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INTRODUCTION TO BIM AND VDC

Building Information Modeling and Virtual Design and Construction

Completed in 2017, the Queensferry Crossing bridge in Scotland represents one of the largest infrastructure projects ever constructed in Europe. It required sophisticated reinforcement, with a main span width of about 0.4 miles and three pylons rising to nearly 700 feet tall to accommodate the shipping channels below it on the Firth of Forth. Complicating the construction of the Queensferry Crossing bridge was the presence of two other bridges located in the immediate vicinity of the estuary, one used for rail traffic and the other for remaining traffic. In order to ensure success, virtual design and construction (VDC) methodology was utilized for the bridge's reinforcement and execution plans.

Located in Scotland, construction of the Queensferry Crossing bridge was a massive infrastructure undertaking made possible through VDC.

WHAT IS VDC?

As a concept, VDC focuses on the entire lifecycle of the bridge to be constructed. It is a system of enhanced information-sharing and workflows encompassing the entire process of building a model straight through to utilizing it for design and construction applications, including detailing, virtual fit-up, quantities, bar lists, schedules and conflict checking. "What it means in practice is that you're able to use building information modeling (BIM), 4D staging tools, embedded information, and terrain models, all combined in a way that enables you to put a project through a virtual construction process before you actually build it," says David Loughery, Business Development Manager for Allplan.

Along with using a BIM model, the VDC process allows real-time information-sharing so that every stakeholder in a bridge project has access to the same constantly-updated project data. A scheduling problem, design modification, or spatial conflict can be documented, resolved, and communicated immediately to every involved party. That provides greater insight into working budgets and schedules, and less wasted time and money.

It also affords better control of the final product by confirming the constructability of the project before work ever begins on it. This allows owners and other stakeholders to view the completed structure beforehand to ensure they will get what they expect long before the final deliverable stage, reducing the likelihood of rework and lawsuits.

VDC's transparent, multi-discipline workflow also ensures a healthy and safe working environment. By identifying and minimizing onsite hazards, workers will be better able to focus on the tasks at hand and are less likely to be injured.

In order to better understand how VDC technologies address complex and large-scale projects, let's dig deeper into VDC and how it relates to the more commonly-known term BIM.

VDC VS. BIM

The terms BIM and VDC are sometimes used interchangeably, and they are closely related. BIM is a virtual model and set of principles by which a project or asset is developed using 3D technology, while VDC is a system of enhanced information-sharing and workflows built on that model.

The federated BIM model is more than a 3D representation of a bridge—it assimilates data from all disciplines working on a bridge project. While this process was conceived in the second half of the 20th century, the term BIM became a standard in the early 21st. As computers grew more powerful and software developers began to create new and better tools for designing virtual models, forward-thinking project owners and engineers began to realize the value of this technology.

In addition to the three spatial dimensions of a 3D model, a comprehensive BIM design incorporates the elements of time and cost (sometimes called 4D and 5D). It includes information about how components of the bridge interact with each other and the terrain, and any change is immediately populated throughout the information disseminated to all stakeholders and disciplines.

While there are various BIM solutions available, they must be designed on an open platform to effectively share data with VDC and other applications.

The term VDC came into use around 2000, introduced by the Center for Integrated Facility Engineering at Stanford University. Where BIM creates a virtual plan with embedded data, VDC is a powerful and dynamic process that utilizes that data, along with other information, and combines it into an efficient workflow. In other words, a BIM model by itself is not all there is to the process of VDC, although it's a fundamental component of it.

"BIM is a model-authoring tool designed to allow creation of an integrated 2D and 3D deliverable for a bridge," says Loughery. "BIM has VDC tools embedded in it and can be used as part of the VDC process—in fact, VDC wouldn't be very effective without it. Without a BIM model, you don't know what materials are needed, what they're made of, what they weigh, how they'll be erected, and so on."

However, VDC takes BIM a step further. It combines all the information from BIM with 3D models of the terrain, roadways, even the equipment itself. That integrated data allows the stakeholders to know if the equipment will fit into the space available for it, for example, or whether there are geospatial obstacles that must be worked around, which saves time, money, and on-site headaches.

VDC is also a workflow and data management tool that minimizes cost and waste. "I can query quantities from the model with VDC," says Loughery. "I can look at bar lists, calculate how much earth must be moved, know how much concrete needs to be poured, understand how many precast elements are going in. I know whether the equipment will fit, where material will need to be stored, and can minimize the footprint of my site in environmentally sensitive areas."

Instead of Gantt charts which must be updated as work progresses, VDC tracks construction progress and updates

VDC takes BIM a step further by combining information with models of the bridge site's terrain, roadways and other key variables.

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schedules for the contractor. Design changes that may become necessary as the project moves forward are communicated to every discipline in real time.

WORKING ACROSS THE BRIDGE'S LIFECYCLE

Let's examine the lifecycle of a typical bridge project in terms of how VDC can be leveraged for each.

CONCEPT

Whether the project is a new bridge, a replacement, or a significant renovation, the owner wants to know not only what the bridge will look like, but whether it can handle both current and future demands, and how much it will cost to build. Conceptual 3D models can paint a clear picture of the proposed structure's appearance, and when combined with VDC analysis, can facilitate cost and completion date comparisons among different designs.

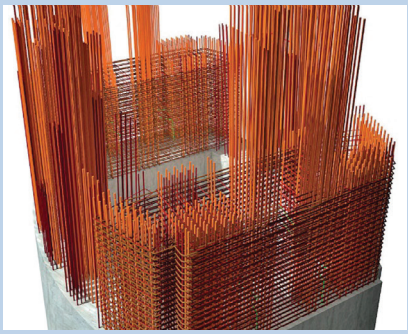
Loughery says, "If you get an RFI (request for information), you're not getting paid for the time it takes the engineers to respond. If the concept is difficult to visualize, that costs money, so clarity at this stage is key." BIM and a VDC workflow provide a clear picture of the proposed structure and what it will take to build it in terms of time, money, and materials. Plus, using technology at this first step will provide virtual resources that can be leveraged and refined as the project evolves.

DESIGN

Once the concept has been approved, the design can be refined in BIM for incorporation into a VDC workflow. The model from the concept stage is enhanced to create a detailed design and rich data, which are useful in the bidding process. Quantities, cost estimates, reinforcement detailing, and a realistic visualization are produced at this stage, and that information can be shared with stakeholders, governments, contractors, and even the general public.

Gone are the days of confusing iterations of revisions and expensive manual reworks. Modifications made during the design process are instantly populated throughout the VDC workflow. This ensures the bridge will be built as designed, and compromises and last-minute changes will not be necessary during construction. As Loughery puts it, "The idea is if we start with a BIM model from the very beginning and we work in 3D and information-rich environments to create the design deliverable, then when we go to do VDC as a contractor or at the DOT level, we already have all the information we need."

Case in point: In the Queensferry Crossing project, the pylons taper from about 46 x 52 feet measured at the upper edge of the foundation, narrowing to around 25 x 16 feet at the tip. This made a reinforcement strategy a monumental challenge due to the tapering cross-section. Engineers Leonhardt, Andrä und Partner chose Allplan as the solution to creating the reinforcement design in three dimensions, ensuring a precise fit—there was literally no room for error.



Rendering of one of the pylons of the Queensferry Crossing bridge

CONSTRUCTION

Loughery describes this pre-construction process as being without consequences because you can virtually test-drive your plan ahead of time without ever doing any actual construction. You're able to tweak the quality of the final deliverable before ground is broken without any downstream risk, such as being sued by the contractor for problems experienced onsite. Pre-construction analysis also makes it extremely unlikely you'll discover that things won't fit only after construction has begun, which can cause delays and significant cost overruns.

During the construction phase, the whole site is managed by BIM and VDC. This reduces change orders, controls costs, mitigates potential safety issues, minimizes overruns—and even legal risk—during construction.

Another benefit in the construction phase is that VDC allows engineers greater insight into the actual construction process—they develop a deeper understanding of what goes into the project, even if they don't spend much time onsite. And from the contractor's perspective, it's no longer necessary to pay a team of people to pore over plans to develop quantity estimates, saving significant time and money while all but eliminating the potential for miscalculation.

There's also little chance of receiving poorly fitting precast elements because BIM provides exacting specifications to the manufacturer. Unforeseen issues, such as scheduling delays due to weather or equipment problems, are quickly assimilated, the schedule adjusted, and that information communicated to every discipline so they can reallocate their resources accordingly.

VDC and BIM in combination also address the terrain-associated challenges of construction. The process used for a railway bridge in Germany spanning the steep Grubental Valley combined a 3D representation of the structure with a digital terrain model to precisely plan excavation and calculate mass. This resulted in better scheduling and use of resources, and allowed for collision tests with horizontal element foundations, also generated in 3D.

MAINTENANCE AND REPAIR

The VDC process doesn't end when construction does. As the bridge ages, the rich data contained within the 3D model can be utilized to develop a plan to restore it.

For example, rebar replacement typically requires a certain degree of guesswork in traditional construction, because its location is often not documented or has been changed at the last minute to avoid a conflict. This can result in wasted time, expense, and materials. A BIM model, on the other hand, prevents conflicts in the first place, and accurately documents the position of every structural element. This can be utilized by VDC to calculate the cost and resources needed to maintain or repair the bridge.

One research study even suggests that a data-driven workflow may in time evolve into a more automated process for bridge inspection and evaluation.

THE BENEFITS

As we've seen, a VDC structured around a data-rich BIM model offers numerous benefits:

- Better visualization and less costly RFIs
- Comprehensive and coordinated communication throughout the project lifecycle
- Less cost resulting from miscalculations, errors, and rework
- More efficient project management throughout construction and beyond
- Reduced risk of lawsuits resulting from construction errors and onsite safety issues

Products like Allplan and Bimplus can help integrate BIM with VDC workflows to enable seamless data-sharing at every step of the process.

Loughery says, "The Queensferry project was proof-of-concept for VDC—to make certain the bridge could actually be built as detailed. Going in, the engineers weren't sure that they could really build it, even though it was the best and cheapest option. The technology established that this design was constructable and would make sense from an economic standpoint."

After almost 6 years of construction, the Queensferry Crossing bridge was ultimately completed on time and inaugurated by Queen Elizabeth in September 2017.

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Allplan is a leading vendor of OpenBIM solutions for precast companies, project managers, civil & structural engineers. Our software facilitates the integration of 3D into preexisting 2D workflows, and allows different disciplines and trades to collaborate in a streamlined, efficient workflow. Allplan is committed to developing programs that enable the designing and building of sustainable infrastructure for the future of the US and the AEC industry. Currently, our solutions are used by over 240,000 engineers and AEC professionals in 52 countries around the world.

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