Infrastructure Lifecycle:
A Case for Change

A Digital Twin Consortium Technical Brief

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Many papers and presentations present the use of digital twin technology to enhance the processes needed to deliver infrastructure such as a building, road or tunnel. In this paper, the term infrastructure is used in a broader sense to include buildings and any other part of the built environment.

Digital twins enable an increase in productivity, quality and efficiency within the world of the built environment. However, we have learned that the benefits of a digital twin may not be fully realized when applied to an existing process. The process must change to unlock all the benefits of digital twins. The impact is best illustrated by the way that transformational thinking regarding the use of digital twins changed the way we looked at the day-to-day activities that we performed in our corporate roles and discussed within the Digital Twin Consortium Infrastructure Working Group.

1 OUR JOURNEY

The Infrastructure Working Group began its journey to generate use cases to demonstrate the power of leveraging a digital twin. Our approach was to align with traditional lifecycle phases undertaken by the infrastructure sector, Plan & Design, Construct, and Operate, as illustrated in **Error! Reference source not found.**. How wrong could we have been?

Figure 1-1: The conventional focus of the phases of infrastructure development.

From the list of our use cases, some sat within traditional silos, for example "capturing and accessing data in relation to the construction, commissioning and handover of the digital twin as the single source of truth" sits nicely within the construction silo, but "design for manufacturing and assembly of high-performance façade systems approach" would straddle design and construct. It became evident that a new lifecycle model was needed to accurately place some of these use cases onto the project lifecycle.

2 STAGE 1 – EXPANDING THE LIFECYCLE

The first change was to expand the four phases into a more detailed depiction Figure 2-1.

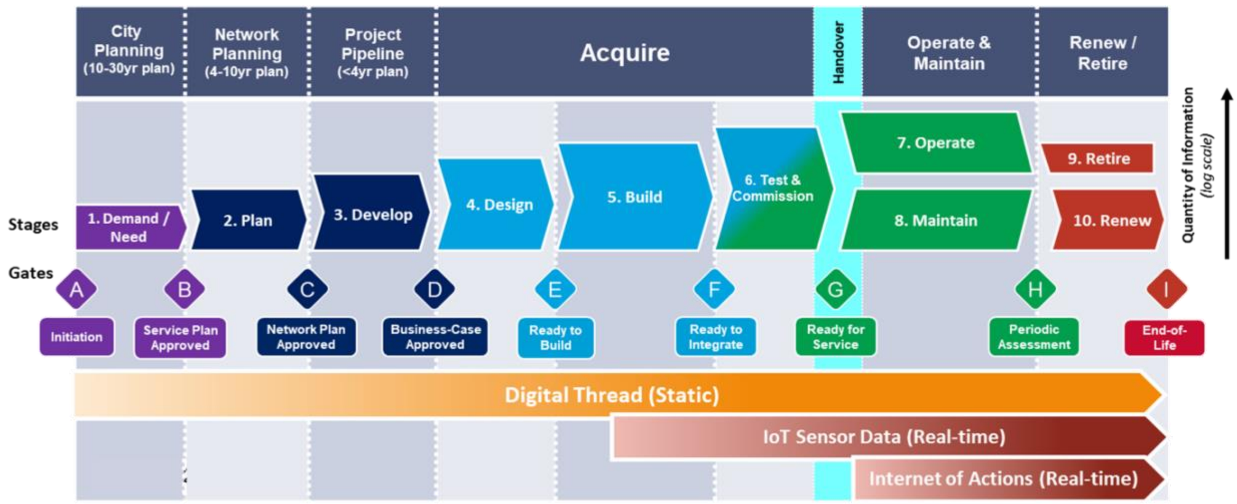

Figure 2-1: Expansion of the traditional lifecycle diagram.

Key to this change was the introduction of the following concepts:

- Additional planning cycles for traditional linear infrastructure systems and networks that are common in "horizontal" or infrastructure projects but maybe less common in "vertical" or building projects, largely because of public procurement rules.
- Movement from construct to build and test/commission to represent a more systemized approach rather than the traditional bespoke method.
- The expansion in operations to incorporate the concept of a lifecycle for maintenance and renewal.
- Gates to recognize/govern the progress from one phase to the next.

A digital thread was introduced onto the lifecycle diagram to represent the linking of data created in different phases, enabling collaboration as the infrastructure moves through its lifecycle.

But whilst this defined the use cases more definitively, the additional complexities made the diagram difficult to comprehend and did not add value.

3 Stage 2 – The Transformation from Project to Product Approach

Digital twins involve designing and building through scalable industrial manufacturing processes – a more automated approach. A focus on outcomes meant that they needed to be planned or simulated in a closed-loop process.

Continuous improvement must be a core tenet and lifecycle management must be applied to the whole, making the process circular. Rather than depicting a built-environment project being a one-off project with a distinct start and finish, the majority of work we undertake is on brownfield sites, or in tenant improvement or retrofit of existing facilities. It was evident that we needed to rethink our lifecycle diagram, from linear to circular.

The Centre for Digital Built Britain (CDBB) had developed its concepts around the asset lifecycle, and the introduction that the initial construction lifecycle is only a small part of the overall timeline. With permission from *CDBB,* we used their diagram as a template to overlay the phases in more detail, the diagram evolved, as illustrated in Figure 3-1.

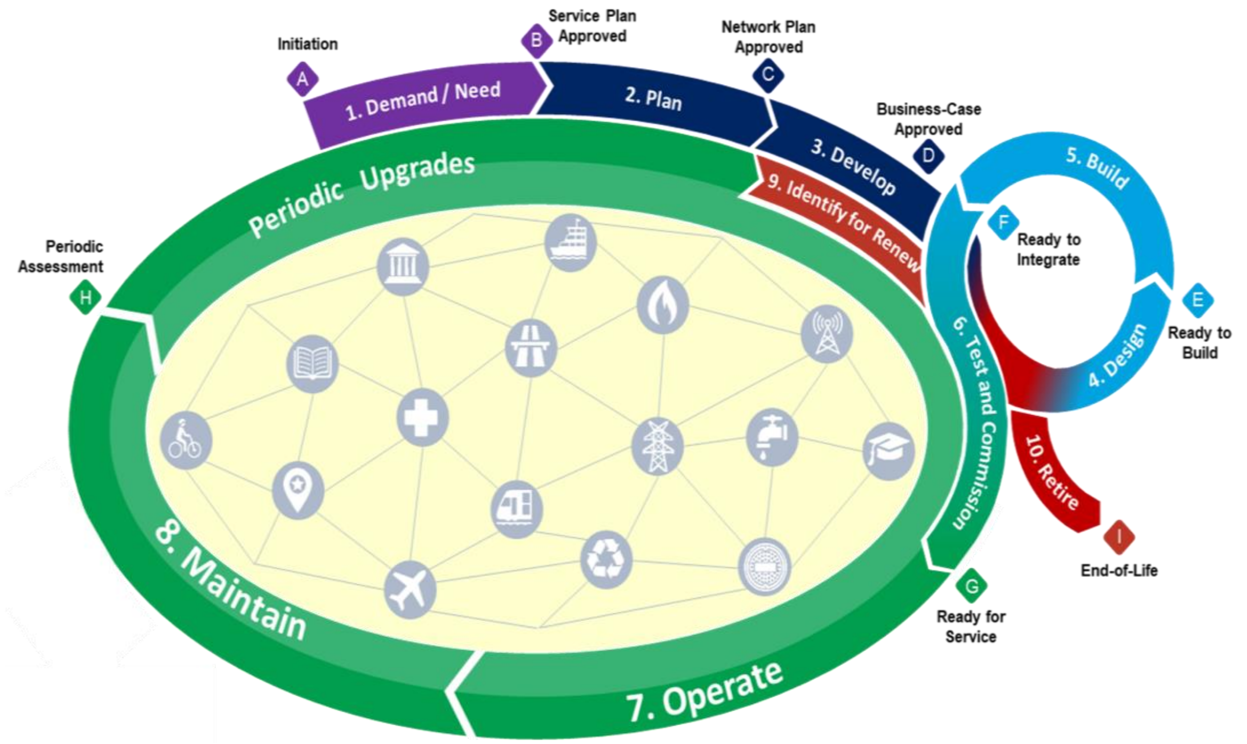

Figure 3-1: Assigning a lifecycle approach to the lifecycle diagram.

Key to this version was the introduction of the following concepts:

- Overlaying the developed phases onto the lifecycle template,
- Inclusion of smart IoT devices interfacing with each of the phases and
- The plan through test and commission phases are reduced in size to better represent the actual Lifecycle.

Through learning and feedback and to simplify the diagram, we removed:

- The reference to the digital thread, recognizing that this would form another diagram, and
- Detailed stages of planning and design associated with linear infrastructure, ensuring a more generic application.

4 STAGE 3 – SIMPLIFICATION OF THE LIFECYCLE

Figure 3-1 still had a start and a stop, suggesting it was a linear process and the wording had legacy processes from design and build; it did not incorporate an industrialized approach.

The next iteration introduced feedback links, demonstrating continuous improvement in the lifecycle and depicting a more circular product-based approach that creates repeatable processes that can be used on multiple projects. In addition, color coding was introduced to show the steady state (green) and change (blue).

The lifecycle in this form demonstrated the context of where our use cases and discussions were focused and so helped rapidly advanced our progress. However, further simplification was required to ensure the lifecycle, a description of the highest abstraction level of process of the built asset, did not represent the lifecycle of a digital twin, nor was it intended for this diagram to represent all views.

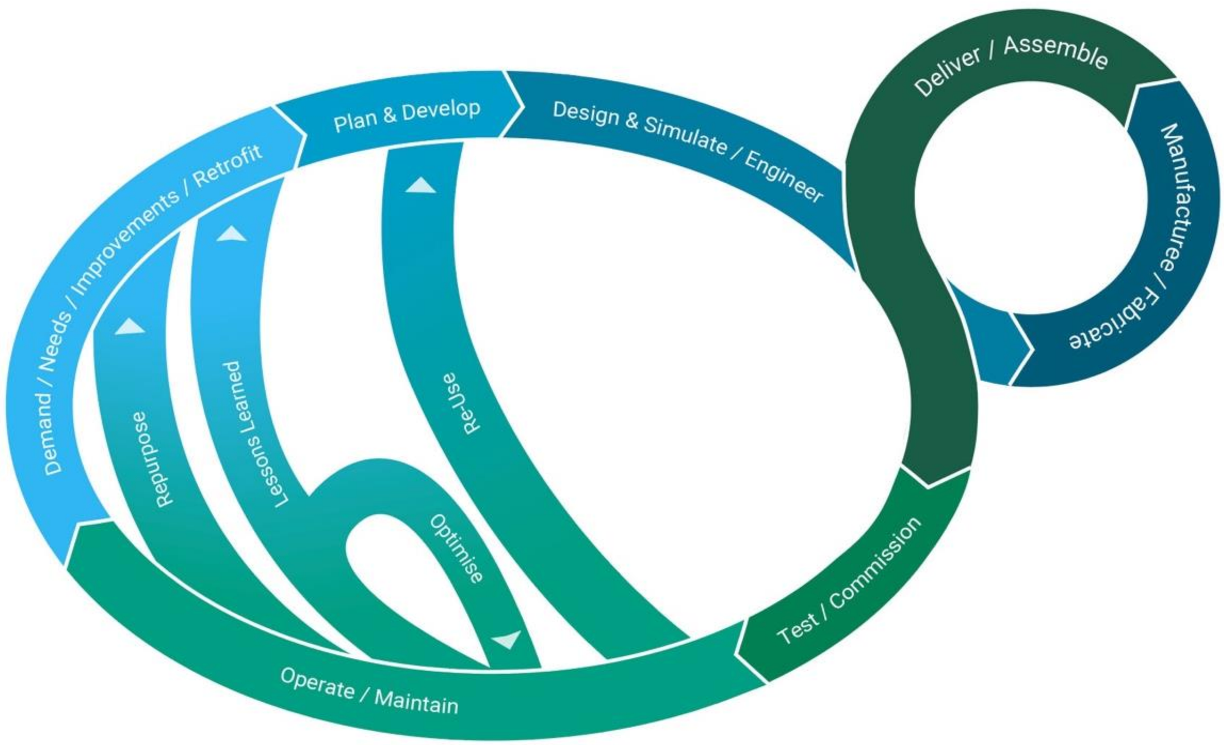

Figure 4-1: Original infrastructure Working Group Digital Infrastructure lifecycle diagram.

This “simplification” stage introduced the following:

- Wording that better reflected an industrialized process,
- Re-use and lessons learned from the operate / maintain phases of the asset to better inform plan and develop, i.e. not to make the same mistakes twice,
- Optimized the infrastructure asset operation and management,
- Identified that the building contents and its materials can all be re-purposed and should be re-used, if possible, to support sustainability and a circular economy,
- Simulation, the ability to fully test the design in a virtual way before any physical building has taken place, and
- No start and finish points, to show that the lifecycle is continuous.

Through additional learning and feedback, we removed:

- The reference to the IoT devices, as it did not add value, and
- Gates, as they did not add value.

A different lifecycle for greenfield versus brownfield development was suggested, and it was unclear where the lifecycle started as there was not a point 0 or 1. This is a key point in infrastructure–there is always something there, whether a building that needs demolishing, a building in operation that needs renovating, or just a plot of land.

Additional findings:

- Data is the only single common element that exists in every segment of the digital lifecycle, it is connected by the digital thread, and
- Benefits must be derived throughout every segment of the digital lifecycle, ultimately received by the owner/operator/occupants.

5 Stage 4 – The Physical Twin Emerges

Manufacturing and industrialization enabled by utilizing digital twins was added to the model, including the generation and existence of part-based systems. This recognized that owners of buildings with similar footprints, or those trying to achieve a consistent brand look (like hotel chains, residential developers, data centers), have created material catalogues and templates for design, which they provide to their architects and engineers as part of their design specifications.

The "Path to Realization" was added to indicate the point at which a physical asset is created that corresponds to the virtual representation of the planned asset.

Note that the orange "Realization" marker only reflects one milestone in the path to realization and the physical twin of the infrastructure constructed on the site is not realized until that component makes its way from the factory and gets installed and commissioned. It is at this point where the physical twin is fully synchronized with the virtual representation, the point at which the plan/design has been fully realized.

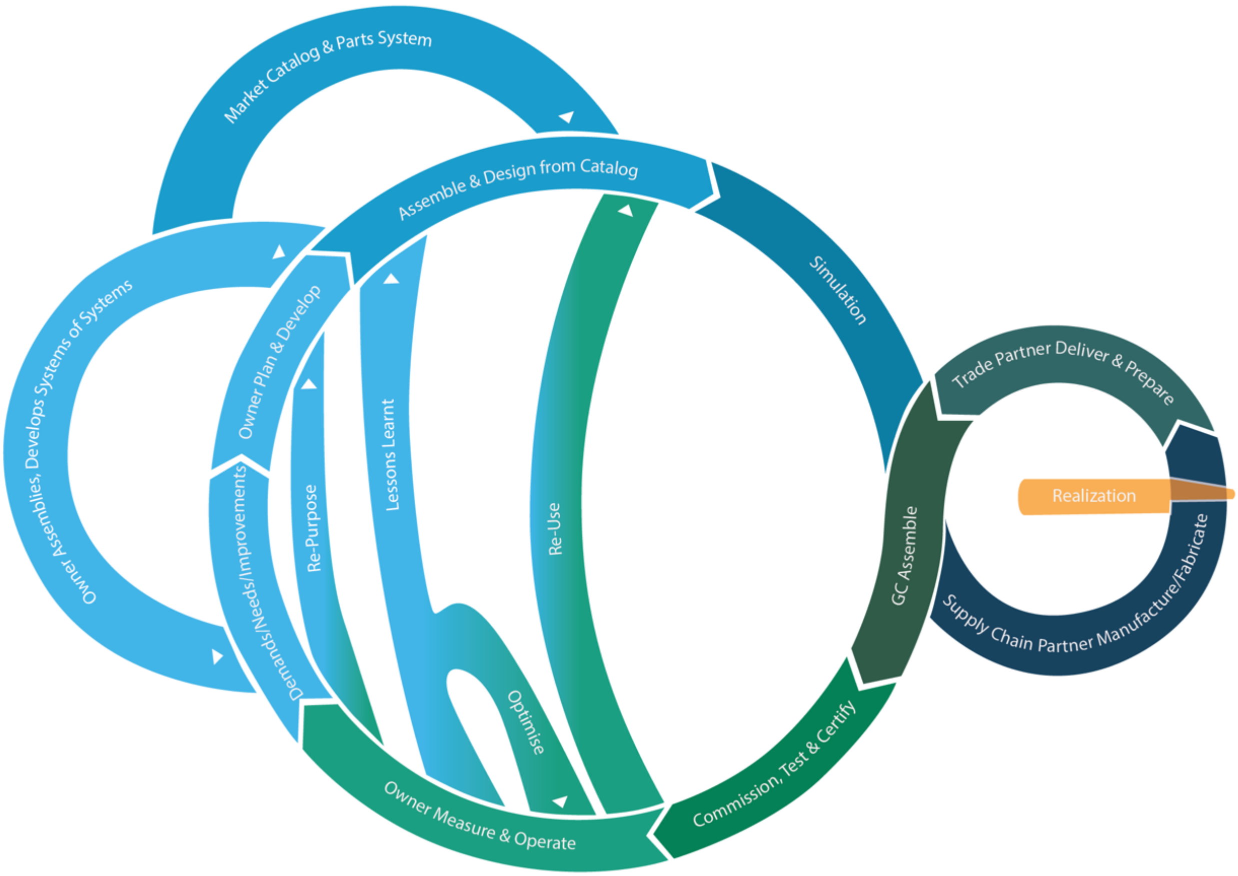

Figure 5-1: The Digital Twin Consortium's representation of the
Digital Infrastructure Lifecycle in the built world.

6 USING THE REVISED LIFECYCLE

So, what are the practical applications of the revised lifecycle? This is illustrated with two examples.

In the built environment we are used to looking at our projects through the perspectives of people, process and technology. The model gives us a perspective on the new process that we should apply when considering using digital twins. A holistic approach is not yet the case in practice. Referencing the Digital Twin Maturity Model for Infrastructure illustrates this. Building owners are still evolving from their siloed history, as is illustrated in Figure 6-1.

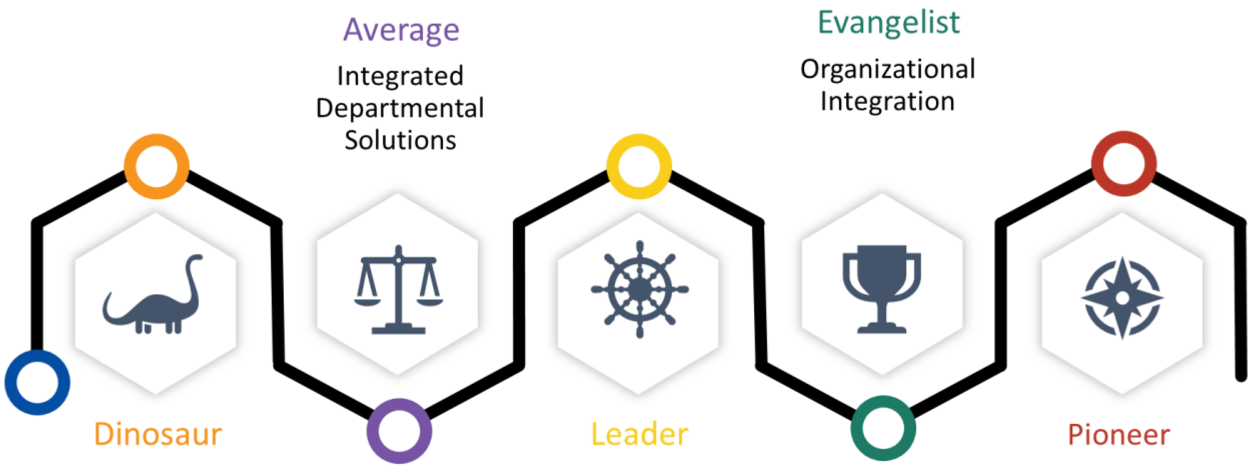

Figure 6-1: Evolving levels of digital twin maturity in infrastructure.

The Digital Twin Maturity model provides five dimensions of reference to determine an organization's digital twin maturity level. These dimensions are:

1. Organizational Structure – who are the participants in the overall digital building lifecycle and how do they interact. Who owns what?
2. Organizational Performance incorporating three perspectives into KPIs and dashboards: process, results and predictive (closed loop performance) metrics.
3. Use and enhancement of the digital thread to support the complete organizational structure and enable digital transactions.
4. Integration of business functions through linking additional information with / using the digital thread (scope, cost, schedule, assets, sustainability, risk and supporting functions like document management).
5. Use of catalog and repeatable design and construction elements.

The lifecycle abstraction provides context to developing organizational structure in each of the phases, together with the accompanying analysis of organizational performance and the development of the digital thread to enable each of the phases to be linked to support communication and collaboration. The lifecycle enables the business functions to be analyzed and developed holistically to support the other dimensions. The catalog aspects are called out clearly in the need to consider industrialized construction, a catalog approach of manufactured products.

While a holistic and unbroken approach is advocated, this may not be possible in many organizations at the start of the journey, and so Figure 6-2 illustrates how the lifecycle can be applied now.

Consider where we started. This four-phase approach will be recognizable by many organizations and is shown in Figure 6-2. Alongside it is the evolution of these four phases into the approach that is advocated through the use of transformational improvements with the use of digital twins. All are in alignment with the phases as advocated in the lifecycle.

Figure 6-2: The evolution of a conventional process with the application of the phases advocated in the revised lifecycle.

7 Conclusion

A digital twin approach enables a transformation of the infrastructure lifecycle that unlocks new value and efficiency. The approach is a journey through the Digital Twin Maturity Model for Infrastructure. This is an evolving world. We look forward to seeing you on our mutual journey.

8 Definitions

Demand/ Needs / Improvements

A business-case outcome is identified and defined such that use-case activities and deliverables can be specified and planned ensuring total performance objectives (utilization, technical and financial) are determined.

Assemble & Design from Catalog

A response to the brief is prepared, resolved, tested (fully proven), costed, and approved coherently.

Simulate

The process of reality is simulated in a digital twin virtual environment in such a way that participants can experience, validate, explore it and perform tests on that aspect as if it would be in the real world.

Supply Chain/ Partner Manufacture/ Fabricate

The design response is manufactured ensuring timing and costs are managed across value chain within the required safety, quality and other metrics and KPIs.

TRADE PARTNER DELIVER AND PREPARE

The delivery of the physical systems is managed ensuring timing and costs are managed across value chain within the required safety, quality and other metrics and KPIs.

GENERAL CONTRACTOR (GC) ASSEMBLE

The assembly of the physical components ensuring timing and costs are managed across value chain within the required safety, quality and other metrics and KPIs.

COMMISSION/ TEST CERTIFY

The process of verification and measurement that the physical systems reflect the digital systems and meet the needs defined by the design.

OWNER MEASURE & OPERATE

The process and resources required to ensure digital<>physical synchronization and that the installed systems continue to meet the total performance needs defined by the design.

REPURPOSE

The totality of process to identify and manage the adaption of the existing assets to meet another purpose.

LESSONS LEARNED

The process and capture of data and information and using it to improve the next time we do something and set the new educated metrics for total performance and total cost.

OPTIMIZE

The process and capture of data and information and using it to improve the thing we are doing now.

RE-USE

The ability to re-use materials and resources from the existing asset in the new. Much of this should be defined in the pre-physical segments.

REALIZATION

The point at which the virtual transforms into physical.

OWNER ASSEMBLES/ DEVELOPS CATALOGS, PARTS AND SYSTEMS

Design material and method solutions that respond to a variety of predefined variables and meet owner requirements and performance criteria.

MARKET CATALOG PARTS AND SYSTEMS

Design material, component and assembly solutions that respond to a variety of predefined variables and meet a set of defined requirements and performance criteria.

AUTHORS & LEGAL NOTICE

This document is a work product of the Digital Twin Consortium (Infrastructure Working Group) name, chaired by John Turner (Gafcon) and Salla Eckhardt (Microsoft).

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