INFORMED INFRASTRUCTURE
WHITE PAPER

How BIM Changes the Game for Transportation

EXECUTIVE SUMMARY

The movement toward building information modeling (BIM) for transportation projects has proponents around the globe, but it has yet to expand into widespread adoption. The reasons include entrenched practices that worked well for a long time, an older generation hesitant to learn new skills, and engineers' conservative nature when it comes to technology that hasn't been tried and tested. However, with a proliferation of visible benefits, BIM is being extended to much broader applications than just buildings.

Transportation is perhaps the largest beneficiary of this managed modeling approach, given the state and quality of transportation infrastructure. The will to address the increasing need to replace deficient infrastructure (particularly bridges) also can be fortified by BIM tools, because they model detailed construction costs and reduce construction errors for better value for each taxpayer dollar.

The BIM approach centers around an intelligent model shared across team members, acting as a collaborative hub throughout the entire lifecycle of an asset. The model can start at asset conception or later via highly detailed and automated data-capture technologies. The model gains intelligence as it gets passed among different practitioners who add their expertise, document conditions, or add operations and maintenance actions. The well-documented work assists and improves operations while reducing costs.

The game-changing processes and workflows start when companies adopt BIM tools to create a business advantage as well as differentiate and market themselves against competitors. BIM adoption culminates when it becomes standard business practice, as it has in many engineering and infrastructure design and construction firms. Owners are increasingly mandating a BIM approach, and it's being adopted by project participants who understand they can deliver a better product at a lower cost and differentiate themselves as industry leaders.

This white paper takes stock of the current adoption and documents some of the advantages of BIM for transportation projects and practice. There are benefits along the lifecycle of an asset, which translates to growing acceptance of BIM for new projects as well as ongoing operations.

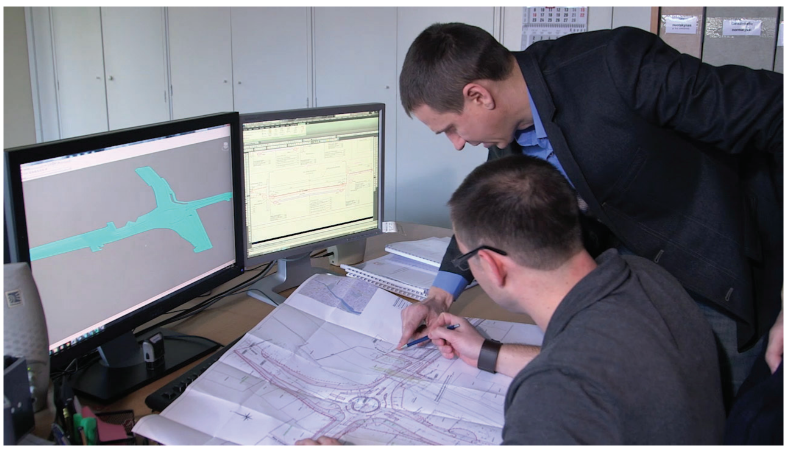
As the evidence for cost savings and improved efficiency accumulate, there's growing interest to mandate its adoption. In the United Kingdom (UK), the government used BIM in high-profile projects and advanced its adoption by extensive nationwide training. The government sees the approach as an advantage and an economic driver, where British firms will stand above others as well as command a higher wage.

Adopting new financing mechanisms for infrastructure projects, such as "Public-Private Partnerships (P3)," stands to accelerate adoption. This business approach will demand a higher degree of cost accountability due to the Wall Street investment and oversight, and BIM is poised to provide that.

Ultimately, this model-based approach ushers in next-generation transportation options that promise more-efficient movement of people and goods with reduced traffic congestion and emissions, and far greater safety. Autonomous vehicles are one such advancement, and these computer-driven cars are greatly helped by the detailed road models that BIM can provide to assist their navigation.

TOPICS

Kelprojektas



For Kelprojektas to stay competitive, remain a leader in Lithuania and expand globally, it is necessary to integrate BIM with transportation projects.

WORKFLOW EFFICIENCY GAINS

Every infrastructure project takes a phased approach, involves multiple stakeholders, and requires many coordinated teams for design, engineering and construction. The projects' complex nature generates a lot of information that requires coordinated sharing as well as detailed management of the construction timeline, materials ordering and overall cost.

BIM has advanced primarily because of this information-sharing requirement, avoiding the bottlenecks that a paper-based or 2-D digital representation entail. The modeling, and more specifically the collaborative work around a shared model, provides a leap forward in efficiency. Modeling also eliminates most of the costly misunderstandings when coordinated teams become uncoordinated. The model provides the means to share each phase of work and resolve any conflicts with the individual project components or schedule before they become time- and money-wasting issues on the ground.

Workflow is where model usefulness becomes most apparent, largely due to the complexity of infrastructure projects. Transportation projects bisect the underground infrastructure of water, sanitary and storm sewers, and electrical and gas infrastructure. Details on these existing conditions and the potential for conflicts must be known and recorded. The model becomes the place for that, with the modeling process progressing from planning to preliminary design, detailed topographic and asset surveying, detailed design, construction, and then maintenance. BIM is helpful for all such phases of design and engineering as well as along the project construction timeline and assets' entire lifecycle.

Winning Projects

The civil-engineering business model operates on a traditional sales funnel with the project universe at the top. Companies must seek out projects and clients, provide concepts to compete, and show why their firm should win these projects and represent the client. As the business-development funnel shrinks, it's critical to turn those prospects/projects into clients and business.

This can be very expensive when bidding and developing concepts on a number of projects. With the ability to rapidly generate "in-context" models, with multiple alternatives and approaches to prospective clients, companies can generate ideas, validate preliminary constructability and demonstrate that they're innovative from a bid-proposal standpoint as well as more apt to successfully execute the project through better public stakeholder understanding with rich and intelligent 3-D modeling.

Planning

In a project's planning phase, managers work to prioritize the dollars they have to invest, singling out the most critical maintenance tasks, and prioritizing new projects based on impacts and objectives. A city, county or state transportation department will have a detailed representation of their roadways as well as a backlog of projects that have received some form of vetting and approval.

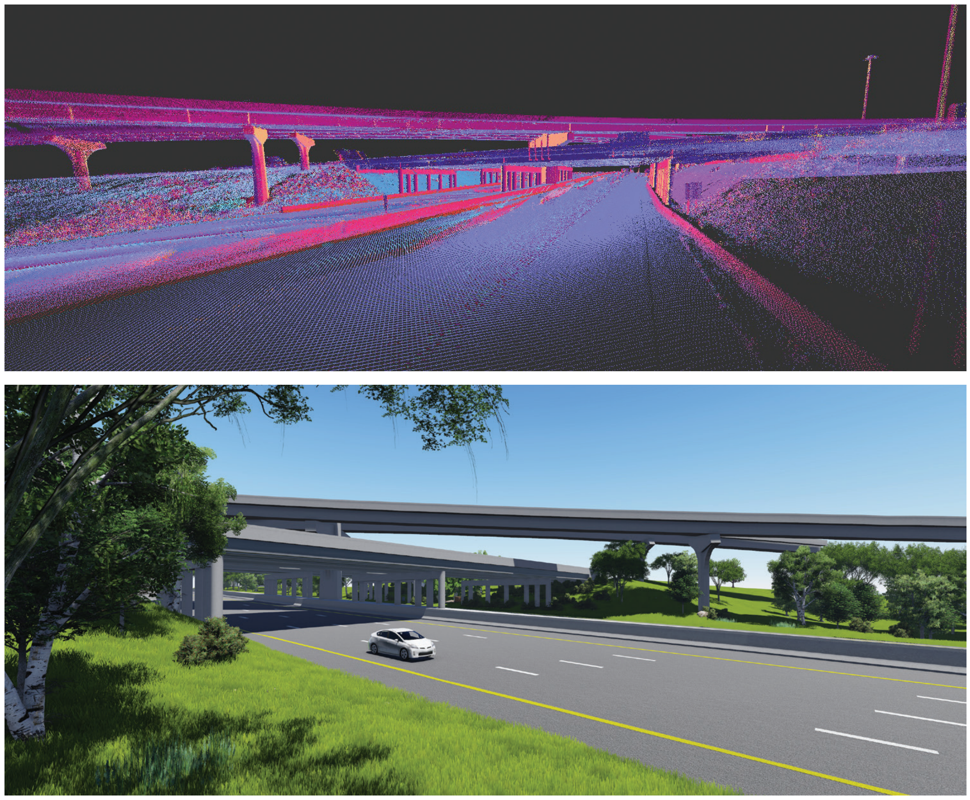
Often this information is map-based, but BIM is increasingly the decision-making tool that combines existing knowledge with plans. This phase involves comparing costs and effects as well as some modeling of different scenarios before any dollars are spent in the field. After projects are vetted and approved, they're sent to a designer for final design and plan documentation, and then let out for bid by contractors.

Data Capture

Before the design phase begins, a topographic survey is needed with an accurate 3-D representation of the project area. Traditional data collection involves professional surveyors capturing measurements and providing a 2-D map view with contour lines for elevation changes. New tools have advanced that deliverable to return a highly accurate 3-D representation that forms the basis for design and simplifies communication.

"Reality Computing" is a new term that encompasses the many ways data are captured from the physical world, put to use with digital tools to create designs, realized with land change and visualized for communication. For anyone engaged in the design, delivery or management of physical projects such as transportation, Reality Computing breaks down the barriers between physical and digital worlds.

New technologies enable the direct capture of spatial information about the physical world for integration into design processes. Design context is moving from geometry (modeled representations of the physical world) to captured reality data. Reality Computing helps design teams improve accuracy and accommodate physical-world conditions through customized fabrication of a design shaped to fit precisely with real-world conditions and environments. Furthermore, a technology explosion is affecting how digital projects or products can be realized in the physical world, from 3-D printing and machine-controlled grading to augmented-reality devices that allow users to see above and below ground.



Caltrop

LiDAR scan data (top) provide input for 3-D modeling and rendering (bottom), which was created in Autodesk InfraWorks.

Light detection and ranging (LiDAR) uses infrared laser light, instead of radar, to bounce off objects and return details about surroundings in what's called a "point cloud," with each point representing a surface that the light bounced back from. The point cloud provides detailed ground-surface measurements as well as accurate representations of roadside assets such as lamp posts, curbs, storm drains, guardrails, signs, overpass and underpass clearance and complexity, and surrounding vegetation.

Mobile LiDAR flown on helicopters, airplanes and UAVs, or mounted to vehicles that drive roadways, provides detailed capture of an entire project site more quickly and cost effectively than traditional survey methods. Such detailed 3-D capture is tailor made for the BIM starting point, as it provides the measurements and visualizations that can easily be turned into a model. More automated processes are coming to market to extract features from point clouds for faster movement from point-cloud capture to the realization of models that represent true project conditions.

Detailed Design

True modeling begins at the detailed design phase. Existing conditions are brought into the modeling environment, where designers build detailed 3-D models for creating construction plans and drawings as well as measurements and details of the required materials and quantities to begin procurement.

Designers also are increasingly turning to BIM to understand performance. They can model different types of intersections and roadway configurations and use simulations to show the actual traffic volumes at different times of day to see how different options perform. Such testing with simulated traffic volumes becomes a critical input to the decision-making process to find design alternatives that perform best.

With each added degree of project complexity, BIM proves its worth that much more. Such complexities may include a need to widen roadways while increasing bridge clearances, providing for better stormwater management, buffering around a landfill site, accommodating new development, and incorporating light-rail corridors and connections. Although this may be an extreme example, competing design parameters often need to be carefully weighed and tracked, and detailed models provide the means to achieve greater awareness.

"I don't want to say the 'old days,' because it wasn't that long ago, but we would march further ahead in the design process before coming to the presentation stage. If there needed to be a significant amount of change, then there was a considerable amount of redesign before you got back to presentation stage. Now that whole process is to design a little, present a little, and it's much more efficient."
- Scott Reed, PE, Huitt-Zollars

BIM ensures efficient data movement and a common understanding of what the design entails. The incremental "design and present" phase tunes models to stakeholders' goals and objectives, providing engineering rigor to ensure a lasting project.

Collaboration and Communication

With a shared model, designers, owners and contractors have a central place to work through the design for tradeoffs related to costs of different approaches and materials as well as design "constructability." Owners stay engaged in the process through the shared model, and contractors can use the model to create an informed bid without cost surprises.

Team members can look at the same detail, and discuss and walk through how to construct the design. If needed, compromises can be worked out regarding what works and what's the most-effective construction approach prior to pouring any concrete.

American Structurepoint

The Keystone & 131st project by American Structurepoint models vehicles and pedestrians. A visual simulation with realistic animation can be viewed at https://youtu.be/jHY2aUYBgbE.

The model also becomes the primary means to communicate project details to the public. For stakeholder meetings, a 3-D design can be overlaid on a model of existing conditions to create a realistic depiction of what the project will look like after construction. The 3-D presentation, in the context of what's there now, along with the information behind the model, provides a compelling and intuitive understanding to non-technical people. Modeling ease is changing this exchange to the point where suggestions can be input during a meeting and be displayed and analyzed in real time to accelerate consensus.

Earthwork and Construction

Today's earthwork machines are equipped with automated controls that take input from a model to cut and fill the earth to the contours of the project plan. The machines are equipped with sensors and actuators that tie into an accurate position via GPS, with the angle and depth of the earth-cutting blade driven by model details. This nearly robotic machinery eliminates the need for surveyors to stake out and continually assess the grading work, greatly speeding the process and adding accuracy, because the machine matches the model.

"The majority of contractors are taking the two-dimensional plans that we give them during the bidding process. If they win, then they are taking that and hiring a consultant to develop the three-dimensional model that they can load into their equipment for machine control and grading as well as paving in some cases."

- Cash Canfield, PE, American Structurepoint

During more-detailed phases of construction, the model again comes into play for constant review and, in some cases, revision as unforeseen circumstances arise.

As-Built Data

For those yet to adopt an integrated BIM workflow, the process involves the parallel creation of traditional 2-D design and 3-D visualizations. 3-D modeling often is done in parallel or after the design is complete to generate cross sections and earthwork quantities. The model is rarely, if ever, provided to the contractor, nor is it updated for as-built conditions. Such disconnected modeling isn't done in the same software and doesn't tie back through the decision-making process or contain much detail about design work.

Ideally, the BIM model is used as the project's living and central record that informs ongoing maintenance and future actions. The shared model becomes the place to generate cross sections and earthwork quantities, without additional software. It also provides the means to measure and track work progress.

Detailed as-built representations can be collected via LiDAR to create an accurate representation that can be compared with LiDAR collected prior to construction work. LiDAR provides an easy means to help document change against a model, because it involves the visual and algorithmic comparison of 3-D models. Although LiDAR is very important prior to starting a project, it's increasingly being used to document progress compared to the model.

FINANCIAL ADVANTAGES

The bottom line for such process change is to save dollars. Cost savings are achieved, but often not quantified, because it's difficult to compare old ways to new techniques. This is certainly the case with BIM, as most who adopt the process quickly acknowledge that there's no going back. The tools afford new means and advantages that prior processes can't match.

Although direct comparisons and dollars saved overall are difficult to calculate, incremental and anecdotal cost savings are significant. The biggest plus in terms of financial advantage over prior processes is improved project management, although it's still "early days" for best practices to be worked out or widely adopted.

Cost Savings

With every project, there are competing spheres of schedule, scope and cost. With more time, developers can come up with more solutions, but taking that time impacts the schedule and cost. With prior 3-D modeling solutions, calculating costs took far too much time to try multiple design scenarios or model different cost scenarios.

BIM provides the ability to understand quantities across the entire project, and it becomes much easier to test, get quantity takeoffs and calculate costs. Various design options can be tried against various objectives, and it can be determined within a reasonable timeframe which scenarios achieve optimal outcomes at the least cost.

There also are cost savings throughout the full life of an asset with a model-based approach, because you can use and reuse all the project data, rather than wasting time and money to recreate data. With a model, there's no wondering about the unseen, such as the depth and detail of elements underground, because there's a record of exactly how things were constructed. The goal is for the central model and data-management approach for one project to be preserved and used for all subsequent projects in the same place.

Transparency

With a BIM approach to infrastructure project delivery, the model contains a detailed representation of the job site to the point where virtual construction is possible. With a roadway, that translates into a more-detailed understanding of needed volumes of cut and fill, and a clear idea of road leveling and repaving challenges. The model contains an easy means to order materials and ensure they're being applied at the rate and thickness of the roadway repair or construction-engineering plan.

"When you have a 3-D design where you can calculate quantities, it's really easy to come up with the cost. Before, it would have been a very segmented and time-consuming process to get to those costs."

- Scott Reed, PE, Huitt-Zollars

With exacting quantities comes enhanced transparency, because the contracting agency and bidders are clear on the model's material outputs, and they can receive their own copy of the model to test and help them complete their bid.

The public, who pay for most roadway, rail and airport projects, gains greater confidence that their government is efficient, because the model becomes the reality. The model also helps simplify complex engineering tasks for a greater understanding of where dollars are going.

P3 Possibilities

Because capital is so constrained, new financing mechanisms for infrastructure projects, such as Public-Private Partnerships (P3), are taking hold. City, county and state governments are turning to the private sector to fund projects more frequently. Part of the reason is the decline in government transportation funding along with the need to accelerate the replacement of aging infrastructure.

With P3 projects, they're generally "design-build" and sometimes "design-build-finance-operate-maintain," where the contractor takes the lead on all aspects. With the contractor's role expanding, there will need to be much tighter coordination and collaboration with designers. The bottom-line cost is critical in P3, and this tighter alliance will ensure that if there are issues in the field, the design will get updated rapidly so no workers are idle, and the overall construction timeline moves faster.

P3 stands to accelerate BIM adoption on transportation projects thanks to the need for tighter integration between design and construction due to increased focus on project cost and schedule. The enhanced bottom-line scrutiny will demand a higher degree of accountability, and BIM is poised to provide that.

DRIVING THE ECONOMY

Jumping from BIM advantages on project work to BIM fueling economic expansion of a nation might seem an outsized leap. But with process change that represents such a clear-cut advantage, it pays to be a quick adopter and gain an edge in terms of training and streamlined practice.

Infrastructure projects have high profiles, and there's broad global demand for companies that can deliver the gleaming next-generation project that puts the world on notice that an emerging economy has indeed emerged. This desire to be on the cutting edge is a powerful force that can funnel funds to those ready to meet this demand.

Big-Time Buy-In

With the economic downturn and financial crisis hitting hard, BIM mandates in the UK are a play for economic advantage. The government recognized that adopting BIM throughout the construction supply chain would put them ahead of the world. It also saw an opportunity to instill confidence to push businesses to invest in process change by taking charge and demanding BIM on high-profile projects of their own making, such as the large-scale Crossrail subway-construction project in central London.

COWI

At regular sessions, the COWI team presents its work to clients by conducting a fly-through of the model. Based on customer feedback, they modify the design, with changes applied in real time during meetings.

Her Majesty's Government set forth a BIM hypothesis that states: "Government as a client can derive significant improvements in cost, value and carbon performance through the use of open, sharable asset information."

This rather simple statement justifies wholesale adoption with laudable goals, but deeper factors are at play. The government understands that the international consultancy market is highly competitive and deems it important that UK companies remain ahead in terms of new technological approaches. The UK's strategy is to use BIM adoption in the domestic market to enhance expertise and maintain the country's leadership in global markets.

BIM practice in the UK is a bright spot in terms of testing adoption strategies, setting global standards, achieving project efficiency and cutting costs. Wholesale adoption, and the level of public discourse and debate, means the country is getting the jump on the best approaches, which undoubtedly will pay off dividends in won work.

Standards and Mandates

The UK government set forth several standards and framed its expectations in terms of BIM adoption. It detailed the natural progression of BIM in terms of levels along a ramp of process improvement, setting the bar by demanding Level 2 BIM adoption on projects. This commitment compels project participants to provide defined outputs via BIM and maintain BIM as a series of self-contained models that allow for information exchange with other participants.

By defining expectations, endorsing existing standards and projecting further advancements, the UK government achieved thought leadership status not for itself, but for its best and brightest.

In the United States, there have been similar attempts to push BIM forward, but with a much less heavy-handed mandate. In the transportation realm, the Moving Ahead for Progress in the 21st Century Act (MAP-21) uses the funding of surface-transportation projects to encourage a performance-based approach through incentives. MAP-21 promises that projects using 3-D modeling/virtual construction and visualization technology will be funded with more flexibility than those that do not.

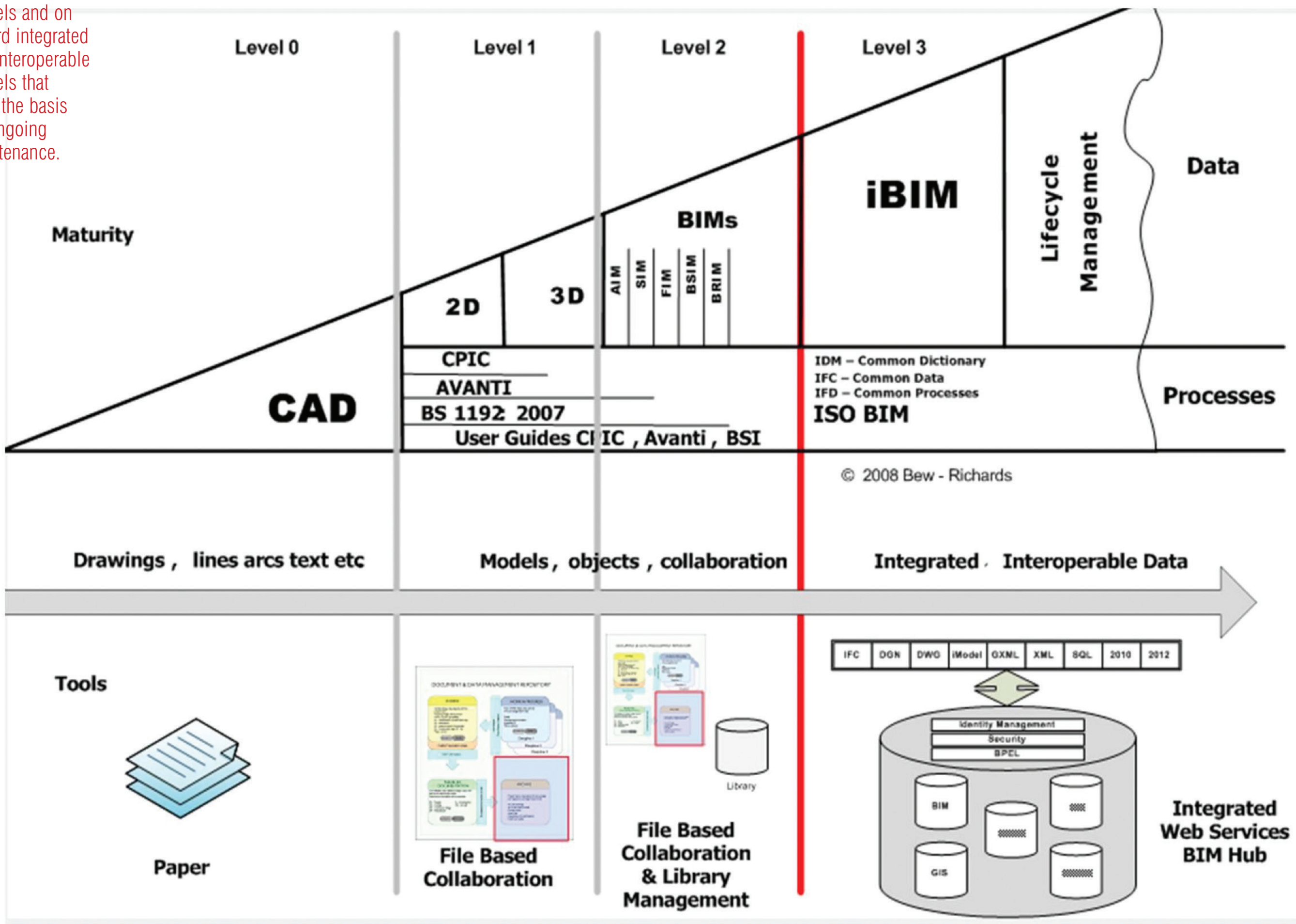
The follow-on to the MAP-21 initiative is a second wave of the Federal Highway Administration (FHWA) Every Day Counts (EDC-2) innovation initiative, which focuses on shortening the time to complete highway projects, and directly specifies 3-D modeling and geospatial data collaboration as key components moving forward. FHWA also is earmarking funds in its Accelerated Innovation Deployment (AID) program to help offset investments in innovation that lead to more-efficient highway project delivery.

"You always hear horror stories where something is wrong with the design. The contractor identifies the problem, but then they have to wait for the designer to get the change made while machines are running. Through these P3 projects, interaction between contractor and designer will be greatly enhanced, which will increase the speed to make changes and complete the construction project."

- Cash Canfield, PE, American Structurepoint

Government incentives are self-serving, given that it funds most transportation projects, as well as altruistic in terms of the desire to see companies thrive in the broader global market. Through standards and mandates, governments are slowly pushing BIM toward its ultimate advantage of collaborative and coordinated use for long-term asset management.

The UK BIM Task Force developed this ramp of different levels of BIM adoption that details the progression from drawings to models to collaborative models and on toward integrated and interoperable models that form the basis for ongoing maintenance.



Quantified Gains

Modeling provides the ability to understand infrastructure more clearly, model the environmental impacts of infrastructure and monitor its performance over time. Model intelligence relates to inputs from individuals as well as sensors that measure environmental forces.

Sensor use is increasing in the infrastructure space, with embedded sensors being added to bridges to detect how they respond to loads, how they may be degrading over time and particularly how they respond to seismic events so safety can be immediately assessed.

This increase in sensors ties to the Internet of Things, where more of the everyday objects around us will be connected to the Internet to communicate their condition. In the infrastructure space, such new connectivity led to the "Smart City," where services and conditions can be addressed by city managers, and citizens can address current status.

The transportation component of the Smart City deals with traffic congestion, parking and access to multimodal transit options. In some early adopter areas, such as New Songdo, South Korea, a central traffic management allows for changes in lane configuration with embedded LED sensors in the roadway that automate the opening of more lanes in any given direction to ease peak-hour congestion.

Corporate Advantages

Just as countries can advance economic advantages by adopting BIM, so can companies. Early adopters have seen billings increase with BIM, although the upfront costs for new training may take some time to pay back.

With BIM, there's added flexibility on detailed design work as well as project management, and most who adopt the approach don't ever want to turn back.

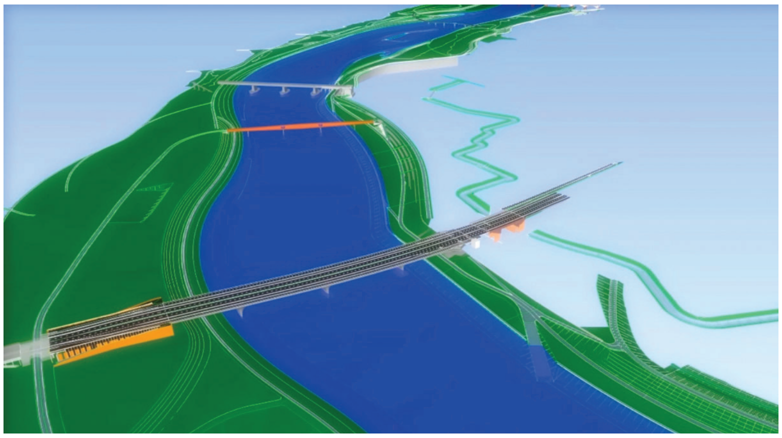
"We aren't selected based on price, but by our qualifications and approach to the project. We create a model and develop different concepts of what the project could look like after construction. We put that right in our proposals and marketing materials, and believe that gives us a competitive advantage."

- Cash Canfield, PE, American Structurepoint

In addition to business advantages from winning new work or being able to bill at higher rates for advanced modeling, there are advantages to how software is delivered. With a subscription-based Software-as-a-Service model, companies set up each project and apply their license toward the mix of tools most applicable to that project. The programs can track software use per project, with licenses fine-tuned to needs. With such reporting, users can bill the software to the project on a regular basis, shifting software costs from what has traditionally been a capital expense to an operating expense, thus helping the bottom line.

TECHNICAL TRAJECTORY

The move toward BIM is fueled by ongoing technology advancements that allow users to make larger models more quickly and cost effectively, while increasing project



INFRANEA

The total cost of using BIM on River Waal project in Nijmegen, The Netherlands was recouped in just six months of construction operations. The integrated project model incorporates existing conditions and survey data, designs for waterworks, roads, bridges, and over 5 million cubic meters of earthworks – combining designs from more than 10 different engineering disciplines.

insights. Companies that create these tools are driven by the possibilities as well as the desire to impact outcomes and win more market share from competitors.

As with all technology, there are tools and tricks that can be borrowed from other markets and applications that, when adopted, can afford an advantage. In the AEC space, the realism and speed of gaming is one of the rich areas to mine for advancements, but so are areas of Big Data analytics and sensing and monitoring to ensure that created models contain human as well as machine intelligence.

Modeling, Simulation and Analysis

BIM helps simulate conditions to enable workflows and models to test and try different things. Simulation is taking an interesting path with the aid of computer algorithms that can replicate patterns in nature. Generative design is the term for this next phase of computer-aided design, where computers keep iterating options that perform well to design guidelines and present options. This may result in new bridge designs with surprising shapes that add strength and resilience via rigorous computer-based tests against possible conditions.

In transportation, simulation is informed by real-world conditions and myriad sensors that count cars and track movement and dispersal around major spikes such as rush hour or a special event. Huge amounts of new data, including a better understanding of people's movements that can be tracked via social media, provide a wealth of new information that continues to improve decision making. The field of Big Data analytics helps make sense of all this information to help inform and modify designs to react better to events and ensure the long-term performance of infrastructure.

Platform Progression

Software has traditionally been discussed as desktop, server or mobile, based on the machines where the software resides. Such lines now are completely blurred due, in large part, to the new infinite computing of Internet-accessible server farms collectively known as "the cloud." With cloud-based computing, users tap into infinite storage and harness the power of multiple computers for such things as the compute-intensive operations of rendering large and highly detailed 3-D models.

Cloud-based computing already is assisting in the transportation design and engineering functions for those who use Autodesk products. Autodesk InfraWorks 360 offers many advanced tools such as automated rules-driven intersection design as well as sight and distance analysis to determine the optical hill grade that allows for the best line of sight.

Additional tools integrating the work of other disciplines that intersect transportation infrastructure projects, such as stormwater modeling, are set to further advance BIM workflows on transportation projects. The extension of tools specific to these disciplines encourages greater collaboration as the model becomes more central to daily operations.

Autonomous Advantages

New means and modes of transportation are being driven by Silicon Valley companies, such as Google's autonomous vehicles, Elon Musk's assertions that Tesla vehicles will lead with advanced autopilot technology, and interest from upstart ride-sharing networks Uber and Lyft to create their own autonomous cars. These sensor-equipped vehicles are coming quickly, with many projecting rapid advancement and such vehicles on the streets by 2020.

Key to their enhanced safety are detailed representations of roadways as the basemap for navigation. Moving toward BIM in transportation appears vital to these advancements as the engineering-grade models from construction projects amass to provide millimeter-level accuracy to vehicles that ply our roadways.

In the trucking sector, such detailed models aid efficiency. With heavy loads, trucks lose speed and wear out breaks over hills and valleys. With an onboard model and adaptive transmissions, trucks can accelerate or downshift to even out the gains and losses for quicker times and less fuel use.

SUMMARY

BIM is taking hold in transportation projects thanks to positive bottom-line results. The coordinated model ensures that projects run efficiently, stakeholder communication helps eliminate costly rework, and project outcomes are met in a timely and cost-effective manner.

Early BIM adopters have seen investments pay off. The process change creates a more-flexible workflow where users can more actively involve owners and stakeholders in decision-making and review processes. They also can engage contractors more closely so they collaborate on project timelines and construction phases before machines and workers are on the ground, minimizing errors and costly holdups, and ensuring the project progresses smoothly.

The global marketplace for infrastructure design and engineering services has few boundaries, and large international firms are working on projects worldwide. Governments have recognized this competitive landscape and have been among the first to adopt BIM practices to help their firms and citizens compete and earn the higher wages that such work demands.

BIM follows a continual technology progression toward more-connected software that automates the drudgery and improves design quality and efficiency construction. The trends of big data and sensor proliferation tie in nicely to BIM enhancement, with transportation data helping to inform the model and sensors providing input on infrastructure performance.

The next generation of transportation infrastructure is working to combat congestion as well as enhance safety and sustainability. BIM provides the means and mechanism to ensure that each new project contributes toward these goals with software that aids advancement in design, engineering and construction via a collaborative and quantifiable process.

RESOURCES

The UK BIM Task Group - http://www.bimtaskgroup.org

The U.S. Department of Transportation, Federal Highway Administration, Moving Ahead for Progress in the 21st Century (MAP-21) - http://www.fhwa.dot.gov/map21/

The U.S. Department of Transportation, Federal Highway Administration, Every Day Counts (EDC-2) innovation initiative - http://www.fhwa.dot.gov/everydaycounts/

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