Our Artefacts:
Our Stories
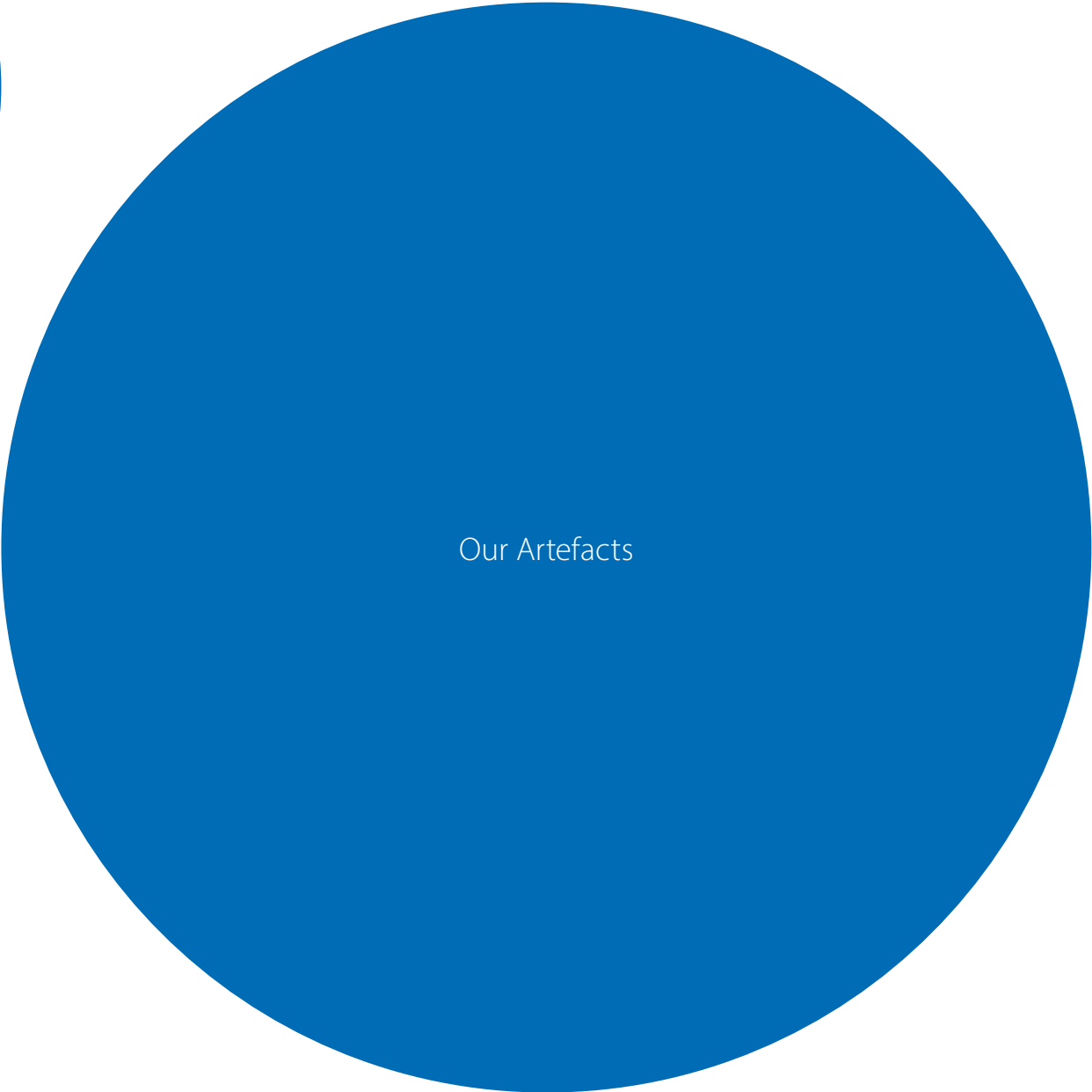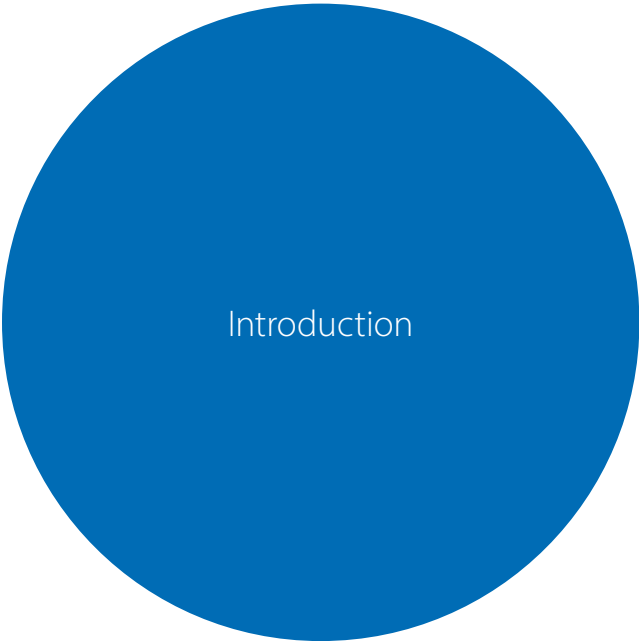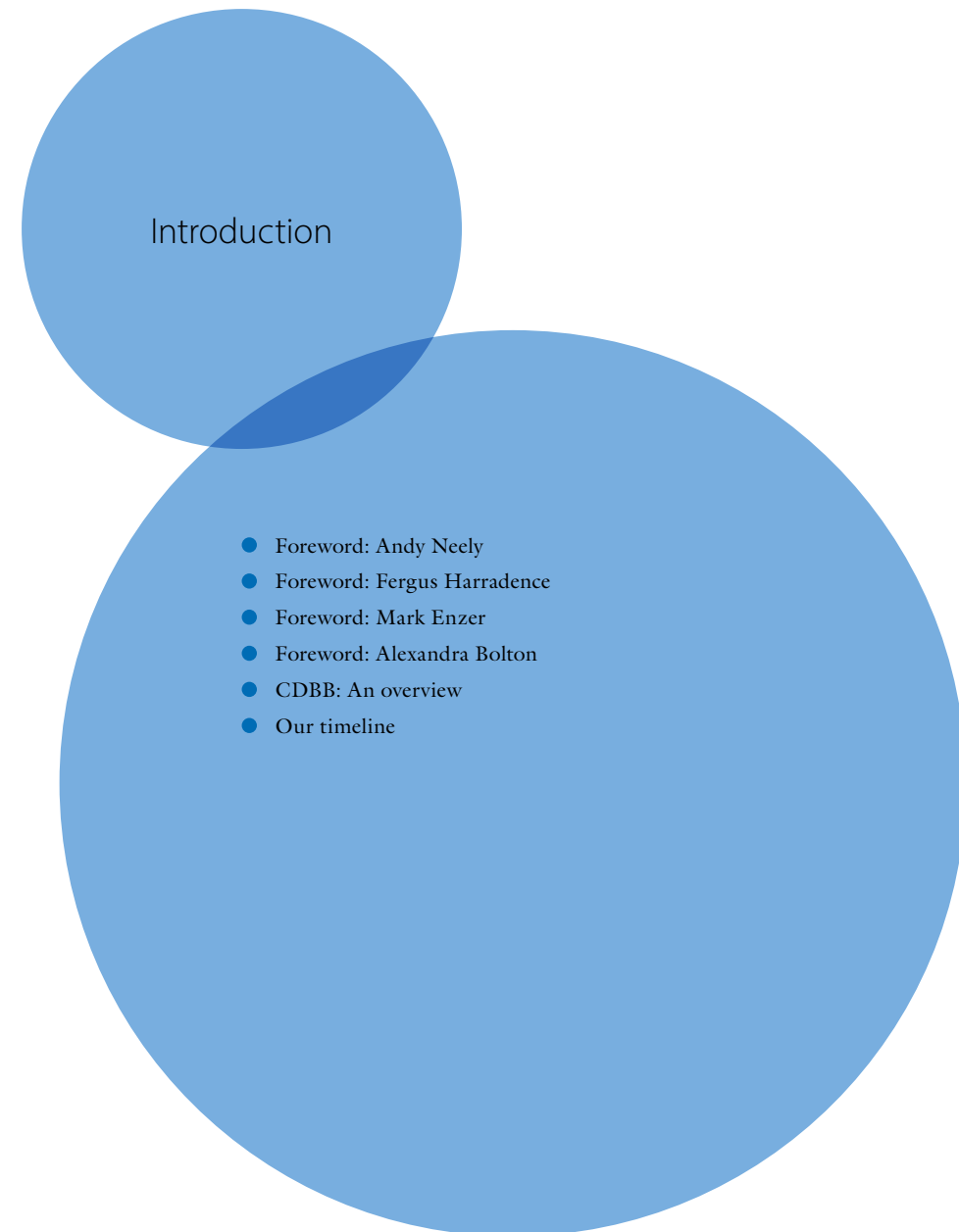
The foundations of a digital built Britain

OUR ARTEFACTS:
OUR STORIES

The foundations of a digital built Britain

cdbb

Click the spotlights to navigate through the book

Introduction

Our Artefacts

Acknowledgements

Introduction

Our Artefacts

Acknowledgements

- Foreword: Andy Neely
- Foreword: Fergus Harradence
- Foreword: Mark Enzer
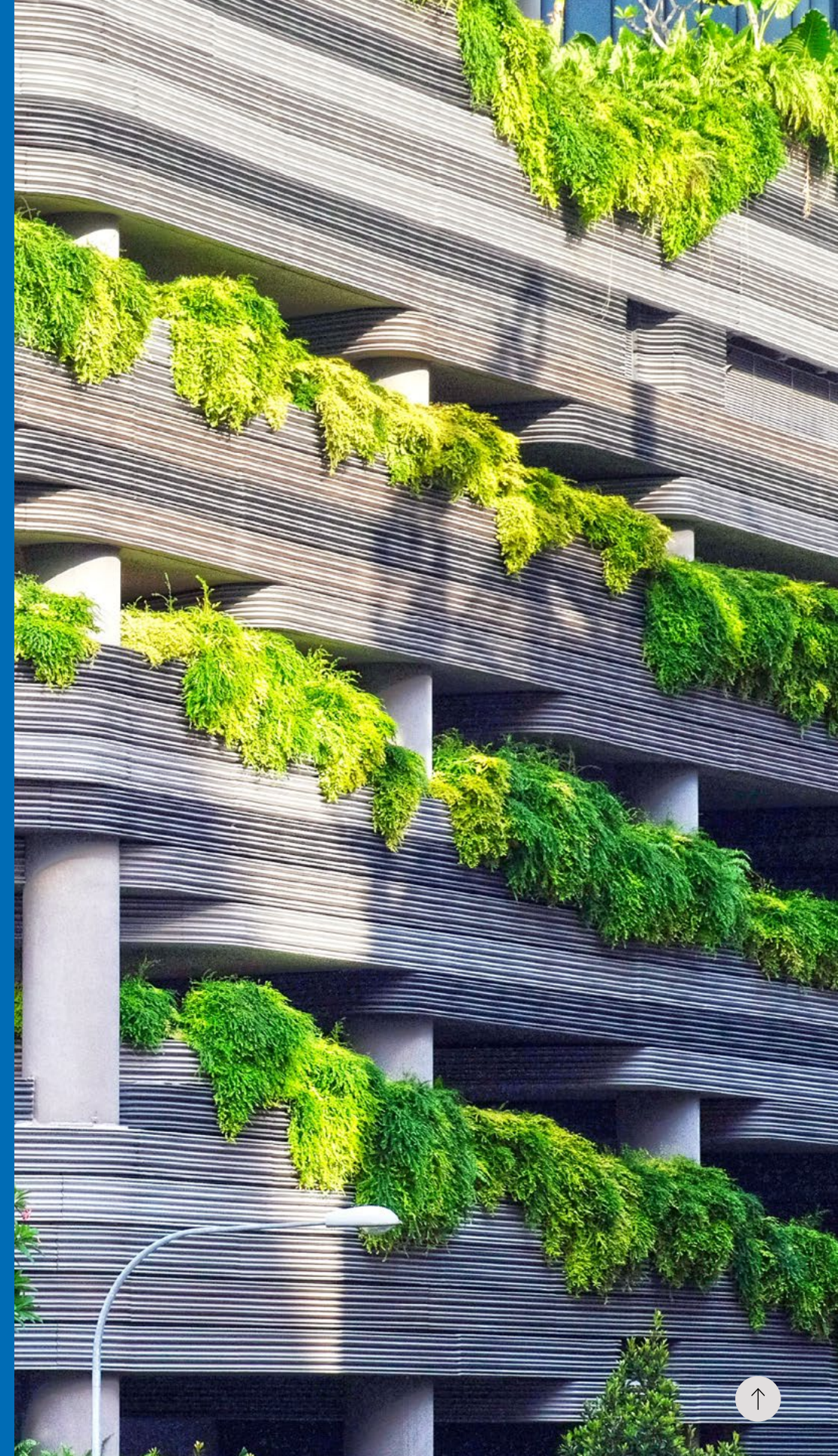- Foreword: Alexandra Bolton
- CDBB: An overview
- Our timeline

"CDBB has been the accelerator of the digital revolution in UK infrastructure"

Richard Threlfall
Global Head of Infrastructure

KPMG International

Introduction

Forewords

Prof Andy Neely OBE
Founding Director, CDBB

Fergus Harradence
Deputy Director for Construction, UK Government's Department for Business, Energy and Industrial Strategy

Right from the start, we knew the success of CDBB would hinge on its ability to be interdisciplinary. We knew that shared conversations – and ultimately a shared vision – would bring strength, purpose and clarity to our mission to support the digital transformation of the built environment.

In this book, you will find stories from industry, government and academia of foundational work that has been undertaken to deliver a digital built Britain. This ranges from cutting edge smart infrastructure, visionary thinking that has shaped policy here and abroad, practical tools and standards that are delivering better homes, schools and hospitals, and glimpses at the innovations that will shape our future built environment.

The storytellers through this book are just a small sample of the over 600 incredible contributors to the Centre over the past five years. The team has included engineers, economists, policy-makers, architects, medical doctors, computer scientists, librarians, geographers, lawyers, land economists and more. The through-thread in all of them is a desire to make a positive impact through cooperation, collaboration and a willingness to do things differently.

We set out as a discovery engine driven by research to identify and distil down crucial questions and answers. Over five years our focus has shifted to become part of a powerful delivery engine: helping to ensure that our outputs are translated into meaningful, practical change throughout the sector.

Just as in the health and safety sector advocates have shifted the landscape, we have helped enact the same measure of transformation in how the built and natural environment is managed. Much work is now digital by default. The DNA of the sector has changed, and we are all better placed to face the future because of it.

Over the past decade, government has set an ambitious agenda to transform construction and infrastructure performance to be greener, safer and more productive. The culture change from lowest cost to greatest whole-life value is happening. We are seeing it in the way clients talk about the projects they are commissioning. Sustainability, public good, security-mindedness, systems-thinking and collaboration have been brought to the forefront of decision-making.

Digital has always been a key enabler of government's vision for a transformed sector. The implementation of BIM on capital projects has delivered millions of pounds in savings for taxpayers. The information we are capturing about our infrastructure will be essential for addressing the systemic challenges we face, from post-pandemic economic recovery, supporting the levelling up agenda, to acknowledging the central role the built environment will play in the climate emergency.

The work of CDBB, and the UK BIM Task Group before it, has bolstered the UK's reputation as a leader and a convenor in the digital built environment. We have been pace-setters in collaborative work, partnering with over 3000 members and more than 100 nations to share knowledge and spark change through the Digital Twin Hub and Global BIM Summit.

Thanks to government, industry and academia working together through CDBB, the foundations for a digital built Britain are firmly in place. There is a supportive policy environment, a shared vision for the built environment, and the legacy of guidance, research and tools. I look forward to watching the momentum grow.

Mark Enzer OBE
CTO, Mott MacDonald; Director, CDBB

I am simply amazed how far we have travelled in such a short time. This book is a wonderful celebration of that journey – the fantastic people who have contributed and the great work that has been done.

But if so much has been achieved in the past five years, how far can the industry go in the next five, and beyond? Very far. Yet somehow I believe that we will still be able to detect the DNA of CDBB and its partners.

We'll see that DNA in the delivery of flagship Government policies for the built environment like the Construction Playbook and Transforming Infrastructure Performance: Roadmap to 2030. We will also see that DNA wherever it is recognised that the built environment has a purpose, and that purpose is 'to enable people and nature to flourish together for generations'. Data and digital will remain a key enabler in making this vision a reality.

For the past five years, CDBB, its partners and networks have driven forward the vision for a digital built Britain. The 'drive' will continue because our industry is blessed with passionate capable people who will step up, so I am truly excited about what the next five years, and beyond, will bring.

Alexandra Bolton
Executive Director, CDBB

This book celebrates the achievements of a five-year foundational journey to make digital built Britain a reality. It showcases the real-world impact of CDBB and its partners through a carefully curated collection of artefacts. Together they tell the stories of the people, projects, places, and processes quietly revitalising our natural and built infrastructure and its services.

These stories mark the milestones of an incredible group effort to develop and demonstrate policy and practical insights helping us all to tap into new and emerging technologies, data and analytics to enhance the natural and built environment.

CDBB has built on the great work of the UK's BIM Task Group before us. Our work marks the first time an interdisciplinary approach of such breadth and depth has been taken. Groups from across industry, academia, and policy have shared their time, resources, and expertise to create a big picture view of the built environment now and into the future. The levels of co-operation and collaboration are astounding.

I want to thank everyone who has worked for CDBB over the past five years. I'd also like to thank all those individuals and organisations who have partnered with CDBB, and those people and organisations who have adopted and utilised the outputs created by us all. Your passion, expertise and enthusiasm have produced these fantastic outputs.

No single organisation can change a sector. CDBB's successes are the result of the work and successes of many. I am honoured to have played a part in a programme of such depth, breadth and significance.

Centre for Digital Built Britain (CDBB)
was founded as a partnership between
Department for Business, Energy
& Industrial Strategy (BEIS)
and the University of Cambridge

We opened our doors
in autumn 2017
with a clear mission:
to expand and embed
the digital transformation
of the UK's built environment

CDBB:
An overview

Together with our partners in industry, academia and government, we have made extraordinary progress. CDBB's overarching role was to bring people together, to convene, connect and coordinate across the whole of the built environment. We did so with energy and commitment.

As a result, we have radically increased the UK's digital-built ambition, produced resources and training that have grown global capability in Building Information Modelling (BIM) and digital twins, and undertaken key, foundational work to deliver the National Infrastructure Commission's recommendation to create a National Digital Twin (NDT) of the built environment.

The outputs of our programmes will deliver better outcomes for people and the environment, for generations to come. Now referenced in the Construction Playbook, the Construction Leadership Council's Roadmap to Recovery programme and the Infrastructure and Projects Authorities Transforming Infrastructure Performance Roadmap to 2030, the UK BIM Framework and Information Management Framework (IMF), both developed by CDBB, are helping the public and private sectors to improve the social, economic and environmental impact of homes, schools, hospitals and community facilities.

This book is not a comprehensive account of our work. Rather it aims to capture something of the essence of CDBB through a set of 'artefacts', each introduced by its own curator. The stories presented should provide a sense of both what we achieved and the spirit that drove us.

And as we mark the completion of our mission, if not our impact, we are proud to say that our most significant legacy should be that of a healthier planet, a happier society and a more balanced economy.

Our sincere thanks go to everyone who has been involved in our programmes over the past five years. Your passion and expertise helped contribute to CDBB being a provider of uniquely valuable knowledge and a wonderful place to work.
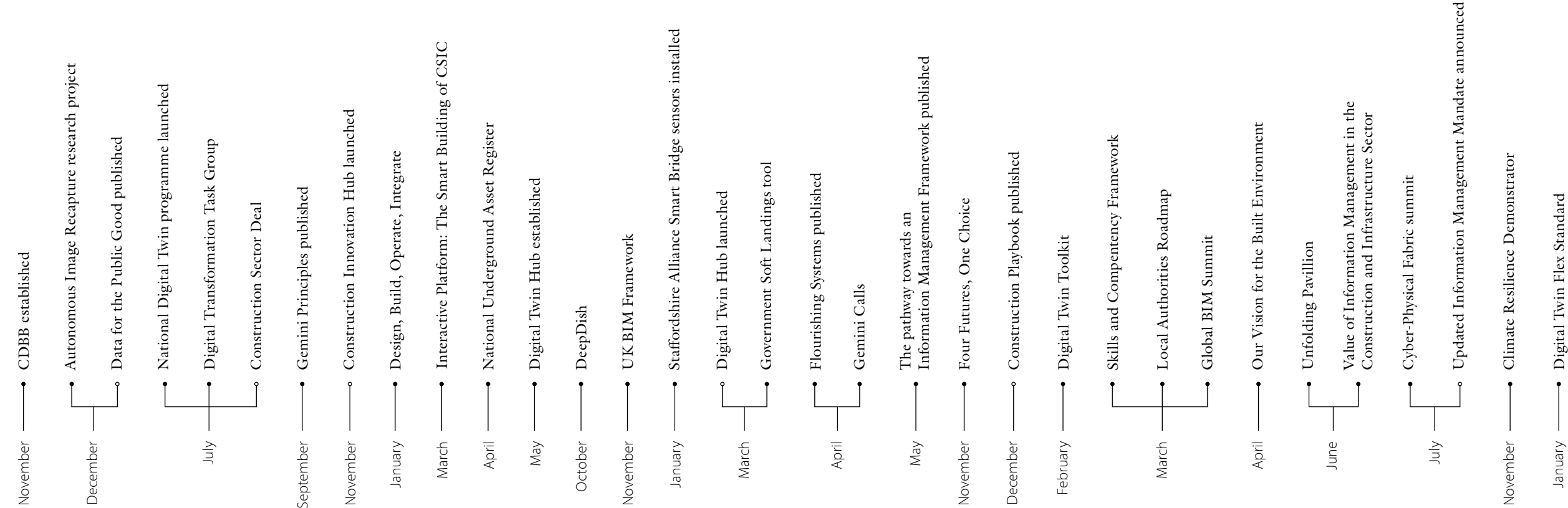
Five years ago, CDBB didn't even have an office. Now there are literally thousands of people working on the digital built Britain agenda: tens of thousands if you include the people making use of our materials and our outputs. In five hectic, inspiring and hugely rewarding years, we have evolved from a mission to a movement.

It is time to turn the page, but this is not the end of the story. The digital evolution of the built environment continues. It will be fascinating to see where it leads.
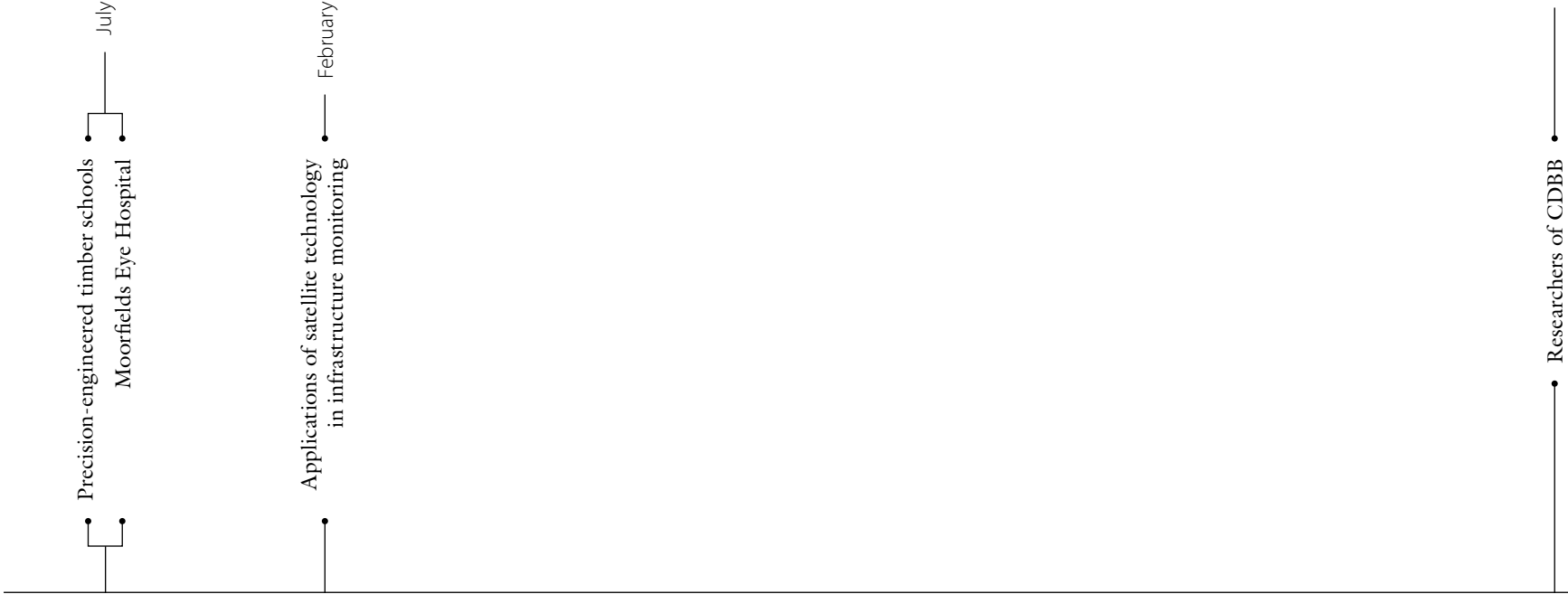
Our timeline

2017
- November — CDBB established
- December — Autonomous Image Recapture research project
- December — Data for the Public Good published

2018
- July — National Digital Twin programme launched
- July — Digital Transformation Task Group
- July — Construction Sector Deal
- September — Gemini Principles published
- November — Construction Innovation Hub launched

2019
- January — Design, Build, Operate, Integrate
- March — Interactive Platform: The Smart Building of CSIC
- April — National Underground Asset Register
- May — Digital Twin Hub established
- October — DeepDish
- November — UK BIM Framework

2020
- January — Staffordshire Alliance Smart Bridge sensors installed
- March — Digital Twin Hub launched
- March — Government Soft Landings tool
- April — Flourishing Systems published
- April — Gemini Calls
- May — The pathway towards an Information Management Framework published
- November — Four Futures, One Choice
- December — Construction Playbook published

2021
- February — Digital Twin Toolkit
- March — Skills and Compentency Framework
- March — Local Authorities Roadmap
- March — Global BIM Summit
- April — Our Vision for the Built Environment
- June — Unfolding Pavillion
- June — Value of Information Management in the Construction and Infrastructure Sector
- July — Cyber-Physical Fabric summit
- July — Updated Information Management Mandate announced
- November — Climate Resilience Demonstrator

2022
- January — Digital Twin Flex Standard

Legend
- Year ●
- Artefact ●——
- Milestone ○——

Ongoing projects
- July — Precision-engineered timber schools
- July — Moorfields Eye Hospital
- February — Applications of satellite technology in infrastructure monitoring
- Researchers of CDBB

Back to index ↑

Our Artefacts

Acknowledgements

Introduction

- Centre for Digital Built Britain (CDBB)
- Autonomous Image Recapture
- National Digital Twin programme (NDTp)
- Digital Transformation Task Group (DTTG)
- The Gemini Principles
- Design, Build, Operate, Integrate
- Interactive Platform
- National Underground Asset Register (NUAR)
- Digital Twin Hub (DT Hub)
- Precision-Engineered Timber Schools
- Moorfields Eye Hospital
- DeepDish
- UK BIM Framework
- Staffordshire Alliance Smart Bridge Project
- Satellite Infrastructure Monitoring
- NHS Scotland (NHSS), Government Soft Landings (GSL) Navigator
- Flourishing Systems
- Gemini Calls
- Information Management Framework (IMF)
- Four Futures, One Choice
- Digital Twin (DT) Toolkit
- Skills and Competency Framework
- BIM Early Steps Roadmap
- Global BIM Summit
- Our Vision for the Built Environment
- Unfolding Pavilion
- The Value of Information Management in the Construction and Infrastructure Sector
- Cyber-Physical Fabric Summit
- Climate Resilience Demonstrator (CReDo)
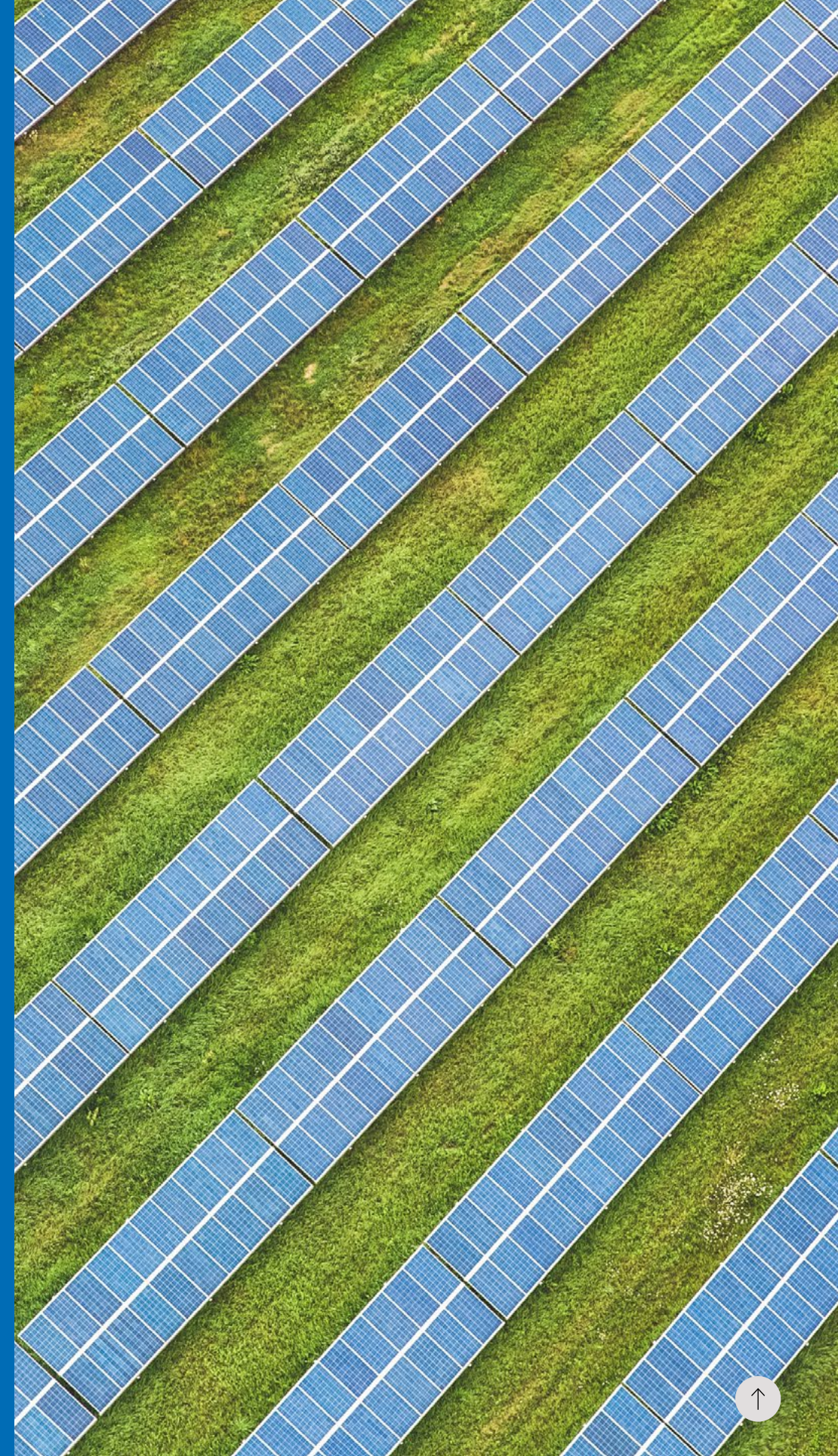- Digital Twin (DT) Flex Standard
- Researchers of CDBB

"CDBB has played a foundational role in the global digital twin marketplace over recent years.

In a truly trailblazing way, it's done much of the heavy lifting"

Adam Beck
Executive Director

Smart Cities Council Australia New Zealand

Our Artefacts

Centre for Digital Built Britain (CDBB)

Partnership between the Department for Business, Energy and Industrial Strategy and the University of Cambridge.

The mission became a movement

CDBB was launched by the UK government in 2017, with a mission to support digital transformation and the use of technology in the built environment. It soon became clear that to achieve this goal it had to contribute at different points in the technology lifecycle, from discovery to delivery.

As the Centre evolved, several key elements of the mission emerged. It funded and supported a research programme to increase our understanding of future practices and technologies. It encouraged and promoted the development of emerging innovations and accelerated their adoption by the market. As the home of the UK's National Digital Twin programme (NDTp), it built the framework for an ecosystem of connected digital twins to derive better outcomes from our built environment. As part of the Construction Innovation Hub, it worked alongside more than 300 partners. In all these initiatives, CDBB made a significant contribution to the creation and progress of a range of projects, from overarching principles to specific technology applications.

Over time, the mission has become a movement. CDBB has engaged with and encouraged a wide and growing community, across government, industry and academia, in the UK and overseas. It has been both convenor and catalyst, making vital connections across disciplines and accelerating new ways of working in the built environment that are making a tangible difference to people's lives. It has helped create commercial opportunities and enabled individuals and organisations to collaborate more closely and effectively than originally seemed possible.
It has also maintained a security-minded approach that aims to protect people, built assets, data and the environment.

Over its five-year lifespan, CDBB has adapted to the changing needs of society and industry. People have come and gone, but the Centre's unique ethos and energy have remained. Together we have helped pave the way for a smart digital economy in the built environment. Thanks to work done by, and in collaboration with CDBB, the UK and other countries are changing the way we plan, build, maintain and use our social and economic infrastructure – to create a brighter future.

Andy Neely OBE,
Founding Director, CDBB

Professor Andy Neely was the founding director of the CDBB. He is pro-vice-chancellor for enterprise and business relations at the University of Cambridge and former head of the Institute for Manufacturing. He is a fellow of Sidney Sussex College and founding director of the Cambridge Service Alliance. He was formerly deputy director of AIM Research, the UK's management research initiative. He is a fellow of the Sunningdale Institute, the British Academy of Management, the Academy of Social Sciences, and the European Operations Management Association.

Autonomous Image Recapture

Research project using advanced image processing
and computer vision techniques.
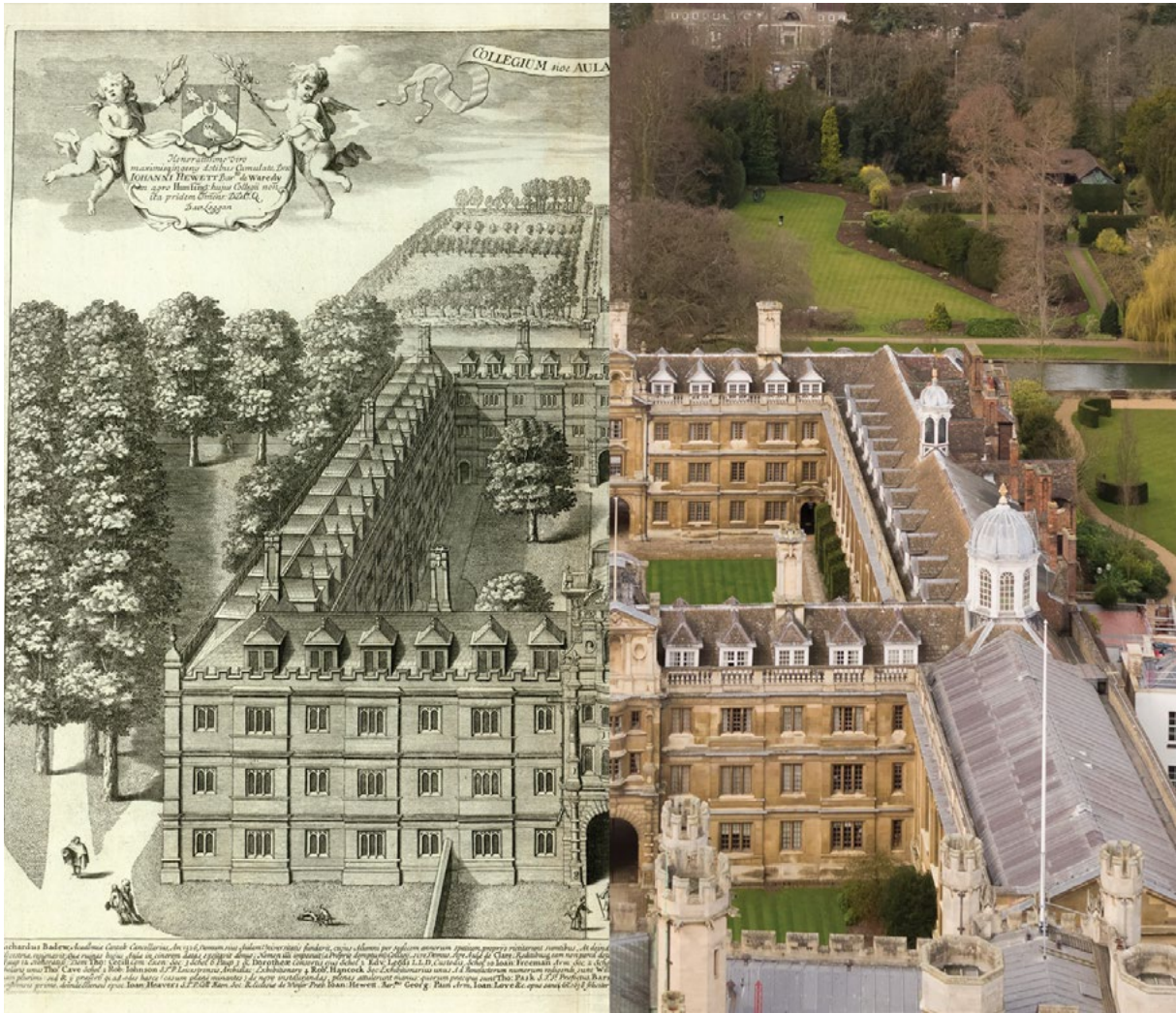
Engravings and algorithms

A set of 17th century engravings led information engineers and architects to fly a drone over Cambridge and develop algorithms that will help us to both analyse these engravings and compare the current state of these historical buildings to those depicted.

The engravings in question are stunning line drawings of Cambridge colleges made by David Loggan. The drone enabled us to recreate the geospatial viewpoints taken up by Loggan's imagination. GPS tracking provided fairly accurate camera positions, from which we extracted features such as lines and corners of buildings. With enough images and spatial information, we could reconstruct objects in 3D.

We tested out some of our newer techniques to extract lines, as well at points, and from multiple views to then create a wireframe model. The first college to be reconstructed was Clare College. We then took Loggan's etching of Clare and extracted lines from that using image processing techniques. With a bit of manual help we matched these lines to our 3D wireframe. Once we knew which line was where, we were able to move a simulated camera around the wireframe to see what it revealed. When we were as close as possible to Loggan's viewpoint, we flew the drone back up to that position, took another picture and compared the two.

By overlaying the image and the drawing we could observe differences and similarities. We could see how buildings have changed since the late 17th century and where Loggan used artistic licence, for example to straighten the College courts into nice perpendicular rectangles. Some art historians even think that this flexibility suggests he wasn't the artist of certain works; it is possible that Loggan actually had a 'school' of artists, which might explain the huge number of engravings.

During the project we developed potentially widely applicable computer vision algorithms, including one called REFORM (Rotor Estimation From Object Resampling and Matching). This involved nice mathematical techniques for averaging geometric objects, which we've also used in other work. It was a good test bed for us – and offers a low-cost option for showing how the built environment changes over time.

From 17th century art to 21st century algorithms. We all learnt a lot on this project.

Joan Lasenby,
Professor of Image
and Signal Analysis,
Department of Engineering,
Cambridge University

Joan is currently Professor
of Image and Signal Analysis in
the Department of Engineering,
where she is also Deputy Head of
Department (Graduate Studies).
She is also a Fellow and Director
of Studies in Engineering
at Trinity College.

National Digital Twin programme (NDTp)

A socio-technical change programme of national significance driven by the public good.

This stuff works

From day one, the NDTp has attracted people who are passionate about changing the world by shaping the future of infrastructure and the built environment.

Our mission? To coordinate and align, working with academia, industry, and Government. We engaged with infrastructure owners, operators, investors and suppliers who are invested in serving the public to help shape the programme. We also engaged national initiatives specialising in cyber-physical infrastructure, articifial intelligence, manufacturing and others.

The programme's strong ethos of collaboration, improvement and transparency was embodied within all team members, partners and across all key projects. On the CReDo, major utilities and delivery partners came together to share data across organisations. On the Digital Twin Hub (DT Hub), the shop front to the programme, a vibrant community showed a real desire to share knowledge. The Information Management Framework aims to allow high-quality data to flow securely across organisational boundaries and inform better decisions.

Since day one the NDTp has produced a large number of impactful outputs: the Gemini Principles, Flourishing Systems, Pathway towards the Information Management Framework (IMF), and the Tomorrow Today film that premiered at COP26. The programme was referenced in several high-level government strategies including the National Infrastructure Strategy, National Data Strategy, National Innovation Strategy and Transforming Infrastructure Performance. All of these make us really proud of the work we have done.

The programme has created a strong international movement around how digital twins can be connected and provide better outcomes for people and nature. It has enabled alignment on common principles nationally and also demonstrated how a collaborative delivery vehicle, a sociotechnical change programme and systems thinking approach are the right ingredients for transforming an entire industry. These will remain lasting impacts.

For so many of the people involved, this is a deeply meaningful venture. They believe in the public good and are determined to keep the momentum aligned to this purpose. This stuff isn't just important; it works, and it needs to carry on.

Peter El Hajj,
Programme Lead, NDTp

Peter leads the NDTp at CDBB. He is responsible for the delivery and strategic alignment of the programme. Peter's background is in civil engineering with a PhD in Data Driven Asset Management. He is experienced in infrastructure finance, public-private partnerships and ESG. Peter is currently an InfraTech advisor at KPMG UK.
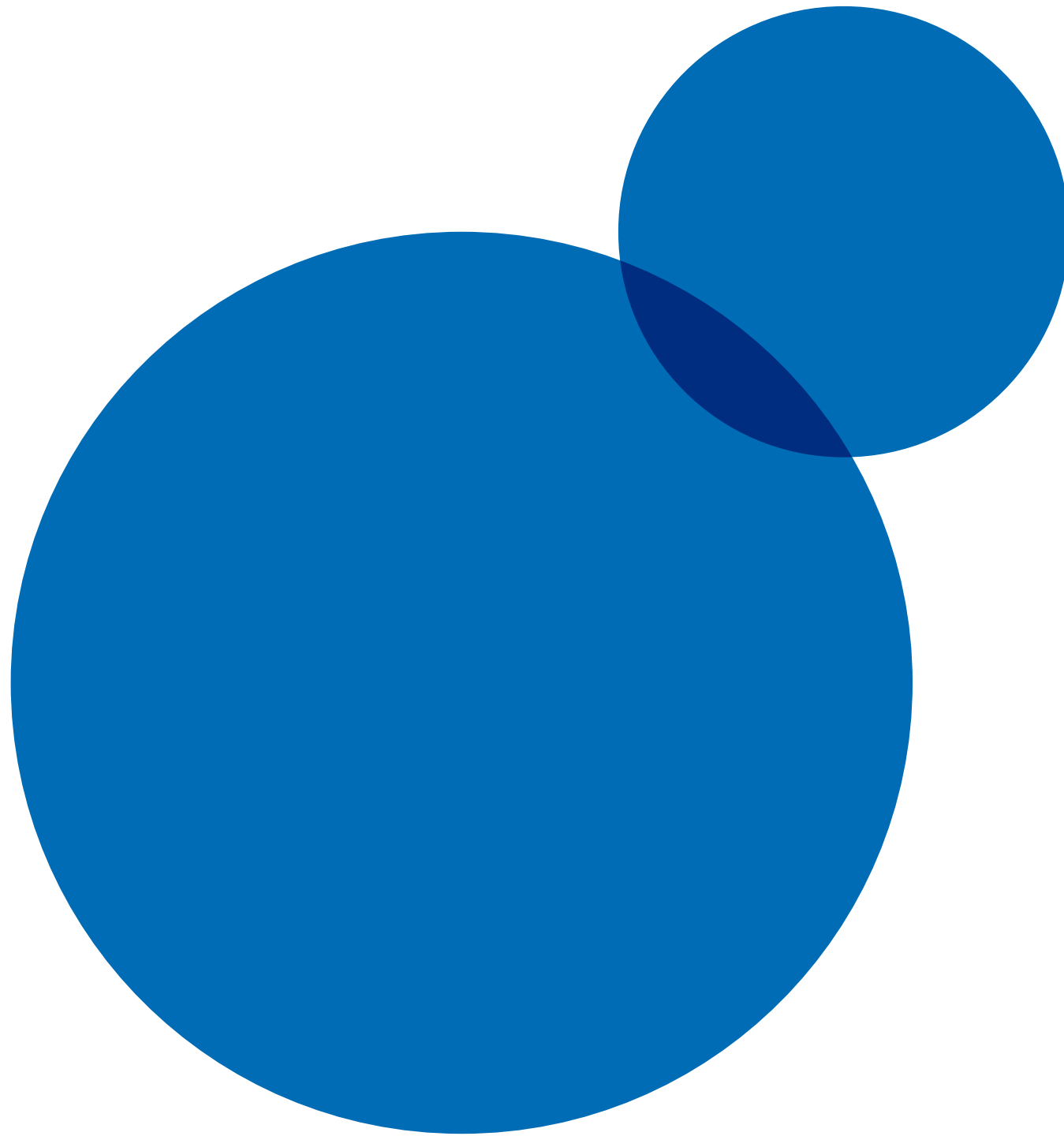
"CDBB has provided the environment and foundations to support the creation of a model of decision making in which data can underpin an understanding of our interlinked built and natural environments"
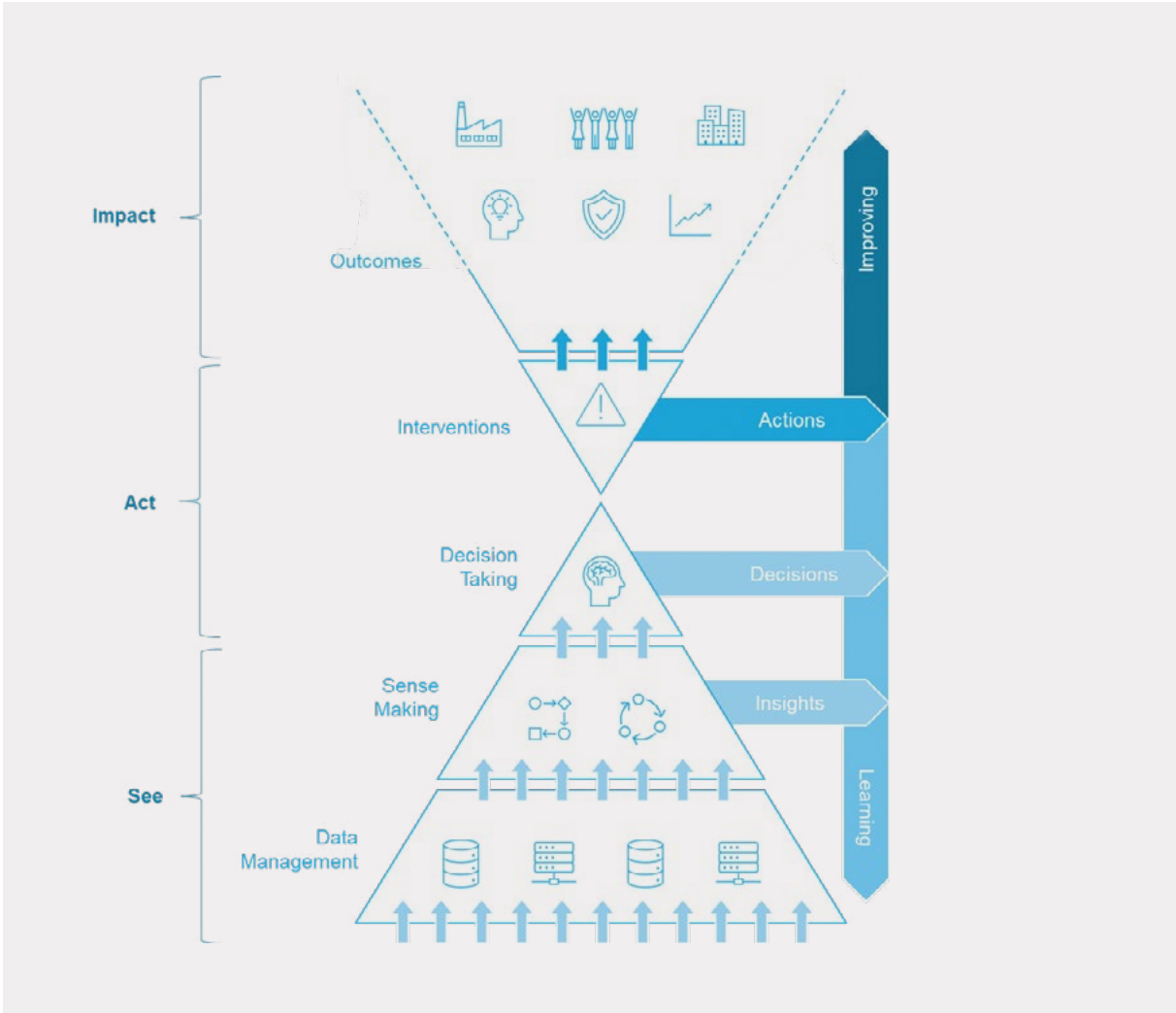
Nick Smallwood
Chief Executive Officer

Infrastructure and Projects Authority, Cabinet Office

Digital Transformation Task Group (DTTG)

Forum for infrastructure clients to share best practice on digital transformation.

Bright sparks make a flame

Imagine a homework sharing club for CEOs. That's a fair description of the Infrastructure Client Group (ICG). They gather under Chatham House rules to share mistakes and best practice. Water companies learn from nuclear, telecoms learn from transport and so on.

The DTTG, which evolved from the Project 13 Pillar, does the same for chief data officers. These are the people with strategic responsibility for transforming organisations that collectively invest around £20 billion per year, 40% of the national infrastructure construction pipeline.

They don't just want to build things quicker or cheaper. In fact, in a way, they're trying not to build anything at all to help us on the Net Zero journey. Can they optimise what is already there? Can they modify it? And if there has to be something new, can it be an intervention on the overall system, not a standalone project?

The guiding principle is that every organisation should have a holistic digital transformation strategy that includes its supplier ecosystem. The group advocates benchmarking and publishes an annual report so progress can be measured. The rest is about creating spaces of trust for the sharing to take place in order to accelerate the adoption of the best practice. If one member creates a plan or authors on a topic, the rest of the group is invited to apply their collective mind to help improve it, all while benefitting from having learnt about it themselves.

The DTTG has learnt that digital transformation is only partly about learning how to incorporate digital technology into infrastructure projects. It's mostly about culture and behaviour: ensuring the right people have the right information at the right time to make better decisions.

So, DTTG doesn't simply exist to produce guidance or toolkits. Instead, by helping clients share best practice and avoid mistakes, it potentially saves the economy billions. And because there's almost no money involved in running the group, the model could easily be adopted and applied in any country.

Why does it work so well? Maybe because the DTTG members have recognised they aren't in competition. They are consciously driving industry transformation from within, not letting the market decide. Or perhaps the real question is: why wouldn't it work? When you combine the brightest sparks from across industry, they will make a flame.

Melissa Zanocco,
Head of Programmes, ICG

Melissa is head of programmes for the ICG. Her main areas of focus are Project 13, the industry change movement, and digital transformation (including smart infrastructure, connected digital twins, data and information). She is a member of the World Economic Forum Infrastructure 4.0 Community, Global Infrastructure Hub InfraTech Leaders Ecosystem and co-chair of both the Project 13 Adopter Community and the Digital Twin Hub Community Council.

The Gemini Principles

Nine guiding values for the National Digital Twin (NDT), comprising 99 words and published in autumn 2018.

The Gemini Principles

Purpose:
Must have clear purpose

Public good
Must be used to deliver genuine public benefit in perpetuity

Value creation
Must enable value creation and performance improvement

Insight
Must provide determinable insight into the built environment

Trust:
Must be trustworthy

Security
Must enable security and be secure itself

Openness
Must be as open as possible

Quality
Must be built on data of an appropriate quality

Function:
Must function effectively

Federation
Must be based on a standard connected environment

Curation
Must have clear ownership, governance and regulation

Evolution
Must be able to adapt as technology and society evolve

An ethical bridgehead

The Gemini Principles are the conscience of the NDT. NDT is about socio-technical change that improves outcomes for people, society and nature over decades, so it had to be built on timeless, ethical foundations.

Our starting point was the National Infrastructure Commission's 2017 Data for the public good report. The default driver for gathering and sharing data may not always be ethical – some countries will want to use it to control their populations; some companies will want to exploit it purely for commercial gain. Therefore, our objective was to establish an ethical bridgehead to NDT.

We were lighting a beacon on the hill. We understood the potential power of NDT and were demanding that it should always serve in the best interests of the people.

We began with a blank sheet of paper and a small group of enthusiastic experts from across the built environment. Their initial ideas were shared with a wider group, which added new ideas and perspectives. We then identified and categorised patterns and, once again, passed to the wider group, which refined our thinking. The process was both discursive and discussive – a coalescence of ideas – but in the end a consensus emerged. We presented it as a compact grid under three headings: purpose, trust and function.

After six months' work, we published the Principles. They were the first major output of the NDTp, and they struck a chord. People in a range of sectors saw them as a real step forward, and the Principles soon began to pop up everywhere.

Of course, we can't police how they are used. We're casting bread on the waters and we don't know what will come back. There will be challenges and there's no guarantee of success. However, it's a bold initiative and it seems to be having an energising and inspiring effect. We know that people want to be part of it.

Without the Gemini Principles, NDT is just another programme. With them it has real meaning and huge potential to deliver genuine public benefit.

Mark Enzer OBE,
CTO, Mott MacDonald;
Director, CDBB

At Mott MacDonald, Mark Enzer is accountable for technical excellence. As chair of CDBB's Digital Framework Task Group, he is one of the leaders of the NDTp. He was the digital transformation workstream lead on "Project 13" for the Infrastructure Client Group, which represents the UK's major infrastructure client organisations and lead author of the Infrastructure Carbon Review, published by HM Treasury.

Design, Build, Operate, Integrate

A simple visual representation of a digital built Britain.
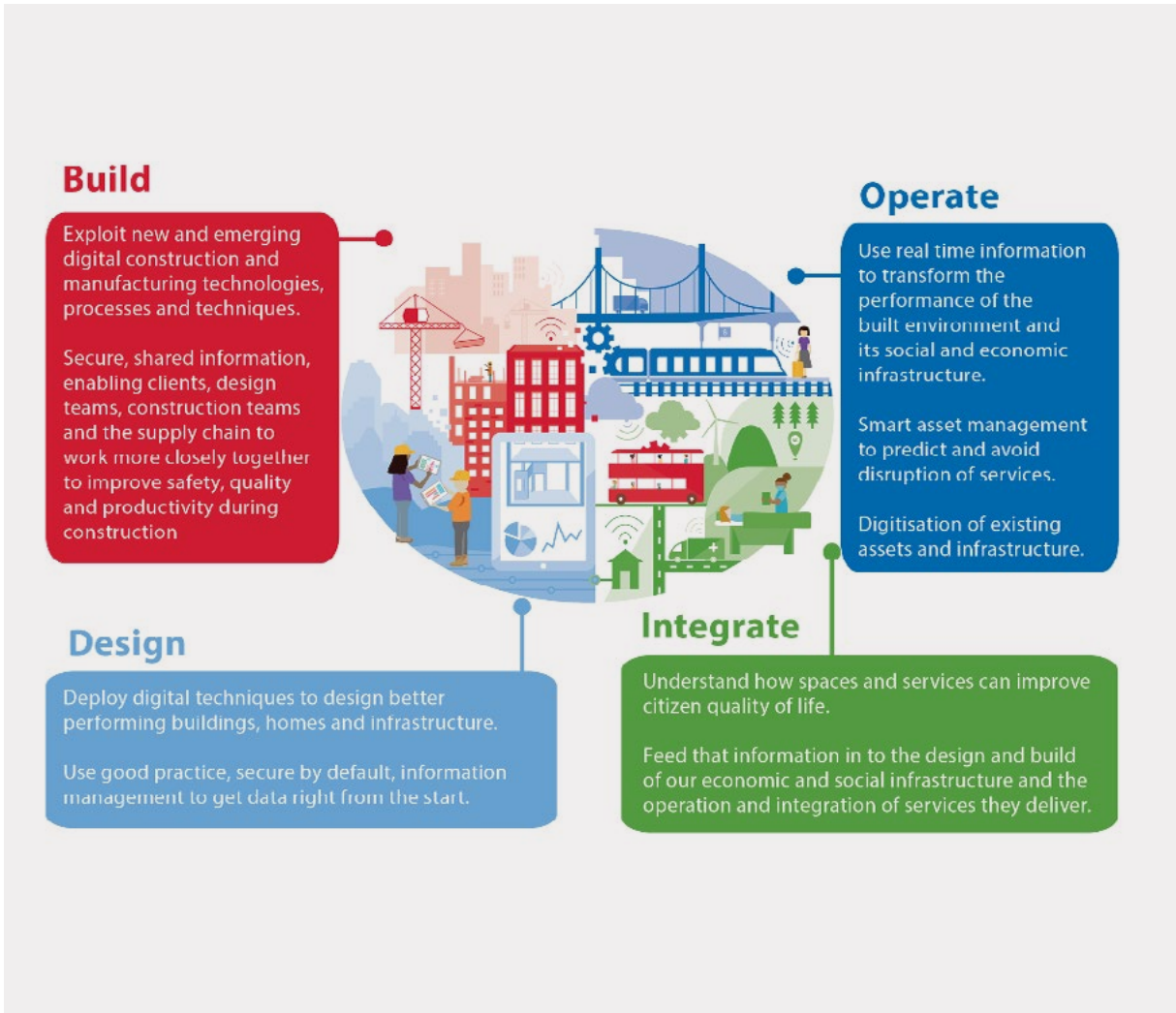
What is a digital built Britain anyway?

We have made so much progress. It's easy to forget that five years ago it was quite an undertaking to convince people our mission was worth getting behind. I was the first Head of Engagement at CDBB, and my team's first job was to find a clear way to describe and depict what a digital built Britain was.

During CDBB's first few months we met with experts and the passionately curious in industry, academia and government to understand progress to date, and aspirations for the future. Early adopters of BIM were reporting cost savings, better collaboration with clients and the supply chain, safer sites and less waste. There was growing excitement about the possibilities that could come from doing more – integrating sensors, digital twins, virtual stakeholder engagement, predictive asset management. The through line of this excitement was the profound difference that the digitalisation of the built environment can make for people.

We knew that for a digital built Britain to become a reality we needed to inspire more people. We wanted researchers, research and development initiatives, industry, policy-makers and clients to collaborate and exchange knowledge. We needed to capture the hearts and minds of those who hadn't started their digital transformation journey. Feedback from early workshops showed we had to shift away from levels of BIM to language that made sense to the C-suite, policy-makers and the public.

The Design, Build, Operate, Integrate graphic, designed with Alice Hunt, became our visual representation of a digital built Britain. It helped us explain our shared goal. It set the benchmark for our future visual communications and is as relevant today as it was in 2017.

Now, the conversation is not about "doing BIM better". It's about how digital enables better outcomes for people and the environment throughout the lifecycle of an asset. I think we can claim a role in making that shift happen – and I want to personally thank all the current and former members of the comms and engagement team for their efforts.

The foundational work is done: the next step is yours.

Amelia Burnett,
Former Head of
Engagement, CDBB

Amelia Burnett is a strategic communications, change, and engagement specialist based in Aotearoa, New Zealand. She is the Director of Clementine Consulting Ltd, which provides strategic advisory services to projects and organisations seeking to affect positive change in the built environment sector. She has global experience shaping the change strategies for infrastructure transformation programmes, including the NDTp, the CDBB and the Construction Innovation Hub.

Interactive Platform

Online virtual environment of the smart building of the Centre for Smart Infrastructure and Construction (CSIC).
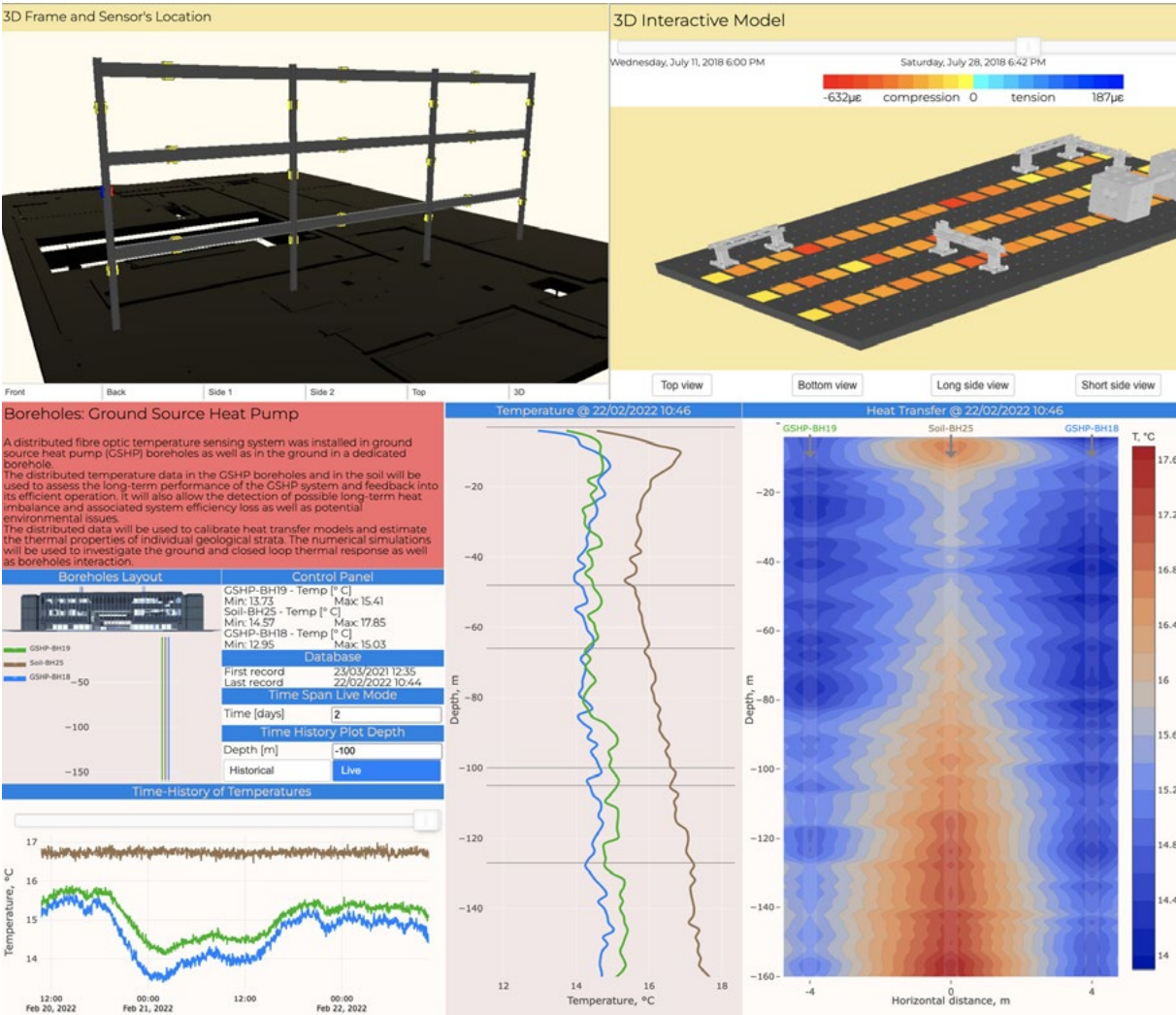
The ethos of openness

Sensors are usually only deployed in buildings when you have an operational problem. In the case of the University of Cambridge Civil Engineering Building, home to CSIC, a whole system of sensor packages, powered by fibre optics, was integrated during construction. The sensors measure various aspects of the building's performance, from the steel frame structure to the heating system.

But the key to this project was connecting them to an interactive platform that visualises the data and brings the whole building to life. We then created an online resource that anyone can play with, explore and use as a model for their own digital twin.

By building a virtual environment that displays data from physical measurements in real time, you can pursue the implications for issues such as vibration levels and energy consumption. This helps facilities managers monitor and refine the performance of this specific building and prolong its life, but it also establishes a benchmark for future construction. In the longer term it should help us develop a digital twin of the entire university campus.

The platform has provoked significant interest from industry and research groups, and we are gradually convincing the private sector that this kind of system can solve problems and save money in the long term.

It's worth remembering that this involves an enormous amount of data. We have applied the Gemini Principles throughout, but we are aware that we will need to move beyond them, progressing from data to information. By learning to reshuffle the data so we can read it better, we should be able to develop guidelines for the kind of information we require from a specific asset, whether it's a house or a bridge, before we decide which sensors to install.

Above all, this project embodies the CDBB ethos of openness. The platform was launched at the first virtual version of the Cambridge Festival, making it accessible to a broad range of audiences.

Miguel Angel Bravo-Haro,
Research Associate, CSIC, CDBB

Miguel is a researcher at the CSIC where he has been leading the digitisation of smart assets, from buildings and bridges to novel structures. Miguel holds a PhD in earthquake engineering from Imperial College London. He has experience in computational methods for the characterisation of nonlinear structural behaviour and structural dynamics. He has also worked on probabilistic methods applied to engineering, data-visualisation, software development, information theory, cloud computing, and hardware development for structural health monitoring.

National Underground Asset Register (NUAR)

Digital map of underground pipes and cables.
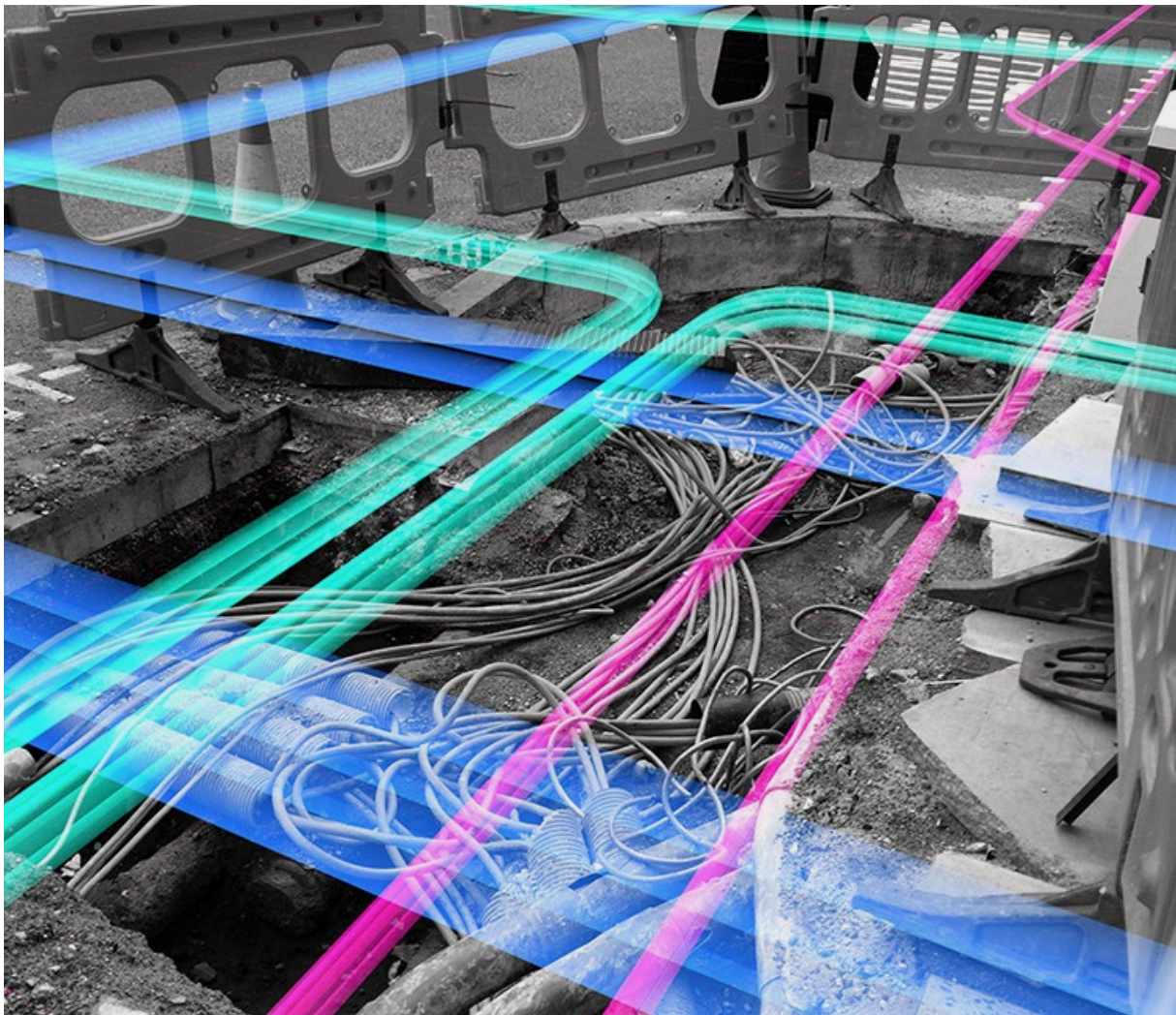
Unearthing the truth

Leonardo da Vinci said we knew more about the movement of celestial bodies than about the soil underfoot. Today we can fly drones on Mars, but we are unclear about exactly what's under our pavements and roads. The Geospatial Commission was created in 2018 and we are building the National Underground Asset Register (NUAR), as part of a drive to improve access to location data.

Things are complex underground. Soil, geology, groundwater and archaeology – and four million kilometres of pipes and cables carrying gas, water, electricity and telecommunications. Every year around four million holes are dug (many in the wrong place) to access or add to this network. This causes around 60,000 pipe and cable strikes, leading to delays, disruption, injury and even death.

NUAR aims to make underground works safer and more efficient by creating a national interactive digital map of the UK's buried assets. This involves getting plans and maps from hundreds of organisations, because every local authority and utility company has its own records. After user testing and training, we aim to deploy NUAR within three years.

There is a clear link to the digital twin philosophy. We're creating a single digital replica of physical assets in the ground – and we're doing it for the public good because a lot of the infrastructure we are talking about is buried under public land. NUAR must also be a secure, not open, system, because of commercial sensitivity and national security concerns. And data standards are important, so we describe and display a pipe in the same way, wherever it is and whoever owns it. As the map builds, people will see errors in their own data and each other's, so we need to encourage a culture of continuous improvement. If you're digging a hole and find something that shouldn't be there, you can report it digitally.

NUAR entails new ways of working, as we learn to trust each other and make something better together. This isn't just a map for tomorrow, it's an everlasting improvement of how we view and manage the ground beneath our feet.

Holger Kessler,
MSc CGeol FGS FRGS, NUAR Stakeholder and Comms Lead Geospatial Commission, NUAR Delivery Cabinet Office

Holger is currently on secondment from the British Geological Survey to the Geospatial Commission at the Cabinet Office, where he leads on stakeholder engagement and communications for the NUAR. He has more than 20 years experience in developing scientific, technical, operational and policy solutions to geoscientific issues at local, regional, and national scales. He specialises in making geoscience data, information, and knowledge available and accessible to improve planning and decision-making, particularly in the environmental, water resource, engineering, and infrastructure sectors. Holger is a fellow of the Royal Geographical Society nd a Chartered Geologist at the Geological Society of London.

Digital Twin Hub (DT Hub)

Online community, launched in 2020, for digital twin owners, suppliers, and experts.
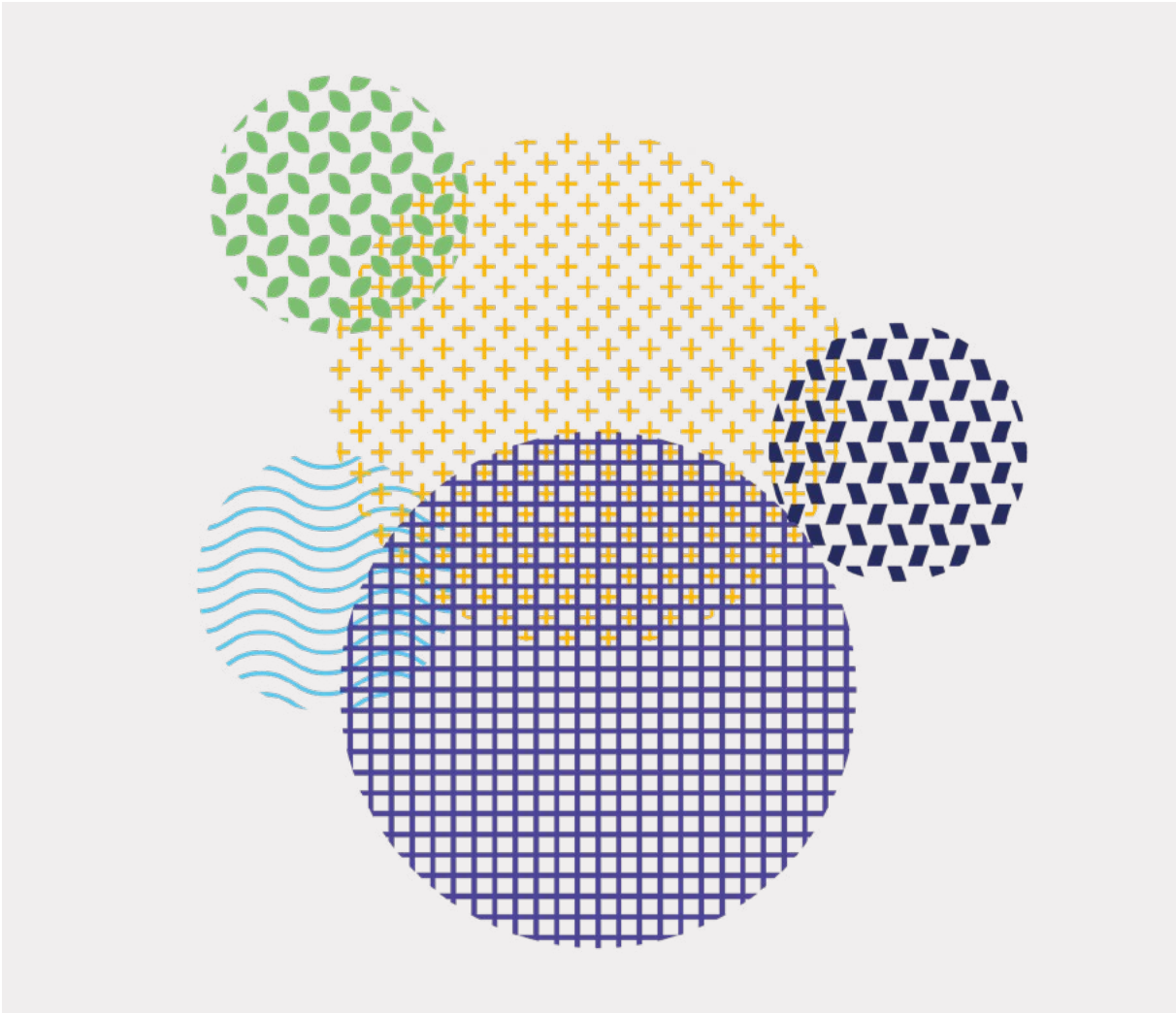
Empowered community

If you believe that digital twins need to be owned, adopted, and used by everyone, people must feel they have a vested interest in seeing them succeed.

That's why we built the DT Hub. Not with the expectation that everyone would just fall in line, but to create a strong sense of collaboration and community within digital twin users. Unfortunately, Covid prevented us having a strong physical presence but, in a way, it helped us adapt and develop our online community.

Starting with a small tightly focused group, we thought that attracting 100 members in the first year would be fine. Three years later we have 3,500 members, from more than 70 countries and over 1,500 individual organisations. It's free to join and members have access to a huge range of resources. What's more, we're now seeing the community take responsibility for the DT Hub, including the creation of a community council that aims to consolidate that sense of empowerment.

Contrary to our initial assumptions, people tend to engage with the DT Hub positively and openly. They share experiences and are less guarded than you might expect. We now find we can sit back and let interesting conversations grow organically.

We were determined to avoid the sales atmosphere that can develop in an industry forum, and we seem to have succeeded. The DT Hub is all about working together on a shared challenge. Clearly, we celebrate success but in a workshop environment where nothing is recorded we manage to (almost) celebrate failures too, because they are huge opportunities for people to learn from each other.

The first 18 months of the DT Hub were spent on two main things: agreeing what a digital twin was (or agreeing to differ), and establishing a common language. Now we are more focused on real, existing digital twins. More people are coming forward with their own digital twins and the community is steadily seeing the value of connecting them. It may take a little time, but the DT Hub gives them confidence that we will get there.

Sam Chorlton,
Chair, DT Hub

As chair of the DT Hub, Sam provides guidance and oversight to help industry and government adopt digital twin techniques and later enable the development of the NDT. He previously led the creation of the Data & Analytics Facility for National Infrastructure at the Science and Technologies Facilities Council (STFC) Rutherford Appleton Laboratory. Sam is a technical architect and data visualisation specialist with experience spanning the defence and cyber sectors. He specialises in the design and development of platforms to support large scale and heterogenous data analysis.

"CDBB has played a pivotal leadership role in helping to establish the vision for a UK National Digital Twin and for the development of the Information Management Systems"

Paul Clarke CBE FREng
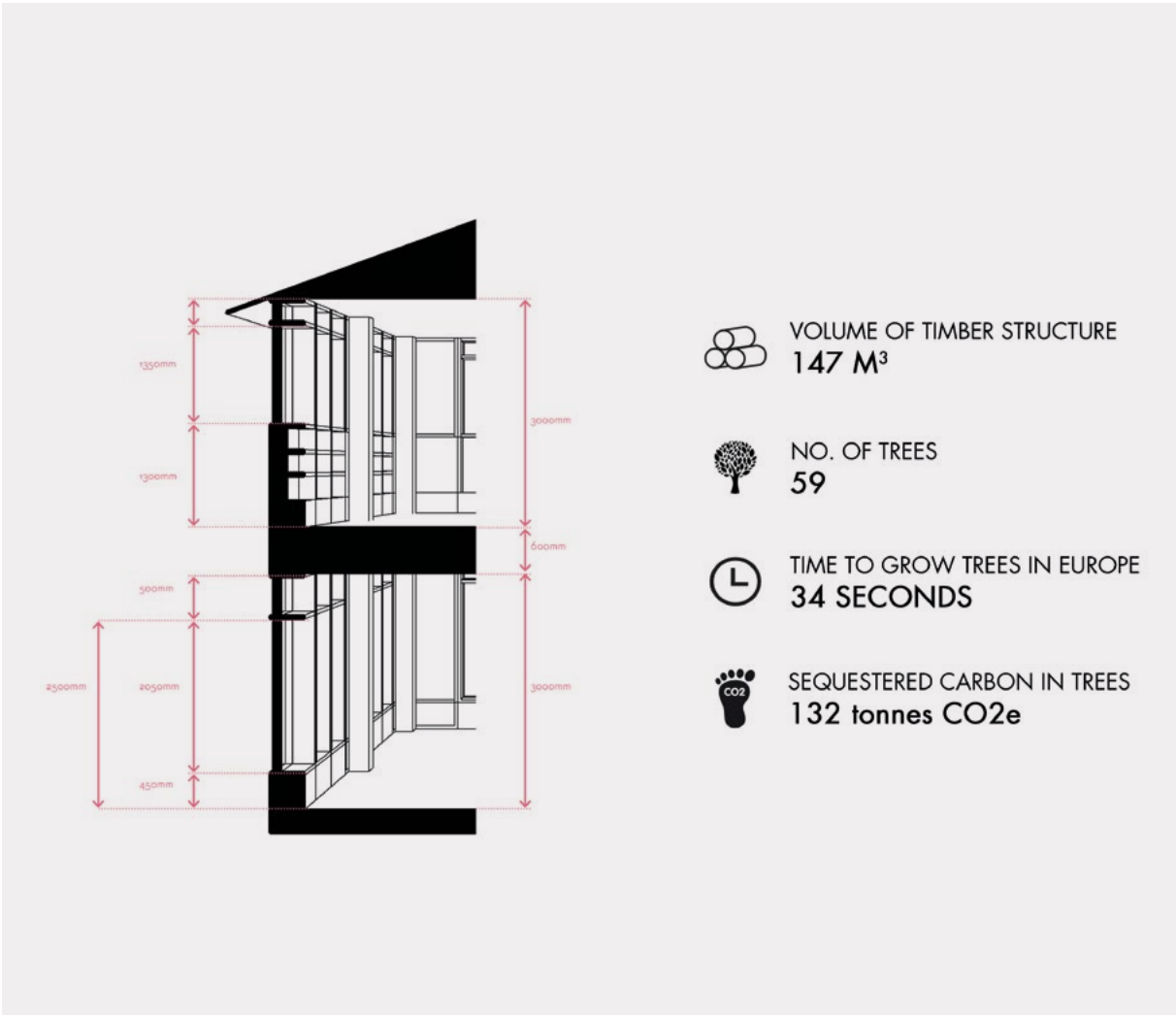Independent advisor to government, industry and startups
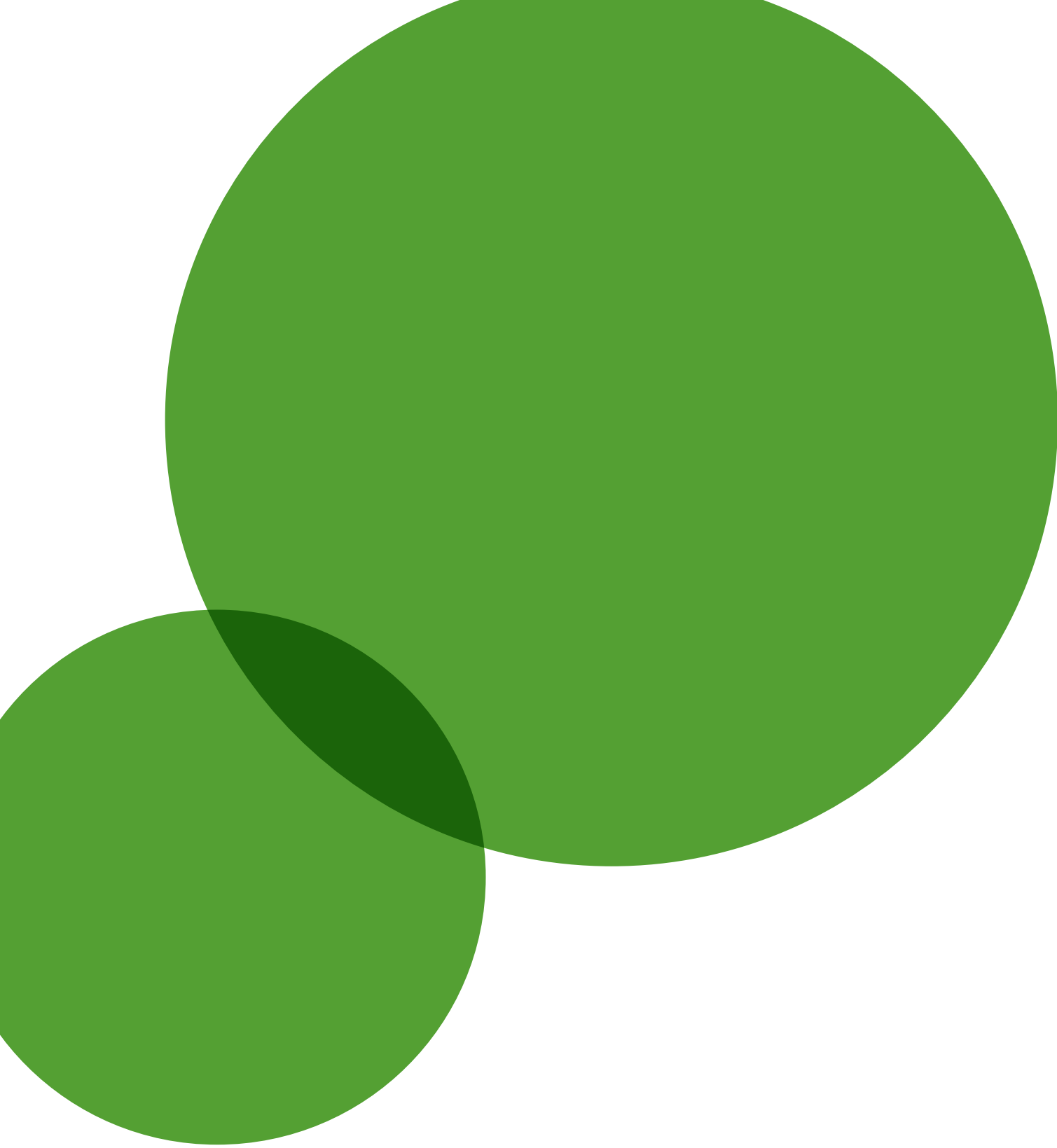
"Without CDBB's research, reports and events our knowledge would have been greatly diminished"

Duncan Reed
Business Development Manager,
Strategic Accounts and Major Projects

Trimble

Precision-Engineered Timber Schools

Research that assesses the potential impact of prefabricated construction methods on the UK's school building programme.

VOLUME OF TIMBER STRUCTURE
147 M³

NO. OF TREES
59

TIME TO GROW TREES IN EUROPE
34 SECONDS

SEQUESTERED CARBON IN TREES
132 tonnes CO2e

Kids learn better

There are already plenty of wooden schools in the world, so we don't have to convince anyone that they're possible. But we do need to show that engineered (cross-laminated) timber is the best construction material when you're procuring a wide range of schools.

First, by any measure it's the least intensive material for large buildings. Every kilogram of wood stores the equivalent of 1.8 kilograms of carbon dioxide, retaining the carbon and releasing back the oxygen for us to breathe. A highly efficient engineered timber building might cost a little more up front, but we need to think differently about its true cost.

Second, offsite construction, which by definition includes engineered timber, is generally a good thing. Building sites are dangerous and not conducive to good secure jobs. Offsite factories are safer and more gender equitable, you're inside and the jobs tend to be relatively high-skilled. Plus, the construction projects are faster and less disruptive.

Third, we can support the UK forestry industry.

Fourth, students and teachers in wooden schools have a healthier physical response to their building: less stress, lower heart rate and feeling calmer. They learn better and have a stronger affinity to the natural environment. Our task is to find measurable ways in which to quantify these benefits for budget holders.

Our programme illustrates these benefits through desk-based research and a real-life project. Our research group is working alongside practising engineers, architects, and environmental engineers to design and build a multipurpose hall extension to a local state primary school. It's an interesting challenge because this kind of government initiative dictates you have to design with a kit of parts. We need to give architects the tools to make every school extraordinary, even though they are all built from broadly the same components.

Ten years from now, we should be talking about why timber schools were so successful and why jails and hospitals are next. The UK is such a leader in this field that maybe 90% of our new buildings could be constructed from engineered timber.
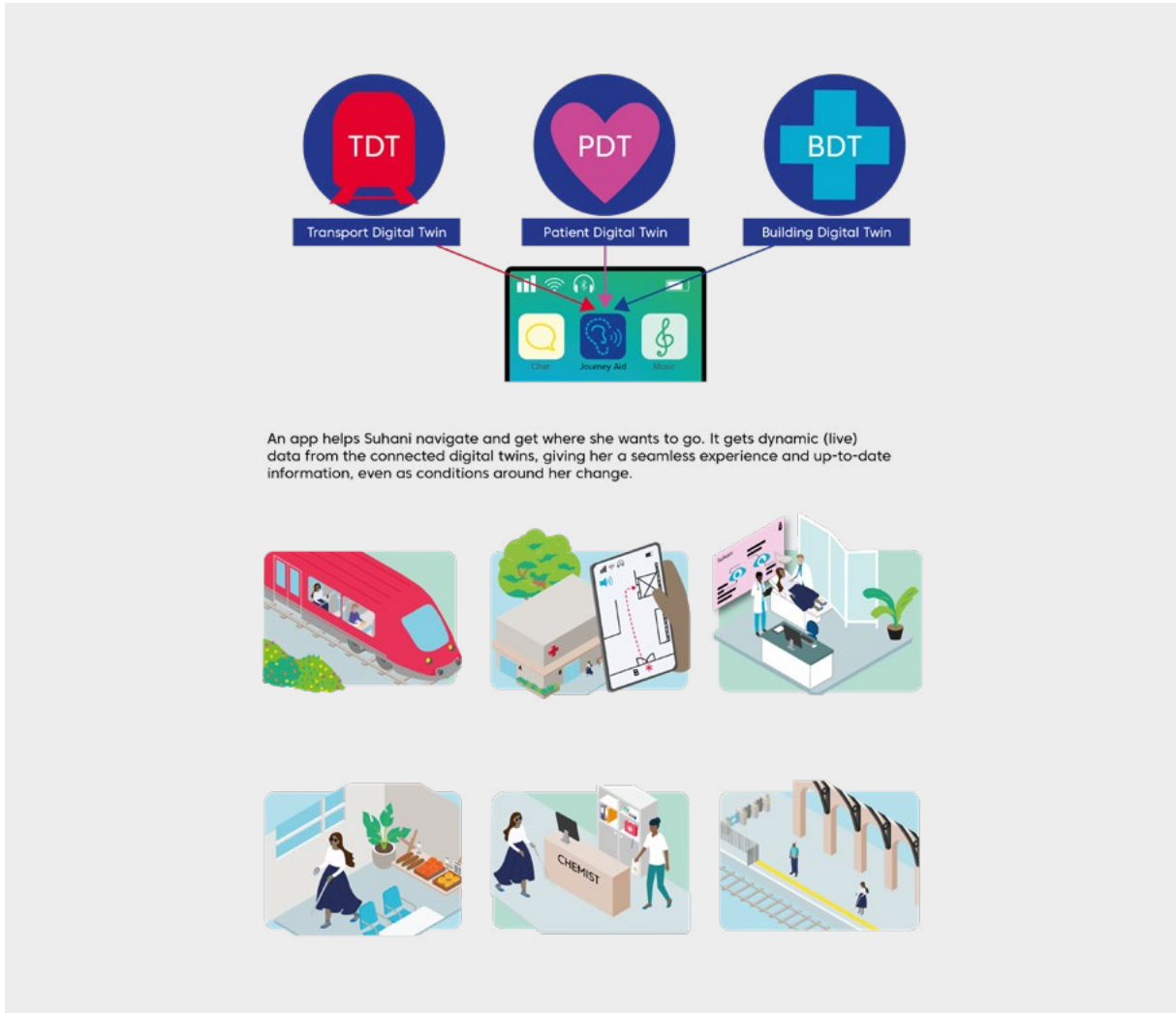
Michael Ramage,
Reader in Architecture
and Engineering in the
Department of Architecture,
Cambridge University

Michael is Reader in Architecture
and Engineering in the
Department of Architecture
at Cambridge University,
where he founded and leads
the Centre for Natural Material
Innovation. He is a Fellow and
Vice-master of Sidney Sussex
College, a chartered engineer,
member of the Institution of
Structural Engineers, Fellow of
the Society of Antiquaries and a
founding partner of Light Earth
Designs. He studied geology and
archaeology as an undergraduate,
followed by architecture at MIT,
and worked for engineering firm
Conzett Bronzini in Switzerland
prior to teaching and gaining
a PhD at Cambridge.

Moorfields Eye Hospital

Partnership examining the potential impact of digital technologies in healthcare.

An app helps Suhani navigate and get where she wants to go. It gets dynamic (live) data from the connected digital twins, giving her a seamless experience and up-to-date information, even as conditions around her change.

The possibilities are amazing

From robotic surgery to telemedicine, new technologies are transforming healthcare. In planning its new world-leading eye care centre, Moorfields Eye Hospital has been exploring the potential role of digital twins.

One major problem for people with impaired vision is the journey to the hospital. The new Moorfields site is a 10-15 minute walk from King's Cross railway station, and to reach it, patients will have to navigate a major transport hub with six Tube lines and 11 entry/exit points, then negotiate busy London traffic.

Putting ourselves in a patient's shoes, we found it easy to get disoriented within the underground system and at street level, and confused by the regular unplanned and sudden changes to services. Closed exits and road diversions all add to the confusion.

The current solution is a green line painted on the ground from Old Street station to the existing hospital, but one has to travel about 100 metres outside the station before you discover it. It is also vulnerable to fading over time, and of course it doesn't accommodate for any unplanned changes. A few possible alternatives, such as shuttle buses and existing navigational apps, are also unable to solve all the listed pain points.

A digital twin, however, would have an unprecedented scale of live data and could provide customised directions and notifications – for example, letting one know when a busy train is about to deposit its passengers on a nearby platform. This idea could be extended to the hospital itself. When a patient walks in, they are directed to precisely the right location, even if there's a change or delay. They can get reassurance that they're in the right place, and have time for a toilet/coffee break (which they can also be guided to the appropriate location for). If they get lost, they can ask for help digitally. These experiences can be highly stressful for patients, if they don't know where they are, or who best to talk to.

More broadly, we are also thinking about the integration of the above with patient digital twins, where you have a scan of yourself and add new data every time you see a doctor. Security and ethical issues need to be tackled, but you can imagine the benefits. The possibilities are truly amazing.
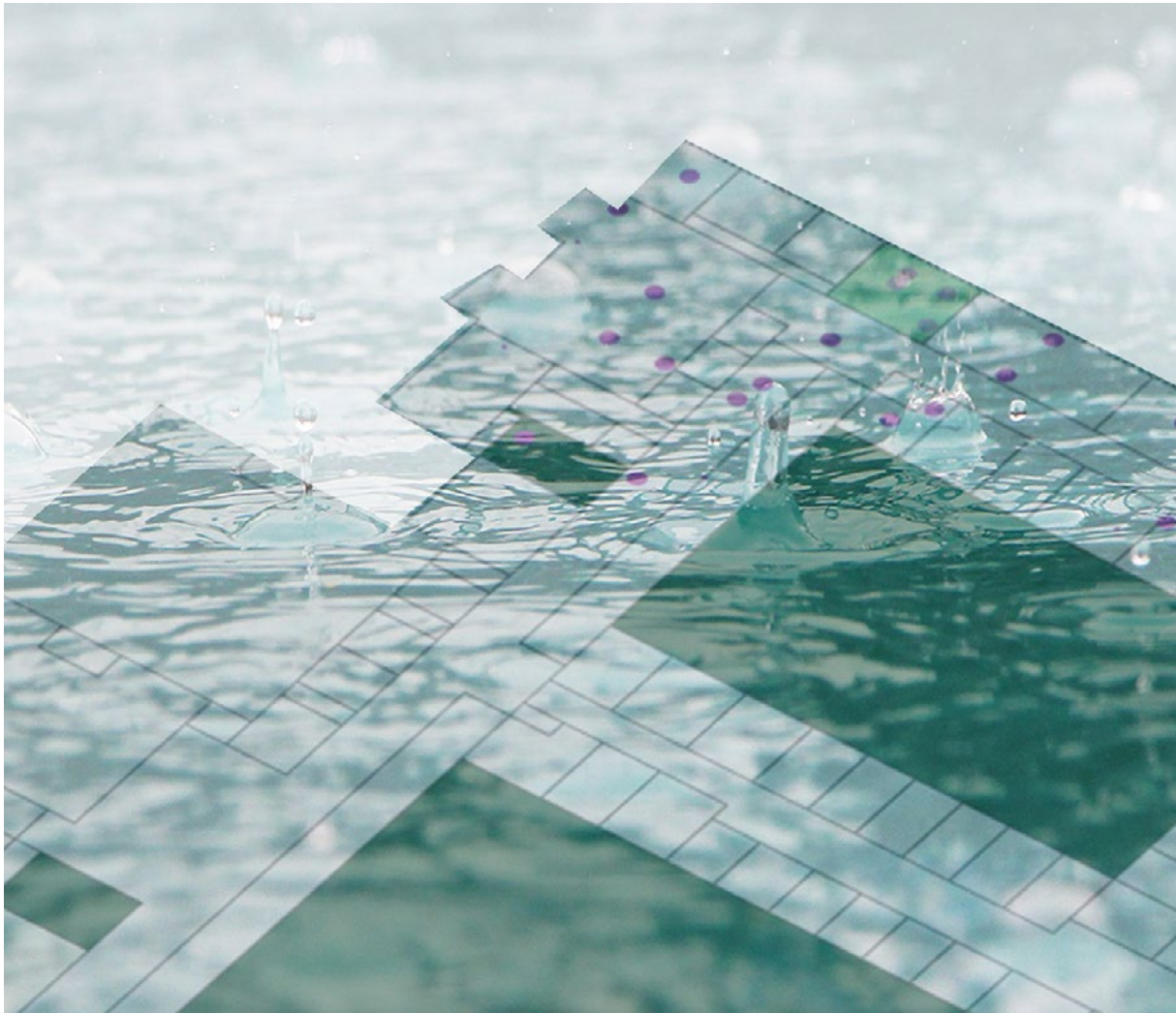
Edwin Lee,
Research Associate in Digital Innovation and Policy, CDBB

Edwin is a research associate in digital innovation and policy at the CDBB and the Cambridge University Judge Business School. His PhD, from Bayes Business School (formerly Cass), focused on continuous and cross-disciplinary innovation in professional service firms. Edwin also holds an M.Phil. and B.A. from the University of Cambridge, and has been a visiting PhD at Harvard University. Outside academia, Edwin has worked with the United Nations International Telecommunication Union on innovation projects.

DeepDish

Spatio-temporal insight

Intelligent sensor that tracks the movement of objects for real-time reporting.

When data falls like rain, you don't learn much by looking in the bucket. You know the overall quantity of water, but nothing about the flow pattern over space and time. Just as importantly, you have no idea if this is unusual and if you need to do anything. Imagine if you had a high enough density of sensors to detect every single raindrop, and an intelligence platform that could instantly analyse this. How would it help you manage a building or a motorway for the benefit of its users and the environment?

DeepDish is an example of an intelligent sensor that counts people as they move, which is in itself a complex measurement requiring sophisticated computation. However, finding value in the data depends on the transformational power of networking, instant communication and a new generation of batteries that remove the need for mains power. It also requires engaging ways to visualise the output, using 3D models and virtual reality. Once we put these elements together, we can deploy vast numbers of relatively inexpensive sensors across the built environment and instantly understand what they are telling us. We can also reprogram the sensors to change what they measure. And we begin to see the enabling power of the internet of things.

We can see this demonstrated in the digital twin of the University of Cambridge West Cambridge campus, where collections of sensors act in combination to detect intelligent 'events' rather than just readings. The temporal aspect of this is particularly important. Computers are equally adept at recognising patterns in time as in space (while humans usually aren't). When you harness this, you make it easy for building managers to understand what normal looks like and whether action is needed, for example in response to a system failure or emergency.

Whether we like it or not, soon sensors will densify and become more intelligent, data will become more immediate, and we will all be affected by the decisions that result. We're already working on a robust privacy framework to address the ethical implications.

Ian Lewis,
Director of Infrastructure Investment, University of Cambridge

Ian is director of infrastructure investment at the University of Cambridge and head of the adaptive cities programme in the university's Computer Laboratory. This involves researching appropriate architectures for real-time information flow in the city of the future, where the effective density of sensors is expected to be in the millions, each providing real-time data accumulating billions of measurements per year. He also works closely with the local regional authorities to establish an appropriate digital infrastructure in the region.

"CDBB has been instrumental in providing a focal point and a forum to take forward discussions regarding ethics and digital twins"

Kevin Macnish
Digital Ethics Consulting Manager

Sopra Steria

"CDBB has been a great ambassador in coordinating, supporting, and realising the benefits possible from a connected digital world"

Peter Vale
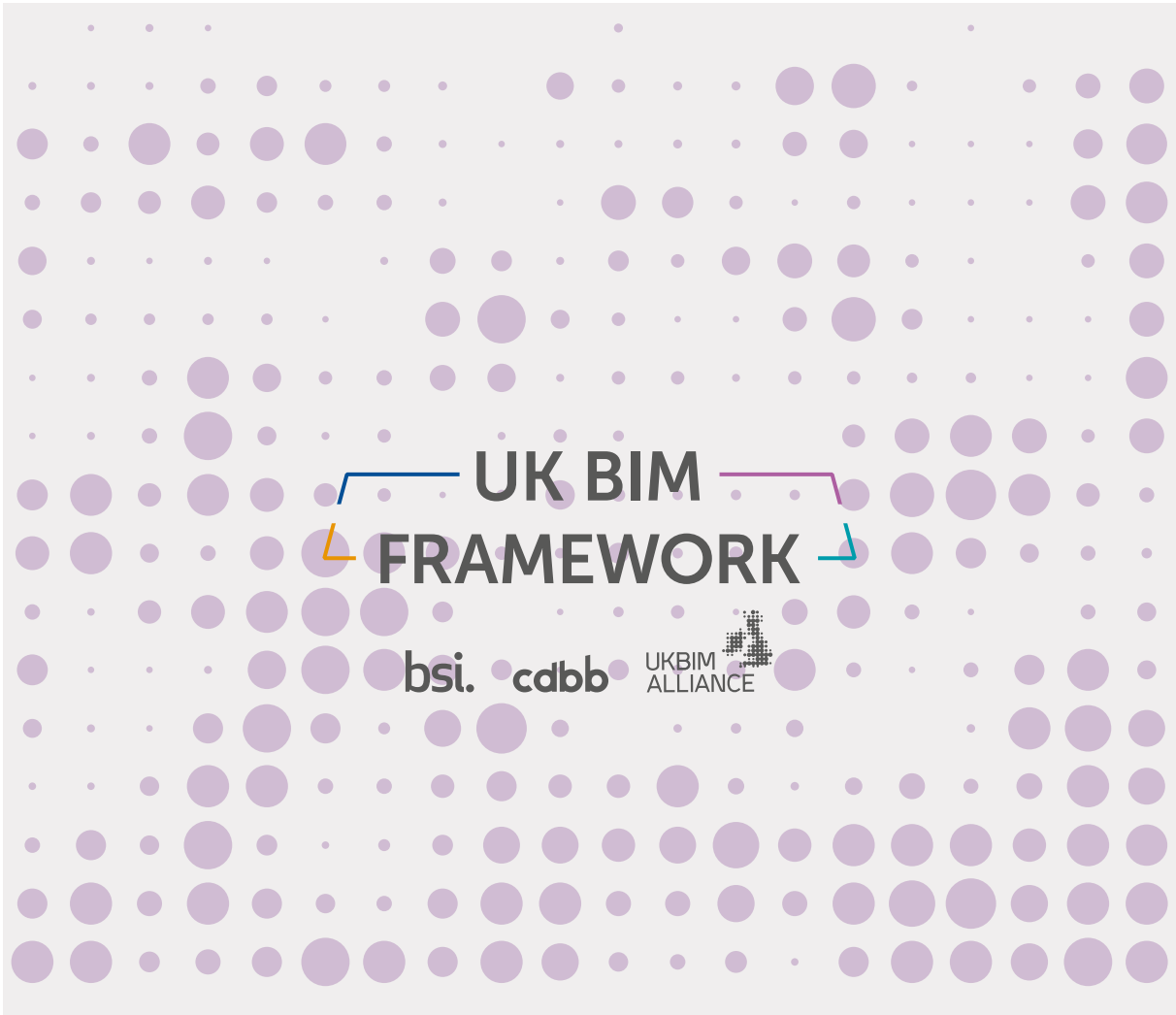Engineering Information Manager

Tideway

"CDBB has been a fantastic springboard for the understanding and development of digital twins in Britain"

Sarah Rock
Senior Associate

Fladgate LLP

UK BIM Framework

Overarching approach to implementing BIM in the UK, comprising standards, guidance and other resources.

Communicate like never before

It seems logical that collaborating on construction and asset management projects should save time, reduce costs and lessen environmental impact. If you make information more open and shareable, you are likely to spend less time making mistakes. People used to attempt this by sending drawings to each other by post, but by the time you'd received and responded to a draft, it could easily have changed. By the 1980s, computer networks, project servers and agreed methodologies were starting to have an impact, which eventually led to BIM.

BIM uses a common data environment that enables engineers, owners, designers and contractors to communicate and coordinate like never before. Since 2016, to be involved in construction projects for central government that involve public money, you must conform to the standards relating to information management using BIM.

The UK BIM Framework provides a consistent reference point for the industry, but because technology and working practices are constantly changing, a dynamic wrapper was created around it. Going forward, the UK BIM Framework is being jointly curated by the British Standards Institute (BSI) which sets the standards and the UK BIM Alliance which has developed the guidance. CDBB joined BSI and the UK BIM Alliance in helping to set up and establish the UK BIM Framework in its first formative years.

No single entity owns the UK BIM Framework – this is a genuine partnership with a clear common vision. We are committed to supporting organisations of every size and type, right across the sector, so we meet regularly to decide what should be included and hold events to promote BIM and its benefits. Whatever role you play in the life of an asset – briefing, designing, construction, operation or decommissioning – the UK BIM Framework is relevant to you.

The encouraging news is that research by the UK BIM Alliance in 2021 reported that 65% of respondents across the sector say their organisations are currently implementing BIM. Many of them are getting information and guidance from the UK BIM Framework and its curators. And they are highlighting tangible benefits in terms of better quality, less rework, smarter decision making, timely delivery and improved sustainability.

Dan Rossiter,
Sector Lead (Built Environment Digital Transformation), BSI

Chartered Architectural Technologist Dan Rossiter FCIAT is an active supporter of the built environment, both nationally and internationally. Nationally, Dan provides digital transformation thought leadership at the BSI where he also provides subject matter expertise to several national committees relating to information management, technical documentation, and terminology. Outside of BSI, Dan contributes to several working groups, and is an ambassador for both the UK BIM Alliance and the National Digital Twin programme. Internationally, Dan convenes CEN and ISO terminology and strategy working groups relating to the digital transformation of the built environment.

Staffordshire Alliance Smart Bridge Project

Long-term performance monitoring using fibre optic sensors.

The first smart bridges

Much of the transport infrastructure in the UK is over 150 years old and it's almost impossible to assess its actual operating capacity. Standard procedure is to conduct visual inspections and carry out maintence and weight programmes based on very conservative assumptions. This leads to speed restrictions on thousands of railway bridges, for example, and huge repair costs. When CDBB got involved in this project with Network Rail, our objective was to use sensors to develop a predictive maintenance tool – and deliver the UK's first truly smart bridges that would permit safer and more proactive maintenance programmes and better future designs.

We integrated fibre optic sensors in two new bridges installed in Staffordshire – one made of steel and one of precast concrete, the two most common bridge types in the transportation network. A 24/7 monitoring system measures deformations on the bridges, along with the train loading that causes them. This process generates huge amounts of data, which we can then use to create digital twins of the bridges. These will not only help predict when bridges might fail or need repairing, but also allow Network Rail to reduce the number of ease the restrictions, so more trains can run on time. We're learning that bridges are usually much stronger than you may think.

For this project, the two bridges are massively over-instrumented, with hundreds of different sensors and the capacity to generate up to 12GB of data a day. This is because we want to identify what's important and what can be discarded. Obviously, the information has to be useful to Network Rail, and we are testing techniques for potential use in other projects, including on roads and underground networks.

If these smart technologies are deployed across the railway, it should be possible to increase productivity by running heavier loads at higher speeds. This would not only benefit the economy, but also remove thousands of trucks from our roads, and significantly reduce carbon emissions.

More broadly, information from whole life monitoring and data analytics will lead to more efficient design, construction, operation, and maintenance of bridges in the UK and beyond.

Farhad Huseynov,
Senior Research Associate,
University of Cambridge

Dr Farhad Huseynov is a senior research associate at the University of Cambridge, with particular interest in the structural health monitoring of bridges. During his PhD he developed a technique that is by far the most accurate rotation measurement available and has the potential to become a landmark finding. He has also developed an effective bridge condition assessment methodology that can identify defects in bridges using direct rotation measurements. It is one of the first successful demonstrations of a damage detection application on a real bridge. Before joining the University, Farhad worked as a senior bridge engineer in industry.

Satellite Infrastructure Monitoring

Technologies that can measure movements of built environment assets over time.
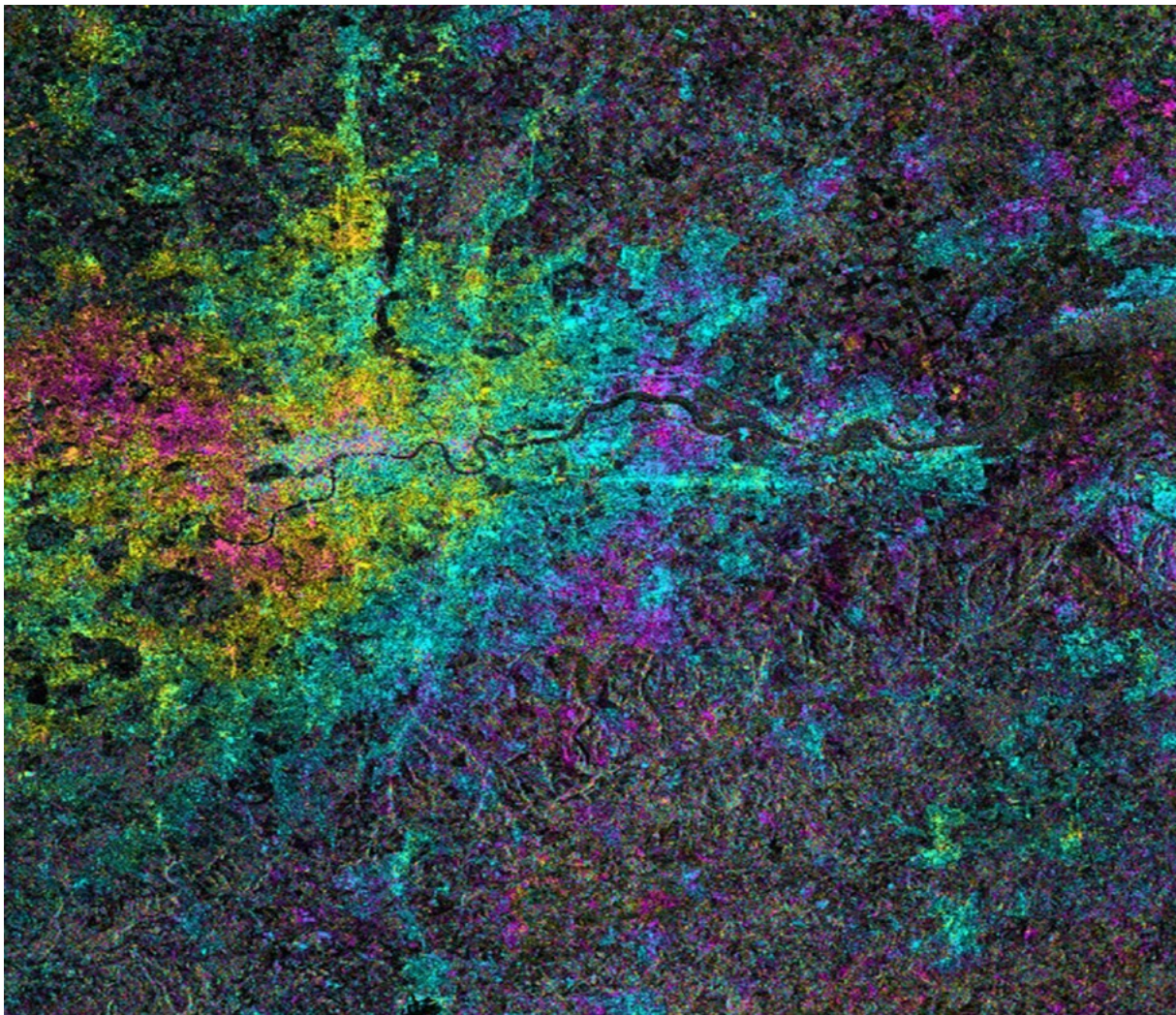
Monitoring bridges from space

For a long time we have monitored bridges, tunnels and other structures to keep them safe. Historically, someone would go in to inspect the structure, but there are only a limited number of people who can do that – and diving into rivers can be dangerous. Plus we have an increasing number of ageing assets to look after.

Sensors can be effective, but they have limitations if something's very remote, or there's no electricity source nearby, or the maintenance requirements are too great.

Which brings us to satellites. They've been around for decades, and the types of radar satellites we're talking about have been in operation since the 1990s, but two recent developments have made a real difference.

One, the resolution and frequency have improved. Satellites can now record images of objects that are three metres across rather than 30. And they pass overhead every few days, not weeks. This means you can start to monitor how a single structure is moving over time.

Two, the European Space Agency has launched its Sentinel satellites, which pass over Europe every six days. So there's now an openly available source of free data. Dealing with and interpreting large volumes of it is a challenge, but once you can process a whole area, rather than a single bridge, you can monitor how different structures are moving and investigate what's going on because of, say, climate change.

Then there are trees, embankments and other objects that don't give a stable radar reflection but are important to railway infrastructure owners, who don't want a slow failure that closes the track. So we're looking at attaching sets of corner reflectors that point at the satellite and allow us to track earth movements.
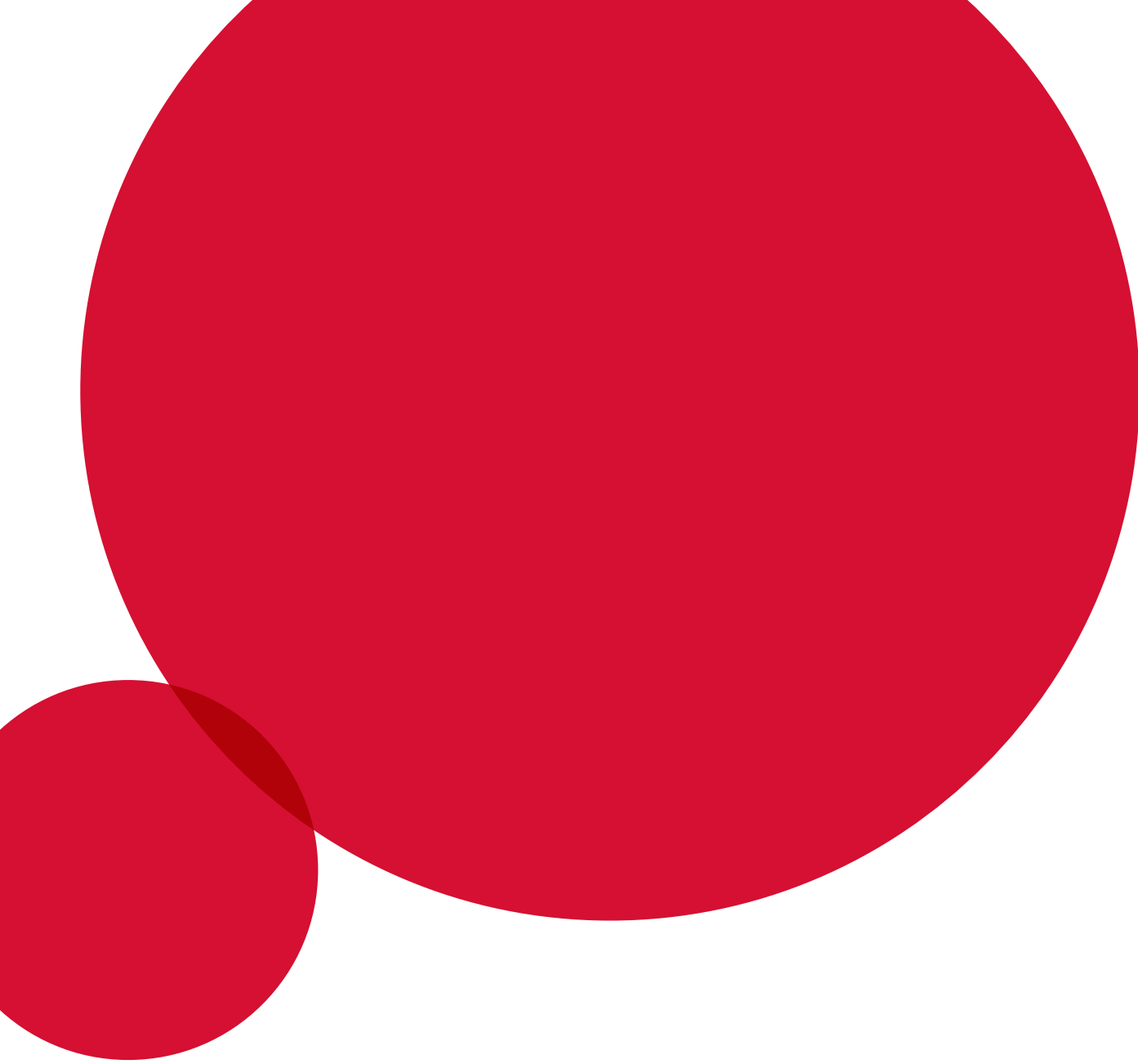
By applying algorithms that are looking for specific structural behaviour, we can help the industry building digital environments, so they can better operate and maintain their assets over the long term.

We're working on the intersection between traditional construction, monitoring and satellite engineering – and trying to make it relevant for the built environment.

Sakthy Selvakumaran,
Isaac Newton Trust
Fellow in Engineering,
University of Cambridge

Sakthy is the Isaac Newton Trust Fellow in Engineering at the University of Cambridge and founder of tech start-up BKwai. She is a chartered civil engineer with over a decade of experience working internationally in design, construction and infrastructure asset management on projects from the London Crossrail train line to reconstructing earthquake-damaged houses in Peru. She was included in the Forbes 30 Under 30 Europe List (2016), and the Financial Times Top 100 Most Influential Women in UK Engineering list (2020).

"CDBB should be congratulated on its contribution to making the UK an international pioneer for digital processes and technology exploitation across the AEC sector

Marek Suchocki BEng CEng CITP FBCS FICE MCInstCES
Global Business Development Executive

Autodesk Ltd

"I truly believe
CDBB has strengthened
digital twin capabilities
and collaboration
in the UK"

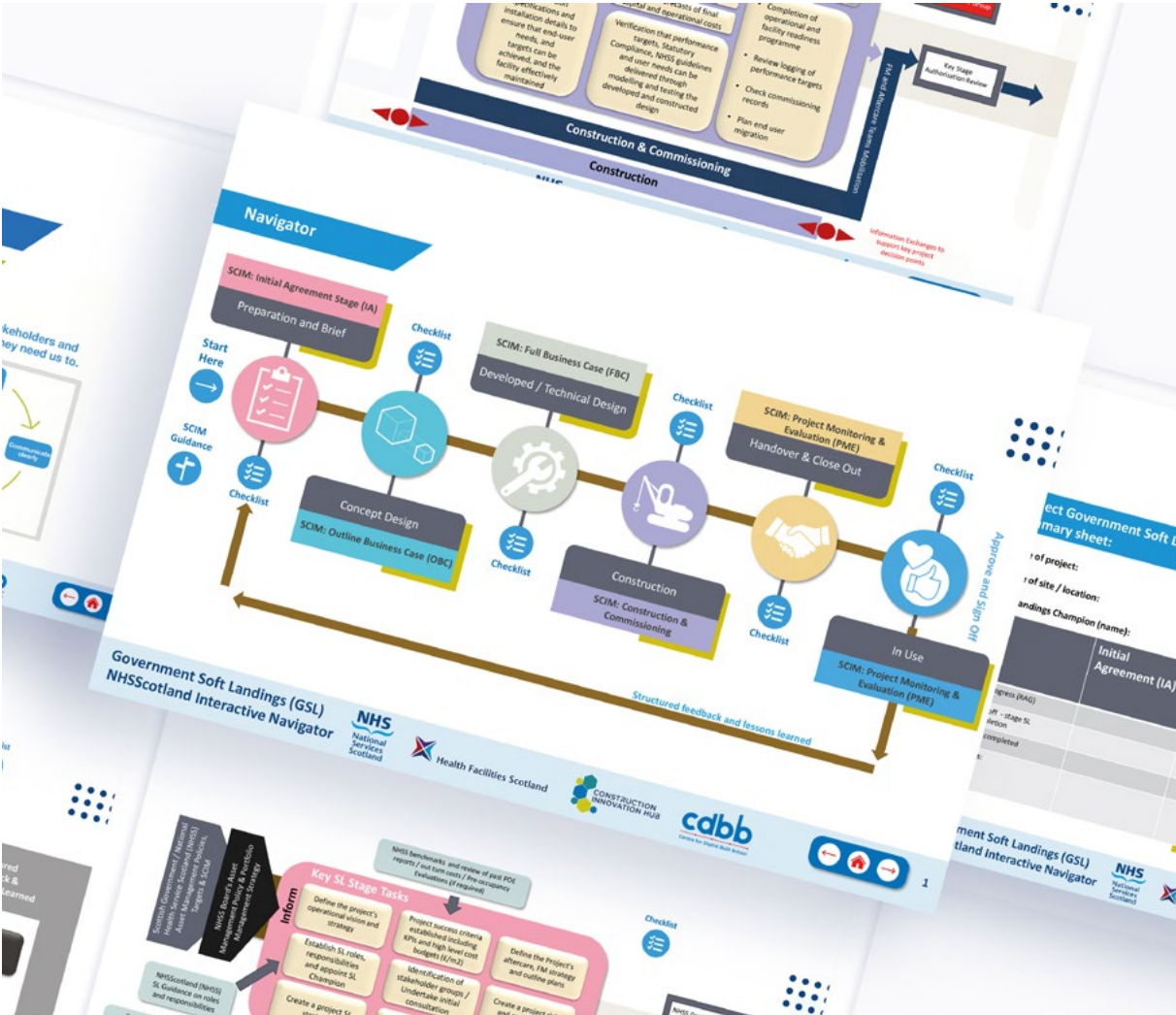**Dr Peter van Manen**
Principal Consultant

Frazer-Nash Consultancy

NHS Scotland (NHSS),
Government Soft Landings (GSL) Navigator

Specimen interactive process map for public sector construction projects.

Building for a better society

Of all the wicked challenges we face, one of the biggest is how to build assets that improve service performance. Each year construction output in the UK contributes 7% of GDP and we can increase the value it delivers by aligning the interests of those who design and construct hospitals, schools and so on, with those who subsequently use them. We need to bridge the operational chasm.

GSL is a key element of this, maintaining the 'golden thread' of a built asset's (buildings and liner-infrastructure) purpose throughout its entire lifecycle. It brings together 'design and construction' and 'operation and maintenance' and uses structured information to test the performance of the asset as it evolves.

NHSS was keen to maximise the soft landings opportunity, but it's also a large, complex ecosystem of 21 different boards. Although soft landings standards and guidance already existed, we wanted to make the concepts come alive for a wide range of NHSS organisations, from GP surgeries to acute hospitals. The result was the NHSS GSL Navigator, which frames the journey in practical, relevant terms.

From the beginning we partnered with Health Facilities Scotland (HFS) and their stakeholders including estates, facilities management teams, clinicians, patient groups and more, to ensure project briefs can be aligned with their desired performance outcomes.

Digital technology and structured information models help by creating virtual environments that inform the clinical planning process. You can enter a digital version of your new operating theatre and make early decisions about how to lay it out. It's like a sophisticated version of virtually trying out your dream kitchen – and learning how much it will cost – before you buy and install it.

We usually estimate design and construction at 20% of total expenditure on an asset, with operational costs at 80%. But now we can also consider the societal impact, which might be a thousand times greater. Imagine if you could improve patient recovery rates, enable students to achieve better exam results or reduce reoffending among prisoners, all because they're in a better environment.

This isn't building for the sake of it. It's about gaining the line of sight between creating something and the impact it makes. Not an end in itself, but a catalyst for a better future.

Dave Philp,
Impact Director for Digital,
Construction Innovation Hub

Dave is a chartered construction manager and director of digital consulting, strategy and innovation for AECOM, having previously worked for Mace and Balfour Beatty. He was seconded to the UK Cabinet Office in 2011 as head of BIM implementation and has been a key contributor to the UK public sector BIM mandate (GCS 2011-2016). He is impact director at the Construction Innovation Hub and chair of the Scottish BIM delivery group at the Scottish Future Trust. He is a fellow of ICE, CIOB, RICS and CInstCES and vice chair of the Construction Scotland Innovation Centre.

Flourishing Systems

White paper that calls for a new understanding of
national infrastructure, published as a 24-page PDF.

The tide is turning

It started on a whiteboard. A discussion between colleagues about why infrastructure isn't just about engineering, but a platform that enables society to flourish.

It culminated in the collective output of a broad mix of people, including academics, industry experts, policymakers, and a Catholic nun, who has spent decades thinking deeply about how we actually live.

The original idea was born of frustration. We tend to place enormous emphasis on building structures rather than managing them over their lifecycle, which could last for centuries. Because while an asset may have a notional design life, the reality is it will rarely ever be decommissioned. It gets adapted and added to – and it becomes part of this highly complex system of systems we know as the built environment.

This is important because the difference between living in a favela and living in Manhattan is largely down to infrastructure. London had hideous cholera epidemics before Bazalgette built the sewerage system in the 1860s. We're only really doing a major augmentation of it now.

Some of the challenges we face are that governments tend to think in electoral cycles; our economic models typically focus on capital investment not operational costs and opening shiny new things is more exciting than managing the old ones better. Yet even with huge investment in new infrastructure, we still only add about 0.5% by value to our existing built environment each year.

So this white paper is all about the idea that infrastructure is a network, not a series of projects. It examines how it should serve people, the sociotechnical connections that support it, the need for sustainability and resilience, and the impact of digitalisation.

Above all, it tries to get people to think of the natural environment and the built environment as one system. Since the pandemic struck, it's been encouraging to see many other people engage with this idea too.

The tide may not have turned quite yet, but it's turning.

Jennifer Schooling,
Director, Centre for Smart
Infrastructure and Construction

Dr Jennifer Schooling OBE is Director of the Centre for Smart Infrastructure and Construction (CSIC), at the University of Cambridge. Jennifer is passionate about changing the way the infrastructure and construction industries view data, to become a vital asset in its own right, and as an engineering tool for tackling the key challenges facing our industry, including climate change, resource constraint and resilience. She is a member of the UK's DFTG, the DTTG and held a range of leadership roles within CDBB. Jennifer was lead author for the Carbon Reduction Code for the Built Environment. She formerly worked for Arup and Edwards Vacuum and has a PhD in Materials Science from the University of Cambridge.

Gemini Calls

Joining forces

Weekly call for National Digital Twin programme (NDTp) and industry members, launched in April 2020.
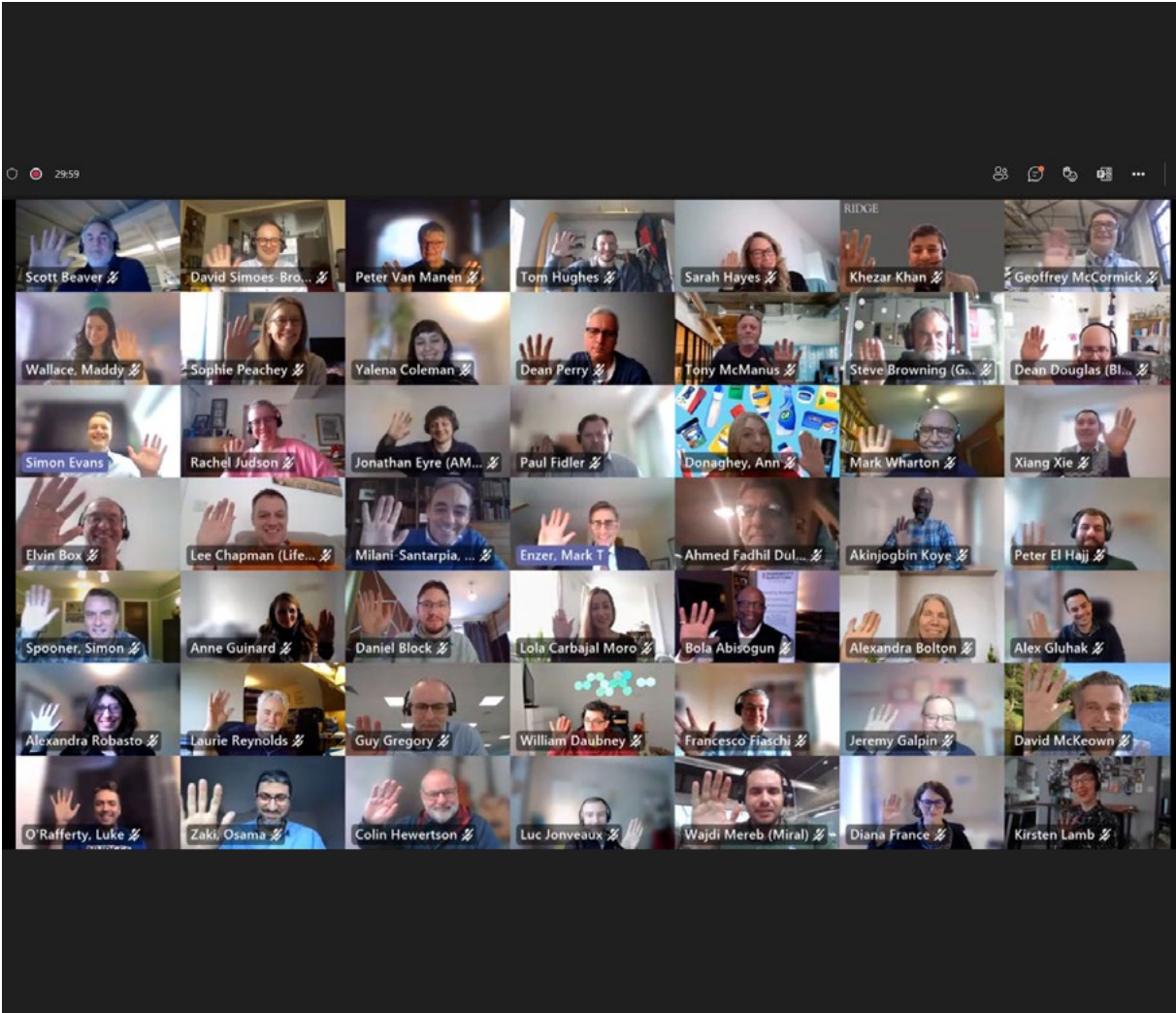
Now the calls are well established, we often get more than 100 participants. Some say it's the highlight of their week. The concept is simple: there's a lot of great stuff happening around digital twins and people want to find out about it. Few of us have time to read long emails or join online forums, so a phonecall every Tuesday morning, with a strict maximum length of 30 minutes, is a practical solution.

It's the regular heartbeat of digital twin development and a rallying point where everyone can gather and exchange ideas. Each call comprises a summary of current activity in the NDTp and presentations from other members of the community, followed by questions and discussion. CDBB acts as the convenor, but the calls are open to everyone. We have rules of engagement and the tone is always very respectful, but you can ask anything you like.

The way the calls have evolved is very exciting. We have seen how people who are usually in competition are joining forces. This is because our collective aim is to help facilitate the creation of an ecosystem of connected digital twins that will allow humans to flourish. If we had a mantra, it would be: "Collaborate on the rules, compete on the game".

One of the most striking features is how the calls connect people and clarify the issues surrounding digital twins. They give practitioners direct access to the leaders of this particular programme, and the opportunity to hold them to account.

We welcome new people every week, but we also see many familiar names. We try to ensure the content caters for both. Two years down the line it is clearly working. Together we have built and grown a meaningful community; we are all learning by doing and progressing by sharing.

Simon Evans,
Delivery Team Lead,
Gemini Call Chair, NDTp

Simon is the Global Digital Energy Leader and Global Digital Twin Leader at Arup. He is also the delivery team lead for the NDTp, part of the CDBB, and chairs the Gemini Calls. He is a fellow of the Institution of Mechanical Engineers, author of the digital twin maturity spectrum and co-host of the digital twin fan club podcast. Simon is a technology developer and a chartered engineer (CEng), with a background in renewables and offshore oil and gas. He was previously director of digital engineering for Atkins and SNC-Lavalin.
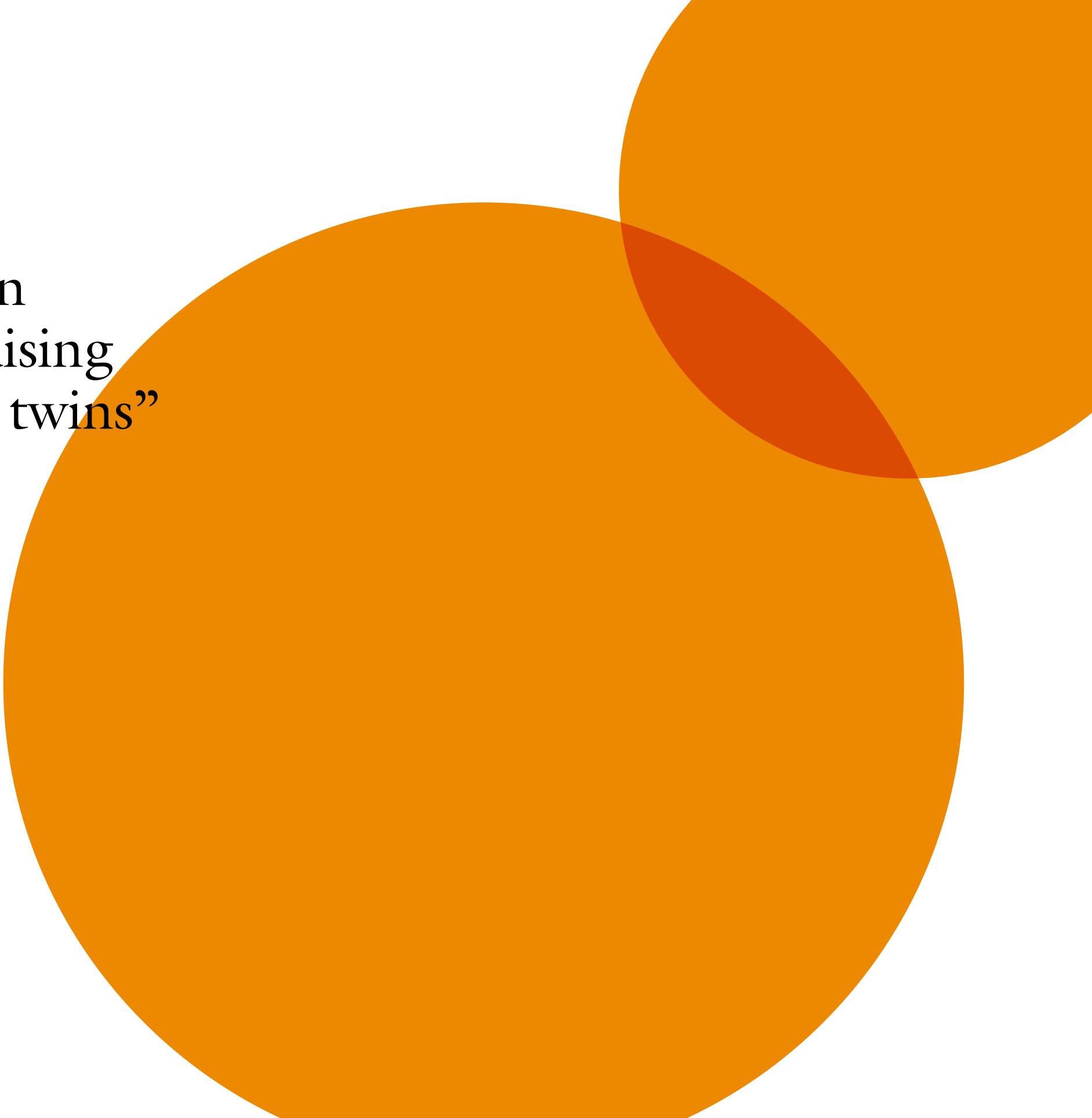
"We are proud to have been associated with CDBB, having contributed to all of CDBB's programmes.

It is clear that CDBB's collaborative approach to digital transformation has laid firm foundations for the broader industry now to build on. Digitalisation is an imperative that we must pursue"

Mike Haigh
Executive Chair

Mott MacDonald

"CDBB has played an important role in raising awareness of digital twins"

John Erkoyuncu
Professor and Head of the Centre for
Digital Engineering and Manufacturing

Cranfield University

Information Management Framework (IMF)

Body of standards and software that enable effective information management across the built environment and beyond.

Vital information within a matter of hours

Immediately after the Grenfell Tower disaster, investigators asked which other tower blocks in the UK had the same cladding. Finding the answer took three months.

Despite the best efforts of many people, the information was in different formats and stored by different local authorities. Yet with the NDT in place and the relevant details held as data that conforms to the IMF, they could probably have found out in a few hours.

An effective IMF helps us share data to better understand the built environment in new ways, that not only prevent disasters but increase resilience, reduce disruption and waste, and make life better for us all. It defines how we manage information effectively, which is vital to the creation of a NDT that users will trust to help them make better decisions.

In structural terms, the IMF is a kind of hub and spoke. When we organise data by joining things up point to point, each interface is bespoke. That's okay for a while, but as we scale up – for example, with the NDT – it doesn't work.

The built environment is a system of systems, and the hub and spoke structure means each system can connect to every other via the hub. For example, a bridge across a river may carry both power and telephone cables. The data about the two networks will overlap, so you need ways to see the connections if a flood damages the bridge – or you want to do routine maintenance.

This means creating the IMF is inherently cross-discipline, drawing on industry, academic and government expertise. Together we are producing a body of documents and software that will eventually become international standards.

Predicting the final outcome is a bit like asking Christopher Columbus what he will find on the other side of the ocean. This isn't a traditional type of project; it's more a journey of discovery.

Matthew West,
IMF Technical
Team Lead, NDTp

Matthew leads the technical work on the IMF for the NDT programme. Originally a chemical engineer, he has a PhD in numerical modelling. He worked for Shell for 30 years in a variety of roles, with a particular interest in information management. He has been a key technical contributor to a number of international standards. In 2008 he cofounded Information Junction, providing information management consultancy to industry and government. He has been a visiting professor at the University of Leeds and is the author of Developing High Quality Data Models. He was awarded an OBE for services to information management in the 2021 New Year's honours list.

Four Futures, One Choice

Four scenarios of what Britain could look like in 2040,
presented in a range of formats for different audiences.

Deciding today for tomorrow

This was a unique project that seemed to capture the spirit of the moment.
It was a description of four potential futures for the UK, depending on the choices
we make now.

In 2020 Didem Gurdur Broo and Andrew Smith of CDBB brought together
researchers from different disciplines, from economics to cyber-physical systems, to
explore the future of the built environment through the process of scenario mapping.
It was a brilliant opportunity to take people out of their specialist areas and collaborate.

The scenarios showed how we could develop a built environment in line with the UN's
Sustainable Development Goals and reduce our negative impact on the planet.

The experience and the results were important beyond academia, so we decided to write
a book for a broader audience. We even created an interactive e-book aimed at children.
After all, everyone thinks about the kind of future they want to live in.

Through this work, we discovered that we're not fully on the path to any one of the
four outcomes, but the decisions we make now will commit us more towards one than
another. This isn't about predicting the future but describing what might happen – and
how best to find the right direction.

We highlighted the need for thoughtful investment in digital technology, which aligns
with the Gemini Principles. We prioritised decarbonisation and biodiversity, and
focused on governance today for a better tomorrow. We tried to encourage people away
from short-term decision-making and toward making the decisions future generations
need us to make right now.

These aren't things you would typically hear from a built environment sector
organisation, but they are crucial for the sector to consider. That's what made this such
an exciting project. Beyond another expert report, it's something with real purpose that
can help us prepare for a better tomorrow.

Since the book was published, we've started hearing more people talking about the huge
responsibility the built environment sector has towards people and nature. This wouldn't
have happened even two or three years ago.

Kirsten Lamb,
Communications Manager,
NDTp and Construction
Innovation Hub

Kirsten joined CDBB in 2017
as an embedded librarian and
information specialist. In their
time with the programme they
have worked to communicate
the Centre's research, the
importance of information
management and the role of
digital technology in enabling
better decisions for people
and the planet.

Digital Twin (DT) Toolkit

Practical guide to developing the business case for a digital twin, published as a 33-page PDF.

Cultural change is coming

CDBB wanted to build a toolkit – including the why, the what and the how – that would allow any client to develop their own digital twin and become part of the national ecosystem of connected twins.

A group of 25 academics and practitioners brought different ideas to the table and provided a unique opportunity to bring the Grenfell Tower tragedy to life, by driving us towards that golden thread of chronological, immutable evidence that demonstrates exactly what decisions were made, when and by whom. Like a black box for construction. A digital twin becomes the bedrock of truth for a project. If there had been one for Grenfell Tower, we wouldn't have needed an enquiry.

The DT Toolkit became the ground zero, helping people to use structured data and an information management framework to demonstrate that they are maintaining assets in a legally compliant way.

It's a game-changer because the digital twin does so much that the industry traditionally doesn't. It turns the engagement model on its head, encouraging people to collaborate seamlessly, accountably, and transparently.

By creating an environment where everybody has skin in the game, you begin to tease out a cultural dynamic about how we really work together. The DT Toolkit demands teamwork, commitment and mutual respect. It means dealing with the consequences of collective, rather than individual, risk. It bypasses the adversarial attitudes that are prevalent across the industry.

In climate terms, if you develop a digital twin, you can measure your carbon emissions both internally and through your supply chain. Your thinking shifts and you achieve better outcomes for stakeholders and for humanity.

We had to make digital twins relevant to everyone, from sole traders to 1,000-person outfits. We also thought about the global scale, because emerging markets have even more to gain from their own national digital twins. They currently have so little infrastructure that the potential for value creation is immense.

Wherever they are used, digital twins mean it's no longer business as usual. The black box doesn't care who you are. You're just another part of the solution.

Bola Abisogun OBE,
Gemini Council, CDBB

Bola delivers Digital Twin solutions and specialises in built asset assurance and compliance. Bola is an independent management consultant, chartered construction manager, chartered surveyor and Fellow of the Royal Institution of Chartered Surveyors (RICS). Since 1999 he has procured and delivered more than £8 billion in capital projects across a range of sectors, and he has extensive (UK) public sector procurement and contract management experience. He was awarded an OBE in the 2019 New Year's Honours for services to diversity and to young people in the construction industry.

"CDBB was early to recognise that the digitisation of the built environment is a critical enabler of a better, cleaner and fairer world"

Paul Campion
Chief Executive Officer

The UK's Transport Research Laboratory (TRL)

Skills and Competency Framework

86-page document developed as the people enabler for the IMF.

Shift in mindset

While responding to climate change was a factor in the creation of the Skills and Competency Framework, one driver that everyone related to was Grenfell Tower. In this situation, there was no way for government to accurately and quickly identify which other buildings had the same cladding. It was clear that a NDT could have this power – the information to keep people safe. But it was also clear that we didn't have enough people with the right skills to make this happen.

Developing the Framework was a reminder of how times have changed. Once, you relied on your IT department to have digital skills; now digital skills and business skills are needed throughout organisations. As people are taking on new roles, they are recognising their responsibilities as data producers and data consumers, and we must prepare them for these new responsibilities.

The Framework defines specific digital skills, such as data modelling and quality management; and business skills, such as transformational leadership and communication. It sets four different competency levels for each skill and includes a programme that helps organisations take action. You don't have to be a data scientist or engineer to play a role on this journey.

A valuable gap analysis expressed a need for skills, but this is only half the story. It also describes a shift in mindset for everyone and the need to retrain the existing workforce not just recruit from universities.

The Framework includes indicators that enable you to assess your own or other people's behaviour. And while you don't have to go from zero to 100 straight away, it helps you see that you're at 20 now and you probably need to be at 70 or 80%. As well as the organisational level, it points to the roles we need nationally. There's a real requirement for policymakers and data regulators who approach things in a new way.

Since we published the Framework, it's been really rewarding to see several of the organisations we interviewed during its development, including Sellafield, National Highways and National Grid, start to take it on board and adapt it for their own use. Connected Places Catapult have even developed their own research off the back of it. This is what it's all about.

Ashleigh Monagle, Innovation Consulting Lead, Mott MacDonald

Ashleigh is an experienced digital consultant who partners with senior executives and leading infrastructure organisations to transform and advance the value of their digital capabilities and social usefulness. Ashleigh was part of Arup's data leadership team and led the programme delivering the company's data strategy. She has operationalised corporate start-ups and set up thought partnership programmes. Ashleigh is certified in digital business transformation management, Agile, human-centred design and programme management. She holds a master's degree in cultural management from Kings College London and was awarded a certificate from Bocconi University in Private Equity & Venture Capital.

BIM Early Steps Roadmap

26-page toolkit to help local authorities adopt a data-led approach to estate management.
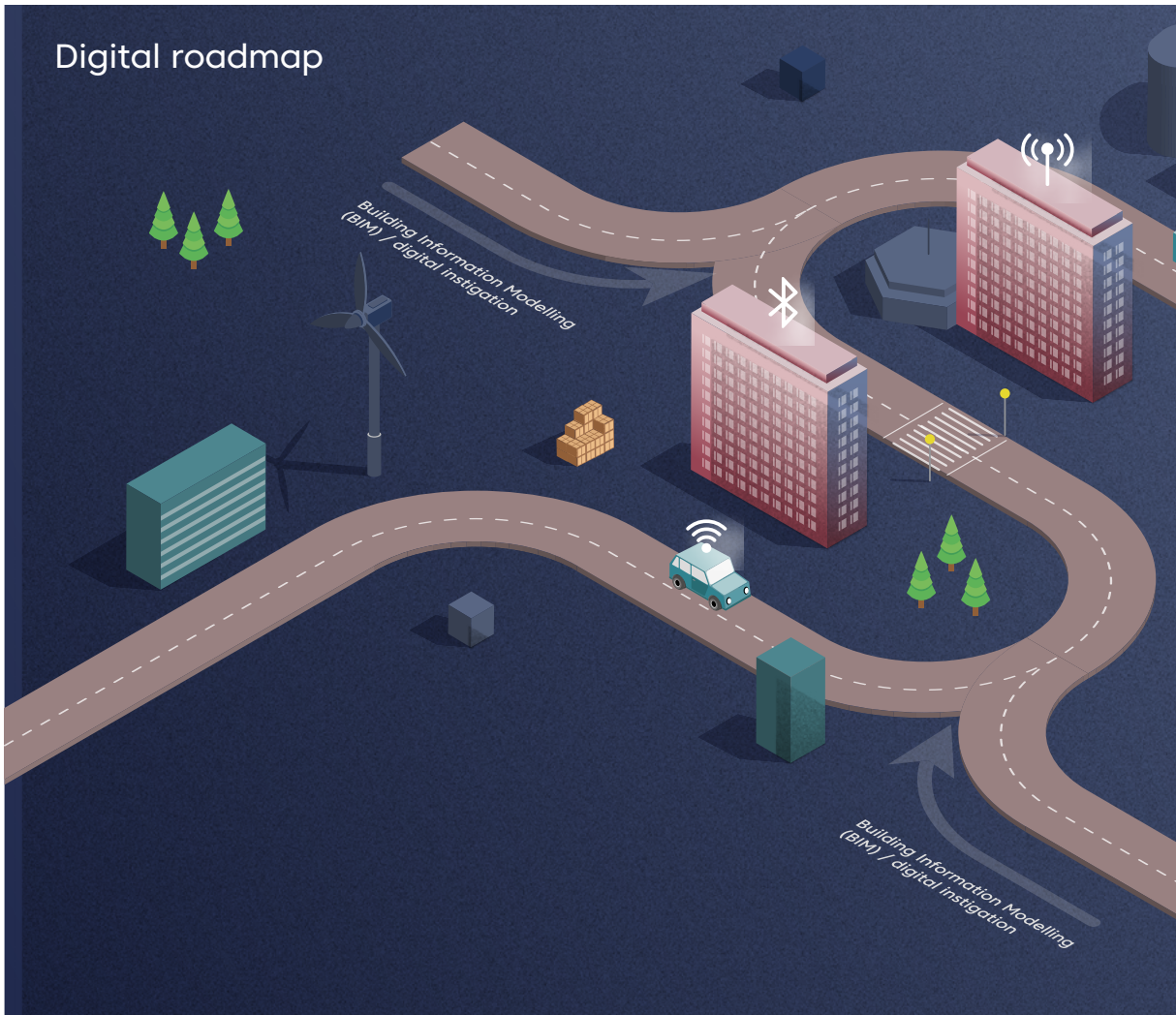
It's like an ice cream

When we asked local authorities why they weren't adopting digital technology to manage the built environment, we unearthed a lot of misconceptions. They believed they would need expensive IT systems; it would be massively disruptive and cost a fortune in professional fees.Thanks, but no thanks.

In fact, there are massive benefits in taking the digital route if only they could see them. We needed to devise something unthreatening, easy to engage with, and inexpensive to show the way.

We created the roadmap, which depicted the asset management cycle of a building: coming up with a programme, procuring it, delivering it, putting it into operation, and closing it down at the end of its life.

It's interactive, so users can click on an area and up pops an explanation of what digital implementations they can do, their impact and the benefits. It asks simple questions, so they can identify the data they really need. Before this, they often gathered information on every single radiator valve and pump socket – with no idea what to do with it.

The roadmap strips it all back. No three-letter acronyms, no jargon, just the information you need to maintain your asset, delivered as a single PDF. It's a bit like an ice cream: you can add sprinkles and a flake – 3D models, automated walkthroughs – but if you want plain vanilla that's also fine.

It gets the capital projects team talking to the facilities management team, which doesn't always happen, and it helps everyone collaborate with their supply chain. They get data back in a form they can use, and it doesn't cost a fortune. This is a crucial first step for many local authorities – and some have embedded it across the whole of their department.

If you get this wrong, you've got 60 years of getting it wrong. Get it right, and you can drive maintenance costs down, increase productivity and keep people alert. It's all about putting in the effort at the right time.

Terry Stocks,
Information Management Consultant, UK Implementation

Terry is a chartered engineer who was an early champion of modular construction, component standard libraries and BIM. He also led a construction 'Lean Approach' that achieved capital and operational delivery efficiencies of over 20% at the UK Ministry of Justice. Under Terry's leadership the MOJ delivered the UK government's first fully BIM project at HMYOI Cookham Wood. He has been a non-executive board member at Build Off Site and has worked with Lean Construction Institute UK. Terry chairs the Public Sector BIM Working Group and works closely with the UK Cabinet Office IPA.

Global BIM Summit

Online conference streamed live and available as a recording.

Remove the competition and the whole world wins

After over a year of preparation, the Global BIM Summit was held virtually on 17th March 2021. It was the first major event for the public sector and by the public sector to focus on digital transformation in the built environment. It was supported by the UK Government and the Construction Innovation Hub.

CDBB acted as a convenor, first holding a series of four pre-event webinars. Government representatives from ten countries and two global regions shared their digital transformation journey to date. Attendees gained insight into how governments and multilateral funders are driving productivity in the global construction market through the introduction of digital and standardisation. The pre-event series provided context for the main summit event. Speakers also discussed the social, economic, and environmental benefits and the real-world impacts of digital transformation in the design and delivery of national infrastructure.

The summit itself, hosted by Philip Bernstein of Yale School of Architecture, attracted 2,244 representatives from 97 countries, reached 154,000 people on social media, and was broadcast live in English and Spanish. Participants engaged with 19 leadership speakers from across the world, asking questions, taking part in discussions, and responding to live polls, all of which reflected the increasing global interest in the shared benefits of implementing national BIM strategies in infrastructure delivery through public procurement.

Specific subjects included cross-border collaboration and investing in digital transformation to improve global prosperity. Representatives from international government and multilateral organisations spoke about their experiences of BIM implementation to deliver societal benefits including improved transparency, efficiency, sustainability, and resilience.
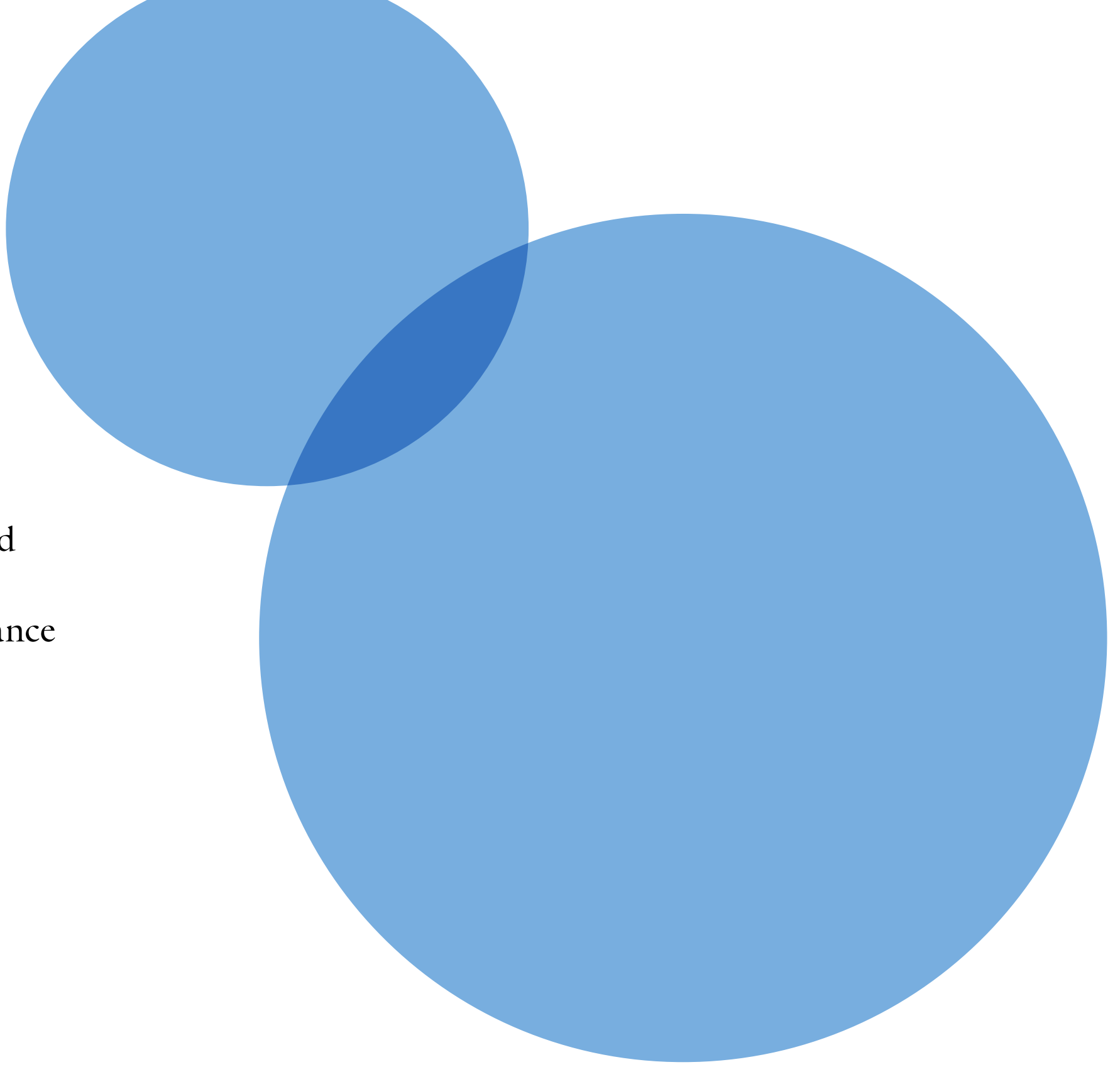
The summit was also the launch of the Global BIM Network which, building on previous successful collaborations between governments, provides a forum where policy makers, public procurers and infrastructure investors can exchange knowledge, insights, and experiences. The Network, chaired by CDBB's Head of International Adam Matthews, aims to foster a more productive and collaborative global digital built environment that deliver benefits for people and places.

Now over 1000 members strong, the Global BIM Network continues to grow since its launch at the Global BIM Summit.

Alanna Gluck,
Policy and Public Affairs Manager, CDBB

Alanna worked in local, regional, and national government programme delivery in the United States and Spain before relocating to the UK, where she received her MSc in public policy and management from King's College London. While at CDBB she has contributed to steering groups and programme teams, providing insight on built environment policy development and consensus building, and leading on national and international government engagement activities. She is also delivery lead for the Global BIM Network, managing the secretariat on behalf of the UK government.

"CDBB is empowering policymakers and operators to use the unprecedented amounts of data now available to plan infrastructure better, rethink maintenance systems and improve resilience across networks"

Sir John Armitt
Chair

National Infrastructure Commission

"CDBB has created a seed for digital innovation which has the potential to affect everyone"

Prof Liz Varga
Director of the Infrastructure Systems Institute

University College London

"CDBB's leadership in bringing diverse communities together has been exemplary"

Professor James Hetherington
Director, Advanced Research Computing Centre

University College London

Our Vision for the Built Environment

22-page document comprising the collective work of 75 individuals representing 45 organisations. Published as a PDF in 2021.

Better ancestors

CDBB always had a clear mission, but over time we realised there was no overarching vision for the built environment itself. This document provided that grand, unifying approach.

Conversations were already happening around better transport systems, improving affordable housing standards, and so on. But these were occurring in silos. We knew we could tell a more powerful story, and ultimately create a bigger impact, if we began to think more holistically and work more collaboratively. Instead of continuing to do things unilaterally, creating a jigsaw that doesn't really fit, we could set out what we wanted the complete picture of our future built environment to be.

CDBB became a convenor, an independent voice at the centre of an industry-wide effort to create a more connected, interoperable and efficient built environment, founded upon a highly collaborative system of systems. It followed naturally that we should apply systems thinking to the challenges we face as a planet, from climate change to poverty, from health to trade.

It was ground-breaking to bring together so many people to develop our collective Vision. We were struck by how interconnected everything is. We realised how closely aligned and committed to finding better solutions all of our contributors are. In the end, we are all searching for ways to be better ancestors to the hundreds of billions of people set to inhabit Earth beyond our lifetimes.

The Vision is our first step on a long road to a healthier planet, and it's an important one. It has helped people see they are part of something bigger – and that jointly they can make a much greater difference. It represents huge progress compared to where we were ten or twenty years ago. Of all we achieved at CDBB, our Vision is the accomplishment that could evolve most people's thinking. It's the big picture combination of everything that we've done.

For me, it is our single most important legacy.

Alexandra Bolton,
Executive Director, CDBB

Alexandra is CDBB's Executive Director. She works across CDBB's programmes, including the NDTp and the Construction Innovation Hub. She works to advance and drive a digital transformation of the built environment that will ensure that people and the planet can flourish together for generations to come.

Unfolding Pavilion

Exhibit at the London Design Biennale, 2021.

Enveloping the future of design

For the London Design Biennale, we designed a pavilion on the theme of sustainability and innovation, focusing on the relationship between nature and cities. It was made of engineered timber – a material fit for the 21st century.

The world faces a climate emergency and the built environment is responsible for 40% of carbon emissions. We need to drastically reduce these and create sustainable and healthy urban environments. So, instead of extracting building materials from the planet, we can start growing them again.

Timber has been used to build homes and infrastructure for thousands of years. It has excellent structural performance and is a natural construction material that can sequester carbon in its cells while it grows. New digital tools mean we can now design and construct with it more efficiently, reducing build time, minimising emissions and cutting transport miles.

In contrast to traditional timber frames, engineered timber is made by placing thin layers in different orientations to make thicker panels. Producing it in the factory environment gives you greater control of the structural properties of the end-product.

Working with the Centre for Natural Material Innovation at the University of Cambridge and PLP Architecture, first we sourced the raw material from sustainably managed forests. Then we scored patterns on timber sheets using a technique called kerfing, which enables you to bend and fold them into lightweight, flexible and transformable components. They are easy to transport as flat pieces, assemble on site, disassemble and reuse. The six large components of the unfolding pavilion took less than two days to erect.

With engineered timber you can go higher than traditional wooden frames which includes housing, offices, hospitals, and prisons. So, our next objective is a real infrastructure project. We're planning to use the material on a primary school extension in Cambridge. The people who learn and work there will experience how nature can revitalise their environment and contribute to solving the climate crisis.

Antiopi Koronaki,
Assistant Professor in Design Computation and Fabrication, Centre for Natural Material Innovation, Department of Architecture

Antiopi is an architect engineer working in the Centre for Natural Material Innovation. Her research explores the potential of engineered timber in off-site manufactured school buildings in the UK. She holds a PhD from the University of Bath on the optimisation of large-scale structures for construction.

The Value of Information Management in the Construction and Infrastructure Sector

104-page report written by KPMG and Atkins, published in 2021 as a PDF.

The missing piece of the jigsaw

This story starts on Thursday 14th December 2017 at the Institution of Civil Engineers, when the National Infrastructure Commission launched a report called Data for the Public Good.

It was radical and brilliant. It effectively said that, in the interest of effective public policy, information on the built environment, except for personal data, should be free and open between the responsible public and private sector organisations. And it led to the establishment of CDBB.

In 2020 CDBB asked a simple question at the heart of the whole issue: can we prove that there is a benefit to digital collaboration? This was important for two reasons: first, this sector integrates to a huge extent with the rest of the economy; second, in terms of efficiency, it lagged behind most others.

This report answered the question – and provided the missing piece of the jigsaw. If you're trying to influence government policy, you need numbers that show there is a hard-edged impact. That's why it was led by Chelsea Dosad, who is an outstanding economist. She demonstrated that a 1% improvement in asset efficiency would save the UK £32 billion.

It landed well within government and across the private sector and we're now starting to see asset owners look at the implications of digitalisation, from design to construction to operation – as well as the knock-on effects on other sectors. For example, if you invest in electric vehicle infrastructure, what's the impact on energy demand?

You have to crunch a phenomenal amount of data to be able to get this sort of insight – which you couldn't do ten years ago. Today however, because no government wants to waste money and infrastructure assets are phenomenally expensive, there's a digital tide flowing through the industry.

Data for the Public Good was picked up all over the world. We can hope that this report might, in due course, gain a similar following.

Richard Threlfall,
Partner and Global Head of Infrastructure, KPMG

Richard is Global Head of Infrastructure at KPMG. He has over 20 years' experience in infrastructure policy, governance, strategy and financing, advising both public and private sector clients in the UK and overseas. He began his career at the UK Department for Transport where he held positions in the road, rail and aviation directorates. Richard has advised on the governance and financing of some of the world's most complex civil engineering projects. He is a Fellow of the Institution of Civil Engineers and a member of the Infrastructure Board of the Confederation of British Industry. He also chairs the Advisory Council of The Infrastructure Forum, an independent think-tank.

"Britain can either be a leader or follower in digitisation of the built environment. CDBB put us on the front foot in creating a future that we all want to live in"

Jim Hall
Professor of Climate and Environmental Risks

University of Oxford
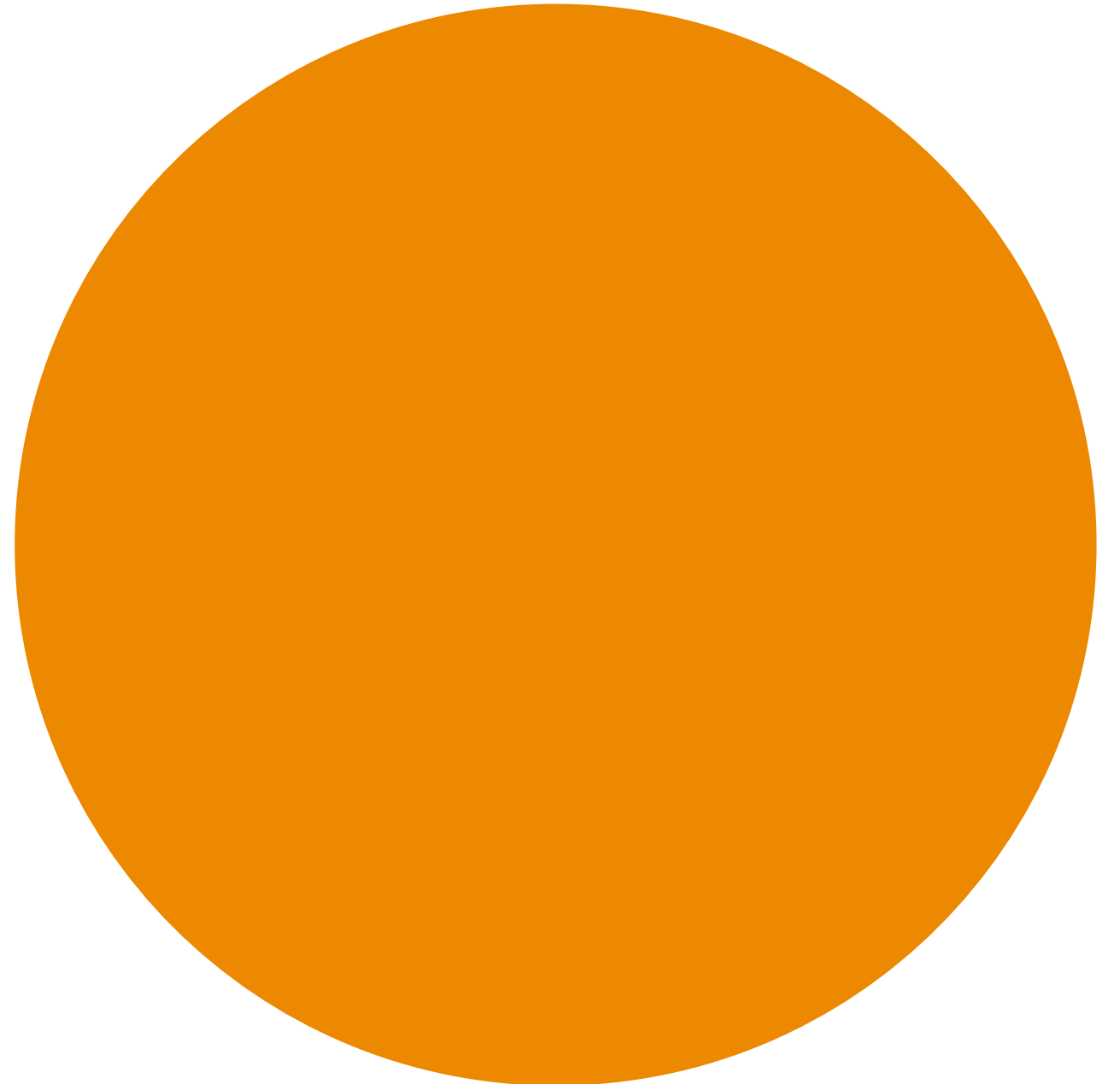
Cyber-Physical Fabric Summit

Conference held on 19th July 2021 to explore a vision
for cyber-physical infrastructure.

Agility eats planning for lunch

If the pandemic has taught us anything, it's that we must learn to see around corners. We need new tools and infrastructure that will enable us to innovate quickly and safely. Peter Drucker famously said culture eats strategy for breakfast. You could also argue that agility eats planning for lunch.

Three things come to mind:

• First, technologies such as synthetic environments, digital twins, robotics and living labs are all transformative, even disruptive, on their own. But they're even more potent when you put them together in a cauldron. (As long as you have the recipes.)

• Second, innovation isn't neat and tidy. It's messy, risky – you could even say naughty. Many people and organisations struggle with this idea. So we have to de-silo those technologies and find different ways to think and collaborate.

• Third, we tend to split the world into the digital and the physical, whereas the most exciting stuff happens at the intersection. Magical beasts live here, in the form of digital twins, smart machines and living labs.

We organised the summit to coalesce this cyber and physical thinking, talk about the ecosystem and support those key technologies and recipes. It brought together experts from across government, academia, industry and the public sector – and was open to the general public too.

The level of interest was fantastic. More than 450 people attended and the energy in the discussions was like a fireworks display. We had panel sessions on the vision for the cyber physical infrastructure, data and technical interoperability, research, adoption and next steps. Afterwards we published written and video summaries.

People talk about it being one minute to midnight. If it is, we're going to need technologies we haven't invented yet, so we need to be able to innovate quickly and use modelling to explore potential solutions before we build them.

The pandemic has been a warm-up act. Tackling climate change will require a cyber physical intervention on an unprecedented planetary scale. The summit was a pivotal moment on our journey.

Paul Clarke,
CBE, FREng

In November 2020, Paul Clarke stepped down as Chief Technology Officer at Ocado, where he had led the sharp end of their innovation factory for many years. He believes building a successful innovation factory is all about the people, culture, creativity, leadership and vision rather than just the underlying technologies, and he has spent much of his career being a piece of disruptive grit in a number of different oysters, trying to help people see what they can't see and trying to inspire teams to do things they never dreamed possible. He now sits on a number of government and industry advisory boards including the AI Council, Robotics Growth Partnership (co-chair), National Physical Laboratory and Health Data Research UK, whilst at the same time advising a portfolio of exciting start-ups.

Climate Resilience Demonstrator (CReDo)

First phase of a project, running from April 2021 to March 2022. It aims to show how digital twins can improve climate resilience across infrastructure.

Demonstrating real benefits for real people

This is about how we actually adapt to climate change. If there's a bad storm, what happens to the local power network? How do you communicate? What are the knock-on effects for vulnerable people?

CReDo is a pilot project for the NDTp. We took the NDT vision of an ecosystem of connected digital twins and developed a model to demonstrate how this could deliver real benefits for real people.

The model broke new ground by using real data from three asset owners across different industry sectors: Anglian Water, BT and UK Power Networks. This means we can explore interdependencies in a particular geographical area and see the impact of extreme weather events on local infrastructure and the people who use it.

Our first use case was to observe the hypothetical impact of flooding, resulting from climate change. We took data about the built assets (where they are, what they do, their height above sea level, what they connect to) and created a bird's eye view of the whole system. Then we began to stress test possible scenarios. For example, if a power substation is flooded, will it go out of service? If so, how will this consequently affect telecommunications and water systems?

Using this approach in the future, asset owners can plan how to protect the overall infrastructure system – and decide how much to invest. In future, we will look to incorporate the use of live data in order to respond in real time to extreme weather events.

To communicate the NDT message to the wider public, we produced a short film that coincided with COP26. It presented alternate visions of the future for a particular family, including one in which a digital twin engineer has the right information at her fingertips to make better decisions. We also developed an interactive app that uses a fictional town to portray how planners can use digital twins to increase resilience.

CReDo is a collaborative effort across asset owners, universities, government-funded bodies and commercial companies. It's a first of its kind, showing what's possible if we develop and connect digital twins. We hope others will follow our lead.

Sarah Hayes,
CReDo Project Lead, NDTp

Sarah is an experienced economist and the author of the report 'Data for the public good', which recommended the development of the NDT and the creation of the IMF. She is the CReDo project lead for the NDTp, leading the delivery of the project and the dissemination of the findings and recommendations.

Digital Twin (DT) Flex Standard

Agile approach to producing standards for digital twins.
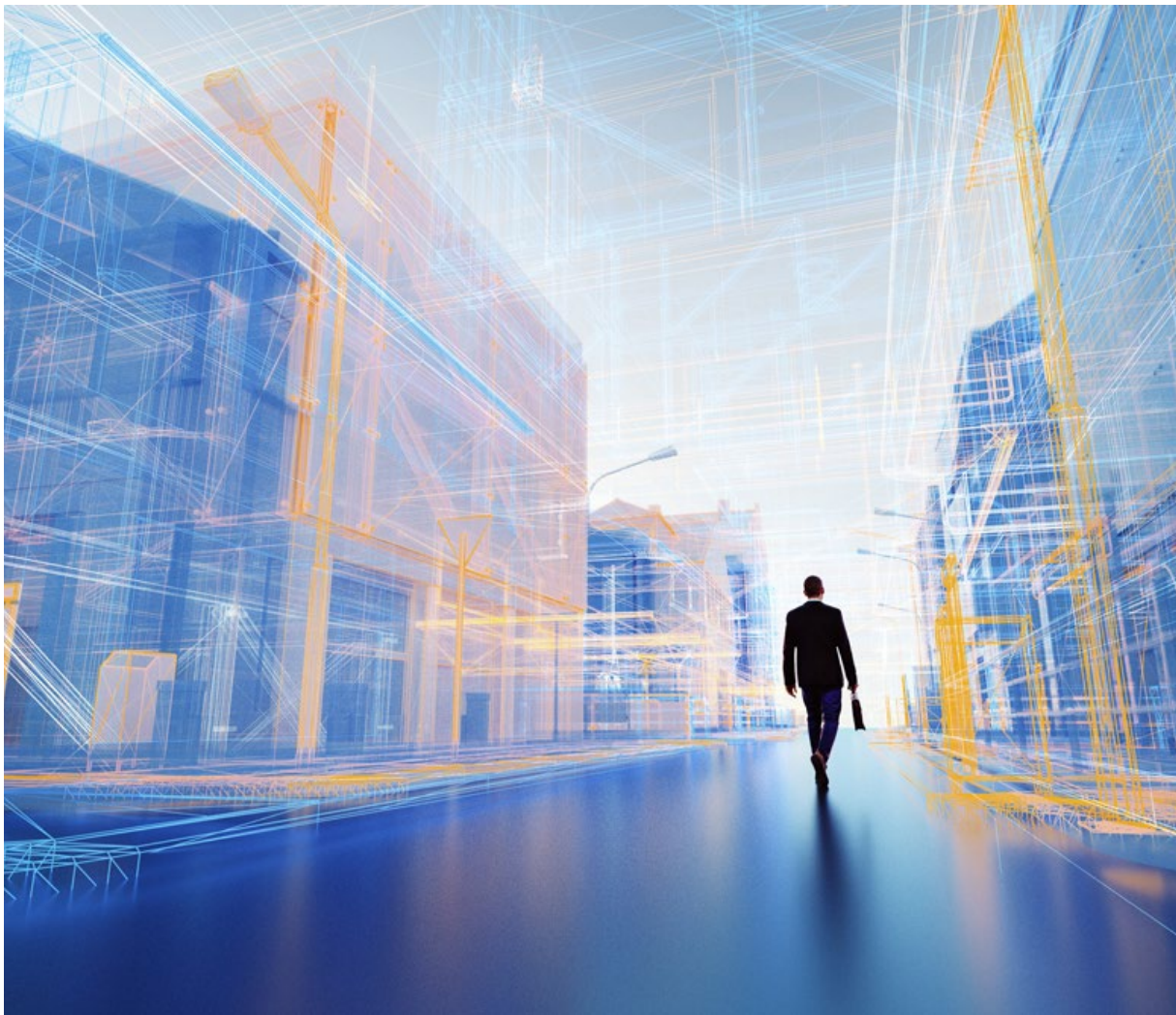
Perfectly imperfect

As digital twins developed, an interesting debate emerged. Can you – and should you – test whether something qualifies as a digital twin or not? Maybe it doesn't matter. This is an emerging technology, after all, and as long as a tool is useful, why does it have to be a particular shape or size? Don't you risk curtailing creativity and diversity? On the other hand, unless we define it, there's nothing to stop people claiming to have created a digital twin when they've done nothing of the sort. And the industry will lose faith.

In the end we decided to put a stake in the ground and produce standards that provide clarity and consistency. However, we were acutely aware that, especially in a broad-spectrum marketplace like this, the traditional methodology would deliver them too slowly.

So, the NDTp, the Construction Innovation Hub and the BSI decided to explore the benefits of developing standards in a more dynamic way. By adopting BSI Flex, a new agile standardisation service, we realised we could produce standards much faster. Everyone who wanted to contribute could get involved and we could iterate quickly. It was the perfect approach for digital twins, which are by definition cross sectoral and therefore require standards that are broad and general, not deep and slow.

We consulted highly skilled experts with deeply held views, who thrashed out their differences in a collaborative and constructive process. It was amazing to receive 290 technical comments on the initial draft: a level of engagement that proved how important this was.

We were trying to thread a needle: to make our standards relevant to a whole range of people in the built environment, while at the same time reflecting standards in other industries, such as manufacturing.

It was hard, but we got there. The standard is now out in the global marketplace, incomplete but invaluable. It's already attracting attention, inspiring participation and driving consensus. It's building a responsive framework that perfectly fits this dynamic technology environment.

Miranda Sharp,
Chief Executive Officer,
Metis Digital

Miranda Sharp set up Metis Digital to connect data and people to value. She advises commercial clients alongside acting as Non-Executive Director to the Transport Research Laboratory (TRL) trustee to the Centre for Cities think tank and member of the Mayor's Smart London Board and Information Commissioner's Office (ICO) Technology Advisory Panel.

Researchers of CDBB

More than 220 academics from 15 universities working on 68 discrete projects.

Licence to explore

The CDBB research programme may not be a unique enterprise, but it is certainly rare. Starting from scratch, CDBB commissioned an initial set of short studies to scope out the potential breadth of its activity. As a result, it took on projects that had started elsewhere and gave them room to grow. It also established a bridgehead between different research endeavours.

When the research programme launched, it had two main characteristics. First, more than half the projects were led and supported by early career researchers – a strong signal that CDBB was laying foundations for the long term.

Second, it covered a wide range of topics and disciplines. In fact, there's probably no subject studied at Cambridge that couldn't, in principle, be folded into some or other research activity. Obviously, it incorporated architecture, engineering, maths and statistics. But also linguistics (for example, how to classify terms for mutual understanding) and philosophy (such as the ethical implications of artificial intelligence). It was a real joy when disparate disciplines came together across the 'divide', for example, to produce Four Futures, One Choice.

In the same spirit, communications and engagement specialists translated academic papers into social media posts, blogs and videos. They also built a knowledge base navigator to help people investigate further.

Because CDBB's mission was so far-reaching, researchers had considerable freedom. There were many exciting opportunities to get out into the field, for example, the Unfolding Pavilion, the Staffordshire bridge project and Satellite infrastructure monitoring. The outputs from all of these are still cascading out.

There was also a remarkable level of engagement from external stakeholders. One project is developing a digital twin of the ultra-modern buildings in the University's West Cambridge campus. The primary stakeholders here are the estate managers and building operators, who are trying to optimise the working environment for their occupants. This was a great reminder to the researchers that they are all part of a bigger effort that is making a real difference on the ground.

Andrew Smith,
Research Programme
Manager, CDBB

Andrew is research programme manager in the core team at the CDBB. He is responsible for operational management of the research bridgehead, including the delivery of research outputs from the funded programmes, and supports the bridgehead's strategic direction. Before joining CDBB, he was business/project manager of multi-disciplinary EU- and UKRI-funded consortia and centres hosted by UK HEIs at Sheffield, Glasgow and Edinburgh universities. Andrew spent 11 years in New Zealand, at an economics, engineering and environmental consultancy, as corporate planner at a city council, and as a strategy adviser at a Crown Research Institute. He has a degree in economics from Cambridge University.

"CDBB has proven time and again that focusing on public good creates the right behaviour to drive positive change"

Kevin Reeves
Industry Exec, Energy & Utilities

Microsoft UK
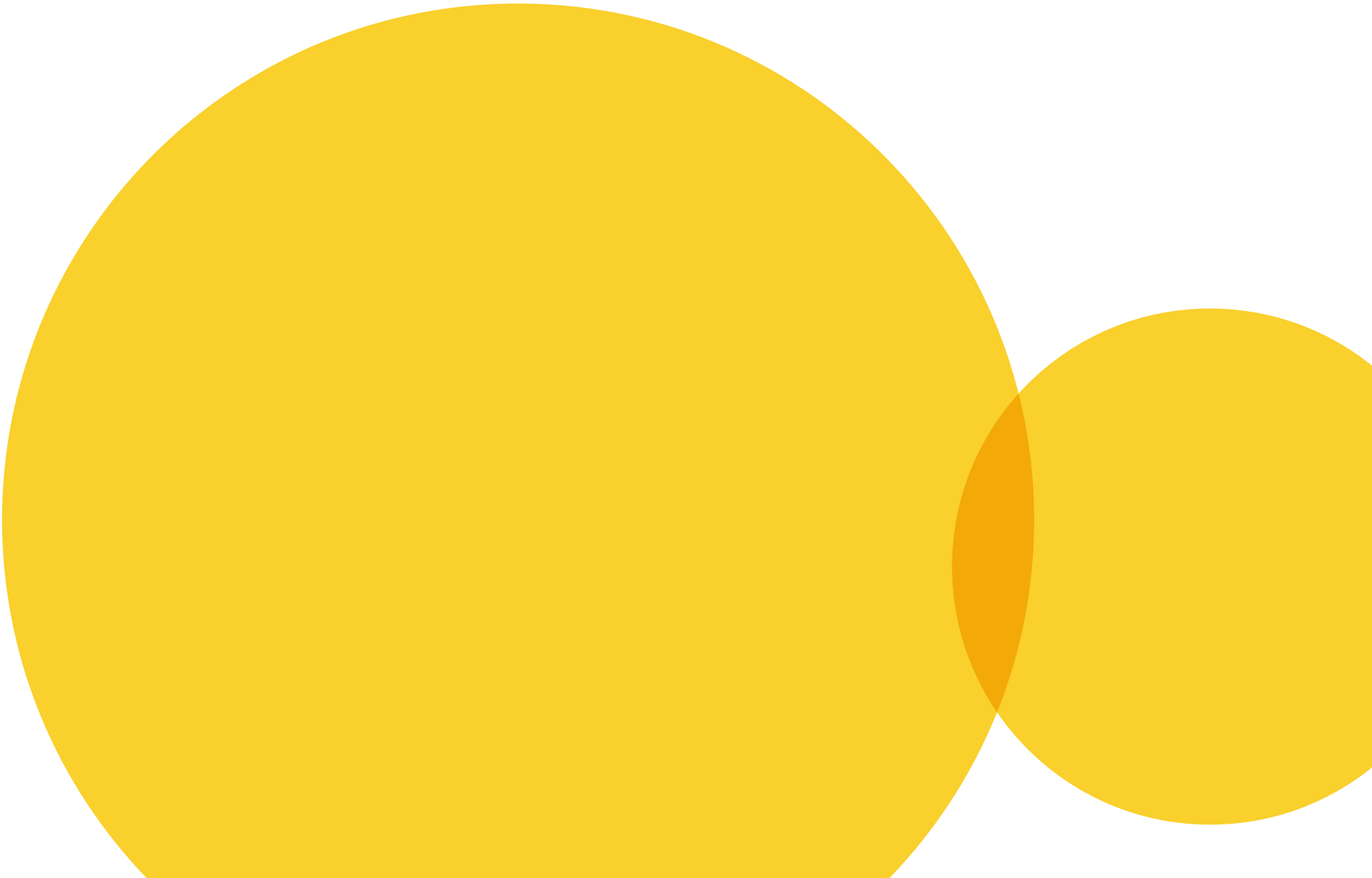
"CDBB will leave a vital lasting legacy that will provide significant economic and societal impact to the UK"

Dr Robin Pinning
Chief Technology Officer

STFC Hartree Centre

"Over the past four years CDBB has driven cross-company collaboration, provided essential leadership and direction, created an inspirational vision for the built environment, and delivered high quality guidance to get us started.

Without them our National IMF foundations would not be attainable"

Matt Edwards
Head of Enterprise Data, CDO

Anglian Water Services

Acknowledgements

CDBB wishes to thank all
staff and contributors
who have walked alongside
us on this journey

Contributors

Abigail Plet

Adam Anyszewski

Adam Beck

Adam Matthews

Adam Robinson

Adar Pelah

Adrià Salvador Palau

Aftab Jalia

Agnese Meloni

Ajith Kumar Parlikad

Al Cook

Alan Penn

Alanna Gluck

Alessandra Luna Navarro

Alex Gkiokas

Alexandra Bolton

Alexandra Dale

Alexandra Luck

Alexandra Robasto

Algan Tezel

Ali Nicholl

Alice Hunt

Alistair Boxall

Alistair Law

Amalka G.N Ranathungage

Amanda Druce

Amanda Prorok

Amanda Wyzenbeek

Amarynth Sichel

Amelia Burnett

Amer Hijazi

Dr Amit Bhave

Ana Gatóo

Anais Tugler

Ananya Jaidev

Andrei Popa

Andrew Bellerby

Andrew Gamblen

Andrew Nightingale

Andrew Jordaan

Andrew Mitchell

Andrew Mylius

Andrew Robinson

Andrew Smith

Andy Boutle

Andy Mitchell, CBE

Prof Andy Neely, OBE FREng

Andy Parnell-Hopkinson

Andy Robinson

Andy Smith

Angela Thompson

Dr Anil Madhavapeddy

Ann Woulfe

Anna Burrows

Anne Guinard

Dr Anne Kemp, OBE

Ant Burd

Dr Antiopi Koronaki

Prof Anurag Agarwal

Dr Arnab Mukherjee

Prof Arto Kiviniemi

Ashleigh Monagle

Astrid Schmidt

Audrey Despinasse

Dr Aurimas Bukauskas

Dr Barry Blackwell

Bassel Cassia

Ben Thomas

Dr Benjamin Lucas

Benjamin Mawdsley

Bill Davis

Bill Murray

Bola Abisogun, OBE

Brendan Bromwich

Brett Plant

Prof Brian Collins, CB FREng

Brian Matthews

Dr Brinder Singh Mahon, OBE

Prof Campbell Middleton

Dr Carl Gamble

Carol Bruce

Caroline Key

Caroline Yan-Man-Shing

Carsten Roensdorf

Casey Rutland

Catharine Dass

Catherine Condie

Dr Chara Makri

Dr Charles Boulton

Prof Charlotte Lemanski

Chris Cooper

Prof Chris Dent

Chris Donnachie

Dr Chris Doran

Prof Chris Harty

Chris Hinton

Chris Loades

Prof Chris McMahon

Chris Partridge

Prof Chris Young

Christine Sheldon

Christos Vidalakis

Claire Dowdall

Claire Flowers

Claire Williams

Prof Claudia Eckert

Colin O'Toole

Prof Colin Taylor

Colin Williams

Dr Cristian Genes

Cristina Savian

Crown Commercial Service

Dale Evans

Prof Dame Wendy Hall, FRS FREng

Prof Dan Osborne

Dan Rossiter

Danial Popov

Daniel Block

Daniel Braund

Daniel Clarke

Prof Daniel Coca

Dr Daniel Nurkowski

Dr Daniel Summerbell

Dr Danny Murguia

Dr Dario Marino

Darrell McMurray

Dr Darshil Shah

Darya Bahram

David Churcher, MBE

David Cuckow

David Holland

David Jones

Prof David Lane, CBE FREng FRSE

David McKeown

David Morteo

Prof David Mosey

David Ocio

David Owens

David Philp

David Shepherd

David White

Davide Stronati

Dr David-John Gibbs

Dawn Matthias-Jackson

Dean Perry

Debbie Deng

Dr Deborah Pullen, MBE

Debra Royal

Prof Denise Bower, OBE

Prof Derwen Hinds

Dhowal Dalal

Dr Didem Gürdür-Broo

Dionne Weston

Prof Duncan McFarlane

Duncan Reed

Dr Edwin Lee

Eivor Oborn

Prof Elisabete Silva

Dr Elliot Christou

Elvin Box

Dr Emilie Vanvyve

Dr Emily Paremain

Emma Hooper

Emma Wright

Erik B. Johnson

Dr Erika Pärn

Dr Ettore Settanni

Evelyn Tehrani

Dr Ewa Luger

Dr Faisal Rashed

Dr Farhad Huseynov

Felix Jones

Fergus Harradence

Dr Filip Babovic

Fiona Moore

Francesca Karabyn

Francis Gross

Dr Franziska Sielker

Freddy Wordingham

Dr Gabriel Martín Hernández

Gary Aker

Gavin Fraser

Prof Gavin Shaddick

Gavin Starks

Dr Gemma Burgess

Gemma Gordon

Gemma Schroeder

Dr George Brownbridge

Geraldine Wintour Aust

Dr German Terrazas Angulo

Dr Ges Rosenberg

Dr Gilbert Owusu

Prof Gillian Rose

Dr Giovanna Biscontin

Glenn Worrall

Dr Gokcen Yilmaz

Prof Gordon Mackerron

Prof Gordon Masterton

Grace Tortoise

Graeme Bell

Contributors

Graeme Tappenden

Graeme Thomson

Graeme Wildridge

Dr Greg Hawkridge

Hadeel S. Saadoon

Haifeng Niu

Dr Hailiang Dul

Hannah Holmes

Hannah Vickers

Harpreet Kaur-Hansi

Hasan Omar

Heather Jones

Helen Alexander

Dr Helen Manchester

Helena Brimson

Henry Fenby-Taylor

Prof Henry Wynn

Holger Kessler

Hugo Hadfield

Huong Tran

Prof Iain Grant Gordon

Iain Miskimmin

Ian Blackman

Ian Chambard, FRGS

Ian Gordon

Prof Ian Leslie

Dr Ian Lewis

Ian Neild

Ian Rush

Prof Ioannis Brilakis

Dr Isabel Gonzalez

Islington Council

Jack Ostrofsky

Jacopo Chiaro Benincasa

Dr Jagjit Singh Srai

James Harris

James Heaton

Prof James Hetherington

James Salter

Dr James Talbot

Jamie Mills

Jamie Young

Dr Jamil Nur

Dr Jan Boehm

Jan Kaiser

Jane Cummins

Jane Peacock

Jason Sun

Prof Jason Underwood

Javed Edahtally

Jeannine Gavaghan

Jeffrey Lake

Jennifer Myers

Dr Jennifer Schooling, OBE FICE

Prof Jennifer Whyte

Dr Jens Jensen

Prof Jeremy Watson, CBE FREng FIET

Jerry Dillon

Dr Jethro Akroyd

Jiawei Lai

Jiayi Zhao

Prof Jim Hall

Jim Smith

Yingyan Jin

Dr Jingchen Hou

Jo (Giuseppina) Daye

Jo Dickson

Jo Winston

Prof Joan Lasenby

João Soliman Junior

Prof John Beckford, FRSA FIET

John Cantwell

Prof John Clarkson, FREng

Prof John Ahmet Erkoyuncu

Prof John Fitzgerald

John Ford

John Inglis

John Moulson

Prof John Orr

John Park

Prof John Polak

John Seed

Dr John Siddorn

John Whelan, FIMechE

Johnny Furlong

Dr Jon Roozenbeek

Jonathan Avery

Jonathan Glerum

Jonathan Williams

Prof Jordan Giddings

Dr Jorge Merino Garcia

Joseph Murphy

Prof Joseph Tah

Dr Jozef Doboš

Dr Judith Shawcross

Julia Sigles Robert

Julian Buhagiar

Juliana Parise Baldauf

Julie Alexander

Justine Robinson

Justine Webster

Karen Alford

Dr Karen Blay

Dr Karl J Prince

Dr Katherine Lovell

Kate Bond

Kate Mitchenall

Dr Kate Parsley

Katie (Kathryn) Butler

Dr Kaveh Jahanshahi

Prof KC Sivaramakrishnan

Keiran Millard

Keith Heard

Keith Waller

Dr Kell Jones

Dr Ken Pierce

Kerry Scott

Kevin Reeves

Kevin Wilson

Kim Hetherington

Kirsten Lamb

Kirstine Dale

Kjeld Jensen

Kok Foong Lee

Dr Krisztina Kelevitz

Dr Kwadwo Oti-Sarpong

Dr Lars Schewe

Laura Mills

Laura Murzinaite

Lauren Parker

Lawrence Chapman

Leigh Dodds

Lex Wilson

Dr Li Wan

Liam Barnett

Lisa Millard

Lisa Wears

Liz Salter

Prof Liz Varga

Lloyd Evans

Dr Long Chen

Lorraine Butler

Louis Hynes

Louise Dobson

Louise Krug

Luca Philo

Luke O'Rafferty

Dr Lyndsay Grant

Mac Muzvimwe

Maksims Abalenkovs

Prof Manohar Bance

Dr Manuel Davila Delgado

Marek Suchocki

Sister Margaret Atkins OSA

Maria Manidaki

Mariam Helmy Ismail Abdelaal

Dr Marianthi Leon

Mariel Reyes Salazar

Marion Lurock

Marion Samler

Dr Mark Allen

Mark Bew, MBE

Mark Coates

Mark Enzer, OBE FREng

Prof Mark Girolami

Mark Hansford

Mark Thorneloe

Prof Markus Kraft

Martin Baker

Martin Gooch

Prof Martin Mayfield

Martin Simpson

Marzia Bolpagni

Mathew Brett

Matt Edwards

Matt Webb

Prof Matthew Chalmers

Dr Matthew Danish

Matthew Evans

Matthew Seed

Matt Watchorn

Dr Matthew West, OBE

Dr Mauro Overend

May Tu

Dr Mehdi Kadivar

Melanie Jans-Singh

Melissa Zanocco

Mia Dean

Prof Michael Barrett

Michael Hillman

Prof Michael Keith

Prof Michael Kenny

Prof Michael Lewis

Michael McLornan

Prof Michael Ramage

Dr Michael Sanderson

Dr Miguel Angel Bravo-Haro

Mike Sweeney

Prof Mike Kagioglou

Contributors

Mingfei Ma

Mingyu Zhu

Miranda Sharp

Prof Mohamad Kassem

Dr Mohamed Zaki

Dr Mohammad Samie

Monika Podbielska-Szostak

Nadia Jaynes

Dr Naoum Tsolakis

Naqash Tahir

Dr Neil Carhart

Neil Pennell

Neil Thompson

Niall Ferguson

Nick Brown

Nick Mansley

Nick Nisbet

Nick Smallwood

Nicola Hudson

Dr Nicola Moretti

Nicola Pearson

Nicole Badstuber

Nik Thomas

Nikkie Basquine

Prof Nilay Shah, FREng

Dr Nirit Pilosof

Nirmal Kotecha

Dr Noura Wahby

Olivier Thereaux

Owen Parry

Pam Bhandal

Paolo Ettore Giana

Prof Patricia Tzortzopoulos

Patrick Driscoll

Prof Paul Alexander

Paul Campion

Paul Clarke, CBE FREng

Paul Dodd

Paul Fidler

Prof Paul Linden

Paul Louth

Paul May

Paul McGivern

Paul Shillcock

Paul Turney

Paul Wilkinson

Pauline (Polyxeni) Tzachrista

Prof Payam Barnaghi

Peter Burnett

Dr Peter Demian

Peter Durante

Peter El Hajj

Peter Fleming

Peter Lee

Peter Runacres

Peter Turner

Peter Vale

Peter van Manen

Prof Phil Allmendinger

Phil Orde

Phil Read

Philippa Rubin

Polly Hudson

Dr Poonam Yadav

Prof Lord Robert Mair, CBE FREng FRS

Qi Li

Dr Qiuchen Lu

Dr R. Elena Francu

Prof Rachel Armitage

Rachel Boyd

Prof Rachel Cooper

Rachel Judson

Prof Rafael Sacks

Raj Chawla

Rana A. Mohamed

Dr Reyhaneh Shojaei

Rich Howes

Rich Stevens

Richard Buckingham

Richard Lane

Prof Richard Mortier

Richard Mumford

Richard Petrie

Richard Threlfall

Richard White

Dr Richmond Juvenile Ehwi

Rick Hartwig

Rob Jackson

Robbyn Guild

Robert Walsh

Dr Robin Pinning

Robin Webb

Prof Roger Kemp, MBE FREng

Prof Roger Maull

Dr Rohit Verma

Rollo Home

Ron Bakker

Ron Oren

Dr Rosamunde Almond

Dr Roxana Vornicu

Roy Evans

Prof Ruchi Choudhary

Ryan Elliot

Ryan Tennyson

Dr Sabina Maslova

Dr Sakthy Selvakumaran

Sam Stacey

Samuel Chorlton

Sara Hugosson

Sarah Davidson

Sarah Delaney

Sarah Fell

Sarah Hayes

Sarah Hollingsworth

Sarah Rock

Sarah Snelson

Sean McGuire

Dr Sebastian Mosbach

Prof Sergio de Cesare

Sevcan Birdal Aktas

Dr Shan Luo

Shona Jenkinson

Simon Davids

Simon Duddy

Simon Evans

Simon Lewis

Simon Patterson

Dr Simone (Simonetta) Castello

St John Barton

Stefania Ferrucci

Steffy Velayudhan

Stéphane Côté

Stephen Batcheler

Steve Baker

Steve Denman

Dr Steven Yeomans

Prof Stuart Barr

Stuart D'Henin

Dr Subhrajit Bhattacharya

Sukhmit Singh Chaggar

Suliman Banora

Tamar Loach

Tammy Au

Dr Tanya Filer

Teresa Gonzalez-Rico

Terry Stocks

Dr Thayla Tavares De Sousa Zomer

Dr Thies Lindenthal

Thomas Durcan

Dr Thomas Stone

Thomas Twitchett

Tianren Yang

Prof Tim Broyd, FREng

Dr Tim Hillel

Dr Tim Hobson

Prof Tim Ibell, FREng

Tim Kersley

Tim Powell

Prof Tim Wright

Dr Timea Nochta

Timothy Butterfield

Tim Perree

Timothy Ståhle

Dr Tom Beach

Tom Burgoyne

Tom Collingwood

Dr Tom Dolan

Tom Henderson

Tom Hughes

Tom Reynolds

Tom Scholes

Tom Van Den Driessche

Dr Tomas Sanchez Lopez

Tony McManus

Vasilis Papakonstantinou

Veronica Hernandez

Dr Veronica Martinez

Vidya Kamath

Dr Vladimir Vilde

Wenying Wu

Werner Jansen van Rensburg

Will Squires

Will Varah

William Daubney

Dr Xiang Xie

Prof Yacine Rezgui

Prof Ying Jin

Dr Ying Wang

Yiping Meng

Dr Zahra Sadeghi

Dr Zaid Alwan

Dr Zakaria Dakhli

Dr Zakwan Skaf

Zane Ulhaq

Centre for Digital Built Britain (CDBB)

Our Artefacts: Our Stories

The foundations of a digital built Britain

The Centre for Digital Built Britain is a partnership between
the Department for Business, Energy & Industrial Strategy (BEIS)
and the University of Cambridge

Department for
Business, Energy
& Industrial Strategy

UNIVERSITY OF
CAMBRIDGE

The Centre for Digital Built Britain also acknowledges
the support of the following organisations

Foreign, Commonwealth
& Development Office

Department for
International Trade

UK Research
and Innovation

CONSTRUCTION
INNOVATION HUB