Digital Innovation and Organizational Change in Design Practice

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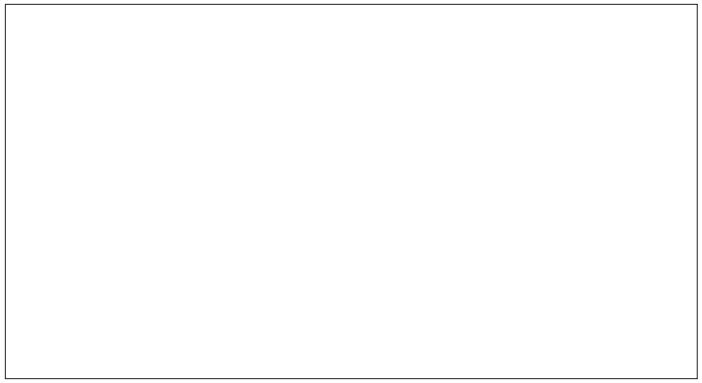
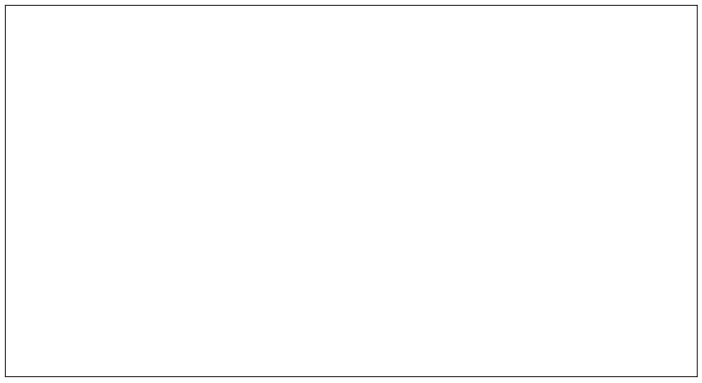
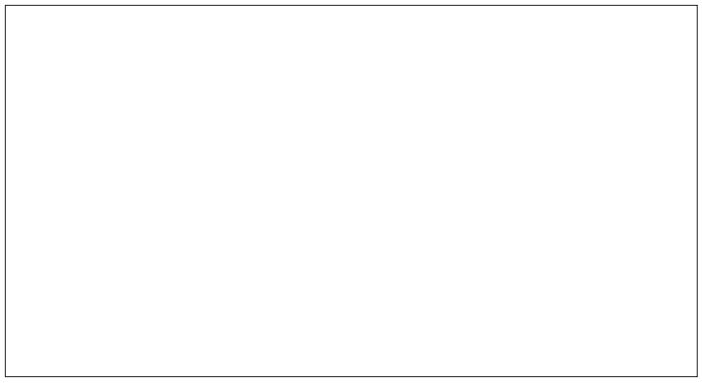
Abstract

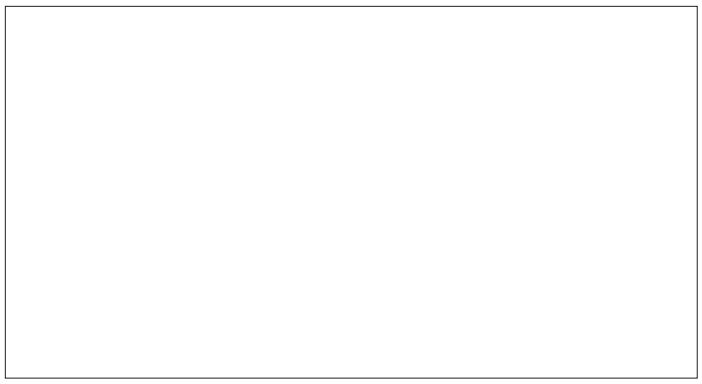
The real estate and construction industry is among the largest industries in the world. It also is one of the most fragmented industries, with few economies of scale and historically low productivity. Recent technological advances in the use of information and communication technology have the potential for dramatically improving construction productivity. But substantial organizational barriers exist that inhibit the effective adoption of these technologies.

This research project (in progress) examines the practices of selected, innovative firms in order to develop an in-depth understanding of the factors that have influenced the effective adoption of information and communications technology in the design and construction industry, and, potentially, provide examples that may provide prototype models for an alternative, future organization of the AEC industry.









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1 Introduction

In our previous research (Johnson et al. 2002), we have argued that there is an interrelationship between business goals, work processes, and the adoption of information technology. That is, changes in business goals generally require revising work processes which can be enhanced further by the introduction of information technology. But we also recognized that innovations in information technology create possibilities for new work processes that can, in turn, alter business goals (see Figure 1). In order to understand how information technology influences architectural practice it is important to understand all three of these interrelated elements.

Figure1. Business Goals and Information Technology.

This model seems to be useful to understand the role of technology in other industries. History has demonstrated that the introduction of new technology into an industry often results in dramatic changes in that industry. For example, the industrial revolution had significant and long-lasting impacts on many industries, such as the transportation industry. Automobiles are now produced in a manner that fully integrates design, engineering, and manufacturing. Additionally, many virtual organizations have emerged that could not have been imagined before the introduction of the Internet.

In contrast, the practices of architecture and construction have not changed very much despite the introduction of the Internet and, earlier, computer aided design. The reasons for this are varied and complex. We suspect that the fragmented nature of the building design and construction industry has been an inhibiting factor. Furthermore, technologies such as CAD (Computer-Aided Design or Computer-Aided Drafting?) and project management systems can be used without any major organizational changes. More significant integration in the industry is inhibited by designers, developers, contractors, and construction managers all of whom tend to focus on their own areas of expertise and protect their own interests in the building process (Henderson 2002). It is unlikely that major innovation in the building industry will take place without a change in the rules that promote fragmentation

There are a number of technological innovations emerging that may help to change some of the rules. The changes we are most interested in are those that have been in development over many years though the efforts of many academics too numerous to mention; cooperative organizations, such as the International Alliance for Interoperability; software developers, especially the relatively recent agreement regarding the terminology of the building information modeling (BIM); and users of organizations in the design and construction industry. Much of this research is reported in Eastman's book on Building Product Models (Eastman 1999). Building Information Modeling (BIM) refers to an agreement among major design software developers about the terminology, originally adopted by Autodesk, describing the use of object-oriented, parametric solid-modeling systems (see especially issues 15, 16, 17 and 18 of the Laiserin Letter, www.laiserin.com, for a discussion of this agreement).

The purpose of the research now underway and reported in this short paper is to understand how leading, innovative companies are adopting these technological innovations. This research project examines the practices of these firms in order to develop an in-depth understanding of the factors that have influenced the effective adoption of these technological innovations in the design and construction industry and, potentially, provides examples that may describe quite a different future for the AEC industry.

2 Research Methods

The exploratory nature of this research suggested the use of a case study for these investigations. Half-day site visits are being conducted with approximately 6-12 firms from various sectors in the AEC/FM industry in the United States. These firms are being selected primarily from referrals and industry publications. For each site visit we first develop an overall understanding of the organizational structure of the company and obtain a description of any long-term relationships with other companies (e.g., alliances). When possible, information is gathered prior to the visit and may include a description of the history, organizational structure, current business context (including mission statements), and future business trends of the company. A fundamental part of each site visit is to determine the degree that information and communication technology solutions have been used to help improve the delivery of design and construction projects. This part of the site visit will provide a description of the decision-making process used to determine the need for information technology solutions.

At this point in our research we have completed one site visit. Others are in progress. The case study was written and submitted for review by the company we visited. The entire case study is reproduced below. Due to the requirements of the

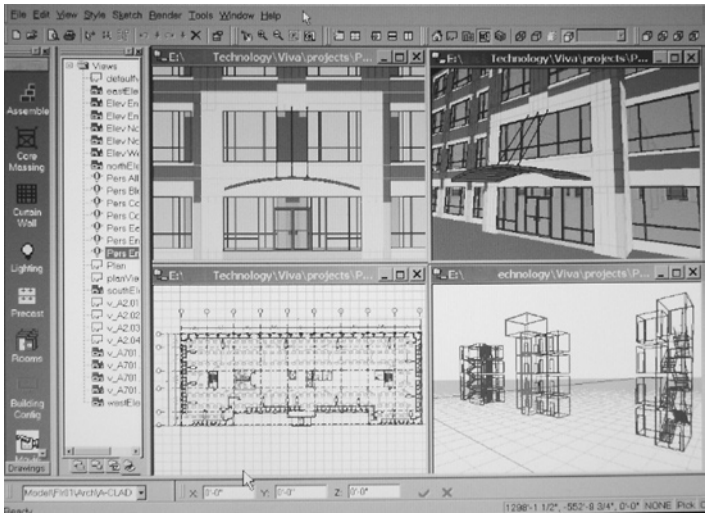

Figure 2. Screen Shot of Solid Modeling Application

human subject review process, all references to the company or individuals who we met during our site visit remain confidential.

3 Case Study: Achieving Integrated Project Delivery

The following case study is an example of the result of our research. It describes how the legal rights to a Building Information Modeling system were purchased by an integrated architecture, real estate, and construction company and later used, together with significant organizational changes, to achieve what they have called “Integrated Project Delivery.”

The organization described in this case began as a 90-year old, established, family-owned construction company. There are more than 600 employees, distributed among 10 offices nationwide and internationally. Their 70-80 percent repeat rate with customers shows they have been successful.

The company determined that the construction business was becoming increasingly competitive. Average profit margins for constructors had been reduced from 5 percent to about 2.5 or 3 percent. They believed that continuing to do business the traditional way was fruitless.

Rather than continue their traditional construction business, they decided to take the lead and help reinvent the industry. This meant developing a totally integrated approach to building. The goal of this organization was to reduce both the cost and time of construction by removing the “pain” in the construction process on a project-by-project basis.

The company has made many, permanent changes to achieve its goal of integration. Several years ago, it merged completely with an architecture firm and added to its staff experts in real estate development. It has also formed formal alliance agreements with manufacturers and suppliers and invested heavily in software development. Changes made in the company, culture, and work processes are:

3.1 Acquisition of architecture and real estate expertise

The company recognized the need to systematically include other disciplines into their internal work processes. Therefore, in 1999 the company merged with a 45-person architectural firm. Previously, real estate development experts had also been added. This additional organizational capability provided the foundation for an integrated approach to design and construction, and provided the basis for internal organizational learning.

3.2 Changes in company leadership and culture

Over a period of several years, the board of directors changed from those with an all-construction background to directors with a wide range of backgrounds. The 10-member board of directors now includes representatives from architecture, real estate, and financial management as well as construction. At the operational level, interdisciplinary project teams were also established. The architecture and construction groups initially maintained separate offices. Recently, the lease and renovation of additional space has allowed these project teams to become fully integrated groupings of estimators, architects and constructors.

3.3 R&D software investment

As the organization was changing, the leadership of the company strongly believed that “technology tools dictate the way we work.” Thus, the company began searching for software to facilitate the integration of design and construction information. They were unable to find an “off-the-shelf” software solution. After some research and experimentation the company bought the rights to a parametric, object-oriented, solid modeling software package, Reflex, and hired in-house software developers (see Figure 2). This software initiative began in 1996, but it has only been within the past 18 months that it has been used on projects by this company.

The software can best be described as providing value engineering at very early stages in the building design process. It incorporates a great deal of specific information, such as building codes for specific locations, costs provided by specific suppliers, and engineering calculations for systems such as the building structure and energy analysis. It also contains construction rules so that the concrete pours can be calculated. Structurally, the system can perform detailed calculations down to the level of determining rebar and mesh sizes.

The outputs of the program consist of detailed cost estimates, architectural details, outline specifications (in Microsoft Word format), and a construction schedule (in Microsoft Project format). The level of detail provided by the program is very extensive. It will soon be able to produce cut ticket details for manufacturers

and suppliers. Due to the user interface, significant training is required before a user can become proficient. At present, the program models about 70 percent of a building, mainly the core and shell.

To date, this software has mostly been used as a cost estimating and planning tool at very early design stages. One of the first integrated projects to be modeled with this software was a 200,000 sq. ft. office building. Using this software and working as an integrated team the company was able to obtain a cost savings of about 18 percent and a reduction in delivery time of 30 percent.

3.4 Work process changes

This company believes that subcontractors possess most of the knowledge in construction. Gaining access to this knowledge and integrating it into the work process is fundamental to developing an integrated delivery system. By developing on-going relationships with subcontractors, suppliers and manufacturers, it was possible to identify redundancies, inefficiencies and time-consuming tasks that increase costs. The key to making these improvements in the work process is a separate, customized alliance contract with each subcontractor. The goal for every alliance contract is to reduce delivery time, get a better price, and improve methods of working together.

Each alliance agreement is different because each supplier is different. Typically, suppliers successfully bid only a fraction of their jobs. This results in significant unnecessary work and increases supplier costs. The alliance contract guarantees that there will be no bidding and that suppliers will participate during design and disclose their pricing information. Obviously, this requires both trust and appropriate incentives. The incentive for suppliers is the “no bid” guarantee.

3.5 New Marketing Approaches

When selling this integrated delivery process, their reputation as a very good “traditional” contractor is not an advantage. An integrated construction process is significantly different. This has required the company to communicate the benefits of the new process not only to owners, but also to employees who have been involved in their traditional construction business. The integrated delivery process is becoming accepted: 40-50 percent of the remainder of the jobs for the current year is integrated projects.

3.6 Summary and Discussion

Throughout its history this company had developed a reputation as a quality, traditional construction company. In the last few years, it has radically reinvented itself in response to a changing business environment. It has heavily invested in a process and supporting software that is only just beginning to show positive results.

The technology highlighted in this case study was the use of Building Information Modeling together with other organizational changes to achieve a level of vertical integration and efficiency that is unusual in the building and construction industry. The use of a single building model is not a new idea. In an article by (Novitski 2000), Robert Aish explained how Alias Sonata, a single building model system, was introduced to the U.S. only to fail, at least in part, because it required detailed input by architects for the benefit of “downstream” contractors and engineers. The extra effort of the architects was not rewarded by extra compensation. In this case, the incentive issue was either handled internally or through alliance contracts.

4 Very Preliminary Conclusions

For this research purpose, it was our intent to seek out only those companies who are at the leading edge of innovating with the use of information technology. The knowledge obtained from the case study above cannot be generalized to all practices. The AEC industry is very diverse with a wide range of sizes and types of firms. Each time we complete a case study we are presented with ideas worth pursuing instead of conclusions. Here are several ideas that might be worth pursuing.

1) Information technology. This case-study company made a substantial investment to acquire the rights to an object-oriented, parametric modeling system. This indicates the importance of this decision to achieving their vision of integrated project delivery. However, they also realized that this technology alone would not be sufficient. At this point in their evolution, the case-study organization has concluded that successful, integrated projects are due 80% to the changes in work process and only 20% to the software technology.

2) Work Process and Collaboration. Work group productivity and process improvement are two areas that are heavily influenced by information technology. However, this case study points out that the technology may need to be augmented by other work process issues. Internally, the case-study company reformed all of its work processes into multidisciplinary teams that were previously co-located. Furthermore, various organizations in the design and building process have a tendency to protect their own interests. Sharing competitive information is not the norm in this industry. The alliance contracts with external suppliers were the mechanism used to overcome this potentially significant obstacle. The building information modeling that was done on each project using internal software was the key to facilitate the integration of information.

3) Cost and schedule reductions. In our case study, the company’s main business goals were reductions in cost and schedule. Merging multiple organizations under the

umbrella of a single company can eliminate some scheduling problems and reduce costs. As indicated by one author (Coase 1937), transaction costs that occur within a firm are lower than transactions costs using the market. He also determined that the cost of constantly developing new contracts with outside firms can be higher "relative to those of signing a long-term contract with an employee who agrees to carry out the commands of the employer."

4) Incentives. The numbers of external subcontractors on even medium sized-projects are too numerous and diverse to merge into a single company. The ability to achieve significant collaboration in this case study was may be addressed by improving incentives through specific alliance contracts with each external subcontractor and supplier. Trust was maintained by a specific guarantee that the subcontractor would not be asked to submit bids to be considered on projects. This case study suggested that the lack of appropriate incentives may be an important reason why collaborative design tools do not achieve their full promise.

The purpose of this on-going study is to identify innovative approaches to the delivery of design and construction projects that rely heavily on the use of digital processes for their effectiveness. While we do not expect to be able to generalize the findings, we anticipate that these examples may provide interesting prototype models that may point the way to the future of the design and construction industry.

During the site visit our informants said they had participated in a seminar conduced by Clayton Christensen (Christensen 1997), whose book, *The Innovator's Dilemma*, raised some interesting questions and potentials for their company. Christensen argued that major innovations are not likely to be developed by large, established companies. His research suggested that truly revolutionary innovations—those that could change industries—are most likely to come from small companies who do not have an established market with established customer expectations. It will be interesting to see if the company reported in this case study will achieve its goal of reinventing the design and construction industry.

We plan to conduct additional site visits to innovative firms that explore various parts of the design and construction industry. Among the types of organizations that we plan to contact are: 1) one of the "virtual" architectural practices that have formed out of several smaller firms in separate geographical locations, 2) an innovative supplier or manufacturer, 3) a large owner, and 4) other firms offering integrated services under one roof.

References

Christensen, C. M. (1997). *The innovator's dilemma.* New York: Harper Business.

Coase, R. (1937). The nature of the firm. *Economica* (November 1937):386-405.

Eastman, C. (1999). *Building product models: computer environments supporting design and construction*. CRC Press.

Henderson, L. (2002). Paths to collaboration. Artifice, Inc. Available from: http://architectureweek.com/2002/0522/tools_1-1.html

Johnson, R., M. Clayton, G. Xia, J.-H. Woo, and Y. Song. (2002). The strategic implications of e-commerce for the design and construction industry. *Engineering, construction and architectural management* 9(2):241-248.

Novitski, B. J. (2000). Turning today's research into tomorrow's software. Artifice, Inc. Available from: http://www.architectureweek.com/2000/0705/tools_3-1.html