cdbb
Digital Twin Hub BETA

Digital Twin Toolkit

Developing the business case for your digital twin

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Foreword

In the face of unprecedented levels of uncertainty and emerging risk, digital twins are already delivering radically new possibilities for improved creativity, competitive advantage, and human-centred design across the UK.

As the UK looks to respond, adapt, and thrive post-COVID, accelerating the development, adoption, and diffusion of digital twins will be integral to the UK's ability to confront grand challenges, such as delivering on net zero 2050 objectives, reducing social inequalities, and driving R&D-led growth. However, while innovators across the UK are constantly coming up with brilliant new ideas for digital twin initiatives, one of the first challenges they often face is building an effective business plan.

Writing an effective business plan is important for several reasons, including gaining buy-in, generating enthusiasm, raising capital, and sustaining support for a digital twin initiative. Whether the intention is to build a new digital twin from scratch, expand an existing initiative, or collaborate with an established organisation, building a business plan provides an opportunity to thoroughly evaluate your digital twin early on. A clear plan will also enable stakeholders – namely, investors, managers, and the people who control vital resources that are needed to initiate a digital twin – to assess the feasibility of the initiative in-question.

As such, the CDBB's *Digital Twin Toolkit* is an important resource that can be leveraged to build a business plan for a future-proofed digital twin initiative. Whilst this toolkit will not generate a digital twin for you, it does provide a set of principles that, if followed, can foster a foundational environment for the development of scalable, extensible, and interoperable digital twins.

Its value is also in its interdisciplinary perspective. Over the last six months, I have witnessed first-hand the coming together of diverse thought leaders, academics, industry experts from across the UK's built environment. Drawing from multiple disciplinary backgrounds in this way has driven a continuous learning experience, enabling those at the bleeding edge of the UK's digital twin ecosystem to learn from each other and co-design creative solutions to complex, interconnected challenges.

Looking to the future, my hope is that this report will provide an accessible resource for a wide cross-section of society. People should feel empowered to test this toolkit, improve it, and take it further. In doing so, they will undoubtedly face hard questions- especially during the early phases of each unique digital twin journey- yet a brighter future awaits those who do pose these critical questions and seek to provide answers.

Tom Henderson
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techUK
FOR WHAT COMES NEXT

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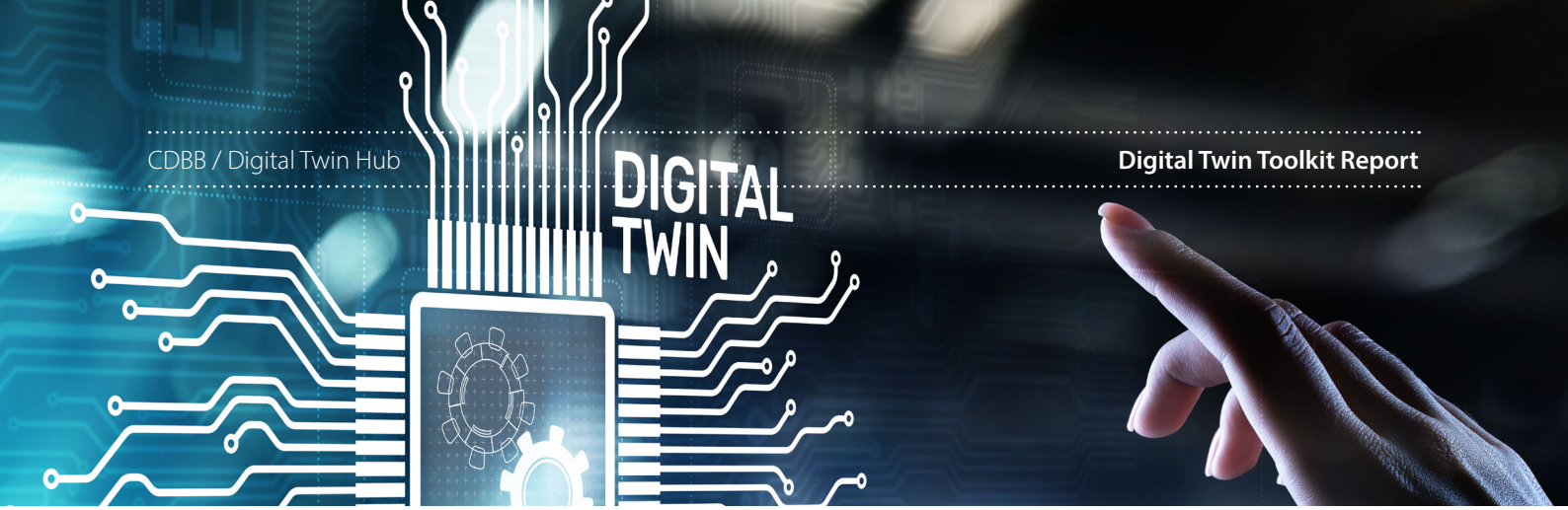


This toolkit was created by members of the DT Hub with the intention to aid you and your team as you consider the need for a digital twin and what it can be used for. The toolkit demonstrates their collective experience in developing digital twins as well as the expertise they bring from within their roles and organisations. The report will take you through some of the key considerations and steps in developing your digital twin and the accompanying business case template (appendix 2) can be used to help you formally articulate your business case for one.

The DT Hub is a community built on learning through doing and progress, whether as an organisation or as a collective, by sharing lessons and experiences. This edition of the toolkit is the beginning of collecting shared learning for the benefit of the whole community and we want to develop it further with your feedback. With this toolkit, we are supporting the growth of connected digital twins.

I.
What is a Digital Twin?

Digital twins still mean different things to different people, but they all share a common characteristic: data is at their core. The purpose of this toolkit is to help organisations put together the business case for a digital twin. It is not to determine whether you have a digital twin or not.

For the purposes of this toolkit, we understand a digital twin to mean:

A computer model as a digital representation of a physical asset (e.g. a 3D model of a housing block);

A digital asset where the physical twin may exist or may not yet exist (e.g. a model of an unbuilt tunnel);

A dynamic data connection between the physical twin and the digital twin. How this data is updated between the physical and the digital will vary (e.g. sensors on a bridge informing predictive maintenance). It should be at the 'right' time, focusing on the use case sought, and therefore does not necessarily need to be real time.

Digital twins can vary greatly in how complex they are – it all depends on the purpose to which they are put. The complexity then relates to the requirements, the level of data access, the physical situation and the business case. Algorithms and ultimately Artificial Intelligence (AI) can be applied to make digital twins more sophisticated, more automated and to provide further insights.

The key purpose of a digital twin is to enable better decisions faster, creating benefits through financial, environmental or socio-economic value. They are not a new fad; they are an inevitable step on your data journey.

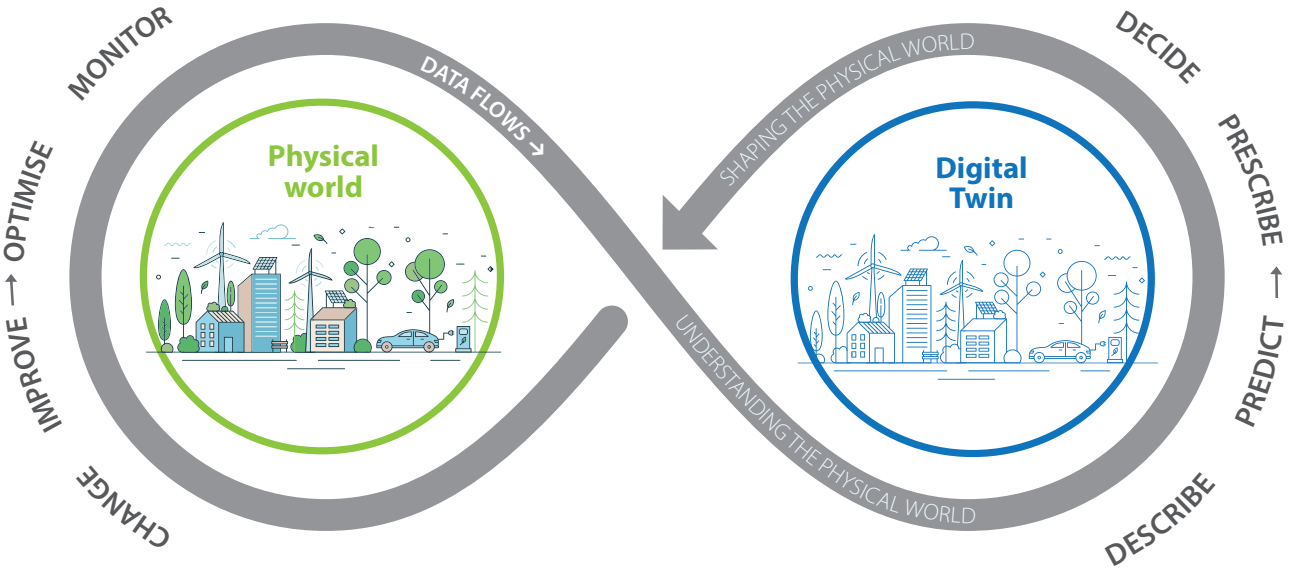


Figure 1. *What is a digital twin?*

Digital twins rely on a base level of information management maturity and connectivity. Having the right information management processes in place will enable you to securely connect your digital twin to others and reap the benefits of data sharing.

The upfront costs required to acquire and manage your data can be a challenge to accurately estimate and will be dependent on your organisation's level of information management maturity and that of any third party you depend upon for data. The Information Management Framework, being developed under the National Digital Twin programme, will help to reduce the overall costs of connecting digital twins by using one framework rather than many, so that each organisation does not have to reinvent the wheel.

You do not need a complete data set to benefit. This toolkit is intended to help organisations put together the business case for a digital twin and get started on their journey, wherever they are at.

What you do need is:

A clear purpose for the digital twin; a use case or use cases

Data relating to the physical twin (whether directly measured or inferred)

A format for using that data (such as a model)

The ability to use the digital twin to influence decisions and consequent interventions

A way of connecting your digital twin with other digital twins to generate added insights and benefits

(Optional) Imagination for what your digital twin could be developed to achieve in the future

What is the Information Management Framework?

The mission of the National Digital Twin programme is to enable the National Digital Twin, an ecosystem of connected digital twins that will deliver better outcomes from the built environment for society. The Information Management Framework (IMF) currently under development will be the underpinning structure of the National Digital Twin, defining a common means by which digital twins of the built and natural environment can communicate securely and effectively to support improved decision making by those operating, maintaining and using built assets and the services they provide to society. CDBB published in May 2020 the *Pathway towards an Information Management Framework* report, which proposes three building blocks to form the IMF:

The Foundation Data Model – a consistent, clear understanding of what constitutes the world of digital twins

The Reference Data Library – the particular set of classes and the properties we will want to use to describe our digital twins

The Integration Architecture – the protocols that will enable the managed sharing of data

By setting out a framework for connecting digital twins, the IMF will reduce the overall cost of point to point connections (bespoke, localised data-sharing connections between digital twins) and will improve the quality, consistency and security of data-sharing across sectors with greater resilience and agility. The Information Management Framework is a work in progress and CDBB invites you to help collaborate on its development.

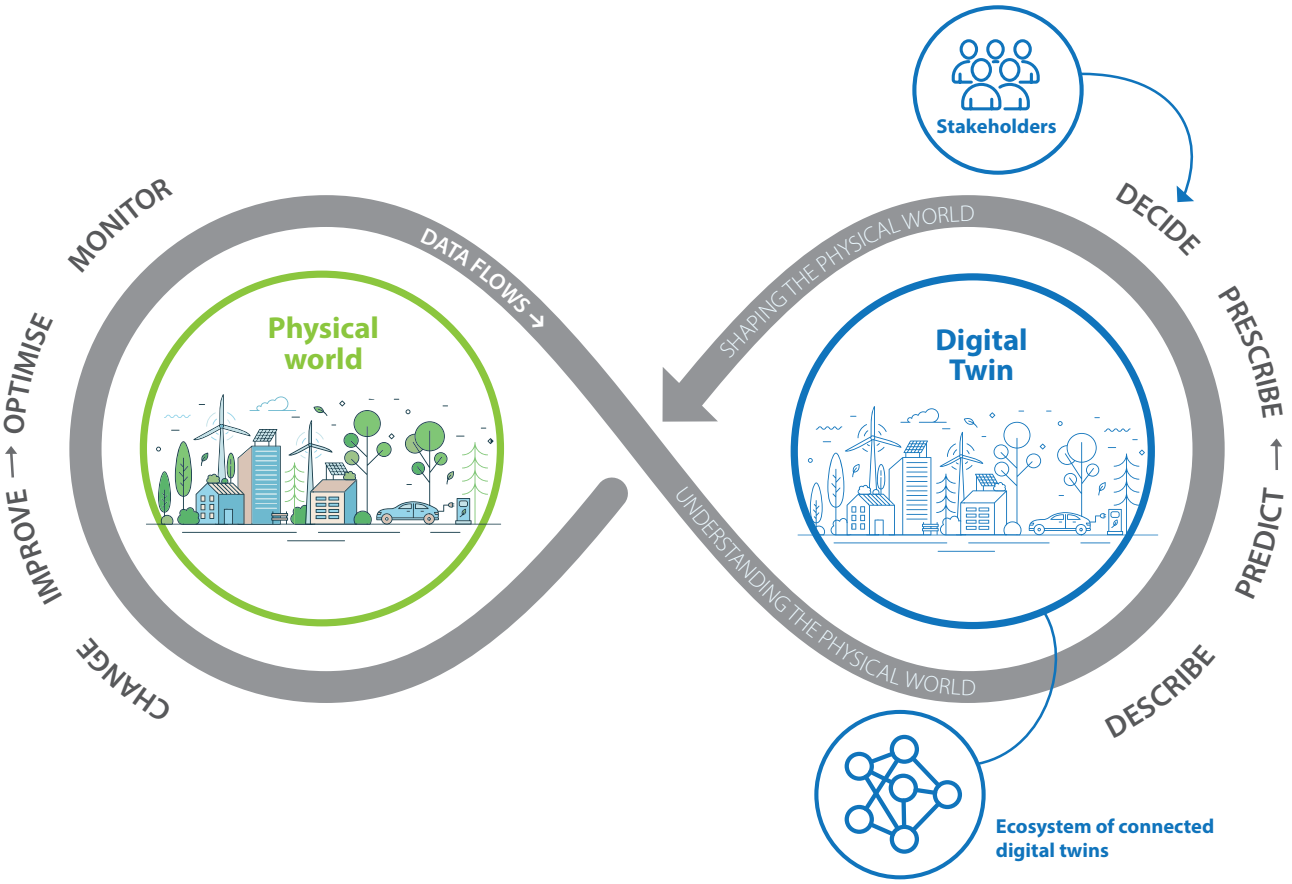


Figure 2. *Digital twins will realise their real potential when we ensure people are part of the process and digital twins are connected in a secure way, such as through the Information Management Framework*

Ensuring success in your DT journey

The applications of digital technologies in their many forms can deliver unexpected results. To help make your DT journey a success, we recommend to:

Increase trust on the guidance provided by this new digital source

Align your aspiration and reality: your organisation needs to understand what the technology can and cannot do

Define achievable expectations for business benefits

Understand the impact that the technology will have on organisational processes

Communicate the goals of the project across the business chain and ensure there is sufficient leadership in place to achieve 'buy in' for the technology application

Mitigate the risk of competing centers of power and finance which have differing objectives

Recognise the roles that the supply chain and customers will have in a successful deployment

Ensure the supply chain has the right level of digital development to undertake the required participation

Prepare your infrastructure for the adoption of the digital technology and make sure that the associated cost, complexity and the time to make ready are understood

Organise and equip employees with the right skills and mindset

It's important to bear all of this in mind so you are best equipped for your DT journey.

II.
Use Case Framework

Digital twins are used to support decision-making, helping to make well-judged and well-timed interventions, and create confidence in planning. They help make sense of complex and uncertain situations.

Investing in a digital twin is rarely a single, one-time effort. It involves setting up a digital asset that can evolve and grow to answer new questions that arise over the lifecycle of the thing(s) it represents. The starting point is the original purpose of the digital twin, the use it is being developed for. The toolkit team examined a wide range of digital twin use cases and narrowed them down to three high-level use case areas.

Figure 3. *Use case framework*

A. Strategy & planning

Digital twins may be developed to inform government policy, an organisation's strategy or to plan the construction of a new asset. For example, a local authority might need information about the current housing stock and infrastructure to inform decisions on new housing developments. Developing a digital twin of the region allows them to incur minimal environmental impact and to plan for augmented infrastructure services, such as water and sewage, electricity supply, broadband coverage and transport connectivity.

Or a private company considering a merger with another company would need to identify what the benefits and costs could be. This use case area focuses on the system level view and may use multiple data sets spanning multiple organisations to piece together the system level view.

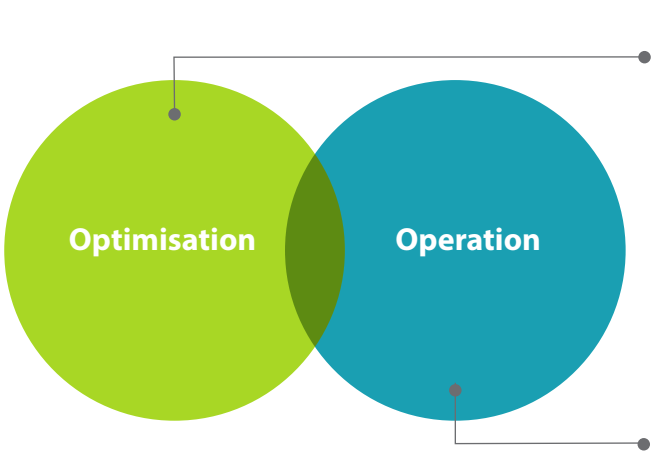
Such digital twins support multi-criteria decision making, looking for trade-offs in the face of different values and preferences. It is a collaborative decision-making tool, exposing a range of optimum choices for interested parties to consider. For a corporation, they might consider the impact across a whole enterprise. For a government, across a whole region. They reduce uncertainty to a level that makes forecasting trusted and meaningful. The time window of interest can be months, quarters, years or decades, reflecting the different pressures on affordability, technology & data readiness, social-economic impact and the environment.

These are more than digital planning tools. They exploit operational feedback from a range of data sources to continually update and improve the cost and benefit estimates of different options.

B. Managing assets

Digital twins may be developed to improve the performance, availability and safety of assets, processes and enterprises. These digital twins consider how assets are used and degrade over their lifecycle, supporting different approaches to maintenance, repair and overhaul. These are typically used to support 'capital versus operating' expenditure decisions, balancing cost and future revenue. There are two approaches that are typically taken in developing these digital twins, either bottom-up or top-down.

Bottom-up is starting with particular assets and building up to a more comprehensive whole. Top-down is starting with the whole and breaking it down into the particular assets over time.



Digital Twins can be used to help test several options of a solution through virtual prototyping and experimentation (such as through the exploration of 'what-if' alternatives) to identify optimum product and process designs for implementation. For example, using a digital twin to optimise an asset's performance over its lifetime by enabling predictive maintenance

Digital Twins can help to extract maximum value from a solution once it is implemented, by adapting its operation based on frequent feedback on conditions of use. For example, using a digital twin to enable the autonomous operation of an asset

Figure 4. *Managing assets can cover both operation and optimisation*

C. Assurance

Digital twins may be developed to provide assurance for the safety and resilience of an asset, process or system. For example, digital twins may be able to provide certification of levels of safety for buildings to comply with building regulations.

These digital twins normally rely upon physical models and strong probabilistic methods to forecast expected behaviour with a high level of certainty. The forecasting window may be months, years or decades, with certainty reducing over time. This use case has tremendous importance in periods of great technological, social and environmental change. It is also important when seeking life extension of high value assets that are used in critical applications.

Such assurance digital twins are used in aviation. Detailed 3D models of aircraft are created and used for a variety of uses including manufacturing, assembly and validation and verification for certification. Physical testing is used to verify the simulations and then real time data from the in service aircraft is used to update models which can impact on the aircrafts safety, projected life, model changes or replacement. The digital twin is continuously enhanced along with the aircraft.

A digital twin of a regional electric vehicle (EV) charging network might cover all three use case areas:

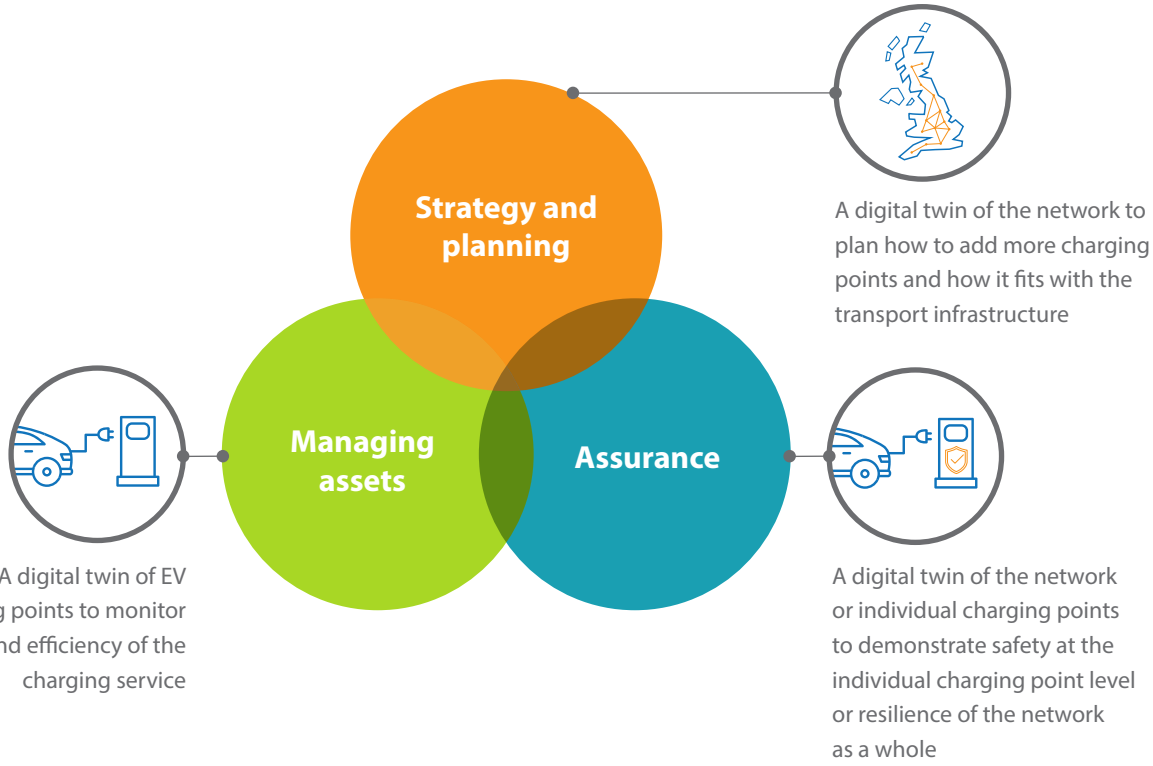


Figure 5. *Application of the use case framework to electric vehicle charging*

It is likely that a digital twin will align to a primary, intended use case area based on business drivers, however, it may indirectly cover other use cases. For example, in managing assets for life extension purposes, there will be assurance and compliance benefits.

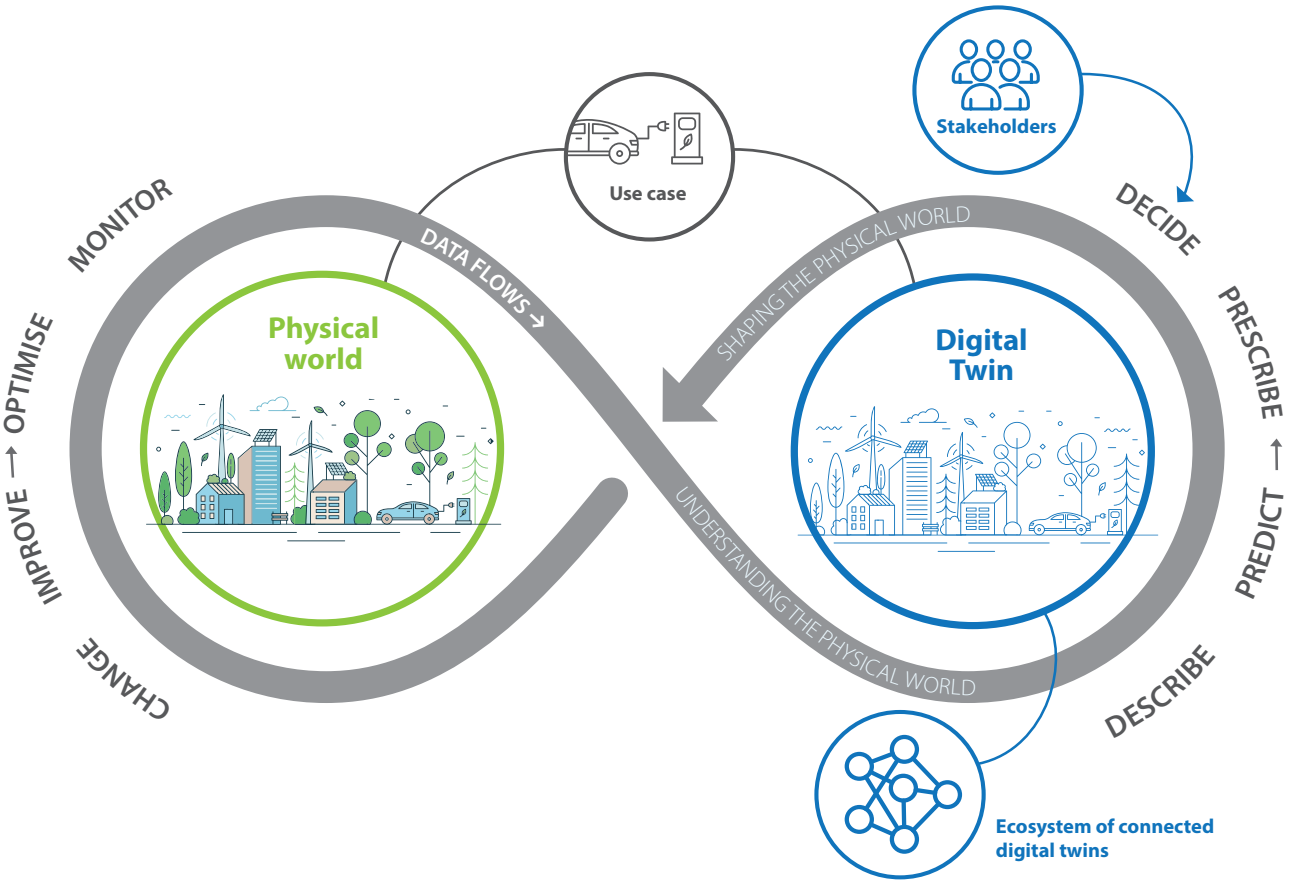


Figure 6. *Defining the use case and the data required is essential to developing a digital twin that helps to solve the problem identified*

Feedback from asset owners on the digital twin use case framework

A group of Chief Data Officers and Senior Data Leaders across a number of different organisations and sectors discussed the Use Case Framework, alongside the planned and implemented digital twin use cases within their businesses. There was general consensus that the Use Case Framework resonated with each organisation. A useful extension talked about space (a hierarchy from asset to ecosystem), time (days to decades), and certainty (greater with better data and high fidelity) which helped to frame where both individual and connected twins play their part.

Whilst most organisations represented are on their own 'digital twin journey', there are examples of digital twins in operation that look at resource optimisation to aid strategy and operational decision making; energy consumption and optimisation contributing to better decision making around utilisation and carbon emissions; and the optimisation of assets through their lifecycle to enable more efficient operation and maintenance.

A key component that touches on all aspects of the Use Case Framework is how we as humans interact with the environment. What role do people play at different stages in the lifecycle, for example people who are creating, planning and operating. Modelling and understanding this behaviour will enable better societal outcomes.

When explaining the purpose of a digital twin, we find that it is helpful to start with **one** of these areas to set the context before drilling down into the detail. We set out the following use cases to demonstrate examples:

Strategy & planning

Sub-level	Use case
Use of water and waste network models (plan for future investment)	Exploit a flow model between sources & destinations to identify hotspots across the network in which there is an actual or forecast likelihood of leaks, standing water and water quality problems. Feed the model with data from sensors embedded in water treatment plants, sub-stations and elsewhere on the water network in order to adapt and keep the model current. Target investment in maintenance and new capital equipment based upon the forecasting from the digital twin over different investment periods.
City wide digital twin for transport modelling	Optimise traffic light sequencing to reduce congestion and journey times in the context of normal and disrupted roads.
Data sharing for infrastructure construction / co-working in same location	Combine and sequence work when roads are partially or fully closed to minimise disruption. Optimise the number and duration of closures in an area.
Optimisation and resiliency planning for scenarios (e.g. post-COVID, public outrage)	Consider the likely outcomes and associated economic & political capital costs of policy choices and interventions.
Land use policy / density capability	Combine historical and current data (ONS etc) to forecast profitability, productivity and environmental impact of different land use choices to support collaborative decision-making from a range of interested parties with different values and preferences.
Impacts of climate change	Create a regional map of the UK. Superimpose historical and projected climate information and weather data. Characterise state and behaviour of industrial and residential areas in the context of local environmental conditions. Use this digital twin to forecast risk and change and evaluate mitigating interventions.

Table 1. *Examples of specific use cases in Strategy and planning*

Managing assets

Sub-level	Use case
Predictive maintenance / stress testing of existing assets / optimisation of assets	Create digital twins of expensive and critical assets that use available real-time performance data as surrogates for monitoring degradation and residual life. Exploit this data to manage a condition-based repair, maintenance and overhaul strategy that is specific to individual assets.
Monitoring real versus virtual construction / development	Create a digital twin of a construction site and update on a regular basis using images from fixed and drone-mounted cameras and other data sources. Use the DT to adapt daily plans for the site, taking account of deliveries to the site (such as cement trucks), demands upon critical equipment (such as cranes) and deviations from planned activities.
Balance supply and demand of power networks / curing and reducing outage(s)	Exploit a digital twin of the transmission and distribution power networks that includes generators, storage and consumers. Incorporate models of the behaviours of the different consumers to help balance the supply and demand.
Maintenance of key and critical infrastructure	Develop a coarse system model of the infrastructure with high fidelity modelling of key and critical assets and components, fed with data from sensors, inspections and simulations. Exploit physics, empirical relationships and probabilistic approaches to create a trusted picture of the condition of the infrastructure and safe timing of maintenance to deliver acceptable performance and availability.
Cross pollination of various data sets (e.g. weather); scenario planning	Exploit a digital twin based upon knowledge graphs that map the relationships between physical and abstract things (such as an asset and an event) in order to make sense of different data sets. Physical or empirical models, where available, are incorporated to reduce the uncertainty.

Table 2. *Examples of specific use cases in Managing assets*

Assurance

Sub-level	Use case
Health & Safety / regulatory compliance of asset (and changes required to maintain compliance)	Use digital twin of an asset or process to explore the likely outcomes of a range of different operating decisions and conditions in order to collect a body of evidence to support a comprehensive safety case. Real and simulated data can be combined to provide evidence faster and more cost-effectively, provided the digital twin is a trusted representation of the real asset or process in all important respects.
Golden thread / risk management / future-proofing	Maintain an enterprise-wide digital twin that forecasts outcomes and trends over medium to long term horizons, but permits drilling down in more detail in local areas of activity to predict likely behaviour and risks. The golden thread is the base modelling and data feeds that underpin the digital twin and on which other real and virtual data may be associated.
Product failure / fatigue and early stage diagnosis	Establish a digital twin that considers long term failure modes, such as fatigue, creep and corrosion, and relates measurable or inspectable quantities to likely residual life. The digital twin may be used to establish degradation in the face of changing operating conditions and duty cycles and so provide the basis for life extension or performance change decisions.
Pipe burst / leak detection / air quality	Exploit digital twins to interpret data from surrogates, such as weather data, water temperature, gas sensors, etc. to detect unwelcome deviations, and hence deterioration, from acceptable norms.
Virtual training; on the job VR / AR etc	Use digital twins to permit people to make decisions and interventions, and observe the outcomes and potential costs, in a safe environment. The digital twin can operate in parallel with the real assets and processes when not in use, to ensure that it is kept up to date, and then operated offline for training purposes.
Common data / standards	Use the digital twin to deliver standard metadata and metrics from different assets and processes to enable comparisons and benchmarking across and between enterprises.

Table 3. *Examples of specific use cases in Assurance*

III.
Case studies

Although we are still in the evolutionary stages of digital twins, there is already enough evidence of successful outcomes to make the case for a digital twin in your organisation.

We understand that whoever commissions the digital twin will want to know what has worked in the past, what hasn't and what the benefits will be. The *DT Hub* is a resource dedicated to showcasing examples of digital twins, sharing learnings from across organisations so you can find out more about best practice. The *case study register* on the DT Hub provides a bank of knowledge for you to draw upon.

In the *appendix* we set out an overview of a smart energy digital twin. Please see the DT Hub case study register for the *full case study*.

IV.
Business case

You have established the purpose of your digital twin and you have some examples to show this is possible and worthwhile, but how do you examine the costs and benefits of developing the digital twin and consolidate this into a business case?

The HMT Green Book five case model is an effective guide, outlining how to build your case. We suggest also using the 'desirability, feasibility, viability' approach when framing the need for a digital twin:

Desirability is **strategic** case and fit. This is the use cases and the reasons for change.

Feasibility is the **financial & management** considerations, such as affordability and practicality. What needs doing, and in what order, and at what cost, to deliver the value.

Viability is the **socio-economic & commercial** factors. Value for money & achievability. Achievability includes, amongst other things, considers the issue of identifying and securing sustainable access to the data and algorithms required for success.

Quantifying value for money is a crucial step in justifying the investment. After all, the digital twin can be an expensive asset delivering value over a number of years. The 5 Capitals Model offers a template for profiling value[1]:

Natural – environmental impact, use of resources

Social – influence on citizens and the community

Human – safety, security, effects on jobs

Manufactured – impact on production, productivity

Financial – capital & operational costs, revenue

A prerequisite for developing the detailed business case may be getting buy-in from the rest of your organisations or from specific teams.

A Microsoft Word Template (Appendix 2) has been developed to help you put together the business case for your digital twin.

V.
Recommendations for the DT journey

A. Benefits of good information management

The easiest digital twin journeys start with good information management. Implementing the right changes now can cut costs in the long-run. If you're relying on your own organisation's data, then the old adage of garbage in, garbage out applies. An integral step is aligning with the standards and "rules of the game" set through the Information Management Framework. The National Digital Twin programme will set out further steps organisations can take to ensure they are adhering to best practice. For now, it is helpful to bear the Gemini principles[2] in mind that digital twins should have purpose, trust and function, and be based on high quality data.

B. Prioritisation of use cases

Most organisations will have multiple potential use cases for digital twins, some of which are more important, urgent or feasible (or indeed all three) than others. To make a solid business case for investment, it is important to first prioritise the use case that the business case is built on. This is even more pronounced for a digital twin (or federated digital twins) that represents a whole system, where the needs of multiple stakeholders must be balanced (and therefore some stakeholders may only address their second or third priority use case). Prioritisation of use cases requires an assessment framework that considers a range of metrics. One such framework was published recently by the Connected Places Catapult[3], which includes five relevant criteria.

Criteria	Description
Decision support times	Will the use case demonstrate the ability to support decision making within operational timelines?
Efficiency	Will the use case demonstrate viability/efficiency gains in existing processes/operations?
Data availability	Whether the relevant data exists or to enable testing the use case
Strategic Alignment	Does the use case align with key imperatives – levelling up, net zero or post-COVID recovery?
Self-sustaining	Is the use case profit-making or at least self-sustaining?

Table 4. *Connected Places Catapult Use Case Criteria*

C. Guidance on key features / criteria that a DT needs to fulfil

The key use case(s) will inform the technical features of the digital twin itself; but there are several overarching features that make any digital twins more attractive for investment. The same report by Connected Places Catapult considers six criteria for assessment of the digital twin itself:

Criterion	Description
Data exchange	Does it have the ability to ingest real-time data to enable the use case to be tested in real-time ?
Scalable	Is it scalable over wider geographical catchment?
Functionality upgrade	Can functionality be augmented over time?
Multiple scenarios run	Can it optimise multiple scenarios?
Multiple use case	Can it support evaluation of multiple use cases?
Prototype	Is it easy to prototype and incrementally develop through Technology Readiness Levels?

Table 5. *Connected Places Catapult Digital Twin Criteria*

An important consideration, which is rarely part of the business case, is "will my digital twin be connectable with other digital twins?". The business case may address this for connecting digital twins within the organisation and although that is to be encouraged, it may not consider whether the digital twin is connectable with external digital twins and what the benefits of that may be.

For example, if a digital twin of a communications network is ultimately connected to a digital twin of the electricity network and the EV charging network then the benefits of doing so (the communications network facilitating the efficiency of the EV charging network and the electricity network enabling energy to be available where it is needed for both the communications network and EV charging network) will not be captured in the original business case, so the original business case underestimates the value of the DT to the organisation and to other organisations.

D. Digital twin types and sophistication levels

Digital twins can be used for different purposes and the level of sophistication required will depend upon what you need the digital twin for. Here we present an overview of the levels of sophistication.

Capability	Key questions	What is happening to the data?	Considerations
Descriptive			
Collecting and visualising data	What happened?	Handover of Design & Construction 'As Built' data set.	Validation of information
			Modification of Data Stream
			Management and Security
		Dynamic' data aggregation	Interoperability
			Service bus/API, data quality
			Data latency/ streaming/ timing
Informative			
Generating insights through aggregating & analysing data	Why did it happen?	Data analytics using advanced digital techniques	Quality and completeness of data, especially when fusing multiple data sets. Fused data will be as good as the lowest-quality input (if not a little worse), so consistency of quality is almost more important than quality of any one dataset
			Standards and format – the more consistent data sets are, the easier they are to deal with. See IMF
			Provenance, which informs both trust and legal ramifications (ownership)
			Frequency of updates, both of data itself and of its standards/format (i.e. how does the DT respond when one of the data providers chooses to collect its data in a new format)
Predictive			
Real time monitoring & prediction	What will happen?	Data science & machine learning	Same as previous considerations, plus:
			Is it appropriate to the use case?
			Does the culture support it?
Prescriptive			
Prescriptive analytics to propose interventions	What should I do?	Predictive Simulation, optimisation & AI based learning	Bias in datasets needs to be recognised and corrected for
		Run ' what if ' scenarios and measure against true outcomes.	IP ownership – if the DT uses proprietary algorithms based on closed data from different organisations, who owns the insights?
Cognitive			
Autonomously taking some of the actions & interventions	What actions can be taken automatically, within defined boundaries?	Decision automation based upon prediction (ML, DL & IV)	Large data sets to learn from, Robotic Process Automation / Business Process Management to push data in to operational context
			People, Processes and Technology combined to deliver
			Corrective actions can be automated (e.g: raise flood barriers, redirect traffic, switch on additional pumps, prewarn adjacent areas of issues, or just order spare parts etc)
			Determine if the 'scalability' logic holds

Figure 7. *Levels of sophistication*

E. Digital twin roadmap

This roadmap can be used as a checklist to guide you along the main steps of the digital twin journey. It is not yet the definitive guide to developing digital twins and we welcome your feedback to improve this version.

Digital Twin Roadmap

Key Steps	Considerations	Checklist
Why do we need a DT?		
1. Define your digital strategy at the organisational level and understand your level of organisational information maturity	Executive digital strategy definition setting vision of success	✓
	Operational strategies	
	Cultural acceptance	
	Business/customer/supply chain readiness	
What is the DT for?		
2. Understand the problem you want to solve and describe the use case(s). Use the use case framework to help identify the potential use cases. Engage with the right people to help identify the use case (e.g. internal and external stakeholders). Make use of the prioritisation framework outlined above. Define the specific use case you want your digital twin to focus on and your high level information requirements	Knowledge harvesting and evaluation	
	Use case(s) ideation and prioritisation	
	Outline of the data and information requirements to inform the business case (these will be developed further at a later stage)	
	Understanding organisation / project environment and establishing key project outcomes and priorities	
	Business case creation and development	
	Benefits & incidental benefits	
What type of DT do we need?		
3. Define the type of DT needed: descriptive, informative, predictive, prescriptive and/or cognitive	Can be one or all types depending upon level of sophistication required, see sophistication level diagram	
Can we go ahead with the DT?		
4. Develop the business case and obtain organisational buy-in and approval	Finalise business case (see template in Appendix 2) and gain approval	

How are we going to build the DT?		
5. Define the project plan and KPI baselines (What could we do?)	Project plans and KPI baselines	
	Corrective action, escalation and team communication plans	
	Potential barriers	
What information do we need?		
6. Define the information requirements to support the use case(s). Identify potential interventions and the critical components of the real system. Here is where the risks of decision making are greatest, and where fidelity of the digital twin is of most importance. Consider how you will combine different datasets into a common format and how you can align with the Information Management Framework.	Organisation's information requirements	
	Asset information requirements	
	Project information requirements	
	Security requirements	
	Accuracy of information	
	Frequency of updates	
	Interoperability *(see Information Management Framework for guidance)*	
What data do we have?		
7. Assess your data. Identify where your data will come from (internal or external to your organisation; from open or closed sources) and what quality (including standardisation, interoperability, reliability and provenance) it will be. Establish how the activity and operating environment can be monitored, either using direct or inferred data from sensors, inspections and other sources.	Legacy data	
	Organisation generated data	
	Data map creation – suitability, accessibilty, need and 'holes'	
	Provenance	
	Data readiness[4] is an important consideration in the scope and design of the digital twin. Exploiting physical models and probabilistic techniques can help cope with deficiencies in the quality and quantity of available data.	

Who will do what?		
8. Appoint Team and make roles and responsibilities with respect to the data clear. Define what will be provided by whom and when.	Data ownership & Access Rights (internal and external to your organisation)	
	Liabilities	
	Relationships between parties	
What does the model look like?		
9. Sort out the design and architecture of the model of the real system. Use data to train, validate and verify the model.	See type of DT developed (descriptive, informative, predictive, prescriptive and/or cognitive)	
What does the data tell us?		
10. Apply data aggregation, data analytics, machine learning, predictive simulation, run what if scenarios, decision automation depending upon what type of digital twin you are building.	See type of DT developed (descriptive, informative, predictive, prescriptive and/or cognitive)	
How are we doing?		
11. Establish performance and condition metrics for assessing the outcomes of interventions	See type of DT developed (descriptive, informative, predictive, prescriptive and/or cognitive)	
What interventions should we make?		
12. Ask questions. Make decisions. Monitor outcomes		

Figure 8. *Digital twin roadmap*

F. Connecting your digital twin to other digital twins

This is where the magic happens. Sharing data across departments, organisations and sectors will yield benefits we cannot even imagine at this point in time. This makes it harder to make a complete business case, as the up-front cost may not be set against the full range of benefits that can be expected. Once those benefits do become apparent, you should revisit your original business case. Some will be internal to the organisation and some will be public as we all benefit from better information, better decisions and less waste. Just imagine how your digital twin can contribute to the realisation of net zero targets.

The National Digital Twin programme sets the vision for the National Digital Twin as outlined in 'Data for the Public Good[47]' where data can be shared securely across organisations through an ecosystem of connected digital twins. The ongoing development of the *Information Management Framework* sets out the common language and standards for data to connect digital twins. Over time, aligning your approach to data and information management with the Information Management Framework will enable you to seamlessly but securely connect your digital twin with other digital twins.

G. Legal guidance

There are legal considerations in developing a digital twin which should not be ignored. The following list is not exhaustive, but provides an idea of what you need to address:

Do parties' contractual documents contain express clauses or content that deal with the following as a minimum:

1. **Responsibility**: What are the main activities/roles/responsibilities - have these been allocated? (For example, responsibility for checking and updating content/data, responsibility for the frequency of such updates and quality of the content/data, responsibility for storage/back-ups/security, what are each parties' roles in setting up and inputting to the digital twin and for how long)
2. **Liability**: Make a list of what could realistically go wrong – has all the potential liability been allocated and/or appropriate caps on liability inserted? (For example, liability for consequences of errors in the data, corruption of the data and/or gaps in the data within the digital twin; liability for accidental or wrongful sharing of data or the digital twin)
3. **IP Rights/Copyright**: Who owns the data within the digital twin, and the digital twin itself? Do other parties have sufficient rights/licences to use the data, and when should these rights cease (For example, should the project team's rights cease on project completion but the client's rights to all data continue in perpetuity)
4. **Data Restrictions**: Will there be any personal data stored/potentially contained within the digital twin and connected data, and what data laws need to be complied with? Does the client or other parties have any restrictions/requirements on data location which limits where the digital twin and data can be stored, e.g. are there requirements for data to remain within a certain jurisdiction?
5. **Technical Specifications**: Have appropriate minimum hardware and software requirements been specified to ensure all parties can participate without delay throughout the process, including any storage and security requirements? This includes considering obligations to update software/use updated versions of software to avoid interoperability problems of parties using different software versions. Are there requirements for parties to maintain the necessary cloud platform or other appropriate licences to access the selected data storage platform?

6. **Security and Integrity:** When do parties' responsibility for the data cease, e.g. who is responsible for unintended amendments, alterations and/or corruption of the data, and have processes been put in place to record/evidence if and when such amendment, alteration or corruption takes place? Who is responsible to ensure the data remains secure, including during upload or transfer (For example, should all parties be obliged to implement certain cyber security procedures and should there be specifications on the secure storage systems to be used)

Have the parties set up/will they be setting up the following processes to facilitate the efficacy of the contractual framework:

1. Are there sufficient processes in place to keep records of data issued and maintain backups?
2. Will all relevant staff receive sufficient training in advance, and will there be processes for knowledge sharing, update reports and lessons learnt reports between the project team and client?
3. Is it clear who will have access to the data and systems/platforms? What processes are in place to prevent/avoid wrongful access (For example, avoiding sharing of usernames/passwords and removing access as soon as an employee or party leaves)
4. Have all parties checked their insurance cover with their brokers to confirm their participation is covered by their professional indemnity insurance?

Discuss all the above with your professional advisers to ensure your contractual framework deals with the new issues arising from digital twins, to avoid misunderstandings or differing expectations.

DT Project Governance

Project governance needs to be positively managed throughout the digital project from the strategy creation to implementation. This is necessary due to the potential complexity, cost and impact of the digital implementations throughout the organisation.

Key requirements:

Formalised periodic and key achievement reporting

Active risk management

Formal buy in for plans and hard Go/NoGoreviews with remedial action planning

Creation of a communication plan for the full business chain with feedback reporting and action planning for issues

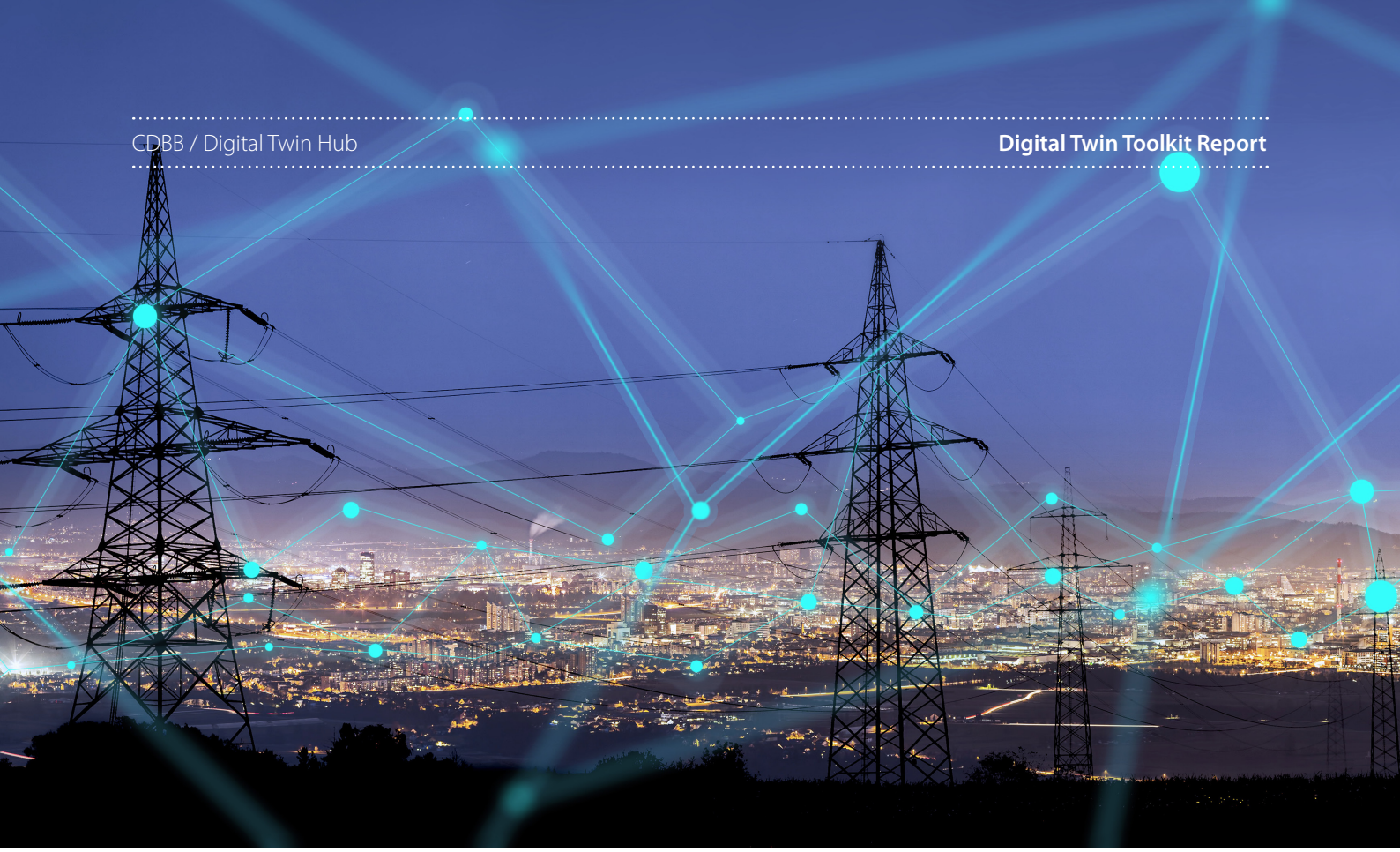
Early determination of the IT/OT interfaces, choice or platforms, linkage to existing systems/review of existing systems capability,etc

Training plans

Early determination of supply chain and client capability and involvement in the project

Determination of any supply chain or client training requirements

Definitions of project responsibilities AND data access management



VI.
Next steps

Whilst this toolkit won't generate a digital twin for you, it will hopefully set you on the right track to developing a digital twin.

This report has been produced as a collaboration of diverse minds across the Digital Twin Hub to bring together guidance on how to get started. Like any toolkit, it makes sense to start with the basics and add in more tools as we go along. We need people to test this toolkit, improve it and to take it further. Please contact us at *ndtprogramme@cdbb.cam.ac.uk* to get involved.

VII. Glossary

This section lists key terms mentioned in this report and their acceptance in the context of the DT toolkit:

Asset: an asset is any resource of value to an organisation. Assets can be physical, such as buildings, machinery and equipment, or digital, such as software, databases and IT systems.[5]

Built Environment: the built environment is made of:

All economic infrastructure: transport, energy, telecoms, water, waste systems

All social infrastructure: hospitals, education facilities, prisons, …

Residential, commercial and industrial buildings

And it's interface with the natural environment.

Business Case: a business case is a structured future-looking proposal, aiming at justifying the future implementation of a project / solution. *As set out in this report*, a business case:

Identifies use cases and reasons for change

Sets out value for money by quantifying expected outcomes (benefits and costs)

Confirms the affordability of the project

Confirms the practicality of the project by suggesting steps to take

Explores the achievability by identifying potential risks and blockers.

Case Study: a case study is a backward-looking description of the implementation of a solution. It outlines the initial expectations and potential triggers to launch the project, the journey (steps taken, blockers encountered, enablers), the solution itself (data, technology involved …), the learnings, and final outcomes (costs and benefits). A case study may be referred to as a use case scenario and may reference *use cases*.

Connection (between the asset and digital twin): the connection between the asset and digital twin is a flow of data which can travel in both directions. Data from the asset is sent to the digital twin, while insights generated by the twin can be fed back to facilitate improvements to the asset. The latter connection may involve a human-in-the-loop. For a digital twin to provide up-to-date information about the asset, the connecting data stream should be regularly updated to reflect the asset's current situation.

Data readiness: An organisation's preparation towards implementing effective data solutions. This means ensuring the completeness, integrity and accessibility of company data. Data readiness can also include changes to an organisation's data culture, and employee engagement or education.

Desirability, Feasibility, and Viability (DFV) Model: a business analysis strategy that considers the ideal innovation process at the intersection of desirability, feasibility and viability to assess the value of a business model; desirability refers to providing solutions that customers really want and need, a feasible solution is one that builds on the strengths of the organisation's current operational capabilities, and a viable solution is one which comes up with a sustainable business model.[6]

Digital Strategy: a digital strategy focuses on improving business performance through technology and information management. This could mean utilising new technologies, or upgrading existing digital assets.

Digital Twin: a digital twin can be described as a realistic digital representation of assets, processes or systems; what makes it a twin is the data connection between digital and physical.[7]

Digital Twin Hub (DT Hub): the CDBB has established the Digital Twin Hub (DT Hub), a community to foster communication, connections and collaboration between digital twin practitioners within the built environment dedicated to exploring and unlocking the potential of digital twins.

Five Capitals Model: a sustainability framework that allows an organisation to develop a vision of what sustainability looks like for its own operations, products and services. The vision is developed by considering what an organisation needs to do in order to maximise the value of each capital.[8]

Five Case Model: the HMT five case model provides guidance to support the development of a holistic and compelling business case covering the strategic, economic, financial, management and commercial cases. It helps the owner to systematically consider and present the impact of the new technology.[9]

Gemini Principles: the mission of the National Digital Twin programme is to enable the National Digital Twin, an ecosystem of connected digital twins that will deliver better outcomes from the built environment. The Gemini Principles are the 'conscience' of the National Digital Twin: nine guiding values, to build consensus for the development and ongoing evolution of the National Digital Twin. The principles create alignment within the programme and keep the focus firmly on the overall objective which is to deliver genuine public good. The Gemini Principles have been welcomed around the world, as they provide a framework for ensuring digital strategies and digital twins have clear purpose, are trustworthy, function effectively and also consider future connectivity.

Information Management Framework (IMF): The mission of the National Digital Twin programme is to enable the National Digital Twin, an ecosystem of connected digital twins that will deliver better outcomes from the built environment. The Information Management Framework currently under development will be the underpinning structure of the National Digital Twin, defining a common language by which digital twins of the built and natural environment can communicate securely and effectively to support improved decision taking by those operating, maintaining and using built assets and the services they provide to society. CDBB published in May 2020 *the Pathway towards an Information Management Framework* report, which proposes three building blocks to form the IMF:

The Foundation Data Model – a consistent, clear understanding of what constitutes the world of digital twins

The Reference Data Library – the particular set of classes and the properties we will want to use to describe our digital twins

The Integration Architecture – the protocols that will enable the managed sharing of data.

Interoperability: It is the ability of two or more systems to exchange information and to use the information that has been exchanged.[7]

Predictive Maintenance: The practice of actively recording and analysing data incoming from an asset, with the view to detecting potential anomalies or defects so that maintenance interventions can be performed prior to failure.

Real Time / Right Time (connection between the asset and the digital twin): A concept stating that how often the data connection between the asset and digital twin is updated, should be at the 'right' time, focusing on the use case sought, and therefore does not necessarily need to be real time.

Use Case: A use case defines the purpose of a digital twin. It includes the description of the problem an organisation is seeking to address and of the outcomes an organisation aims to achieve through the implementation of a specific solution. A use case outlines the motivation to use the solution.

Footnotes

[1] Construction Innovation Hub (2020) "An Introduction to the Value Toolkit"

[2] Bolton, A. et al. (2018) "The Gemini Principles: Guiding values for the national digital twin and information management framework". Centre for Digital Built Britain and Digital Framework Task Group

[3] Connected Places Catapult (2020) "Place-based Digital Twins: use cases"

[4] National Infrastructure Commission (n.d.) "Data for the Public Good"

[5] Gürdür Broo, D. et al. (2020) "Four Futures, One Choice: Options for the Digital Built Britain of 2040". Cambridge: Centre for Digital Built Britain.

[6] Jayakumar, T. et al. (2019) "Design thinking: a working strategy for the third sector". Journal of Business Strategy, 40(5), pp. 28-38.

[7] Burgess, G. et al. (2020) "Flourishing Systems: Re-envisioning infrastructure as a platform for human flourishing". Cambridge: Centre for Digital Built Britain and Centre for Smart Infrastructure and Construction.

[8] Forum for the Future (2018) "The Five Capitals Model: a framework for sustainability"

[9] HM Treasury (2020) The Green Book: Central Government Guidance on Appraisal and Evaluation

VIII. APPENDIX 1
Overview of a smart energy digital twin

I. The use case

Buro Happold has developed an in-house digital twin tool for a district heat network that automates optimised plant, pipe sizing, and network routing based on peak load analysis using real property data in conjunction with established benchmarks. The tool is used to interface with real data from properties and output the network infrastructure results in an interactive digital twin web platform to provide an accurate spatial representation of the network requirements. The tool uses an automated approach for a complex phased development plan and the comparison of multiple options including distributed vs centralised systems that streamline the design process. The tool allows design iterations to be rapidly analysed as soon as new building data becomes available; reducing costs and maximising comfort to consumers.

The key purpose was to address the challenge of heat decarbonisation, thus minimising the reliance on households' use of gas and oil for heating requirements. It is also to explore alternative efficient energy technologies such as ground source heat pumps, air source heat pumps, use of mine water as a centralised source of heat, and decentralised energy systems including hybrid systems.

II. Organisation's information requirements

The approach to determining the organisation information requirements are in twofold. Initially, Buro Happold used the project specifications to carry out an in-depth assessment of data and information requirements based on:

- Household property data energy demands and profiles
- Stakeholder data inputs based on their contribution to the project scope
- Requirements parameters for computation and analytics as to the bases for defining data attributes
- Energy modelling processes

Buro Happold methodology for the development and deployment of digital twin solutions is based on seven integrated modules of Data and Information governance, data warehouse, automation, computation and analytics, visualisation, data integration and interoperability, and technology infrastructure including software. The core of the modules is data and information governance and data warehousing. Through the data governance framework, we use a hierarchy of data and information governance layers that includes global data laws and standards e.g. ISO19650, GDPR, organisational data principles, values, and data governance pillars. The governance pillars encompass data dictionaries, taxonomies, and ontologies including requirements for the energy domain, data security, protection and confidentiality, versioning, data retention and archiving, etc. As such, any smart energy project data specifications are routed through the governance framework to manage the data in a data warehouse in which the other modules revolve.

III. The components of the digital twin

The Digital Twin implemented by Buro Happold automatically generates a digital representation of a smart energy network depending on a choice of different scenarios. Real property data captured via Internet of Things (IoT) sensors are embedded in the computational model. The DT allows users to visualise the impact of the scenarios on the design and functioning of the smart energy network. The DT also assesses the performance of scenarios against high-level indicators (cost, carbon emissions, comfort). As such it performs the functions of a Descriptive and Predictive DT.
The digital twin is intended to be used throughout the phases of the development plan of the heat network. It is currently used to explore design options. It is intended that the DT will become the repository of the 'As Built' datasets further to the implementation of the heat network and that the DT will evolve into the prescriptive and transformative stages of the *sophistication levels.*

Read the full case study here.

IX. APPENDIX 2
Business case template

A Microsoft Word document has been developed to help you put together the business case for your digital twin. This can be accessed via Resources on the DT Hub Website. Sign in or register to access this template via the DT Hub.

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Digital Twin Hub BETA

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Follow progress: **www.digitaltwinhub.co.uk**

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