Design + Construction Strategies
THE POWER OF PROCESS IN THE BUILT ENVIRONMENT™

Technology, Change, and the Building Industry

Louise Sabol

Real Estate Review, Vol. 36, No. 3, December 2007.

Contents

Abstract

The integration of information technologies has allowed every U.S. industry except the construction industry to achieve notable productivity gains during the past four decades. Productivity in the construction industry during the same period has remained essentially unchanged.

Although technology is used widely and routinely throughout the design and construction industry, the fragmented business model of the industry prevents any real efficiencies to be leveraged across disciplines.

Introduction

The integration of information technologies has allowed every U.S. industry except the construction industry to achieve notable productivity gains during the past four decades. Productivity in the construction industry during the same period has remained essentially unchanged, as shown below in a graph compiled by Stanford University's Center for Integrated Facilities Engineering (CIFE).

Although technology is used widely and routinely throughout the design and construction industry, the fragmented business model of the industry prevents any real efficiencies to be leveraged across disciplines.

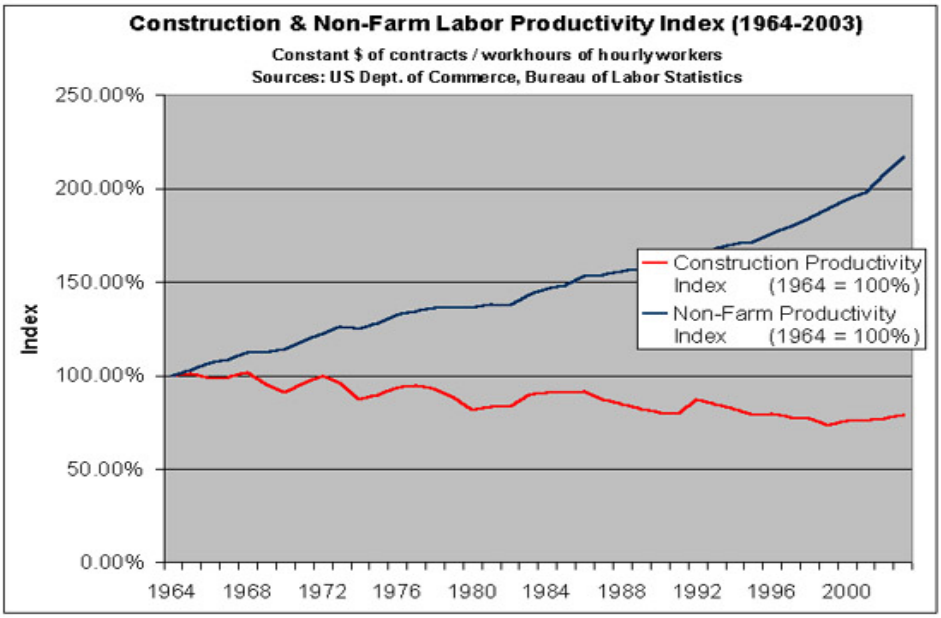

Figure 1: Labor productivity index for the U.S. construction and all non-farm industries from 1964 through 2003.

Similar to most project-based industries, firms in the construction business tend to be laggards in adopting new products and processes. Intent on discovering methods to bridge this innovation gap, Levitt and Taylor of Stanford University[i] recently researched the mechanisms that impact the adoption of systemic innovations in the AEC industry. Their study detailed how innovation is impeded by the "one-off" nature of construction, where each project is essentially a prototype. Contrast this to manufacturing, where once a process is put in place, multiple products can be produced with increased efficiency.

Building project teams have impediments to innovation not only with ongoing projects, but with efforts to incorporate systematic innovations throughout their practices. Since project teams rarely remain the same from one project to the next, information flow and methods of innovation diffusion are hindered

by constantly changing team compositions and lack of teammate-to-teammate familiarity. Multiple, non-hierarchical teams from different organizations find themselves with little incentive to share knowledge or methodologies.

Drivers for Change

Increased Integration and Interoperability

Construction is an information-intensive industry. A large number of documents are produced from multiple sources throughout a construction project. The sheer quantity of documentation often results in miscommunication and errors when the data is not properly managed. Data for a project is rarely centrally integrated or managed. The segregation of information into silos among AEC participants and costly re-entry of information by different parties during the project process is a significant obstruction to increased productivity in the industry as well as a source of incomplete communication.

Evidence for the lack of information coherence can be found from the 2004 NIST publication[ii] *Cost Analysis of Inadequate Interoperability in U.S. Capital Facilities Industry.* This study asserts that at least $15.8 billion per year is lost in the construction industry due to lack of interoperability in the software platforms used for design and construction operations. The report stated that continued use of paper-based business practices, lack of standardization in documentation, and inconsistent technology adoption among stakeholders were key reasons for this massive loss of financial resources. With two-thirds of that cost borne by building owners and operators, there is a huge amount of money that could possibly be recouped by more efficient practices.

Industry stakeholders are beginning to take note. In a whitepaper published in August 2004[iii], the *Construction Users Round Table AEC Productivity Subcommittee* concluded that: "The goal of everyone in the industry should be better, faster, more capable project delivery created by fully integrated, collaborative teams." Four recommendations from this study included:

- Leadership from owners needed to increase
- Integrated project structures should be implemented
- Participants need to engage in open information sharing
- Virtual building models should be employed in projects

Towards a More Integrated Practice

For the first time in the modern era, there is the possibility of significant change to the business model for the construction industry. Members of the AEC industry are beginning to recognize the need for change in their professional practices. Strict segregation of function between disciplines and trades is disappearing. Methods of project delivery are changing as well. The traditional design-bid-build process is being abandoned in favor of more integrated relationships such as design-build and project alliance that return increased efficiencies in time and money. The leadership role in building projects is evolving as owner/developers become familiar with a wider range of project delivery methods. A recent survey of owners[iv] by the Aberdeen Group notes that project leadership is assumed in-house by a majority of all respondents (72%) and not outsourced to construction or program managers.

Improvements owners would most like to see in the design phase would be greater attention to cost models as well as more coordination and collaboration to among team members. When asked about practices owners would use to improve project collaboration, three items topped the list:

- A clear contact should be provided for decisions and approvals (85%)
- Project information be openly accessible/sharable by project participants (83%)
- The project team should be assembled early and meet frequently (80%)

The challenges and opportunities presented by technology both support and expedite new practices. Each of these areas can be enhanced with the use of a good project collaboration tool as well as an integrated data application that everyone on the team can access.

Building Information Modeling

Architecture, engineering and construction (AEC) professionals have begun employing building information modeling (BIM) software applications in their practices to facilitate project design documentation. The American Institute of Architects defined BIM as "a model-based technology linked with a database of project information". BIM offers both a geometrically accurate three-dimensional representation of a building and the capability to affiliate attributes and data to the components and objects inside a model.

Unlike two dimensional drawings which are frequently schematic in nature, BIM models require precise information at an early stage of design. Once modeled, geometrically accurate representations of a design provide for quicker and more informed decisions by all participants of the project team. Project alternatives are easier to generate, and because of the visual nature of BIM, easier to understand. The most immediate and profound attribute of a building model is its ability to facilitate visual decision making.

When the transition from paper-based drafting to CAD transpired years ago, it required changes in work practice *within* AEC firms, but did not affect process interactions between project participants. Project deliverables, both during and at the end of the project, were still based around the traditional construction document set. The recent evolution from CAD to BIM is changing the equation and creating new interdependencies and collaboration requirements for firms participating in a construction project. The BIM model serves as an integrated and collaborative resource for project construction, offering a central repository for data the is meaningful to all project participants. As a project deliverable, building information models are useful beyond construction for continued asset management throughout the building lifecycle. BIM is a database and, as such, provides as much detail concerning a building project as the designers or owners deem necessary, offering a powerful information support tool.

Building information models can readily generate quantity take-offs of materials, which is the first step required for cost estimating. A comparison with traditional costing processes illustrates BIM's advantages. Typically, cost estimates were made at the midpoint and end of the design phases and generally took a couple of weeks for the builder or cost estimator to produce. With BIM, reasonable cost estimates can be extracted early in the process, even in the preliminary planning phases. This works to

avoid painful cost-cutting ("value engineering") exercises that plague traditional construction projects, when accurate costing information is not received until much later in the project. The technology also frees cost estimators from tedious counting exercises to focus on more qualitative tasks. A goal for cost estimating applications, which should be achievable in the next 3-5 years, is "real-time" or instant cost analysis.

As BIM matures as a technology, it may be overly simplistic to assume that only one " building model will exist for a project. It is more likely that each construction discipline will maintain a model for its area of responsibility, linked to a geometrically accurate graphical interface. A designated project coordinator will develop a consolidated model that integrates the component disciplines, resolves conflicts and clarifies omissions. 3D/4D design review software applications have been developed for integrating multiple models into a single entity for shared, coordinated review and further analysis.

With all of its benefits and potential cost savings, why isn't BIM already in widespread use? Cost-conscious, deadline-driven professionals can be hesitant to implement new and complex technologies. BIM also involves changes in project processes through its capability to support multiple participants throughout all phases of the building lifecycle, which may warrant changes in project management practices. In the current project process, no single participant has the incentive or resources to create an integrated information base or collaboration structure that encompasses more than their individual area of participation. This default project organization may need revisiting when a shared collaborative data source becomes integrated throughout the project process.

Current Market Adaptation

Stanford University's Center for Integrated Facilities Engineering (CIFE), a leading North American academic center for the research and practice of AEC technological innovation, has made Virtual Design and Construction a centerpiece of its educational focus. CIFE defines VDC as "the use of multi-disciplinary performance models of design-construction projects, including the product (i.e., facilities), work processes and organization of the design-construction-operation team in order to support business objectives." BIM is a large part, but not the entirety, of VDC.

VDC is a business approach which aims to use technologies to integrate data and to support a collaborative design and construction project process. The process aims to overcome the fragmentation, duplication of effort and inefficiencies inherent in the construction industry. Stanford has identified areas of virtual design and construction that are meeting resistance of current status quo business processes, including:

- *Owner financial management* that assess the costs but not the potential value of projects. In projects without a lifecycle value proposition included, the cost-value analysis defaults to nothing more than a cost minimization exercise.
- *Traditional AEC project orientation.* The culture and practice in a given firm can be fairly entrenched. Investments either of time or of process are often difficult to advocate and implement firm-wide. Innovations or best-practices learned on projects are often difficult to disseminate on subsequent projects because of time constraints or inflexible office processes.

- *Culture of the building industry***.** Building industry professional practice firms, including owners and developers, have a strong orientation on minimizing costs and minimizing project risks.
- *VDC methods and technologies are evolving,* and in a business resistant to innovation and risk, this provides a convenient excuse to avoid adopting new methods and technologies.
- *Learning from experience.* Typical AEC industry business practice tends to limit the ability of individuals, teams, and companies to learn from past experience. The "project-based" nature of the business – where every project is essentially a "one-off" pilot – means processes within the industry itself lack consistency, and do not lend themselves to incorporating process improvements (contrasted against manufacturing, where process improvements have evolved to a science). Also, "post-mortems" to evaluate project processes are rarely conducted either by owners or AEC participants.
- *Integrated applications.* The current lack of interoperability stated by NIST results in real costs for developers, as participants re-enter the same data throughout the building lifecycle for their own particular purposes, without any overall data coordination.

Surveys on VDC and BIM technology use in the AEC industry conducted by CIFE in 2006 and 2007 suggested that its use is expanding quickly and has entered mainstream use.[v] Survey participants noted a number of significant benefits to adopting BIM/VDC:

- Increased engagement of project stakeholders
- Reduction of risk and contingency
- Reduced cost
- Improved schedule conformance
- Reductions in latency

The building information model serves as an integrated information base for a range of business processes improved with VDC. "4D" modeling adds the component of time to the 3D model, useful for scheduling and visualization of the construction process. Clash detection is another collaborative effort possible with virtual design and construction – integrating BIM model input from architects, MEP, and structural engineering models are checked against each other to mitigate design conflicts virtually, before expensive site corrections need to be made on-site. Among the processes VDC can include are BIM-driven fabrication of building components, collaborative document management systems (e-PM), site logistics planning, and virtual job coordination meetings.

In CIFE's experience the biggest driver for VDC methods is "demand-pull", where the senior management drives its adoption, seeing competitive value to using VDC in order to deliver "faster, better, cheaper" (essentially more efficient) projects. Real world experience with using BIM and 4D modeling during the design and construction projects is validating that technology improves the process. An analysis of two different building construction projects - Camino Medical Center in

Mountain View CA, and Sequus Pharmaceuticals Pilot Plant in Menlo Park, CA, found a number of tangible benefits stemming from the use of these technologies.[vi]

- Identification of design conflicts prior to construction
- Significantly improved productivity
- Less rework
- Increased opportunity for pre-fabrication
- Fewer requests for information (RFIs)
- Fewer change orders
- Design errors can be identified prior to construction
- Ability to build the system with a less skilled labor force
- Improved safety performance
- Better cost control

Owner support for VDC and BIM is gaining momentum. Significant efforts can be seen in the U.S. Federal Government. The General Services Administration (GSA), one of the largest property owners in the world, is strongly advocating the use of BIM for its projects. For all major prospectus-level projects receiving design funding in Fiscal Year 2007 and beyond, GSA requires spatial program BIMs be the minimum requirements for submission.[vii] Ongoing pilot projects in this area are focused on improvements for spatial analysis and programming, building data capture and validation, energy analysis, traffic/egress simulation, and project communication improvements.

Other large property owners in the Federal Government are pushing their own BIM/VDC initiatives. In 2008, BIM use will be required for all U.S. Corps of Engineers projects, and the organization expects facility lifecycle interoperability no later than 2010. The U.S. State Department's Overseas Building Operations (OBO) department is implementing BIM to assist in its ambitious design-build Standard Embassy Design (SED) program. This agency aims to improve project performance and expedite delivery of its embassy project, by employing a repeatable kit-of-parts methodology or template design. The U.S. Coast Guard has developed a database of geospatial and architectural information to provide an enterprise-wide strategic asset management program.

Opportunities for Owner Leadership

Building owners are the largest beneficiaries of a technology-enabled collaborative construction process. In additional to better budget management, owners will possess more detailed data earlier in the process which will help to make more informed decisions. As de facto CEO of the construction project, the building owner is in a position to create an appropriate business environment that will optimize the use of the technology, producing the best possible result. Owners are also the best positioned to take a hard look at current business practices and change them if they do not add value to the process.

Successful implementations of technology do not happen without a well-crafted business framework to support the processes information systems serve. Some processes that owner/developers might review in light of the changing landscape in the building industry include:

- *Revised standard contracts:* Many boilerplate contracts contain a hodgepodge of language that was developed in response to historic or unique circumstances that are not useful for an integrated process. Eliminate unnecessary or onerous contract clauses and tailor contract language to establish a foundation a trust among team members. The DC Court of Appeals, currently embarking on a $110 million renovation and addition, decided to completely revise their boilerplate contract and incorporate industry standard language from AIA Documents. A review of their existing boilerplate contract, which was based on a generic DC Government procurement contract, revealed six separate anti-collusion and anti-bribery clauses, two sections related to a drug-free environment, a lengthy and poorly worded requirement for an apprentice program and no mention of shop drawings, construction administration or substantial completion.
- *Develop new contracts to foster collaboration:* In the AIA's *Report On Integrated Practice*, the authors state that "Delivery models must motivate all participants to optimize value of the end result, realizing that motivation derives from financial gain. There is a need to articulate project goals, define metrics and experiment with contract alternatives that link participant's financial rewards with project goals."
- *Establish buffers to deal with inevitable changes***.** Construction projects are complex and highly variable. The process requires agility to endure labor problems, material shortages, sudden price increases and bad weather. Establish rules and a project structure that accommodate for variability in a project, and allow owner to manage the problems effectively.
- *Define and delineate team roles*. How will information be shared on the project? Who manages the model? What kind of electronic project management and collaboration software will be employed? The owner is the entity best positioned to make these decisions for the entire team.
- *Project coordination and conflict resolution***.** Develop a process that tracks problems and strives to resolve them quickly. Anticipate unforeseen issues and make conflict resolution a routine part of the business process.

Improved Lifecycle Management and Cost Savings

Facilities become obsolete for many reasons – corporate missions change, building codes are revised, new regulations concerning health and safety occur, environmental compliance and security requirements increase, and water and energy conservation needs escalate. At some point in a building's lifecycle, the decision needs to be made as to whether or not a facility meets its intended requirements at the minimal lifecycle cost. At these junctures, information support is critical to the decision-making process. Facility managers tend to collect information focused on condition, operations and maintenance. Planners are more concerned with function and if the building still meets occupant and/or corporate requirements.

Without a consolidated database, such as building information modeling offers, facility data is often recreated from one phase of the lifecycle to the next (e.g. planning vs. operations). This not only takes time and money, but undermines efficiency and information accuracy. Data collection is the most costly

phase of creating a building database. The most cost effective means to developing a building information database will be to start during the planning phase – ensuring the data is entered only once and leveraged completely.

A recent study by the Aberdeen Group[viii] found that real estate and facilities lifecycle management can serve as a strategic advantage and positively impact the business when the right technologies are matched with efficient processes and properly prioritized.

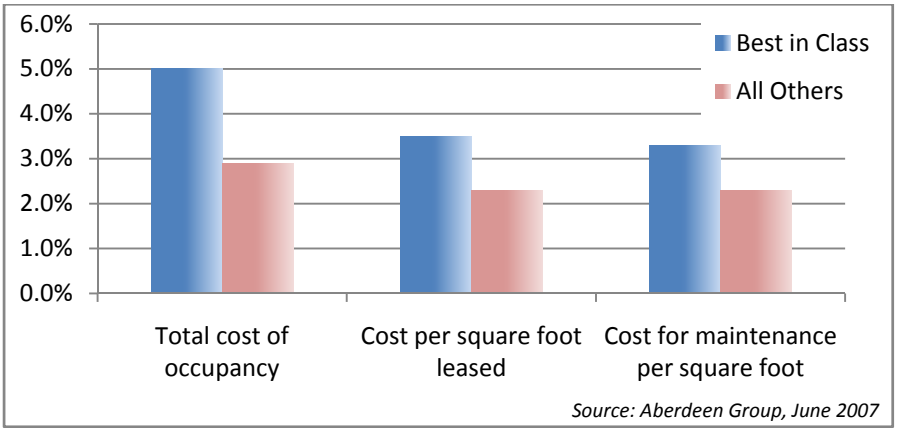

Figure 3 : Savings Rates Credited to Technology Usage

The best-in-class enterprises surveyed employ strong technology usage as well as a centralization of processes and policies, in order to enable heightened spend and process visibility. Notable facts from the survey for best-in-class enterprises:

- They are between 22% and 77% more likely to automate any one stage of the real estate and facilities lifecycle.
- Are almost twice as likely to standardize processes for the management of real estate and facilities operations.
- Are almost 40% more likely to utilize key metrics to measure the performance of their real estate and facilities management programs across the entire lifecycle.
- Are 37% more likely to use solutions for space management, establishing 2.5 more visibility into space management process and 5 times more visibility into space management spend.
- Are 47% more likely to use facility capital planning solutions reducing overall corporate spend on facility capital planning and more strategic allocation of funds, reporting 29% savings gains from their use of these technologies.

Conclusion

As a project-based industry, construction has been slow to adopt innovation and technology, and consequentially has not experienced the same productivity improvements seen in the rest of the economy. A lack of interoperability costs the industry billions of dollars a year – a result of a lack of standardization, inconsistent technology adoption, and the prominence of business practices that are

still paper-based. The desire to have more collaboration and interactivity during early project phases remains a common goal among owners. Not coincidentally, this goal is accompanied by a drive to make more information supported decisions earlier in the project process.

Building information modeling is a new technology which offers a collaborative data application to support the entire project lifecycle. This technology presents a more complete representation of a building project than any other traditional form of building documentation or information support tool before it. Virtual Design and Construction, or VDC – is a methodology that encompasses building information modeling, and aims to use technologies to integrate data and to support a collaborative design and construction project process. Real returns are being seen by implementers of BIM and VDC, including a reduction of risk and contingency, reduced cost, improved schedule conformance and reductions in latency. As de facto CEO of the construction project, the owner/developer is in the best position to reap benefits from adopting integrated information technologies into a more collaborative project process.

End Notes

[i] John Taylor and Raymond Levitt. Bridging *the Innovation Gap in Project-based Industries: 2003-2004 CIFE Seed Project Report*, CIFE Technical Report #159, Stanford University, September 2004. Available from http://www.stanford.edu/group/CIFE/online.publications/TR159.pdf

[ii] Michael P. Gallaher, et al. "*Cost Analysis of Inadequate Interoperability in U.S. Capital Facilities Industry*", NIST GCR 04-867, National Institute of Standards and Technology, Gaithersburg, Md. August 2004. Available from http://www.bfrl.nist.gov/oae/publications/gcrs/04867.pdf

[iii] Architectural/Engineering Productivity Committee of the Construction Users Roundtable (CURT). "Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation", WP-1202, August 2004. Available from http://www.aia.org/SiteObjects/files/ip_%20productivity.pdf

[iv] *FMI/CMAA Sixth Annual Survey of Owners*. FMI Corporation, Raleigh, NC(2005). Available from http://cmaanet.org/user_images/sixth_owners_survey.pdf

[v] John Kunz and Martin Fischer, *Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions*, CIFE Working Paper #103, Version 2 (June 2007), Stanford University. Available from http://cife.stanford.edu/online.publications/WP103.pdf

[vi] Sheryl Staub-French and Atul Khanzode, "3D and 4D Modeling for Design and Construction Coordination: Issues and Lessons Learned" *Journal of Information Technology in Construction*, Vol. 12 (2007). 381-407. Available from http://www.itcon.org/2007/26

[vii] *3D-4D Building Information Modeling.* www.**gsa**.gov/**bim**

[viii] *Real Estate and Facilities Lifecycle Management. The Three Keys to Success: Visibility, Visibility, Visibility*. Aberdeen Group. June 2007.

About Louise Sabol

Louise A. Sabol is a registered architect with more than 25 years of experience in the building and technology professions. At Design + Construction Strategies, LLC, Ms. Sabol serves as Director of Technology, providing overall technical planning for the firm's technology integration projects for organizations involved in complex capital projects.

About Design + Construction Strategies, LLC

DCStrategies is dedicated to business technology implementation and the creation of IT-enabled culture in the AEC community.

Our clients include the U.S. Department of State, the General Services Administration, the International Code Council, Autodesk, Inc. and Greenway Consulting.

More information is available at www.dcstrategies.net.

Design + Construction Strategies, LLC
11 Dupont Circle, Suite 601
Washington, DC 20036
(202) 222-0610
www.dcstrategies.net