

Welcome to the Digital Twin Navigator

Enabled by the Construction Innovation Hub, this Digital Twin (DT) framework establishes a set of principles to ensure that digital technology and processes is considered at every stage of the built asset's lifecycle, supporting our mission by driving the adoption of digital approaches that improve the delivery, resilience and performance of infrastructure.

This interactive guide is especially aimed at client bodies and particularly those involved in producing business cases or procuring capital projects with DT considerations.

Enter



Version 01

Acronyms

A number of acronyms are used throughout this document and the most frequently used are shown below for reference. You can also see a developing glossary of terms at:



www.digitaltwinhub.co.uk



AIR Asset Information Requirements	BIM Building Information Modelling	BMS Building Management System	CapEx Capital Expenditure	DT Digital Twin	EIR Exchange Information Requirements	FBC Full Business Case	FM Facilities Management
GIS Geographic Information System	IoT Internet of Things	ISO International Organization for Standardization	LiDAR Light Detection and Ranging	OBC Outline Business Case	OpEx Operational Expenditure	PIR Project Information Requirements	PLQ Plain Language Questions
PPM Planned Preventative Maintenance	ROI Return on Investment	SCADA Supervisory Control and Data Acquisition	SL Soft Landings	SOC Strategic Outline Case	SQL Structured Query Language	STEP Standard for the Exchange of Product Model Data	XML Extensible Markup Language

Introduction

Overview

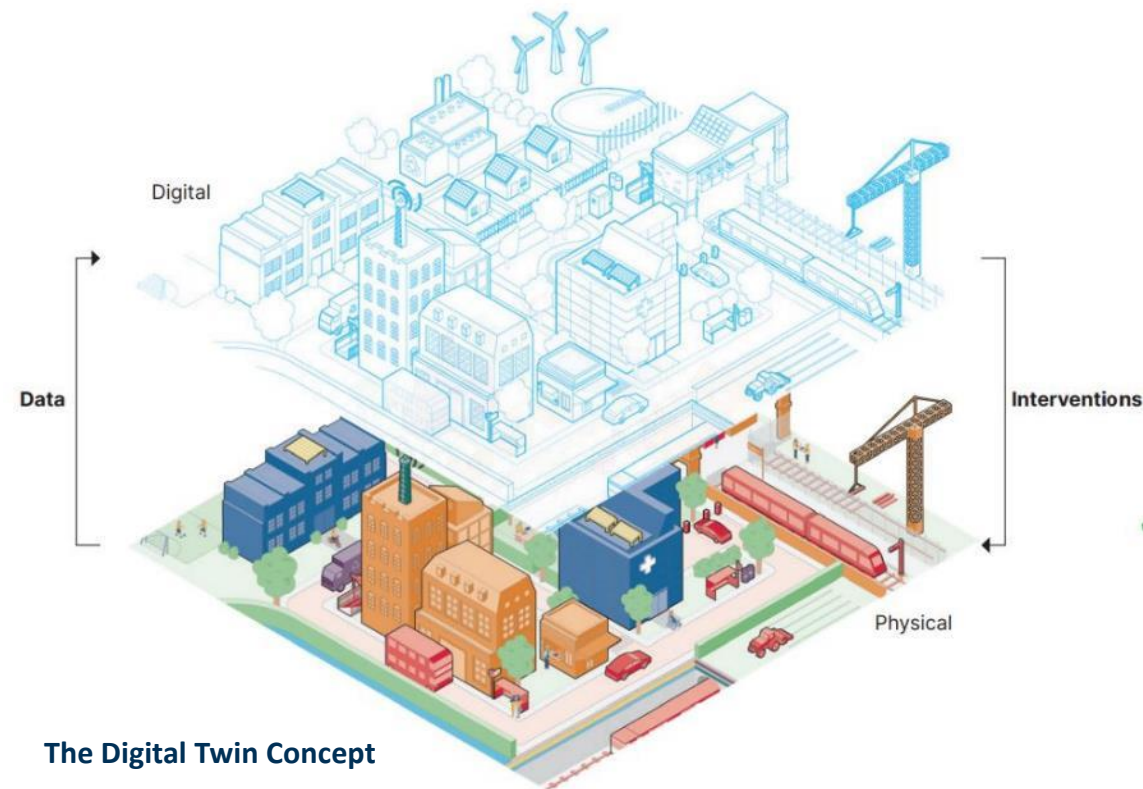
Whilst a Digital Twin (DT), a cyber physical system, can be established at any point in a built asset's lifecycle, it's most successful when deployed at the earliest stage of a plan of work where its vision, technical requirements and any investment needs can be fully incorporated with the optimum return on investment. A DT needs a unified approach across all stages especially the business case stages where it will have the most influence.

A clear DT strategy at these initial stages will influence the brief and subsequently the design and delivery teams during the early engagement stages both in design and selection, specification of data acquisition systems, services and control systems. The DT strategy will also influence any modelling (such as BIM) and IT network architecture which should be aligned with this plan.

This interactive guide is especially aimed at client bodies and particularly those involved in producing business cases or procuring capital projects with DT considerations.

Who is this guide for?

This guide is aimed at an individual project level as opposed an organisational DT strategy however it should be designed to fit within a future enterprise vision and model if required.



The Digital Twin Concept

Additional DT information

It is recommended that this guidance be read in conjunction with the National Digital Twin Programme and their guides and tools which can be found at:

www.cdbb.cam.ac.uk/what-we-do/national-digital-twin-programme



Introduction

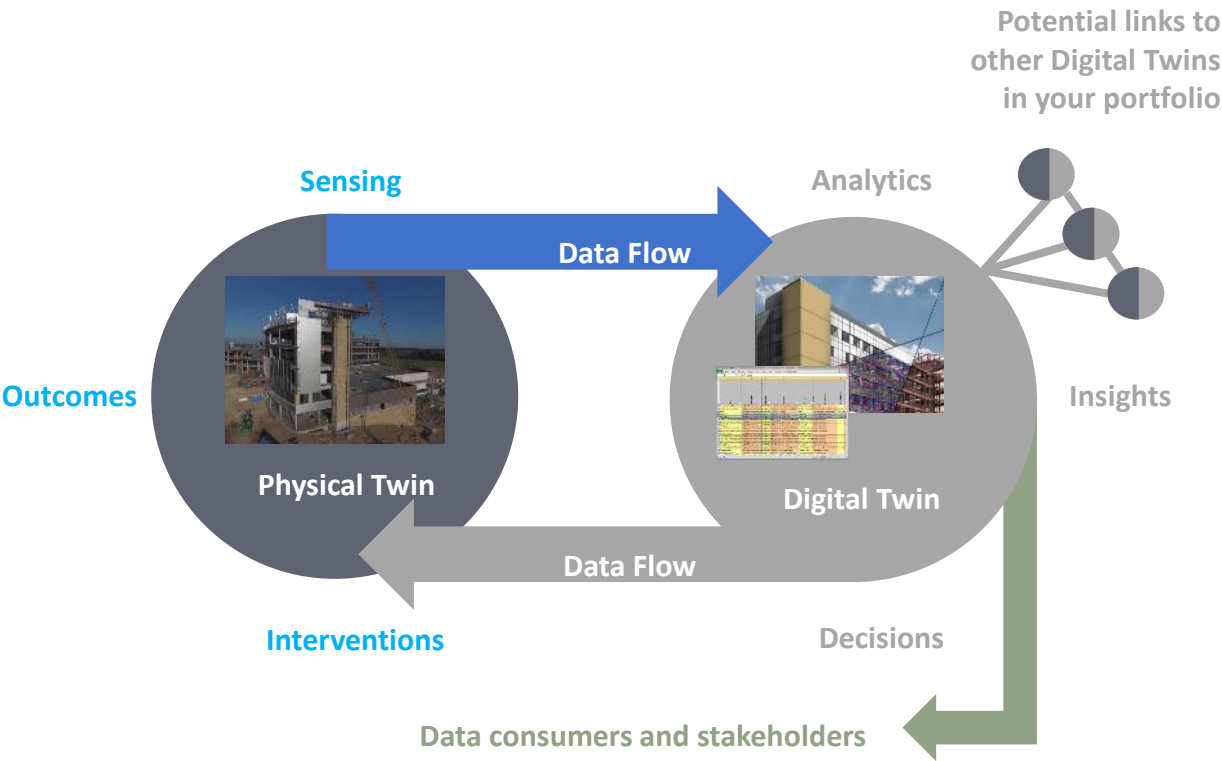
There are always many questions to be asked before you begin your Digital Twin journey. Below you can explore our frequently asked questions.

Q What is a Digital Twin?

A Digital Twins are, in the context of this guide, realistic digital representations of physical built assets including spaces and structures (buildings, roads and rail etc), processes and systems. They unlock value by enabling improved insights that support better decisions, leading to better outcomes in the physical world.

What distinguishes a Digital Twin from any other digital model is its connection (relationship) to mirror the physical twin as illustrated in figure 2 opposite. Based on synchronized data streams from the physical asset or system e.g. dynamic performance data from sensors and operational networks or a static strategic planning model of a system, with input of long-term condition data from the physical twin via corporate systems; feedback into the physical twin via the capital investment process.

The Digital Twin unlocks value principally by supporting improved decision making, which creates the opportunity for positive feedback into the physical twin. This value proposition is enhanced when Digital Twins are consistently federated within an organisation to share and benchmark information.



The Digital Twin Construct

Introduction

Q What's the difference between the 'Golden Thread' and a Digital Twin?

A

The 'Golden Thread' of information is a digital record of building work that is passed across to future building owners, similar to a car's 'log book' outlining the asset's history including the as-built design of the asset and the products that were used. It is a live document, held digitally that captures the digital fingerprints of people, recording their decisions providing a clear accountability trail. Therefore the Digital Twin becomes a vital part of the Golden Thread which can provide a historic, current representation of the built asset and maybe used as a vehicle to simulate future scenarios.

Q What does a Digital Twin include?

A

A true Digital Twin records each step of the construction cycle, so there is lots of data packed into each one. The data may include:

- BIM and 3D models;
- 2D information;
- Schedules;
- Contracts;
- Specifications;
- Construction documents (i.e., submittals, change orders, RFIs, etc.);
- Operational data collected by the embedded sensors ; and
- Data from AI and machine learning technology.



“The Digital Twin becomes a vital part of the Golden Thread which can provide a historic, current representation of the built asset and maybe used as a vehicle to simulate future scenarios.”

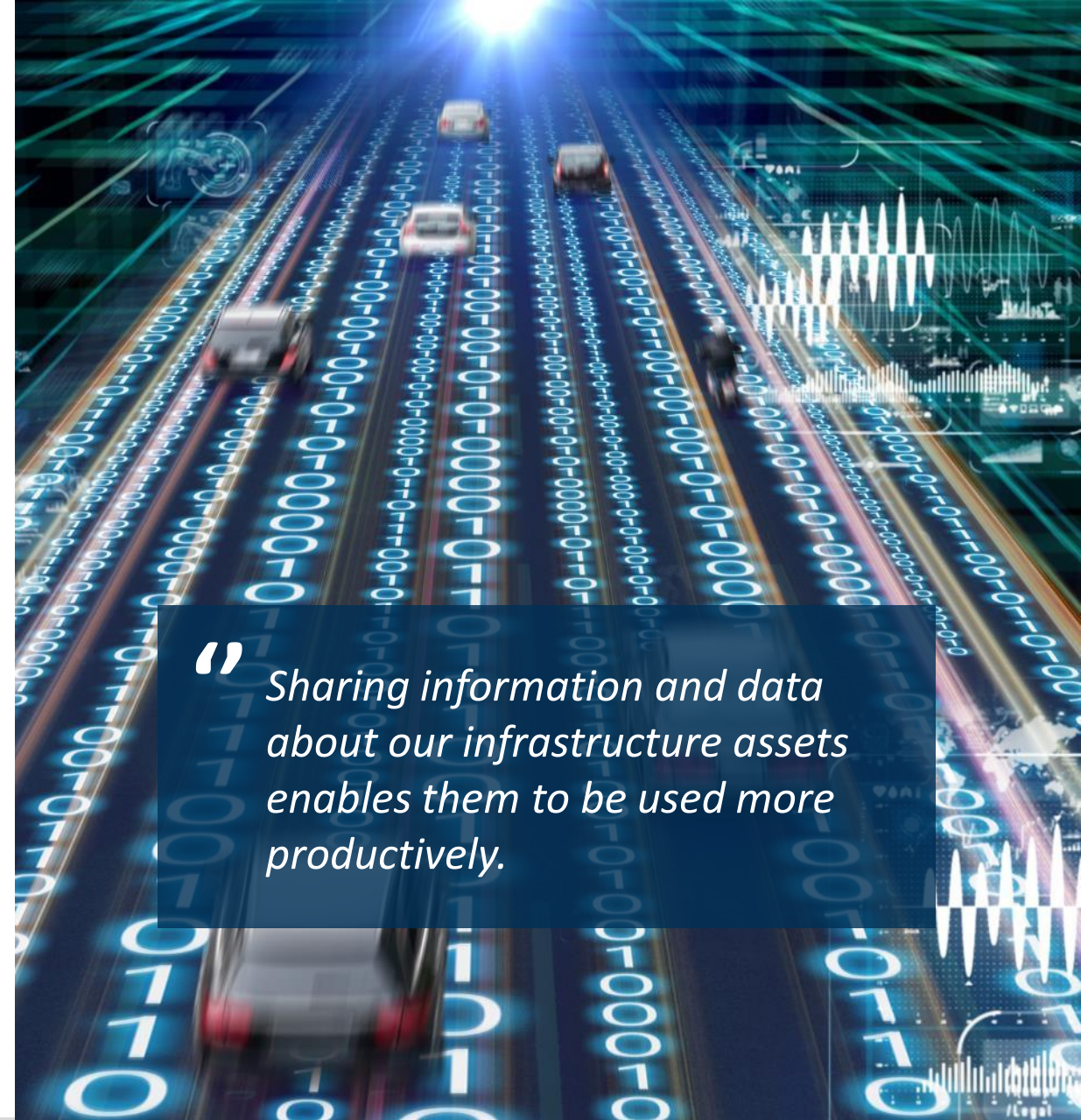
Introduction

Q What is the NIC Report?

A The National Infrastructure Commissions report 'Data for public good' otherwise referred to as the 'NIC report' called for our infrastructure to become smarter, and work as an optimised system in order to help relieve the pressures put upon it from increasing population, economic growth and climate change. The report calls for the preservation of valuable data generated at each stage of assets lifecycle which should be used for the public good. The report examines how opportunities such as, big data, data analytics and machine learning can deliver greater insights into infrastructure assets and systems, enabling greater efficiency. More information data to-day helps us with decision making. However, its not just about collecting data but high-quality data that can be used effectively. Sharing information and data about our infrastructure assets enables them to be used more productively.

Q Is it safe to share data about our assets?

A Information and data that we share about our assets should have appropriate security and privacy arrangements. This means understanding what data can be freely shared as open data, data that can be shared with conditions or under licence or contract and data that is sensitive and can only be shared via secure mechanisms. The NIC report sets out actions for, collecting the right data, setting standards for data and sharing data securely.

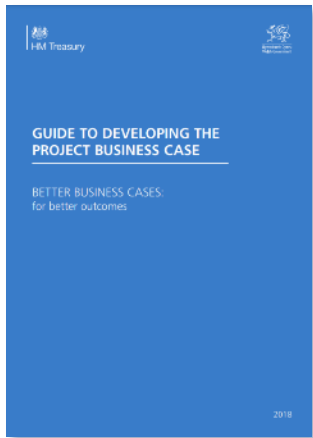


“Sharing information and data about our infrastructure assets enables them to be used more productively.”

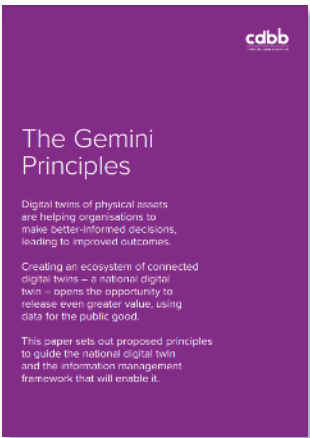
Resources

We make reference to a number of key publications and resources, which are listed below. For up to date news, case studies, blogs and insights that will help further support you on your Digital Twin journey head to the resources section of the CDBB website.

www.cdbb.cam.ac.uk/Resources



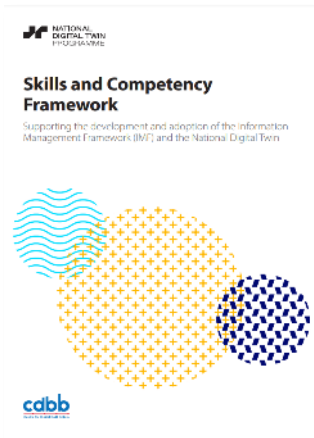
HM Treasury
Guide to developing the project business case



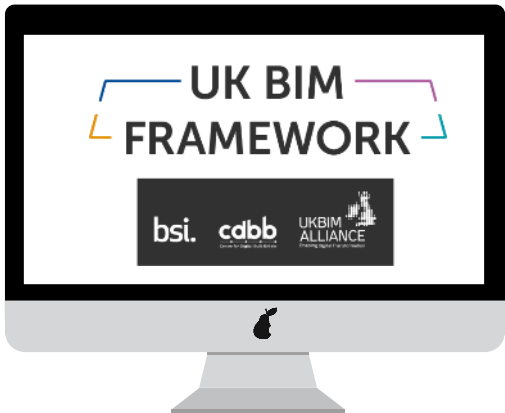
The Gemini Principles



The Pathway towards an Information Management Framework



Skills and Competency Framework




UK BIM Framework

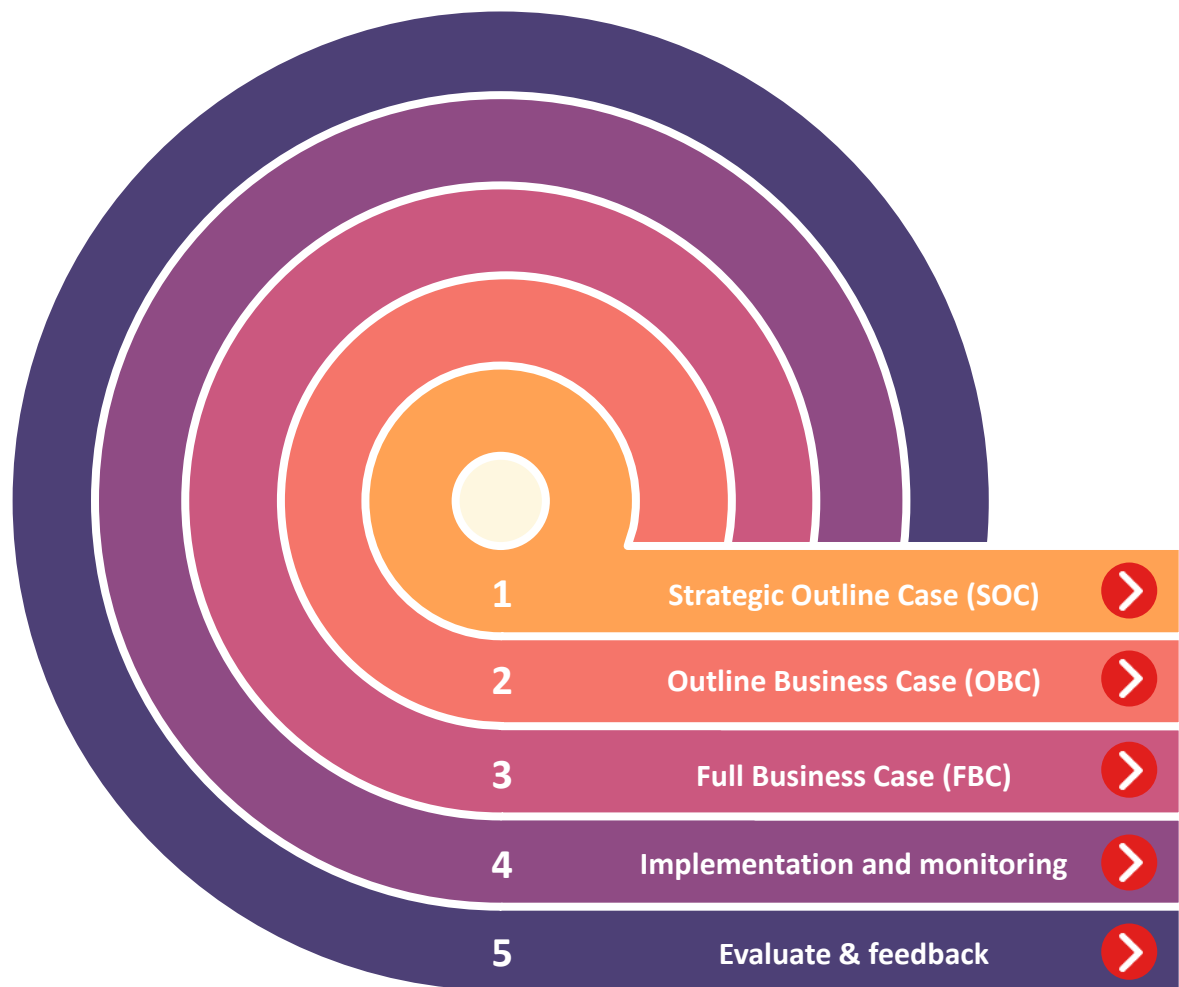


Digital Twin Toolkit
[Sign in](#) or [register](#) to access the [DT toolkit report](#) via the DT Hub




Getting started

Stages		<div>  <div> Cabinet Office Gateway reviews </div> </div>	
1	Strategic Outline Case (SOC)	<p>This is the scoping phase for the project, which results in the production of the Strategic Outline Case (SOC), it is where the strategic fit of the Digital Twin is ascertained and how it can support the developing options. This stage aligns with the Cabinet Office Gateway Review point 1 (Business Justification).</p>	Business Justification
2	Outline Business Case (OBC)	<p>This is the planning phase for the project, which results in the production of the Outline Business Case (OBC). At this stage we are building the user stories and foundational principles as to how the DT functional model will start to build. This stage aligns with the Cabinet Office Gateway Review point 2 (Delivery Strategy).</p>	Delivery Strategy
3	Full Business Case (FBC)	<p>This is the development phase for the project, which results in the production of the Full Business Case (FBC). At this stage we need to understand how the DT fits within the tender and procurement process and how it can be fully evaluated. This stage aligns with the Cabinet Office Gateway Review point 3 (Investment Decision).</p>	Investment Decision
4	Implementation and monitoring	<p>This is the operational phase for the project, which results in the outcomes that were defined in the original strategy. This stage aligns with the Cabinet Office Gateway Review point 4 (Readiness for service).</p>	Readiness for service
5	Evaluate & feedback	<p>This is the operational phase for the project, which results in the outcomes that were defined in the original strategy. This stage aligns with the Cabinet Office Gateway Review point 5 (Operations review & benefits realisation).</p>	Operations review & benefits realisation



Stages

Using the navigator wheel, work your way around the various relevant stages.

Where you see this symbol  you will be taken directly to a stage or section.

You can also navigate the document using the coloured bars located at the top left.



Cabinet Office
Gateway

Business
Justification


Delivery
Strategy

Investment
Decision


Readiness for
service

Operations review
& benefits

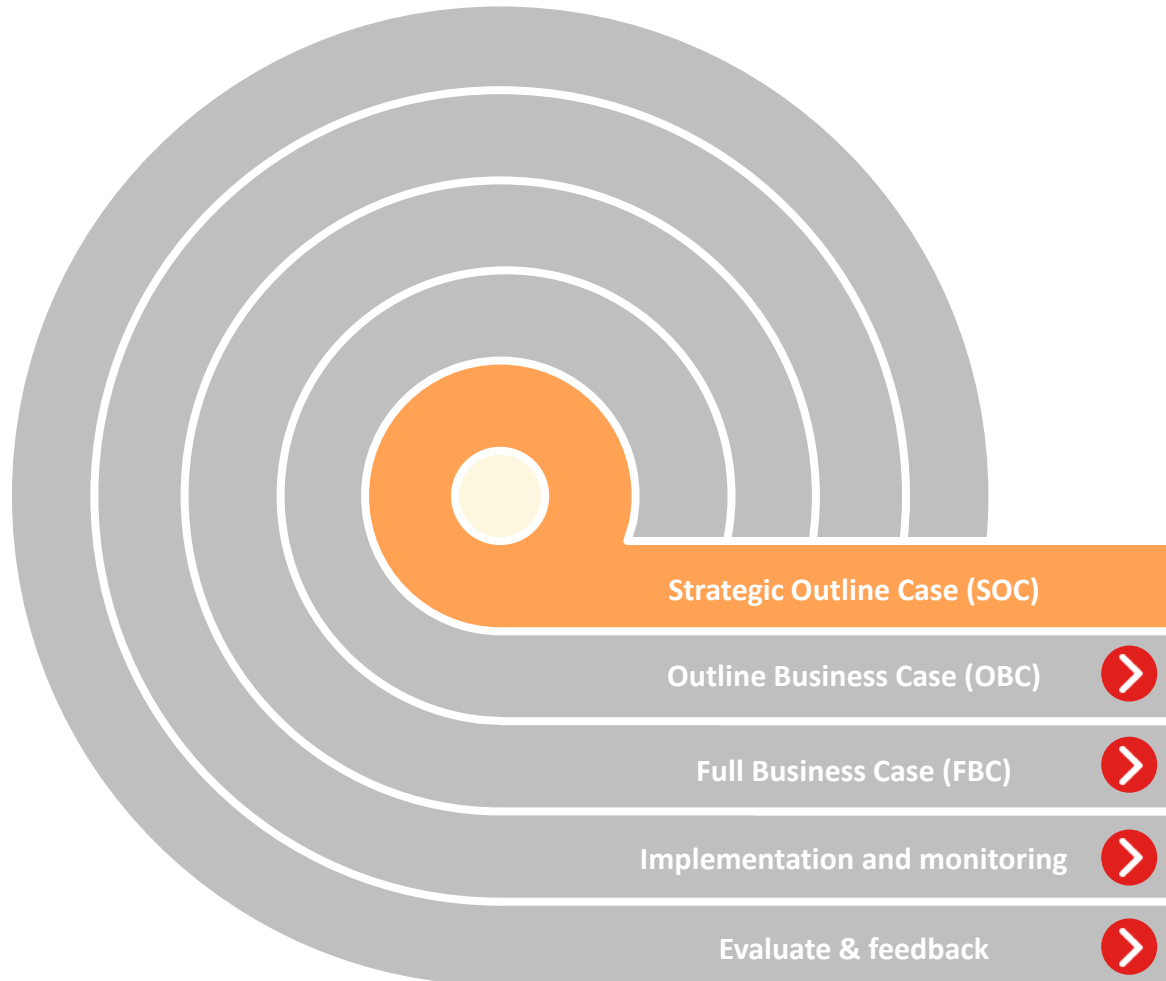
TIP: Look out for helpful tips along the way present within these yellow boxes.

Where you see this symbol  you will be taken to an external link.

Use the back and forward buttons located in the bottom right corner to work your way in a linear path through the document.

You can always return back to this navigator wheel where you see this symbol. 

Strategic Outline Case (SOC)



Stage purpose

The purpose of this stage is to reaffirm the strategic context for the project, because this may have changed if some time has elapsed since the strategic assessment was undertaken; to make the case for change and to determine 'the preferred way forward'.

This is the scoping phase for the project, which results in the production of the Strategic Outline Case (SOC), it is where the strategic fit of the Digital Twin is ascertained and how it can support the developing options. This stage aligns with the Cabinet Office Gateway Review point 1 (Business Justification).

Stage introduction



Define strategy and value



Digital Twin use cases



Digital Twin strategy



Stage checklist



Stage introduction

Strategic Outline Case (SOC)

The Strategic Outline Case (SOC) is where the case for change is demonstrated and how technology and data can support and enable the case such a new capital investment such as a schools or the modification of a linear built asset such as a road or rail network.

The outcome from this first stage should be the establishment of a high level Digital Twin (DT) strategy and related value architecture, the use cases you will want to realize at each stage of your project especially in the operational stage.

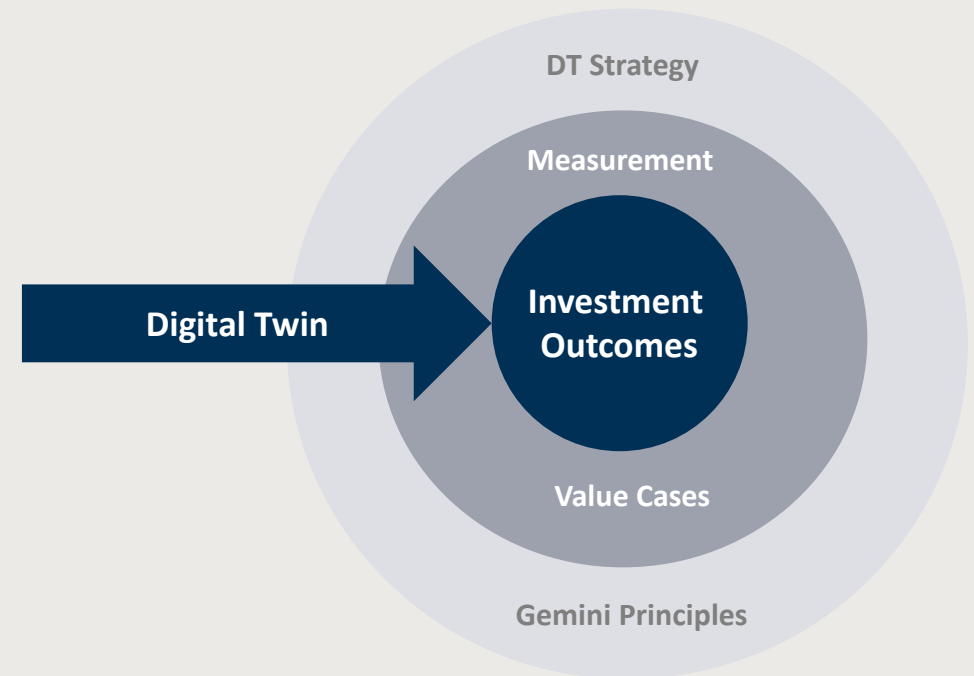
One of the key stage considerations is how performance will be measured and how Digital Twinning can support it. At the conclusion of the SOC, senior management and stakeholders will have a good understanding of how the DT can support the robustness of the proposal and the future direction of travel.

It is important that the strategy is aligned with and can support the proposed project change objectives considered at this stage, especially how it will support the decision making process and better outcomes. It is also important to consider how data from the DT will enable testing of the use cases and tangible assets e.g. performance characteristics from completed projects or intangible objectives such as end user satisfaction.

TIP: Depending on the client's plan of work and procurement strategy it maybe that the strategic outline case and outline business case (OBC) are combined as a single stage.

Stage 1 – Scoping the scheme and preparing the Strategic Outline Case

This is the scoping phase for the project, which results in the production of the Strategic Outline Case (SOC), it is where the strategic fit of the Digital Twin is ascertained and how it can support the developing options.



Define strategy and value

During this initial stage of a potential project the fundamental objective is to define the “why?” a headline strategy and potential value proposition for Digital Twinning and how it can support the key overarching investment objectives such as enhanced user experience and better social outcomes that are being considered as part of the strategic assessment. It is important to prioritise the key use cases.

The strategy at this stage is not intended to be prescriptive, nor does it attempt to provide granular detail of the digital requirements for the project. Its primary aim is to set out a clear Digital Twin vision and direction and a pathway for how this can be achieved. Going forwards in subsequent stages, a detailed implementation plan will be developed to accompany this strategy at a time when key technology requirements and priorities are better understood.

PURPOSE:
Must have
clear purpose

Public Good

Must be used to
deliver genuine
public good in
perpetuity

Value creation

Must enable value
creation and
performance
improvement

Insight

Must provide
determinable
insight into the built
environment

TIP: Depending on the client’s plan of work and procurement strategy it maybe that the strategic outline case and outline business case (OBC) are combined as a single stage.

Digital Twinning has many potential positive outcomes but it needs investment in both the capital and operation stages to be considered at this stage. In some cases it maybe that the use of smart assets is more proportionate and will meet basic value cases.

To do this we first need to determine the foundation of clear purpose for Digital Twinning the potential project. The Gemini Principles, whilst aimed at a National Digital Twin principles can help us frame this.

Define strategy and value

Additional information on Digital Twin types and sophistication levels can be found at the Digital Twin Toolkit Report.

Sign in or register to access the [DT toolkit report](#) via the DT Hub



Temporal scales (time factor)

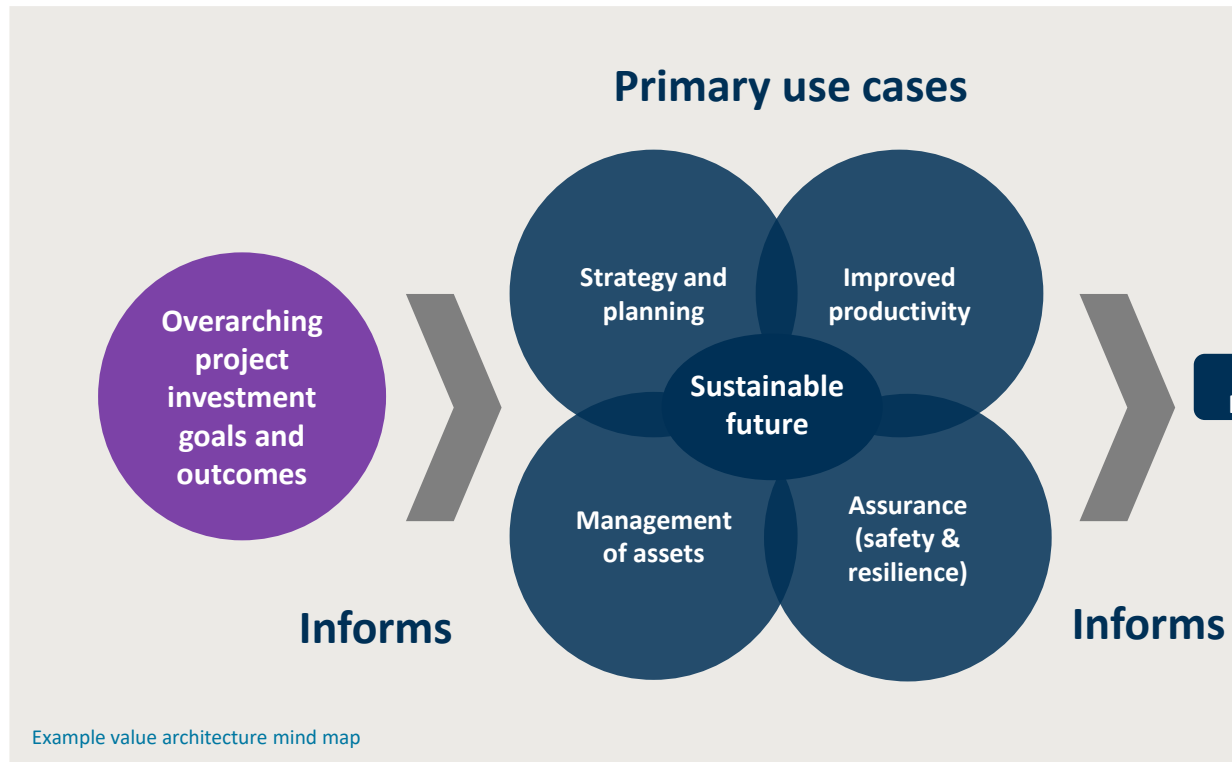
A Digital Twin has a wide spectrum and can be used for a variety of purposes, and temporal scales which should be considered using the table below which is based upon the Gemini Principles, IET Digital Twins for the built environment and DT toolkit report.

Sophistication	Defining principle	Temporal scales
0	Reality capture that is descriptive of existing conditions (e.g. condition survey data, point clouds, photogrammetry, GIS survey data or CAD)	Historic timescale
1	2D map/system or 3D models that is descriptive of existing conditions or the as-built of a capital investment (e.g. no metadata or BIM)	Historical or Capital timescale
2	Parametric models connected to persistent (static) data, metadata (e.g. documents, drawings, asset management systems) to inform operational decision making	Historical (as-built) / Operational timescale: planned maintenance life-cycle
3	Models enriched with real-time data monitoring to optimise and inform operational decisions (e.g. from IoT, sensors, Edge controls)	Operational timescale: operational efficiency
4	Two-way data integration and interaction (feedback loop) that can begin to analyse and prescribe automated status based interventions	Operational timescale: Remote and immersive operations with potential control of the physical from the Digital Twin.
5	Enriched with analytics and decision support tools – predictive simulation with potential cognitive interventions	Potential futures: Strategy and planning support, running ‘What if?’ scenarios, predictive maintenance regimes

Define strategy and value

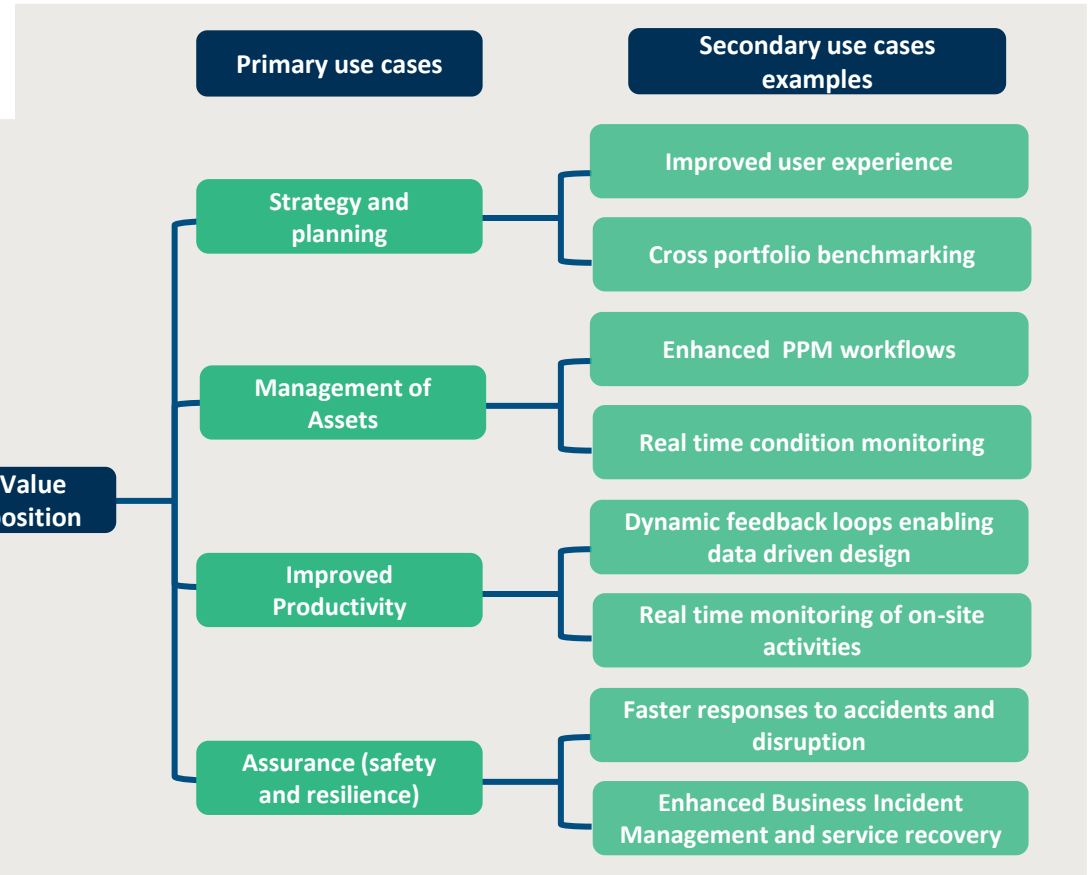
Defining the value architecture of your Digital Twin

To frame your DT strategy and better understand your purpose statements it is important to define the high-level value architecture using a use case framework such as illustrated in the examples below grouped around your primary DT drivers.



Additionally it is important to understand the proposed Digital Twin spatial scale and how it may fit into wider digital ecosystem or digital estate, including:

- Asset or building scale
- Network or campus scale
- System, city or regional scale



Digital Twin Value Proposition



Sustainable future

One of the built environments biggest challenges is creating a sustainable future through optimisation of an asset's operational carbon performance. In most cases the sustainable future will act as a top hat sitting above other value drivers.

Using data capture, unification, and analysis data pulled from transport, logistics, social infrastructure, waste management, utilities and energy management we can create a linked Digital Twin to provide holistic insight and scenario planning.

As the demand for responsive smart built assets grows and more assets are connected the availability and use of space will become maximised through a data driven approach which will optimise the use and build of assets in a way that will maximise carbon reduction.

A useful way of determining how your Digital Twin may enable a sustainable future is to map your objectives to relevant United Nations sustainable development goals.



www.un.org/sustainabledevelopment



Management of assets

At a base level a connected BIM with persistent data will support better Planned Preventive Maintenance (PPM). Real time monitoring of primary asset systems and instant access to operation and maintenance information will help optimise current workflows.

Connected built asset systems will enhance resilience in asset management and service provision through smarter, faster responses to accidents and disruption. This will be enabled by monitoring actual performance data and comparing against theoretical baselines. In some cases, this will allow a shift to condition based, proactive repair before fail models. Using predictive simulation modelling will find patterns in operational data and facilitate a repair before the fail process reducing business disruption costs.

Leveraging data across the whole lifecycle not only facilitates real-time checks on the asset health it also supports better operational responsiveness with optimised maintenance strategies and maximised asset availability with improved asset resilience through smarter, faster responses to accidents and disruption.

Better and more accurate understanding of an asset's genetics or lifecycle profile with unified real-time utility management, occupancy monitoring, performance and condition data will allow degradation studies and future un-availability risk to be calculated. The overall running and maintenance costs of a built asset can be more easily (or potentially in some cases autonomously) controlled through the sensor and actuator technology which is in-built into the asset as part of the Digital Twin strategy.

Digital Twin Value Proposition



Assurance (safety & resilience)

Turning data into safer more resilient outcomes is a key primary objective of the Digital Twin creating an ability to simulate and test different scenarios in a virtual environment.

This is especially important to clients that operate their built asset for example airport operators where state-of-the-art analytics combined with data science can optimise congested and complex airspace, improve capacity management, and predict the impact of decisions before they are even made. At a base level it would also support that operator ensuring that they are complying with the various regulations they must meet.

Better data insight allows predictions of failures before they occur, such as predicting cascade failure scenarios with real time feedback as an asset begins to deteriorate.

Digital Twin Value Proposition



Improved productivity

Many mature clients and procurers are already targeting productivity gains across the whole-life of an asset or estate and are seeing the digital-twin as a valuable enabler.

The mature Digital Twin concept can facilitate real-time monitoring and analysing of operational and occupational data proving valuable insight on how an asset is used and currently performing.

One of the biggest opportunities of Digital Twin use is the feedback loops which reduce uncertainty, delay and mistake enabling designs to be optimised. An example of this is flow optimisation which leads to higher productivity and user well being.

Digital Twin Value Proposition



Strategy and planning

Communicating real-time data, combined with analytics and predictive simulations will enable better understanding of user behaviours and needs. Harnessing and understanding of this data will support better decision making to tailor forward planning and optimise experiences and outcomes for the users of that built asset. A sophisticated Digital Twin can undertake various predictive future scenarios and test various options virtually, especially around investment decisions.

This will be especially true of tracking user movement which provides valuable insight leading to better:

- Way finding;
- Improvements to the spaces in which we live and work;
- Building services environments that are personalized to fit the user's needs;
- Real-time traffic simulation and management;
- Safety and security;
- Targeted social media;
- E-commerce and tailored shopping experience;
- Mobility and Parking monitors
- Equipment management; and
- A portal for asset users to access and process information such as latest status notifications and building permit applications.

TIP: The illustration below shows an example of a Digital Twin strategy appropriate to the Strategic Outline Case (SOC) stage. This scenario is based upon a new infirmary hospital building. An editable version of the strategy is available on the CDBB website.

XXX hospital headline digital strategy and vision

Digital Twinning of the XXXX hospital provides an opportunity to create a built asset where integrated networks, sensors and dynamic data will assist in achieving operational excellence and support the delivery of modern clinical care and a better patient experience. This ecosystem of a secure, connected modern hospital environment will assist estates teams and end users make better-informed decisions leading to improved outcomes.

Sophistication	Defining principles	Temporal scales
4	Two-way data integration and interaction with self governance.	Operational timescale: Remote and immersive operations with control the physical from the digital

Key DT characteristics	Use cases aligned with strategic use cases and organisational objectives	
<ul style="list-style-type: none">• Dynamic virtual representation of the hospital• Integrated networks• Patient empowerment• End user enablement• Interoperability across key systems• Futureproofed• Real time continuously accessible data• Reprogrammable and smart• Exploits ontologies• Machine understandable vocabulary• Self adapting• Closed loop optimisation	Primary Use Cases: <ul style="list-style-type: none">• Strategy and planning• Management of assets• Improved productivity• Assurance (safety and resilience)	Secondary use cases <ul style="list-style-type: none">• Improved user experience• Cross portfolio benchmarking• Enhanced PPM workflows• Real time condition monitoring• Dynamic feedback loops enabling data driven design• Real time monitoring of on-site activities• Faster responses to accidents and disruption• Incident management and service recovery

Digital Twin strategy

TIP: Using the template below create a Digital Twin strategy appropriate to the Strategic Outline Case (SOC) stage. An editable version of the strategy is available on the CDBB web-site.

<Insert project code> <Insert 'Project name' headline digital strategy and vision>

<Insert short high level description of the Digital Twinning strategy and vision of the project>

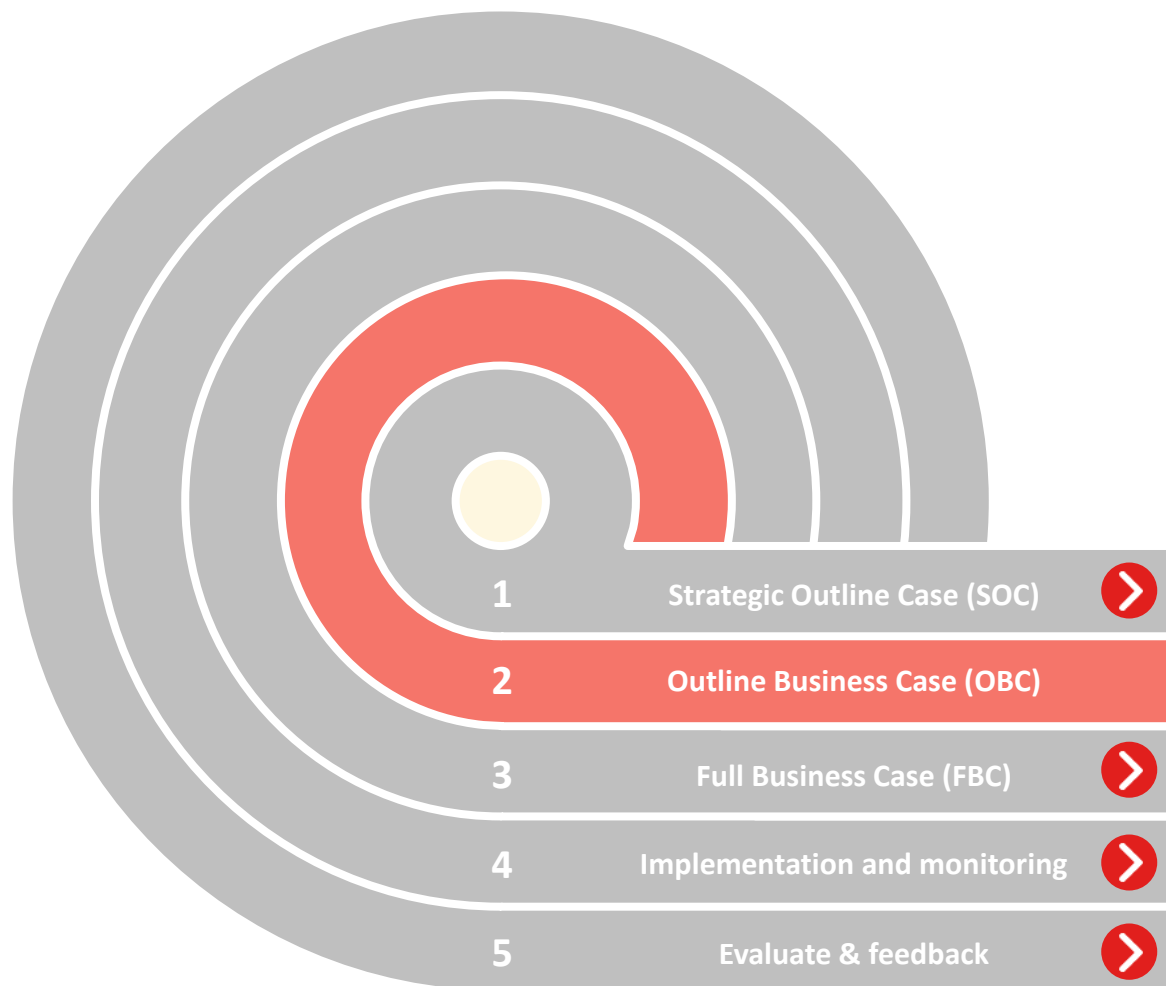
Sophistication	Defining principles	Temporal scales
<Insert DT sophistication element, e.g. 0, 1, 2, 3, 4 or 5>	<Insert defining principle, e.g. Reality capture, 2D Map/system or 3D Model etc>	<Insert temporal scale, e.g. Historic timescale – existing conditions, Capital timescale etc>
Key DT characteristics	Use cases aligned with strategic use cases and organisational objectives	
<Insert Key DT characteristics, e.g. Integrated networks, End user enablement, Interoperability across key systems etc>	Primary Use Cases: <Insert primary use cases, e.g. Strategy and planning, Management of assets, Improved productivity, Assurance (safety and resilience)>	Secondary use cases <Insert secondary use cases, e.g. Improved user experience, Cross portfolio benchmarking, Enhanced PPM workflows etc>

Stage checklist

TIP: Use the Strategic Outline Case (SOC) stage checklist below to confirm the status of each stage task. An editable version of the checklist is available on the CDBB website.

Ref	Stage task	Status
1	Reviewed key baseline Digital Twin (DT) literature and guidance to have good understanding of the high level value proposition	
2	Embedded the consensus values of the “Gemini Principles” into your project	
3	Defined your DT value architecture aligned with your case for change, purpose statements and overall investment outcomes	
4	Identified an appropriate DT sophistication level that considers how performance will be measured	
5	Developed a headline DT strategy based upon clearly articulated purpose(s)	
6	Considered how your Digital Twin can link with other Digital Twins in your ecosystem, now or in the future to allow data sharing or integration	
7	DT recommendations built into project assessment report as appropriate	

Outline Business Case (OBC)



Stage purpose

The purpose of this stage is to revisit the options identified in the SOC, to identify the option which optimises public value ('the preferred option') following more detailed appraisal; and to set out the possible deal while confirming affordability and putting in place the management arrangements for the successful delivery of the project.

This is the planning phase for the project, which results in the production of the Outline Business Case (OBC). At this stage we are building the user stories and foundational principles as to how the DT functional model will start to build. This stage aligns with the Cabinet Office Gateway Review point 2 (Delivery Strategy).

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User stories	>
Trust principles	>
Function principles	>
Alignment with other themes	>
Headline investment considerations	>
Return On Investment	>
Business case	>
DT Legal and Commercial	>
Stage checklist	>

Stage introduction

Outline Business Case (OBC)

During the Outline Business Case (OBC) stage, as a lead appointing party, (usually the client) you will typically have started to ascertain the project business case and strategic brief along with other core project requirements and objectives. At this stage you will also likely have started to appoint a team to support the project development.

This is a critical stage in the Digital Twin development process where the value proposition will become further articulated and the functional reference architecture begins to emerge and align with other key strategies such as building information modelling and the facilities management strategy.

At this stage we need to understand how the DT fits with and supports the projects:

- Evolving strategic case;
- Proposed economic and financial case;
- Management case especially the operational and facilities management plan; and
- How it will fit into the scheme procurement strategy.

TIP: It is important to ascertain at this stage how the DT will support successful delivery and its management cases.



User stories

Create user journeys by persona and how they could interact with the DT

It is recommended that at the outset of the OBC a study be undertaken to map all relevant internal and external DT stakeholders followed by a workshop to bring together all the strategic stakeholders who will use and consume the Digital Twin and its outputs during the “In-Use” stage. The stakeholder engagement analysis undertaken in the parallel Soft Landings process should help inform this.

The workshop should allow you to discover on a typical day how a user would experience the asset, what information or dynamic data they would require and what queries they need answered. These are referred to as user stories or journeys and are simple descriptions told from the perspective of a person who will make use of the Digital Twin functionality. The overall Digital Twin strategy and its functional requirements are informed by an consolidation of smaller user stories.

Often there is connections between the different personas and you need to understand how information flows between the various parties. For example in a healthcare environment a patient coming in for an operation may wish to know in real-time about car parking space availability with sensors detecting what's available and navigate them through the hospital building and potentially make sure that building services are configured to meet the individual needs of the user and their health care experience.

The illustrations right show typical workshops examples which may vary from simple sticky notes to more graphical representations depending on the complexity of the project.



07:30 Sophie prepares for her commute to work by seeing the parking availability before setting off and subsequently books a car parking space via an app. As this is not her normal office location, she reserves a 'hot desk'.



08:50 Upon arrival at the office reception, a proximity notification welcomes her to the office and explains the Health & safety and fire evacuation procedures.



08:59 Using the reception kiosk, Sophie uses the Wayfinding map to locate the hot desk locations and also the in house coffee shop.



11:11 Using a Mobile App, Sophie books a meeting room for 1 pm. Based upon her requirements for three people and a white board, Sophie is allocated meeting room 101. Once in the meeting room and checked in, she notices that the projector remote is missing and generates a support ticket.



13:27 Sophie uses the in room unified interface (via a tablet) to set the room temperature and open the blinds. Her team wish to use the meeting room a little longer than planned and so she checks for availability and extends her booking by 30 mins

User stories

Connected thinking

As part of your workshop and to shape more detailed value architecture of your DT try and define the key plain language questions (PLQs) and the decisions that you want a connected system to support. PLQs in the context of DTs are those questions that a built asset user needs answered as part of their user journey. The answers from interacting with the DT will enable the user to make key decisions. Examples of DT PLQs are set out below:

Systems performance:

How well are my building services performing?
How can I optimise the performance of my building systems?
What is the impact to my systems in the event of a failure?
Can I predict a system failure before it happens?

User experience:

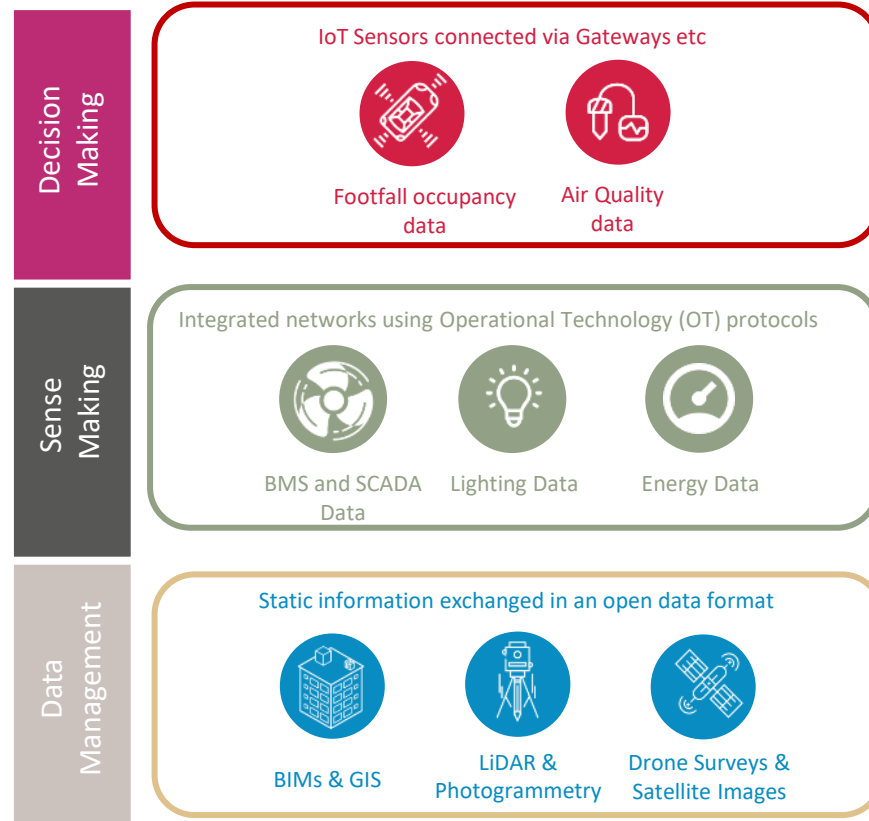
How well are people using my built asset?
Are we getting better business outcomes?
What is the current occupancy level?
How can we improve patient flow?

Asset Management:

What is the current condition of my asset?
When do I need to replace my keys fabric, systems etc?
What forward investments do I need to make?

Plain language question

What is the current temperature in my reception area?



Trust principles

Following development of the user stories it's important at this stage to think about the trustworthiness of your evolving Digital Twin strategy. The Gemini Principles break these down into three sub-themes, Security, Openness and Quality.

TRUST:
Must be
trustworthy

Security

Must enable security and be secure itself

Openness

Must be as open as possible

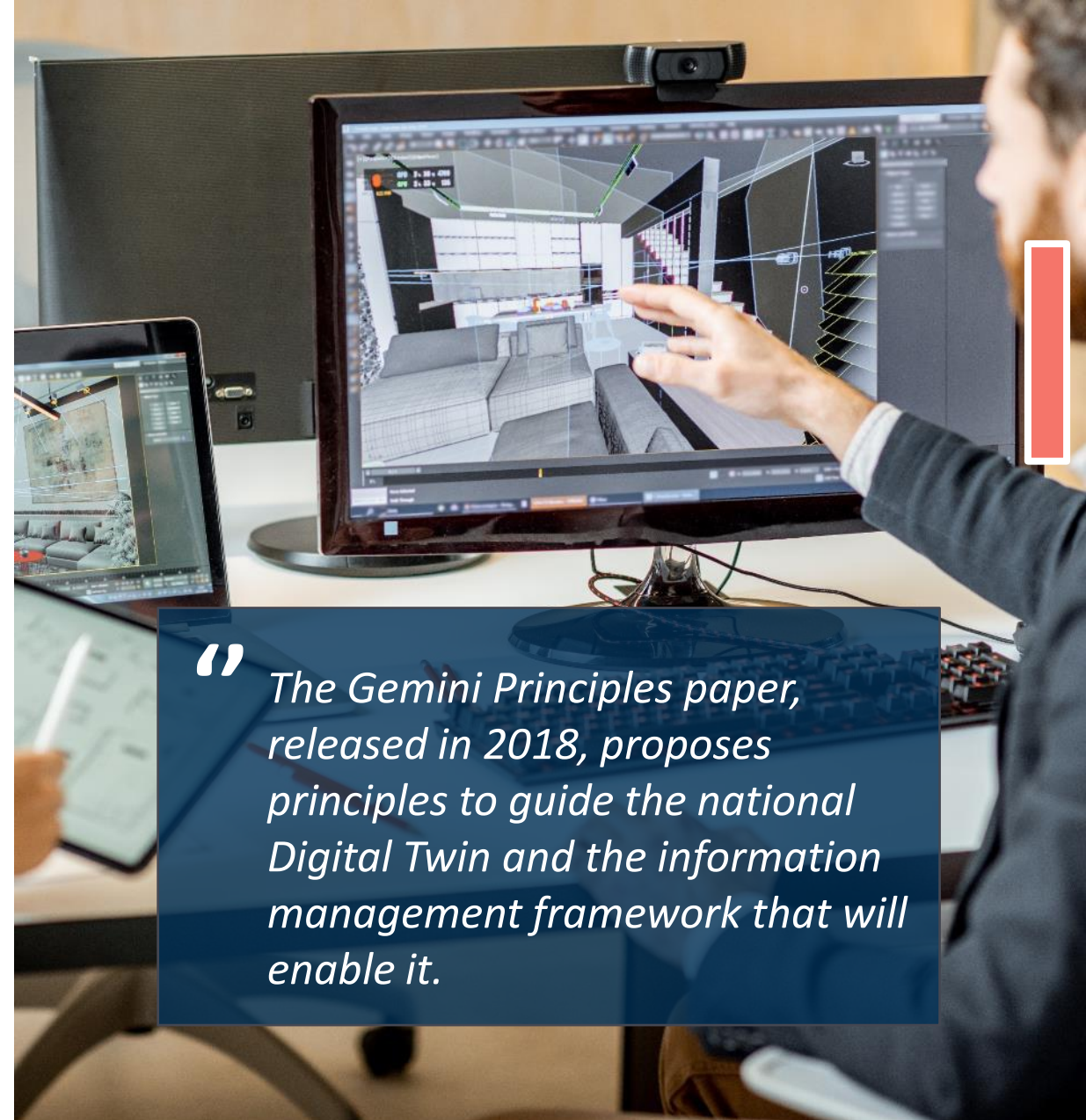
Quality

Must be built on data of an appropriate quality

Security

The increasing sophistication and connectivity of Digital Twins and their cyber physical systems working in real-time to influence outcomes will have a transformative effect on your project. As a consequence of this greater level of digitization and integration there is a need to address inherent vulnerabilities and take appropriate and proportionate measures to protect aspects such as:

- built assets and environments;
- personnel and other occupants or users of built assets, including the built environment's citizens, encompassing residents, business, visitors and commuters;
- data and information, including that which is commercially sensitive or constitutes intellectual property; and
- societal, environmental and/or commercial services.




“The Gemini Principles paper, released in 2018, proposes principles to guide the national Digital Twin and the information management framework that will enable it.”

Trust principles

It is important therefore that a security minded approach be taken when developing a Digital Twin strategy. This should be a holistic approach, taking into consideration personnel, physical, cyber and cross-cutting security, overseen by good governance with clear lines of responsibility and accountability.

The successful formulation of a security-minded approach to a Digital Twin relies on organisations recognising the potential issues and working with their supply chains in order to protect and limit access to the detail of, and information about, sensitive assets. Useful reference documents that should be considered in creating your security minded strategy:

The CPNI Security Considerations Assessment (SCA): process ensures security-related vulnerabilities are considered across a range of activities and processes within an organisation. www.cpni.gov.uk/security-considerations-assessment 

ISO 27001 (Information security management systems): specifies the requirements for establishing and maintaining a management system for information security within an organisation. It does so in a general, pan-sector manner, to enable a consistent and holistic approach to information security management.

BS EN ISO 19650-5:2020: international standard setting out requirements for the security-minded management of sensitive information within building information modelling (BIM).

“It is important that a security minded approach be taken when developing a Digital Twin strategy.”

Trust principles

Openness

This is the central principle for achieving “effective information management of the built environment.” Open-source and collaborative models build trust, reduce costs, and create value more effectively than any other approach. Therefore considering vendor neutral approaches in open standards that can query, interrogate, and integrate should be considered as part of your DT strategy.

Quality

This refers to the quality of the data and information that the Digital Twin is founded upon and is essential before any connections are made. It is important therefore that data quality standards are documented, agreed and enforced throughout the project lifecycle.

During the Outline Business Case (OBC) stage, as a lead appointing party, (usually the client) you will typically have started to ascertain the project business case and strategic brief along with other core project requirements and objectives.



Function principles

It is important at this stage to think about the functionality of your Digital Twin strategy. The Gemini Principles break these down into three sub-themes as illustrated below.

FUNCTION:
Must function
effectively

Federation

Must be based
on a standard
connected
environment

Curation

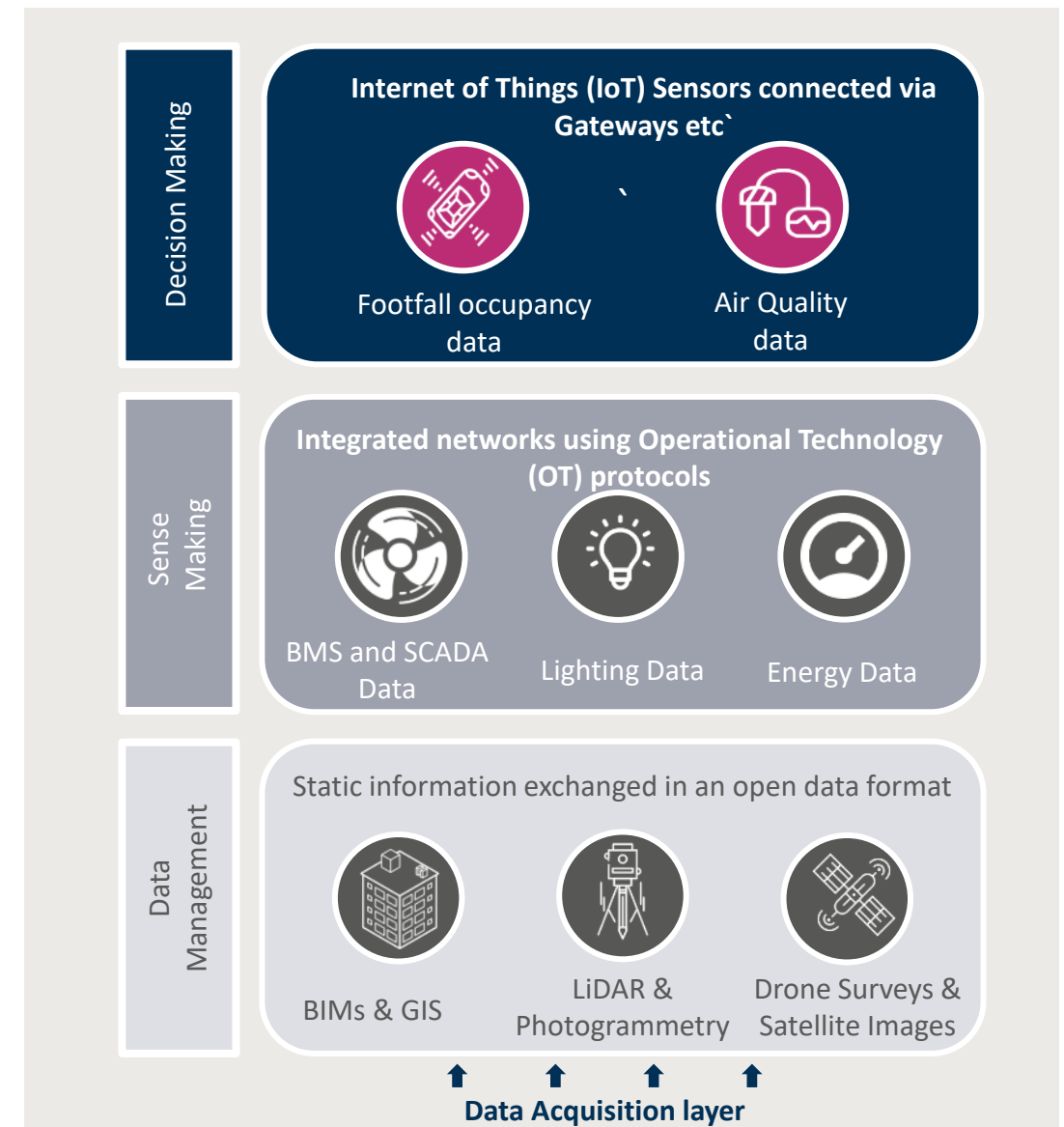
Must have clear
ownership,
governance and
regulation

Evolution

Must be able to
adapt as technology
and society evolve

At this point, likely working with a specialist consultant it will be beneficial to conceptualize the basic [reference architecture](#) of your Digital Twin across the information value chain to show the connection between your data and better decisions and how that can support your investment outcomes.

Firstly, consider your data acquisition layer where there is a need for connectivity between a device, system, model etc and data management layer this may include IoT devices / sensors, control systems, SCADA, networks etc. It is important to consider a fusing of systems such as, operational technologies, and IoT sensing end points to facilitate unified data integration and intelligence. Examples of the this acquisition layer are illustrated right.



Function principles

The data from this layer will move into a data management layer most likely through web-services or a network communications gateways. This layer will include data storage e.g. a secure data lake. It is important that consistent data structure be defined.

Sitting above this is the sense making layer, often linked to the data store via middleware. This layer is where we start sense making through data processing, analytics and modelling. Analytics may include “stream” analytics which focusses on evaluating data as it comes into the system and producing insights in near-real-time for immediate exploitation. Additionally the data maybe computed for simulation and visualisation (this may include simple user interfaces, mixed reality or serious gaming engines). The outcome of this layer is improved insight.

Digital Twin modelling functions need to be aligned with the value architecture and can be broken down into distinct categories:

- Monitoring;
- Simulation;
- Prediction ; and
- Verification.



Function principles

At the top of the pyramid is the decision making layer which may include decision support tools and rule based automation. This layer will also include the user interface.

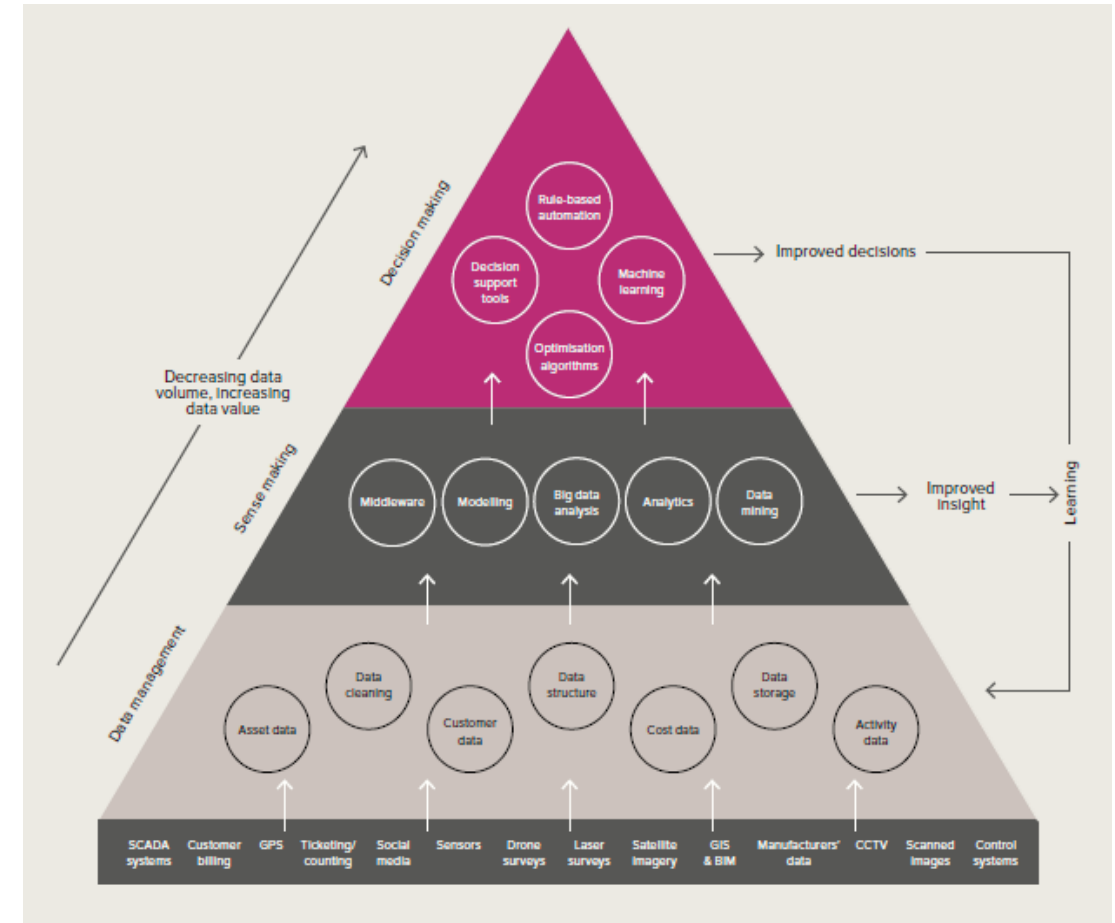
The user interface for your Digital Twin is really important, it should be intuitive and support end user needs in an outcome focused manner from web portals, apps, mobile, kiosks etc that are people centric. From this data Digital Twin, end-user and operational applications provide searching, reporting, contextual control, analytics, and operational workflows or other proposes such as way finding.

The information value diagram right illustrates and contextualises these three key DT layers.


As part of the reference architecture it is important the consideration be given to data structure and a master data management approach. Consideration should be

- Ontologies;
- Semantics;
- Standard for the exchange of product model data (STEP);
- Geospatial modelling;
- Extensible mark-up language (XML); and
- Structured query language (SQL).

Thought should also be given to the curation of the DT and it's various connected systems.



Alignment with other themes

It is important the when defining the programme or project's Digital Twin strategy that it aligns with and fits within the context of any wider digital strategy especially at an organisational level. It is also worth considering how your DT maybe aligned with an Information Management Framework. www.cdbb.cam.ac.uk/news/pathway-towards-IMF 

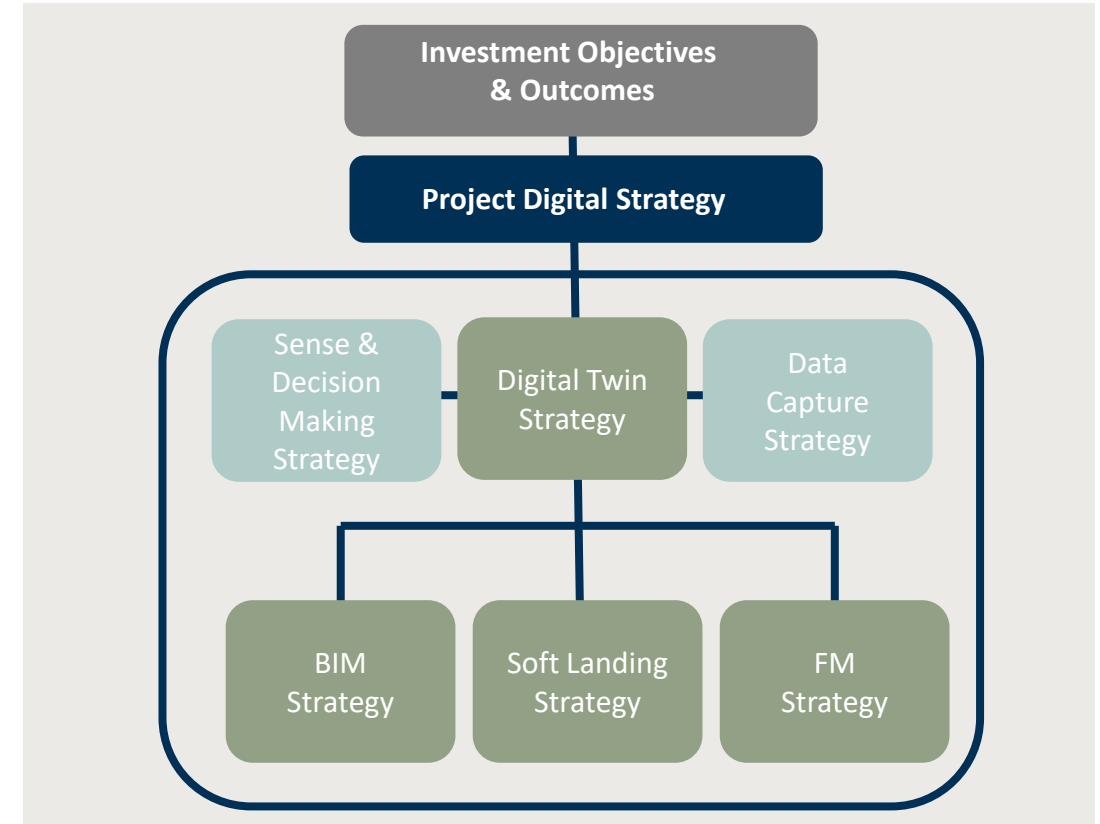
At this stage you are also likely developing your Building Information Modelling (BIM) and Soft Landings information value chain (SL) strategy for your project. It is important that these strategies are also aligned with your Digital Twin strategy (including your sense and decision making strategy).

Firstly, BIM. A Digital Twin is built on data and should have the ability to integrate with other related data platforms. The DT therefore needs a digital representation to link to at a level of appropriate accuracy suited to the DT strategic purposes. A DT goes beyond being a simple model of an asset, it should connect the digital and physical, it may also transmit data and monitor the physical asset in real time.

The intention for the BIM to form a reliable basis for a DT should be clearly established as a strategic purpose in your Exchange Information Requirements (EIR). The BIM must therefore be scaled to allow data visualisation from sensors and other dynamic data sources. In terms of asset management a DT is more information asset rich and analytically capable than BIM.

Secondly, Soft Landings (SL). Your soft-landings strategy will establish performance targets a monitoring plan and plain languages questions which will all need data. These should again be aligned with the DT strategy and its range of purposes.

Additionally, your Facilities Management (FM) strategy should also look to integrate with the DT value proposition including real time decision support and condition monitoring.



Alignment with other themes

The diagram (right) illustrates how the BIM and Digital Twin strategies should align and interface. It is important that there is a holistic set of information requirements for the project both in the context of static and dynamic requirements (consider frequency of exchanges).

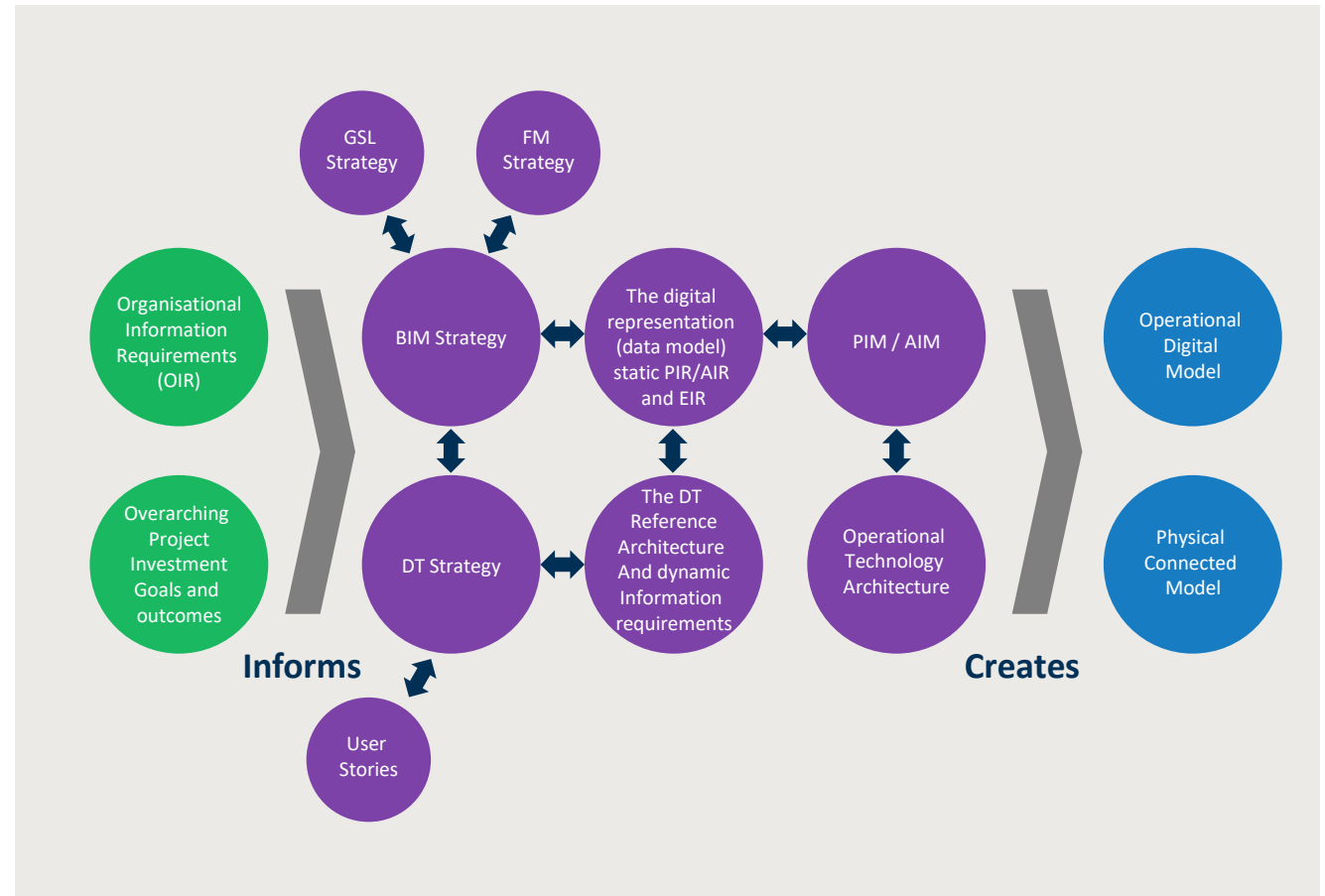
Both sets of data should flow from having clear organisational information requirements and well defined project investment goals and outcomes which should be completed by the conclusion of this project stage.

These will help inform more granular data needs:

- Project Information Requirements (PIR);
- Asset Information Requirements (AIR); and
- Exchange Information Requirements (EIR).

It is also important to consider if any of these requirements are sensitive in nature or will need to be federated to provide insight or support a decision.

The evolved strategies will also begin to help shape the project specification especially in regards to smart sensing and integrated operational technologies.



Headline investment considerations

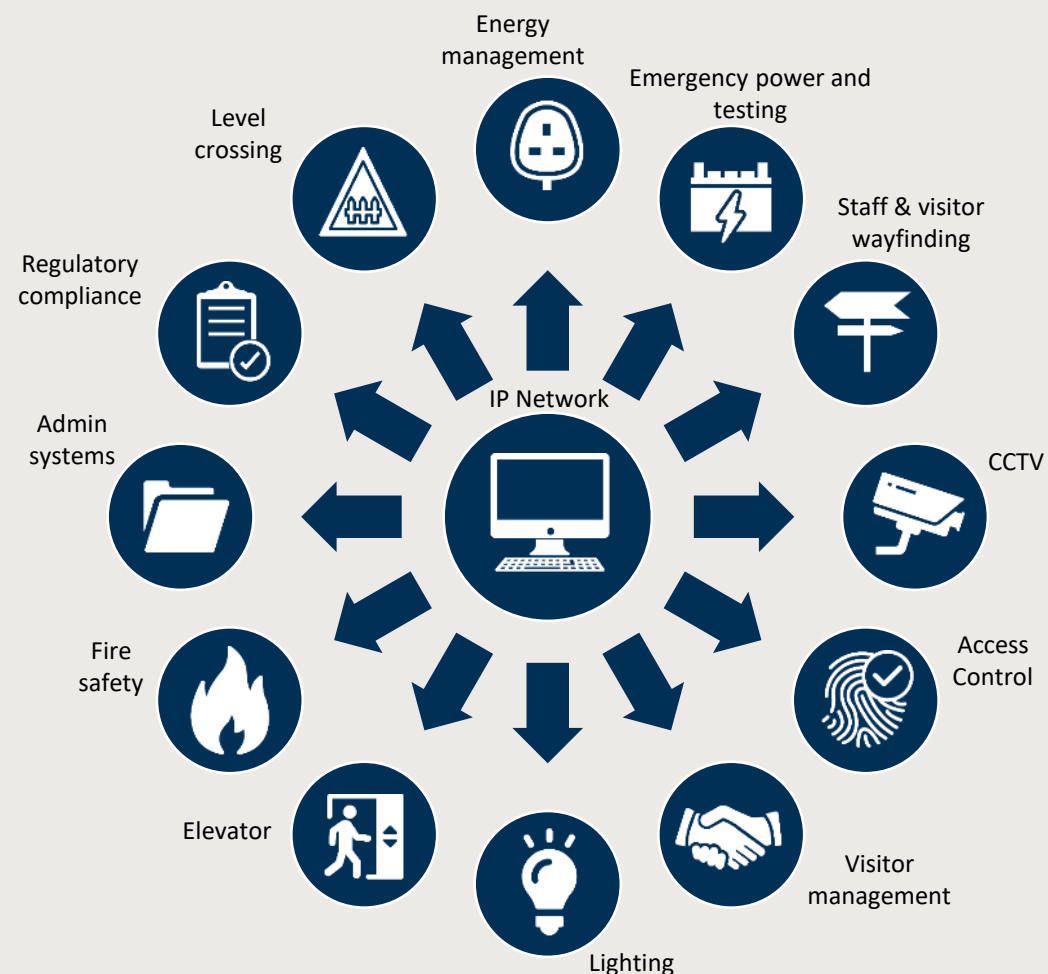
Based upon your proposed DT strategy and the level of Digital Twinning you should consider undertaking a headline return on investment study. This may necessitate the support of a specialist consultant. Typical investment costs should be considered in both capital and longer term operational costs, these may include:

Digital management services:

- Digital Twin consultant to support creation of a DT technical specification;
- Systems integrators who specialize in bringing together component subsystems into a whole and ensuring that those subsystems function together; and
- Training – there maybe a need for levelling up within your organization as to how to use and maintain a DT approach.

Enabling digital technologies:

- Cloud hosting in the operational stages such as a data lake;
- Data analytics platforms (or analytics as a service);
- Embedded IoT and asset / equipment sensors;
- Connected controls such as smart meters, room sensors and controllers;
- Edge controls;
- Enhanced and integrated operation technologies (OT) and networks such as BMS to allow real time sharing of data between systems;
- Software to aggregate and visualise data;
- Operational command centres; and
- Specific Digital Twin end user applications such as operational dashboards and workflows.



A built asset can contain lots of connected or connectable things that can be unified to drive new Digital Twin use cases and provide better experience to asset managers and end users.

Return on Investment

Creating a headline Return on Investment (ROI) model is an important consideration at this stage. As noted earlier it maybe necessary to engage a specialist consultancy to support this due to limited well defined guidelines around DT ROI calculations and limited metrics on quantitative outcomes.

It is important to recognise the timing of when DT benefits will be realised i.e. predominately in the operational, in-use stages beyond the capital stages. These benefits both qualitative and quantitative will likely be unlocked and sustained over the entire asset management period which will optimise the opex budget however there will likely be an enhanced capex budget to enable this. Additionally, depending on the maturity of the proposed DT spectrum many of the benefits will be in service provision with optimised business costs and outcomes.

At this stage the ROI study will be at a macro-level to help establish the overall budget envelope.

TIP: It maybe the case that your project level DT will form part of a wider organisational or portfolio level strategy and cost can be offset against any enterprise investments that may already be underway.

Key considerations:

- Use similar case studies to help inform your ROI model;
- Make sure that you have included for primary capital enhancements such as integrated operational networks and other data capture devices or smarts; and
- Budget for long-term DT opex costs such as data hosting, analytics and if required operational command centres.

Business case

The Digital Twin situation

The Digital Twin big idea

<Insert details of the problems the DT aims to solve for your organisation and the opportunities it creates.

- Insert bullet points
- Insert bullet points
- Insert bullet points>

The Digital Twin history - the current business as usual situation (where are we now)

<Describe the current situation with regards your data value. What is your level of data latency (deterministic / probabilistic) and ability to retrieve information in a digital environment. Can you integrate and analyse your data to give your business foresight etc?>

The Digital Twin strategy

The Digital Twin strategic dimension

<Describe your headline Digital Twin strategy. What options have been considered? Does it align with and contribute to your organisational business needs, spending objectives and service requirements. What are primary direct and indirect benefits that the Digital Twin strategy will unlock?>

The Digital Twin economic dimension

<Insert details of what economic and financial benefits might your Digital Twin strategy unlock??>

TIP: Use the template below to help generate the business case for a DT. An editable version of the business case template is available on the CDBB website.

The Digital Twin ask

What is the scope of your ask?

<Insert scope of the service that you are requesting and the Digital Twin services to be delivered>

What is your Digital Twin solution?

<Insert details of your solutions: technologies, hosting, software, micro-services, training and curation>

What is your Digital Twin delivery plan?

<Insert details of how your Digital Twin proposal can be delivered considering technologies, best practice, resourcing and support>

What is your Digital Twin implementation plan?

<Insert details of how your Digital Twin implementation plan? When and in what form can it be delivered? What are your significant milestones (what are the quick wins that can be tracked)?and impact from these. Will implementation be phased. Will there be a proof of concept?>

What is your Digital Twin funding and ROI plan?

- < Insert and indicative initial cost estimate of funding your proposed scope.
- What is the projected return on investment?
 - How will the project be funded?>

What are the main risks of your Digital Twin strategy?

<Insert the primary risks and controls from you Digital Twin strategy?>

DT legal and commercial

It is important that during the business case stage the legal and commercial aspects of the Digital Twin be considered, risks understood, and mitigations established. A good starting point is establishing an information protocol within each appointment for those creating information on your project to establish respective obligations and rights. It is especially important the Digital Twin be very clear on legal clarity and the strategic purposes e.g. informing key asset management decisions. Key considerations will include but are not exhaustive:

Responsibility: as a DT may have a complex contractual framework it is important that the main activities/roles/responsibilities - have been identified and allocated both for during the capital and operational phases.

Liability: of a DT is often a complex issue with the interconnectedness of systems there is often the question of who will be liable for the service performance and outcomes related to the DT? It is important that any contractual requirements be determined which may require to be stepped up into appointment documents.

Data capture: accuracy and tolerance of any sensing equipment, image capture of users etc. these should also be considered and a clear strategy developed prior to tendering.

Data hosting: issues might include data sovereignty, data back-up frequency, security of data centres, service level agreements. This will again link with liability issues.

Data ownership and intellectual copyright: who own's the various data sets, are there any limitations and restrictions on their use, especially if federated or integrated with other data sets.



Note

It is always recommended that you seek appropriate legal professional advice to assist with ensuring that all DT legal and commercial matters are dealt with appropriately.

DT legal and commercial

The data ecosystem of your DT maybe complex but it is essential that ownership be established especially of the DT as a whole.

There may also be data in your DT that is considered to be confidential. In such cases non-disclosure clauses may be required that is proportionate to the appointment or project needs. Permissions may be required to allow confidential data to only be viewed by certain users.

Software as a service: are there any consideration around service level agreements, unavailability and planned maintenance downtime.

Insurance: will you be using a new business model of equipment that may affect your normal insurance policies and models?

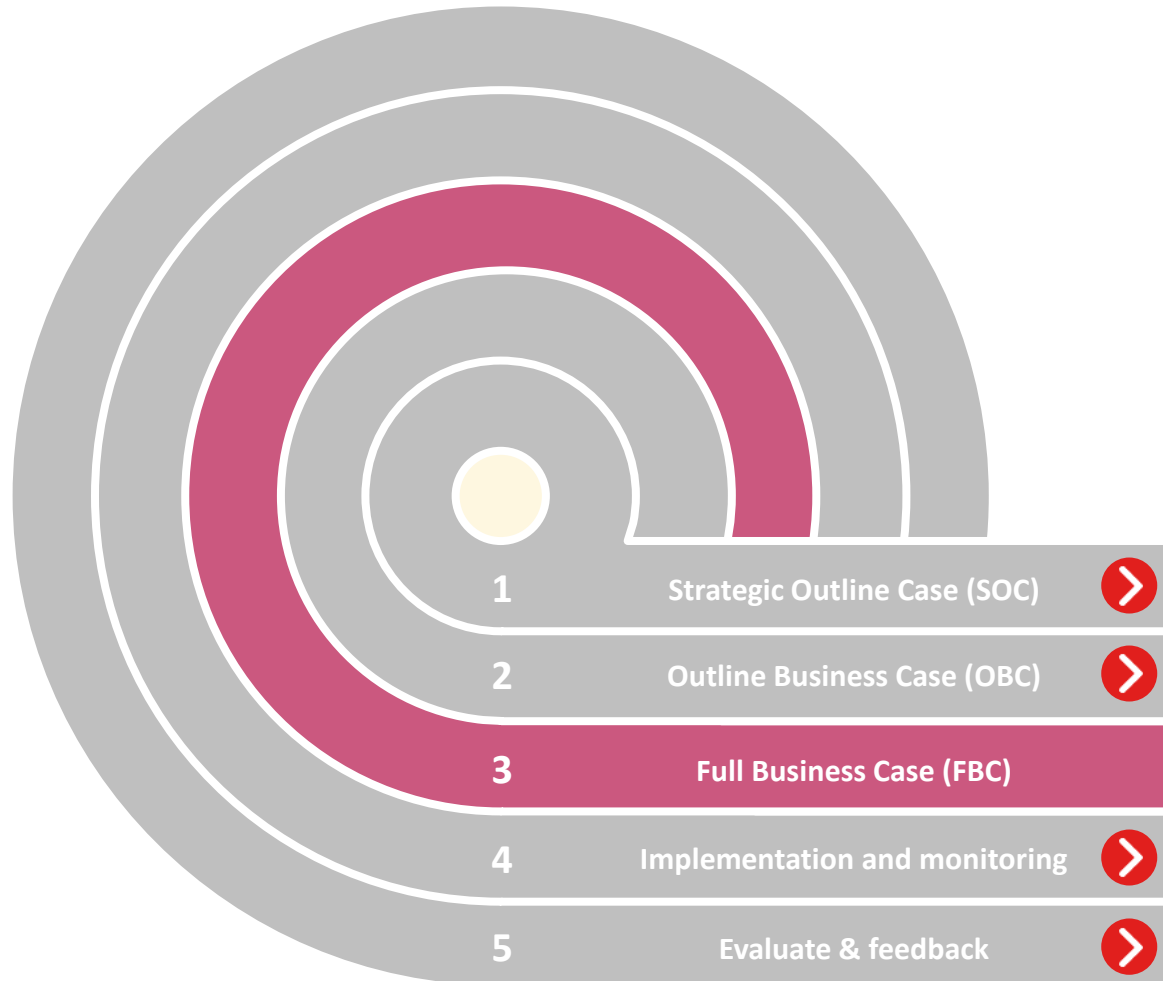


Stage checklist

TIP: Use the Outline Business Case (OBC) stage checklist below to confirm the status of each stage task. An editable version of the checklist is available on the CDBB website.

Ref	Stage task	Status
1	Reviewed key baseline Digital Twin (DT) literature and guidance such as the Gemini Principles	
2	Developed a headline DT strategy based upon clearly articulated purpose(s)	
3	Identified an appropriate DT sophistication level	
4	Defined your key DT characteristics	
5	Defined your DT value architecture aligned with purpose statements and overall investment outcomes	
6	Aligned your DT strategy with BIM, Soft landings and Facilities Management strategy	
7	Identified headline investment considerations	
8	Headline Return on Investment model	
9	DT built into project assessment report as appropriate	
10	Undertaken a DT legal and commercial review	

Full Business Case (FBC)



Stage purpose

This is the procurement phase for the project, which results in the Full Business Case (FBC), following negotiations with potential service providers prior to the formal signing of the contract(s). The purpose of the FBC is to record the findings of the procurement phase and to identify the option that offers the 'most economically advantageous tender' (MEAT) and best public value. In addition, the FBC records the contractual arrangements, confirms affordability and puts in place the agreed management arrangements for the delivery, monitoring and post-evaluation of the project.

At this stage we need to understand how the DT fits within the tender and procurement process and how it can be fully evaluated. This stage aligns with the Cabinet Office Gateway Review point 3 (Investment Decision)

Stage introduction >

Buying the Digital Twin >

strategy and value Stage >

Stage introduction

Full Business Case (FBC)

During this stage the focus is on procuring the proposal and preparing the Full Business Case (FBC)

At this stage we need to understand how the DT fits within the tender and procurement process and how it can be fully evaluated.

It is equally important to determine what aspects of the Digital Twin will remain within the ownership of the client organisation.

We also need to put in place the detailed management arrangements as to how the DT will support the successful delivery, monitoring and evaluation of the scheme.



Buying the Digital Twin

By this point the Digital Twin architecture should be now fully developed along with the operational strategy (data hosting, DT curation etc.) Data hosting should have been considered and the needs for a public cloud or private cloud in a contained data centre or a hybrid approach combining both. Data sovereignty is a key consideration which should also have a key position.

The operational strategy should also have considered how data will be managed during the in-use stage to mitigate against unnecessary growth of data and hence storage costs. Archiving, data cleansing and purging workflows and tools should therefore be defined. If required analytic services and tools if being procured through the capital works should be articulated to bidders.

It is important that the architecture considers how the DT will integrate with other Board platforms. This integration may necessitate 3rd party devices and network management platforms. Device and system management for your DT should also be fully specified.

DT Mobilisation Plan

It is important that the tendering parties develop a robust DT mobilisation plan submitted as part of their tender response. This should set out their approach to the DT mobilisation, this should include:

- The primary priority tasks, their durations, logic pathways;
- Any discovery sessions needed with key stakeholders;
- Design and procurement schedules including approval periods; and
- An outline test and commissioning strategy.

Invitation to Tender (ITT)

It is important that the Digital Twin is fully scoped out in an Invitation to Tender (ITT) it should clearly articulate:

- The goal and objectives of the Digital Twin;
- Service requirements e.g. analytics and data management;
- Technology and software;
- Security requirements;
- Commissioning and testing;
- Training ; and
- On-going support and maintenance.

Buying the Digital Twin

Implementation plan

Prior to work commencing on site it is important that a robust implementation plan is established with a detailed DT programme in place that can be monitored. It is essential that sufficient time is given to commissioning, testing, verification and validation. These periods should not be compromised.

Good project management is essential and the programme should be monitored on a weekly basis with extra efforts during deployment. Whilst there should be a detailed stand alone DT schedule this should be able to be rolled up and fit within the master project programme and link across to any dependent tasks especially from a services perspective.

TIP: A kick-off meeting should be held prior to works commencing with all methods statements, integration, commissioning and testing plans in place along with a RACI which includes interface and configuration management.

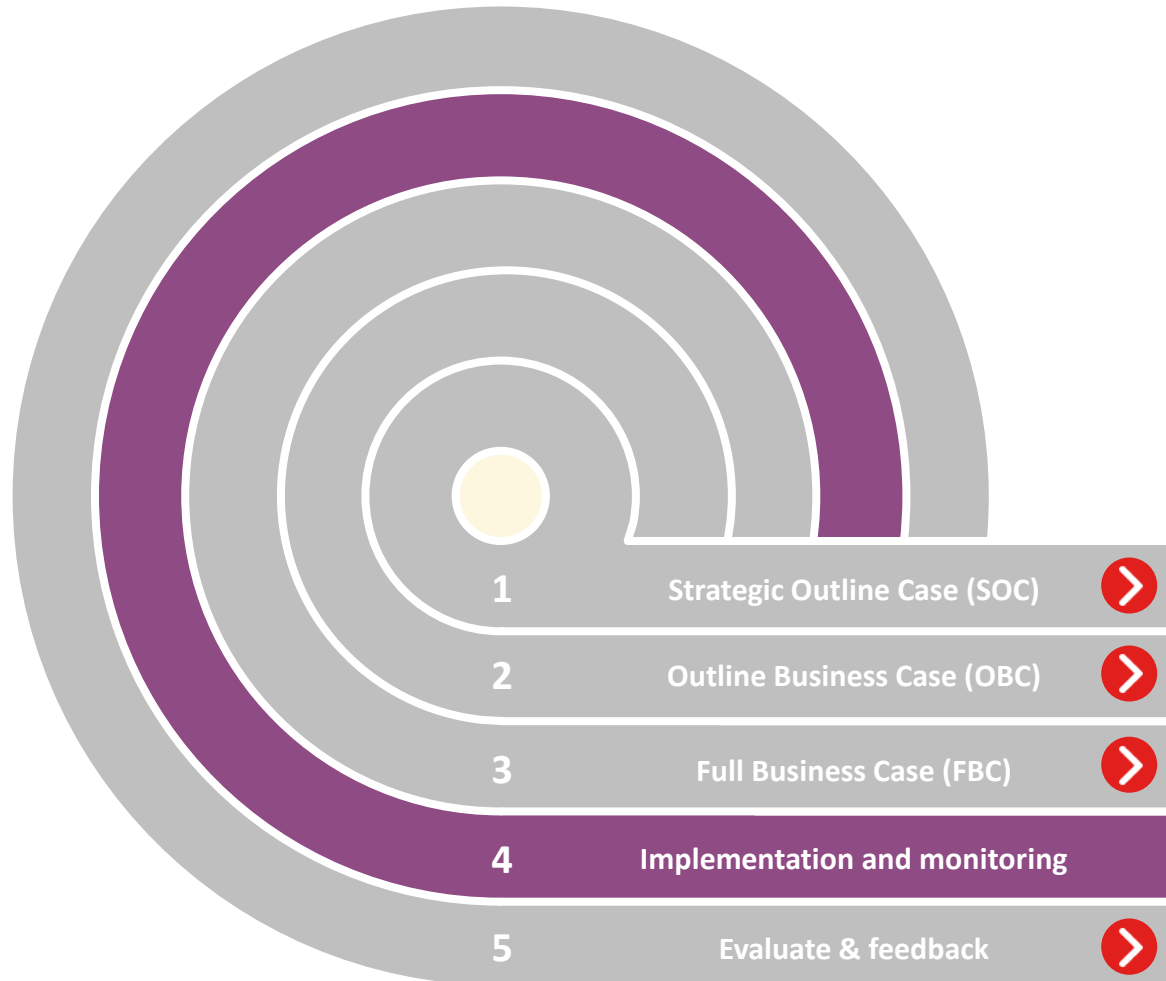


Stage checklist

TIP: Use the Full Business Case (FBC) stage checklist below to confirm the status of each stage task. An editable version of the checklist is available on the CDBB website.

Ref	Stage task	Status
1	Developed Digital Twin architecture along with the operational strategy	
2	Considered data hosting options and data sovereignty	
3	Developed a fully scoped out Invitation to Tender (ITT)	

Implementation and monitoring



Stage purpose

This is the Operational phase for the project, which results in the outcomes that were defined in the original strategy. This stage aligns with the Cabinet Office Gateway Review point 4 (Readiness for service).

Stage introduction ➤

Capture and create ➤

Stage checklist ➤

Stage introduction

Implement and maintain

This stage of the project aligns mainly between FBC approval and the Cabinet Office Gateway Review point 4 (readiness for service). It focuses on the transition from business case to technical design and delivery.

During this stage we are managing the Digital Twin (DT) delivery as part of the overall project delivery.

As we move from defining to delivery, we are ensuring that those appointed to deliver are procuring technologies and services which are well aligned to meet the specification.

It is important also to monitor the development of the digital models and representation to ensure that at handover it will integrate with associated data sensing and analytic layers.

DT will also form an important element of the project's commissioning, handover and training plan which all must be considered from the outset of this stage and embedded into the contract requirements.



Capture and create

At this stage it is important that the developed Digital Twin specifications and installation details have been reviewed to ensure that the goals and objectives can be met. It is especially significant that the proposed infrastructure (such as embedded IoT sensors, smart connected products) and building management system (BMS) requirements, integrated IT/OT systems have been selected to meet the DT objectives.

Often DT functionality is eroded through poor procurement choices e.g. not buying integrated controls and network but trying to link low-cost systems from numerous vendors as opposed a unified solution. Also consider the security vulnerabilities of any connected product especially those from Original Equipment Manufacturer (OEMs). Security is a vital consideration at this stage and only an authenticated and trusted ecosystem should be created with operational security and privacy by design a critical enabler.

The building information models (BIM) and any other digital representations such as gaming engines should be monitored throughout the construction stage to ensure they are aligned with the DT requirements and future connection points.

Integration of IoT sensors and gateway networks to the building management system if scoped should be completed at this stage. The often complex relationships between these cyber physical systems and their data sets may face interoperability issues which should be tested and resolved early on in this stage. During the commissioning period the performance of the DT should be tested against logged data.

At the point of handover and close out the operational digital model (as-built BIM and potentially a serious gaming engine) should now be fully connected to the unified operational data layer and user acceptance testing undertaken.

Testing the DT security (including audits) and integration with other related asset management systems (AMS) should be fully verified.

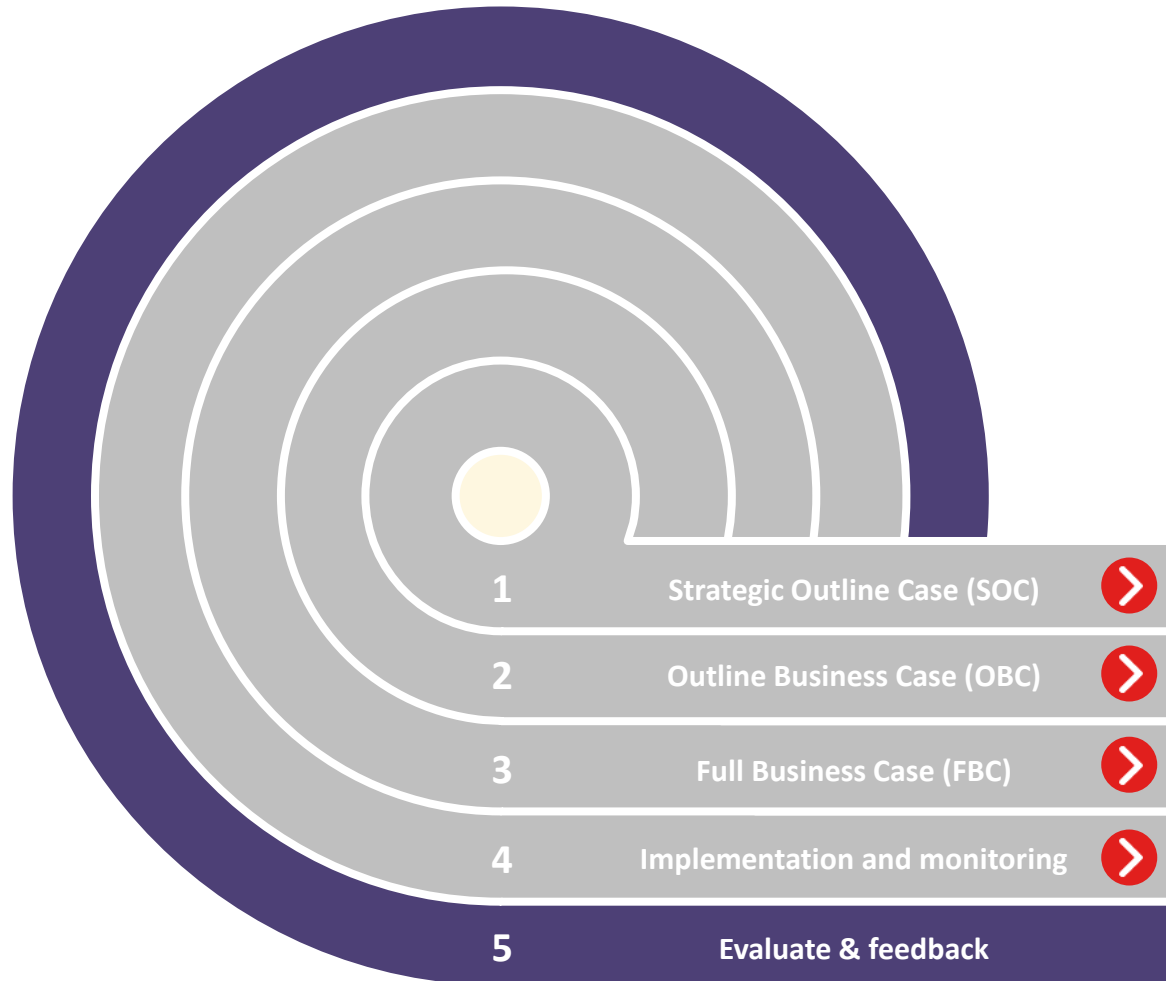
It is important that user training be undertaken and processes to curate and maintain the Digital Twin in place.

Stage checklist

TIP: Use the Implementation and monitoring stage checklist below to confirm the status of each stage task. An editable version of the checklist is available on the CDBB website.

Ref	Stage task	Status
1	Reviewed proposed specifications and installation details to ensure the DT goals and objectives can be met	
2	Security vulnerabilities of proposed connected products and systems reviewed to ascertain and vulnerabilities and develop controls to remove or mitigate DT form part of the mindfully security risk register	
3	Monitor development of digital representation (BIM / Gaming engines) to ensure they will be a suitable interface, and level of information need appropriate	
4	Commissioning of DT data capture in concert with operational technology / BMS commissioning	
5	User acceptance testing and audits of system	
6	User training and operational manuals in place	
7	DT curation strategy in place	
8	Formal sign off that the DT is ready to support service	

Evaluate & feedback



Stage purpose

This is the Operational phase for the project, which results in the outcomes that were defined in the original strategy. This stage aligns with the Cabinet Office Gateway Review point 5 (Operations review & benefits realisation).

Stage introduction >

Collect, analyse and do >

Stage checklist >

Stage introduction

Evaluate & feedback

This stage of the project aligns with the operational stage (Cabinet Office Gateway Review point 5) where the focus is on the Digital Twin (DT) bringing about the outcomes defined in the original strategy.

With the DT now live it is important at this stage be curating the cyber-physical environment which will be constantly evolving.

It is also important the DT use is realizing benefits and lessons learned are being captured.



Collect, analyse and do

Collect, analyse and do

It is important that at this stage to curate and make use of the Digital Twin (DT) to meet the use cases set out in your initial strategy, collecting data dynamically, analysing it and using to support decision making and insight.

In a properly implemented Digital Twin, the interactions between sensors, control data, historical data and other dynamic data should all now be integrated, with a clear user interface, in an easy-to-use structure that can evolve and change with the needs of the built asset's operation.

Usability of the DT is key to successful digital transformation during this in-use stage. The organisations that see the most benefit from DT technologies are those that use them to improve business operations, making it easier for stakeholders to quickly and confidently make the best decisions. This may include the use of micro-services and web applications that are tailored towards very specific

Depending upon level of sophistication your DT may help with safely and securely testing and training new operating environments, providing stakeholders with an accurate simulation of potential outcomes.

DT technology is a foundation on which to support a digital transformation, an effective tool for organisations to support capital project execution as well as operational excellence initiatives for the lifecycle of the project.

“

DT technology is a foundation on which to support a digital transformation, an effective tool for organisations to support capital project execution as well as operational excellence initiatives for the lifecycle of the project.

Stage checklist

TIP: Use the Evaluate & Feedback stage checklist below to confirm the status of each stage task. An editable version of the checklist is available on the CDBB website.

Ref	Stage task	Status
1.	DT is being curated effectively with systems monitoring in place	
2.	Security of DT and related systems being monitored with regular audits	
3.	DT benefits being realised and captured	
4.	A structured feedback loop in place where data can inform future investment decisions	
5.	Lessons learned captured and shared	
6.	An operation and maintenance plan in place for key DT technologies such as edge devices	

No regrets

In most cases your journey into Digital Twinning will eventually transcend an individual project and it is always important to consider the future. Your Digital Twin should be based upon a strategy of no regrets whereby it can increase its use cases and ultimately fit within an ecosystem of other federated Digital Twins.

The National Digital Twin programme (NDTp) run by the Centre for Digital Built Britain highlights that when high quality data can be shared across organisations and sectors there will be substantial impact.

The NDTp is working to develop an information management framework to connect Digital Twins. The Pathway Towards an Information Management Framework: A Commons for a Digital Built Britain, sets out the technical approach for the development of an Information Management Framework (IMF) to enable secure, resilient data sharing across the built environment. Organisations are encouraged to follow the development of the IMF and follow its work and embrace its principles including the need for:

A Foundation Data Model (FDM): a consistent, clear understanding of what constitutes the world of Digital Twins, and how we want to be able to formally describe them and their applications in a machine-interpretable way.

A Reference Data Library (RDL): the particular common set of classes and the properties we will want to use to describe our Digital Twins.

An Integration Architecture (IA): the protocols that will enable the managed sharing of data, the production of models, the scripting of queries and the analysis, interpretation and application of model outputs.



The Pathway towards an Information Management Framework



Engage and join the conversation

Please share comments on the Digital Twin Navigator:
enquiries@cdbb.cam.ac.uk

Follow progress: www.cdbb.cam.ac.uk



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Centre for Digital Built Britain



www.digitaltwinhub.co.uk



About the Construction Innovation Hub

The Construction Innovation Hub's vision is a world leading construction and infrastructure sector, future proofed through collective innovation, that delivers long term environmental, economic and social benefits for the UK. The Construction innovation Hub is funded by UK Research and Innovation through the Industrial Strategy Challenge Fund.

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