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## What does BIM mean for civil engineers?

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### ***Road and highway projects can benefit from design using building information modeling.***

A few weeks ago, I was on the phone with a civil engineer who needed help with a question he was asked by an architecture firm: "Are you BIM ready?" The civil engineer had a good understanding of the benefits of building information modeling (BIM) for building design, and had ideas about how those benefits might extend to civil engineers. But he wasn't sure how to answer the question. Did BIM even apply to civil engineers? And if it did, would he have to use new software to be "BIM ready?" What if he wasn't working on projects that involved buildings? Could he still do BIM?

As BIM adoption has become more of a standard in architecture and construction, civil engineers have been taking notice and are asking the question: What does BIM mean for me? For civil engineers who regularly work with architects or structural engineers, BIM may already be part of their vocabulary. But for those who spend their days designing roads and highways, BIM represents a whole new world, one that is highly relevant now and will continue to grow in importance.

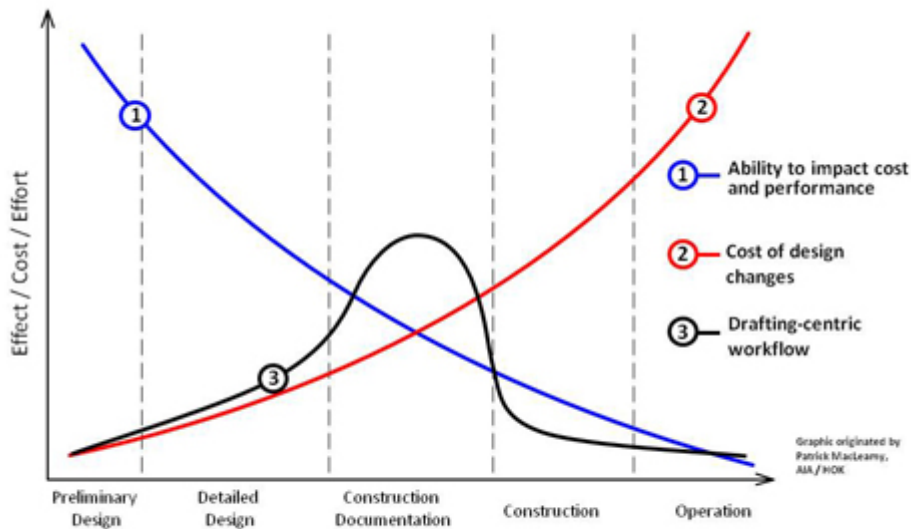
### **What is BIM?**

Building information modeling—BIM—is not a product or proprietary software program. It is an integrated process built on coordinated, reliable information about a project from design through construction and into operations. BIM is not just for architects. While it has its roots in architecture, the *principles* of BIM apply to everything that is built, including roads and highways, and the *benefits* of BIM are being experienced by civil engineers in the same way they are enjoyed by architects.

BIM is not just about 3-D (although that is part of it). BIM allows engineers more easily to predict the performance of projects before they are built; respond to design changes faster; optimize designs with analysis, simulation, and visualization; and deliver higher quality construction documentation. Furthermore, it enables extended teams to extract valuable data from the model to facilitate earlier decision making and more economic project delivery.

### **Drafting-centric design limitations**

To understand how BIM applies to civil engineering, and to road and highway design projects specifically, it is helpful to first take a look at the legacy 2-D drafting-centric design process. This process, which can best be described as "siloeed," starts with preliminary design, moves to detailed design, and then on to construction documentation. Each step is completed before the next one begins, and collaboration is very limited. This process works well until the inevitable design change needs to be made, at which point time-consuming and error-prone manual drafting updates are required. As such, this process has inherent practical limitations.



The graph in Figure 1 (above) maps the level of effort required over the life of a typical road design project from preliminary design all the way through to construction and into operations. As the blue line indicates, the ability for the civil engineer to impact project cost and performance over the project lifecycle is at its maximum during preliminary design, but sharply decreases as the project progresses. The red line shows how the cost of making and executing design changes is low during preliminary design, but sharply increases during the project. Finally, the black line illustrates where civil engineers and designers expend the most effort and resources with a drafting-centric process—during the construction documentation phase.

The problem with this picture is that the peak of the effort (black line) coincides with a point in the project when the ability of the engineer to impact project performance is declining and the cost of making design changes is increasing. This gets to the heart of the limitations of a drafting-centric workflow. While it is theoretically possible to use this process to perform iterative design for optimizing project performance, realistically, very little of this is done. It is just too costly to make multiple design changes and evaluate impacts on project performance once the documentation is started. As a result, a drafting-centric process typically yields the first design that meets code, and not necessarily the optimal design.

### New workflows with BIM

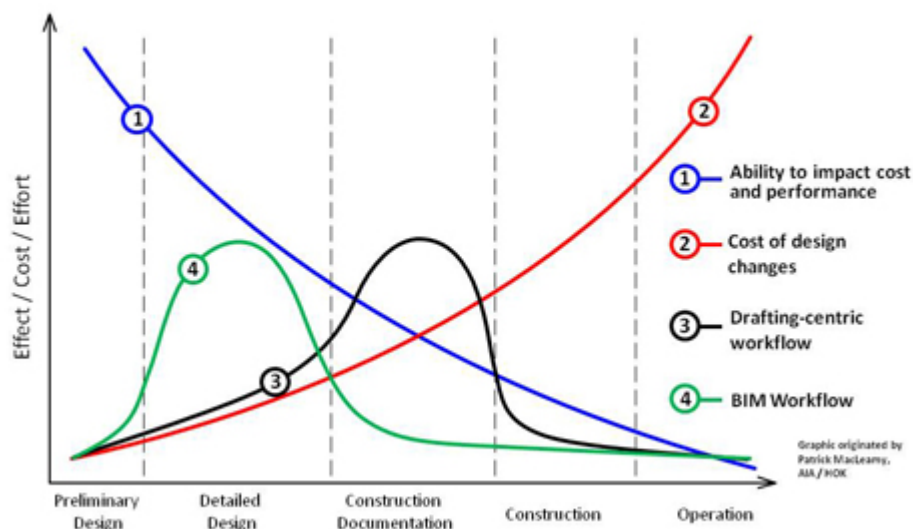
Contrast this legacy approach with one that is becoming a standard across the AEC industry—BIM. Implementing a BIM process for road and highway design starts with creation of coordinated, reliable design information about the project. This results in an *intelligent* 3-D model of the roadway in which elements of the design are related to each other dynamically—not just points, surfaces, and alignments, but a rich set of information and the attributes associated with it.

For example, perhaps halfway through a roadway design project the profile needs adjustments to a vertical curve and the grades. By adjusting the profile, all of the related design elements update automatically, allowing the designer instantly to see the impact to cut and fill and right-of-way.

In this way, BIM facilitates evaluation of many more design alternatives. As part of the design process, civil engineers can leverage the information model to conduct simulation and analysis to optimize the design for objectives such as constructability, sustainability, and road safety. Finally, with a BIM process, design deliverables can be created directly from the information model. Deliverables include not only 2-D construction documentation, but also the model itself and all of the rich information it contains, which can be leveraged for quantity take off, construction sequencing, as-built comparisons, and even operations and maintenance.

So what about this BIM approach is different? The use of modeling, 3-D visualization, and analysis is nothing new

for road and highway design professionals. The difference is that with traditional drafting-centric approaches, design, analysis, and documentation are disconnected processes. This makes evaluation of what-if scenarios inefficient and cost prohibitive.



As the green line in Figure 2 (above) demonstrates, by dynamically connecting design, analysis, and documentation in a BIM workflow, most of the effort in a roadway design project is shifted back into the detailed design phase when the ability to impact project performance is high and the cost of making design changes is low. This allows engineers to spend more time evaluating what-if scenarios to optimize the design and less time generating construction documentation. With this in mind, consider how adopting a BIM process translates into real benefits for road and highway design.

### BIM benefits

The most immediate benefits of BIM for road and highway design are better designs and increased efficiency and productivity. Because design and construction documentation are dynamically linked, the time needed to evaluate more alternatives, execute design changes, and produce construction documentation is reduced significantly. This is particularly important for transportation agencies because it can shorten the time to contract letting, resulting in projects being completed sooner and within more predictable timetables.

Beyond efficiency and productivity, BIM facilitates roadway optimization by including visualization, simulation, and analysis as part of the design process. Following are two examples of the many criteria that can be assessed to achieve an optimal roadway design:

**Constructability**—Civil engineers typically design for code compliance, not for constructability. But incorrect interpretations about design intent made in the field because of ambiguous documentation can lead to delayed schedules, change orders, and RFIs after construction begins.

Consider a typical new highway construction project with bridges and interchanges budgeted for \$100 million. Typically, about 7 to 8 percent of that will go into design development. Reducing the design spend by 35 percent with a more productive process saves \$2.6 million. But reducing the construction portion by 15 percent by considering constructability during design saves nearly \$14 million. And these savings don't take into account litigation that can result from mistakes in the field. Designing for constructability can help reduce these mistakes before they become a problem.



**Road Safety**—Analysis to ensure safe stopping and passing sight distances is a key factor driving design decisions. Traditional sight distance analysis is based on mathematical equations applied to vertical curvature in the road profile. But this approach fails to take into account factors such as horizontal layout and visual obstructions. Integrating interactive visualization and sight distance simulation into the design process (see Figure 3 above) allows the civil engineer quickly to identify whether the road geometry meets critical safety parameters related to sight distances, including grades, curvature, and visual obstructions such as barriers, berms, and foliage.

Probably the most significant advantage of BIM compared with a drafting-centric process is the ability to extend the use of the information model beyond design, analysis, and simulation into construction and, eventually, operations. For example, transportation agencies increasingly are using the 3-D model for operating construction equipment with GPS machine guidance. Benefits include increased productivity and accuracy, reduced survey costs, lower equipment operating costs, and an extended work day.

**The promise of BIM for road and highway design**

Constructability and road safety are two examples of analysis and simulation that a BIM process facilitates. But that is just the beginning of the story. At the Wisconsin Department of Transportation (WisDOT), which is in the process of implementing AutoCAD Civil 3D, Autodesk’s civil engineering software built for BIM, road design, geotechnical, stormwater, and bridge teams use specialized analysis applications and custom tools to simulate and analyze different aspects of project performance.

However, in most cases, these tools are being used as part of a disconnected workflow. The analysis and simulation is being done outside of the design environment by different parts of the organization, and, as a result, it is difficult to coordinate one type of analysis with another to achieve optimal results.

Autodesk representatives recently shared with WisDOT the value of a BIM process where many types of analysis and simulation would take place as part of the design process, allowing engineers quickly to cycle through iterations and get instant feedback on project performance. Traffic capacity, noise, lighting, drainage, and signage analysis could all be done earlier in a project as part of the design process, well before significant effort is invested in construction documentation. WisDOT engineers acknowledged the benefits and that, if the technology was heading in this direction, they looked forward to experiencing this reality.

From my experience with the WisDOT team and many conversations with civil engineers during the last year, I am convinced of the value of BIM for road and highway design both now and in the future. Organizations such as WisDOT are well on their way to becoming BIM-ready.

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