Gemini Papers: Why connected digital twins?

cdbb

Executive Summary

This paper is the second of three, addressing the What, Why and How of ecosystems of connected digital twins[1].

It advocates:

- Why we need connected digital twins by setting out the social, environmental, economic and technical benefits they enable;
- why connected digital twins are essential tools to address our most systemic challenges like climate change; and
- why a socio-technical change programme is the best approach.

This paper demonstrates the value of connected digital twins by setting out the benefits they enable. It shows why alignment under a common principled, collaborative and purpose driven approach is fundamental to ensuring better outcomes for people and nature. Over a number of years of consultation and collaboration, CDBB has worked through its programmes to identify how we can avoid divergence in approach and enable these outcomes.

We know data has value in isolation. Our work proves that new and increased value is realised when it is shared and connected.

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Advances in digitalisation have increased access to technology. Cheaper, faster and more powerful computers have resulted in an expansive cyber-physical world that continues to grow and evolve. While the collection of data is accelerating, the value of the information it can provide is limited by the lack of a strategy for interconnections, resilience or long-term outcomes.[2] We need a socio-technical change programme to ensure alignment under a principled, people-led approach.

Buildings and construction accounted for 37% of global energy related CO_2 emissions in 2020[3] and continue to drive the depletion of planetary resources. Due to its complexity, it is difficult to understand the entire picture of the built environment and the social and environmental layers with which it intersects. Connected digital twins are a potent tool to help do that.

An ecosystem of connected digital twins breaks down the complexities of understanding the system as a whole. This system-based outlook will help us all understand the knock-on effects and the trade-offs that a decision could cause. By connecting physical assets, processes and systems with shared digital connections, we will gain insights that will enable improvements, optimisations, and better interventions across scales.

Better decisions faster – unlocking value through connected digital twins

An ecosystem of connected digital twins pushes the information value chain further by driving innovation, increasing infrastructure resilience and optimising the use of resources. This leads to better outcomes for all.

By sharing data across organisational or sector boundaries we can identify interdependencies. This leads to improved decision making that just wouldn't happen immediately if each silo of data were considered independently. Better decisions, based on better analysis of better data, drive better outcomes for people.[4]

Purpose-driven digital twins organise data from across our built environment and unlock valuable insights, not solely for commercial gain and efficiency, but for better outcomes for people, place, and nature.

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Infrastructure is an amazing, interconnected machine that underpins and serves society. Yet this increasing interdependence means risks of failure can cascade faster and wider than ever before. Greater digitalisation and the increased use of technology are inevitable fixtures of the future. They make systems-based thinking and action possible.

We have seen how digital twins unleash value by enabling better decisions — in use, operations, maintenance, resilience, planning, investment and more — across the built and natural environments. But we know this technology must be guided by appropriate values for humans and nature to flourish for generations to come.

We must address the challenges of resource constraints, waste, the impacts of climate change and transition of the whole economy to net-zero greenhouse gas emissions. This is no easy task. Our essential challenge is to do more with less. Today's infrastructure has been sustained through maintenance, repair and adaptation. This reactive approach has largely occurred at the asset level with little consideration of larger outcomes at systems scale.

Positive outcomes for people, society and nature must be the objective of our built environment to ensure sustainable development, wherein present needs are met without compromising the ability of future generations to meet their own needs.

We must optimise the whole life-cycle and make infrastructure systems sustainable, secure and resilient. It is essential that we deeply understand future challenges in the context of the make-up, interdependencies, and performance of our built and natural environments. Our work proves that an ecosystem of connected digital twins provides a platform to access this understanding.

From international objectives such as the UN Sustainable Development Goals (UNSDGs) to hyperlocal community-based initiatives, digital twins create the opportunity to ensure that specific targets, as well as more intangible benefits, can be measured, considered, and optimised to enable informed decision making across different scales.

Tangible goals guide us in the delivery of projects and programmes on the ground. We must collaborate digitally to overcome cultural barriers and adopt more enduring delivery models and different ways of thinking about value and reward. Digital twins facilitate the democratic process by enabling transparency

and engagement for better outcomes for the public, the ultimate customers. Placing people at the objective core of technology ensures that systems are designed and optimised to meet the needs of the local community. By integrating participatory feedback into connected digital twins, we can identify shared experiences, challenges, and opportunities to inform planning and design interventions with a greater collective benefit.

A few of the UNSDGs that can be addressed most tangibly by connected digital twins are:

Ensure access to affordable, reliable, sustainable, and modern energy for all.

By providing a time appropriate view of energy use and generation, connected digital twins enable the integration of intermittent renewables through enhanced grid flexibility. By shifting non-essential operation automatically, they can ensure energy is being used when the grid mix is cleanest and demand is lowest. This decreases costs and minimises total generation capacity needed by reducing waste and underutilisation.

Make cities and human settlements inclusive, safe, resilient, and sustainable

By enabling participatory democracy, connected digital twins give agency to the people who make up the urban fabric. They allow people to voice their challenges and aspirations to inform policy, planning, and design. They also enable decarbonisation and resilience (see 7, 9, 13) to improve wellbeing through better air quality, physical safety and more.

Build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation

By linking infrastructure assets with each other and the social and physical dynamics that act upon them, connected digital twins help identify interventions that maximise systems resilience and efficiency (e.g. CReDo - Climate Resilience Demonstrator).[5] They also ensure equity and accessibility, maximising opportunities for innovation in industry.

Take urgent action to combat climate change and its impacts

By maximising efficiency at systems scale, connected digital twins support the decarbonisation of our economies. By identifying core resilience challenges through the simulation of climate scenarios, they can help us quantify the cost of inaction and inform interventions that maximise resilience, carbon sequestration and storage (e.g. nature-based solutions).

Environmental benefits: accelerating the path to net zero and improved resilience

The built world is embedded in the natural world, relying on healthy natural ecosystems for the provision of freshwater, materials, the regulation of weather, and so much more. Over generations, urban infrastructure sought to manage uncertainty and variability in natural systems by containing them; diverting rivers for floodplain development; paving over grassland to enable mass transit, and so on. Yet, in doing so, our built systems have become less resilient to weather extremes and our interventions have focused on symptoms rather than the health of the natural systems on which we rely. We are seeing mounting challenges in our conflict with nature.

Paradigm shift – in harmony with nature

Connected digital twins can characterise physical risks and facilitate the design of resilience interventions, both nature-based and hard infrastructure, by informing location and design and simulating services through value chains to enable their financing. In this way, trade-offs between cost and resilience can be assessed to inform the most effective leverage points for intervention with the greatest net benefit. Similarly, they can demonstrate and value the core provisioning services already provided by the healthy natural systems underpinning our built environment and economy to enable ecological preservation and restoration.

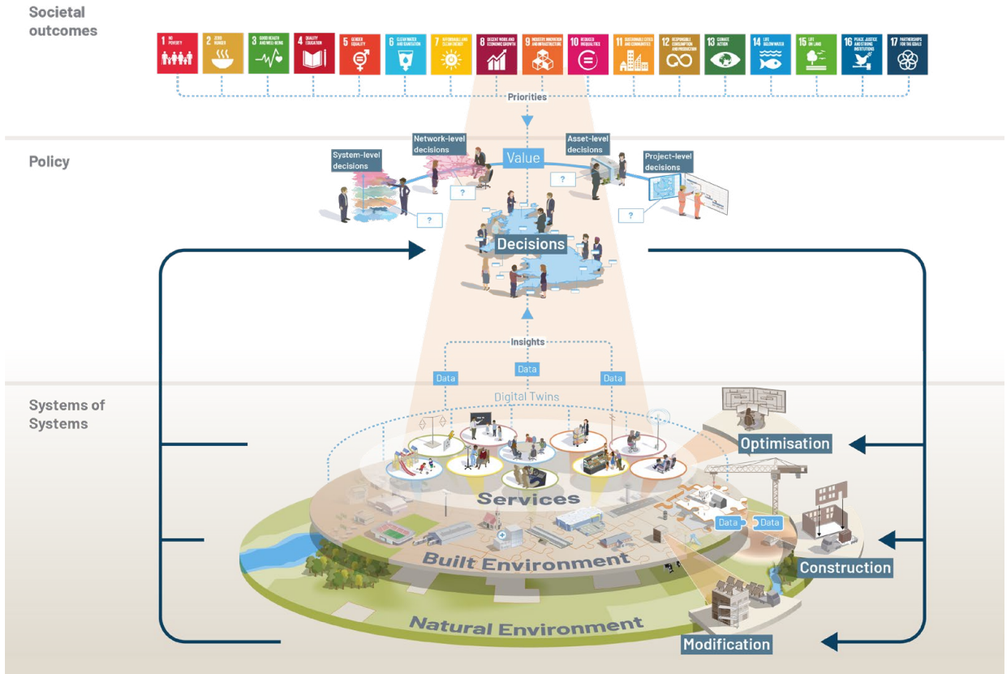

Figure 1. The Built Environment Model (IPA Transforming infrastructure performance: Roadmap to 2030)

Enabling a net zero, circular economy

Our infrastructure can play a fundamental role in ensuring that energy and material inputs and waste outputs are within our environment's capacity. Our work proves that digital twins can play a key role in enabling the efficiency of our built systems. Digital twins can help identify waste streams and their potential as resources; maximise operational efficiency and resource use through waste elimination and re-use with a cradle-to-cradle approach; and account for environmental costs to inform circular and net zero interventions. Designing out waste will be fundamental to meeting net zero targets, both from a resource and energy perspective. Only through a dynamic understanding of what we have in our built environment, can we make sustainable choices.

Economic benefits: connecting data with value

The National Infrastructure Commission report ‘Data for Public Good’ promoted the advantages that data sharing can have when it comes to infrastructure, releasing a potential £7bn of benefits per year across the UK infrastructure network.[6] The Value of Information Management in the Construction and Infrastructure Sector report estimated that every £1 invested in information management could potentially secure up to £6 of labour time savings while boosting government efforts to reach net zero carbon emissions by 2050.[7]

Fundamental to economic productivity is designing out waste, maximising efficiency, and supporting the public goods that underpin physical resilience and the provision of resources, now, and in the future. Connected digital twins provide the systems view to identify waste streams at all scales, from a leak in a pipe to waste heat from a transport network. They inform rapid repair or recovery for re-use, thus maximising the performance of the entire system and the whole-life value of resource inputs. Similarly, digital twins help us identify points of critical vulnerability through the simulation of stressors such as flooding and wind damage or cyber-security threats, demonstrating the knock-on effects of failure. This reveals key leverage points in the system so interventions with the greatest net benefit can be implemented and financed by the greatest beneficiaries. Fundamentally, connected digital twins enable us to look at trade-offs between resilience, efficiency and cost from a holistic economic perspective.

Benefits to businesses

Connected digital twins enable decision-making that is better, faster, and cheaper, unlocking value and saving time through automation, for example.
By integrating information across systems, decisions will be better because they will maximise value by responding to opportunities for greater systemic efficiencies while mitigating vulnerabilities from stressors outside the traditional operating space of a business.

Digital twins are game-changing tools. They help us manage assets, processes and enterprises, improving their performance, availability and safety. They communicate how assets are used and degrade over their lifecycle. They support different approaches to maintenance, repair and overhaul, underpinning ‘capital versus operating’ expenditure decisions to balance cost and future revenue.

Every £1 invested in information management could potentially secure up to £6 of labour time savings while boosting government efforts to reach net zero carbon emissions by 2050.[7]

Technical benefits: connecting information for good

We know that technology alone is not the solution to the challenges we face, but technology applied wisely is a key enabler. We need purpose-led technology, not technology-led change.[8]

Connected data

Data flowing within a system creates value that transcends the value of the data itself. Connected data systems are readable, communicable, transferable, transparent and traceable. The current approach keeps data in silos making it inaccessible and hindering strategic planning and innovation.

Access to data ensures decisions are made based on the best information available, provided at a time appropriate to the required purpose. The data sharing between systems, assets and processes enabled by ecosystems of digital twins can provide more dynamic and robust data.

Strategic benefits of a common framework

Having a common framework for data sharing like the Information Management Framework (IMF) reduces the time and cost of reusing data and maintaining connections between data systems. A common framework ensures that the greatest value is extracted from that data using a method that is transparent, open and accessible. An information management framework provides a common language to securely share high quality data in a secure and resilient way. This allows the ecosystem of connected digital twins to grow in line with the many additions to the built environment.

Access to data ensures decisions are made based on the best information available, provided at a time appropriate to the required purpose.

Why is a socio technical change programme needed?

We need behavioural and cultural change at an industry level to enable effective connected digital twins.

Technical solutions are clearly necessary, but they are not sufficient. For a national-level connected digital twin programme to be successful, it must also address human and organisational factors. It must address: ethics and skills; commercial, legal and regulatory solutions. Nowhere is this clearer than in enabling data-sharing across organisational boundaries, but it is equally important in the hard work of driving an increase in information management maturity in every organisation. This is why the overall programme needs to be 'socio-technical'. This is what we need for each organisation to benefit from better decision-making and for connected digital twins to deliver better outcomes across the economy.

At a national level, it is important to foster alignment between industry, academia and Government. Visionary boundary-spanning leadership is required to convene, connect and coordinate the key players across the connected digital twin landscape. Collaboration is needed to have a common vision, a coherent narrative and shared roadmaps. In short, a socio-technical change programme for connected digital twins is the route to better outcomes for people, society and nature.

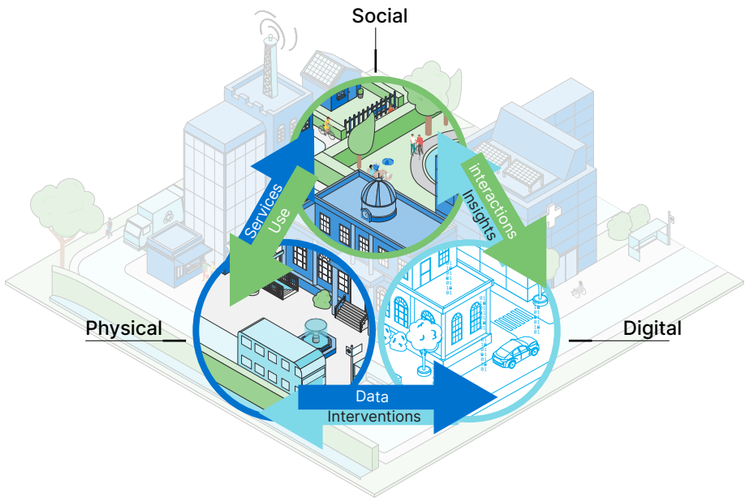

Figure 2. A socio-technical change programme is needed to effectively integrate social, digital and physical spheres.


Resigned to our fate


Too little, too late


A legacy of hope


Generation zero

Possible Futures

Our future is uncertain, yet understanding the dynamics of our built, natural, and societal systems allows us to simulate stressors to identify resilience interventions and encode local strategic objectives into planning and policy. Thus, a national digital twin programme provides a systems view to simulate future scenarios and shape a future with positive outcomes for people and nature.

Understanding change and planning in the face of uncertainty has been a perennial challenge for our political leaders; those who shape our built environment; and those who manage the allocation of capital. As the global population continues to grow and migrate, the stressors of climate change and environmental degradation compound societal challenges including health, hunger, and poverty.

CDBB's Four Futures - One Choice[9] presents four possible future scenarios for what the UK built environment sector of 2040 could look like depending upon the decisions that are made from 2021. The resulting narratives help to build consensus on a desired outcome so that we can advocate for decisions that will create a resilient and sustainable digital built environment.

To build these futures, experts who specialise in the built environment, technology, economy, design and society, came together to identify potential driving forces and factors that may influence future outcomes – these were then classed as certainties and uncertainties. Exploring how the uncertainties intersect with each other enabled the experts to build views of how the future may unfold. The two core axial uncertainties selected were:

1. The United Nationals Sustainable Development Goals' 17 goals set by the United Nations that envision a world where the built environment is a platform for the flourishing of society and the natural world.

2. The Age Dependency Ratio is a measure of the number of dependents aged 0-15 and 68 plus, compared with the total population aged 16-67.

Why do we need to understand risks across boundaries? Disclosure and accountability

When information is transparent and accessible, stakeholders, institutions, regulators, shareholders, lenders, and the public can all take an interest. When the information concerns environmental impacts and resilience, these same stakeholders are increasingly demanding that it be shared in the hope that impacts can be better understood and accounted for, and that damages may be mitigated to reduce exposure to physical, financial, and reputational risks.

This is particularly salient with the climate crisis; environmental and resource challenges; and social equity. With climate change, for example, there are physical risks associated with the increased frequency and intensity of extreme weather events. There are also transition risks inherent in changing strategies, policies and investments as the economy decarbonises. And there are liability risks from people or businesses seeking compensation for losses they may have suffered from the physical or transition risks from climate change outlined above.

Formal mechanisms for Environmental, Social and corporate Governance (ESG) disclosure are proliferating and will increasingly become mandatory as information quality increases with better data capture and integration. Requirements such as the Task Force on Climate Related Financial disclosures, the EU Taxonomy and others are essential to track alignment. If you have the means to understand it, you must share it.

Investors, asset owners, local authorities and cities must understand their exposure to risks, as well as the present and future implications of inaction. Connected digital twins can play a fundamental role in robustly simulating physical risk exposure, and its associated finances, at a systemic level by integrating knock-on effects that may not have been visible with traditional hazard modelling.

Why it matters: What you need to know and what must happen next

CDBB has done the foundational work. We know that:

- Connected digital twins are tools to enable a systemic understanding of risks and opportunities; and
- Connected digital twins bring social, environmental, technical and economic benefits;
- There is a shared responsibility between decision-makers in government, industry and academia to ensure that the technologies being implemented today are people-led and designed with inclusion at the core to benefit everyone equally.

To carry the baton into the future we must all:

- Consider the purpose of public good at all levels of data gathering, modelling, decision-making and interventions;
- Break down silos by connecting information, organisations, and processes through an industry-wide socio-technical change.

We must be people-led and technology-enabled. By coordinating the built environment this way, we can:

- Deliver desirable outcomes for people and nature;
- Intervene better on the existing system of systems;
- Unlock more value from what we have already built;
- Provide the resilience and capacity for regeneration that society requires of its infrastructure;
- Encourage innovation and unlock value across the built environment; and
- Inspire greater trust between our interconnected systems and earn the trust of people and communities who engage with the built environment.

This is why ecosystems of connected digital twins have value, and why we should consider carefully how we implement them.

An ecosystem of connected digital twins is a game-changing tool for us all to navigate an uncertain future.

End notes

1. The Cyber Physical Infrastructure Vision (https://www.gov.uk/government/consultations/enabling-a-national-cyber-physical-infrastructure-to-catalyse-innovation) uses the term ‘federated digital twins’ when referring to ‘connected digital twins’.
2. Transforming infrastructure performance: Roadmap to 2030: https://www.gov.uk/government/publications/transforming-infrastructure-performance-roadmap-to-2030/transforming-infrastructure-performance-roadmap-to-2030
3. 2021 Global status report for buildings and construction: https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction
4. Flourishing systems: https://www.cdbb.cam.ac.uk/files/flourishing-systems_revised_200908.pdf
5. CReDo - Climate Resilience Demonstrator: https://digitaltwinhub.co.uk/projects/credo/what-is-credo/
6. Data for the Public Good: https://digitaltwinhub.co.uk/files/file/4-data-for-the-public-good/
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8. Our vision for the built environment: https://digitaltwinhub.co.uk/files/file/81-our-vision-for-the-built-environment/
9. Four futures - One choice: https://www.cdbb.cam.ac.uk/fourfutures

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