3D Infrastructure Modelling and BIM

DETAILS

SECTOR | Transport, Energy

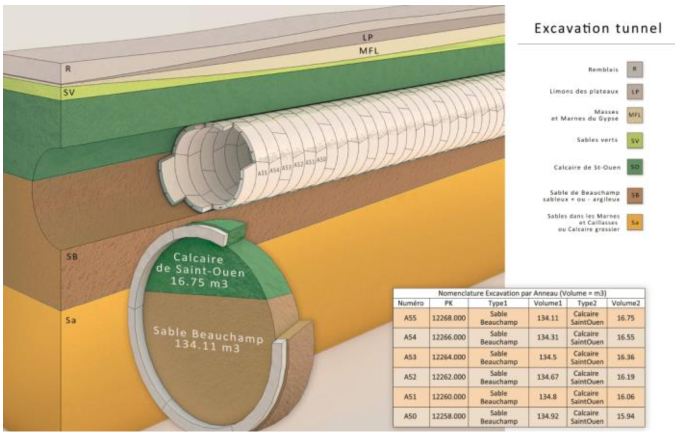
STAGE | Strategy and Planning, Project Delivery, Operations and Maintenance

TECHNOLOGIES | 3D Model, Building Information Model (BIM), Digital Twin

SUMMARY

3D Infrastructure Models are built to digitally visualise design information (technical drawings, plans, elevations, etc.) for infrastructure projects, which can provide stakeholders with a 3D view of the asset. They are developed before an infrastructure project is built, allowing stakeholders to understand the design of the asset more completely and identify issues early in the project lifecycle. 3D infrastructure models are used across the planning, design and construction phases of a project and have been used in this capacity across many major global infrastructure projects built in the last 10 years.

Building Information Models (BIM) are an intelligent type of 3D model that is used to digitally represent the physical and functional characteristics of an asset. BIM can be used as a resource to share knowledge about the asset between stakeholders and can form the basis of decision-making during the asset's lifecycle, from conception through to demolition. In the model, granular information like materials, water pressure in pipes, wind forces etc. is collected to enable stakeholders to understand the impacts of their decisions on the asset and environment, as well as their constraints and opportunities. BIM enables the integration of architecture, engineering, and construction to more efficiently plan, design, construct, manage and operate infrastructure assets.



Nomenclature Excavation par Anneau (Volume = m3)					
Numéro	PK	Type1	Volume1	Type2	Volume2
A55	12268.000	Sable Beauchamp	134.11	Calcaire SaintOuen	16.75
A54	12266.000	Sable Beauchamp	134.31	Calcaire SaintOuen	16.55
A53	12264.000	Sable Beauchamp	134.5	Calcaire SaintOuen	16.36
A52	12262.000	Sable Beauchamp	134.67	Calcaire SaintOuen	16.19
A51	12260.000	Sable Beauchamp	134.8	Calcaire SaintOuen	16.06
A50	12258.000	Sable Beauchamp	134.92	Calcaire SaintOuen	15.94

An example of BIM used to support project delivery at early design stage during the Toulouse Metro tunnel project (image source Systra BIM presentation[1]). The BIM model was used to communicate several options to

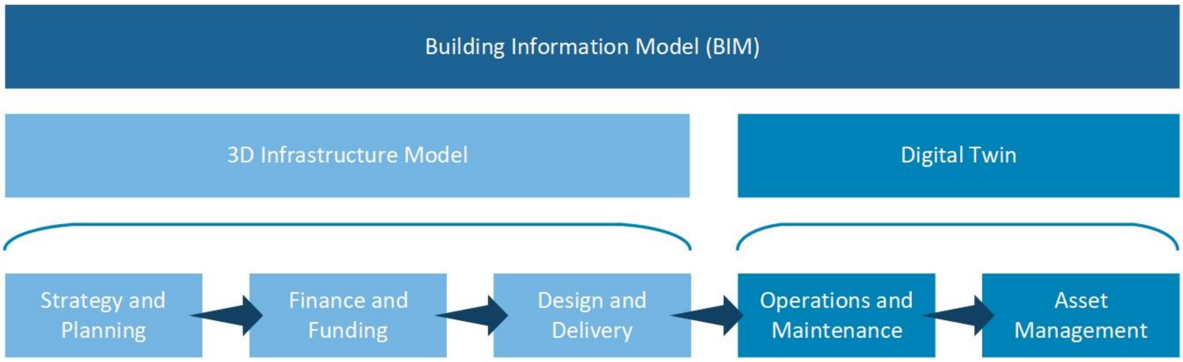
[1] "Case Studies: Improving Rail Project Delivery, Operations and Asset Management", Systra, December 2019.

client stakeholders that enabled them to visualise the infrastructure in its environment. The BIM model identified potential issues for the tunnelling route such as existing utilities and infrastructure. It also was combined with Geographic Information System (GIS) and geotechnical conditions to determine the volume of soil to be excavated and a path and depth of the tunnel that would result in minimal construction constraints, such as avoiding basaltic soil.

3D BIM models are also used to effectively communicate between different disciplines and provide interfaces between different engineering disciplines (geotechnical, electrical, mechanical, civil, etc.) and architects. The use of 3D BIM to improve coordination during the design stage has been shown to result in a knock-on 10% cost saving at construction phase and a 7% reduction in project time[2]. This is in part due to BIM's ability to coordinate the design in such a way that enables the detection of potential clashes. This reduces the chance of rework or cost overruns during construction phase. Additionally, information on the project's advancement can be visually shared with clients to demonstrate that the project requirements have been met and to generate future scenarios of infrastructure development faster.

3D models make it possible to optimize the design of a single asset or several infrastructure assets together. This can lead to optimisation through the reduction of the total volume of materials to be used, limiting the impact on the environment from spoil materials or soil works. 75% of companies that have adopted BIM have reported positive returns on their investment[3].

Digital Twins *(see Digital Twins use case)* are a 3D digital replica of a piece of infrastructure that are used during the operational stage of the asset. They differ from other 3D Infrastructure Models because they are built from real-time operational data collected from sensors and Internet of Things (IoT) devices to replicate infrastructure already in operation to be used for condition monitoring and asset management. They can be used to find ways of improving asset operations and maintenance, thereby extending its life. The next step for infrastructure modelling is to integrate Digital Twins into BIM models, which will enable an asset to be modelled from conception to asset management and enabling optimization of the asset across all lifecycle stages. The below diagram (source Systra) outlines the usage of each type of model across the project stages.



[4]

It is also expected that 3D models in the future will enable more communications between sectors on infrastructure projects and enable even more financial benefits, through optimised asset management and operations. Models can be developed to include time (4D model), cost (5D model) and asset data (6D model) to enable greater visibility and management of project and operational schedules and costs and their interfaces with other project elements. "Mixed reality" technologies like virtual reality and augmented reality can be used to complement 3D models, by blending the physical world with the digital world, thereby enabling stakeholders to enter a immersive environment that enables then to view the infrastructure in its environment and interact with data within the model *(see also the Virtual and Augmented Reality for Planning and Design Use Case)*.

[2] "Building Information Modelling", MyHSR Corp, Accessed 3 June 2020.
[3] "Imagining Construction's Digital Future", McKinsey, Accessed 7 June 2020.
[4] Systra diagram

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce construction costs associated with issues and delays by developing a resource that allows for the exchange of data with and from other systems easily. This will enable the optimisation of infrastructure layouts. For example, GIS can be combined with geotechnical information, to help identify the preferred route for a tunnel that avoids difficult geotechnical conditions. This will provide greater certainty on the time and costs of construction works by reducing risks and unforeseen issues.
- Enable the development of more accurate and efficient workflows and scheduling from concept design to construction and maintenance phase, thus saving time and costs for each stage of the project. For example, models minimise time-consuming manual operations such as producing and maintaining a complete set of drawings, which also minimises the possible sources of errors that may result in delays.
- Provide the potential to decrease construction costs further by optimising the use of materials and the planning of construction works. This will reduce government investment cost in infrastructure.
- Reduce operational costs by utilizing BIM models (and integrating Digital Twins) to identify opportunities for improving asset operations and maintenance processes and thereby improving efficiency and productivity and extending the asset's life.

Enhancing economic, social and environmental value:

- Improve collaboration and project understanding amongst stakeholders by presenting 3D visuals, illustrations and/or animations instead of drawings, and demonstrate how the infrastructure will be implemented in its environment. Utilize Virtual and Augmented Reality technologies to enable an immersive visual experience for stakeholders *(see also the Virtual and Augmented Reality for Planning and Design Use case)*.
- Improve decision-making at design stage by applying draft designs to the 3D model to receive early feedback from the stakeholders, enabling the design to be adjusted to meet their requirements at an early stage, reducing delays or the need for rework. Multiple scenarios and options can be presented to stakeholders to enable early stage communication and option selection.
- Enable engineers to visually explore project constructability, manage project cost more effectively and better predict project outcomes. Models can also enable a greater overview of construction visually and help identify hard points such as risks and clearance requirements with existing utilities/infrastructure.
- Improve convenience and security by having digital files which can be stored and accessed remotely. Hard copies of drawings are not convenient to store and transport and can be easily damaged or lost/stolen.
- Increase the visibility of the project's environmental impacts by overlaying relevant data (such as carbon emissions created from concrete or steel production) into the 3D model, which allows for the quantification of environmental impacts.

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments must work on standardising the requirements for 3D models and their expected use from project planning stage through to operations and maintenance stages. They can do so by developing a digital engineering framework that identifies the information requirements, business processes, data standards, tools and systems to be used to ensure 3D models are consistent, interoperable and reliable across projects. Digital engineering standards should be developed covering concepts and principles and requirements (e.g. business architecture, data standards, data migration, file management, data assurance) as well as an execution plan for rolling this out across infrastructure projects.

Effective institutions: Specific certified institutions need to provide trainings for professionals to develop their skills in creating and working with 3D models in their public or private entities. Governments should and are promoting the benefits (environmental, economic, etc.) to encourage the transition to 3D Infrastructure Modelling. Also, Governments must collaborate with academics and universities to ensure education is delivered to meet the current and future demand for relevant skills. For existing infrastructure, existing drawings will need to be converted to 3D models to enable their integration with future projects.

Transition of workforce capabilities: The transition from a traditional design and delivery model to the implementation of 3D models across all project stages will result in a higher demand for resources with experience and skills using relevant systems. Governments will need to develop a change management plan that details how employees will be trained to use these software applications to create 3D models. This training should ensure there is a consistent understand of the models and objectives of their use.

Procurement and contract management: Governments are increasingly requiring 3D models to be provided as part of new infrastructure projects. Contractors will therefore need to include 3D models or 3D BIM models as part of their tender submissions. Multiple models can be combined, and Digital Twins can be integrated into 3D BIM models to enable the model to include the operational aspects of the assets *(see also the Digital Twins Use Case).* Therefore, data standardization will be required to enable models and Digital Twins to be integrated.

Funding and financing: The implementation of the systems to support the development and use of 3D models must be consistently done across the private and public sectors, so that both private and public sectors can collaborate. Collaboration is required to enable the identification of risks and issues. As a result, funding for the development of these systems should be a combination of both private and public.

IMPLEMENTATION

Ease of Implementation 	3D models are already implemented in new projects in developed countries and are increasingly being explored as part of early project requirements. However, given the regulation requirements and ongoing need for skills transition in both public and private sectors, the models are still not straightforward to implement.
Cost 	Investment costs to develop 3D models are relatively high and include the development of software applications, their installations and licences, as well as training for employees. However, operating costs, once the models are in use, provide significant reductions in project time and costs. Direct benefits can be seen in the design and construction phases, which have an indirect knock-on effect to operations via the improvement in operations productivity.
Country Readiness 	A shift to 3D modelling has already been initiated for many major projects in developed countries, especially during the design and construction stages. Using them across all project stages, from planning to asset management, will create even higher optimisation of the asset. 3D modelling is less widely used in developing countries and the relevant software and skilled employees are not always available. The global trend is to re-orient engineering education to include 3D modelling, as the demand for these skills is expected to rise globally. Private companies are also investing in supporting employee professional development in that regard.
Technological Maturity 	While current systems are mature enough and capable of creating 3D models for many projects, a greater systems integration to enable the full use of models for the whole of project lifecycle *(see also the Digital Twins Use Case)* still needs to be developed. Such advances will increase the efficiency of the software in use and will also enable governments to set the right requirements (regulations and technical) for the use of 3D models for infrastructure projects.

RISKS AND MITIGATIONS

Implementation risk

Risk: If 3D models are not developed in a standardized way, they will not be able to interface easily with other models and external planning systems such as AutoCAD Civil 3D, Revit, Dynamo Studio etc. that may be used during operations and asset management stages. Any lack of compliance with existing standards will also result in this issue, which would require unnecessary additional work (therefore additional time and costs) to enable integration.

Mitigation: Governments along with private sector stakeholders should collaborate to set the right requirements and Key Performance Indicators (regulations, technical standards and contractual obligations) for 3D model use on infrastructure projects.

Economic risk

Risk: The use of 3D models will require employees to use new methods to delivery infrastructure projects. Therefore, upskilling employees to meet this need requires investment and time. However, employees and clients may be reluctant to undergo these changes and undertaken the required investment.

Mitigation: Communication and government support is essential to demonstrate the benefits of this transition and the opportunity it represents for the existing and future workforce. A change management plan should be developed that identified the training and/or education employers will provide to support their staff's professional development during this transition of delivery methods.

Safety and (Cyber)security risk

Risk: 3D models are heavily reliant on data to build their 3D visualizations and to identify areas for optimization across project lifecycles. There is therefore a cybersecurity risk to the system which puts the data collected at risk of theft as well as tarnishing the reliability of the data collected, as it may be altered.

Mitigation: Institutions should ensure their systems are robust to eliminate the risk of cybersecurity breaches and governments should set the legislative frameworks to outline the requirements for data protection.

EXAMPLES

Example	Implementation	Cost	Timeframe
Helsinki Kruunuvuorensilta Bridge, Finland	A 3D model of the bridge was overlain on to drone footage of the area to provide the client with greater insight into the project's complex lighting design.	High investment.	Used for design and delivery.
Toulouse Metro	A 3D model was developed for Toulouse's first metro line that included 27km of track and 20 stations.	The model was used to identify tunnelling options for capital investment savings.	Using both geotechnical and civil information in the model, saved time to identify the constraints and define the right tunnel path.
Vrbnica – Bar Railway Line, Montenegro	The project focussed on the inspection and rehabilitation planning of the 106 tunnels on the railway line. To create a BIM for the operational stage a 3D model of all the 106 tunnels was established. This was achieved with a combination of laser scanning and video	EUR 140 million was invested in the railway line of Montenegro.	Used for design and delivery. A BIM model was also generated for the operations stage.

	imagery sampled by a 360° camera.		
Hydropower Project, Norway	A 3D model was created incorporating data from an aerial LiDAR scan, a terrain model, aerial photos, and sonar recordings to provide underwater topography of the lakes and sea. Additional data (existing structures, heritage sites, risk areas as avalanche-prone slopes) were also imported.	High investment.	The construction works started in 2015 and were completed in three stages in 2019.

CONTACT INFORMATION

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