Digital Twins: The Path to Maturity

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As of the time of writing, the topic of digital twins seems to have the capacity to excite emotions and spark the kinds of debate we are more used to in the sphere of post-truth politics or contact sports. Either digital twins are a must-have for any self-respecting engineering consultant; or they are dismissed as the latest shiny object dreamed up by VC-fueled 'constructech' mania. On the one hand, digital twins are important enough to warrant their own National Digital Twin Day; on the other, proponents are accused of 'digital-twin-washing' BIM just like they 'green-washed' their eco-sustainability credentials, driven by fear of missing out (FOMO).

Part of the problem is that digital twins are so new in infrastructure that there is inevitably and regrettably a certain amount of jockeying for position over definitions and terminology. This has led some chief digital officers to apply a form of digital twin purity test. It can only be a digital twin if… it is used in operations; it includes real-time IoT data; it is used to control the physical asset; it incorporates AI and machine learning; it is autonomous and thinks for itself; and so on. But what is the point of applying a digital twin purity test, when digital twins are providing insights and enabling value creation and performance improvement?

Of the more than 500 submissions for Bentley's *Year in Infrastructure 2019* Conference, nearly 25% identified their project as leveraging or aspiring to innovation in digital twins. This represents a remarkable year-over-year increase and is incontrovertible evidence of value created. These more than 125 projects span industry segments, regions, lifecycle phases, and contracting approaches, and are a unique sample set to analyze and learn from. What do they tell us? What can we learn from these world-class projects that might inform our definitions and terminology? What were the approaches, practices and plays that led to value creation and successful outcomes?

Digital twins and digital twin methodologies apply to all phases of the lifecycle. The earlier that a project starts with digital twins in mind, the richer the data and insights. Digital twins serve many purposes; there is no single digital twin. Different stakeholders interact with digital twins from different perspectives and derive different types of value.

Many digital twins start with reality modeling and drone surveys. A digital representation of the construction site facilitates visualization and is often combined with immersive user experiences to provide an intuitive understanding of the context. In the planning phase, digital twins are used to prove constructability and model construction sequencing and logistics. This is a very popular application of digital twins and typically incorporates real-world site conditions and changing positions of equipment and materials. There is also a clear pattern of value created by digital handovers where the engineering consultant delivered a digital asset alongside the physical asset. Typically, the paperless handover was much more efficient, resulted in operational readiness that beat benchmarks, and increased ROI.

Our analysis of these digital twin projects identifies three characteristics that are typical of digital twins: digital context, digital components, and digital chronology. By digital context, we mean the environment, terrain and subsurface; every asset is located somewhere on this planet and that location is often a major risk factor for its safety and resilience. Digital components enable designers and engineers to benefit from proven, performant designs while standardizing for manufacturing and fabrication. By digital chronology, we mean that digital twins capture engineering change over time and provide an accountable record of who-changed-what-when. What is also abundantly clear is that most digital twins had a strategy to overcome challenges concerning data quality and completeness. Engineering data originates in diverse, multidiscipline applications and requires a great deal of aligning, validating and scrubbing which can turn out to be as laborious as it sounds. The golden rule is to ensure that data is accessible; in other words, don't get locked in by proprietary formats.

With this sample set, we can also learn some lessons and draw some conclusions about maturity. What makes for mature digital twins?

Here is our take on the practices and approaches that characterize different levels or stages of maturity of digital twins:

Level 1: Project heroes, i.e. project managers or business units do enough to be competitive.	• There are limited capabilities due to paper-based and PDF workflows • 3D models may exist but are limited to single discipline and single scope • Reality meshes may exist but are not used except for specialist applications • Changes to assets or related asset information are not captured in the digital twin
Level 2: Industry-driven, i.e. some industry standards are being used. Standards such as IFC and ISO 19650 are observed, but delivery is still separated from WIP in ways which make these unproductive.	• The concept of digital twins is established but is limited to new modifications or newly acquired components • Reality meshes may exist but are not used except for specialist applications • Standards are acknowledged / delivered but the downstream use of those standard deliverables is limited • Changes to assets or related asset information are not captured in the digital twin or are kept in document-based systems in parallel
Level 3: Project heroes are still ruling, but corporate digital governance applies some rigor to deployment onto other projects.	• A digital twin exists based on BIM models of the as-constructed assets but is not maintained or updated to reflect current conditions • Reality meshes may exist but are not used except for specialist applications • Standards are acknowledged / delivered but the downstream use of those standard deliverables is limited • Changes to assets or related asset information are not captured in the digital twin or are kept in document-based systems in parallel • Some manual connections exist between the information stored in the digital twin and the operating/maintenance systems

Level 4: Corporate governance allows alignment across all project data sources. Business departments as well as business units en-able instance alignment for connecting up project and enterprise data sources.	• A digital twin exists and is used for understanding the design basis of assets • Reality models of the physical assets are part of the digital twin as reference for the "as-is" state of the asset • Majority of deliverables and records remain stored in document-based formats but are linked in some form of viewing from the digital twin ('hot spot') • Changes to assets or related asset information are captured in the digital twin with some delay, but with no ability to track status of implementation or current operation conditions
Level 5: Decision making is moving towards digital stakehold-ers as well as visualization of current and what-if events on the context-en-abled digital twin. Digital components are used to re-view performance benefits across assets.	• A digital twin exists and is used on a daily basis for managing and modeling the performance of assets • Reality models of the physical assets are created and curated and included in the digital twin to enable users to see current asset conditions • Digital information is created and linked with the digital twin to enable complete access to necessary information for monitoring asset performance • Changes to digital twin assets and related asset information are captured in the digital twin in near real time, and changes are traceable across time

If you are the creator or curator of digital twins, how can you get to the next level? What are the scopes of work and work package deliverables that you can apply? Is there a blueprint or framework to guide your initiatives? Change is hard. As a software company, our focus is primarily on how to deploy digital twin technology, but it is important to emphasize that people and process have as much influence on successful outcomes as the technology factors.

Here are our recommendations for plays and practices based on our experience of implementing digital twins for heavy civil / transportation projects, processing plants, and smart cities. The practices outlined below are based on organizational capabilities. While an organization may have a fully intelligent, asset-linked digital twin, they may not have in-house capabilities to keep it evergreen to provide reliable current status and may be unable to undertake the next steps. These practices require a multi-phase plan that considers not only how the digital twin will be established and delivered, but also how it will be consistently maintained, curated, and consumed. If a digital twin is allowed to become stale, it will of course lose its value and will undermine an organization's digital strategy.

Practice 1:	**Project-driven practice**	Create and maintain a 3D model in a common format
		Establish standards, requirements, procedures, and guidance to establish and maintain an asset register and then introduce an asset register
Practice 2:	**Industry-driven practice**	Capture all new modifications and facilities in a common format with common attribution in accordance with relevant asset classifications
		Automate the relationship between documents and 3D elements to enable searching and navigation
		Identify facilities and areas that have no 3D models or restricted information
Practice 3:	**Good practice**	Capture a complete 3D reality model of the asset or facility. Ensure reality models are geo-coordinated
		Implement a procedure for updating the main 3D model of the facility
		Implement a tagging strategy that enables 3D elements to be related to external data sources on a common business key
Practice 4:	**Best practice**	Implement data enablers to facilitate linking of disparate data sources
		Utilize digital twin for design review and insights. Digital twin is maintained with all updates in common format
		Implement data enablers to ensure 3D model is linked to data sources based upon multiple criteria
		Capture reality model for “as-is” which is geo-coordinated and classified from 3D model
Practice 5:	**Next practice**	Utilize digital twin across operational roles for operational and performance decisions
		Utilize IoT data for right time monitoring and what-if analysis

What value should you expect to drive if you follow these recommendations and put into practice these plays?

Having a digital twin is a game-changer because it enables engineers to troubleshoot design complexities within the context of the asset and its actual, real-world surroundings. In the words of one project manager, “We estimate that using the digital twin in design saved us hundreds of hours of design time and resulted in a far superior design. We eliminated a review cycle for each of the project drawing release packages saving hundreds of resource hours, reduced the need for site visits in half, and produced an interference-free design. Having a digital twin allowed our engineers to efficiently problem solve and be 100% confident in the impact of their designs. Of the estimated 3,000 physical plant drawings, we eliminated 45% of these drawings from the comment-issue cycle by performing collaborative design reviews with the owner."

Digital twins have broad application in advanced design environments, in which a fully functioning, fit-for-purpose virtual model is developed, allowing it to be improved by analyzing different design choices, right up to the project/prototype phase with a more evolved approach compared to conventional methods. According to the manager of one transportation infrastructure project, "The innovation consists of not only having a static design that represents a clearly defined phase, but also a model that evolves over time as the asset is constructed, up to the management of maintenance and any subsequent decommissioning. The task of a digital twin created in this way is to represent with the appropriate degree of fidelity of the state of the physical asset at any given moment during the work management phase, with the advantage that simulation algorithms can be applied to it to evaluate how the physical asset would react by varying the operating conditions. The digital twin has the great advantage of being accessible from anywhere, regardless of where its physical twin is located."

Digital twins prove the constructability of the project. One project has a digital twin that represents the current situation on site, with a short- to medium-term look ahead to test that material lay-down areas, people, plant segregation and construction works do not clash. The digital twin is used to demonstrate options so that worksite leads can make decisions based on actual information. This resulted in adjustments to make sure that construction was possible, and the workforce could go about their activities safely and not under pressure to cut corners.

According to one engineering consultant, "Data-centric design processes allow for the virtual build of the plant before anyone hits the field. We can simulate construction and optimize the productivity at each workface. The digital processes resulted in complete engineering – no claims for scope omissions, and we are proud that our construction rework rates dropped to less than 2%. That is significant value for our client's project and business. The ultimate benefit of digital project delivery is the ability to deliver a complete digital twin to our clients, loaded with valuable information that can be used to operate the asset more efficiently and at a higher capacity for decades."

In operations, owners of a power plant experienced a significant improvement in the plant's overall availability and reliability, achieving overall cost savings by avoiding unnecessary scheduled maintenance. A continuously updated digital twin provides a fully operational picture of the reliability and performance of the physical assets that is used for inspections, simulation, and maintenance purposes. By using the digital twin, operators can visualize the assets, check their status, perform analyses, and generate insights to predict and optimize performance. Combining asset models with a reliability-centered maintenance approach has resulted in reductions of 10% in maintenance activities, reducing forced outages by 25%, leading to a 10% increase in asset availability.

Owners of a steel mill use a digital twin to conduct operator training, carry out emergency simulations, and prevent accidents. For the operator of a water and wastewater network, having a digital twin of the system opened up ways for engineers and technicians to investigate and analyze the networks in more detail and from different perspectives, with opportunities for tests and simulations of scenarios that would not have been achievable in the real world. The modelling of flooding and pollution events specifically has proven to be a powerful capability to prompt action before any potential damage occurs.

At the *Year in Infrastructure 2019* Conference, we saw some great examples of digital twins. It is striking how quickly the landscape is evolving and how much more is possible today compared to only three years ago. Above all, the ability of digital twins to improve decision-making and reduce decision-making cycles means that projects are more likely to come in on-time and on-budget and assets will be safer and more resilient. There is ample evidence to demonstrate that digital twins are on a path to maturity. What will the digital twin projects of the *Year in Infrastructure 2020* Conference look like? A safe bet is that there will be more examples of digital twins with innovative applications of machine learning.