Meeting Today's Challenges, Reaching AEC's Future

CIMdata Commentary

Key takeaways:

- *The Architecture, Engineering, and Construction (AEC) industry faces severe challenges, with productivity issues topping the list.*
- *Construction firms need to better leverage advanced computing technologies and off-site fabrication to improve competitiveness and efficiency.*
- *Tools and experience supporting other major industries with off-site fabrication—such as automotive, aerospace, and shipbuilding—can be leveraged to great benefit.*
- *To best meet these challenges, companies need open, integrated systems that enable the free flow of information from product concept, through design and construction with current and future partners, and eventually through to owner operators.*

Industry Challenges

Most of the built world results from work by the Architecture, Engineering, and Construction (AEC) industry. Buildings, bridges, roads, processing plants, and other engineering marvels come from professionals in this important global market. The AEC industry's mission is to complete the projects that shape our world. The AEC industry, estimated by some to be as high as 10% of global GDP, is an engine of the economies around the world. (In 2012, the global world product value was estimated at nearly $85 trillion.)

Just as in other industries, this global powerhouse faces significant challenges today and in the years ahead that impact both the top and bottom lines. Traditional building methods are reaching the limits of productivity improvement. Companies face rising costs on a number of fronts, including materials and insurance. New standards such as the desire for "green" buildings entail increased costs and complexities.

At the same time, the dynamics of the market, and the relationships between buyers and suppliers, are creating additional challenges. Historically, many projects had a clear separation between the engineering and construction of the physical asset, and the owner-operators who ran, used, and managed the asset throughout its life. Now, to save money and reduce risk, new models of collaboration, delivery, and management, such as public-private partnerships (PPPs) and private finance initiatives (PFIs), are making project management, subcontract management, and other skills, more essential to achieve shrinking margins. In response, some architects are moving to an integrated project delivery (IPD) model, a form of contractual agreement that helps information flow more freely among the participants, which is showing promise to address some of the issues facing AEC. But like any new approach, it too changes the relationships between the parties and requires new skill sets to be successful.

Players in the AEC industry are looking for ways to protect and increase their margins in this dynamic business environment. Just like their counterparts in automotive and aerospace value chains before them, they are looking to raise their stature by providing more value-added products and services that give them a unique competitive advantage. One example of this trend is the rise of specialty contractors who provide more comprehensive engineering

and construction services.[1] But with all of these changes affecting the industry low productivity is the most critical issue. AEC industry leaders agree there is at least 25% waste built into current projects. A benefit of focusing on productivity is that if it can be successfully addressed, it could be a lever to achieving other goals for the market.

What is the vision to achieving productivity improvement? How can the construction industry become more competitive? The recommendations from a recent study by the US-based National Research Council (NRC) provide some useful guidance.[2] They point to five key areas that are ripe for change and improvement:

1. Widespread deployment and use of interoperable technology applications
2. Improved job-site efficiency through more effective interfacing of people, processes, materials, equipment, and information
3. Greater use of prefabrication, preassembly, modularization, and off-site fabrication techniques and processes
4. Innovative, widespread use of demonstration installations
5. Effective performance measurement to drive efficiency and support innovation

The focus of this paper is on three of these areas: the use of improved technologies, off-site fabrication, and more effective performance measurement.

Using More Advanced Tools: Leveraging Models Across Domains

The AEC industry is a project-based business where groups of independent specialists come together to collaborate to complete a specific project like a building, plant, or bridge. To work together effectively, these companies need to exchange information about the various aspects of construction, including graphical representations of the desired results.

In some respects, the AEC industry is following a digital trail blazed by the automotive, aerospace, and high-tech industries over the last thirty years. Companies in those industries have moved away from a reliance on 2D information and locking up vital data in documents and drawings. Currently, the AEC industry is moving towards relying on "a digital representation of the physical and functional characteristics of a facility, …a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition."[3] Models are developed from various perspectives, e.g., virtual design models, energy models, construction and scheduling models, cost estimating models, and ingress and egress models. Just as in manufacturing, all of this information is associative, so that changes in one area should be immediately reflected in the other views.

This approach is also being expanded beyond 3D information to cover more aspects of the lifecycle. Some include the time dimension and refer to 4D, allowing participants to visualize the entire project duration as a series of events and display the progress of construction activities through the lifetime of the project. The next added dimension, cost, is essential to getting the higher productivity and cost savings necessary to move the industry forward. Referred to as 5D, this addition enables the various participants to visualize the progress of construction activities and their related costs over time. The next dimension refers to the handing over of 5D data for use in facilities management. In this way, 6D is replicating the

[1] http://california.construction.com/california_construction_news/2013/0321-subs-engineers-clamor-for-collaboration-at-futuretech.asp

[2] National Research Council. "Advancing the Competitiveness and Efficiency of the U.S. Construction Industry." Committee on Advancing the Competitiveness of the U.S. Construction Industry. 2009.

[3] National BIM Standard—United States. National Building Information Model Standard Project Committee. http://www.buildingsmartalliance.org/index.php/nbims/faq/

experience in aerospace, where the builder of an asset (in this case a jumbo jet) and the eventual owner can be different organizations. This is especially important in the aerospace and AEC industries as more and more asset creators rely on after-delivery service and support for their profits.

Currently digital techniques that support AEC are being adopted most heavily in the United States, but a wave is starting in Europe, and emerging countries like China see the value of moving to 3D. In many ways, this is the AEC industry's product lifecycle management (PLM) approach—one that integrates the people, processes, and information systems used to design, construct, and operate facilities. Just as in PLM, clear, concise, and valid information is crucial to success.

While these new techniques and solutions provide some 3D capabilities, many of the partners in such projects still rely on 2D drawings for communication and collaboration. Just as manufacturing has benefited from the move of value chains to full 3D, so could the AEC space.

Recent CIMdata research focused on how building product manufacturers can support this need for a 3D approach to provide a major area of benefit. Companies designing and building physical assets need to (virtually) combine all of the mechanical CAD (MCAD) data for building products and equipment with the 3D models from AEC solutions to provide a comprehensive picture of the project. MCAD solution providers with strong positions in the market for building equipment design will have a leg up in supporting the AEC industry with complete 3D information reaching all project participants.

Off-Site Fabrication

Because much of the cost and waste in construction comes from on-site building practices, the NRC recommends off-site fabrication of major elements of a project to take advantage of factory-like efficiencies. Many of us know this as "prefabrication" or "prefab," which has a negative connotation in the public realm due to a history of poor quality products. The bad reputation was often well deserved, and the rebranding of this approach as "off-site construction" was a conscious decision to change perceptions.

Construction costs fit into three primary categories: installation cost, material cost, and fabrication cost. Most construction projects depend on on-site installation, using highly skilled workers doing on-site fabrication consuming a large portion of total materials, which drives up installation costs. The more that can be fabricated off-site, the less space is needed to store materials on site. In many cases, lower priced workers can do the fabrication in factories, reducing overall labor costs. The fabricated units can be delivered just in time, like in automotive, and installed using less-skilled teams. The ability to plan accurately, unaffected by weather, subcontractor availability, or other constraints can also improve cash flow. Using 3D tools to support the modeling, simulation, fabrication, and installation can greatly improve the effectiveness of off-site approaches.

Of course, many components have been fabricated off-site for some time; a practice that has provided significant value. A current example from infrastructure is prefabricated bridge elements and systems.[4] These highly engineered components are fabricated off-site, delivered just in time, and installed rapidly. Benefits cited by this program include reduced traffic disruption, construction zone safety, environmental sensitivity, and improved constructability, with increased quality and lower lifecycle costs.

[4] http://www.fhwa.dot.gov/hfl/innovations/pbes.cfm

Industrial companies have proved the value of off-site fabrication for large, complex deliverables in automotive, aerospace, and shipbuilding for many years, supported by PLM strategies and enabling solutions. Leveraging this experience in AEC could be greatly beneficial to all involved. This point is strongly argued by Kieran and Timberlake in their 2004 book *Refabricating Architecture: How Manufacturing Methodologies are Poised to Transform Building Construction*.[5]

This approach is being promoted globally. For example, practitioners in the United Kingdom are being urged to adopt off-site fabrication in the short term.[6] Rapidly growing economies like China will not be able to meet their aggressive development goals without it. The approach has the added benefit of helping Chinese firms and agencies address their often conflicting speed and quality demands.

Off-site construction allows for grouping similar methods, supporting repeatability and consistency, all with a reduced need for skilled trades on site. Construction is completed in a controlled environment, improving quality and precision, while reducing waste. This echoes the concept of "lean," another idea from the automotive industry (an early investor in PLM), which has great applicability in AEC.

Off-site fabrication benefits include:[7]

- More controlled fabrication conditions
- Fewer environmental impacts at job site
- Compressed project schedules
- Fewer crew-scheduling conflicts, more efficient use of craftspeople
- Reduced on-site storage requirements
- Increased worker safety

The use of off-site manufacture and modern methods of construction can drastically reduce construction waste. Big waste streams in traditional construction include packaging (up to 5%), timber (up to 25%), and plasterboard (up to 36%). By eliminating wood pallets, shrink wrap, and cardboard, and reducing waste plasterboard, timber, concrete, bricks, and cement, companies can reduce such waste by up to 90%.[8]

Off-site fabrication changes the AEC process on-site from construction to manufacturing and installation. The Modular Building Institute claims that buildings can open 30-50% faster when off-site fabrication is used in construction.

Effective Performance Measurement to Drive Efficiency and Support Innovation

Some of the existing solutions in the AEC space enable improved performance measurement with project or program management functionality. More advanced firms may use standalone project management tools like Microsoft Project or Primavera, but adoption is limited across the value chain. As in other areas, the solution used most often is Microsoft Excel.

[5] Kieran, Stephen, and James Timberlake. *Refabricating Architecture: How Manufacturing Methodologies are Poised to Transform Building Construction.* McGraw-Hill Professional. New York. 2004.
[6] http://www.buildoffsite.org/
[7] www.modular.org/marketing/documents/WRAP_ModernMethodsConstruction_Report.pdf.
[8] Ibid

Companies can improve their performance by using an integrated tool to track project status and costs in real time. Having a platform that can be used to both plan and execute the complex tasks in most projects can provide significant value. This is another area with proven results over many years in the PLM space. Management is greatly improved if the project management tools are integrated with solutions to manage 2D documents, 3D models, and other artifacts necessary for project execution.

Getting There

Many tools exist to help address these problems and to support new AEC paradigms. Existing solutions targeted at the AEC space can support some use cases. Some firms are also working to apply mechanical design tools in the AEC domain. To achieve the maximum benefits, the best of the AEC and mechanical domains must be integrated. Tools to support complex project management must also be part of the solution.

Just like in PLM, the ability to leverage technology is limited by an organization's ability to make process changes. AEC companies have to be willing to change their longstanding work processes to be successful. This is no small feat. In spite of all of the success of 3D CAD in designing manufactured goods, many supply chains and shop floors continue to run on 2D drawings. For AEC, the chosen solutions need to support collaboration across domains within firms and across the entire extended enterprise—to include all project stakeholders across the entire lifecycle. To reiterate what was said earlier in the commentary, what is needed is an integrated platform for managing 3D (and other information), that supports modeling and analysis for 4D and 5D. When employed appropriately across the project life to capture all data, it could be delivered as a single source of truth to enable 6D.

Just as in manufacturing, these types of tools will enable users to conduct complex tradeoffs among competing objectives. For example, solutions could help define an optimal sourcing approach, in this case the mix of on-site and off-site fabrication. Users can develop initial plans, and then run simulations to find the right combination.

Building and enhancing such a platform requires a commitment to openness. New standards are emerging, such as Industry Foundation Classes (IFCs). Like manufacturing, the AEC space has many standalone legacy tools that must be included (or replaced) to support all lifecycle requirements.

Looking to the Future

The AEC industry is just beginning its journey to support the full lifecycle of construction assets (buildings, plants, infrastructure, etc.) using 3D tools, collaborative platforms, and integrated project management. The world of manufacturers has advanced because of the adoption of PLM strategies and supporting solutions.

Dassault Systèmes, a leading PLM solution provider, has some experience supporting the use cases necessary to support AEC, and is building on this learning to develop new offerings for the AEC market. The Lean Construction Solution Experience is a good first step toward meeting this vision. To build this solution, they applied key learnings from their leading customers, including:

- Skanska, who showed the value of a platform approach for supporting integrated program management to reduce cost
- Hardstone Construction used CATIA for complex 3D modeling on a Las Vegas project

- SHoP used CATIA and CNC to create the unique façade of the Barclays Center in Brooklyn, New York

These projects demonstrate the applicability of tools and learning from the PLM market applied to AEC business problems. Dassault Systèmes has a range of technologies with potential applicability, so it will be interesting to follow the evolution of their AEC offerings.

Conclusion

The global construction business faces huge challenges. Meeting the NRC recommendations highlighted in this commentary will require significant changes for both AEC companies and solution providers. Beyond these objectives there are other challenges and opportunities going forward. For example, the NRC report also references the provision of real-time information for improved management at the job site. Mobile access to decision-making tools for the "deskless" (i.e., those who work away from offices, often in remote locations) is already emerging, mostly through custom applications, as highlighted in a recent CIMdata presentation at our PLM Market & Industry Forum. Given the high collaboration requirements in the AEC space, there are certainly openings for other Information Technology solutions like social computing applications to capture and more readily leverage the many conversations that take place during project execution.

One thing we do know: today's challenges are just the start. New problems will certainly emerge, and AEC firms will need to adapt accordingly. Any solutions they adopt today or in the near future must be flexible enough to expand to meet tomorrow's requirements.

About CIMdata

CIMdata, an independent worldwide firm, provides strategic management consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM). CIMdata provides world-class knowledge, expertise, and best-practice methods on PLM. CIMdata also offers research, subscription services, publications, and education through international conferences. To learn more about CIMdata's services, visit our website at http://www.CIMdata.com or contact CIMdata at: 3909 Research Park Drive, Ann Arbor, MI 48108, USA. Tel: +1 734.668.9922. Fax: +1 734.668.1957; or at Oogststraat 20, 6004 CV Weert, The Netherlands. Tel: +31 (0) 495.533.666.