Más Alla del BIM: Gemelos Digitales para Entregables Digitales en 3D

Beyond BIM: Digital Twins For 3d Digital Project Deliverables

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RESUMEN

El propósito de este artículo es mostrar cómo se puede generar un gemelo digital utilizando diferentes archivos creados en diferentes formatos y aplicaciones, y al mismo tiempo conservar dicha inteligencia en el modelo 3D. Luego, este gemelo digital o digital twin se puede utilizar en un entorno colaborativo para revisiones de diseño, detección de conflictos, planificación de la construcción, operaciones y gestión de activos.

ABSTRACT

The purpose of this paper is to show how a digital twin can be generated using different file formats created by different applications, while retaining the intelligence of the 3D model. Then, this digital twin can be used in a collaborative environment for design reviews, conflict detection, construction planning, operations and asset management.

PALABRAS CLAVE: Modelo 3D, Gemelo Digital, BIM, Modelo analítico, Modelo físico.

KEYWORDS: 3D model, Digital twin, BIM, analytical model, physical model

1. Introduction

BIM (Building Information Modeling) for Bridges or BrIM (Bridge Information Modeling) has evolved from being a catchphrase to reality in which stakeholders are demanding more intelligence inside the model. The 3D model of the structure that is the cornerstone of BrIM started as a mere CADD model, and now, the same 3D model can be enriched with information. The relevant properties of the 3D model are not anymore, level or layer, color, or thickness of the lines, but what the elements represent: columns, pile caps, beams and the embed properties like concrete strength, steel grade, thickness of the steel plates, tendon types, etc.

As technology progressed, planners, engineers, and contractors realized that the 3D models could be used not only as a final deliverable, but the same 3D model could be used during construction and later inspection and maintenance. Cutting sections or views from the 3D model to produce plans is not the final goal of BrIM but to include more information to the model: specifications, physical properties, reports, geotechnical data, material descriptions, etc. as they are defined at the beginning of the project using the level of development (LOD) definition used by the BIM Forum [1].

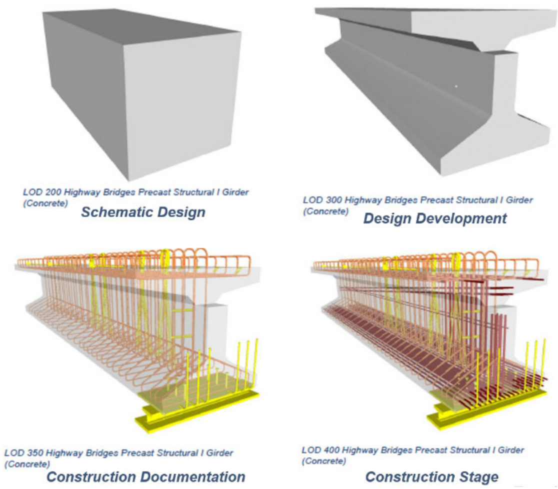

Figura 1. Level of detail of structural elements using the Level of Development (LOD) defnition.

2. BIM for Linear Infrastructure

Commonly known as BrIM or Bridge Information Modeling, it is the application of the BIM concept used for buildings in bridges or more generally in any linear infrastructure project like roadways or tunnels. Concepts like BIM, BrIM and CIM (Civil Information Modeling) are sometimes used interchangeably. Then, we can define BrIM, as the "tools, processes and technologies that are facilitated by digital, machine-readable documentation about a structure, its performance, its planning, its construction and later on its operation" [2].

The BIM models created using various software solutions have not only the geometry information of the structure but are able to hold intelligent information or metadata that relates to the structure itself (concrete strength, rebar sizes, steel grade, tendon properties, etc.) or the project (project number, design engineer, revision dates, etc.) as these properties are intrinsic of the software solution used or customized by the user.

Then, using the geometric and intelligent capabilities of such 3D models, we have the ability now to verify clearances, generate geometry reports, quantities reports and, this is just during the design phase. As the BIM model is used during construction, more information could be added regarding to that phase: material specifications, time and dates of construction, installation reports, quality control logs and any other that a contractor deems important to store in the model.

These 3D intelligent models allow users to use digital project delivery capabilities such as 3D visualization, virtual assembly, automated machine control, fast routing and permitting, and control inventory.

Figure 2. 3D Digital Delivery for Bridges using the 3D model as a legal document.

However, these BIM models could be considered a snapshot in time and accessing the latest information as being designed, constructed, or operated requires constant updating of the model using the authoring software for the specific part of the model as it was created and later, it needs to be republished and disseminated to the model stakeholders. Then, it is when the concept of a digital twin emerges.

When the as-built model with design and construction information is published, it becomes the final BIM model. Adding reality data, sensors, drones, point clouds, and inspection photos make the digital twin come to life.

3. Digital Twins

We can state that a digital twin is the digital representation of a physical asset, process, or system that it is continuously synchronized from multiple sources and allows for performance predictability and optimization. The information collected in the field could be manually updated into the digital twin, but the automation is truly achieved through what it is called the Internet of Things.

Figure 03. Adding intelligence to a bridge via monitoring sensors (Internet of Things, IoT)

The Internet of Things is a system of interrelated computing devices, mechanical and digital machines, or objects that are provided with unique identifiers with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

In linear infrastructure projects like bridges, digital twins provide a more reliable basis for decision-making throughout the structure's lifecycle. Using digital twins, or iTwin models as Bentley Systems calls them, owners can continuously monitor and visualize the bridge, track changes, and perform analyses to better understand and optimize its performance. This helps predict behaviors and apply corrective measures. For example, if a sensor detects abnormal vibrations on a bridge, the digital twin identifies the sensor's location and the related structural element. This information is then communicated to engineers, who can run structural analyses and take appropriate action. In a more automated approach, artificial intelligence can use sensor data to assess the bridge'sstructural safety and determine the necessary actions.

However, the concept of a digital twin could be applied at many different levels as the definition is generic. What is it considered a digital twin? Just a digital representation of bridge, or multiple bridges inside a corridor? a roadway, or the entire roadway interchange? Does it include bridges, ramps, ponds, culverts, storm sewers? What about existing services? Proposed services? The answer will depend on how owners want to manage the future assets and the available technology to produce and manage these digital twins.

Then, this vast amount of information that it is generated by multiple disciplines using multiple resources with possible multiple formats needs to be properly managed. A central repository of all of that information is known as a CDE (Common Data Environment).

4. The Need for a Common Data Environment

A common data environment is one of the tenets to start a BIM model and further a digital twin. In a centralized connected data environment, a single centralized physical model can be utilized by different disciplines and their specific applications that interact with the BIM model. Any modification done on the centralized BIM model is reflected in the other applications, such as analytical models, 2D drawings or rebar detailing.

The issue that a true common data environment needs to address is how to manage the information being generated from different disciplines and its level of accuracy. The issue of different file formats has been approached by the industry by establishing format exchanges from DWG, RVT, NWD, XML (import/export) among applications, a neutral format exchange (IFC) or just using the same format (DGN) with no transformations for all the related applications in the project. Moreover, it is recommended that format exchanges be reduced to a minimum as the risk of errors in translations, or even the lack of automatization in the updates can leave the model with outdated information.

The proper application of these common data environments solutions enables a true synchronization among the design software used and the final BIM model, that in turn will produce a digital twin.

5. Bentley's Digital Twin

Bentley Systems uses the term iTwin to refer to a digital twin [3]. Bentley's iTwin spans the entire asset lifecycle as users at all stages can make better informed decisions for better outcomes. The iTwin becomes a federation of repositories of different types: documents, data, BIM models, photos, internet of things elements and other data information.

The backbone of a digital twin is called iModel which is a specialized container for infrastructure information.

The iModel contains digital components assembled from many sources and it is on a SQLite relational database format. These different iModels come from different disciplines (roadway, bridge, drainage, utilities, building and more), and even from different sources, not necessarily Bentley's, are stored on a cloud base repository called the iModelHub. This Bentley's iModelHub or clould repository coordinates the concurrent access to the iModels as they are related by a geographically referenced coordinate system. The iModelHub manages the different iModel versions generated as all these models connected are presented now as digital twin or iTwin thru a web platform.

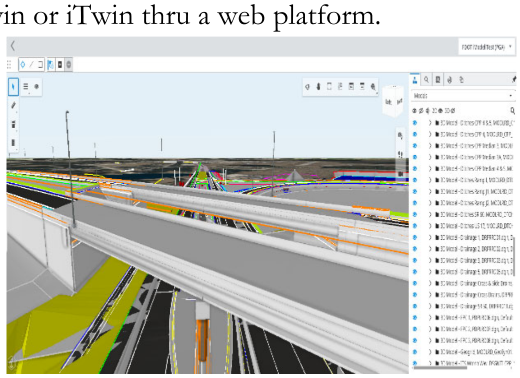

Figure 04. Digital Twin stored in the cloud

Moreover, the generation and utilization of digital twins is based on an open source and cloud architecture IModel.js library that can be used for developing applications that create, align, access, visualize, mine and synchronize infrastructure digital twins.

The use of a digital twin is encouraged at all phases of the project even while the BIM model is being created as they feed information to each other in any phase. A digital twin can be used during the planning phase collecting and processing site survey and reality capture data; during the design phase it will facilitate stakeholder engagement, planning, visualization, and collaboration among the multiple disciplines involved in the project.

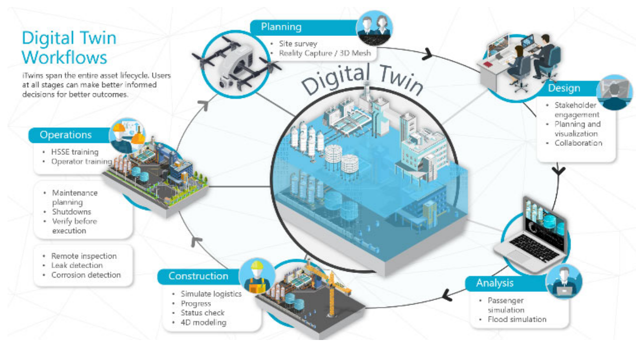

Figure 05. Digital Twins Workflow during the structure lifecycle

As the digital twin becomes more robust with more information, it can be used to analyze passenger flow on a train station or flood simulation on a city. During construction, multiple BIM models from different disciplines becoming part of a single digital twin can be used for logistic purposes, simulations, and track the advancement of the project.

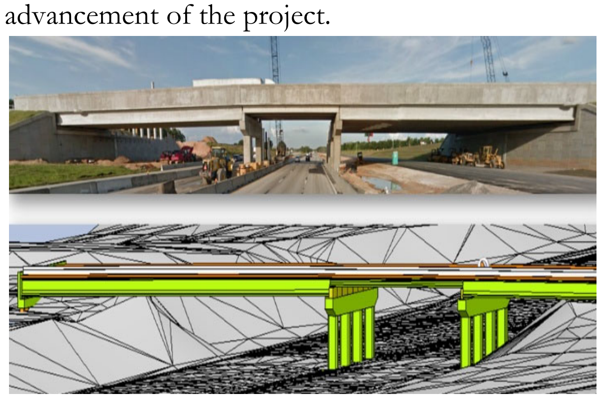

Figure 06. As-Built Bridge and its Digital Twin Representation

Finally, during the operations phase and with all BIM models being in the as-built phase a final iTwin is generated for maintenance, operations, corrosion detection or on-going simulations due to external events.

6. State of the US Transportation Industry and Digital Twins

The US transportation industry is reflected on the efforts of the Departments of Transportation (DOT) to incorporate the new BIM methodology, creation of 3D models and generation of digital twins into their current practice. As their efforts started around 2008, the use of roadway civil software that incorporated 3D models consolidated in 2023.

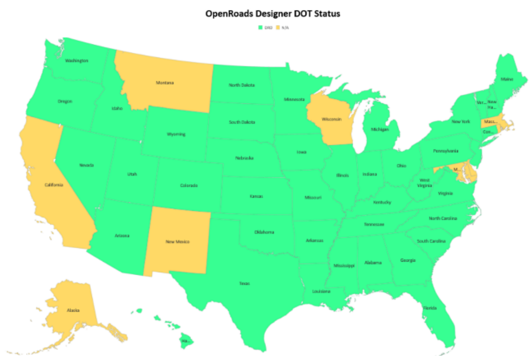

Figure 07. USDOTs using Bentley OpenRoads for Roadway 3D Models.

Following the USDOTs highway practice, their bridge counterpart has also moved forward with the adoption of 3D models and digital twins.

However, this has been at a slower pace since their current practice was still relying on drafting plans in 2D with generic CADD software (not bridge specific) with little automation. Therefore, the switch from 2D plans to 3D models, to plans generated from the models and generation of digital twins was seen as a daunting task with no immediate benefit in the short term. In recent years, the rate of adoption has increased in part due to the demands of the roadway departments of such DOTs that required the 3D bridge portion into their project's digital twin generation.

Moreover, more proactive US DOTs are studying to deprecate the use of 2D plans completely and require 3D models as a legal document (MALD) in their final deliverables. This involves the creation of an integrated digital twin of the project as it will later be used for the DOTs operations and maintenance processes.

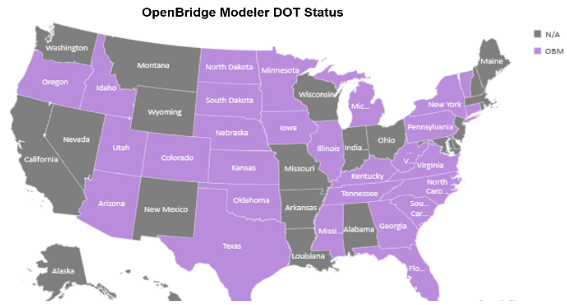

Figure 08. USDOTs using Bentley OpenBridge Modeler for Bridge 3D Models.

7. Use Case: Southern Program Alliance Project in Australia

The Parkdale level crossing removal project is part of the Victorian Government's initiative to remove 110 level crossings across Melbourne by 2030 to improve community safety, reduce traffic congestion, and support sustainable transport connectivity.

Involving rail and road removals, and construction of a viaduct and new station along the Frankston line, the project presented a narrow rail corridor with nearby heritage sites.

Figure 09. Checking Vertical Clearance using a Digital Twin

Leveraging Bentley's open modeling applications and ProjectWise, WSP established a connected data environment and digital twin, streamlining workflows to meet the project objectives. Working in an interoperable, web-based platform minimized rework and accelerated informed decision making, reducing modeling time by 60% and saving 15% in resource hours during the design delivery process. The technology solution optimized material usage, reducing bridge materials by 7% and the carbon footprint 30%.

Figure 10. Digital Twin Model as a Final Contractual Delivery

8. Conclusions

The generation of digital twins for linear infrastructure projects is slowly being adopted by organizations that are still grasping the concept of BIM and 3D model generation. However, they see the advantages of such an approach as it reduces risk and increases efficiency in their projects. Even as owners do not require digital twins in their tenders, consultants have incorporated BIM and digital twins into their own practices as they can see the benefits in their interactions with contractors, especially in design-build projects.

As new technology is utilized and final delivery of projects changes, some contractual specification and legislation needs to be updated as 2D plans will not be used anymore as sign and seal documents but electronic models.

References

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[3] Bentley Systems (n.d.). Digital Twins. Retrieved: https://www.bentley.com/software/digital-twins/