

PREPARING THE AEC INDUSTRY FOR THE KNOWLEDGE ECONOMY

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ABSTRACT

The AEC industry is poised to undergo a phenomenal transformation. There are several forces that are driving this change, including the major changes that have occurred in political parties and government in various countries across the globe, major economical changes, access to global markets, information technology, etc. Among these, information technology is perhaps going to be the most powerful catalyst for the changes that the AEC industry will undergo in the next 2 decades. The reason is that the use of information technology (internet, intranet, and extranet) as a core business strategy will lead to the evolution of fundamentally new business models in the AEC industry and totally new realms of competition and collaboration. The challenges that need to be overcome to prepare the AEC industry for this new era goes beyond basic information technology challenges such as software integration. The fundamental question that each company will need to address is how it can optimize its business by simultaneously considering five dimensions of its business. Namely, (1) product, (2) process (construction), (3) organization (structure and business processes), (4) a supply web and complimentary partners, and (5) time (life cycle of each of the above 4 dimensions). Optimization of the business model along these 5 dimensions will be to achieve multiple (possibly conflicting) objectives such as maximization of wealth, minimization of risk, maximization of quality/safety, minimization of time, maximization of responsiveness/agility, maximization of sustainability, and maximization of asset utilization. Clearly, the research issues that need to be addressed to prepare the AEC industry for the new internet economy requires a truly multidisciplinary approach as well as one that incorporates active involvement from industry in the research. Another important challenge for the AEC industry and for academia will be to ensure that a new generation of workforce is created that is appropriately prepared to lead the AEC industry into the next century.

FORCES FOR CHANGE AND IMPLICATIONS FOR THE AEC INDUSTRY

Over the last two decades there have been some major trends and fundamental changes that have occurred. Over the last five years, particularly with the emergence of electronic commerce, the speed of change and the scope of its impact has been escalating rapidly. The changes that have occurred at a global level in the technological, political, and economic environment has led to major changes in the behavior of customers, companies, and their competitors. The globalization of the economy and the ready access to information about companies across the globe is creating a new realm of competition in cyberspace.

In this competitive environment, companies need to be agile and be able to respond quickly and effectively to customer demands. Customers, too, are becoming increasingly selective and their expectations (ranging from customized products to quick response) have also been reaching higher levels on a continuing basis. In order to survive in this highly competitive environment, companies are resorting to higher levels of outsourcing and collaboration with complimentary partners, while focusing their attention on their own core competencies. In addition to such changes at a business level, there are also occurring some very important changes and developments at the construction process technologies level that are destined to have a major impact on the way the AEC industry conducts business.

While the concepts of construction, automation, and views of information technology is not new, what we are seeing now is the emergence of new technologies that allows us to envision construction processes from a micro-level (example: using embedded technologies and sensors) to a global scale (for example: real-time global navigation of autonomous devices). Another important force of change that will have a major impact on the AEC industry is the growing appreciation for environmental issues.

The growing emphasis on the conservation of natural resources and minimization of waste will impact not only the development of new construction processes, but also the

manner in which projects are managed and executed. Another important force for change is the realization that our skilled workforce and human resources are the most valued asset of any organization. The implications for an AEC firm that is operating at a global level, for example, is that it needs to create mechanisms for global distribution and leveraging of the knowledge capital and human resources.

CRITICAL RESEARCH AREAS

The AEC industry is uniquely positioned to benefit from the various forces of change, particularly in the area of information technology (internet, intranet, extranet). AEC projects are categorized by multiple players, the need for highly distributed decision making, heterogeneity among the players (small contractors and large engineering firms), and constantly changing (often unpredictable) working environments. By leveraging internet, intranet, and extranet technologies, AEC industry can create fundamentally new ways of doing business that will have an impact on the complete spectrum ranging from project solicitation, collaborative engineering, outsourcing, project execution, and project management. In the remainder of this section, we highlight some of the key opportunities available for the AEC industry and identify some of the critical research challenges that need to be overcome.

3D Digital Prototyping

A variety of technologies such as parametric 3D solid modeling, virtual reality, immersive environments and collaborative design platforms have been in existence for several years and many of these technologies are already being used in other industries (specifically the manufacturing industry). The AEC industry has a significant opportunity to benefit from the use of these technologies and to elevate their use to a higher level of performance to meet the specific characteristics of AEC projects. One of the defining characteristics of any AEC project is the number of simultaneous subsystems, activities, and work tasks that need to be designed, planned and implemented in order to complete the project. For example, a building project requires the integration of the structural, architectural, mechanical, and electrical systems.

There is a need for the development of an environment that will enable truly collaborative and concurrent decision making so that it will be possible to create high-fidelity 3D digital prototypes of the project and simulate it from its start to the finish by simultaneously defining all the activities that need to be performed. No such collaborative design and engineering environment currently exists that can simultaneously consider the trade-offs between various design, engineering decisions, and the choice of processes and methods for all the various subsystems involved.

To make such an environment possible requires the creation of a highly information-rich information model of the project. Current information models are often fragmented and numerous and are not easily integratable. For example, information regarding the dimensions are stored in the form of engineering drawings, but the geometric modeling representations that currently exist are not rich enough to incorporate all the variety of information (non-geometric) that needs to be associated with the geometric description of the project. One of the key benefits of being able to create a truly digital prototyping environment will be that much of the decision making at the conceptual design stage can be done with confidence and a greater level of certainty. This confidence comes from the ability to incorporate the input of all the various project players thereby enabling “what-if” scenarios to be explored and to gain insight into the range of potential outcomes. For example, multiple alternative conceptual designs can be evaluated from a cost and time perspective.

Collaborative Project Life Cycle Management

One of the ways in which AEC firms will position themselves to compete in the internet economy is by transforming their business into a “full service provider model.” By this, what we mean is that the AEC firm will take responsibility not just for the design and construction of the facility, but also for monitoring and maintenance of the facility through its entire life cycle. The difference here compared to current practice is that using internet technologies it will become possible to approach maintenance in a proactive and preventive manner rather than in a reactive mode. For example, it will become more

prevalent to embed a variety of sensors and other performance measurement devices in various facility components (ranging from structural columns to air conditioning units) to be able to measure system performance in real time over the internet. This will enable efficient operation of the facility and enable condition-based maintenance.

Since there are typically partners in the ownership, management, and maintenance of a given facility, what is required is a truly collaborative and shared information infrastructure that will allow the appropriate party to be notified of any action that needs to be taken, while at the same time ensuring that others who may be impacted by these corrective/maintenance actions are also notified. Imagine, if you will, the opportunity to use a 3D CAD model of a facility as the central storage of information regarding the life cycle of the facility represents an existing future possibility.

The ability to assess the performance of the facility at any level of abstraction represents attractive benefits. For example, evaluating the performance of a variable air volume HVAC system in a specific. Think of the possibility of clicking on any specific element of the CAD model such as an air conditioning unit and being able to assess its historical performance in real-time based on data being collected from its sensors. Imagine being able to access the installation and maintenance history of this air conditioning unit and having access in real-time to a team of experts who may be needed to diagnosis a specific problem with the unit. While none of these capabilities are currently beyond reach individually, they do not have a unified information management and decision support environment that will allow us to manage a facility from its conceptual design through its complete life cycle.

Knowledge Management and Corporate Learning

Much of the decision making in the AEC industry is knowledge and experience based. Often the expertise is resident in the heads of the few highly trained and experienced individuals. These individuals become highly sought-after and are rare resources in the organization. To compete successfully in the emerging internet economy, the AEC industry needs to discover ways in which it can leverage internet technologies to

manage information, transform it into knowledge, and promote corporate learning and mind sharing across the organization. As an example, the ability to store and extract lessons learned and best practices in a company can greatly enhance its competitiveness and prevent the repetition of errors or inefficient decisions. The challenge here is to figure out how to aggregate information from a large number of highly distributed and heterogeneous sources and to transform it into a personalized and to enable effective decision making.

While the internet technologies provide access to large amounts of data, the challenge is in developing complimentary capabilities that will allow us to transform this information exchange instantaneously into usable knowledge and to make it available across the globe. Developments, such as XML, show a lot of promise; however, to take full advantage of XML, the AEC industry will need to develop an industry-specific vocabulary and protocols for use of XML. New and effective forms of data searching, information filtering, and knowledge extraction needs to be devised, so as to prevent “information overload” for the user. Further, the knowledge representation and extraction methods should be capable of handling large volumes of information but at the same time be able to account for small nuances that ultimately could make significant differences in the outcome of the decisions made.

Virtual Enterprises and Supply Networks

In the internet economy, the importance of lead time reduction in every phase of the project delivery process will be more important than ever before. Companies will focus increasingly on their core competencies and outsource all other tasks to other companies and business partners. We are already seeing this trend in the manufacturing industry. For example, Hewlett Packard has outsourced one of its warehouses to Federal Express for management because it recognizes that Federal Express is far better at logistics and moving inventory than Hewlett Packard will ever be. This growing trend towards outsourcing and the internet’s ability to quickly enable interactions and alliance formation among various companies will lead to the formation of virtual enterprises (collection of companies) that are dynamically formed to meet a market opportunity as

and when it arises. This capability is particularly significant in the AEC industry because of the number of players that are typically involved in any construction-related project.

However, before the AEC industry can embark on this new paradigm of business that will support seamless and dynamic formation of supply networks and virtual enterprises, some significant research issues need to be addressed. The first set of research issues in this context relate to how alliances between various business partners will be formed using internet technologies. For example, how will project-related information be distributed for bidding purposes? How will companies that are interested in bidding for jobs make themselves known in cyberspace? And how will matchmaking occur between customers that want the projects to be conducted and potential supplier companies and project participants who are capable of executing that particular job?

There will be the emergence of new breeds of companies that act as trusted third parties and intermediaries and in full mediaries that will facilitate the matchmaking and coming together of those projects to be executed and those capable of executing them. While the notion of bidding and auctions is not new in the AEC industry, it presents completely new opportunities and new ways of competing in the internet economy. A key research issue here is: How can a company make decisions under uncertainty and incomplete information about potential projects and form alliances with other companies in order to submit a bid for these potential jobs? In order to do this, there is a need for unified protocols and rich information models that will facilitate the seamless and dynamic configuration of a virtual enterprise for a specific project opportunity. For these virtual enterprises to function efficiently and effectively there will need to be a shift towards greater parallelization of all the activities associated with any project (ranging from conceptualization through design and construction and life cycle management).

New modeling capabilities are needed in order to characterize and simulate the entire construction process. There is a need for new design methodologies and concurrent product and process and supply network design so as to achieve production and lead time and cost without sacrificing quality and reliability. On the construction process front,

there is a need for highly adaptable and reconfigurable construction processes and systems, not only at the hardware level, but also at the construction project level as well.

We also need to construct new decision systems that can take advantage of the real-time information available from the construction equipment and systems and incorporate that in all stages of decision making of the project ranging from bidding through actual execution of the tasks. In this context there are a number of key issues that need to be considered such as: How do you model risk and uncertainty in decision making in this highly distributed environment where you have multiple companies collaborating to achieve the same end goal of the project? Beyond the technological integration that is needed there is also going to be some fundamental challenges that the AEC industry will face in the area of organizational change.

To gain full advantage from the use of information technology, companies will need to completely rethink their business processes, their organizational structures, and the manner in which multiple companies collaborate and make decisions. There is a need for research on how organizations can be re-engineered to make the most of the advantages offered by internet technologies and what are the most effective ways in which companies can work together in this new way of doing business. Companies will need to recognize that since the internet removes many of the barriers that exist in the physical world, how can they take advantage of this new freedom to gain competitive advantage in a global economy.

An important issue to consider here is the scalability of such approaches. For example, while periodically it is possible for companies to interact with and form partnerships on a dynamic manner with other companies across the globe, our state-of-the-art in understanding how these partnerships can be formed and the technological infrastructure to support it is severely lacking. Current software (enterprise resource planning systems) is typically very rigid and often dictates how an organization and its processes should be redesigned to fit the needs of the software instead of vice-versa.

If the AEC industry is keen on preparing itself for the internet economy and for the new rules of the game, it needs to participate in a significant research venture in collaboration with the companies that are developing the hardware and software technologies to support internet business to make sure that the software and the technologies are open and can be easily adapted to fit specific business needs instead of having the software dictate how the business should be run.

Hence, there needs to be a significant research emphasis in understanding how virtual enterprises operate and how to maximize their performance. There is a need for the development of theories for modeling simulation and performance assessment of virtual enterprises and supply networks and to understand how to make these systems highly adaptable and reconfigurable and scalable.

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