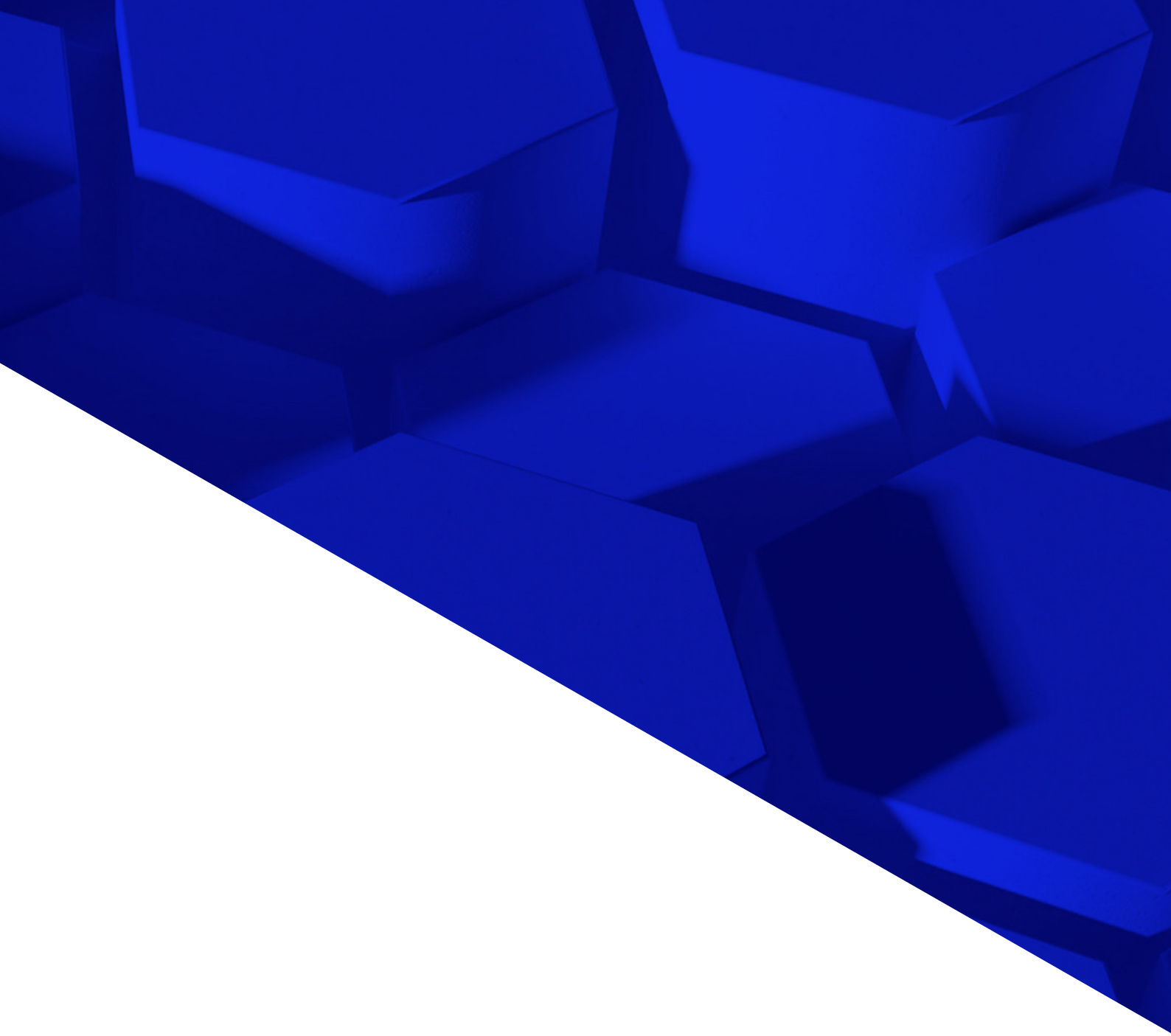

The Digital Innovation Imperative

Advancing progress towards a digital built Britain

September 2021

CONSTRUCTION INNOVATION HUB

INDUSTRIAL STRATEGY

UK Research and Innovation

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1.0 Context: The time to act is now

The ripples of infrastructure decisions are wide. Our modern lives continue to be shaped by decisions made by the Romans and Victorians. As digital technology and data increasingly permeate throughout our lives, we are presented with a unique opportunity to harness them to ensure the decisions we make about our built environment today enable a bright future for tomorrow.

To be resilient to risk and uncertainty we must know where the built environment is performing beyond its design life and intended capacity. The interconnectedness of our infrastructure means the effects of one failure can be wide ranging, setting off a chain reaction of subsequent failures and issues. Insights from data and the application of new technologies can help improve asset performance; increasing resilience and adaptability as well as identifying potential points of failure and means to both prioritise and defer capital investment and the replacement of existing assets.

Ten years ago, HM Government set out an ambition to embed Building Information Modelling (BIM) into centrally procured government construction projects from 2016. This set up the UK as a world leader in information management in the built environment, with UK standards now adopted as the international standard worldwide.

Improving construction sector efficiency was just the beginning. Through the Centre for Digital Built Britain, and a continued concerted effort through central government policy, a shift to digital by default throughout the built environment is occurring as organisations embrace data-driven decision-making.

The built environment is key to the UK economy and its environmental footprint, and the use of data critical to helping to mitigate it's impact. Infrastructure systems currently contribute the majority of the UK's emissions, with transport and energy alone account for around 60% of the UK's CO2 emissions.[1]

The construction sector contributed £118.9 billion to the economy in 2019 and supported over 1.28 million jobs.[2] The UK stands to gain an estimated £7 billion per year in economic benefits from the digital transformation of its infrastructure industry,[3] but this first requires a concerted effort to digitise our existing assets.

Worldwide responses to the Covid-19 pandemic provide an unprecedented opportunity. Government economic recovery packages worth trillions of dollars have prioritised significant investment in infrastructure. In the UK up to £37 billion of public sector contracts across economic and social infrastructure will be brought to market over the next year.[4]

The **State of the Nation** outlined in this report suggests we are well-positioned to respond to government's call to build back better, if we strengthen our foundational capabilities and continue to innovate at pace.

Technology alone will not deliver meaningful change. A sustained, aligned, change programme is needed. Clients, professional institutions, trade associations and training providers must align initiatives to upskill the wider supply chain. We must work together to embed the foundational digital capabilities, such as the UK BIM Framework, to use better information to improve the way we design, build, operate and integrate the built environment.

The economic imperative is clear for the built environment sector to respond in new, more innovative ways. We can use digital tools and processes to tackle the sector's productivity challenge once and for all and to innovate to provide better outcomes for citizens and the environment. This is our **Vision** for a digital built Britain.

Above all, this report is a rallying call. If we do not accelerate the pace of innovation and adoption of digital technologies, we stand to cede our global position at the forefront of the digital built environment. Right now, we have an opportunity to do things differently: to protect and cultivate our natural capital whilst simultaneously reducing our dependency on fossil fuels, stimulating the economy and providing for the needs of future generation. The **Roadmap** sets out the expectations for us all as we continue on this journey.

1 Institute of Civil Engineers (2020) State of the Nation 2020: Infrastructure and the 2050 net—zero target. https://www.ice.org.uk/news-and-insight/policy/son-2020-infrastructure-and-2050-net-zero-target.
2 Office of National Statistics (2021) Construction Statistics, Great Britain, 2019. https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/articles/constructionstatistics/2019
3 National Infrastructure Commission (2018) Data for the public good. https://nic.org.uk/app/uploads/Data-for-the-Public-Good-NIC-Report.pdf

4 Cabinet Office (2020). Construction Playbook. https://www.gov.uk/government/publications/the-construction-playbook

2.0 Executive Summary

The UK has set bold targets for reducing social inequality, achieving Net Zero and improving the whole-life performance of our nation's built assets. From our homes to underlying water, waste, energy, communications and transport systems, these assets can work together to support human flourishing without compromising environmental goals.

The UK is a world leader in information management and has a bold vision for a digital built Britain: using data-driven decision-making across the investment lifecycle of the built environment to generate positive social, environmental, and economic impact. Yet there remains a gap between policy and practice, and we have not yet reached a critical mass of people and organisations with the right digital skills.

2.1 The capabilities to deliver a shared vision

In April 2021, more than 75 industry leaders and more than 35 cross-industry bodies from across the built environment have come together to publish a shared vision that calls for a built environment that enables people and nature to flourish together for generations. The Vision states that

> **"It is only when we shift our focus from creating the built environment to the outcomes enabled by it that people and nature can thrive together for generations to come."[5]**

Driving digitisation and innovation are critical enablers of the Vision. The Construction Innovation Hub commissioned this report to signpost the progress made so far and provide a roadmap for where more effort is needed to reach maturity. Its purpose is to inspire greater adoption of the capabilities needed to accelerate the digital transformation of the built environment to achieve this vision. It is written with policymakers, built environment decision-makers and current and future practitioners in mind, and targeted actions are presented for each stakeholder group [Section 11 – An Industry Roadmap]. It should be read alongside the recently published The Value of Information Management in the Construction and Infrastructure Sector report produced by KPMG and Atkins for CDBB on behalf of the Hub.

The roadmap towards a digital built Britain is not owned by one organisation. By moving in lockstep, we are already achieving change. Much more remains to be done, and more voices need to be heard.

2.2 Process

To prepare this report, the Construction Innovation Hub commissioned Atkins and Clementine Consulting to engage with expert stakeholders in academia, industry and government and undertake desk-based research to understand the UK's progress towards a digital built Britain. The scope of the work was to reflect the sector's progress since the government's BIM mandate came into effect in 2016 and to signpost where capabilities need to be developed.

The findings in this report are based on research and stakeholder engagement. Together, they serve to showcase the UK's progress towards a digital built Britain. The report identifies best practice and emerging thinking in each of these categories and areas where further action is required.

5 Centre for Digital Built Britain (2021) Our vision for the built environment. https://www.cdbb.cam.ac.uk/news/industry-unites-behind-vision-built-environment.

2.3 Key Insights

The vision for a digital built Britain

Stakeholders reviewed the 2017 vision:

> **"A digital built Britain harnesses the wealth of data being created by digital construction, high performing assets, smart cities, the digital economy and connected citizens to deliver a Britain that is fit for the future. The exploitation of data will enhance natural and built infrastructure services, driving up citizen quality of life and well-being, and commercial competitiveness and productivity."**

The consensus was that while the vision for a digital built Britain is still largely the same, it does need to be updated to reflect the challenges being face by the sector. To align with the cross-sector vision and current sector priorities, it needs to have a stronger focus on systems-thinking, the role of better quality data in improving social and environmental outcomes across the built environment lifecycle and public access to data.

> **"The public must have a say in data for the public good."**
> **– Workshop participant.**

State of the Nation

Stakeholders were engaged via workshops and a survey and asked to measure the sector's progress towards delivering the seven capabilities categories identified in the 2019 Capability Framework and Research Agenda for a Digital Built Britain: stakeholder value, services, built environment, data, information and models, governance, learning and adaptation, and context drivers and trends.

Analysis of responses showed that while the sector's adoption of BIM has improved construction efficiency and safety, challenges remain with quantifying the benefits of digital transformation and with data access, quality, and interoperability. Workshop participants commented that there is a gap between policy and practice, with further coordinated effort needed to improve consistency and address the digital skills gaps at every level of the built environment.

Stakeholders commented that the technical capabilities needed to realise a digital built Britain are largely developed, but adoption is slowed by a hesitancy to innovate, legal and cultural barriers.

There was an awareness that there is a lot of research underway and pockets of excellence across the sector. However, some stakeholders expressed there was not enough evidence, case studies, and support needed to underpin digital transformation at scale. There were also requests for greater clarity about the interdependencies and links between the digital initiatives led by the Construction Innovation Hub, CDBB, the Infrastructure Clients Group and the Construction Leadership Council.

2.4 What is a digital built Britain?

In a digital built Britain data-driven decision-making enables better outcomes from the built environment for people, the economy, and the planet. It will be achieved through changing the way we design, build, operate and integrate our physical, social and economic infrastructure and the services they deliver.

It is:

Data-driven: better data provides greater understanding about the real, predicted and potential performance of our built and natural environment: continuously improving decisions and outcomes.

People led: people are empowered with the skills, oversight, and voice to ensure inclusive, just and sustainable outcomes. We will all be citizens of a digital built Britain; we should all have a role in shaping it.

What is data-driven decision-making?

Insights from assured data can improve decision-making at every stage of an asset's lifecycle, from business case to decommissioning, to enhance societal, economic, and environmental outcomes from the built environment.

Digital tools and processes support stakeholder engagement so that our spaces are shaped by community needs and data is used for the public good. Secure, resilient information sharing empowers society to build digitally first to model the impact of infrastructure decisions on people, nature, and the wider system.

3.0 Report at a glance

Delivering a digital built Britain is founded in addressing key observations relating to the six capability focus areas.

Governance

Establishing how to govern and manage a digital built Britain and its most complex projects.

1. Policy can drive safety, cost efficiency and performance improvements when effectively implemented through procurement.
2. Digital initiatives should have a clear purpose and be proportional.
3. Data should be used responsibly, and citizens should have a say in data for the public good.

Value

Putting social, environmental and economic outcomes at the centre of data-driven decision-making about today's and tomorrow's infrastructure.

1. Value is being redefined.
2. Engage end-users in built environment decision-making.
3. Metrics for measuring and evaluating the benefits of digital need to be considered early.

Systems Thinking

Using data and digital tools to operate the built and natural environments, and the services they deliver, as an interconnected system.

1. The built and natural environments are complex interconnected systems and should be managed as such.
2. We need the right digital infrastructure to improve decision-making.
3. The right incentives need to be developed to improve data quality and sharing.

Information Management

Gaining insights from data and models to improve decision-making.

1. Interoperability should be considered up-front.
2. Information management is a core business function.
3. Information Management practices must evolve to support secure, resilient, data sharing.

Built and Natural Environment

Embracing digitalisation to transform the way we design, build, operate and integrate the built environment and its services to lessen impact on the natural environment.

1. The built and natural environment cannot be managed in isolation from each other.
2. Technology must be applied deliberately.
3. Removing barriers to innovation would improve lifecycle delivery and operation of the built environment and its interfaces with the natural environment.

Skills

Addressing the sector's digital skills gap.

1. A digital built Britain and the development of a National Digital Twin will create multiple new roles requiring new business and technical skills and competencies.
2. All digital initiatives should include a skills strategy.
3. We need a clear understanding of the current and potential gaps in our workforce skills and a roadmap to address this.

Sections 4 to 9 contain descriptions of each of the capabilities, including an evaluation of progress to date and areas requiring further attention – be it through greater definition, investment or understanding. You will find an overview of the capabilities expected from a digital built Britain in section 11 [the roadmap].

The current maturity of the related technologies, processes and examples for any capability category is shown using the following colour code:

- Areas where existing practice and knowledge can be adopted or adapted to build capability.
- Areas where practice and knowledge are being developed but more work is needed.
- Areas where there is little activity to develop the capabilities needed or where fragmented work needs unifying.

4.0 Governance

Governance refers to the capabilities needed to govern and manage a digital built Britain and its most complex projects.

Capabilities:

- G1 Supportive central government policy
- G2 Procurement frameworks
- G3 Safety frameworks
- G4 Security-mindedness frameworks
- G5 Gemini Principles
- G6 Defining the human-computer interface
- G7 Methods to minimise model bias
- G8 Digital ethics

4.1 Stakeholder insights:

Policy can drive safety, cost efficiency and performance improvements when effectively implemented through procurement.

Central government policy, including the introduction of the 2016 BIM mandate through the 2011 Government Construction Strategy, has enabled the adoption of digital tools and processes in the sector. Procurement models, safety and security frameworks are major enablers of the effective delivery of these policies, as well as private sector and local authorities' organisational strategies. Not acknowledging and accounting for digital requirements & drivers may limit the success of a project.

Digital initiatives should have both a clear purpose and proportionality.

Clients and practitioners should ensure that all digital initiatives have a clear purpose. Technology alone will not deliver meaningful change – it must be applied with a clear purpose and, in consultation with its intended beneficiaries, address specifically identified needs.

Resources are available to support clients and organisations to define the right level of digitisation, digitalisation, or digital transformation on a project, across a portfolio or at an organisational level.

Data should be used responsibly and citizens should have a say in data for the public good.

Decisions are increasingly driven by data. Robust governance frameworks and processes need to be established to ensure that data is collected, used, and shared in a way that ethical, just and appropriately transparent.

4.2 The capabilities explained

G1 Supportive central government policy

New policies published in support of the 2020 National Infrastructure Strategy are reaffirming the government's commitment to information management, and signposting the steps the wider sector need to take to achieve the digital transformation needed across the system of the built environment.

- **Construction Playbook and Treasury's Green Book:** Aimed at setting up construction projects and programmes correctly, the Cabinet Office produced this report to set clear guidelines for the central government departments and arms length bodies (ALBs) to implement the recommendations of the National Infrastructure Strategy. It promotes outcomes-based specifications to deliver better whole-life value and specifies the use of the UK BIM Framework on a comply or explain basis.
- **Building Safety Bill:** The Building Safety Bill is taking forward the fundamental reform of the building safety systems to assess the recommendations made in the Building a Safer Future review by Dame Judith Hackitt DBE. This will include recommendations for putting in place a 'golden thread of information'. Practitioners and clients should prepare for upcoming fire and building safety reform by upskilling in information management.
- **Transforming Infrastructure Performance: Roadmap to 2030:** The recently published policy paper by the Infrastructure and Projects Authority reaffirmed the government's commitment to BIM with a refreshing information management mandate.

G2 Procurement frameworks

Clients should review procurement frameworks to ensure alignment between policy objectives, such as Net Zero and the levelling up agenda, and decisions made during value engineering and project delivery. A number of resources are available to support this process.

- **Information Protocol Template:** Building on the Construction Industry Council's BIM Protocol, this resource, now in its third edition, is freely available on the UK BIM Framework website to support contracts that use ISO 19650.
- **Collaborative procurement:** Funded by Construction Innovation Hub, Professor David Mosey and Professor Campbell Middleton are leading a research team analysing programmes that have delivered significant improvements in long-term performance and better outcomes for all stakeholders through collaborative procurement and contractual techniques.

G3 Safety frameworks

Clients and practitioners should use better quality, digitally accessible, information to improve health and safety outcomes in project delivery, and throughout the life of an asset. All too often the 'golden thread of information' needed is not currently captured or adequately curated, meaning risks are not always flagged to the right users at the right time.

- **Improving Health and Safety Outcomes in Construction:** Making the Case for Building Information Modelling (BIM). In 2018 Health and Safety Executive's (HSE) Construction Division called for, but did not mandate, the increased use of the BIM methodologies during construction and the post-occupancy management of assets to improve health and safety outcomes in the construction sector.
- **Discovering Safety Programme:** Via Lloyd's Register Foundations funding, the Health and Safety Executive is delivering a programme to improve H&S through better insights from data. This includes using digital tools like 3D Repo's SafetiBase to collate a Risk Library as well as determining leading indicators for H&S risks to construction sites. Practitioners should engage with this programme to find ways to promote best practice and drive further, meaningful use cases.
- **Construction Leadership Council (CLC):** The Health, Safety and Wellbeing arm of the CLC is working closely with the HSE on how industry can focus on structuring, sharing and using its H&S data to augment the effective use of digital tools and techniques. As a representation of our industry, practitioners should glean advice from CLC's recommendations and engage as representatives of their respective areas.

G4 Security-mindedness frameworks

All organisations in the built environment must place great emphasis on security-mindedness. The increasing use of digital technologies, including BIM, across the lifecycle of built assets has led to a proliferation of data. This offers many benefits, but if security-mindedness is not applied and championed there is a risk that loss or disclosure of information could impact the safety, security, and resilience of:

- personnel and other occupants or users of the built asset and its services;
- the built asset itself;
- asset information; and/or
- the ability of the built asset to deliver its intended social, environmental and/or commercial benefits.[6]

- The Centre for Protection of National Infrastructure has produced a range of guidance on how to take a security-minded approach to digital engineering projects and initiatives, including BIM. Together with BS EN ISO 19650-5:2020 these resources provide a framework for the security-minded management of sensitive information that every organisation creating, using, or holding information about a built asset should consider.

G5 The Gemini Principles

These principles, developed as the guiding principles for the National Digital Twin, can be applied to any digital initiative to ensure it is appropriately co-designed with the relevant stakeholders. Enshrined in these values is the notion that all digital twins must have clear purpose, be trustworthy and function effectively.

Case study
National Underground Asset Registry (NUAR)

The Geospatial Commission has used the Gemini Principles to identify the appropriate data quality and digitisation approach required on the NUAR programme. The estimated economic cost of accidental strikes on underground pipes and cables is £1.2 billion a year. Using the Gemini Principles, the project team determined the purpose of the project was to digitise records to make them more accessible to help save lives and reduce the disruption caused by accidental strikes on underground pipes and cables. This informed the level of data quality required for the prototype system, which had to be fit for the purpose of strike avoidance when sharing data. The NUAR platform pilot publishes data "as is" and provides a feedback loop facility to flag data quality issues to data owners. The potential benefit of the NUAR is £245 million per annum. It is anticipated that collaborative sharing and the development of trust in the platform and its users will lead to incremental improvement of data.[7]

6 Centre for the Protection of National Infrastructure (2020) Establishing a dialogue about the security of digital built assets. https://www.cpni.gov.uk/digital-engineering
7 Centre for Digital Built Britain (2020) NUAR case study. https://www.cdbb.cam.ac.uk/news/case-study-NUAR-pilot-programme

G6 Defining the human-computer interface

We must define the human-computer interface more clearly. What decisions will it be safe and socially acceptable for a machine to make and what will require human input? Much more work remains to be done around the extent to which people will be able to interpret data, around transparent decision processes, and the creation of clear guidelines and processes for liability and accountability. We must ensure clear advocacy on behalf of people, living things and natural processes that are unable to speak for themselves.

In 2020, Ofqual used a computer-generated score to administer GCSE and A-Level results to pupils after exams had to be cancelled due to the Covid-19 lockdown. The use of the algorithm was revoked after the algorithm was discovered to reinforce existing inequalities in the UK's education system, thereby assigning lower scores to disadvantaged pupils from schools with historically lower success rates.

- A National AI Strategy will be published in late-2021 and is expected to address responsible use of algorithms in data-driven decision-making.

G7 Methods to minimise model bias

We must be able to trust the information being delivered in our models and on our apps. If we allow systems to semi-self-govern, we must develop ways to prevent systemic or historic bias from influencing data-driven decision-making. The Centre for Data Ethics and Innovation (CDEI) is connecting policymakers, industry, civil society, and the public to develop the right governance regime for data-driven technologies.

- CDEI's 2021 review into bias in algorithmic decision-making identifies concrete steps for government, regulators, and industry to build the right systems so that algorithms improve, rather than worsen, decision-making. Progress to implement these recommendations is ongoing.

G8 Digital ethics

Agencies and organisations are driving forward work to ensure the benefits of data and AI are justly and equitably distributed. The UK Government's Department for Digital, Culture, Media & Sport (DCMS) is collating existing ethical principles for data and AI, developed by government and public sector bodies. It intends to provide clarity and guidance for public servants working with data and/or AI.

- UK National Data Strategy: Updated at the end of 2020, the National Data Strategy drives the UK in building a world-leading data economy while ensuring public trust in data use. It views data and data use as opportunities to be embraced, rather than threats against which to be guarded. At the same time, it seeks to address privacy and security concerns around the use of personal data to ensure data is appropriately accessible, safe, and trusted.[8]
- Research programmes at the Alan Turing Institute and Ada Lovelace Institute are studying the impact of data-driven technologies on social and health inequalities to understand how regulation should be evolved to protect and ensure equalities in an AI-driven world.

Case study:
Highways England & Digital Ethics

Highways England is developing a digital twin policy that includes digital ethics. There is generally an inherent bias in historical data sets. This policy aims to provide a meaningful alignment to address that as the organisation develops and uses digital twins for improved decision-making.

8 Department for Digital, Culture, Media and Sport (2020) National Data Strategy. https://www.gov.uk/government/publications/uk-national-data-strategy/national-data-strategy#data-1-3

5.0 Value

Value refers to the capabilities needed to put social, environmental and economic outcomes at the centre of data-driven decision-making about today's and tomorrow's infrastructure.

Capabilities

- V1 Methods for redefining value
- V2 Digitally enabled stakeholder engagement
- V3 Digital inclusion
- V4 Methodology for measuring BIM benefits and maturity
- V5 Digital benefits measurement methodology

5.1 Stakeholder insights:

Value is being redefined.

National and international policy alike are driving a shift of focus from lowest price to greatest whole-life outcomes throughout the built environment investment lifecycle with the purpose of guaranteeing greater value for investors and wider society. Existing transactional procurement models are not optimised for this increasingly outcome-focused approach.

This is happening during a time of significant need for new and existing infrastructure to meet Sustainable Development Goals (SDGs). OECD calculations show that every year between 2016 and 2030 an average of US$ 6.9 trillion [£4.95 trillion] of investment in infrastructure will be required to support economic growth while meeting the SDGs.[9]

In order for this to be successful, action is required from stakeholders additional to central government/policy makers. Local authorities and the private sector should also adopt the principles in the Green Book and the Construction Playbook. Equally, business leaders and practitioners in the service sector need to re-align their business models to define value in terms of social, human, natural and produced capitals. A range of resources are available and under continual development to support organisations transform their business models.

Engage end users in built environment decision-making.

We must shift to building digitally by default to improve early-stakeholder engagement. Early adopters have shown how building digitally before building physically presents unprecedented opportunity to engage end users from the early stages of project delivery (for more information on the tools, technologies and processes available see the Built and Natural Environment chapter). The drive to digital can leave stakeholders behind; digital inclusion should be considered to ensure a wide range of end-users can be engaged in decisions about the infrastructure that will impact their lives.

Metrics for measuring and evaluating the benefits of digital need to be considered early.

Practitioners need to put in place metrics for measuring and evaluating the benefits of digital. Stakeholders cited a lack of evidence of the wider benefits of digitalisation as a key barrier to greater adoption. Practitioners can make use of a growing body of tools and case studies to measure and demonstrate the impact of digital innovation. Where possible, benefits realisation should be well-documented and promoted to build the evidence base for change.

9 United Nations Environment Programme (2021) The International Good Practice Principles for Sustainable Infrastructure. https://www.unep.org/resources/publication/international-good-practice-principles-sustainable-infrastructure

5.2 The capabilities explained

V1 Methods for redefining value

Principles and tools have been developed to support clients to define value beyond capital cost and make value-based investment decisions.

- **Principles of Integrated Capitals Assessment:** In the UK, benefits could be gained from applying the Principles of Integrated Capitals Assessment alongside the Value Toolkit and UK BIM Framework. Practitioners can apply these to factor how changes in one capital stock (natural, human, social or produced) will affect others through decision-making.
- **Value Toolkit:** In the UK, the Value Toolkit empowers public and private-sector organisations to make more informed, value-based decisions using a capitals approach. It sets out a series of integrated activities which a client should undertake over the lifecycle of a project or programme to support value-based decision-making, aligned with the Construction Playbook. The Value Toolkit is in its beta-testing phase, ahead of a 2022 public launch.
- **Project 13:** Early adopters of this framework have demonstrated that an enterprise approach delivers a wider range of benefits than traditional infrastructure delivery. The Infrastructure Client Group's Project 13 Programme has developed resources and case studies that support the wider adoption and continual development of this approach via the Project 13 Community.

Case study:
Anglian Water Strategic Pipeline Process

Anglian Water recently used the Project 13 principles to set up an enterprise project to deliver its Strategic Pipeline Process. This is a five-year £350 million programme to deliver 500km of interconnecting pipelines to enable water resources to move more freely from areas of surplus in North Lincolnshire to Essex where there is less available. Procurement documents clearly stated the purpose, goals and outcomes for the enterprise, and the capabilities and behaviours required to meet them, including the requirement for a digital twin to support network and systems integration and optimisation. This has allowed all parties involved to focus on the outcomes being sought by Anglian Water – to secure water supplies for the future.[10]

10 Costain (n.d.) Optimising the delivery and management of a strategic water network. https://www.costain.com/solutions/case-studies/strategic-pipeline-alliance-digital-twin-project/

V2 Digitally enabled stakeholder engagement

The Government Soft Landings process, supported by the use of models and data visualisation (see BNE) can support stakeholder engagement.

- **Government soft landings (GSL):** GSL can be used by clients procuring design and construction works, and maintenance-focused activities to deliver better performance and end-user experience. It puts in place a process to align the interests of those who commission, design and construct with those who will use and maintain the finished structure. Revised Government Soft Landings guidance and tools to support implementation are available for free on the UK BIM Framework.

Case study:
University of Cambridge Project Capella

On Project Capella[11], a new building on the University of Cambridge's Biomedical Campus, main contractor Kier Construction found the 3D models to be a useful feature for stakeholder engagement.[12] A 'fly-through' model was used to market the building to future users and potential funders, and to evaluate the impact of the Capella on surrounding buildings and employees on the campus. The analysis found that the use of BIM models in the design review process improved user satisfaction with the building in operation, with a project manager commenting '...as we near completion, no one is surprised at what they see, in terms of the community that will move into it, because they have seen these images and these fly-throughs before.'[13]

V3 Digital inclusion

A digital built Britain must be for everyone. Design teams must account for a potential lack of societal digital literacy as engagement and consultation are moved online. Project teams must not exclude those who do not have the means to access the technology or are not adaptable enough to change, whether through age, demographics, economic or other factors. Many projects, including London's Digital Exclusion Taskforce, have been set up to address this need but much more remains to be done nationally.

11 Zomer, Thayla (2019). Towards a Digitally Enabled Estate, Project Capella. https://doi.org/10.17863/CAM.35318
12 Offsite Hub (n.d.) Kier Construction - Project Capella. https://www.offsitehub.co.uk/projects/kier-construction-project-capella/
13 Construction News (2017) 'Supply Chain Excellence: Winner'. https://www.constructionnews.co.uk/events/cn-awards/supply-chain-excellence-winner-3-14-07-2017/

V4 Methodology for measuring BIM benefits and maturity

Clients must consider benefit measurement from the project outset. A methodology for quantifying the benefits of BIM on a project that was developed and tested with the Public Sector ISO Transition Working group, and is available for wider industry use.

- **BIM Benefits Measurement Methodology:** A methodology developed by PwC for CDBB is freely available to help practitioners define and measure BIM benefits throughout project delivery.

V5 Digital benefits measurement methodology

Further work is needed to help organisations to quantify the social, environment and economic benefits of digital transformation. This extends from understanding the economic value of data, to the need for a strong evidence base of case studies that can be used to encourage wider investment and adoption of emerging practices.

- **Smart Infrastructure Index:** Infrastructure and building owners can use the Smart Infrastructure Index to measure their digital maturity and identify appropriate digital capabilities to adopt or enhance. The Index has been developed by Mott MacDonald to cover the whole asset lifecycle, from capital delivery through to asset management and operations. It has been adopted as the standard methodology by the UK's Infrastructure Client Group and is used globally by clients worth more than £225 billion, enabling comprehensive industry benchmarking of digital performance.
- **Transforming Construction Story Catalogue:** Industry can find a range of case studies that capture the benefits and impact of projects funded under the Industrial Strategy Challenge Fund to put whole-life value at the heart of UK construction.
- **CDBB Evidence Base Navigator:** This digital tool is connecting policymakers with the supporting evidence base being developed by the research community.

6.0 Systems Thinking

Systems thinking refers to the capabilities needed to use data and digital tools to improve how we operate the system of systems that makes up our infrastructure.

Capabilities

- ST1 Systems Thinking
- ST2 Exploratory modelling
- ST3 National Digital Twin
- ST4 Incentives for data sharing
- ST5 Addressing risk and liability with data sharing
- ST6 Processes to scale solutions

6.1 Stakeholder insights:

The built and natural environments are complex interconnected systems and should be managed as such.

If we consider interconnected systems in isolation, we are liable to miss interactions and dependencies. Sometimes these dependencies can lead to improved performance and better outcomes but other times they can have catastrophic consequences. It is therefore an imperative that we do not consider either the built or natural environment in isolation from the other.

Sitting within the natural world, the built environment is a complex system of connected assets and networks across social and economic infrastructure. We can also expect it to become ever more deeply intertwined as our cyber-physical systems and data infrastructure evolve. By adopting a system of systems approach in our policies and strategies, it will enable us to extract more performance and functionality from what we already have, deliver better outcomes with less and enhance the nature-based solutions we use.

We need the right digital infrastructure to improve decision-making.

We must ensure decision-makers have the right information, at the right time, to make balanced and long-term decisions in the face of the challenges of today and tomorrow. More investment in communications infrastructure, smart asset management, and the National Digital Twin programme is needed to digitise key metrics about the built and natural environment.

The right incentives need to be developed to improve data quality and sharing.

The value of data will grow as it is shared. The National Infrastructure Commission's 2017 report Data for the Public Good[14], states that data is now as much a critical component of national infrastructure as steel, bricks, and mortar. Data sharing across organisational, sectoral, and national lines is a key enabler of a shift to a systems approach to managing our built and natural environments.

14 National Infrastructure Commission (2018) Data for the public good. https://nic.org.uk/app/uploads/Data-for-the-Public-Good-NIC-Report.pdf

6.2 The capabilities explained

ST1 Systems thinking

Managing the built environment as a system is only possible if all stakeholders who manage both built and natural services work together using aligned outcomes, integrated business models and interoperable processes. Effective exploitation of data and digital technologies will be critical to achieving this.

Applying systems thinking to infrastructure is a rapidly developing research field, with many research initiatives underway, including in the UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC), UCL's Infrastructure Systems Institute, and the Alan Turing Institute.

- **Flourishing systems:** Industry should adopt the recommendations put forward in Flourishing Systems[15] and the Vision for the Built Environment[16]. Backed by key figures in government, academia, and industry, these papers call for a fundamental change in how we view and run our nation's infrastructure. It sets out a systems-based, people-focused view of infrastructure with an emphasis on people, connections, sustainability, and digitalisation.

ST2 Exploratory modelling

Advances in exploratory modelling are showcasing what is possible when data sources are brought together to anticipate future scenarios and understand trade-offs when making decisions. Much of this work is limited to the research community. Investing in these capabilities at scale would give the UK an opportunity to maintain its position as a leader in the digital built environment.

- **Data and Analytics Facility for National Infrastructure (DAFNI)** Policymakers should work with researchers at the DAFNI to model future scenarios before making infrastructure investment decisions. DAFNI is home to the National Infrastructure Systems Model (NISMOD), which can be used to simulate the future energy, transport, digital communications, water, and waste network needs of the UK's regions, at a national level and globally. Industry, researchers and policymakers can analyse a range of scenarios to understand the potential positive and negative impact of decisions before they are made, to make the best choice for people and the environment. Based at the Rutherford Appleton Laboratory in Harwell, Oxfordshire DAFNI uses advanced computing to collate infrastructure data from multiple sources, map and model it, and use advanced visualisations to demonstrate and explore scenarios. It is setting a precedent for digital modelling across the built/natural environment divide.

ST3 National Digital Twin

Practitioners and clients should work with the National Digital Twin (NDT) programme. Supported by Government, this brings together the knowledge of construction professionals and experts to set the framework that will empower others to advance change and embrace connected digital twins within their own organisations. The NDT delivers key recommendations of the National Infrastructure Commission's 2017 'Data for the Public Good Report'. It is run by the Centre for Digital Built Britain. For further information on the NDT see **IM3**.

Case study:
Modelling the Cambridge Oxford Arc

Data is playing a significant role in analysis of the potential social, environmental, and economic impact of a sustainable Oxford-Cambridge corridor. The Oxford-Cambridge Arc contains some of the fastest growing and most productive towns and cities in the UK, but its position as a key economic zone may be limited by infrastructure constraints. It is home to 3.7 million people, over 2 million jobs and contributes over £110 billion of annual Gross Value Added (GVA) to the UK economy.[17]

The Government has designated the Arc a key economic zone. The Infrastructure Transitions Research Consortium's (ITRC) MISTRAL (multi-scale infrastructure systems analytics) methodology assessed the Arc's future housing, rail and road transport, energy supply, digital communications, environmental, and water needs. For the first time, the modelling provides an integrated view of the implications of changes to grey and green infrastructure, employment, and housing. Integrated analysis provided powerful new insights for how the Arc could proceed and the key policy decisions and actions that need to follow – including a range of recommendations for how to achieve the goal of a carbon-neutral Arc.[18]

15 Centre for Digital Built Britain and Centre for Smart Infrastructure and Construction (2020) Flourishing systems: re-envisioning infrastructure as a platform for human flourishing. https://www.cdbb.cam.ac.uk/news/flourishing-systems
16 Centre for Digital Built Britain (2021) Our vision for the built environment. https://www.cdbb.cam.ac.uk/news/industry-unites-behind-vision-built-environment

17 ITRC Mistral (2019) A sustainable Oxford-Cambridge corridor? Spatial analysis of options and futures for the Arc. https://www.itrc.org.uk/wp-content/uploads/2019/11/arc-report-2019-V4.pdf
18 ITRC (n.d.) Low carbon energy supply strategies for the Oxford-Cambridge Arc region. https://www.itrc.org.uk/casestudies/low-carbon-energy-supply-strategies-for-the-oxford-cambridge-arc-region/

ST4 Incentives for data quality and sharing:

Significant work needs to be done to develop the right frameworks and regulations and to create the right incentives for data sharing and to reward organisations for data quality.

ST5 Addressing risk and liability with data sharing

Further work is needed to address the risk and liability around data sharing.

ST6 Processes to scale solutions

A significant portion of our built environment is managed by smaller organisations – such as local authorities and private organisations. We must ensure the processes we are developing are also fit for purpose for these smaller organisations.

Case study:
Greater London Authority Infrastructure Coordination Service

Over the last few years, there has been substantial progress made to reduce disruption and adverse effects caused by street works and roadworks in London. This work has been driven by the Greater London Authority's Infrastructure Coordination Service, convening local Highway Authorities and utility companies to pilot new, collaborative approaches early in the scoping and design stages of projects.

The approach is underpinned by the early sharing of geospatial data relating to infrastructure investment needs, enabling asset owners to identify joint working opportunities and to factor in collaborative efficiencies and cost sharing prospects. It has also required improvements to data quality, the development of interoperable data models, new data sharing agreements and data sharing platforms along with wider aspects of organisational and procedural change.

Incentivisation has been benefits driven; both financial and socio-economic. Aligning capital programmes helped Thames Water avoid £5.2 million of costs during AMP6, alongside preventing 3,800 days of disruption across London roads.

To date six other collaborative schemes have been successfully delivered on London's streets through the GLA Infrastructure Coordination Service, with a combined total of over a year's worth of days saved compared to carrying out the works in isolation. The largest scheme at Stoke Newington in Hackney alone achieved 242 days saved, a construction cost saving of £415,000 to works promoters and an estimated wider social value of £2.3 - 4.1 million.

As the approach continues to scale, the successful benefits realisation is unlocking diverse funding streams including private sector seed funding, utility capital expenditure overheads, industry funding from Transport for London's lane rental surplus fund and the introduction of a regulatory incentive by Ofgem.[19]

19 Mayor of London (2018) Infrastructure and development coordination team. Mayoral Decision MD2386. https://www.london.gov.uk/decisions/md2386-infrastructure-and-development-coordination-team

7.0 Information Management

Information Management refers to the capabilities needed to manage data, information, and models to improve decision-making.

Capabilities

- IM1 Addressing BIM Interoperability
- IM2 Guidance to support UK BIM Framework adoption
- IM3 Tools to support standardised UK BIM Framework adoption
- IM4 Information Management processes to support secure, resilient data sharing

7.1 Stakeholder insights

Interoperability should be considered up-front.

Information management can ensure a golden thread of information that delivers value throughout the lifecycle of an asset. To ensure information interoperability from design, through construction to operation requires early planning and end-user engagement to determine what the right quality and quantity of data is needed to improve decision-making and integrate with existing systems.

Information management is a core business function.

Clients and practitioners should view information management as a core business competency. Information management is the process of specifying, delivering, and curating the right quantity and quality of data to create a golden thread of information that can be used throughout the whole life cycle of an asset. When specified correctly, information management can deliver efficiencies and savings at project, organisational or national level.

Information Management practices must evolve to support secure, resilient data sharing.

Currently, each sector of the built environment has its own data standards and processes. This needs to be addressed urgently to enable sectors to work together more effectively and deliver the better outcomes demanded by the public. Devising a way for historical and future data to be shared, securely and appropriately, requires input from a wide range of subject matter experts including security, data science, mathematical, and information management specialists. A clear roadmap to transition from BIM to the Information Management Framework must be developed in partnership with industry, government and the technical community.

7.2 The capabilities explained

IM1 Addressing BIM Interoperability

BIM interoperability cannot be easily achieved with current practices. This can prevent information captured during the construction phase from adding value during operations without bespoke solutions, such as in the Environment Agency case study below.

Following public consultation, the Construction Innovation Hub's 2020 BIM Interoperability Report made a series of recommendations to government on the interventions needed to achieve interoperable information exchange across the asset lifecycle. These included the need for continued government leadership, greater standardisation, education, and upskilling.

- **BIM Interoperability:** Practitioners and clients should work with the Government and Industry Interoperability Group (GIIG) to address the technological, contractual, and cultural changes required to ensure BIM Interoperability.

Case study:
Environment Agency's Object BIM Requirements

The Environment Agency's (EA) Object BIM initiative aims to improve information quality, consistency, and reliability to improve decision-making for all parties involved in capital delivery and to ensure a seamless transition from projects into asset management. The process enables digital information to be captured at the earliest opportunity and ensure it can be seamlessly integrated into existing and new EA enterprise systems to be used in operations. Alongside addressing information interoperability, the requirement to provide asset information as data offers the opportunity to apply digital solutions to automate much of the process. This reduces the time required to collate and publish asset data. The process ensures asset data is accurate, creating a golden thread of information.

IM2 Guidance to support information management

Clients and practitioners can use freely available guidance resources to develop appropriate information management processes within their organisation.

- **BIM Early Steps Roadmap for Local Authorities:** Local Authorities new to BIM should use the roadmap to ease the switch towards a data-led approach to the management of buildings and estates. Developed by the Construction Innovation Hub's Local Authority Working Group, the roadmap enables estate managers to create a low-cost proof of concept trial which can be tailored to suit an organisation's information needs and capabilities.

Case study:
Stockport Metropolitan Borough Council

Stockport Metropolitan Borough Council used a roadmap developed by the Construction Innovation Hub's Local Authority Working Group to run a low-cost proof of concept trial and embed a BIM approach for its property services across multiple teams. Council saw advantages in de-risked design and contracting of projects, and reliable data being delivered to support better decision-making and management. Among other benefits, the project allowed greater collaboration across all disciplines within council and showed early in the procurement of new construction projects that the approach was bringing cost benefits to council.

- **UK BIM Framework**: Clients and practitioners should use the UK BIM Framework to implement BIM processes in their organisations and projects. The UK BIM Framework has been developed by BSI, CDBB and the UK BIM Alliance to provide supportive guidance and resources for organisations and individuals to implement information management in the built environment using BIM.

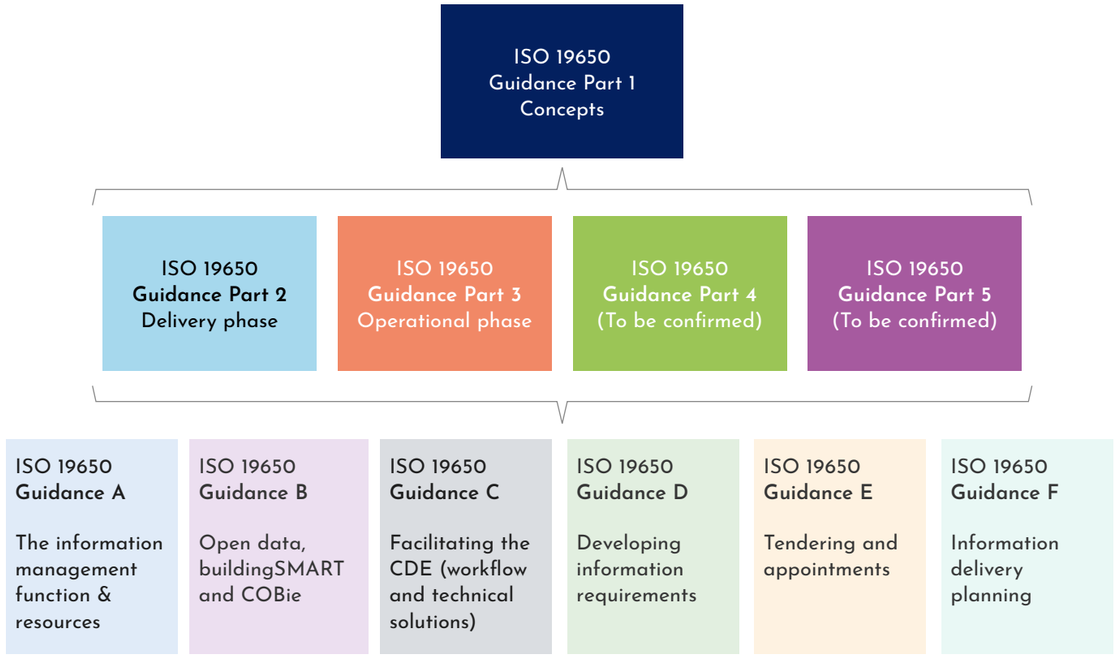


Fig 1 Guidance to support BIM implementation from the UK BIM Framework.[20]

20 UK BIM Framework (n.d.) Standards and guidance. https://www.ukbimframework.org/standards-guidance/

IM3 Tools to support standardised UK BIM Framework adoption

Practitioners and clients should work with the UK BIM Framework, Construction Innovation Hub and the Construction Leadership Council's Digital Workstream to support the development of tools that help individuals and organisations to implement the policies of the Construction Playbook and Transforming Infrastructure Performance: Roadmap to 2030.

- **UK BIM Framework:** The UK BIM Framework will continue to evolve and change in line with industry practice, government mandates and new and emerging standards. This should include the development of dashboards, templates, tools and machine-readable guidance to support wider adoption. The UK BIM Framework is working closely with the National Digital Twin programme to ensure the initiatives evolve in a complementary way.

IM4 Information Management processes to support secure, resilient data sharing

Close collaboration is needed between industry, government and the technical community to evolve information management processes and standards to support the transition from BIM to the Information Management Framework.

- **Emerging digital twin standards:** Practitioners and clients should review the Digital Twin Hub's Digital Twins Standards Roadmap to understand the current best practise and emerging thinking on the global standards for digital twins. The roadmap covers both published standards and various 'live' standardisation projects due to published by international standards bodies within the next 2-3 years.
- **Information Management Framework:** Clients and practitioners developing digital twins of the built and natural environment should engage with the National Digital Twin Programme to support the development of the Information Management Framework (IMF). Developing the IMF for the built environment is one of the most complex challenges faced by the data scientists this century. The way that digital twins are connected is important to ensuring security and to improving the resilience of assets and systems. The IMF will set out the technical standards, processes and interoperability frameworks needed for information and data to be compatible across the built and natural environment.

What is the Information Management Framework?

The Information Management Framework (IMF) is being developed to ensure that the right information about the built environment can be made available at the right time, to the right people and that the quality of the information is known and understood.

The IMF comprises three main elements:

A Foundation Data Model;

A Reference Data Library; and

An Integration Architecture.

The Foundation Data Model and Reference Data Library together provide a language, an inter-lingua, so data can be shared consistently and used to support decisions without requiring any further "data wrangling".

The Integration Architecture provides the transport mechanisms, together with authorisation and security protocols, to ensure that information can be accessed seamlessly, but only by those authorised to do so.

The IMF is the key enabler of the National Digital Twin. Without it, data to improve systems-level decision-making cannot be shared across multiple sectors and domains in a way that is effective, resilient, and secure.[21]

21 Hetherington, J., & West, M. (2020). The pathway towards an Information Management Framework - A 'Commons' for Digital Built Britain. doi.org/10.17863/CAM.52659

8.0 Built and Natural Environment

Built and natural environment refers to the capabilities needed to embrace digitalisation to improve how the built environment performs across the asset lifecycle, including in its interaction with the surrounding natural environment.

Capabilities

- BNE1 Data visualisation and modelling
- BNE2 Infrastructure sensor technologies
- BNE3 Collaborative project delivery
- BNE4 Connected and autonomous plant
- BNE5 Natural materials innovation
- BNE6 Digitising existing assets and estates
- BNE7 Smart asset management
- BNE8 Complex decision-making

8.1 Stakeholder insights

The built and natural environment cannot be managed in isolation from the other.

We cannot make decisions about the built environment that do not consider the environment and people. You cannot have the built without the natural: people need both to function.

Today, these two systems are connected but not in balance. We cannot undo the decisions of the past, but we must ensure the steps we take going forward can allow us to challenge the status quo where appropriate. The Anthropocene era has had significant impact – with many human societies living beyond the planet's ecological limits. We need to keep maintaining the infrastructure we have and retrofitting it to be more efficient and resilient, as well as implementing novel nature-based solutions to provide services. For more on this topic see **ST1**.

Technology must be applied deliberately.

We are now better placed than ever before to understand, manage and intervene effectively in complex, interconnected systems thanks to developments in systems engineering, complexity science, information management and data science.

During this digital transformation we must recognise the vulnerability it introduces. We must not place all of our capability to provide services into a digital system with single points of failure. We cannot digitise without addressing the environmental footprint of data. Nor can we allow historic prejudices to be replicated by artificial intelligence. As we move towards collective intelligence, where humans and machines are working together, we must ensure the correct human oversight of cyber-physical systems are in place. For more on this topic, see **G4, G5, G6, G7.**

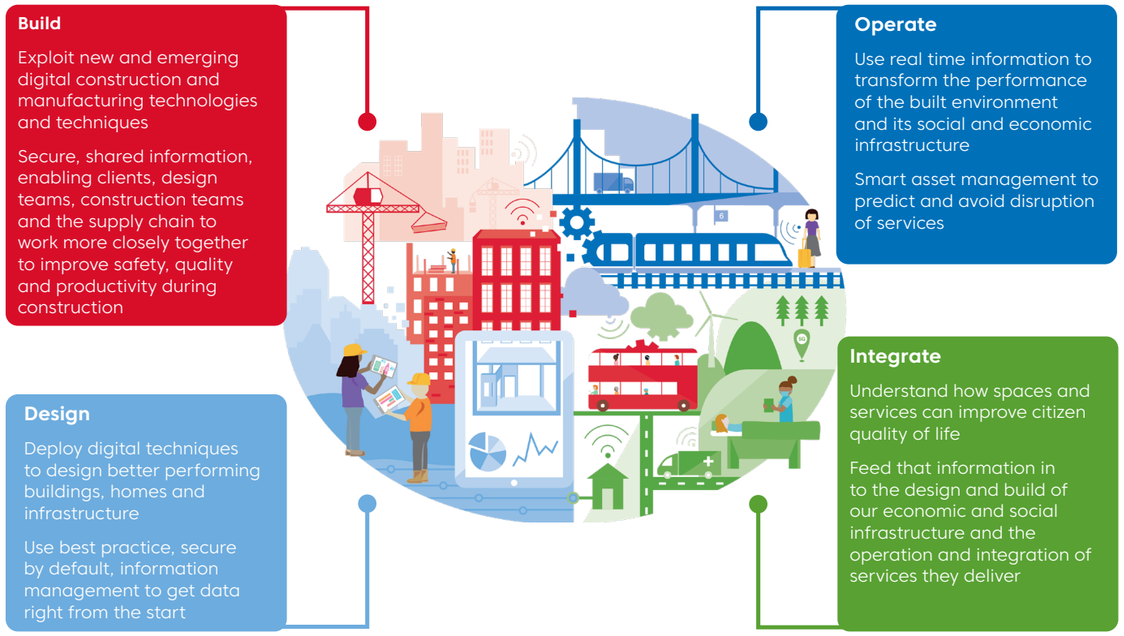
Removing barriers to innovation would improve lifecycle delivery and operation of the built environment and its interfaces with the natural environment.

The technical capabilities needed to realise a digital built Britain are largely developed but adoption is slowed by a hesitancy to innovate. Stakeholders interviewed for this report gave a number of reasons for this; contractual barriers, low profit margins removing incentives to take risks, lack of senior buy-in for of the value of digitalisation, fear of investing in a technology that will prove to be a fad ("I don't want to buy the next Betamax"), and a lack of people with the right skills throughout the supply chain.

Stakeholders spoke of their awareness of a high volume of research underway and progress being made but that more needs to be done to share lessons so they can be applied across the sector.

8.2 The capabilities explained

The following pages showcase resources that are ready to be adopted and highlight emerging best practice. To align with established ways of presenting a digital built Britain they have been divided into capabilities to change the way we design, build, operate and integrate the built environment. Some capabilities will extend across the full lifecycle of the built environment, and have been placed in the area where they featured most prominently in stakeholder feedback.



Transformation will require changing the way we design, build, operate and integrate the built and natural environment. Image courtesy of the Centre for Digital Built Britain.

Design

The planning and design process should consider whether or not a new asset is required, or if other interventions such as repair, retrofit or restoration of natural habitat would deliver better outcomes. This approach encourages decision-makers to view investment in terms of the intervention it would make on the complex system of systems that is our natural and built environment. Further guidance on outcomes-driven decision-making can be found in the Governance and Value chapters.

BNE1 Data visualisation and modelling

Advances in data visualisation and modelling, and the application of machine learning and AI, have the potential to optimise planning and design decisions to deliver the right performance and outcomes. These innovations have given rise to a growing construction technology start-up and scale-up market in the UK.

- **Augmented Reality (AR) and Virtual Reality (VR):** Practitioners should investigate how using AR and VR applications to visualise data could improve outcomes from projects. The technologies are being used in the sector for training for remote and hazardous sites, visualisation of IoT data, occupancy surveys, lighting design, generative design, 4D construction sequencing and digital rehearsals. AR and VR are still to reach maturity both from a technological and application perspective but could play an important role in making sense of the vast amounts of data already collected to support design and investment decisions.
- **Modelling trade-offs:** Clients can use connected models to ensure assets are aligned with outcomes set by global sustainability goals, local needs, and funder priorities. Digital modelling also helps us understand how decisions at the local scale link into what is needed at the macro scale. Local scale decisions on whether to use timber, retrofit an existing building, establish a green roof, install solar panels or select another option carry implications not just in terms of Net Zero or net negative carbon, but also for dimensions such as biodiversity, energy resilience, logistics, enabling the circular, or thermal properties. Through modelling, these trade-offs and interdependencies can be explored before decisions are made.

Case study:
Environment Agency Damage Prediction Modelling

The Environment Agency (EA) is using predictive modelling to understand damage to assets and property and the impact of interventions (built or nature-based). An example is the Thames Estuary 2100 plan which considers the interactions between the built and natural environment over the long term over a huge, heavily built-up catchment area based on the best data now. The EA has committed to revisiting the modelling every five years to augment the plan if needed. Using the models, the EA is able to consider a mix of built interventions (e.g. walls, dikes) and natural solutions (preserving or returning land to wetland/marsh that can act as a sponge for flooding). This is a good early example of a project that brings together the ability of present and future generations to flourish, using the best solution for the context using the best evidence we have to date, across multiple stakeholders and jurisdictions.

BNE2 Infrastructure sensor technologies

The development of new, or novel applications of existing sensors to better understand the condition of assets throughout their lifecycle.

- **Sensor-optimised design:** Practitioners can use insights from sensor technologies to challenge traditional construction approaches to validate leaner designs and new materials. Researchers at the Centre for Smart Infrastructure and Construction (CSIC) embedded fibre optic cables in the sprayed concrete lining (SCL) at junctions in the tunnels at Liverpool Street Station, as part of the Crossrail project. CSIC was able to use sensor data at an unprecedented level to observe the behaviour of the SCL during excavation. Models showed that the effects of cross-passage excavation extend to a much smaller area than previously thought. Further research is required, but preliminary findings suggest similar projects could reduce SCL thickness, with significant time, material and labour savings for clients.[22]
- **Reusing structural elements:** Practitioners can use the golden thread of information generated through information management processes to identify where key structural elements, such as foundation piles, can be reused. Arup has recently completed a significant refurbishment project at 1 Triton Square, London. Reuse of the piled foundations contributed approximated 24% of the reused structure and enabled savings of 35 000t of concrete, 840t of reinforcement and 340t of steel. The design team was able to do this with minimal site investigations as comprehensive record information was kept from the original construction. A 3D finite-element model was used to estimate the performance of the strengthened system.[23]

22 Centre for Smart Infrastructure and Construction (2014) Lightening the load. https://www-smartinfrastructure.eng.cam.ac.uk/news/20142710-Lightening-the-load-deBattista
23 Tayler, H. (2020) A short guide to reusing foundations. https://www.istructe.org/IStructE/media/Public/TSE-Archive/2020/A-short-guide-to-reusing-foundations.pdf 28 March 2021.

Case Study:
Intelligent rail bridges

Researchers at the University of Cambridge have used fibre optic sensors to develop a novel method for monitoring the long-term performance of rail bridges with Network Rail. The bridges have been constructed with integrated fibre optic sensor systems enabling a degree of monitoring not previously possible. The project provides an industry case study for the use of real-time data analytics and integration with digital twins and demonstrating the capability of the monitoring system for remote, real-time condition assessment over the lifetime of a structure. Organisations owning bridges as part of an asset portfolio will be able to refer to the outcomes from this project to better evaluate investment in monitoring and maintaining bridge stock to potentially increase safety and efficiency while reducing carbon and waste.

"The project is a key platform for enabling whole life cycle monitoring of Network Rail's transport infrastructure and has the potential of transforming asset management practices."
Nataliya Aleksieva, Senior Engineer, Network Rail[24]

BNE3 Collaborative project delivery

- **Collaborative design:** To improve data sharing in interdisciplinary project teams Buro Happold, 3D Repo, University College London (UCL) and a consortium of industry collaborators have developed AEC Delta Mobility. This is an open-source, software-agnostic solution funded by UK Research and Innovation via the Industrial Challenge Fund to streamline secure data exchange between design teams. Users can live-stream individual changes instead of sharing large attachments to streamline data-exchange and improve collaborative working. Lead partner Buro Happold has estimated productivity gains of up to 15% over the next five years, representing 2.5 million person-hours saved by its business.[25]
- **Building Information Modelling (BIM)**: BIM is a mature process for digital information management for the built environment. It supports collaborative project delivery between clients and design teams by clearly specifying the right amount of information concerning the design, construction, operation and maintenance of buildings and infrastructure. The ISO 19650 series of standards for BIM can be used throughout the whole life cycle of all types of assets in the built environment – including buildings, infrastructure and the systems and components within them. For more information see IM2.

24 Centre for Digital Built Britain (2021) Research Profile: Staffordshire Bridges - Long term performance monitoring using fibre optic sensors. https://www.cdbb.cam.ac.uk/news/research-profile-staffordshire-bridges-long-term-performance-monitoring-using-fibre-optic.
25 Transforming Construction Story Catalogue (2020). AEC Delta Mobility. https://tc-catalogue.strongerstories.org/stories/aec-delta-mobility/.

Build

Significant public and private-sector investment in construction technology is making project delivery faster, greener, safer, and more efficient.

BNE4 Connected and autonomous plant (CAP)

CAP techniques are being used to improve the safety and efficiency of new construction projects. CAP technologies can be used for the remote collection of data for design; geofencing to alert users of proximity to hazards, and to assist construction activities. A 15-year CAP Roadmap launched by Highways England, i3P and TRL, predicts that adoption of this technology across the construction sector could assist with 47% of construction activities currently performed, reducing sector fatalities by 37% and annual savings of £53 billion across new construction work.[26]

Case study:
Highways England Connected and Autonomous Plant

Highways England is using CAP to reduce disruption from roadworks and the risk of road workers being injured on site. Automated dump trucks were trialled on the recently-opened A14 Cambridge to Huntingdon improvement. The trucks were programmed remotely to follow a pre-determined route and have the capability to detect and avoid obstacles and other vehicles, along the routes as they drove. They provide the potential for round-the-clock working, helping to reduce the length of time roadworks are on the ground. And by being automated they reduce the risk of road workers being involved in incidents on site, allowing jobs to be moved to other skilled areas. On the A14 and on motorways, a robot is saving drivers from hundreds of hours of disruption. It uses precise positioning technology to mark out where white lines need to be painted on new or resurfaced roads and puts roadworkers at less risk of an accident.[27]

BNE5 Natural materials innovation

Practitioners should work with the academic community to speed the adoption of natural material innovations and novel building methods that can accelerate the path to Net Zero. Modelling and insights from sensors validate new, sustainable materials and building techniques and optimise the volume of traditional materials used. Cement production accounts for around 8% of global CO2 emissions.[28] Conversely timber structures capture and store carbon. By reducing the amount of steel and concrete used in construction we can keep more carbon out of the atmosphere.

Case study: University of Cambridge Centre for Material Innovation

Construction Innovation Hub has funded researchers from the Centre for Natural Material Innovation at the University of Cambridge to work on a project partnership with the Department for Education, Cambridge City Council and Smith and Wallwork. The project aims to unlock the potential of prefabricated engineered timber construction methods to help meet the demand for new primary and secondary school buildings.

It is assessing the benefits and the whole-life cycle of engineered timber products, ranging from forest management and carbon sequestration to supply chains and policies. The automation and off-site manufacturing embedded in processing engineered timber building systems could help ensure the timely and efficient delivery of a large number of primary and secondary school buildings.

This project presents evidence-based insights for the development of prefabricated engineered timber construction strategies which could contribute to delivering the required number of new schools within sustainability targets. Researchers will build as a demonstrator project an extension to an existing school building in Cambridge, UK, using prefabricated engineered timber construction methods. Construction is planned for 2021/2.[29]

26 TRL (2020) Connected and Autonomous Plant (CAP) set to revolutionise construction: CAP Roadmap to 2035 issued by Highways England, i3P and TRL. Retrieved from https://trl.co.uk/news/connected-and-autonomous-plant--cap--set-to-revolutionise-construction March 28 2021.
27 *TRL (2020) Connected and Autonomous Plant (CAP) set to revolutionise construction: CAP Roadmap to 2035 issued by Highways England, i3P and TRL. Retrieved from https://trl.co.uk/news/connected-and-autonomous-plant--cap--set-to-revolutionise-construction March 28 2021.*

28 Lehne, J. and Preston, F. (2018) Making concrete change: innovation in low-carbon cement and concrete. Chatham House Report. https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete
29 Centre for Digital Built Britain (2021) Precision engineered timber: digital design and delivery of healthier schools. Research Profile. https://www.cdbb.cam.ac.uk/news/research-profile-precision-engineered-timber-digital-design-and-delivery-healthier-schools

Operate

Much of our country's built environment is performing beyond its design life and intended capacity. A 2021 Annual by the RAC Foundation found the number of substandard road bridges managed by councils across Great Britain is increasing, yet budget remain the same. Between them, councils say they would ideally want to bring 2,256 substandard bridges (73 percent of the total substandard bridge stock) back up to full carrying capacity. However, budget constraints mean they anticipate that only 392 of these will have the necessary work carried out on them within the next five years.[30] The systems nature of infrastructure means the effects of one failure can be felt far beyond the asset itself. Digital tools, processes and applications

BNE6 Digitising existing assets and estates

- **Processes for appropriately digitising existing assets**. We lack sufficient information about the quality and performance of the built environment. Industry and academia should collaborate to scale the adoption of methods to digitise existing estates and built assets. This will allow more asset owners and operators to understand the true condition of assets and estates to guide maintenance and investment decisions. Through insight from data, decisions can be made about lengthening the service life of assets, without compromising safety, to reduce the need for new builds and associated carbon emissions. Performance data, captured in-person or using sensors, supports predictive maintenance so that interventions can be carried out at a time that minimises disruption.

- **Intelligent infrastructure:** Asset owners and operators should invest in appropriate sensor solutions to understand the performance of new and existing assets. The Centre for Smart Infrastructure and Construction and National Research Facility for Infrastructure Sensing at the University of Cambridge are driving research and demonstrating the benefits of the use of sensors in the built environment. Data acquired from the sensors can be used to compare the design models and guidelines with the actual building performance and to inform future designs. For more, see BNE2.

30 RAC Foundation (2021) Number of substandard bridges on the rise again. https://www.racfoundation.org/media-centre/ number-of-substandard-road-bridges-on-the-rise-again.

BNE7 Smart asset management

Insights from data and applications of new technologies can help to prioritise where investment is needed and improve asset performance to be more resilient and adaptable to changing demands and conditions.

- **Satellite technology in infrastructure monitoring:** Clients and practitioners should monitor emerging research at the University of Cambridge and Leeds University exploring the capabilities of satellite monitoring for infrastructure. Early findings show that satellite-derived data can mitigate the risk of failure and provide significant cost savings as it facilitates non-intrusive structural health assessments of assets.[31] The approach can provide significant value to industry by reducing human effort, and minimising construction and O&M costs. It can also provide useful structural health information to ensure rapid and effective decision-making.

- **Digital Twins:** The Gemini Principles define a digital twin as a realistic digital representation of something physical. In the context of a digital built Britain, a digital twin is a "realistic digital representation of assets, processes or systems in the built and natural environment".[32] Its primary purpose is to create a cyber-physical system that represents physical reality at an appropriate level of accuracy to improve decision-making. Not all twins will need real-time data, detailed data visualisation, or to be connected to the National Digital Twin. The use of the Gemini Principles while developing digital twins can ensure that they are designed and implemented in service of their purpose. The Digital Twin Hub community has developed a Digital Twin Toolkit to provide a software-agnostic roadmap on the steps an organisation needs to take to develop a digital twin from business case to implementation.

- Digital Compliance: Currently the process of checking compliance with contractual requirements, regulations and environmental performance requirements is a manual, resource intensive task that must be performed throughout an asset lifecycle. Records are often kept in formats that are not machine-readable, which can have major consequences when looking for critical information. This was demonstrated after the tragedy at Grenfell, when it took weeks before many local authorities could ascertain whether or not they owned buildings with the affected cladding.

The D-COM network was formed in 2018 to drive the adoption of the digitisation of regulations, requirements and compliance checking systems in the built environment. Early research to utilise innovative methods for data capture for regulatory compliance checking found that using "off the shelf" hardware for collecting data to monitor the compliance of built assets and mitigate the risks associated with their operation across their lifecycle, has the potential to save time and cost, reduce emissions and increase whole-life value and demonstrate increased transparency and auditability.[33] The network is now working with the Construction Innovation Hub to digitalise selected Approved Documents and develop a digital ecosystem to facilitate automating parts of the Building Regulations compliance checking process. The project and supporting proof of concepts is due for completion by summer 2022.

31 Centre for Digital Built Britain (2021) Application of satellite technology in infrastructure monitoring. Research Profile. https://www.cdbb.cam.ac.uk/news/research-profile-application-satellite-technology-infrastructure-monitoring.
32 Bolton, et al. (2018) Gemini Principles. https://www.cdbb.cam.ac.uk/system/files/documents/TheGeminiPrinciples.pdf.
33 Beach, TH. (2020) Utilising innovative methods of data capture for regulatory compliance checking, Report for Industry. https://www.ucl.ac.uk/bartlett/construction/sites/bartlett/files/industryreport-cardiffuniversity.pdf.

Integrate

By integrating information and data sets from the built environment, we can better understand how spaces and services can improve quality of life and put in place feedback loops to improve future decisions about the built environment.

BNE8 Complex decision-making

- Collaborative Data Sharing: More organisations are exploring the benefits that can be gained by connecting digital twins, data sets and models to improve decision-making. This secure-resilient data sharing can take place within or between organisations.

Case study:
Planning London Datahub

Planning London Datahub (PLD) is a collaborative project between all of the Planning Authorities in London to build a single open data set the develop a single, easy-access, open data set of development proposals in the planning process. Using the platform, non-technical stakeholders and citizens can engage with the planning process and monitor how the city is changing.

The dataset is owned and contributed to by everyone in the planning and development industry and would not be possible to produce unless all parties contribute. PLD works by connecting the 36 Authorities disparate back-office systems through the medium of an open data standard, automated data pipelines and an open-source database to provide a single source of truth for London's planning system – the change control system of the built environment.

While the DataHub itself is purely a dataset, PLD is working to enable access to the data in many ways to make it useful and usable to everyone, and it's plumbing provides a new mechanism to share data between authorities in an interoperable manner following the Gemini Principles.

- Model-led collaborative decision-making: Built environment decision-makers should identify practices to bring a broader range of perspectives into investment decisions. Engaging end users and local communities benefits projects by helping to identify risks and opportunities for designing resilience and adaptability into the system. An emerging practice is to bring together a broad range of stakeholders to ask better questions and use integrated models to understand the options or trade-offs available in complex decisions. This is explored in 'Modelling across the built and natural environment divide'.[34] For example, traffic congestion could be addressed through building more roads, or by reducing parking capacity and improving walking, cycling and public transport options. These options could bring additional community, social and environmental benefits.

- Connected digital twins: Practitioners should join the Digital Twin Hub to drive progress towards digital twins. Connecting digital twins of assets, processes and systems in our built and natural environment would provide the context to understand and manage complex systems. Through greater context will come better decision-making. The National Digital Twin project aims to enable the secure, resilient, and reliable integration of twins in different domains.[35] The IMF (see IM3) is being developed to connect digital twins together to make cross-sector observations, decisions, and interventions, and to evaluate the impact of those interventions.

Case study:
West Cambridge Digital Twin Research Facility

The West Cambridge Digital Twin Research Facility, funded by the Construction Innovation Hub, is a demonstrator of the potential benefits of connected digital twins. The project is generating digital twins of three University buildings and the surrounding environment at the campus site.

The digital twins should enable the University to derive the best trade-off between cost, risk, and performance over the life of the assets. They will offer information useful to the Estates Division at the University of Cambridge which is responsible for a portfolio currently valued at £3 billion and featuring buildings from 800 years old to the present day.

This is the first time such an initiative will address all the core aspects of a National Digital Twin (NDT) as defined by the nine Gemini Principles that enshrine the 'conscience' of the NDT. Learnings will be shared with the CDBB's Digital Framework Task Group (DFTG) and Digital Twin Hub (DT Hub).[36]

34 Lamb, K. (2021) Modelling across the built and natural environment interface. National Digital Twin programme. https://www.cdbb.cam.ac.uk/files/workshop_report_290521v2.pdf
35 Hetherington, J., & West, M. (2020). The pathway towards an Information Management Framework - A 'Commons' for Digital Built Britain. doi.org/10.17863/CAM.52659
36 Centre for Digital Built Britain (2020) West Cambridge Digital Twin Facility. Research Profile. https://www.cdbb.cam.ac.uk/news/research-profile-west-cambridge-digital-twin-facility.

9.0 Skills

Skills refers to the capabilities needed to address the sector's digital skills gap.

Capabilities

S1 **Develop skills and competency frameworks**

S2 **Strategy for addressing digital skills gap**

S3 **Critical mass of digital skills training programmes and initiatives**

9.1 Stakeholder insights

A digital built Britain and the development of a National Digital Twin will create multiple new roles requiring new business and technical skills and competencies.

People at all levels will need to acquire new business and technical skills and competencies to establish and curate a digital built Britain. Early indicators suggest that the emergence of new roles will break down traditional professional silos and require individuals to span a wider range of disciplines and tools.

The power of digitalisation lies in the integration and co-ordination of collaborators along a supply chain, from the client, or consumer, through the network of providers and suppliers. For successful change, breaks in that chain must be avoided. Yet, despite multiple initiatives, the adoption and exploitation of the opportunities that a digital built Britain offers remain fragmented and piecemeal.

We need a clear understanding of the current and potential gaps in our workforce skills and a roadmap to address this.

Organisations must employ and deploy staff with sufficient skills to collect data of the right quality and generate insights from that data. We must identify the steps required to upskill individuals in specific areas, while building a talent pipeline for the workforce of the future.

Many organisations do not understand the need for in-house 'business as usual' information management capability. This capability needs to be intrinsic, integrated, and independent of bought-in services and consultancy.

As digital skills, such as coding, become a prerequisite for new graduates, organisations should foster environments that encourage ground-up innovations. There are a growing number of industry initiatives looking to explore and address skills gaps and set out roadmaps to support individuals and organisations evolve.

All digital programmes should have a skills strategy.

For those client bodies lacking the capability to innovate at the speed of the road map, could skills become part of the supply chain's business model? Could we bring together clients and their supply chain to co-develop common processes that advance information creation and information flow within the project, alluding to handover and ultimately operations and maintenance? This field is rapidly evolving.

By making skills development a core part of all projects and initiatives we can ensure the cultural change happens alongside the technical. It widens the understanding of the value of data and the importance of data quality management. The UK BIM Alliance and its Affiliates and the Construction Leadership Council's Digital workstream are leading on this work, and encourage engagement from the wider sector.

9.2 The capabilities explained

S1 Develop skills and competency frameworks

Skills and competency frameworks, based on standards or broad stakeholder engagement, ensure greater alignment and consistency across the sector. They also provide a user-friendly means for organisation and individuals to plan their capability enhancement programmes.

- **UK BIM Framework Learning Outcomes Framework:** The UK BIM Framework has released a free resource to support the development of training content for building information modelling (BIM) aligned with current standards. The Learning Outcomes Framework can be used to assess whether training programmes are aligned with the ISO 19650 standards for BIM. - the UK BIM Framework Learning Outcomes Edition 1
- **Information Management Framework Skills and Capability Framework:** The National Digital Twin Programme has developed a Skills and Competency Framework: Supporting the development and adoption of the Information Management Framework (IMF) and the National Digital Twin. This framework can be used to future-proof organisations with the right technical and business skills needed to be ready for the introduction of the IMF.

S2 Strategy for addressing digital skills gap

Aligning the sector behind a clear strategy to address the digital skills gap.

- **Construction Leadership Council Skills Roadmap:** This year the CLC launched a five-year skills roadmap for the sector. The Industry Skills Plan for the UK Construction Sector 2021-2025 outlines timelines and responsibilities towards commonly understood and embedded standards and statements of expectations and supporting structures that enable education, career training, learning and development.

The roadmap encompasses steps to help develop: skills for smart construction that enable a modernised industry; more widespread digital and data analytics skills to underpin future collaboration and productivity improvements, including among SMEs; and non-technical skills, enabling individuals to work effectively across teams to deliver digitally enabled projects.

- **CITB Digital Skills Strategy:** A 2018 CITB report Unlocking Construction's Digital Future: A skills plan for industry had identified a lack of consensus on what digital construction means and a consequent inability to define the skills needed. Among other findings it concluded that technology-specific skills are not the problem. Rather, difficulties often stem from a lack of broad skills and competencies at various levels within organisations.
- **Digital Twin Hub:** The CDBB has launched the Digital Twin Hub (DT Hub), a collaborative web-enabled community for those who own, or who are developing, digital twins within the built environment. The DT Hub gives members a safe space where they can learn from, and share with, others who are on the same journey. Members can participate in events that will not only develop their own capabilities, but also advance the state of the art in digital twins. The Hub is steered by a group of experts from academia, government and industry, and chaired by Sam Chorlton.
- **Graduate Digital Skills report:** Design Council and the Centre for Digital Built Britain are exploring the digital skills required across built environment professions. The Graduate Digital Capabilities for Built Environment Professionals Project will identify and address the digital skills gap for recent graduates across the full range of built environment disciplines.

S3 Critical mass of digital skills training programmes and initiatives

UK BIM Framework partners BSI, CDBB and the UK BIM Alliance are developing resources in the form of Standards, Guidance, and other resources to support individuals and organisations in the UK to understand the fundamental principles of information management according to the IS0 19650 series. However, as new processes, tools and technologies such as exploratory modelling, systems thinking, digital twins and automated compliance reach maturity they must be supported by effective training which is accessible to individuals and companies seeking to improve their capabilities.

Case study:
Embedding upskilling in project delivery

Crossrail-Bentley Information Academy: Crossrail established an academy to help project team members, contractors and the supply chain understand the organisation's technical information (BIM) strategy. The Crossrail-Bentley Information Academy enabled Crossrail to openly share information, and the supply chain to innovate and produce world class information deliverables. The academy aimed to enhance knowledge, drive improvements, encourage best practice and facilitate the transfer of knowledge to other infrastructure projects.

Attendees learnt how Crossrail manages information across multiple, interlinked technology platforms to create a 'Single Source of Truth' within a Common Data Environment.

Feedback of the Academy sessions was consistently positive, with attendees stating that they had a better appreciation of Crossrail's information strategy and the value of data as an asset. Of key importance was the enablement of direct contact with Crossrail's contractors and supply chain to 'spot fix' any information related issues.

The academy gained a significant boost from attendees of its Crossrail BIM Overview Session acquiring Continuing Professional Development certification.[37]

37 Ahmad, T. (2016) Information Academy. Crossrail. https://learninglegacy.crossrail.co.uk/documents/information-academy/.

10.0 Conclusion

The state of the nation presents an overwhelmingly positive indication that digital innovation & adoption can be an enabler in delivering a more sustainable, inclusive future – as outlined in the vision on page 5.

The scale of the challenge can, at times, feel overwhelming. Now that much of the foundational work has been done, the benefits of digital transformation outweigh the risk. We can all find ways of using the insights from this report to optimise our organisations, programmes and projects to deliver better outcomes.

The state of the nation indicates a number of a number of areas where further collaborative effort is needed to put in place the appropriate policies, guidance and processes to make a digital built Britain a reality.

The interplay between model bias, digital ethics & data sharing and the legal implications of outsourcing responsibility to machines are as yet not fully understood and there is a pressing need for robust governance frameworks to shape this process for the correct universal outcomes. As we offer increasing autonomy for programmed machines to administer the built environment, we must similarly enhance our capabilities to perform checks and balances on the outputs.

Data is only useful if it can be used to generate the information and insights needed to improve decision-making. The digital transformation of the sector is not a race to fill a data lake. Having too much data, the wrong data, or inaccessible data will not improve the performance of the built environment. We must act deliberately, mindful of future we want to create to ensure we are specifying, procuring, curating, sharing, and valuing data appropriately.

As the value of data increases there is a need for appropriate regulation and frameworks to ensure data quality and secure data sharing. The risks & liabilities associated with improper management pose particular risk to smaller organisations who will need support in this area.

The need for greater co-ordination underpins a number of the capability areas as we begin to make far-reaching decisions that will impact a diverse group of stakeholders. A clear roadmap to transition from BIM to the Information Management Framework is a practical example that must be developed in partnership with industry, government and the technical community.

There is similarly a need for greater recognition of the disparities between organisations on the journey towards digitisation and digital adoption. Co-development of new skills & capabilities should be made an integral part of the client-supplier relationship through a skills strategy to deliver the necessary cultural change underpinning technological advancement.

The 2019 Capability Framework and Research Agenda for a Digital Built Britain laid down a marker for the research community, outlining where their contribution was most urgently required to address knowledge shortfalls.

This report details a re-appraisal of the Capability Framework, seen through the eyes of a separate group of built environment stakeholders encompassing policymakers, built environment decision-makers and current and future practitioners. The outcome of this comprehensive consultation is a re-positioned vision for a digital built Britain based on the current state of the nation.

What follows is a roadmap that provides practical guidance for organisations & individuals to accelerate our shared journey towards a digital built Britain. There has never been a better time to change. Start your digital transformation today.

11.0 An Industry Roadmap

The built environment is supported by a hugely diverse industry of policymakers, built environment decision-makers and current and future practitioners. It is not possible nor realistic to present a single roadmap for all stakeholders to follow. Identifying the appropriate actions for an individual or organisation will depend on a range of factors including their current digital maturity, their role or services and capability to embrace change and manage associated risks.

The following diagram reflects the portfolio of high-level actions to be implemented (by a range of built environment stakeholders) to build the capabilities outlined throughout this document and support our journey as a nation towards a digital built Britain. We hope it provides a useful overview from which individuals and organisations are inspired and empowered to develop their own roadmaps.

11.1. How to use the roadmap

- **Areas where existing practice and knowledge can be adopted or adapted to build capability**

Green boxes reflect mature concepts where there is a good level of understanding and objectives and actions are well defined. Insights can be readily taken from exemplar case studies, research and literature to help individuals and organisations develop.

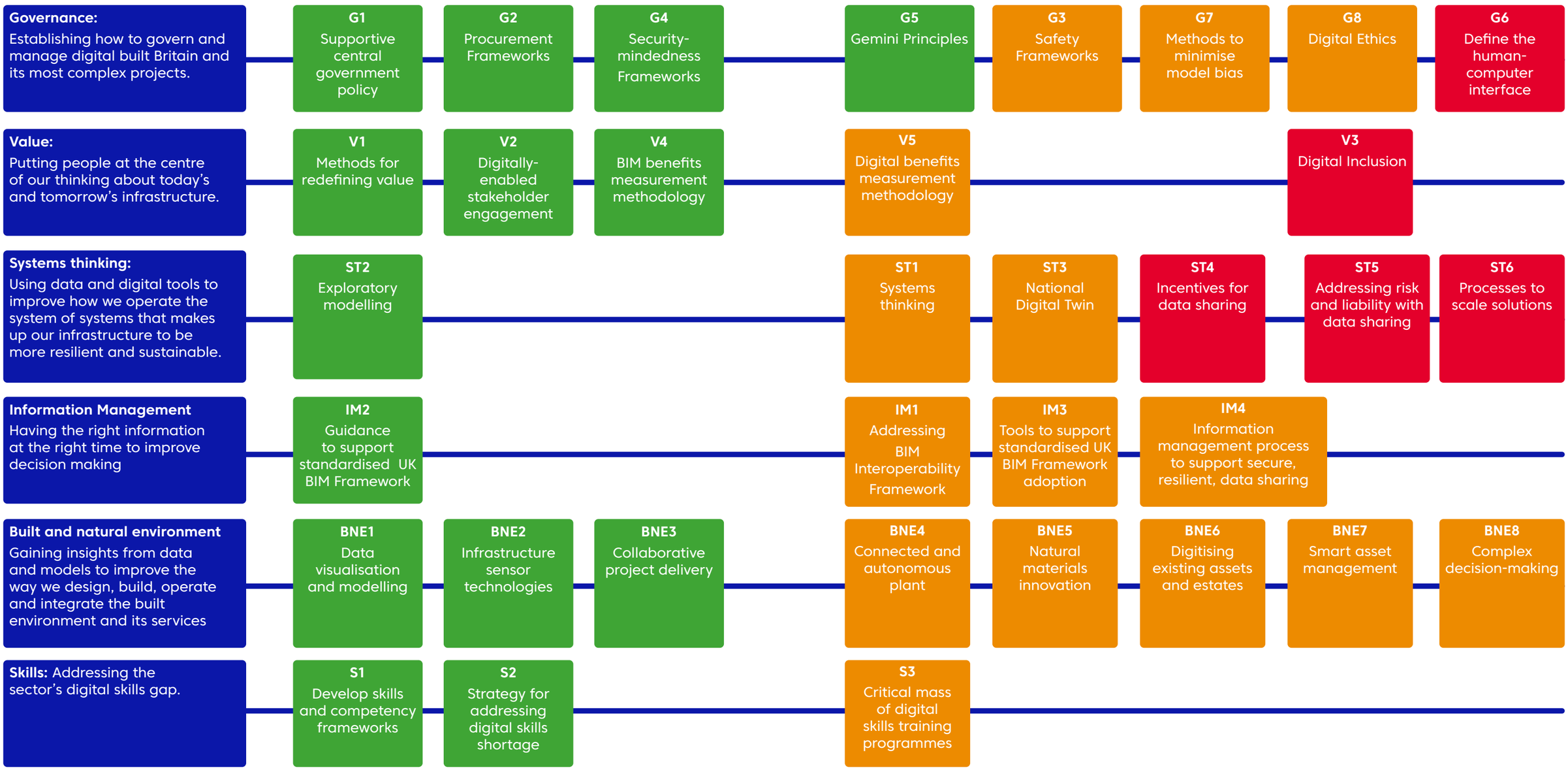
- **Areas where practice and knowledge are being developed but more work is needed**

Amber boxes denote concepts that are less mature or established. There may be a limited number of case studies and ongoing research but insufficient evidence or insight to define best practice and clear objectives. Notwithstanding, these constitute important aspects of the capabilities and practical steps are underway; ambitious and mature built environment stakeholders may wish to focus on these aspects

- **Areas where there is little activity to develop the capabilities needed or where fragmented work needs unifying**

Red boxes identify concepts that are under-developed and urgent work is required to explore and develop the frameworks and insight needed to support change. Addressing the maturity of these areas so that they are sufficiently well defined for industry-wide adoption is likely to take several years and so will likely position them towards the end of organisations and individual's own roadmaps

Roadmap



Key:

Green Areas	where existing practice and knowledge can be adopted or adapted to build capability.
Amber Areas	where practice and knowledge are being developed but more work is needed.
Red Areas	where there is little activity to develop the capabilities needed or where fragmented work needs unifying.

12.0 Next steps

Take the findings from this report to develop either your own organisational or personal roadmap.

12.1 Organisation

1. Define your purpose: set a clear purpose for why you want to develop the capabilities explored in this report. Is it to inform policy development, to comply with regulations, to take advantage of a new market opportunity, to upskill your team, to meet social, economic, and environmental targets, or a combination of the above?

2. Establish your baseline: interview key team members and external stakeholders to understand the strengths, skills, and competencies you have within your organisation and supply chain. Analyse existing policies and procurement processes to see if they empower procurement teams to make decisions aligned with your purpose. Use this to understand your current position and where there are opportunities to improve your social, environmental, and economic objectives through digital transformation.

3. Set a purpose-driven digital strategy: enshrined in the Gemini Principles (G4) is the notion that digital initiatives must have a clear purpose, be trustworthy and function effectively. Use the framework to develop your organisational digital strategy to ensure supporting initiatives remain focused on the outcomes sought.

4. Develop a capability enhancement plan: use the skills and competencies resources in S1 to understand and address your skills gaps.

5. Measure your progress: use the collateral signposted in this document to benchmark your organisation's digital performance and awareness of the move towards a digital built Britain.

6. Start small: run proof-of-concept trials to build and refine processes that work for your organisation and end users.

12.2 Personal

1. Define your purpose: set a clear purpose for why you want to upskill yourself and respond to the capabilities explored in this report. Consider current and potential future social, economic, and environmental targets.

2. Develop a capability enhancement plan: use the skills and competencies resources referenced on page 50 to understand current and potential future skills gaps in the marketplace.

3. Explore and define where opportunities may lie for you: given your current and future skill set, ambitions and circumstances, what role could you play?

4. Roadmap your own future: develop a personal career plan. Review and fine-tune it regularly.

5. Be an ambassador for change: a real shift towards a digital built Britain will only be successful if stakeholders commit to starting the journey together. Use the capabilities, case studies and opportunities outlined in this report to catalyse further transformational change.

12.3 Dual responsibility (organisation & personal)

Share your story: the scale of the challenge is immense, but so are the benefits. This is a cultural change process, so share the outcomes you are seeking from changes to win hearts and minds. Join or continue to support collaborative initiatives to drive collective innovation.

Collaboration is key: Through collaboration we will get there faster. There are many communities that are supporting each other through change, including the Digital Twin Hub, the UK BIM Alliance, UK BIM Framework Project 13, Building Clients Group, Local Authorities Working Group, and Construction Leadership Council. Professional institutions and bodies are developing digital skills programme. Reach out to learn from those who have gone before you.

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About the Construction Innovation Hub

The Construction Innovation Hub brings together world-class expertise from the Manufacturing Technology Centre (MTC), BRE and the Centre for Digital Built Britain (CDBB) to transform the UK construction industry.

With £72 million from UK Research and Innovation's Industrial Strategy Challenge Fund, and working around the four core themes of Value, Manufacturing, Assurance and Digital, we are changing the way buildings and infrastructure are designed, manufactured, integrated and connected within our built environment.

We are a catalyst for change. We are driving collaboration to develop, commercialise and promote digital and manufacturing technologies for the construction sector. We are helping build smarter, greener and more efficient buildings much faster and cheaper than we currently do.

Research is helping us understand how the industry needs to change in terms of skills, product standards, capacity and innovation. This is combined with an academic programme to create the security-minded frameworks and rules that will underpin the future digital built environment and grow exports for UK know-how.

We are working closely with other initiatives as part of the Government's Transforming Construction challenge programme. Through collaboration across the sector, we can provide a better-built environment for future generations.

Further information
For further details about the Construction Innovation Hub please contact:

Construction Innovation Hub
info@constructioninnovationhub.org.uk
www.constructioninnovationhub.org.uk

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