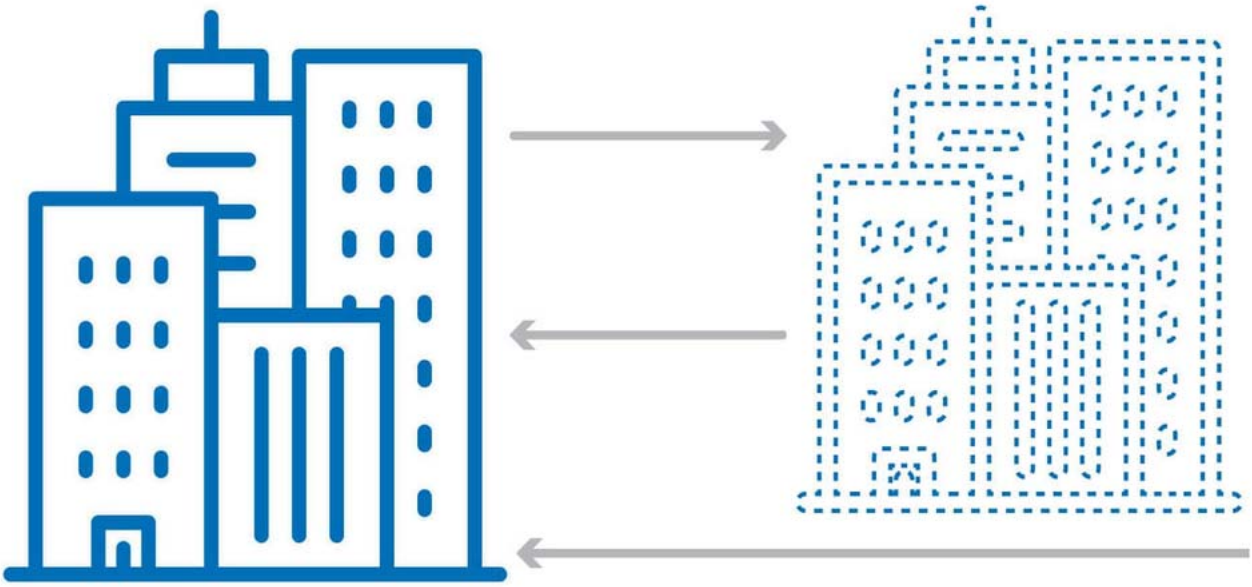
DIGITAL TWINS

An ABAB position paper

January 2021

Digital Twin: A realistic digital representation of assets, processes or systems in the built or natural environment. The complexity of that representation, and degree of connectedness, varies depending on maturity.



Australasian BIM Advisory Board (ABAB)

In May 2017, the Australasian BIM Advisory Board (ABAB) was established by the Australasian Procurement and Construction Council (APCC) and the Australian Construction Industry Forum (ACIF), together with NATSPEC, buildingSMART Australasia and Standards Australia. This partnership of national policy and key standard-setting bodies represents a common-sense approach that captures the synergies existing in, and between, each organisation's areas of responsibility in the built environment. It also supports a more consistent approach to the adoption of Building Information Modelling (BIM) across jurisdictional boundaries.

The establishment of the ABAB is a first for the Australasian building sector with government, industry and academia partnering to provide leadership to improve productivity and project outcomes through BIM adoption.

The ABAB is committed to optimal delivery of outcomes that eliminate waste, maximise end-user benefits and increase the productivity of the Australasian economies. The ABAB has evolved from a previous APCC–ACIF collaboration established in 2015 at a BIM Summit. This summit produced resource documentation to support BIM adoption (refer to www.apcc.gov.au for copies).

Members of the ABAB have identified that, without central principal coordination, the fragmented development of protocols, guidelines and approaches form a significant risk that may lead to wasted effort and inefficiencies, including unnecessary costs and reduced competitiveness, across the built environment industry.

www.abab.net.au

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Executive Summary

Context

This ABAB position paper has been prepared to outline the value that Digital Twins and Building Information Modelling will deliver for governments.

Purpose

It is important ABAB has a good understanding of Digital Twins so that it can continue to provide informed and appropriate advice to government agencies and ultimately industry.

Overview of Digital Twins

Section 2 introduces the basic concepts and key topics associated with Digital Twins including:

- Definition: To enable informed dialogue about Digital Twins by the many stakeholders, there has to be a common language for describing them. A Digital Twin can range from monitoring the key readings of a single asset to a 3D visualisation of a city integrated with live information from an Internet of Things. An appreciation of this diversity helps stakeholders avoid talking at cross purposes.
- Evolution: Briefly examines how the concept of Digital Twins has developed in other sectors such as the aerospace industry before it was applied to the built environment.
- Related concepts: This section places Digital Twins in the context of related concepts such as BIM, Digital Engineering, Smart Cities and Intelligent/Smart Infrastructure and the relationships between them.
- Potential benefits: These include increased productivity and collaboration, reduced construction and operating costs' improved safety and optimised asset performance, compliance and sustainability.
- Issues and challenges: These include communication about Digital Twins between stakeholders, security, data provenance, interoperability, business models for sharing data and ongoing maintenance.
- Examples of recent Digital Twins: International examples of Digital Twins of buildings, e.g., County Hall building, The Hague and cities, e.g., Hong Kong, Singapore and West Cambridge.

Frameworks for evaluating Digital Twins

Section 3 examines frameworks for evaluating Digital Twins. Frameworks or metrics including maturity, complexity, vitality and use cases are particularly useful when planning a Digital Twin because they focus attention on its purpose and what type of response is appropriate.

Organisational decision making about Digital Twins

This section covers organisational – government and industry – decision making about procuring and using a Digital Twin. It builds on concepts introduced earlier such as evaluation frameworks. It examines the value of Digital Twins to an organisation.

Digital Twins for governments

This section examines Digital Twins more specifically from a government perspective. It provides a summary of the key organisations actively involved with Digital Twins in Australia.

ABAB position and role regarding Digital Twins

The ABAB Digital Twins working group concluded that the need for a nationally consistent approach to Digital Twins, interoperability, open standards, etc is just as important as it is for BIM, and it is critical ABAB has a good understanding of Digital Twins to continue providing informed and appropriate advice to government and industry.

The working groups' position is to align with and support those organisations that already have made a significant contribution in this area and those that align with ABAB's stated vision and principles.

The working group identified the following broad options for ABAB:

1. Continue to raise awareness of issues such as the importance of national consistency in policies and standards for Digital Twins.
2. Support policy and standards developed by others through participation with relevant bodies.

ABAB DIGITAL TWINS REPORT

1 INTRODUCTION

1.1 Context

- There has been increasing interest in Digital Twins and their application over the last few years, as evidenced by the large number of articles published and seminars held on the topic. This interest is driven by the enormous potential for efficiency and productivity Digital Twins appear to offer. They could be characterised as the current 'hot topic' relating to the digitalisation of the built environment. Recent government initiatives such as the NSW Spatial Digital Twin are manifestations of this trend.
- At ABAB's 11 February 2020 meeting the board decided to review its objectives and agenda with regard to Digital Twins and develop an ABAB position on them.

1.2 Purpose

- The purpose of this position paper is to provide the ABAB Board with sufficient information on the subject of Digital Twins to inform its decisions about what role, if any, it will undertake regarding them.
- To this end this position paper will:
  - Provide a brief overview of Digital Twins to improve understanding of basic concepts, benefits and issues relevant to them.
  - Distinguish the difference between Digital Twins and related concepts such as BIM, Digital Engineering and Smart Cities.
  - Explain how BIM impacts on, and connects with, Digital Twins.
  - Summarise published government positions on Digital Twins in Australia and NZ.

1.3 Audience

- ABAB board members and their constituents, typically those in strategic and executive roles in government agencies or private organisations responsible for managing relatively large portfolios of built environment assets, and who may be considering Digital Twins to assist them with their responsibilities.

2 DIGITAL TWINS OVERVIEW

2.1 Description

It is difficult to find a single universally accepted definition of Digital Twins because of the range of implementations the concept encompasses. A Digital Twin can range from monitoring the key readings of a single asset to a 3D visualisation of a city integrated with live information from an Internet of Things.

Typical descriptions include:

- A digital twin is a digital representation of a physical asset, process or system, as well as the provider of information that allows its users to understand and model its performance. A digital twin can be continuously synchronised from multiple sources, including sensors and continuous surveying, to represent its near real-time status, working condition or position. A digital twin enables users to visualise the asset, check status, perform analysis and generate insights to predict and optimise asset performance. [1]

- Data from multiple Digital Twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes. [2]

2.2 Digital Twins - evolution

- NASA were pioneers of Digital Twins for remote monitoring, controlling and running simulations of their spacecraft from Earth.
- The aerospace and defence and nuclear sectors are frequently cited as the next most advanced in digital twin use, using them to manage highly complex assets.
- Offshore oil and gas use Digital Twins to monitor and predict maintenance schedules for their structures in the interest of safety and efficiency.
- Digital Twins are used in manufacturing at various scales – from component to factory to wider logistics levels – to manage process efficiency, control, safety and logistics.
- The use of Digital Twins for the built environment is just beginning to take off. Fully realised examples are rare, even at the level of individual assets. [3]

2.3 Related concepts

The concept of Digital Twins derives from – and shares many features with – other digital technology concepts. It is important to understand the differences between them when discussing them with others to avoid talking at cross purposes. In addition, Digital Twins and the related concepts described below can be implemented in a wide range of ways. So, it is also important to establish a common understanding of their scope and sophistication of implementation to avoid large differences in aspirations and expectations arising.

2.3.1 Artificial Intelligence (AI)

AI is the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions. The term may also be applied to any machine that exhibits traits associated with a human mind such as learning and problem-solving. In the context of Digital Twins it usually applies to a digital system that is able to recognise patterns in data about a physical asset – generally provided by sensors – and make appropriate responses – generally through digital controls and/or actuators – to achieve goals such as operational efficiency and safety.

2.3.2 Building Information Model (BIM) – Product

An object-based digital representation of the physical and functional characteristics of a facility. The Building Information Model serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its lifecycle from inception onward. [4]

2.3.3 Building Information Modelling (BIM) – Process

BIM is a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations. BIM is a strategic enabler for improving decision making for both buildings and public infrastructure assets across the whole lifecycle. It applies to new build projects; and crucially, BIM supports the renovation, refurbishment and maintenance of the built environment – the largest share of the sector. [5]

2.3.4 Digital engineering

Digital Engineering is a collaborative way of working, using digital processes to enable more productive methods of planning, designing, constructing, operating and maintaining assets. [6]

2.3.5 Digital thread

A digital thread describes the framework which connects data flows and produces a holistic view of an asset's data across its product lifecycle. This framework addresses protocols, security, and standards. Typically, the digital thread connects digital twins, digital models of physical assets, or groups of assets.

The term digital thread is also used to describe the traceability of the digital twin back to the requirements, parts and control systems that make up the physical asset. [7]

2.3.6 Intelligent/Smart Infrastructure

Smart Infrastructure combines physical assets and digital technologies to improve planning, delivery and management of services. Smart Infrastructure leverages remote monitoring, cloud computing and digital twin technologies to enable real-time data analytics, predictive maintenance and improved network management. [8]

2.3.7 Internet of things (IoT)

The Internet of things (IoT) describes the network of physical objects—“things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet. [9] In the context of Digital Twins, Smart Infrastructure and Smart Cities it enables the connection between physical assets and digital models.

2.3.8 Smart Cities

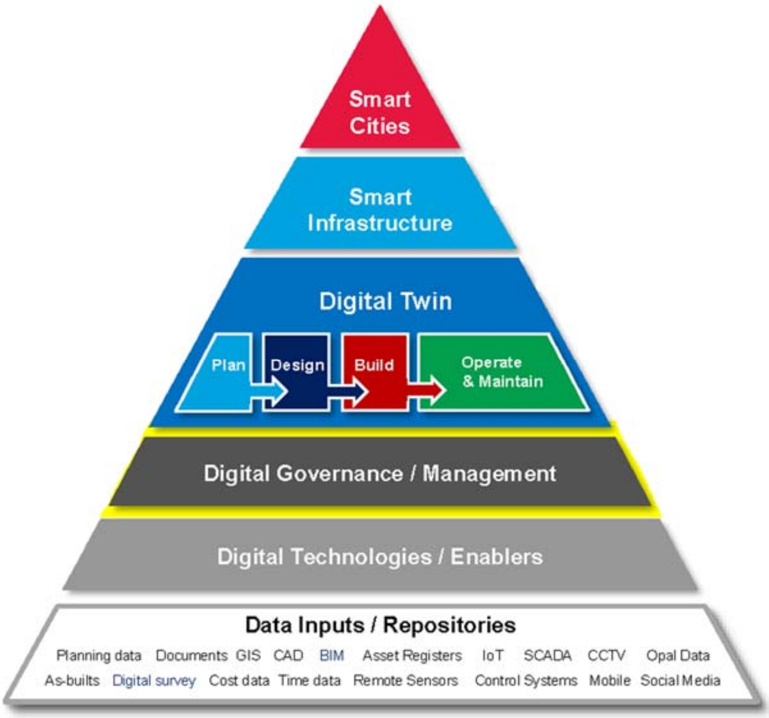
Smart Cities use data and new technologies to deliver improved services that create more liveable, workable and sustainable communities. Smart cities coordinate information using integrated platforms to optimise government services across sectors. [10]

They apply the new generation of information technologies, such as the internet of things, cloud computing, big data and space/geographical information integration, to facilitate the planning, construction, management and the provision of services for cities. [11]

The main reasons for developing Smart Cities include:

- Improving city management;
- Improving the lifespan, reliability and resilience of assets;
- Improving the effectiveness, reliability and security of public services;
- Improving the quality of the urban environment and liveability;
- Integrating Smart Infrastructure.

A smart sustainable city ensures that it meets the needs of present and future generations with respect to economic, social and environmental aspects. While the term Smart Cities is generally applied to an aspirational outcome, related concepts such as BIM, Digital Engineering and Digital Twins are the enablers of the outcome.



Source: Vaux, S. *How do we build Smart Cities?* TfNSW presentation

Figure 2.3.8 Digital Twins, Smart Cities and Smart Infrastructure

2.4 The difference between Digital Twins and BIM models

The Centre for Digital Built Britain (CDBB) notes: "what distinguishes the digital twin from any other digital models is its connection to the physical twin." [12] It could be added: in particular, the bi-directional exchange of data between the two. This differs from BIM, which traditionally does not include real-time data collected from the construction site or building in operation.

A Building Information Model is converted to a digital twin by enriching the model with static and live data. This includes the asset register, maintenance logs, warranties and O&M manuals — as well as live data from the building management system. [13]

A BIM model can be part of a digital twin, but a digital twin generally encompasses other relevant infrastructure assets and is continuously updated to reflect the near real-time status of the physical assets. [14]

2.4.1 Commentary on Digital Twins and related concepts

Digital Twins are a reframing and extension of concepts that have existed in BIM or Digital Engineering (DE) for some time. Although the term Digital Twins was coined by Dr Michael Graves in 2003, they have been used in a wide range of industries for many years, but that term was not used to describe them.

Digital engineering is generally seen as a broader term than BIM because it applies to the process of using digital processes including virtual models to deliver assets of all types, not just buildings.

Building something twice – first virtually to resolve design and construction issues before constructing it in the physical world – is a fundamental concept of DE and BIM. The benefits of virtual construction – the optimisation of designs before they are finalised and the optimisation of their delivery and operation – are applicable to all the concepts covered here.

While the early focus in DE and BIM was on the delivery phase of assets, over time this broadened to include the operational phases. The concept of as-built models and their use for asset or facility management has now been a recognised BIM use case for some time.

As more people started to specify and create as-built models, different levels of implementation could be identified. These differences related to geometric accuracy, scope of data incorporated in or linked to the model, and the extent to which the model was validated against specified information requirements and the physical asset it modelled. Also, the provisions made for updating the model to reflect those in the physical asset became important considerations.

Just as the scope of use cases regularly implemented expanded over time, the scale of things modelled expanded from buildings to infrastructure and from facilities and campuses to city precincts to cities, even national infrastructure networks.

The section **Complexity** outlines how the complexity and interconnectivity of Digital Twins can vary widely from a single asset to large systems of assets. Just as the term BIM became widely adopted because it seemed to encapsulate a set of concepts in a succinct and memorable way, the term digital twin seems to have captured people's imagination for similar reasons.

As noted in **The difference between Digital Twins and BIM models**, the key difference between a BIM model and a Digital Twin is the latter's connection to the physical twin. Whereas BIM models typically need to be updated manually, what sets a Digital Twin apart is the model being updated by data gathered directly from the physical twin. This is enabled by sensors and communication channels such as cables, radio links or the internet. The concept can be extended to bi-directional exchanges where automated systems including those applying artificial intelligence (AI) are used to control the operation of the asset. This connection makes Digital Twins attractive to infrastructure agencies and urban administration bodies because of their potential for effectively managing complex and dynamic systems that have a significant impact on many people's lives.

The term Smart Cities is closely related to the concepts embodied in Digital Twins, particularly when applied to extensive models of urban areas dynamically updated with data.

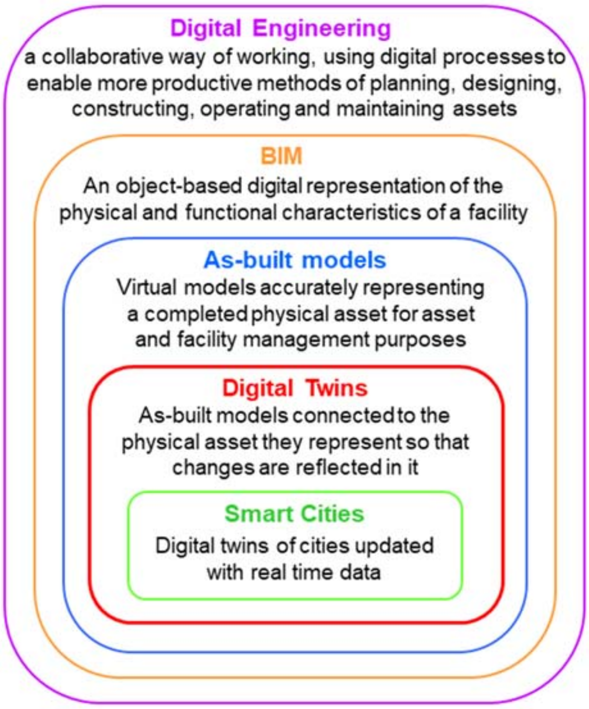


Figure 2.5 Overview of Digital Twins and related concepts

The recent interest in Digital Twins, intelligent infrastructure and smart cities reflects the diffusion of ideas about digital engineering. Concepts initially of interest to designers progressively spread to contractors, asset owners and operators, and now urban management bodies, as each became aware its potential benefits and enabling standards and technologies became more accessible.

2.5 Potential benefits

Increased productivity and collaboration

Vital information about the built asset such as design documentation can be stored and analysed throughout its lifecycle and kept current. This information can be easily accessed and used to assist decision making and de-risk project execution.

Reduced construction and operating costs

Virtual scenarios on construction sequencing and logistics can be run and visualised, familiarising workers with required tasks and reducing costly re-works. Data-driven decision-making can be used for predictive maintenance planning and responding to unexpected events, which helps streamline costs throughout the asset's operational life.

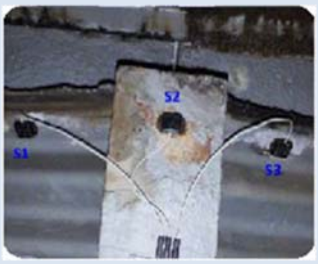
Improved safety

Digital Twins can be used to interrogate the design to identify, eliminate or minimise safety hazards during construction and operation of an asset.

On-site workers, occupants, visitors, passengers, etc can be given real-time tracking and alerts about a site or location, including hazard notifications and emergency situation response instructions.

Sensors can be attached to critical infrastructure and the data gathered linked to a Digital Twin so that its condition can be continuously monitored and asset managers alerted to any potential failures in good time. In 2018, the Morandi Bridge in Genoa collapsed, killing 43 people. It is less likely this would have happened with an arrangement like this in place.

Case study – Sydney Harbour Bridge (SHB)


In the late 1950s, when the the tram tracks on the SHB were replaced by two extra road lanes (Lanes 7 and 8), their substructure was strengthened with 800 concrete and steel jack arches, each about a metre and a half in length. These lanes take the highest traffic load on the bridge.

In 2014 Data61 & Cisco developed an IoT monitoring system for the jack arches. Prior to this, they were manually inspected at 2 year intervals

3 low cost tri-axial MEMS accelerometers were installed on each of the 800 jack arches, i.e. 2400 sensors in total. Monitoring is now conducted 24/7, enabling early defects to be detected.

Further benefits have been achieved with Machine Learning and predictive analytics.

Sensors are linked to Baasis (Bridge and Asset Spatial Information System), which is a complete 3D model of the SHB in ERSI ArcGIS. This model is used to track the condition of individual elements e,g, structural and fatigue capacity, paint condition.

Routine maintenance is now prioritised based on specific element condition, average condition, accessibility or visibility to the public. The system also helps to identify 'hot-spots' and predict the future condition of the bridge. See https://data61.csiro.au/

Source: Vaux, S. *Digital Engineering - Transforming Infrastructure* TfNSW presentation

Optimised asset performance and sustainability

Operational and occupational data can be monitored and analysed in real-time, providing valuable insights on how the asset is used and currently performing. This provides the ability to identify areas of poor performance or risk, and model options or scenarios for rectifying or mitigating them. [15] AI/machine learning can also be used to provide predictive analysis.

Ongoing compliance

Digital twins could be used to check compliance with regulations and codes when they are amended.

2.6 Issues and challenges

Communication

The visually compelling presentations of Digital Twins that abound can sometimes create heightened expectations about them. At first sight they "*may appear to be an exact replica, however, Digital Twins are not necessarily realistic representations, but are rather relevant abstractions of the physical asset. It is not necessary for even the most advanced smart city to digitally replicate the fluting of every column or the mortar of every brick. In other words, we need to develop Digital Twins that are fit for purpose, and the level of fidelity will vary depending on the primary use cases. Digital Twins need not attempt to mirror everything about the original system*." [16]

It is worth outlining the evolution of Digital Twins in the context of other paradigms such as DE, BIM and Smart Cities and many of the concepts they share because the issues that arose – and continue to arise – with BIM, e.g. differing understandings, interpretations and expectations of stakeholders, also arise with Digital Twins and smart cities.

For effective communication on the subject, shared terminology, concepts and understanding are needed. For their effective decision making about them, a clear understanding of the potential costs, benefits and constraints associated with the range of options available is needed. At the heart of the decision-making process is a clear understanding of what value an organisation is looking for them to provide and how its requirements can be articulated to those appointed to satisfy them.

Security

Inevitably the aggregation of data in Digital Twins also creates a security risk, particularly for critical national infrastructure. Likewise, it creates a need to validate and authenticate data and prevent unauthorised changes, which is compounded in situations with multiple parties and sources. [17] This complex topic is not discussed in detail within this document, but anyone considering implementing a Digital Twin should make themselves aware of the potential risks.

Data provenance

Digital twins are reliant on the accuracy and currency of their constituent data. Rigorous processes for checking the provenance and reliability of data are essential for them to be trusted and effective.

Interoperability

Probably the biggest technical challenge to creating Digital Twins is managing the interoperability of the different software packages required to create them. Open standards such as buildingSMART's Industry Foundation Classes (IFC) can assist but a coordinated approach by all members of the team creating the Digital Twin must be established early in the process. Updates to software means that addressing interoperability issues is an ongoing process.

Business models for sharing data

The data used to create and manage a Digital Twins comes from many sources. Agreements that define the responsibilities and authority of parties providing data, and their financial rewards, have to be negotiated.

Ongoing maintenance

Because of software updates and inevitable changes to the physical model, ongoing maintenance and management has to be factored into the planning of Digital Twins. As for physical assets, these costs represent the largest proportion of the total life cycle cost of an asset.

2.7 Examples of recent Digital Twins

County Hall building – The Hague

This Digital Twin of the Dutch government's County Hall building in The Hague is a replica of an office building of around 16,000 square metres. Over 30,000 data points from the existing Building Management System were first extracted. Next, another 350 IoT sensors were added, specifically tailored to measure user interaction. The model of the building was created through 3D scanning, and linked to a scientific simulation model which is fed data from the sensors. [18]

Neuron City – Hong Kong

This Digital Twin of Hong Kong city, called Neuron City, is a platform that maps physical spaces and people to a virtual city (i.e. the Digital Twin). Its operators are able to monitor, predict and control aspects of the physical city by a closed-loop data stream, GIS, BIM, IoT, cloud computing and AI. The first-stage work was completed in 2018/19. The prototype included the following functionalities:

- 3D modelling and spatial analysis

- Visualisation of simulation data and statistics
- Building data dashboard
- Parametric design module
- Real-time data visualisation and analysis. [19]

Singapore Digital Twin

From bus stops to buildings, Virtual Singapore is a data-rich, live Digital Twin developed to produce a central platform for the modelling done by different government agencies. The Digital Twin draws on IoT sensors, big data and cloud computing, combined with 3D models, geospatial datasets and BIM. Virtual Singapore was co-developed by Arup and Dassault Systèmes, by leveraging its existing software platform. The interplay of map and terrain data, real-time traffic, and demographic and climate information show how a single change could affect the lives of millions of people, and the systems they depend upon. Virtual Singapore offers a platform that can be used by urban planners to simulate and test solutions in a virtual environment. [20]

West Cambridge Digital Twin

The aim of the project is to develop a dynamic Digital Twin of the Institute for Manufacturing (IfM) at the University of Cambridge, along with the wider West Cambridge campus, to demonstrate its impact on facilities management, productivity and wellbeing.

Its goals are to:

- Demonstrate the impact of digital modelling and analysis of infrastructure performance and use on organisational productivity.
- Provide the foundation for integrating city-scale data to optimise services such as power, waste management and transport, and understand the impact on wider social and economic outcomes. [21]

Other recent Digital Twins

- Birmingham CIM model
- Helsinki
- Rotterdam
- Schiphol Airport

Australian examples are included under **Current Digital Twin initiatives**.

3 FRAMEWORKS FOR EVALUATING DIGITAL TWINS

Frameworks for describing and evaluating Digital Twins are useful for establishing a common understanding between stakeholders and facilitating fruitful dialogues about them.

Some of the facets of frameworks developed to describes and evaluate Digital Twins include:

- Maturity
- Complexity: scale, scope and interconnectedness
- Vitality (the level of information exchange between the physical asset and the model)
- Use cases

These facets are described in more detail below.

3.1 Maturity

A number of scales to measure the maturity of Digital Twins have been proposed.

They grade Digital Twins from static virtual models with little attached data and connection to the physical twin through to ones that, through two-way data integration and interaction, can autonomously manage aspects of the physical twin.

Maturity dimensions include:

- Connectivity modes: how the data transfer takes place, from manual and unidirectional to automatic bi-directional connectivity.
- Update frequency: how often the model is updated, from monthly or weekly to real-time or event-driven.
- Integration breadth: how widely integrated the Digital Twin is with other systems; from individual assets to global interoperability.
- Digital model richness: how varied and descriptive the data are; from descriptions of geometry, position and so forth to multivariate modelling of physical behaviour.
- Simulation capabilities: how predictive it is of future states; from a static representation of the current state to the ability to look ahead and prescribe actions based on simulations.
- Human interaction: how users can interface with the model; from smart devices to intelligent multi-sense coupling (via augmented/virtual reality).
- CPS intelligence: how capable the cyber-physical system is of automating decisions and interventions; from human-triggered to full-autonomy.
- Product life cycle: how much of a product or asset's life cycle benefits from insights from a Digital Twin; from a focus on the beginning-of-life (design and build) to whole-life monitoring. [22]

Digital Twin maturity

Maturity*	Defining Principle	Outline Usage
0	**Reality Capture** e.g. point cloud, drones, photogrammetry, or drawings/sketches	• Brownfield (existing) as-built survey
1	**2D Map/System or 3D Model** e.g. object-based, with no metadata or BIM	• Design coordination • Asset optimisation
2	**Connect Model to Persistent (static) Data, Metadata** e.g. documents, drawings, asset management systems	• **Digital Engineering** • 4D/5D simulation • Design/asset management
3	**Enrich with Real-Time Data** e.g. from IoT sensors etc	• Operational efficiency
4	**Two-way Data Integration and Interaction**	• Remote and immersive operations • Control the physical from the digital
5	**Autonomous Operations and Maintenance**	• Complete self-governance • Total oversight and transparency

*based on log scale of complexity & connectedness

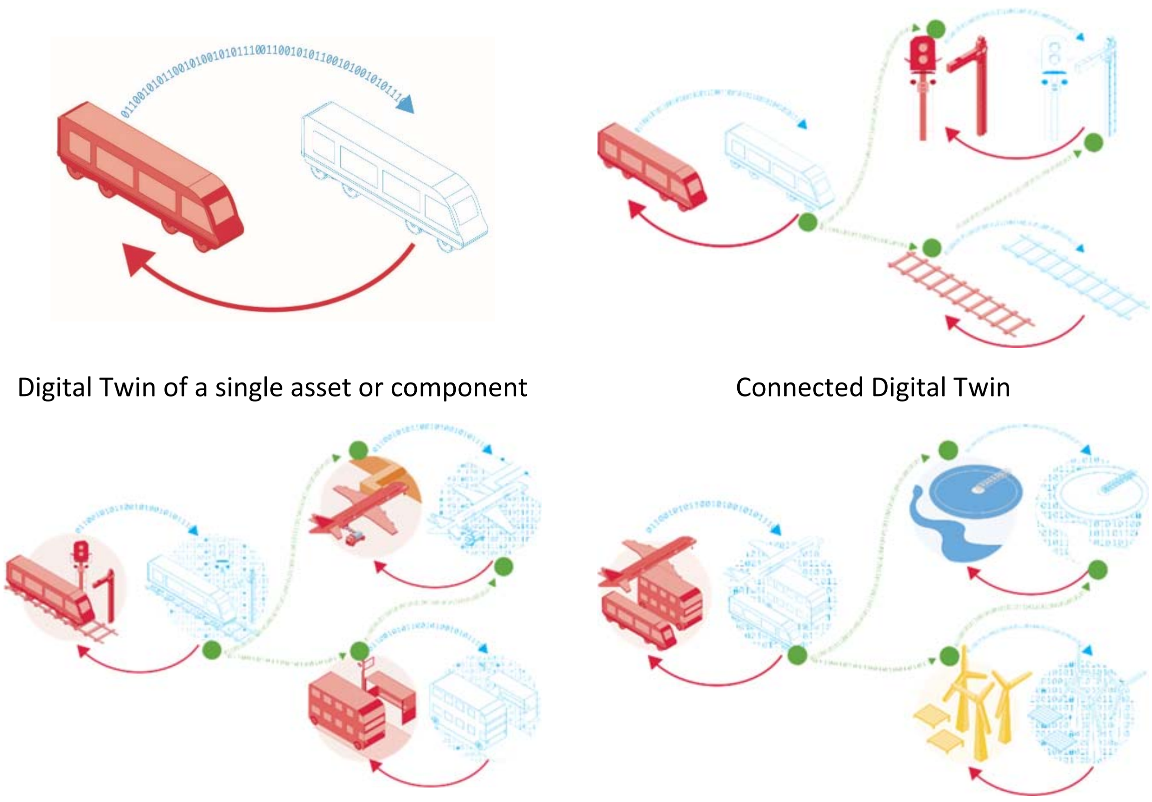
Source: IET 2019 *Digital twins for the built environment*

3.2 Complexity

Digital Twins for the built environment range from basic to complex. Complexity derives from aspects such as scale, scope, the granularity of representation (how accurate it is on spatial and temporal scales, for example) and interconnectedness.

Digital Twins can exist at many scales of complexity. For example:

1. A Digital Twin of a single asset or component: digital model communicating to and from its physical twin;
2. Connected Digital Twins: one or more Digital Twins connected, with communications flowing between multiple Digital Twins and their corresponding physical twins;
3. Ecosystem of connected Digital Twins: series of Digital Twins created within a single service network (i.e. for a network of health facilities or for a transport network). Through the connection of multiple Digital Twins, organisations can transform previously stand-alone systems into integrated networks that leverage greater computer capabilities and data analytics to improve productivity and efficiency;
4. National (or State) Digital Twin: a complex web of connected Digital Twins (including multiple ecosystems) for the whole of a geographic area, allowing communication across multiple different types of service networks (i.e. where Digital Twins for transport networks can communicate to Digital Twins for health, education and other services). Communication across service networks facilitates improvements to all services. (example – Digital Twin of a sporting or entertainment venue can communicate with the transport Digital Twin ecosystem to improve transport services at peak times). [23]



Digital Twin of a single asset or component — Connected Digital Twin

Ecosystem of Digital Twins — National Digital Twin

Source: Lamb, K. 2019 *Principles Based Digital Twins: A scoping review* CDBB

Figure 3.2 Digital Twins – from simple to complex

Different assets, especially those supporting quite disparate service functions, will be managed to achieve different outcomes. However, users wanting to leverage the benefits that accrue from multiple Digital Twins require a common ground for information management and decision-making. Creating ecosystems of Digital Twins requires a focus on technical and semantic interoperability.

3.2.1 Metrics for describing complexity

An Arup document *Digital Twin – Towards a Meaningful Framework* [24] proposes grading Digital Twins into five levels of complexity based on the following four metrics:

- Autonomy
- Intelligence
- Learning
- Fidelity

3.3 Vitality

The level of data exchange between the physical asset and the model can range between two broad poles:

1. Dynamic: The model is fed or updated by live data flows from a physical asset, e.g. a building, or one of its components, like a lift motor. Insights from the Digital Twin can then be used to make changes in the physical twin, e.g. shutting down a lift for maintenance. This type of model is used for the real-time management of a building or infrastructure network.
2. Static: The model changes periodically as long-term data about the physical asset are added. This type of Digital Twin is used for strategic planning, and feedback into the physical twin is achieved through the capital investment process. Sometimes referred to as a "digital shadow" to differentiate it from more dynamic types of Digital Twins. [25]

3.4 Use cases

3.4.1 Typical use cases

How Digital Twins are intended to be used – their use case/s – is a fundamental consideration when planning for and designing them. Digital Twins have been used for numerous purposes across many sectors. See **Digital Twins – evolution** for a description of some of them. Some uses for the built environment include:

Infrastructure and building development – delivery and operation

- Support a range of asset management functions across the whole-of-asset-lifecycle.
- Scenario planning and risk modelling to inform design.
- During delivery – improve approval processes, enabling automated progress monitoring, assessing as-built to as-designed, improving resource planning and logistics, monitoring safety and quality, assurance and compliance.
- Assess the effectiveness of approval processes to ensure alignment with strategic development objectives.
- Long-term views of maintenance needs to inform planning and scheduling
- Identify efficiencies in utility use to optimise demand, improve cost efficiency and lower costs for consumers.

Risk management

- Scenario planning can assist in identifying risks to an asset and analysing the likelihood of that risk materialising and quantifying the impact (and associated costs) of that risk being realised.
- They can be used in the delivery of infrastructure to assist the early management and prevention of risks.

3.4.2 Selecting appropriate use cases

Questions that influence the choice of appropriate use cases include:

- What goals and objectives does the Digital Twin serve?
- What problems is the Digital Twin intended to address?
- What information does it need to provide to answer these questions?
- What are the information priorities?
- In what structure and format does this information need to be provided?
- For whom, when and how?

4 ORGANISATIONAL DECISION MAKING ABOUT DIGITAL TWINS

This part covers organisational – government and industry – decision making about-procuring and using a Digital Twin rather than the decision-making opportunities that arise once a Digital Twin is developed and adopted in an organisation.

It addresses questions such as:

- Does my organisation need a Digital Twin?
- Is a Digital Twin a potential solution to my problems?
- Could a Digital Twin improve my organisation's planning and decision-making capability more broadly?
- Should my organisation deploy a Digital Twin with other digital engineering and/or data tools?

4.1 Value of Digital Twins to an organisation

Digital Twins can support a large and diverse range of uses at different scales, for different sectors and for different uses ranging from asset management to exploring policy options. Therefore, it is quite likely that an organisation could benefit from implementing a Digital Twin.

A Digital Twin could be of particular use if an organisation:

- Is responsible for infrastructure design, development, delivery, construction, operation and maintenance;
- Is responsible for developing options to respond to policy challenges (such as resilience to climate change, planning for population and demographic change, etc) and is required to do scenario planning / simulation testing to understand the short-, medium- and long-term impacts of different responses / options;
- Undertakes horizon scanning or long-term planning to proactively identify problems or emerging problems, and facilitates early intervention;
- Wants real-time data to better control the correlating real-world physical twin;
- The more complex the problem / challenge, the greater the potential benefits of a Digital Twin;

A Digital Twin can be used as one of many tools within an organisation's digital engineering approach, particularly in conjunction with BIM and GIS.

4.1.1 General considerations

While there may appear to be a compelling case for a Digital Twin within an organisation, or to support a particular project, it is imperative to-consider the value it will add and whether the organisation is ready to make effective use of it. Digital Twins are time- and cost-intensive;

investment in a digital solution should only proceed where there are the appropriate resources available for its development and, more importantly, its ongoing use and management.

It should also be recognised that BIM/DE methodologies in themselves are not sufficient to address complex project challenges and risks. Other factors such as integrated planning and business cases, efficient choice of contracts, government and political engagement and well-considered decision making by experienced project personnel are critical to successful outcomes. [26]

Equally important as the technical and financial considerations are those about organisational readiness. Is there the buy-in and commitment across the organisation to make the necessary cultural change to support a Digital Twin's implementation and take full advantage of it afterwards?

Considerations include:

- Is there senior executive-level commitment to a Digital Twin solution? If not, then support for the use and ongoing upkeep of the twin is likely to dwindle over time.
- Is the organisation sufficiently technologically mature to realise the benefits of a Digital Twin?
- Does the organisation have the data needed to develop and continue to update the Digital Twin? If not, what is the strategy for obtaining and managing the data? Are the organisation's data management practices sufficiently mature to support the development and ongoing use of the Digital Twin?
- Does the organisation have the appropriately skilled resources and on-going capacity to develop and manage a Digital Twin?
- Does the organisation have the systems in place to manage and curate the data models underpinning the Digital Twin in perpetuity? (i.e. what does a Digital Twin mean for the organisation's record management practices and policies?)
- Will a Digital Twin provide a sufficient return on investment to justify its implementation? A cost-benefit analysis should be undertaken to confirm the case for investment. Not all benefits will be financial, but still need to be evaluated in a consistent and considered way.
- What are the other options, and what will a Digital Twin provide that they do not?
- How can a Digital Twin complement other tools and systems? Is it likely to become the primary decision-making tool, or will it simply be an input to a broader decision-making system?

4.2 Selecting the appropriate type and scope of Digital Twin/s for an organisation

When thinking about deploying a Digital Twin, practitioners should think beyond the immediate need and consider how it could support the organisation's needs more broadly.

Consider:

- Not only the requirements needed to solve the immediate problem, but requirements needed to support the organisation's longer-term needs. Think strategically about other potential uses for the Digital Twin and develop a scope taking them into consideration but be careful not to gold-plate potential solutions in the process.
- Interoperability with other Digital Twins already developed for the organisation's Digital Twin ecosystem – open standards developed by organisations such as buildingSMART, the Open Geospatial Consortium (OGC), ISO and IEC are crucial for ensuring interoperability;

- Connectivity to the organisation's (current or future) Digital Twin – do not become locked into one type of proprietary software.
- Interoperability and compatibility with Digital Twins used by other organisations that your organisation may wish to connect to.

4.2.1 Type and scope considerations

When ascertaining the appropriate type and scope of the Digital Twin required, consider:

1. Its purpose (and there may be more than one purpose) and operation. Key question: What is the function of the Digital Twin?
2. Data: the type of information required across the life cycle of the asset, where that information is stored and how it can be accessed and used. It is important that information is structured in a reusable way that can be quickly and effectively exchanged between systems.
3. Access: who will have access to the information within the Digital Twin or gain control of the physical asset through it.

4.3 Implementing Digital Twins

The enabling technologies needed to integrate the physical asset with its Digital Twin can only be decided after the issues noted above have been considered. Then the types of software and IT infrastructure required need to be clearly specified.

It is important to consider interoperability when thinking about the type of Digital Twin you may develop.

Most Digital Twin implementations start small, such as monitoring the performance of a single part within an asset but expand over time. This happens in two ways. Firstly, an organisation may bring a number of smaller Digital Twins together to give a complete picture of an entire asset, system or business process. Second, organisations add more sophisticated capabilities – such as simulations – into an existing Digital Twin.

In either case, having to rebuild functionalities within the Digital Twin to meet these evolving requirements should be avoided. Plan for securely scaling up functionalities while maintaining performance to meet the extra data that needs to be gathered and managed.

Avoid being locked into proprietary software that will not meet-an organisation's evolving needs.

As for BIM and Digital Engineering, early involvement of those who will be responsible for managing and maintaining the Digital Twin with those responsible for delivering it is critical to its success. This approach is more likely to both improve delivery of the physical asset and facilitate its effective operation after handover.

4.3.1 Implementation considerations

Considerations include:

- Privacy, ethics and security concerns (of the organisation, of external parties, of communities / citizens) [27]
- Document management

For Government users, it is important for them to consider their Digital Twin policy settings.

- Australian governments will be expected to comply with principles set out in the Australian BIM Strategic Framework;
- Governments may have begun development of a state or city Digital Twin – ideally as these develop, governments will want each individual Digital Twin that is brought into the ecosystem to have the same "look" – therefore some governments are beginning to develop

technological and visual standards that will underpin the development of Digital Twins in their jurisdictions.

4.3.2 Specifying Digital Twins

Many government agencies have already generated BIM/DE specifications for design and D&C contracts. These can be used to develop a specification for Digital Twins. Specification development would include liaising closely with the users and custodians of existing asset maintenance and operation systems and with the delivery team to ensure data can be used at each stage of the project.

Typical elements of the specification include:

- Function of the Digital Twin
- Interoperability with client systems
- Defects liability period
- Instruction manual/User guide
- Training in the use of the Digital Twin

5 DIGITAL TWINS FOR GOVERNMENTS

5.1 Value

By definition, Digital Twins are digitised data repositories and virtual representations of one or more physical assets. Governments are typically the largest asset owners and operators, with buildings, infrastructure and other asset holdings across the spectrum of services. Therefore, Digital Twin offer significant potential value and benefit to government users in the management of assets across the whole-of-asset-lifecycle (including planning, design, development, construction, handover and operation).

However, their value to government is not limited to asset management. Digital Twins and ecosystems can support government contemplate policy challenges and response options for a diverse range of issues.

5.1.1 Use cases of value to governments

Some uses of Digital Twins and their value to government include:

- Infrastructure planning, e.g. overlaying planned infrastructure on existing infrastructure to show service need and interdependencies and evaluating optimal timing of bringing investments forward. Digital Twins are increasingly being used to support the planning and development of new urban developments.
- Supporting place-based planning: Digital Twins are becoming more relevant as place-based planning becomes more common and replaces portfolio-based planning.
- Supporting multi-scale and multi-stakeholder decision making environments: The Government decision-making environment is becoming increasingly complex, with greater and increasingly complex stakeholder relationships, greater competition for scarce funds and increasingly complex regulatory systems and policy settings. Digital Twins can support the increasingly difficult analysis needed to underpin decision-making processes.
- Digital Twins of a planned project can assist with impact assessment, planning and consultation processes by creating visual models in a virtual reality setting to improve stakeholders' consideration of project impacts.

- Optimising transport network planning and use by integrating public transport location, speed and carrying capacity data with other data (including from within a transport ecosystem or across ecosystems for different services – e.g. can communicate traffic flow issues to emergency services or conversely could receive data from entertainment venues, etc to provide advanced warning of demand peaks).
- Modelling population dynamics and movements in planned developments to optimise accessibility and efficiency.
- Anticipating and modelling the impact of natural disasters on the community and infrastructure, improving emergency management by monitoring infrastructure and populations in real time and better planning response, recovery and reconstruction efforts. Digital Twins can help build resilient infrastructure.

5.2 Digital Twins in Australia

Australian and New Zealand Land Information Council (ANZLIC) is the peak government body in Australia and New Zealand responsible for spatial information.

The *ANZLIC Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* outlines the vision of a federated ecosystem of securely connected Digital Twins. It contains high-level principles to help industry, government and the research sector develop Digital Twins in a harmonised way that considers common requirements and interoperability. The principles draw on the UK's Centre for Digital Built Britain's Gemini Principles.

The opportunity of developing Digital Twin ecosystems within and for Australia is significant and represents significant value. However, to realise this value and benefits will be challenging.

It will require:

- "a shared vision, clear objectives, guiding principles, appropriate standards and defined roles and responsibilities".
- collaboration and coordination across industry, government, the research sector and the community.

A national digital twin for Australia

A digital twin ecosystem for Australia would bring together a broad range of government, industry, construction, manufacturing, transport and utilities sectors. It would have no single owner or contributor, but comprise interoperable data and connected Digital Twins likely set within a set of common and open standards.
Data sharing is the primary lever to realising the benefits of a digital twin ecosystem, however this must be governed by security rules and authorisation processes to enable appropriate, role-based access to securely shared data. Governance must maintain clear data custodianship for contributors, appropriate protections for private, confidential and sensitive information and consideration of commercial impacts, such as intellectual property.

Key elements of a Digital Twin ecosystem in Australia include:

- Agreed rules, protocols and standards to create, contribute, discover, share and access data, services and capability, including appropriate security;

- Ensuring data custodianship and authority remains with the contributing organisation so that custodians can maintain control over shared data and authority for their respective functions and data (custodians responsible for the veracity, reliability and integrity of their data);
- Defining Digital Twin-compatible and standards compliant data that will allow for Digital Twins in different sectors and government jurisdictions to mature at different rates and levels of complexity, while maintaining interoperability;
- Seamless integration of data from multiple sources and sectors, defined and open APIs to enable data sharing across multiple sources and platforms;
- Maintaining data currency;
- Customisable, user-driven access to data in a form that can leverage new technologies and adapt to user needs, such as connecting Digital Twins in a particular region or city for localised insights. [28]

5.3 Current Digital Twin initiatives

A Digital Twin for Sydney

The Government of New South Wales is creating an open-source interactive platform on which to capture and display real-time 3D data and 4D data on the urban environment. The project, which enlists the help of DFSI's Spatial Services and CSIRO's Data61, aims to stimulate development in the region. The twin will assist with planning in, design for and modelling of the city. The project, currently at the proof of concept stage, will eventually be publicly accessible through standard internet browsers. Industry players and government at all levels will collaborate to give users access to a wealth of information to apply in their work and lives. Meanwhile, the government will invoke applications ranging from natural disaster response, to transport scheduling, to security. www.spatial.nsw.gov.au/what_we_do/projects/digital_twin

Infrastructure Data Management Framework (IDMF)

The NSW Department of Customer Service IDMF provides guidance to support the management of data created and used during the planning, design, construction and operation of infrastructure across NSW Government. It was developed in response to recommendation 27 of the NSW State Infrastructure Strategy 2018-2038, alongside initiatives such as the 4D Foundation Spatial Data Framework, the NSW Digital Twin, the Internet of Things Policy and the Asset Management Policy. The IDMF helps NSW Government to realise its smart places vision, as part of broad reforms focused on the convergence of digital and infrastructure. Guidance on the creation and management of digital twins features heavily. https://data.nsw.gov.au/IDMF

Smart Cities Standards Roadmap

Standards Australia, in partnership with the Smart Cities reference group (made up of stakeholder organisations from a range of key bodies across Australia), recently released its *Smart Cities Standards Roadmap*, which highlights participation on the ISO/IEC Joint Technical Committee JTC 1/Advisory Group 11 (Digital Twin) as a priority to develop standards related to Digital Twin technology and their application within Smart Cities. Smart Cities Standards Roadmap

Digital Twin is considered to be an essential part of the Smart Cities initiative, both internationally and nationally. Key points:

- Recommendation 6 of the Roadmap is: "Australian stakeholders nominate experts to participate in the JTC 1/Advisory Group 11 Digital Twin, to develop standards related to Digital Twin technology and application within Smart Cities".

- At a project level, Smart Cities projects include the digital transformation of paper-based processes and a range of 'smarts' that include: Smart bins, Smart waste, Smart mobility and Digital Twins.
- Mapping of existing ISO and IEC committees to understand their relationship to the many aspects of Smart Cities has already commenced as part of this initiative.

Cooperative Research Centre for Low Carbon Living (CRC/LCL): Precinct Information Model (PIM)

Research project details: www.lowcarbonlivingcrc.com.au/research/program-2-low-carbon-precincts/rp2011-pim-open-digital-information-standard-throughout

5.4 Organisations actively involved with Digital Twins

Australian and New Zealand Land Information Council (ANZLIC)

The peak government body in ANZ responsible for spatial information. Its role is to develop policies and strategies to promote accessibility and usability of spatial information. ANZLIC is an advocate for the resolution of national level issues and provides a link between government and industry, academia and the general public. ANZLIC's vision is that spatially referenced information that is current, complete, accurate, affordable and accessible is used to inform decision making for economic, social and environmental outcomes. www.anzlic.gov.au/

CSIRO Data61

CSIRO Data61 recently built a Digital twin prototype of Western Sydney in partnership with the NSW Department of Customer Service's Spatial Services. The NSW Digital Twin is built on Data61's TerriaJS platform, an open-source technology that also powers National Map and the National Drought Map. It incorporates Data61's open source catalogue technology MAGDA, whose built-in security features ensure only authorised individuals have access to certain types of data.
https://data61.csiro.au/en/Our-Research/Our-Work/Future-Cities/NSW-Digital-Twin/NSW-Digital-Twin

Digital Twin Consortium

A global ecosystem of users who are accelerating the Digital Twin market and demonstrating the value of Digital Twin technology. Members set de facto technical guidelines and taxonomies, publish reference frameworks, develop requirements for new standards and share use cases to maximize the benefits of Digital Twins. www.digitaltwinconsortium.org/

Smart Cities Council Australia and New Zealand (SCCANZ)

A member-based organisation dedicated to helping catalyse action and investment in technology and data solutions that can be used to create smart, sustainable cities and communities with high-quality living and high-quality jobs. https://anz.smartcitiescouncil.com/

Virtual Australia & New Zealand Initiative (VANZI)

A not-for-profit entity established in 2011 to broker the creation of Virtual Australia & New Zealand (VANZ), a federated, fully integrated, 'photo-realistic' secure 3D dataset that enables users to model the natural and built environment across Australia and New Zealand - using any software and portal of their choice. www.vanzi.com.au/

6 ABAB POSITION AND ROLE REGARDING DIGITAL TWINS

6.1 Digital Twins working group findings

The working group's research revealed significant interest in Digital Twins across the built environment sector by governments, government agencies, industry organisations, companies and individuals. This interest has also resulted in substantial initiatives across these sectors, i.e. interest has translated to action.

This document reflects the need for clarity of definition and an understanding of appropriate use.

BIM is a foundation of Digital Twins. Because of their potential scale, the need for a nationally consistent approach to Digital Twins, interoperability, open standards, etc is just as important as it is for BIM. Again because of scale and a potentially much larger group of stakeholders, realising this will be even more challenging than for BIM.

6.2 Suggestions

ABAB has been providing advice to government on BIM and it is critical it has a good understanding of Digital Twins to continue providing informed and appropriate advice.

The working group supports ongoing **alignment with** those organisations that align to ABAB's stated vision and principles.

This approach would include:

- Support for open data exchange standards necessary for the interoperability of Digital Twins developed by organisations such as buildingSMART, the Open Geospatial Consortium (OGC), ISO and IEC. Unless you have interoperability across different data sets and contributors you cannot realise the full potential of Digital Twins.
- Support for government and peak body initiatives seeking to create a nationally consistent approach to Digital Twins including, but not limited to those described in the previous section.
- A similar approach to working with the Board of Treasurers on the *Australian BIM Strategic Framework*.

buildingSMART International (bSI) has identified three areas to focus further developments. They are closely related to the topic of standardisation:

1. standards for data models.
2. standards for data management and integration.
3. data security and privacy. [29]

6.3 ABAB's position

ABAB's involvement with policy and standards development:

1. Raise awareness of issues such as the importance of national consistency in policies and standards for Digital Twins.
2. Support policy and standards developed by others.
3. Support policy and standards development work by others through participation.

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