CONSTRUCTION, CITIES & TERRITORIES

INFRASTRUCTURE LIFECYCLE MANAGEMENT THROUGH VIRTUAL TWINS

White Paper

EXECUTIVE SUMMARY

This white paper is presenting industry trends in Construction, Cities & Territories covering infrastructure lifecycle management through virtual twin. Building Information Modelling (BIM) is currently taking over the traditional methods for infrastructure developments, operation and maintenance. Using BIM and Virtual twin allow collection, analysis, and aggregation of data and enhances collaboration between different stakeholders, from design to operation and maintenance.

Dassault Systèmes' solutions provide 3D technology for lead development in civil engineering and infrastructure management. This paper presents business cases to highlight how virtual twin contributes to design, construction and capital efficiency.

DASSAULT SYSTEMES

INTRODUCTION: A SOLUTION FOR SUCCESS

Infrastructure development is forecast to see phenomenal growth worldwide. By 2030, the global construction market will grow by 85 percent to US$17.5 trillion, according to Global Construction 2030, the fourth construction forecast sponsored by PricewaterhouseCoopers. Infrastructure development spending in the ASEAN market is estimated at around US$1 trillion per annum by 2030. Globally, China, India and the U.S. will spearhead the boom, accounting for 57 percent of overall growth.
Yet, Construction is behind other industries in terms of automation, to increase productivity in different steps from the conception to the operation of any infrastructure. Industry players are demanding innovative solutions to integrate models and assets they design. Dassault Systèmes' **3D**EXPERIENCE® Platform is an innovative platform, where all data is integrated and managed processes through concept, design, manufacturing, construction and maintenance.

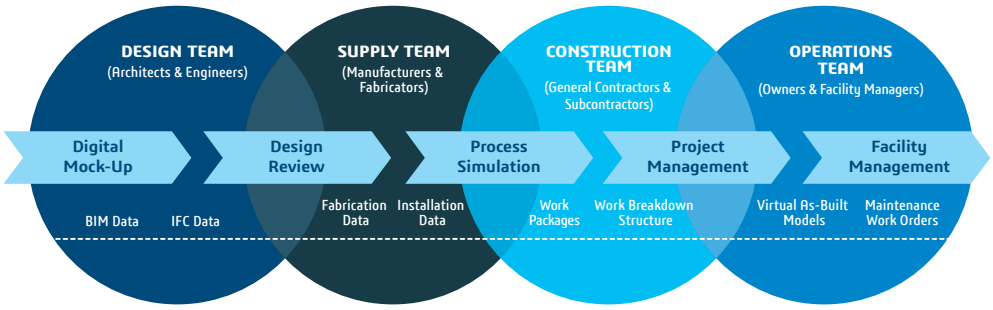
1. DATA CONTINUITY FOR SUCCESSFUL PROJECTS FROM CONCEPTION TO OPERATION

No infrastructure is the same. The number of 2D design drawings is huge, and sometimes, lack of data consistency and continuity can be the cause of serious onsite problems.
The **3D**EXPERIENCE platform allow teams to allocate roles and build up knowledge and data continuity

Maximizing project outcomes during full project lifecycle

The project-based nature and fragmentation of the construction industry makes it difficult for civil design and construction teams to standardize all work onto an integrated platform and efficiently share information. The risk is that competitive bidding practices and functional silos can lead to padded estimates and poor outcomes.

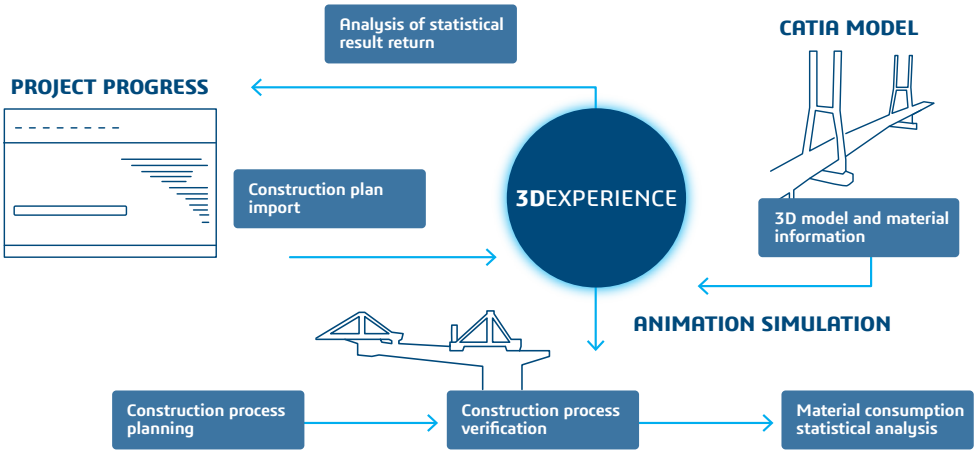
A more effective process for civil design and construction requires dissecting traditional industry practices and rethinking assumptions about collaboration, execution and information. Innovations like prefabrication, 3D modeling, real-time project management tools and predictive models are empowering teams to build collaboratively, in the long term, while avoiding conception mistakes and loss of critical data.



High performance teams apply efficient process proven in Manufacturing industries, leveraging integrated data to support the entire building lifecycle.

Dassault Systèmes' DELMIA application provides a virtual environment that allows construction planners to validate construction activities before construction begins. The resource cataloguing and simulation capabilities can be deployed to allocate the right resources for each job. 4D simulations bring together the multiple players in the supply chain to give them a better understanding of all the interactions and dependencies. With the collaborative **3D**EXPERIENCE platform, all stakeholders can validate construction and maintainability, and work together to create a fast-track project environment.

Using the preformed catalogue, real-time site data and information imported from a range of platforms, users can easily create infrastructure and highly complex projects of any size. Operation and maintenance can be planned predictively with the virtual twin technology.



> "Benefits are immediate for better communication and productivity in all lifecycle from infrastructure planning to operation and maintenance, design and construction efficiency also prevent risks and reduce waste, as well as deliver project on time and on budget."
>
> Akio Moriwaki, Industry Marketing Director, Construction, Cities & Territories Industry, Dassault Systemes.

One of the benefits of using a virtual twin is that it can maximize profits by providing precise calculations of materials and construction costs, even in managing operation and maintenance processes. In general, a project has two kinds of costs – design and construction, as well as operation costs. Normally, design and construction costs account for 20 percent of the overall cost, while operation costs take up 80 percent. For the project owner, a better management of maintenance and operation with virtual twin reduce the total cost of operation and sustainability.

> "Having all data in a central, easily accessed location, equips civil designers, engineers, and contractors with the insights to more efficiently plan, design and construct infrastructure, and can save money during an infrastructure's operation and management."
>
> Jonathan Riondet, Senior Technical Director, Construction, Cities & Territories Industry, Dassault Systemes.

Rethinking Project Lifecycle

Project owners, engineers and contractors alike benefit from the **3D**EXPERIENCE Platform.

Owners get real-time insight into their projects as they progress. They can monitor project status and schedules to make sure everything is on track and within the agreed-upon scope. They have access to all the data created during the entire life cycle of the project. After project completion, the virtual twin gives them an organized, comprehensive tool to operate and maintain their infrastructure.

Civil Engineers get design automation, faster design iterations, and can facilitate better decisions during the design and engineering phase. A common data environment offers time-savings over traditional plan workflows by streamlining communication between project stakeholders. This also reduces the hours engineers must spend addressing requests for information before construction, by allowing them to provide a detailed and realistic virtual model of the infrastructure.

Contractors save time and money on drawings, fabrication, and construction models. The 3D model and associated data enables them to create more accurate construction sequences and better schedules, saving time and money. Simulating construction activities gives contractors the opportunity to validate methodologies without additional costs. Unbuildable conditions are identified, and issues resolved in a virtual pre-construction world where plans can be modified easily and inexpensively. Simulations also give contractors the visibility they need to identify risks and improve safety.

A new era for infrastructure maintenance and operation

Project managers are facing a growing pressure to deliver more efficient projects and operational processes.

Therefore, the use of Virtual twins has been increasing in infrastructure management. The basis of advantages is an increased collaboration between different project members including operation and maintenance teams. Data can be accessed on a single platform, which creates a better insight to operations. Asset and facility managers can focus on work by planning and anticipating the necessary maintenance instead of reacting to reported problems. In fact, the operations can be planned for long periods, which saves time and money.

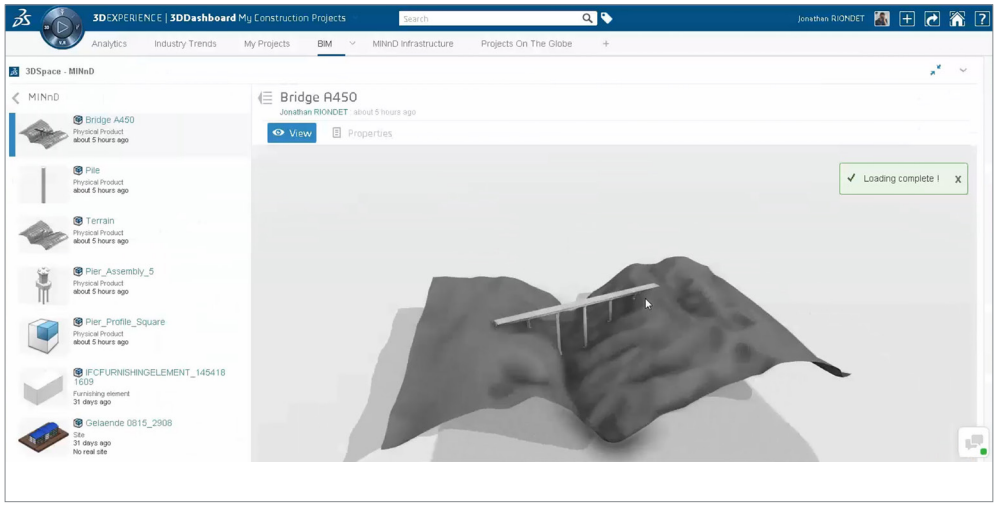
In terms of capital efficiency, the operations and maintenance phase of infrastructure will persist longer than any other project phases. Therefore, the advantages gained have cumulative effects. Dassault Systèmes integrated solutions allow a rich information stream where information can be updated in real-time. Project managers benefit from detailed information and predictive analysis to enable the infrastructure to meet future needs. Better decisions can be made based on higher quality information and expand the infrastructure security, quality and lifespan.

2. A CONNECTED PLATFORM FOR SUCCESSFUL TEAMS

A fundamental requirement of successful teamwork is to establish a common data environment that acts as a platform to facilitate the collection, storage and dissemination of information from all areas and phases of the project. The challenge also lies in the efficient interoperability between software used by each specialist discipline within often large multidisciplinary infrastructure projects.
With a robust data platform at the core, the essence of the **3D**EXPERIENCE platform is to complete the virtual cycle through the design phases from concept, to operation and maintenance stages with a minimal amount of information lost, duplicated or having to be recreated.

> "Each civil design project brings a new combination of project members. Communicating and collaborating effectively across widely dispersed, multi-national, multilingual teams is challenging. It's critical to openly share and accurately convey data across all project contributors, and to convert information to be relevant and coherent to each project stakeholders."
>
> Kevin Zhu, Senior Business Consultant, Construction, Cities & Territories Industry, Dassault Systèmes .

Simultaneous real-time access to design models and project data from anywhere and across different disciplines is made possible with the **3D**EXPERIENCE platform. Customers can import data from any number of platforms to create a single-source mock-up where all parties — owners, designers, engineers and fabricators — can work together as part of an integrated design community.



Building something in a complex ecosystem requires effective and holistic information management. While all data exists in various external sources, Dassault Systèmes' solution brings all live streams of complex information into one single platform.

> "**3D**EXPERIENCE is not a file-based, but a data base driven system. One of the main differences with any other solutions is the architecture of our solutions. We don't sell software; we propose roles to the platform depending on jobs. Roles provided by our solutions are targeting specific users. Collaboration and life cycle is key for us, from traceability, revision in design and change."
>
> Jonathan Riondet, Senior Technical Director, Construction, Cities & Territories Industry, Dassault Systèmes.

3. DIGITAL INFRASTRUCTURE FOR URBAN DEVELOPMENTS

While enterprise systems have been evolving with advances in computer and software For a better quality of infrastructure, project stakeholders are now connecting all ecosystems, including infrastructure maintenance, even new urban developments.

Extension coverage of digital infrastructure

Cities and territories are now focusing on how they can make a better ecosystem for the cities' infrastructures at the start of any project. Virtual twin of infrastructure are utilized for future cities and territories developments. There are business opportunities for civil design and construction players for urban development leveraging infrastructure projects.

> "For managers of territorial and urban projects, **3D**EXPERIENCE Platform offers game changing innovation to manage territorial complexity, ease the challenges of multi-stakeholders collaboration, and optimize the sharing of data across disciplinary silos to enable territories to transform themselves and become more sustainable, resilient, and resource-full."
>
> Akio Moriwaki, Industry Marketing Director, Construction, Cities & Territories Industry, Dassault Systemes.

Dassault Systèmes' **3D**EXPERIENCE platform brings together a wide range of territorial and infrastructure data with our industry-leading analytical, modelling, simulation and lifecycle management capabilities. Coordinates and terrain information can be extracted to use in the model, or design information can be placed in a true map to provide an accurate site overview and visual context for all users. Predicting the effect, the structure will have on the surrounding area is particularly important in densely built urban zones.

BUSINESS CASES

Following on the previous development, here are some key business cases where the 3DEXPERIENCE made a critical difference in infrastructure development and lifecycle management. Each of these cases showcase the use of Dassault Systèmes' platform solutions by innovative teams wanting to achieve the best in terms of project efficiency and capital efficiency.

CHENGDU URB - MAINTAIN INFRASTRUCTURE ASSETS WITH SPEED AND EFFICIENCY THROUGH BIM TECHNOLOGY ON THE CLOUD

At the time of its completion, Chengdu's Second Ring Road was the city's largest municipal construction project.

Overview

In the Chinese province of Sichuan, Second Ring Road is over 28 km long and 8 lanes wide. The elevated road is managed and maintained by Urban Road & Bridge Monitoring and Service Center, Chengdu City (Chengdu URB). Chengdu's smart city management master plan seeks to horizontally and vertically integrate various resources, create a more refined approach to urban management, and take a holistic view of the maintenance function.

In order to align with the city's larger smart city vision, and to manage Second Ring Road as efficiently and effectively as possible, Chengdu URB turned to BIM technology.

Objectives

Chengdu URB commissioned Chengdu RYD Information Technology Co. Ltd. (RYD) to build an asset management information system. A large number of companies were involved in the construction of the Second Ring Road. Plus, there was an overabundance of construction-related data. As-built data was difficult to find and correspond with completed bridges and roads.

The project aimed to create a modern, contextualized, and visual experience for users by integrating BIM and GIS. In addition, the team intended to digitalize and virtualize the infrastructure by creating BIM model, and to enable mobile monitoring and maintenance processes.

Solution

Chengdu URB and RYD implemented the **3D**EXPERIENCE platform with CATIA and ENOVIA applications from Dassault Systèmes, and to integrate with SuperMap, a local GIS software program.

In Phase 1, RYD engineers selected one complex interchange. Started from 1,300 drawings, they created a large BIM model that is identical to the real interchange with clear detail on a scale from as large as a bridge pier to as small as a rain gutter. The model includes up to 16,000 bridge components, each with its own serial number, allowing workers to quickly and accurately locate issues. After the success of Phase 1, a huge BIM model for entire Second Ring Road was created by RYD.

Outcomes

Using handheld mobile devices, workers quickly gather data and submit damage reports at any time or location, upload data to the cloud, and reference 3D models and technical resources related to their tasks.

For example, as part of his daily inspection, Zhang Zheng stopped at the corner of a guardrail and noticed cracks in the cement block. He took a picture and reported the inspection in the Second Ring Road and Bridge management system through the application on his mobile device. Within a minute, maintenance personnel received the information and rushed to the scene to fix the fault. From issue detection to resolution, the process took less than half a day. In the past, it might have taken several days.

Managers receive, view and assign maintenance tasks, enabling rapid repairs and streamlining issue management. The leadership team can view, search for, and inspect the status of maintenance at any time or place. Moreover, the entire process occurs online, achieving environmental conservation goals by going paperless.

Worker using the system for road bridge maintenance.

> "Previously, we found that addressing road and bridge issues, from reporting to maintenance, took a few days. Now the system automatically dispatches information, which is quickly passed from the scene to the hands of maintenance personnel, greatly shortening resolution time."
>
> Representative of Urban Road & Bridge Monitoring and Service Center, Chengdu City

Chengdu URB now enjoys a highly efficient, high-quality asset operations management process, and continues to push toward smart city management ideals. The implementation serves as a case study for other smart cities looking to implement a highly detailed management system for roads and bridges.

Quantitative outcomes include:

- 8x increase in maintenance speed
- 8.3x increase in labor efficiency
- 4.42x increase in financial efficiency
- 2x improvement in quality

Following completion of the first phase of the Second Ring Road management system, documents and as-built data have become fully digitized. The system accurately locates problem areas, bringing the Chengdu bridge and road management system to into the "cloud management age", which drew interest from major media outlets.

IoT sensors will be installed in the important structural parts of the urban bridge. Intelligent monitoring prevents hidden dangers within the structure not visible by inspectors.

Finally, a real-time traffic monitoring system also ensures the health of the bridge and public safety by preventing vehicle overload. The continuous monitoring system can warn vehicles in advance and alert them to bypass the bridge.

Conclusion

Chengdu URB has demonstrated that digitizing a large infrastructure asset to manage and maintain it within a 3D environment on the cloud delivers impressive results in terms of efficiency, cost savings, and performance.

CHINA RAILWAY DESIGN CORPORATION: A FRUITFUL COLLABORATION

Background

China's rail industry is experiencing considerable growth driven by a soaring economy with rising demands for fast transportation from China's population. China Railway Design Corporation (CRDC) is competing for leadership in this growing market. It is one of China's top railway design companies, and the only integrated Class A survey and design institute affiliated with China Railway Corporation, owner of China's national railway. Class A certification means CRDC meets very specific levels of engineering capabilities and also requires providing software support.

Solution

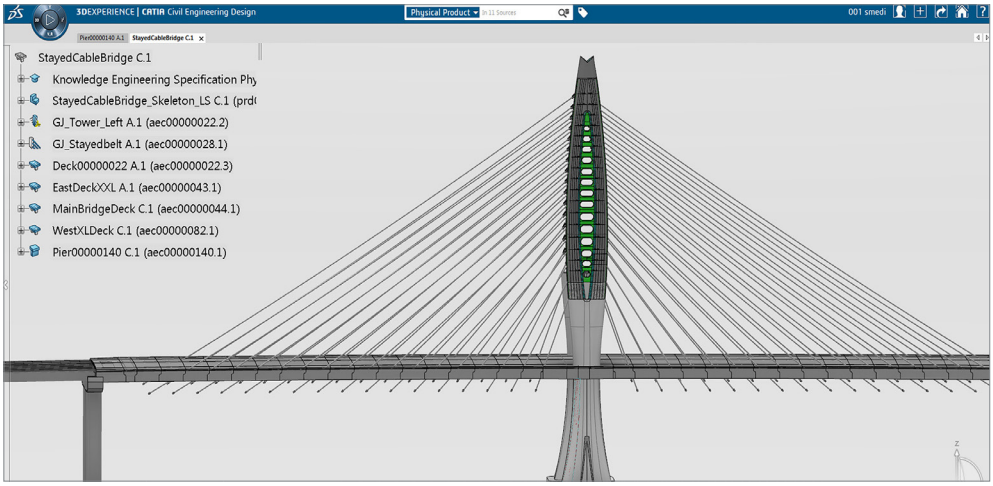
Since 2015, CRDC has been leveraging Dassault Systemes' **3D**EXPERIENCE platform for its large-scale railway projects, the CATIA® application for the design of subgrade, bridges, tunnels, electrical systems and all railway-related components. Dastech, a Dassault Systèmes business partner, implemented the **3D**EXPERIENCE platform at CRDC and provided training and on-site support. CRDC leverages the 3DEXPERIENCE platform's specific industry applications tailored for civil engineering design, steel structure, electrical systems, and water drainage, all needed by the rail industry.

The **3D**EXPERIENCE® platform ensures digital continuity because all applications are integrated.

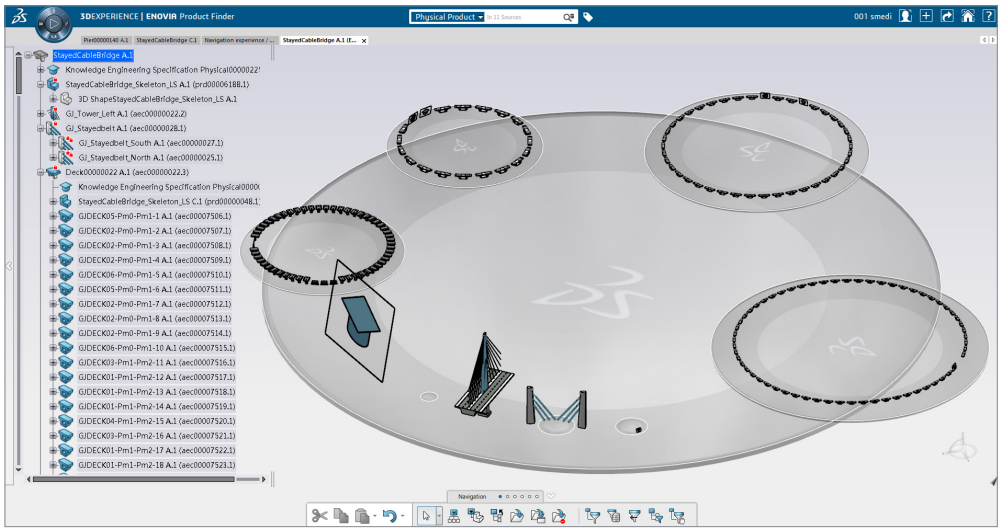
Results

Moreover, CRDC and Dassault Systèmes are working together to implement global railway standards based on the 3DEXPERIENCE platform. They signed a partnership agreement, in which CRDC will provide technical requirements so that Dassault Systèmes can adapt its applications for the specific needs of the railway industry. Already, some of the BIM standards developed by the China Railway company and destined for use by the railway industry have been incorporated into the 3DEXPERIENCE platform.

SMEDI, GANJIANG SECOND BRIDGE - VIRTUAL TWIN FOR DESIGN AUTOMATION



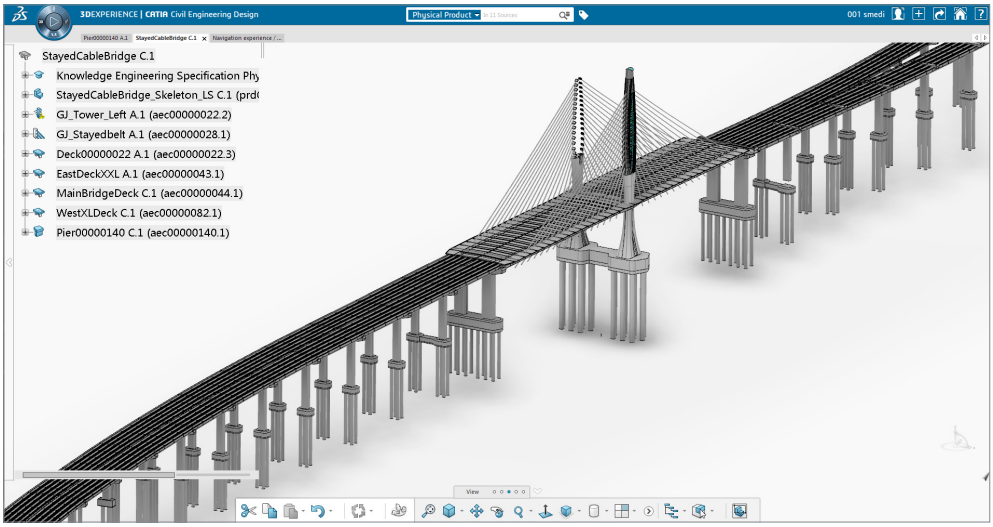
SMEDI is particularly strong in designing bridges. Actually, the Institute designed almost all the major bridges in Shanghai. Of course, SMEDI's work goes way beyond the city of Shanghai. One notable example is the Ganjiang Second Bridge in Jiangxi Province, which has a "fish-like" design that fits very well within the surrounding landscape. The complex structure of the bridge comprises of a steel upper part, a concrete lower structure and in the middle, a mixed concrete and steel section. BIM enabled a clear division of work for the different engineers and their respective components.



Challenges

The design work for the bridge was led by SMEDI, with engineers from different disciplines collaborating. The project manager was a senior civil design engineer. A dedicated engineer designed the skeleton, determining the framework of the entire bridge. Another specialist engineer focused on the steel structure, while a further designer concentrated on creating a library of components for the various distinct features in the bridge.

SMEDI's collaborative design process meant that they clearly defined and divided the work involved, coordinated the roles and tasks and seamlessly managed the entire project.



Solutions

In the conceptual design stage, the software allows designers to quickly create complex curves as skeleton lines and even supports using digital sketch tablets. With the skeleton lines created, the component library is crucial to the success of the project. The components (like piers, beams, columns, etc.) are intelligent, rule-based parametric objects and well-categorized in the library. The designers can select desired components from the library and put them on the skeleton lines and then the components adjust their sizes automatically to fit the skeleton lines and generate the BIM model in a well-coordinated manner. If designers change skeleton lines, it drives all components to update along with it, thus greatly saving modification time.

The SMEDI solutions can be animated to better showcase the proposed design concept, making them more functional than the static 3D visualization drawings which were produced previously.

Results

During the design of construction drawing stage, the software can check for conflicting production directions, as well as design errors. Users input measurements into the software to conduct analysis and optimize the build. These additional safety checks are of paramount importance for bridge design and construction.

Indeed, this software helped make it much easier for SMEDI to make changes to the design, which can be very frequent and even at the last minute. In the past, making design changes could sometimes take even longer than the original design stage itself.

SFEG, ZHOUJIAZUI ROAD CROSS-RIVER TUNNEL- VIRTUAL TWIN FOR CONSTRUCTION SIMULATION:

Background

A key goal in Shanghai's bid to become a global city of excellence by 2040 is the reduction of average commuting times to less than 40 minutes. The 4.45 kilometers Zhoujiazui Road crossriver tunnel, currently under construction, is a key project that will help achieve these goals by reducing traffic congestion on the heavily travelled Yangpu Bridge.

Challenge 1

BIM was mandatory to tender a bid for the Zhaojiazhui Road Tunnel project.

Solution

BIM was used to generate visual representations of the project construction process. Dassault Systèmes' CATIA Application was used to create a 3D model of the tunnel, and DELMIA application was used to simulate in vivid animation how the tunnel would be built. Decision makers were able to instantly understand the entire project, including constructability, resource estimates and the impact of the development on people and the environment. This eliminated the need to hire a design firm to create separate 3D visualization, a traditional route that incurs additional cost. At tender evaluation, scores were split between technical elements and commercial elements. SFEG scored the highest in technical elements and won the bid.

The whole shield tunneling process simulation from transport to the shield conveyor and front installations, which involves not only the speed of the shield movement, but also the arrangement of the entire process flow.

Challenge 2

The tunnel passes through several sensitive areas, such as the Academy Building of Shanghai Polytechnic University, the foundation piles of a pier and a residential area near the construction site.

Solution

SIMULIA® Finite Element Analysis (FEA) enables designers and engineers to create simulations of how the tunnel boring machine (TBM) excavation would impact on realworld forces like vibration and fluid flow, and the other physical effects it would have on the surrounding areas. The software separates the geological model into finite elements and uses mathematical analysis to predict the behavior of each element and the overall impact on the surrounding areas.

As construction progresses, the 3D model with simulation will enable engineers to predict and resolve problems in advance. The data generated is stored in the BIM models, and the FEA results are retrievable at any time for added convenience and to enable speedy alterations.

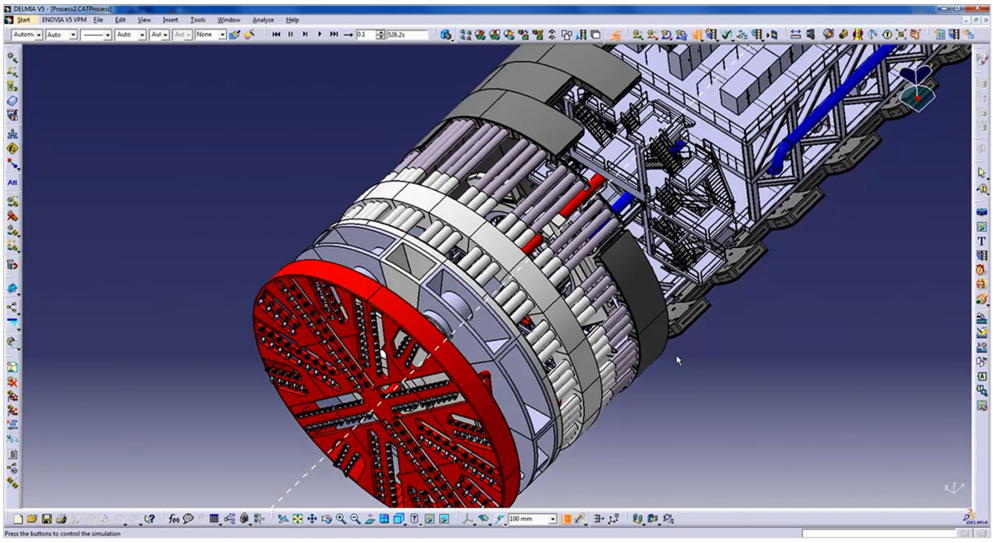
Challenge 3

The movement of TBM may not adhere to the predefined alignment, so there is an allowable construction tolerance for re-calculation and redesign of tunnel tiles.

Solution

Tunnel construction involves multiple parallel construction processes, such as transporting and installing tunnel tiles, advancement of TBM and installation of support structures.

CATIA was used to create a precise parametric 3D model of the tunnel, which is driven by 3D alignment. With advanced measuring technology, SFEG can measure the actual alignment by TBM and use the measured data to update the 3D digital model. Then the digital model will be used to fabricate tunnel tiles, so that SFEG can ensure the fabricated tunnel tiles will match the actual tunnels made by TBM. Also, the updated 3D model will be used to guide TBM, adjust its movement and control the overall tolerance from predefined alignment.



The skeleton models solve the problems of design adjustments by using dynamic design control capability.

Success factor

SFEG efficiently translated the complex construction data and technical issues of the Zhoujiazhui cross-river tunnel project into intuitive digital references. The early identification of risks has drastically reduced problem areas, improved communication and collaboration among multiple parties, and optimized workflow, so that the project can be delivered on budget and on schedule without compromising quality.

CONCLUSION

The benefits of the implementation of BIM and a Virtual twin are clear :

- Digital continuity can counteract industry fragmentation and drive speed and agility within design, engineering, manufacturing and construction processes.
- Reuse of digital know-how and knowledge accelerate project efficiency continuously.
- Easily accessible data about the project and how it has been built is invaluable when making decisions about the asset long after it is built.
- The ability to tie schedules back to the intelligence in the twin model is very useful in terms of eliminating inefficiencies or for predictive maintenance.

As design teams and contractors are up-skilling to take advantage of the benefits of BIM, one of the challenges is to train multidisciplinary teams and work with different generations of stakeholders. The **3D**EXPERIENCE platform and associated BIM and Virtual twin technologies hold the promise of this new age, where construction wastage and cost reduction are givens, alongside enhanced time management and better maintenance and security.

> "Everybody is reluctant to change because of comfort zone. Unless innovation brings new opportunities, change for the same doesn't work. We value our platform for what it allows: creating a shared and larger context. Design is altogether available for project owners, managers and citizens who want to be more involved. Unlocking the data to a larger context brings more value to what people create for other people."
>
> Jonathan Riondet, Senior Technical Director, Construction, Cities & Territories Industry, Dassault Systèmes .

Virtual twins allow the industry players to adopt infrastructure lifecycle management. It covers the areas of not only how to build, but also how to maintain infrastructure. Event in digital infrastructure extends industry player capability to drive new urban developments including efficient urban mobility, 5G speed network engagements and so on. Industry players could be innovators under the new trends leveraging virtual twin technologies and infrastructure lifecycle management.

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