![cdbb — Centre for Digital Built Britain]

Developing the Capabilities for a Digital Built Britain

A Summary of the 'Capability Framework and Research Agenda for a Digital Built Britain'

July 2019

Foreword

Professor Andy Neely
Director of CDBB
Pro-Vice-Chancellor for Enterprise and Business Relations

The UK is on its journey towards a digital built Britain. Data-driven decision-making is driving greater efficiencies in the design, build, operation and integration of our built environment and the services they deliver. Since receiving the mandate from the Department of Business, Energy and Industrial Strategy (BEIS) in 2017, the Centre for Digital Built Britain (CDBB) has nurtured and developed the digital built Britain programme to support this journey.

On behalf of the Centre I am pleased to present this summary of our Capability Framework and Research Agenda for a digital built Britain. This package of work is designed to help policymakers, industry and research funders explore what is currently being done and prioritise the future research agenda and capability development needed for a digital built Britain. I encourage you to explore the full report, which is available as a PDF on the CDBB website.

This report does not define the research strategy for a digital built Britain – instead it provides the evidence base, common language and framework for the wider academic community and strategic leaders to use when defining their own plans.

I would like to take this opportunity to thank all those who have been involved in this process. This report could not have been produced by CDBB alone, and it is a testament to our enthusiastic and forward-thinking community members that they have given their time in workshops, preparing reports and plans, and reviewing documents to enable us to reach this point.

This is a national effort. CDBB cannot and does not intend to perform all of the work proposed herein. This process has

highlighted an existing vibrant research community doing spectacular work towards a digitally transformed and improved built environment – and demonstrates that this community has been successful by forging strong networks and collaborating effectively. CDBB will continue to support this community and the digital built Britain programme, coordinating, facilitating and acting as a central resource for all who wish to work towards a digitally enabled future.

As CDBB moves into its next phase of operation, including via the Construction Innovation Hub partnership with MTC and BRE, we will continue to focus our efforts on increasing our understanding of how future digital technologies will transform construction and the built environment. We will maintain our efforts to support the adoption of digital technologies, deliver the information management framework for the built environment, drive awareness and adoption of building information modelling (BIM) in the UK and overseas, ensure that security-mindedness is embedded from the start, engage with industry and policymakers and deliver training and skills.

We have a shared goal. Enhanced capabilities will lead to better interventions, improving where we live, where we work and how we travel, ensuring the services we need are there when we need them, and that we can deliver on sustainability targets to reduce the impact on our natural environment.

Please enjoy reading what I hope will prove to be an invaluable document providing the long-term vision towards a future where information is used to deliver a built environment that performs for all.

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An introduction to the Capability Framework and Research Agenda

Introduction: **Dr Jennifer Schooling OBE**
Director, Centre for Smart Infrastructure & Construction
Director of Applied Research, CDBB

In the two years that have passed since we completed the digital built Britain research and development study for the Future Cities Catapult, the Centre for Digital Built Britain (CDBB) has continued to evolve the digital built Britain research and development programme and has worked with its partners to deliver on the recommendations, including the creation of the CDBB research bridgehead and the publication of this Capability Framework and Research Agenda.

CDBB is building a multi-disciplinary collaborative community across the UK to understand and promote the digital transformation of the built environment. This significant report is the culmination of the CDBB-funded work of six research networks, comprising over 90 researchers, and insights from four consultancy studies. It represents the first time digital built Britain has been explored at scale and in detail by the broad community that will help to deliver it.

The goal of a 'digital built Britain' is to use digital data and technology to dramatically improve the performance of the country's buildings and infrastructure, to make them more efficient, more productive and more environmentally sustainable, thereby improving quality of life for everyone in the UK.

Achieving this goal will require a wide range of new capabilities. These capabilities will need to be underpinned not only by technological and scientific research – but also by research in the fields of humanities and social sciences. It will also require new ways of working by policymakers and decision-makers in the architecture, engineering, construction and operations (AECO) community.

The work of the Foresight Future of Cities Project's Lead Expert Group commented in mid-2016[1] that, 'there is a considerable knowledge base, though it is often spread across disciplinary perspectives and not fully integrated'. Only by building frameworks within which people and organisations can position their contributions, and from which others can learn, will we ever achieve more than a series of anecdotes among researchers and their collaborators. The pursuit of digital built Britain needs an overarching, capabilities-based approach to research, with an emphasis on designing research, projects, prototypes and demonstrators with the specific objective of building competence and capability beyond the immediate participants.

The full report, and this summary, offer these communities a common language and framework of value, services, built environment, data, information and models, governance, learning and adaptation and context to discuss the capabilities needed to create a digital built Britain. We hope this will allow future research to be performed in a joined-up way, and that it will provide a structure for research funders to prioritise and fund the research to support the government's ambitions.
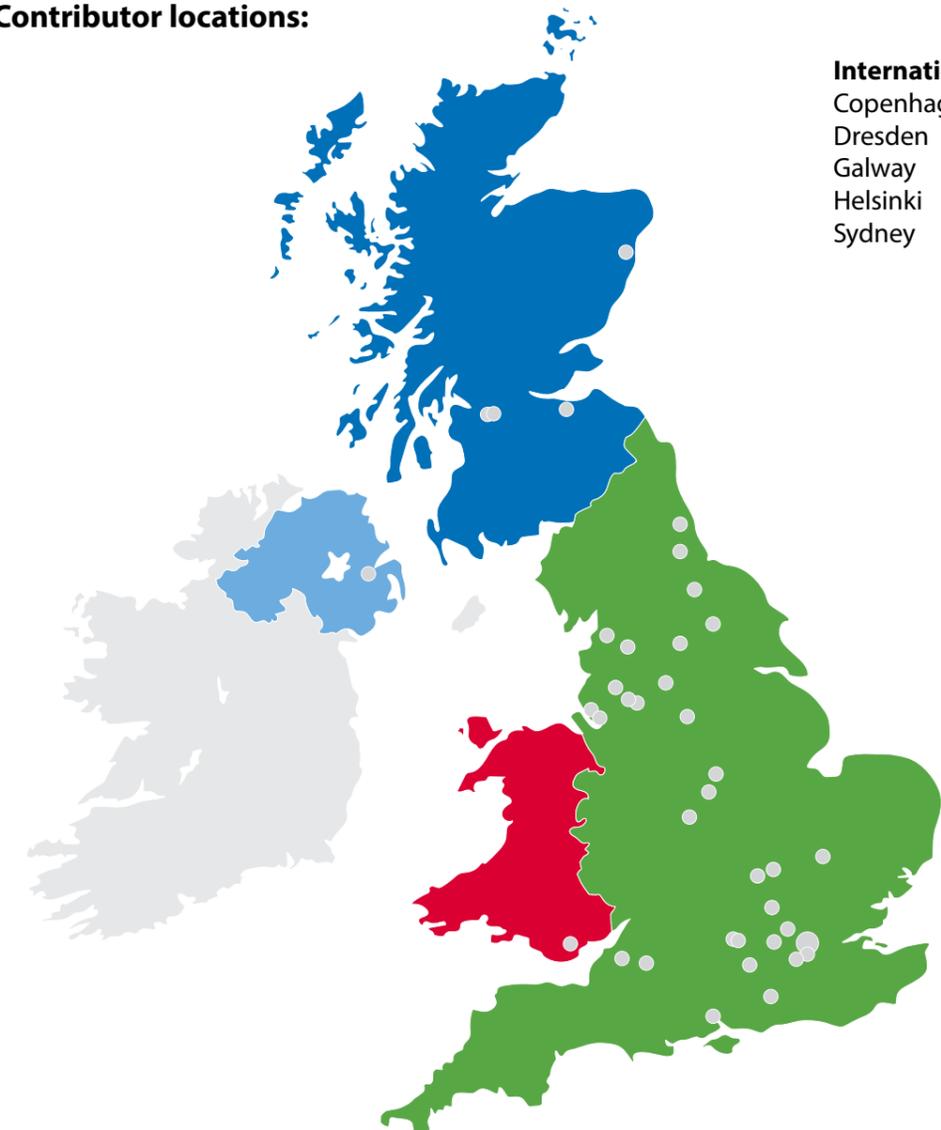
For policymakers and industry, we signpost sources of existing expertise and research to offer a snapshot of the current research and areas of competence. This allows cities and communities to harness the state-of-the-art digital capabilities that Britain has to offer.

This is a community-building report to support structured and informed strategy development. Many bodies will want to contribute to the definition and development of digital built Britain, including government departments, research councils, charitable funders and commercial organisations. Each will have their own specific interests, ambitions, objectives and targets. This summary document and the full report are tools to help each of these audiences to define the important capabilities needed by the UK, to prioritise these in light of their objectives and timeframes, and to identify and procure the necessary portfolio of research.

I look forward to working together with the community on this journey.

Contributor locations:

International:
Copenhagen
Dresden
Galway
Helsinki
Sydney

What do we mean by a digital built Britain?

Digital built Britain incorporates digital data, models and technologies into our built assets – from homes, offices and schools to transport networks, bridges and tunnels. This digital revolution will give us insights that transform how our buildings, infrastructure and services work, and how we use them.

Existing examples of digitalisation include building information modelling (BIM), which, through improved information management, has already brought about huge advances in the way the UK's architecture, engineering, construction and operations (AECO) sectors design, build and manage the country's buildings and infrastructure.

In 2016 the government launched the Digital Built Britain Programme to deliver further digitalisation of the sector. Over the next decade, new digital technologies such as the Internet of Things, digital twins, AI and advanced data analytics are expected to bring about further dramatic changes, transforming the UK's approach to planning, building, integrating and maintaining its built assets.
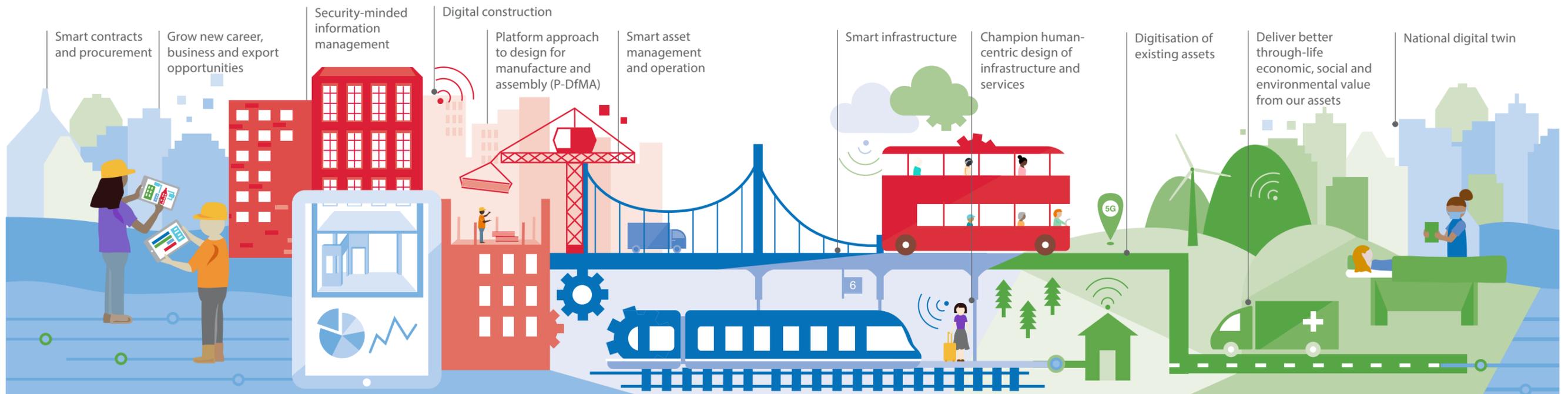
The benefits of digital transformation

If managed well, digitalisation could dramatically improve the performance of the UK's built assets, delivering improved performance, reduced impact on the natural environment and better public and social services. Above all, it will enable Britain to make better use of the buildings and infrastructure it already has.

People will derive greater value and benefit from services that are embedded in, and delivered through, the built environment. For example, smart sensors embedded in roads could be used to control autonomous vehicles and to smooth traffic flows. Using data and information in ways that are smarter – without being intrusive – will enable us to find ways to achieve greater capacity from our hospitals and schools, offices, roads and bridges. For example, monitoring and management of traffic flows and vehicle loads could further enable the extension of infrastructure repair and replacement cycles.

Digitalising the entire lifecycle of our built assets will give us a better understanding of how to create, to manage and to recycle our buildings and infrastructure. For example, data about the provenance and history of the materials within a building could enhance the recycling value of such materials and reduce waste.

Finally, by managing our assets and services as integrated systems rather than separate entities we will be able to deliver significant benefits for the citizens and organisations in the UK. For instance, thoughtful scheduling of services through well-designed transport nodes could increase capacity by reducing transfer and waiting times.

Smart contracts and procurement

Grow new career, business and export opportunities

Security-minded information management

Digital construction

Platform approach to design for manufacture and assembly (P-DfMA)

Smart asset management and operation

Smart infrastructure

Champion human-centric design of infrastructure and services

Digitisation of existing assets

Deliver better through-life economic, social and environmental value from our assets

National digital twin

Design

Use best practice, secure by default, information management and digital techniques to get data right from the start and design better-performing homes, buildings and infrastructure.

Build

Exploit new and emerging digital construction, information management, and manufacturing technologies and techniques to improve safety, quality and productivity during construction.

Operate

Use effective information management to transform the performance of the built environment and the services it delivers.

Integrate

Understand how the built environment can improve citizens' quality of life and use that information to drive the design and build of our economic and social infrastructure and the operation and integration of the services they deliver.

Meeting the challenges involved in creating a digital built Britain

What is the capability framework?

To achieve a digital built Britain, to manage it and to enable people to live and work happily and productively within it, citizens, companies and institutions of the UK will need to develop many new and existing capabilities within an evolving context.
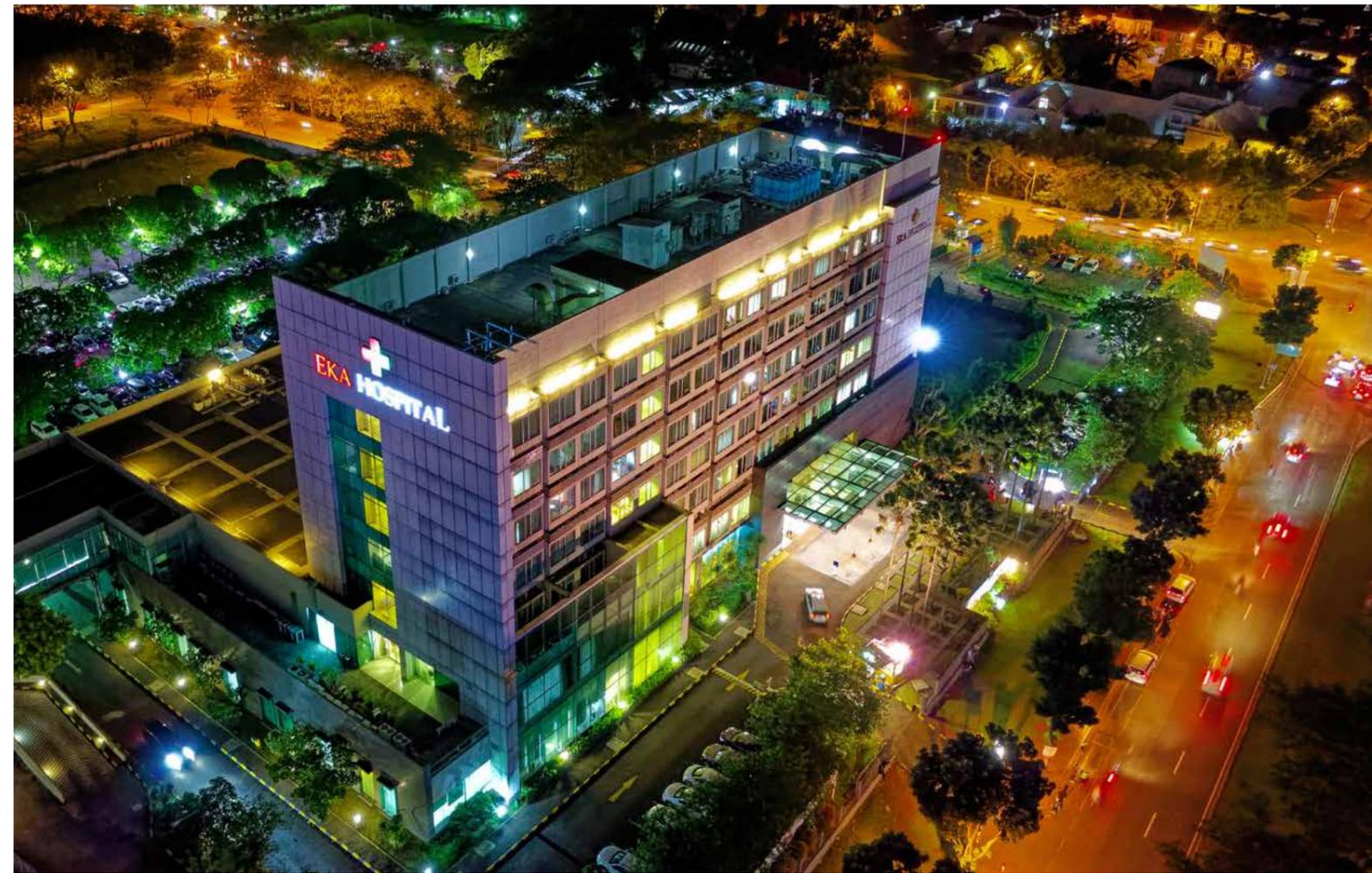
This framework encompasses a set of capabilities that are tightly interdependent and interlinked. Realising digital built Britain will entail developing these capabilities in parallel and recognising their interplay. The value that stakeholders stand to realise will be derived, in large part, from services. We focus here on services that are embedded in or which depend upon buildings and infrastructure within the built environment. Data and information will be gathered from services and assets and used, together with models of those services and assets, to better manage stakeholder value. Governance, through regulations, standards and contracts, sets the 'rules of the game', while skills and insights enable us to design and manage the integrated infrastructure that underpins our country. As the UK embraces digitalisation there is a massive process of continuing learning and adaptation, which will entail new skills and capabilities. Of course, all this will take place within an ever-changing context of drivers, trends and events and we will need to develop broad capabilities to proactively and responsively manage digital built Britain.

The categories of capabilities that form the capability framework are all concerned with developing the UK's ability to better understand and manage the potential of digital built Britain. In each case we have considered the opportunities and threats involved in digitalisation in order to identify the capabilities that will be required to make better decisions, achieve more effective interventions and create better outcomes.

The capabilities needed are likely to vary from sector to sector and will depend on each sector's specific characteristics. Some sectors are more advanced in particular areas and therefore offer opportunities for cross-sectoral learning. Other sectors have characteristics that make them ideal for use in early trials and pilot projects or to act as demonstrators. The capability framework was created as a tool to support the identification and commissioning of research, respecting the differences in context and objectives of policymakers and research funders.

With extensive input from CDBB's network, the capability framework has been designed to address all of these issues and to provide a comprehensive and consistent approach to identify the capabilities needed. It comprises seven capability categories formed around clusters of complex challenges relating to the creation of digital built Britain.

For example:

If a new hospital were to be built in digital built Britain, a decision-maker would first seek to understand who the stakeholders are and what benefits they wanted, such as convenience and patient rooms with pleasant views from the windows. They would gather information about how the new hospital would interplay with existing services, such as transport links, outpatient clinics and local chemist shops. They would consider the surrounding built environment, such as road congestion and walkability. Then they would look to understand how these services and the assets on which they depend would be affected by an evolving context of trends, drivers and events – such as demographic predictions and the changing climate.

They would ensure that those responsible for managing the hospital could do so efficiently and effectively, empowered by appropriately accessible data, information and models.

Finally, investors in the project would be rewarded appropriately for favouring long-term value over minimum initial cost because the benefits to stakeholders and services through-life could be demonstrably evaluated. Understanding and managing all the component parts of a digital built Britain, and the way in which they interconnect, will require a wide range of new skills. These skills will need to be continuously developed as technology, governance and contexts change.

The capability framework categories

Stakeholder value

How do we define the benefits and through-life value of a digital built Britain and how do we pay for them?

Services

How do we develop and manage digitally enhanced services embedded in the built environment?

Built environment

How can we use digital technologies to develop and improve our buildings and infrastructure and their impact on the natural environment?

Data, information and models

How do we manage the data involved and use it to create integrated models of our infrastructure and services, and then use those data, information and models to make better decisions?

Governance

How do we determine the best way to regulate a digital built Britain, to design and manage its complexity and to make decisions that people will support?

Learning and adaptation

How do we identify and teach the skills that will be needed to live and operate in an increasingly digitised environment?

Context, drivers and trends

How do we respond to the constantly evolving drivers, trends and events that will impact the development of a digital built Britain?

Developing capabilities through research

In compiling this report, the Centre for Digital Built Britain has worked with academics from across a wide range of disciplines and UK institutions to consider the capabilities and research needed to create a digital built Britain and to answer three key questions:

Capabilities:
What capabilities do we need that we don't already have?

New research:
What research might be required to underpin these capabilities?

Existing knowledge:
What research already exists that could be useful?

The following sections consider the above. This summary should be used alongside the full report as a tool for policymakers, companies and research funders to explore and prioritise their research agenda for creating a digital built Britain. The full, detailed report can be found on the CDBB website.

The full, detailed report can be found on the CDBB website at:
http://www.cdbb.cam.ac.uk/capability-framework-and-research-agenda.

How to read this summary

To help the reader, the capabilities in this framework have been given alphanumeric codes related to their category. So, for example, capabilities related to the built environment have codes B1, B2, B3, and so on. These are not an indication of their priority, simply a way of distinguishing them. These codes are used throughout the document to help link the capabilities to the identified research areas within the research agenda.

The following pages contain descriptions of each of the capabilities, including the identified areas for future research. You will find an overview of the whole research agenda for digital built Britain on pages 26–27.

The current state of research in each capability category is shown using the following colour code:

● Areas where there is currently little research activity to support the development of important capabilities, or where fragmented work needs unifying

● Areas where there is ongoing research to support important objectives that should continue

● Areas where research already exists that could be adapted or adopted to build capability

Stakeholder value

Define value derived from digital built Britain and find the best ways to pay for it

- Explore and debate benefits and outcomes and ways to measure them (V1)
- Consider the wants and needs of diverse users and translate these into meaningful specifications (V2)
- Find ways to make digital built Britain investable (V3)

The capabilities explained

Understanding the value and benefits that people and organisations seek from digital built Britain lies at the heart of this digital revolution. We need to build the capabilities to discern and articulate that value, to understand how it can be created or curtailed, and to make the right decisions about which benefits to prioritise.

Deciding what we want from digital built Britain is one of the most challenging capabilities to develop and to employ. We need to be able to identify, in detail, what the citizens of the UK value most and to understand which trade-offs they would favour. We must be capable of finding and engaging with all the people likely to be affected, now and into the future, recognising digitalisation's capacity to both help and hinder. Can digitalisation underpin debate and involvement, or will it exclude those who are not 'digital natives'?

We need to find ways to compare tangible and intangible value. We have the ability to put numbers to productivity and to investment; we also need to build a discussion framework that enables consideration of such things as social cohesion and well-being.

We must devise better ways of depicting the future so that people from different backgrounds, organisations and government departments can see what their shared future might look like. If we improve our

ability to make choices, then maybe we can improve our ability to specify the outcomes and outputs we want.

Frameworks and models could underpin new capabilities in understanding cause and effect and feedback loops, and help us to determine the best choices to make in complex situations where the impacts are difficult to predict. A range of frameworks and models are likely to be needed to fully explore the effect of the digital on the lives of citizens and their built environment.

People's behaviour can provide an indication of the things they value – so can social scientists help us identify what people might value in a digital built Britain? Frameworks and models could help architects, engineers, social scientists and policymakers to have a meaningful and auditable debate about the best outcomes and how to achieve them. Making people's mental models explicit enables them to be discussed, shared and used by decision-makers.

Computer models can be used to predict the future behaviour of assets, services and businesses, and of the complex systems of which they form a part. The models will support discussion and debate, enable cost-effective and low-risk experiments and hence build deeper understanding and insights.

The capabilities that we have highlighted here are, in large part, focused on creating better frameworks for thinking, and better models for supporting insight and decision-

making. We need to develop the ability to articulate the outcomes that we seek, and to explain why we believe a particular policy intervention will get us there.

And, finally, we need better ways to measure and understand costs and value, especially over time. The much-vaunted benefits of a digital world often accrue in different places or times than the investment that created them. A vitally important capability, therefore, is to understand the interplay of investments and returns to help us create commercial mechanisms that make digital built Britain investable – for organisations of all sizes. If paying more for a 'digital' building will save the occupants money in the long term, how much more is it worth paying now – by whom and to whom? If digital building controls will save energy and carbon emissions, then who pays the installation bills today to help users in the future? What is 'best value' and who makes the decisions when council budgets are on the line and corporate performance is reported quarterly?

Where do we go from here?

The increasing integration and data sharing around services and built assets will demand new capabilities and tools for thinking and decision-making about value creation at the intersection of the social, political, economic, legislative and technical. A starting point for research to build these capabilities would be to develop existing and new explanatory frameworks that could integrate inputs from across different disciplines in support of better understanding and decisions (V1).
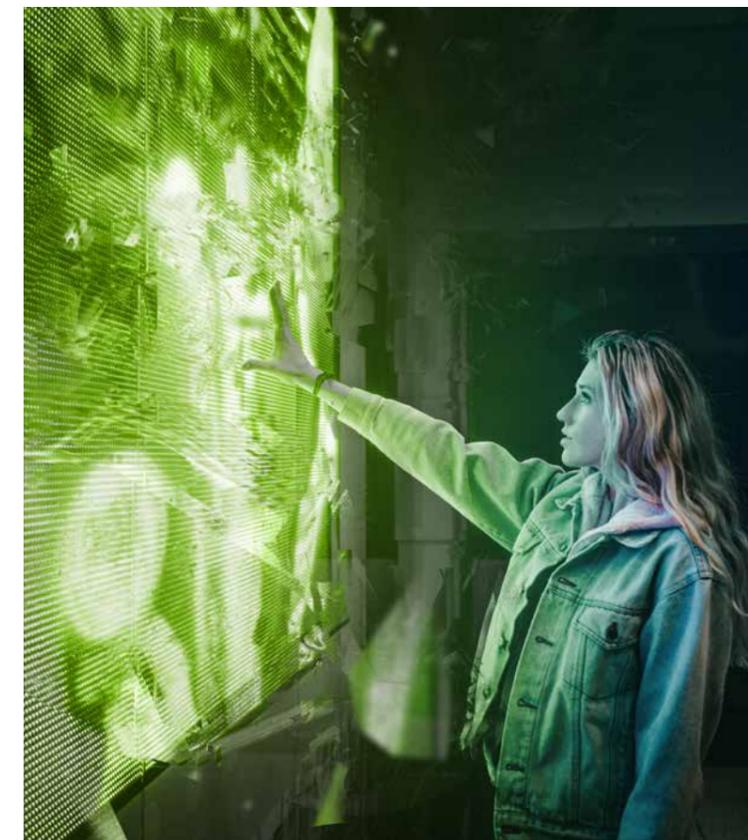
These frameworks could then enable the development of practical tools to support decision-making, prioritise future research and make better use of the insights that already exist, underpinned by research into the best ways to engage with diverse stakeholder groups using digital technologies. Various multidisciplinary research strands that already exist could be brought together to build and test decision-support platforms to help translate wants and needs to specifications for procurement (V2).

Although much research continues into business models, especially in relation to services, there is little that focuses on models

for digitally enabled services embedded in the built environment. The interplay of networks of cooperating organisations, assets and services will make identifying and rewarding value-creation ever more complex. Research is needed into the key question of how to find ways to pay today, for value that will only be captured tomorrow. (V3).

Identified research areas:

V1 Although research exists into key topics, there is little to help policymakers and decision-makers address conflicting demands. Research into explanatory and integrative frameworks would enable better targeting of further work and would support more effective use of current insights.

V2 Research could build on the explanatory frameworks to support stakeholder engagement, and develop tools for prioritisation and specifications for procuring services and built assets that generate value.

V3 Research into business models is essential to enable government and businesses to find ways to pay now for benefits that will only accrue in the future.

Services

Develop and manage services integrated into the built environment

- Define the value and outcomes resulting from services that depend on built assets (S1)
- Identify the interconnections and 'causality' between services and assets (S2)
- Create services that exploit the digitalisation of the built environment (S3)

The capabilities explained

We need to be able to define the outputs and outcomes we want from services that are embedded in, or delivered through, the built environment. In other words, we need to be able to specify the value we want from services. This is not easy, and research is needed to arrive at consistent and comparable ways of defining and measuring service performance. It is important to focus on what the user values, rather than on what is easy to measure. How can digital tools help here? Can we obtain different kinds of data, and how do we preserve privacy? Will the digital divide marginalise those that are less connected? How do we prevent the digitally disconnected – the homeless, the elderly – from missing out on value, bearing in mind the mantra that 'government services will be digital by default'?

We need the capability to make trade-offs and to understand the interplay of cause and effect between services and the assets that underpin them. How can the engineering and design of our built environment enable new and better services? How can digitalisation support this? We need to be able to recognise and design for any dependencies that might be created. If a data stream from the infrastructure fails, can we maintain the dependent services? Will there be ripple effects that will bring our city to a standstill and endanger the public?

Finally, we need to pay for all of this. How do we build business models that reflect the value created by services, the load they place on buildings and infrastructure – and the cost of failure, should it happen? We need tools that model these relationships and simulate the outcomes from decisions so that we can optimise the investment in services and their supporting assets. How do we model the asset capital cost against the lifetime value of a better service to decide who pays for what? All of this must be created and managed in an increasingly complex world where more and more things interconnect and depend on one another.

Where do we go from here?

At the core of a digital built Britain will be the services integrated with, and delivered through, the built environment. Integrative frameworks are needed to explore value and outcomes relating to these services (S1).

There is also a gap in our understanding of the interdependencies between assets and services and the opportunities that digitalisation will offer. Understanding the causes and effects relating to these interdependencies is a specific topic on which there is little research today (S2). Exploring the impact of asset performance (or degradation) on service performance (or failure) would underpin better decisions in relation to designing and managing assets and services as an integrated system.

Current research is looking at how service performance depends upon asset performance, as well as the implications of better asset management on service optimisation. However, this work is being done primarily in relation to road and rail networks. Research could usefully be extended to include different kinds of assets and services and to explore the role of digitalisation in enhancing the design and development of services that are closely linked with, or dependent upon, assets (S3). Business model research will address the ways in which investments in the design and management of buildings affect the services embedded within them, making them more or less valuable.

Identified research areas:

S1 Research is needed to develop integrative frameworks to identify and prioritise the pathways to value from services that are tightly coupled with the built environment.

S2 Research is needed to understand and model the causal interdependencies between assets and services that could underpin better use of data, better decisions and the setting of cost-effective performance requirements.

S3 Extension of current research could explore the role of digitalisation in enhancing the design and development of services that are closely linked with, or dependent upon, assets and the interplay of costs and returns.

Built environment

Enable our buildings and infrastructure to embrace digitalisation across the lifecycle

- Protect the natural environment alongside the built environment (B1)
- Manage interactions between built assets, infrastructure and services (B2)
- Use data, information and models to create and manage value from our assets (B3)
- Develop and adopt new digital technologies and tools (B4)

The capabilities explained

The data generated by a digital built Britain will enable more cost-effective creation and management of our built environment throughout its lifecycle.

However, we also need to consider how digitalisation will enable us to manage the impact of our buildings on the natural environment. Can we use computer models to find ways to mitigate the mechanisms and effects of climate change on the built environment?

We aim to digitise the entire lifecycle of our built assets, finding innovative ways to deliver more capacity from schools, hospitals, roads and rail networks. What new capabilities will we need in order to collect and use more effectively the huge amount of data this will generate?

For example, we need to work out how to collect data from pre-digital buildings that have not been enabled by such technologies as building information modelling (BIM). For buildings that are already digitally enabled, owners and managers need the capabilities to optimise the use of the data throughout the building's lifespan. What kind of value can we gain from a building's historical data sets that could become a tradeable asset and be worth nurturing?

The architecture, engineering, construction and operations (AECO) sectors have already adopted digital tools to support the planning and construction phases of new buildings and infrastructure. However, more needs to be done to understand how to transfer data and information effectively to owners to help them optimise the through-life costs and improve the environmental management of their buildings. This could also maximise the asset's end-of-life value and the potential for re-use of materials.

New technologies offer new promise, but which ones will win out? The key capabilities for embracing digital built Britain involve choosing and adopting the appropriate technology and managing the uncertainties involved. What can we do to reduce the costs and risks of experiments while we learn and choose, especially for smaller companies?

We also need to know how to avoid a world in which there are enthusiastic and competent early adopters at one extreme and a pool of the digitally disadvantaged at the other. A digitally enabled supply chain is only as strong as its weakest link.

Where do we go from here?

The impact of the built environment on the natural environment is increasingly recognised and research is needed into how design and planning could minimise this impact. In addition, and perhaps more significantly, research is needed into how digitalisation could contribute to managing built assets through life to minimise impact and resource use. Some work does exist, but much still needs to be done (B1).

The significance of the interaction between services and the assets on which they depend has already been highlighted. Equally, research could be undertaken into how digitalisation, data and tools could enable the design and management of the built environment specifically to improve services (B2).

Despite high-profile enthusiasm for digitalisation, the vast majority of the built environment consists of pre-digital assets, which will not benefit from the new technologies unless the emphasis shifts. Much remains to be done if we are to take the benefits promised for 'born-digital' assets and provide the same benefits for other buildings and infrastructure. Extracting data, converting it into models and using these models to manage pre-digital assets to reduce cost and environmental impact are important topics for research (B3). We need to research specific problems in this area from which we can extract generic lessons that can be more widely applied. In particular, we need to ensure that the findings include practical approaches to address the problems that industry faces in managing new and existing assets with digital methods.

There is considerable ongoing work into new digital tools and technologies, and methods of using them in the construction sector.

However, adopting such tools represents an investment risk that is often insurmountable, especially for smaller companies. Additional work is needed to explore low-cost and low-risk entry routes (B4) to support wider access.

Identified research areas:

B1 Research could explore digital tools to manage assets for their through-life economics and environmental impact, and could develop tools and processes that help trade-offs and enhancements to manage the impact of the built environment on the natural environment.

B2 Building upon an understanding of service–asset interactions, research could explore how digitalisation, data and tools could enable the design and management of the built environment for services.

B3 Research into digitising pre-digital buildings and infrastructure, and into ways to create data and models to manage legacy assets across organisations and over time, could reduce both cost and environmental impact.

B4 Extension of the current research could explore low-cost and low-risk entry routes to new technologies to the market, especially for smaller companies with limited resources.

Data, information and models

Use data, information and models to support better decision-making

- Use data and information to create value (D1)
- Develop and manage structures, schemas and tools (D2)
- Develop and manage integrated models (D3)
- Manage data reliably and securely (D4)

The capabilities explained

Data will form the foundation for a digital built Britain. We need the capability to understand and specify its use, to manage its access and security, to maintain quality and provenance and to share it with the right people in the right ways.

Companies will need to develop their management processes and policies to deal with more advanced software. Artificial intelligence will have an impact – but where and what will that impact be? Will legislation and regulations need to change?

In light of the tsunami of data that will be generated by digital built Britain, what new capabilities do we need to catalogue it, make it discoverable and maintain its quality over the life of the asset or service to which it applies?

To improve our understanding of digital built Britain and, especially, the move to greater integration between assets and services, we need to develop the capabilities to build and use computational models and data-based tools. The UK must develop its skills in these areas, building on building information modelling (BIM) and today's computer-aided tools for facility management. We need to ensure continuity and create models that can be used by others with confidence after the model's creator has moved on to another contract.

We need to explore how we can combine models of assets to examine not just a single building but a block of buildings, a neighbourhood or a city. Coupled with models of the transport system and other essential services, we envisage the use of large-scale digital twins, as suggested by the National Infrastructure Commission.[2] Capabilities needed include the capacity to store, find, access and share data and models in ways that maximise utility while preserving security and property rights. We need to integrate models of services with models of assets in ways that will enhance-decision making.

Technologies continue to be developed across a range of sectors, from the Internet of Things, to low-power, wide-area networks, to machine learning. These technologies have applications in the built environment, offering new ways to gather and analyse data and information.

New capabilities will be needed in order to make best use of the increasing power of data and models to review the past and to predict the future. Access to data and tools must be managed, recognising the power that access confers. Managers will need to embrace the use of models for the management of services and assets, in much the same way that budgets are used to predict financial futures and to prompt management action.

Where do we go from here?

Other industries, for example aerospace, defence and offshore oil and gas, have evolved their decision-making and management processes to use data and models as part and parcel of business as usual. Research to adapt and adopt the lessons they have learned can help the architecture, engineering, construction and operations (AECO) sectors to digitalise more quickly and effectively (D1).

Using data and models to develop better understanding and improve decision-making is predicated on the seamless and automated sharing of data. Research that extends current work can underpin the creation of robust structures, schemas and ontologies to underpin interoperability (D2).
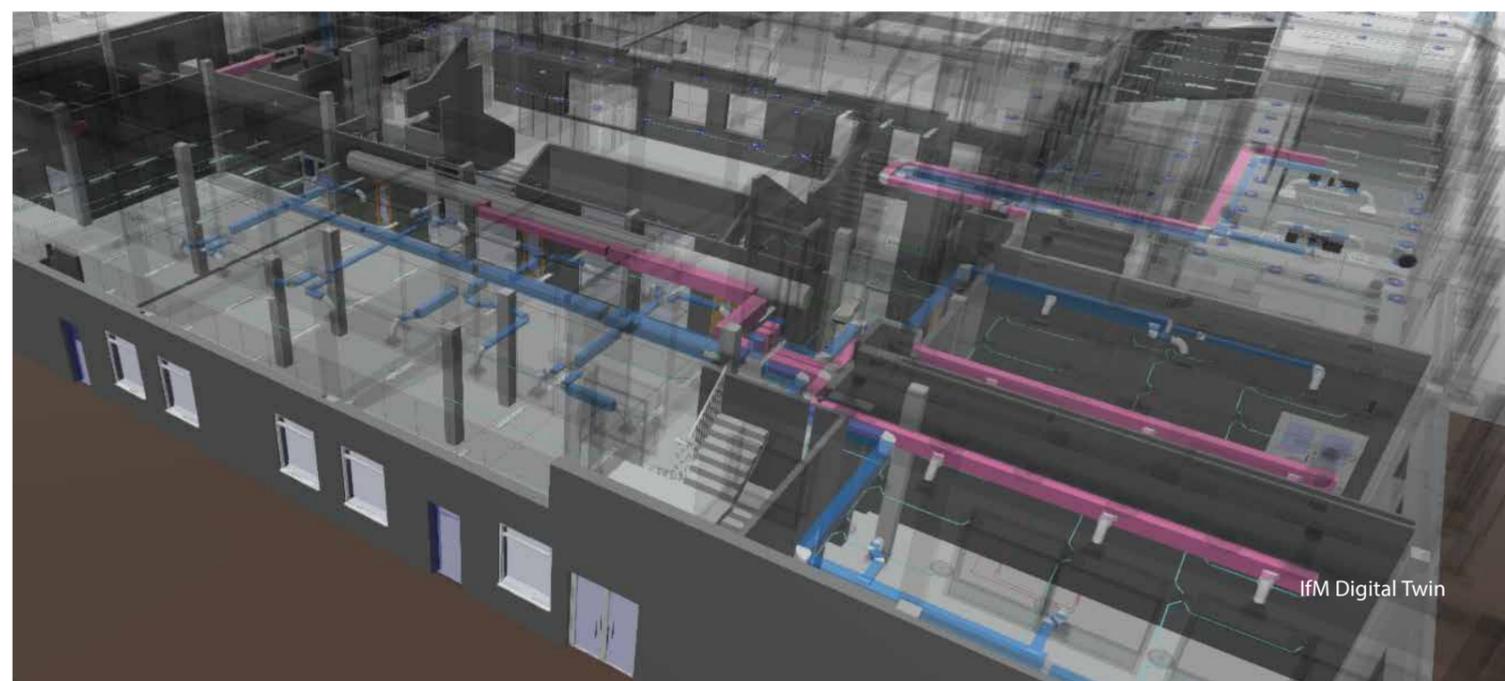
Similarly, work is needed to explore the development of federated models linked to physical assets (e.g. digital twins) (D3) that can be used to broaden and deepen the scope of management insight and to improve through-life management. This research can build on the considerable amount of current activity that exists in this area. CDBB's Digital Framework Task Group[3] has set out a roadmap for much of this work, while developments in models and their use will offer early lessons that can be demonstrated and disseminated.

The effective use of data, information and models to make better decisions will depend upon the accurate specification of data and the integration of insight and opinion with quantitative 'hard figures'. We will also need practical tools to gather data from diverse environments, with minimum disruption and cost, while at the same time respecting privacy and confidentiality. Research into the subtleties and practicalities of developing and managing data sets (D4) is currently active and is fundamental to this area.

Identified research areas:

D1 Research and practice from other industries should be explored and adapted to develop mindsets and processes to use data, information and models as central to business operations across the sector.

D2 Building on research momentum enables the creation of the robust structures, schemas and ontologies needed for interoperability of data and models.

D3 A clear research agenda is emerging, with research groups extending and refining work on the development and application of digital twins, on federated models and on the decision support tools these can enable.

D4 Research into how best to develop, manage and securely share accessible, quality data sets should be extended and adopted.

IfM Digital Twin

Governance

Govern and manage digital built Britain and its projects

- Establish the right regulatory regimes (G1)
- Create and manage consistent standards (G2)
- Design robust supportive contract structures (G3)
- Ensure that complex projects deliver resilient integrated infrastructure (G4)
- Use data and models in structured decision-making (G5)

The capabilities explained

Everything that we do is governed by the laws of the land, its supporting legislation, regulations and standards.

We need capabilities to choose the right regulatory regimes and to create standards that support rather than impede innovation. When creating regulations and standards we need to take into account the fact that data and information often span sector boundaries and that people and companies may need to share their data. A specific example, which highlights many key issues, is the automated checking of digital designs to make sure they comply with codes and standards. For this to work, regulations and standards need to be written in ways that machines can interpret and process.

As new business models emerge, and as services increasingly depend upon the data from built assets, so contractual obligations may extend right across the lifecycle, from construction and operation, to renewal and replacement of assets. If an error within some data set causes a lift to malfunction in a skyscraper, what then might be the liabilities and where might they lie?

We need the capabilities to define, design and develop the complex projects that will create and maintain digital built Britain. The interaction between infrastructure systems and service systems, between collaborating and competing organisations, are already subjects of research. Can we use digitalisation, better data and information, and more subtle and detailed models to improve performance? Can we build the capabilities to design a more resilient digital built Britain, despite the cross-system interactions? Does early work in 'systems of systems' inform our thinking about networked collaborators, all with different organisational priorities?

New data sets, more information and better models will help us develop the capability to refine analysis and we need then to better use the insights from analysis to make better decisions.

We need to know how to work with uncertainty. How much analysis is useful and when is it wasted? Do the decision-makers understand the limitations of the models and adjust their conclusions accordingly?

Digital built Britain will often entail contentious projects embedded in complex systems, involving multiple, sometimes competing, organisations. In such cases, effective communication with the public and all those involved is critical. There is room to improve the way we frame and explain decisions. What can we do to describe and communicate complexity to myriad stakeholders? Is the logic auditable (assuming the value and benefit that we seek is appropriately agreed)? These capabilities will need frameworks and models to underpin collective understanding and justifiable decisions.

Where do we go from here?

The challenge of managing regulations and standards increases as technology accelerates, digitalisation spreads and sectors, services and assets converge. Exploring the opportunities around automated compliance would encompass many key issues relating to drafting and using regulations in a digital world (G1).

As digital built Britain develops, sectors will increasingly converge and interact, and we will need to understand how to manage standards across the boundaries. Managing the convergence of sectoral standards represents an important research topic (G2) that could be developed from current skills and supported by existing networks of interested parties.

As supply networks become more complex, and as digitalisation and technologies, such as distributed ledgers, throw up new opportunities, research may be needed to explore new and digitalised contractual regimes (G3). With the recent launch of new framework contracts, there is an established research base available that could be used.

While huge opportunities are opened up by more integrated infrastructures, increased efficiency and the growing use of digital technologies, this also carries significant risks to the smooth running of complex systems and projects. To manage these risks, we need to determine the right balance between resilience, performance, cost-effectiveness and total expenditure (TOTEX). Networked centres of excellence are well aware of these needs and already offer research that supports tool development and provides insights for use by policymakers and decision-makers. These findings can be used to understand how to develop and manage complex and integrated systems of infrastructure and service in order to deliver a portfolio of objectives and manage constraints (G4). Massive potential value exists in pursuing such research further and the foundations are already well established.

Robust decision processes using data and tools in the best ways possible (G5) will be key to the success of digital built Britain, especially in a world of divergent viewpoints and uncertain data. Research into analytics tools, techniques and methods can enable such processes and there are currently networks of academics and practitioners interested and able to contribute.

Identified research areas:

G1 Research to explore the opportunities around automated compliance would address many key issues relating to drafting and using regulations in a digital world.

G2 Managing the convergence of sectoral standards represents an important research topic that could be developed from current skills and supported by existing networks of interested parties.

G3 Building on established research would enable the development of new and digitalised contractual regimes.

G4 Extending the current research at networks of universities and leading users to explore the interactions and implications for design and management of complex projects and complex systems through life would help to develop this critical capability.

G5 Current research networks and proposals could be used to explore how to create decision processes and tools, applied to current large and complex infrastructure decisions, for both quick wins and more broadly applicable insights.

Learning and adaptation

In digital built Britain, we will know how to

Understand the capabilities needed to create and flourish in digital built Britain

- Overcome barriers to adopting new technologies (L1)
- Identify what citizens and professionals need to know (L2)
- Disseminate lessons and benefits from early projects (L3)

Demonstrating virtual reality in construction projects at the CDBB session during Cambridge Science Festival, 2019

The capabilities explained

Creating a digital built Britain will involve learning and adaptation through a process of continuous change. Fundamental to this is understanding what competencies people will need to perform effectively and deciding how best to teach and enable them.

All users will need to develop the capabilities to use data better and to make educated decisions about their engagement with and navigation of the digitally enabled built environment and its services. Embedding security-mindedness at all levels will be essential to ensure a safe future in a world of ubiquitous data.

Can we develop a competency framework that better reflects value-adding activities in a world of changing job roles? Would this enable a more flexible workforce, and might more young people enter the sector? How might all-pervasive data change an organisation's core processes? Can the universities and professional associations develop to keep pace with digitalisation? How crucial will digital literacy become for citizens in a world of digital services?

Developing digital built Britain will involve many experiments, exploratory projects and demonstrators. Making these sustainable and maximising the lessons we can extract improves the return on investment and provides signposts for all the companies and citizens finding their way through a digitalised and integrated world.

Where do we go from here?

Despite the optimism surrounding digitalisation, the uptake of tools and technology remains fragmented, undermining the promise of improved supply chain productivity. Understanding the barriers to adoption (L1), especially for smaller companies along the extended supply chains of the industry, is important to enable better productivity for all. Research to understand specific problems and identify practical ways of applying the findings is needed to accelerate the uptake of outputs resulting from a wide range of research and new technologies relevant to the industry.

Achieving digital built Britain represents a massive change programme. There is much for citizens, professionals and leaders to learn. Some of this can be achieved by developing competencies that are defined, taught and developed within the context of widely adopted competency frameworks (L2). Perhaps the biggest task here is to align the industry, educational and professional bodies behind such an initiative. However, research could assist by providing insights into the keys to success.

To date and in the future, there will be many case studies, pilot projects and demonstrators that could be used to support learning. Many finish once their funding ceases and the stream of insights dries up. Research to understand how to maximise the sustainability and benefits of demonstrators (L3) would make the most of existing investments.

Identified research areas:

L1 Research to understand the barriers to adoption, throughout the supply chain, is important to enable better productivity for all.

L2 Research into key success factors could support the development and adoption of professional competency frameworks to align industry, educational and professional bodies.

L3 Research to understand how to maximise the sustainability and benefits of demonstrators would make the most of existing investments.

Context, drivers and trends

Manage digital built Britain in response to external drivers and trends

- Detect changing drivers, trends and events that might impact the built environment (C1)
- Characterise the probability and severity of trends and events (C2)
- Predict likely impacts and identify response options (C3)

The capabilities explained

Digital built Britain will exist in a context of external trends, drivers and events such as climate change, demographic shifts, economic cycles and natural and man-made disasters.

The UK will need to develop the capability to discern and monitor such trends and drivers in order to predict their impact on the built environment. We need to consider what frameworks we should use to explore both the social and economic impacts of these factors.

In order to make better decisions about how to manage digital built Britain in the face of these evolving trends we need also to make use of models from other sectors and combine them with models used for the built environment. We can also take advantage of existing capabilities in decision-analysis, planning and policy-making. Then we can make the best plans for precautionary and proactive interventions.

Where do we go from here?

There is a large amount of research into topics such as demographics, climate change, social movements and citizen behaviours and expectations. For policymakers and planners, designers and investors, much of this research can be accessed and adapted to detect new and changing drivers and trends (C1), and to

characterise their probability and potential impact (C2). Lessons from this can then be applied to the big issues that will face digital built Britain. Existing research on adaptive planning and policy creation can be further developed to create tools to develop pre-emptive and responsive options (C3) that will help decision-makers improve the design and management of the built environment subject to deep uncertainty.

Identified research areas:

C1
C2 Research into many of the trends, drivers and events that might impact the built environment could be adapted to detect and characterise new and changing drivers and trends and help make better decisions.

C3 New research could build on the available material to develop tools and designs for pre-emptive and responsive options as decision-support in the face of change.
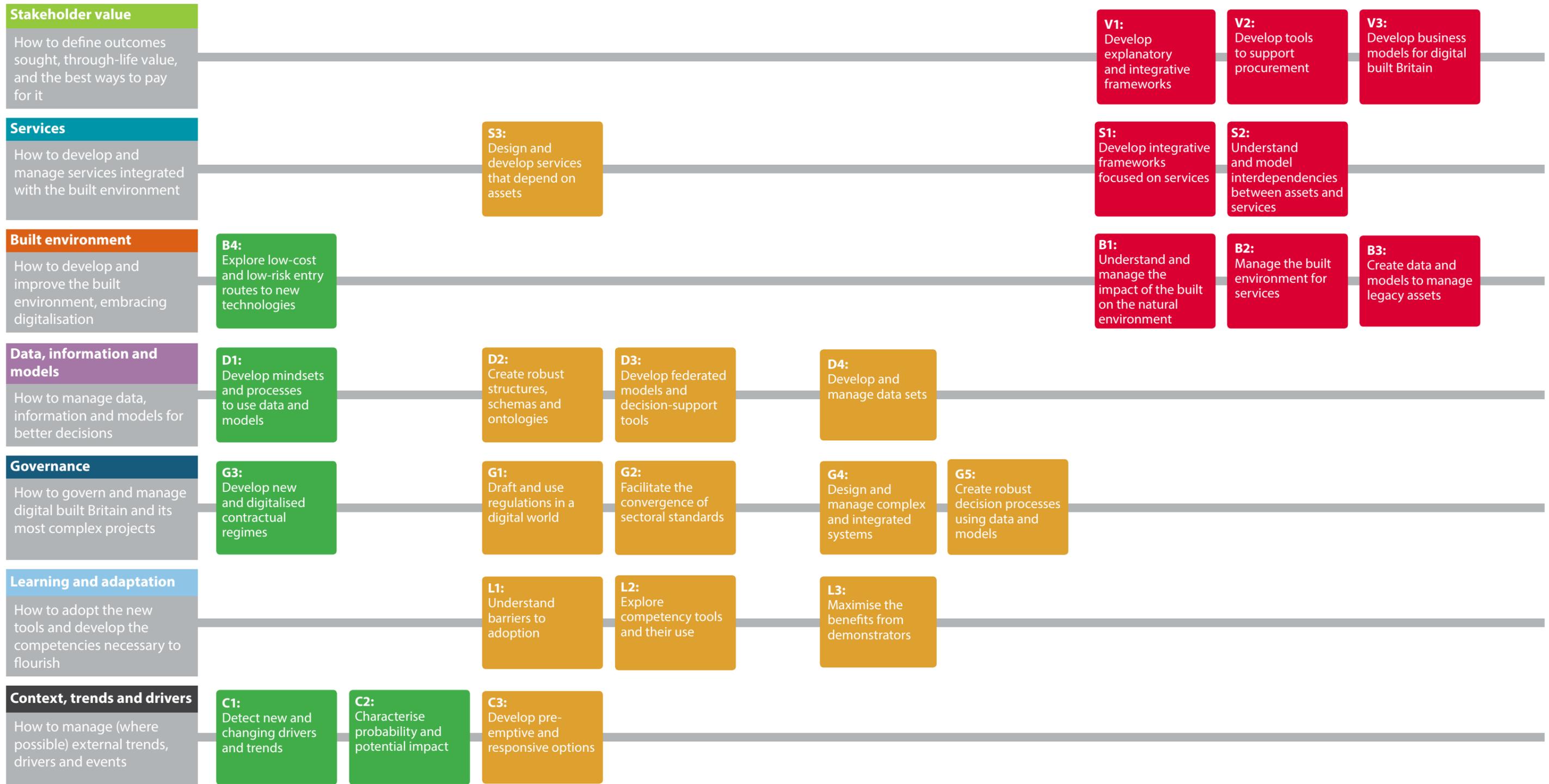
A research landscape for digital built Britain

This represents the portfolio of research needed to support the capabilities outlined throughout this document.

Areas where research already exists that could be adapted or adopted to build capability

Areas where there is ongoing research to support important objectives that should continue

Areas where there is currently little research activity to support the development of important capabilities, or where fragmented work needs unifying

Stakeholder value
How to define outcomes sought, through-life value, and the best ways to pay for it

V1: Develop explanatory and integrative frameworks

V2: Develop tools to support procurement

V3: Develop business models for digital built Britain

Services
How to develop and manage services integrated with the built environment

S3: Design and develop services that depend on assets

S1: Develop integrative frameworks focused on services

S2: Understand and model interdependencies between assets and services

Built environment
How to develop and improve the built environment, embracing digitalisation

B4: Explore low-cost and low-risk entry routes to new technologies

B1: Understand and manage the impact of the built on the natural environment

B2: Manage the built environment for services

B3: Create data and models to manage legacy assets

Data, information and models
How to manage data, information and models for better decisions

D1: Develop mindsets and processes to use data and models

D2: Create robust structures, schemas and ontologies

D3: Develop federated models and decision-support tools

D4: Develop and manage data sets

Governance
How to govern and manage digital built Britain and its most complex projects

G3: Develop new and digitalised contractual regimes

G1: Draft and use regulations in a digital world

G2: Facilitate the convergence of sectoral standards

G4: Design and manage complex and integrated systems

G5: Create robust decision processes using data and models

Learning and adaptation
How to adopt the new tools and develop the competencies necessary to flourish

L1: Understand barriers to adoption

L2: Explore competency tools and their use

L3: Maximise the benefits from demonstrators

Context, trends and drivers
How to manage (where possible) external trends, drivers and events

C1: Detect new and changing drivers and trends

C2: Characterise probability and potential impact

C3: Develop pre-emptive and responsive options

Next steps

In this document, we have laid out the capabilities that the UK will need to develop over the next few decades in order to build and enjoy digital built Britain. We have also identified the research needed to achieve this and, in the full report, provided an overview of existing research activity. From this we have mapped out a portfolio of research directions that could support the creation of the most important capabilities.

New research required

Perhaps the most difficult task facing the UK is to define exactly what we want to achieve in terms of a digital built Britain. Only when we have fully defined our objectives and agreed the trade-offs we are prepared to make will we be able to fulfil its vision.

Research can contribute to this by developing the frameworks to support debate and stimulate new insights. By assimilating and integrating the different elements that will contribute to a digital built Britain, frameworks will also help to build a clearer picture of what is required. In addition, they will support more effective use of existing research and enable better targeting of new projects. The development of such exploratory frameworks will increase collaboration across the research base. Once developed, they can be used to underpin the creation of new tools to support negotiation, specification and procurement of the elements of digital built Britain.

Building and operationalising these frameworks will take a long time and needs to start soon. Initially, the UK needs to take an exploratory approach, engaging widely with relevant work that already exists – and establishing who might contribute. In this way individual projects will avoid reinventing the wheel and can bring together many isolated insights to form a much clearer and more comprehensive picture.

Research should also explore how digitalisation can shape and exploit the interactions between the services, infrastructure and assets of digital built Britain.

To promote uptake, the UK needs to look at how digitalisation can create and capture value from the built environment, in order to produce a return on investment. This research into new business models is vital if we are to make digital built Britain an investable proposition and attract private funding to augment that of the public sector.

Further work needed in this area includes identifying how data, information and models can be used to improve the management of the vast pool of pre-digital (so-called 'legacy') assets – both to achieve better value and to help moderate the impact on the natural environment, through more precise measurement and management of assets. This will involve a shift in focus from digitalising the design and build phase of construction to encompass the entire through-life management of the built environment.

Extending existing research

Secondly, research can build on the considerable body of work that is already ongoing in many academic centres, to deliver both quick wins and deep insights. Various research groups are already collaborating closely with one another as well as with infrastructure owners and developers, consultants and organisations along the entire supply chain. As a result, many of the problems are already appreciated and momentum has been established. The funders and organisations of the UK need to invest further in this valuable work and increase efforts to disseminate the results to industry.

Research exists about topics such as standards and regulations, digital frameworks for interoperable data and models, and the planning, building and management of large, integrated infrastructures. This work could be applied in new ways to deliver quick wins and further synergies. Service development is also a focus of much existing research and this can be extended to services that are embedded in a digitalised built environment.

Much has already been invested in developing case studies and demonstrators. Research is needed to maximise the insights that can be extracted from such projects and ensure they are financially sustainable and able to continue delivering lessons of lasting value to digital built Britain.

Exploiting current insights

Thirdly, there are topics that could make use of existing research capabilities and insights in this and other sectors. There is much to be learned from other sectors, such as aerospace, defence, offshore oil and gas, and manufacturing, that have already embraced digitalisation and widespread use of data, information and models in decision-making and management. Research is needed into how to adapt and apply this to the built environment and to resolve barriers to adoption. Broader issues, concerning digital built Britain's response to trends and events, could also make use of research from other disciplines, including climate change, demographics and social trends. Such work can be used to build proactive policies to manage digital built Britain in an uncertain future.

> Our conclusion is that undertaking new research into frameworks and business models, extending existing work taking place in established research collaborations, and leveraging insights from this and other sectors to accelerate digitalisation provides a robust portfolio of next steps to build the capabilities needed for digital built Britain.

Acknowledgements

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http://www.nic.org.uk/wp-content/uploads/Data-for-the-Public-Good-NIC-Report.pdf

[3] CDBB's Digital Framework Task Group (DFTG) has published a roadmap for delivering the information management framework (IMF) for the built environment, and the Gemini Principles, the IMF's guiding conscience.
Learn more at https://www.cdbb.cam.ac.uk/DFTG

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✉   research@cdbb.cam.ac.uk   🐦   @CambridgeCDBB

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