now required to *record* their CPD.

With the finding from the ICE skills review that the current CPD model is not an adequate means of assurance, the Engineering Council directing that the recording of CPD become mandatory with effect from January 2019, and with sanctions applying from January 2020 for those failing to comply, now is the time for ICE and other PEIs to strengthen their CPD monitoring and enforcement regimes.

Advances in online apps have made the planning and recording of CPD simpler and quicker. Other PEIs have already introduced such capabilities. So it is now timely for ICE to establish a suitable electronic system for capturing and monitoring members' CPD activities.

The whole-life learning process should also be strengthened by introducing a comprehensive assurance system to help members capture and record CPD activities that are relevant and tailored to the individual.

At present, ICE calls for CPD records to be submitted annually from 10% of the membership and audits 10% of those records called in. Consequently, CPD records from some 1% of ICE's members are checked. Whilst this complies with Engineering Council guidelines, an automated system of recording would readily enable a larger sample of members' CPD records to be audited. If ICE were to audit CPD records of 10% of its membership annually, a ten-fold increase, this would provide even greater assurance.

Finally, Professional Reviews are usually carried out at a relatively early stage of a member's career, typically in their mid to late 20s. ICE should explore with the Engineering Council and engineering employers whether it is appropriate to consider periodic evaluation of members' competence by peer-review. Given the rate of change in the industry and society, it could be appropriate to assess members' competence throughout their careers, at intervals of ten years. This would come with significant resource implications, but would enable PEIs to offer far greater assurance to society of the ongoing competence of their members.

Recommendation 5:

Establish an electronic system that captures ICE members' CPD activities, increasing tenfold the CPD returns audited annually; and work with the Engineering Council to explore introducing periodic mid-career peer reviews.

34 ICE Skills Review Group (2018), ICE Professional Skills
35 Engineering Council, Continuing Professional Development

2. CPD content development

ICE hosts a number of oversight bodies, including statutory and non-statutory panels and specialist registers.

The Reservoirs Panel, the only statutory register, was created under the UK's legislative powers to ensure that competent engineers supervise, monitor and inspect all reservoirs of a size that fall within the Reservoirs Act 1975. ICE provides the professional home and support for the Panel on behalf of Government.

Non-statutory groups and specialist registers within the umbrella of ICE include:

- Conservation Accreditation Register for Engineers (CARE)
- Dispute resolution registers, including on adjudication and arbitration
- European Engineer Register
- Health and Safety Register
- International Professional Engineers Register
- Register of Accredited NEC Professionals
- Register of Security Engineering and Specialists (RSES)
- UK Register of Ground Engineering Professionals (RoGEP)

These groups and registers help ensure the availability of relevant knowledge to its members to help support their competence and provide 'matter of moment' knowledge in their own area of expertise. This knowledge is vital in the context of CPD. Core CPD can be informed by the thinking of experts on relevant panels and societies.

Engineering specialisms are on the increase and generalist all-rounders are diminishing. It can be hard for specialist engineers to sift out and identify generally useful or widely applicable CPD development priorities. This might include learning from near misses and incidents, systems thinking and whole-life asset management learning for example. ICE could do more to direct members towards priority core CPD areas, to go alongside their own individual, tailored requirements.

ICE is a Learned Society as well as a professional body. In order to remain relevant today and into the future the Institution has reviewed its Learned Society structure and function. To appeal to a broader group of members and infrastructure professionals, as well as provide more focused and timely knowledge content, the ICE is reviewing the composition and function of its communities of practice. This will enable a more agile response of knowledge needs and a strong governance model.

ICE should investigate how it might utilise the strength of its multidisciplinary panels in creating bodies of knowledge for members to access to keep up-to-date with important developments and lessons learned in key areas of the profession. Such groups could form peer-review focal points for receipt and approval of all relevant information before it becomes CPD.

Recommendation 6:

Identify and communicate mandatory risk-related topics, themes and reading lists for members to include in their annual CPD learning.

3. Code of Professional Conduct

In common with most professional institutions, ICE has a Code of Professional Conduct setting out the professional and ethical behaviour required of a member. The Code applies to all members, irrespective of their grade, professional role or location. Under the Code, members have a responsibility to the public good and are to be honest in dealings with clients, colleagues and other professionals. This includes only undertaking work that they are competent to do.

ICE Code of Professional Conduct

ICE's current Code of Professional Conduct came into effect in 2004 and received its most recent update in 2017. It sets out the standards of professional conduct and ethical behaviour by which members should abide:

1. All members shall discharge their professional duties with integrity and shall behave with integrity in relation to all conduct bearing upon the standing, reputation and dignity of the Institution and of the profession of civil engineering.
2. All members shall only undertake work that they are competent to do.
3. All members shall have full regard for the public interest, particularly in relation to matters of health and safety, and in relation to the well-being of future generations.
4. All members shall show due regard for the environment and for the sustainable management of natural resources.
5. All members shall develop their professional knowledge, skills and competence on a continuing basis and shall give all reasonable assistance to further the education, training and continuing professional development of others.
6. All members shall:
   a. Promptly notify the Institution if convicted of a serious criminal offence;
   b. Promptly notify the Institution upon becoming bankrupt or disqualified as a Company Director;
   c. Promptly notify the Institution where the member, in good faith, believes there has been a significant breach of the Rules of Professional Conduct by another member;
   d. Promptly notify the employer or relevant authority where the member, in good faith, has a concern about a danger, risk, malpractice or wrongdoing which affects others (but this shall be an obligation only where the law of the relevant jurisdiction provides protection for such good-faith reporting under 'whistleblowing' or similar legislation), and;
   e. Support a colleague or any other person to whom the member has a duty of care who in good faith raises any issues covered by Rules 6c or 6d.

ICE's Professional Conduct Panel (PCP) comprises ten to twelve members and meets four times a year to deal with claims about improper conduct of members. Sanctions include membership suspension and fines. Every member that appears in front of the PCP must disclose their CPD record, which acts as evidence that the member is competent to do the job.

Members work in a very different world compared even with a few decades ago. Clients often seek engineering services on a commoditised basis using frameworks. Computer systems that use complex algorithms or artificial intelligence may provide new sources of confidence to clients, who may not always have access to engineers at the right time, with the right perspective. Further, the Panel heard about an increasing possibility of engineers operating beyond the limit of their professional competence – for example, when a broad-based engineer works in areas requiring deeper technical expertise or conversely when a technical expert takes on a wider infrastructure management role.

All members must be fully aware of the Code of Professional Conduct, what it means in practical terms, and abide by it. Steps must be taken to ensure that this happens on a regular basis throughout a member's career.

Compliance with the Code of Professional Conduct could be reinforced by suitable guidance and education; and by publicity being given to sanctions handed down through the disciplinary procedures for non-compliance.

Recommendation 7:

Strengthen awareness of ICE's Code of Professional Conduct through guidance, education, disciplinary processes, sanctions and publicity.

Section 5: Governance

1. Accountability

At the head of all infrastructure-owning organisations, a board or committee holds the ultimate accountability for the safe operation of its infrastructure assets, whether the organisation is publicly or privately owned. The effectiveness of this governance body is a separate and distinct line of defence against the risk of asset failure. A board may delegate the responsibility for the safety of an infrastructure asset to a third party (e.g. a contractor) or a nominated individual, but it cannot delegate its accountability. That third party or individual must be a SQEP, requiring the CPD assurance as outlined in the previous section.

The effectiveness of many of the lines of defence described in this report relies on qualities such as competence, professionalism, values, compliance and culture. The status and consistency of these qualities within an organisation starts at its top. For example, if the board does not adopt safety as a core value, then there is little chance of its being treated as such by the rest of the organisation.

There are two reasons why the governance of infrastructure assets requires a higher standard than the norm.

First, the consequences of failure can be extreme compared with the business of boards which are not accountable for infrastructure assets, given that these assets, and their formation, have the capacity to injure or kill – potentially on a large scale. Hence, whatever is true of good governance in general is doubly true in the case of infrastructure.

Second, the environment in which infrastructure assets are formed, owned and operated is typically characterised by multiple stakeholders who have enduring interests in the way an asset is designed and managed. Their voice is an important influence on the board's decision-making, requiring specific stakeholder engagement processes.

It is appropriate to consider not only an individual's SQEP status, but also that of boards and committees as collective decision-making bodies. This does not mean all individual board members should themselves be SQEP across all aspects of their organisation's activities. Rather, a board should collectively be able to discharge its duty as the accountable asset owner. In particular, boards need to have a range of expertise and skills that enable them to understand the risks and establish clarity of accountability and responsibility for health and safety at all stages of an asset's life.

The formation of new assets adds less than 0.5% each year to the total value of UK infrastructure.[36] Responsibility for operations and maintenance passes over time between successive individuals or organisations, each of which acts as the asset's steward, with a responsibility to safeguard the asset for future generations in accordance with its design life. Stewardship of existing assets is therefore vital and just as important as the design of new assets. Whether an asset is new or old, data relating to its design, construction, maintenance and safety must be retained and passed onto its successive owners and managers when the time comes. The Health and Safety File is a key tool in this regard. Failure to do that properly undermines this important line of defence.

36 Cambridge Centre for Smart Infrastructure and Construction (2017), Smart Infrastructure: Getting more from strategic assets

2. Safety criticality

Some sectors, such as rail, aviation and nuclear, have mature, well-established regulatory mechanisms to protect against failure during the asset's life. The Government may now extend this model to cover higher-risk residential buildings (or HRRBs), as defined in Dame Judith Hackitt's independent review. This raises questions about whether other infrastructure sectors, even if not formally regulated, ought to adopt investment procedures such as preparation of a mandatory 'safety case' as a control point that entrenches the importance of health and safety for all infrastructure asset formations, modifications and renovations.

In addition, Dame Judith's report calls for a 'golden thread of information' to be established at the start of the construction process and handed over to successive asset owners to enable them to manage their asset better. An example of this is the Health and Safety File, which acts as a repository of data and is updated throughout the asset's lifecycle.

The HSE, enforces a common set of regulations for the management and mitigation of health and safety risks in the workplace. With the support of the HSE, the construction industry has made significant progress in improving the health and safety of its employees over the past two decades – the rate of fatal injuries in construction has fallen from 4.6 per 100,000 workers in 1997/98 to 3.4 in 2007/08 and, in the 2017/18 period, stood at 1.6 per 100,000 workers.[37, 38, 39] This progress in steadily reducing workplace incidents in recent years gives considerable cause for encouragement as to what is possible if all stakeholders within a sector – starting with boards and other governance bodies – commit to reducing long-term risk during assets' lifecycles.

There is little guidance available to help decide when an asset class is 'safety critical', other than by looking at historical catastrophic failures. The safety criticality of all asset classes should be regularly reviewed and an enhanced level of risk management should be associated with certain designated assets.

But the industry is not a single entity, nor is it static. Across all sectors, organisations follow the Construction Design and Management (CDM) regulations and other safety-related legislation throughout the asset lifecycle, but with no mandatory reporting on compliance levels nor active policing by some of the regulators, other than when something goes wrong.

The Panel does not believe the Government has any cause to extend regulation to infrastructure in a general sense. However, as seen with the Hackitt Review, there is a case for better defining duty holder responsibilities when it comes to safety critical infrastructure.

It is interesting to compare and contrast the infrastructure and accounting worlds. Chartered accountants, on the one hand, have a statutory role in annually auditing and certifying the accounts of large– and medium-sized firms. Engineers, on the other, have no such obligations relating to the safe, continued use of infrastructure assets, except for dams and reservoirs. At face value, this seems strange: assets come into being through complex design and construction processes involving many management interfaces; they may subsequently change hands as investors buy and sell them. Over time, data records are lost or become neglected. And yet, people's lives depend on infrastructure remaining safe to use. That there is no overall statutory certification process relating to the continued safety of infrastructure assets is a major missing line of defence.

It seems incorrect not to have an engineering certification process in place for infrastructure assets (other than dams and reservoirs) when human lives depend on bridges staying safe, on buildings staying intact, on embankments staying put, on signalling always working, on electricity flowing and so on. ICE has a thought leadership role to play in a structured discussion with Government policy makers, including the Infrastructure and Projects Authority (IPA), regulators and industry on the topic of mandatory certification.

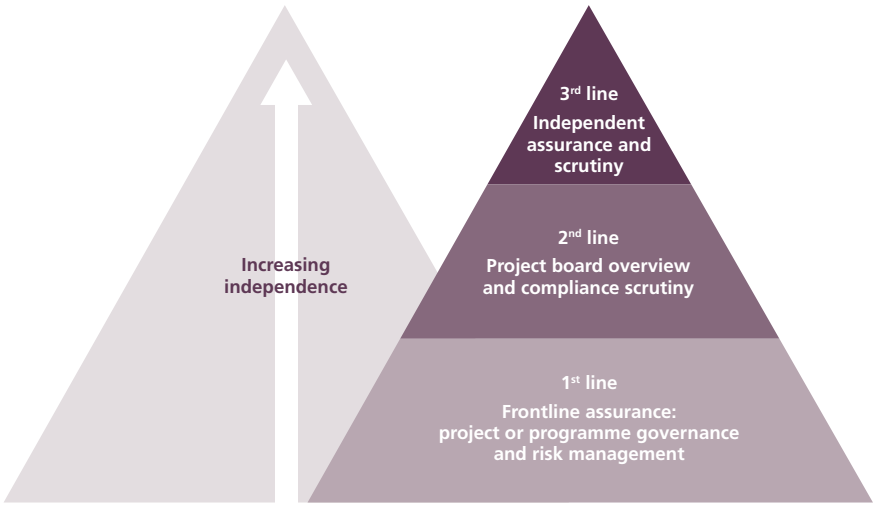
Recommendation 8:

Work with Government to identify any new safety-critical asset classes requiring lifecycle statutory certification.

37 Health and Safety Commission (now HSE), Health and Safety Statistics 2000/01
38 Chartered Institute of Building (2009), Health and Safety in the Construction Industry
39 HSE (2018), Workplace fatal injuries in Great Britain 2018

3. Independent scrutiny and assurance

Figure 4: The pyramid of assurance



Independent assurance is a vital line of defence at every stage in the infrastructure management cycle, from design, through to asset creation through to whole-life operation. It is a key part of good management for an organisation to provide accurate information to its stakeholders about the efficiency and effectiveness of its policies and operations, and about the status of its compliance with contractual and statutory obligations. It helps guard against groupthink, against human error and against system or process failure.

Independent assurance will often have a positive effect on the behaviour of all parties to a project, even before checking starts. It is at its most effective in defending against blind spots when it is part of a deliberate hierarchy of control.

Figure 4 outlines three broad lines of assurance:

- **First line of assurance (Frontline)** – This is carried out from within the project. Examples include project planning, risk management, project reporting and project or programme specific governance arrangements.
- **Second line of assurance (Project Board Overview and Compliance Scrutiny)** – The corporate governance arrangements, both in the employer's and supply chain's organisations, provide assurance that the frontline controls are working and of compliance with design criteria, construction controls and operating standards. This may involve self-certification processes, accreditation standards and systems and, sometimes, insurance support.
- **Third line of assurance (Independent Assurance and Scrutiny)** – This provides independent validation that the first and second lines of defence are robust. External reviewers, checkers or inspectors who are SQEP with knowledge of current practice, provide technical or project-management assurance usually in support of investment decision points.

The amount of effort invested in project assurance usually reflects the level of risk during design, construction or operation. In terms of relative effort, the frontline assurance activity usually consumes the most resources, with independent assurance the least.

The Panel sees increasing complexity in the way clients organise their design process, their construction supply chains and their operational support service contracts. Mature infrastructure organisations set the tone properly at the outset by establishing effective governance regimes supported by well thought-through independent assurance mechanisms. The key to success is in thinking through the three levels of the assurance hierarchy and putting the whole regime in place at the very start, with appropriate resources.

4. The role of the infrastructure owner

Robust governance, independent certification of asset safety and strong effective assurance regimes constitute three strong lines of defence against infrastructure failure. Infrastructure owners may understand those principles, but may not be clear on how to implement them. There have been some calls across the construction and infrastructure sectors for the reintroduction of the roles of Clerk of Works or Resident Engineer. However, major advances in the industry's practices, such as the evolution of modern forms of contract, mean that reintroduction of those roles would be a retrograde step. And, of course, it is worth bearing in mind that these roles were not infallible.

The Panel's view is that it is more important to contemplate the idea of a system-wide approach, with the engineer playing a stronger part in the central ground in whole-life asset stewardship. Modern methods of procurement and project management mean that the engineer is often a part-contributor rather than the enduring guiding voice as assets are designed, built and maintained.

One of the issues highlighted by the Grenfell disaster is the importance of considering the interaction between the different elements or systems that compromised the tower's integrity. Just as Reason's Swiss Cheese Model comprises many lines of defence, any piece of infrastructure consists of interacting systems – be they brick and mortar, or steel and concrete, or signals, wheels and structures. Every interface between systems generates risk, hence the importance of the engineer's voice in aggregating and understanding the whole system risk.

The Panel's conclusion is that the three themes explored above relate to each other. The Institution can play a major part in addressing the weaknesses that are still opening up in the lines of defence against catastrophic failure risk.

It seems wrong that infrastructure owners may know broadly, but not sufficiently, what to do in terms of organising, designing, delivering and maintaining their assets. The Institution could again take a thought leadership position in terms of defining the expected roles of a competent dutyholder – for example with regard to data collection and retention, life-safety principles, procurement arrangements, delivery, handover and operational processes, behaviours and culture. Much good work is already happening in this area, for example, the work of Project 13, and it would not be a major leap to create a best-practice charter for infrastructure owners to sign up to.

Charter for effective ownership of infrastructure assets

1. Developing an organisational culture geared towards designing, creating and maintaining whole-life, system-wide asset quality and safety.
2. Appointing and empowering a SQEP, either an individual or body, as the pivotal point of accountability for each asset at all times in its lifecycle.
3. Making the Health and Safety File the central lifecycle control document, kept up to date and relevant.
4. Establishing purposeful SQEP governance, with a commitment to independent assurance.
5. Gathering, reconciling and reporting asset-condition data throughout its lifecycle.
6. Adopting investment-case evaluation processes geared to long-term fitness for purpose, safety and value for money, both for new and existing assets.

An essential line of defence is in having robust governance and independence assurance regimes operating in harmony. It would be helpful to publish a 'How To' guidance note on best-practice arrangements for governance and assurance in infrastructure creation and management. The principles are straightforward but easily neglected; having an overt benchmark in place would be a powerful enabler.

Recommendation 9:

Set out the responsibilities of a competent infrastructure owner and work with Government to promote a voluntary charter.

Recommendation 10:

Work with other professional institutions to promote a whole-systems multi-disciplinary approach for the lifetime safety of infrastructure assets.

Section 6: After the incident

The Civil Contingencies Act (2004) places statutory duties on many organisations in the UK to prepare for and respond to major incidents and emergencies. This was passed into law following a number of incidents in the UK and overseas, which ranged in size, location and cause, but all affected people and communities. The reviews undertaken after these incidents identified common areas for improvement, such as better joint working between responding organisations, better capabilities and equipment, and better communication processes.

In the immediate aftermath of a disaster, in what may be a confusing and perhaps safety-critical environment, accessing experts who can provide immediate help and specialist advice can take too long. Often this is because a list of named experts in that field does not exist, information on prior incidents – including that from international examples – has not been shared, or planning for an incident has not been appropriately considered. While not universal, past examples of responses to infrastructure incidents globally have tended to be haphazard and uncoordinated – a criticism levelled, for example, at the response to the King's Cross fire in the UK in 1987.[40]

While most post-incident response strategies are kept confidential, it is critical for asset owners to understand the importance of carrying out post-incident evaluation to build back and strengthen their lines of defence. Contingency planning for an incident is also vital.

1. Preparing for an incident

Asset owners usually consider, develop and maintain post-incident responses within the asset's specific local operational environment. The nature of the incident can vary greatly, but preparedness planning determines the initial response, the responsibilities, the longer-term response and any mitigating strategies. Engineers often assist in preparedness planning, augmenting the capability of the wider response team to deal with an incident and provide expertise.

A virtual training environment can enhance the process of testing emergency response plans. Improved training performance, remote participation and evidence of decision testing are strong benefits.[41]

The PEIs, through either expert panels, groups or other channels, have access to networks of specialists. At present, those networks represent a largely unharnessed and untapped resource pool; mechanisms are not in place to enable a rapid coordinated response from the PEIs to an infrastructure disaster. It would not be difficult for the PEIs, working collaboratively, to draw together and maintain lists and contact details of named experts to prepare for and stand ready in support of different types of infrastructure failure. This level of preparedness would be useful to the government, emergency services and the wider industry, saving time in what can be challenging, pressing environments.

40 Department for Transport (1988), Investigation into the King's Cross Underground fire
41 Rogage, K (2018), Virtual training environments for major incident response planning in UK gas infrastructure, International Journal of Disaster Resilience in the Built Environment, Vol. 9 Issue: 2, pp.130-144

Case study box – ENGAGE, New Zealand

Several temporary entities facilitated the infrastructure recovery and rebuilding process following a series of earthquakes across the South Island of New Zealand between 2010 and 2012. But governance and management duplication, a localised focus and specific responsibility on earthquake recovery meant other disasters, such as flooding in other parts of the country, did not form part of their remit.

As a result, in 2018 a pan-New Zealand not-for-profit disaster readiness group called ENGAGE was established. Comprising government (national, regional and local), construction and infrastructure leaders, managers, designers, subcontractors and suppliers, community representatives and the Red Cross, ENGAGE is a collaborative network of expertise and competence that prepares for future disasters. It aims to create a pool of talent to rebuild help after a disaster, while improving the existing construction and infrastructure sector by equipping it with better knowledge, skills and experience. The model means the various stakeholders focus on risk management and mitigation, and understand the process and their respective responsibilities.

This approach recognises that no single organisation or government body has the capacity or capability to respond to an incident and that collaboration in preparedness is vital to assuring the whole-life safety of infrastructure.[42]

2. Learning from failure

First responders to an incident will always be the emergency services.

Following that, there needs to be a swift understanding of an incident's causes and an immediate sharing of lessons learned, within the constraints imposed by investigating authorities and insurance companies.

Where relevant, the lessons learned would feed into the annual event on incidents and near misses, referred to earlier in this report and in Recommendation 3.

Recommendation 11:

The chief officers of ICE and relevant professional institutions to maintain a coordinated disaster response capability and triage decision-taking process, to help Government and the authorities respond to an infrastructure incident.

42 ENGAGE, www.engagenow.org.nz

Section 7: Summary of recommendations

To mitigate the risk of infrastructure failure the Institution of Civil Engineers and the wider infrastructure sector should:

1. Strongly promote the Swiss Cheese Model concept of risk management, emphasising that all engineers have roles to play in mitigating and managing infrastructure risk.
2. Work with professional bodies to scope, sponsor and find funding for a sector-wide organisation to review, comment on and disseminate lessons from concerns, near misses and catastrophic incidents, building on the work of Structural-Safety.
3. Run an annual event with HSE on infrastructure near misses, incidents or forensic reports, to promote understanding and identify sector-wide responses.
4. Encourage engineers to highlight unaddressed infrastructure concerns, risks and near misses to their management and provide guidance via the ICE website on suitable confidential reporting channels should these become necessary.
5. Establish an electronic system that captures ICE members' CPD activities, increasing tenfold the CPD returns audited annually; and work with the Engineering Council to explore introducing periodic mid-career peer reviews.
6. Identify and communicate mandatory risk-related topics, themes and reading lists for members to include in their annual CPD learning.
7. Strengthen awareness of ICE's Code of Professional Conduct through guidance, education, disciplinary processes, sanctions and publicity.
8. Work with Government to identify any new safety-critical asset classes requiring lifecycle statutory certification.
9. Set out the responsibilities of a competent infrastructure owner and work with Government to promote a voluntary charter.
10. Work with other professional institutions to promote a whole-systems multi-disciplinary approach for the lifetime safety of infrastructure assets.
11. The chief officers of ICE and relevant professional institutions to maintain a co-ordinated disaster response capability and triage decision-taking process, to help Government and the authorities respond to an infrastructure incident.

Appendices

Appendix A: Terms of reference

Background and purpose of the review

Following the Grenfell Tower disaster, the Institution of Civil Engineers (ICE) commissioned an independent review to identify any action to improve public safety that should be taken by the civil engineering and infrastructure community. The review seeks to identify and address systemic issues that may possibly increase the risk of a serious failure of infrastructure assets in the UK.

An interim report, 'In Plain Sight', was published in November 2017, which recommended that ICE should establish three task and finish groups to undertake further exploratory work in the following areas

- competence
- governance
- lesson sharing.

The report also recommended that ICE commission an academic exercise to assess the validity of the 12 lines of defence model that its core recommendations were based upon. This has been undertaken by Loughborough University and the findings were that using the model is appropriate, as it is well recognised and understood by a wide range of stakeholders.

ICE will prepare a final report for publication in autumn 2018. This report will draw together the outcomes and findings of the previous stages of work, including: the interim report, the three task and finish groups and the validation exercise. It will also consider events and developments that have occurred since the publication of the interim report.

Relationship to other reports

The final report will reflect on and take into consideration recommendations made in other parallel reviews, including: the *Independent Review of Building Regulations and Fire Safety* and the official Public Inquiry. Its findings and publication will also be coordinated with other key organisations with a specific interest in its remit, including: the Construction Industry Council, Royal Academy of Engineering and the Engineering Council.

Appendix B: Acknowledgements

The Panel would like to thank the following people for their contribution to the review.

Task and finish groups

Sharing of lessons

- Alasdair Reisner, Civil Engineering Contractors Association (Chair)
- Philip Baker, Transport for London
- David Hirst, Ainsty Risk
- Mike Napier, Independent
- Alastair Soane, Standing Committee on Structural Safety

Competence

- Richard Coackley CBE, AECOM (Chair)
- Roger Allport, Imperial College London
- Amanda Clack, CBRE
- Kyle Clough, Kier
- Guy Rigby, Independent
- Jane Smallman, ICE Vice-President

Governance

- Helen Samuels, Network Rail (Chair)
- Mark Fulton, Pivotal
- Mark Lunn, Horizon Nuclear Power
- Frances Morris-Jones, Oil and Gas Authority
- David Pocock, CH2M

Other contributors

- Dr Lee Bosher, Dr Ksenia Chmutina, Professor Andrew Dainty, Professor Alistair Gibb from Loughborough University
- Ian Hodge, Environment Agency
- Ayo Sokale, ICE President's Future Leader
- Pinsent Masons

The Panel would also like to thank the organisations and individuals that contributed to the interim report. A full list of contributors can be found in Appendix 2 of the interim report.

Appendix C: Terminology used and abbreviations

General

The Panel considered the term 'infrastructure failure' to be in line with the definition used by the Health and Safety Executive (HSE) in its 2011 report, *Preventing Catastrophic Events in Construction:* 'events that are beyond the ordinary or routine… characterised by being of low probability but high consequence'. This includes consequences of:

- potential for multiple deaths and serious injuries in a single incidence and/or serious disruption of infrastructure (e.g. road, rail) and/or services (e.g. power, telecoms)

and includes the following features:

- ability to adversely affect organisations commercially either directly or through loss of reputation -
- creation of public demand for action, possibly leading to demand for a public inquiry and/or changes to relevant legislation.

Specific

- Assurance – in the context of this report, the Panel considers assurance of the whole-life safety of infrastructure to be a combination of knowing, applying and ensuring.
- BIM – Building Information Modelling or Building Information Management. BIM is a process for creating and managing information on a construction project across the project lifecycle.[43]
- CDM – the Construction (Design and Management) Regulations 2015. These are the main set of regulations for managing the health, safety and welfare of construction projects. CDM applies to all building and construction work and includes new build, demolition, refurbishment, extensions, conversions, repair and maintenance.
- Competence – the combination of training, skills, experience and knowledge that a person has and their ability to apply them to perform a task effectively. Factors such as attitude and physical ability can also affect someone's competence.[44]
- CPD – Continuing Professional Development.
- Governance – the set of policies, regulations, functions, processes, procedures and responsibilities that define the establishment, management and control of projects, programmes and portfolios.[45]
- Government Soft Landings (GSL) – a procurement initiative where designers and constructors stay involved with the asset beyond practical completion.
- HSE – Health and Safety Executive.
- Independent Review of Building Regulations and Fire Safety – a review commissioned by Government following the Grenfell Tower disaster. Led by Dame Judith Hackitt and published in May 2018, it examined building and fire safety regulations and related compliance and enforcement with a focus on multi-occupancy high-rise residential buildings.
- PEIs – Professional Engineering Institutions, such as ICE.
- SQEP – Suitably Qualified and Experienced Person(s).

43 NBS, 2016, What is Building Information Modelling (BIM)?
44 Health and Safety Executive (HSE), What is competence?
45 Association for Project Management, 2012, APM Body of Knowledge 6th edition

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