17 SOCIAL ARCHITECTURE FOR SUSTAINABLE IT IMPLEMENTATION IN AEC/EPC

Songer, A.D.[1], Young, R.[2], and Davis, K.[3]

[1] Associate Professor, Virginia Polytechnic Institute and State University, adsonger@vt.edu
[2] Assistant Professor, University of Colorado, Boulder, rochelle.young@colorado.edu
[3] Via-Cunningham Fellow, Virginia Polytechnic Institute and State University, kidavis2@vt.edu

Abstract

As the impact of emerging technologies such as 3D visualization, animation, virtual reality, e-commerce, and project specific web sites are ushering global markets into an era of the new economy, the engineering and construction industry must re-invent itself to meet the increasing owner demands of high performance.

This paper discusses research results of a U.S. based study to benchmark current IT practices within the engineering-construction industry. Additionally, the paper provides an emphasis on the cultural-social barriers that exist across organizational boundaries, discusses existing social architectures of organizations in the new economy, and suggests new models of organization which encourage integration and collaboration.

Keywords: *Social Architecture, Information Technology, Organizational Culture, Collaboration*

INTRODUCTION

As the impact of emerging technologies such as 3D visualization, animation, virtual reality, e-commerce, and project specific web sites are revolutionizing global markets into an era of the new economy, the engineering and construction industry must re-invent itself to meet the increasing owner demands of high performance.

Owner organizations are requiring the architecture/engineering/construction (AEC) and engineering/procurement/construction (EPC) industry to perform at extraordinary levels of project delivery (Songer et al., 2000). Advances in project delivery systems and information technologies provide tremendous potential for enhancing the AEC/EPC industry's overall performance. However, the majority of industry participants have been slow to embrace the use of new technologies to enhance project performance to desired levels. Appropriate implementation of information technologies (IT) is a primary focus area that must be addressed by the AEC/EPC industry.

The AEC/EPC industry is largely decentralized, composed of separate organizations, which must participate together on a project by project basis. The multi-participant, multi-organizational framework is a significant barrier to implementing IT in the industry. Nevertheless, the collaborative paradigm essential for IT implementation remains largely unexplored. In particular, the social architecture of organizations relative to implementing advanced technologies into a collaborative, IT driven paradigm must be more fully understood prior to sustainable change occurring in the AEC industry.

This paper establishes general trends in IT among AEC/EPC organizations and provides results of a U.S. engineering-construction industry survey to document and benchmark existing IT implementation efforts with a focus on integration and automation. Additionally, the paper discusses the misalignment of current organizational structures and cultures with IT models for integrated, collaborative work environments. The paper also discusses existing technological cultures of AEC organizations and suggests a model of change for sustainable IT implementations within the context of social architectures.

GENERAL TRENDS

Information Technology implementation in the AEC/EPC industries and its attendant effects, such as Fully Integrated and Automated Project Processes (FIAPP), promise to compress schedules, lower costs, provide higher quality and add flexibility to the AEC/EPC organization. Increasing timeliness and quality of collaboration and concurrency in the EPC process is being driven by key developments such as standards for data exchange, data centric design and construction, life-cycle data management, and Internet distribution.

There is tremendous activity and advancement being made in the areas of automation and integration. Although there is no universally documented vision of the future of fully integrated and automated project processes, general trends are evident from listening to industry leaders and observing the focus at industry conferences during the past year.

- Linking Engineering and Conceptual Design with Facility Design:

The integration of conceptual models, cost estimates, code requirements, and facility configurations conducted during preliminary design phases with 3D design systems provides improved understanding of design proposals. This results in increased collaboration among designers and engineering disciplines.

- Integration of Preliminary Design Systems with Detail Design Software

Reuse of preliminary design information during detailed engineering propagates continuity of design assumptions and improves accuracy of data throughout the detailed design process.

- Facility Life-Cycle Computer Data Preservation

Preserving full life-cycle facility data improves operations, maintenance, and retrofit processes as well as future capital expenditure decisions. Currently there are no formal, accepted methods of documenting and storing life-cycle facility data.

- Data Centric Approach

Current integration efforts are focusing on data centric structures. As these systems mature and are implemented, changes in workflow philosophies will be required. Additionally, associated data and content management efforts are increasingly becoming central investment themes.

The trends in integration throughout the design process will continue to be a focus among AEC/EPC companies. The life-cycle focus will continue to extend integration efforts into construction and maintenance phases. Advances in information technologies are fueling the integration. These include:

- Data Warehousing;
- Standards for Data Exchange;
- Internet/Intranet/Web Applications.

These trends in integration and attendant advances in information technologies will require organizations to pay particular attention to required changes in workflow and organizational issues.

IT IMPLEMENTATION SURVEY

A survey of large U.S. engineering contractors was conducted to establish a baseline for current practice in Information Technology and FIAPP. A corporate executive, project manager, and a member of the information technology staff from each company completed the survey.

The survey queried the following items:

- Respondent's personal willingness to implement information technology;
- Respondent's immediate supervisor's willingness to implement information technology;
- Respondent's immediate subordinate's willingness to implement information technology;
- Organization's top three system technology investment priorities;
- Current information technology spending;
- Future technology spending;
- Barriers to implementing information technology in project execution;
- Impact of information technology on organizational unit's job performance;
- Impact of information technology on overall company performance.

Survey Results

240 surveys were sent to 80 Construction Industry Institute (CII) member companies. 69 individual surveys were returned from 34 companies. This represents a 28.75 % respondent rate. More importantly, the 34 company responses represent 42.5% of CII membership. Owners and contractors were similarly represented in the survey. Additionally, corporate executives and project managers were equally represented. Information technology staff were underrepresented.

Willingness to Implement Information Technology

Respondents were asked to rate their personal willingness to implement information technology. Additionally, they were asked to rate their immediate supervisor's and subordinate's willingness to implement information technology. In general, respondents thought that they were personally more receptive to implementing information technologies than either their supervisor or subordinate. Figure 1 illustrates the overall averages for all respondents.

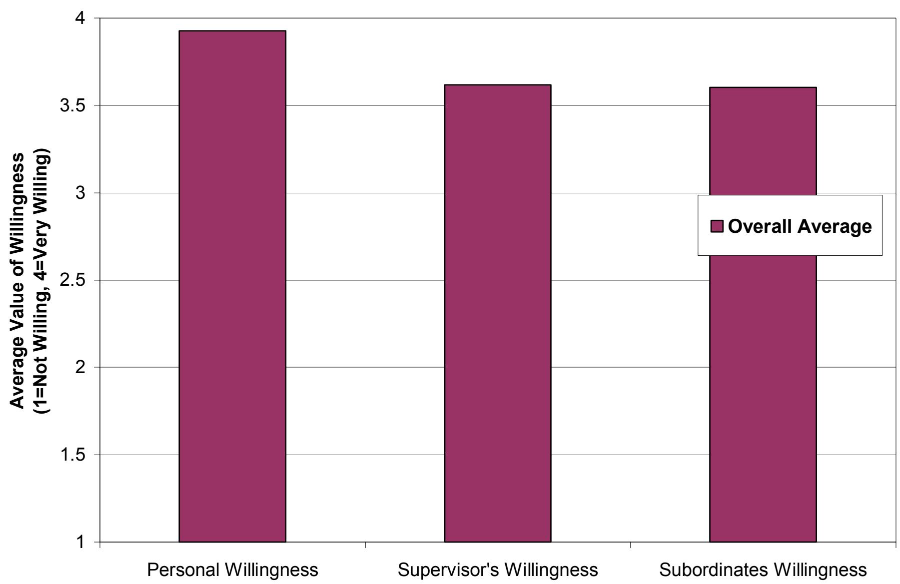

Figure 1. Overall Willingness to Implement Information Technology

Figure 2 illustrates a breakdown of this question among corporate executives, project managers and information technologists. While corporate executives and project managers consider themselves personally more willing to implement information technology than their supervisors or subordinates, corporate executives feel that their subordinates are more willing than their supervisors, whereas, project managers consider their supervisors to be more willing than

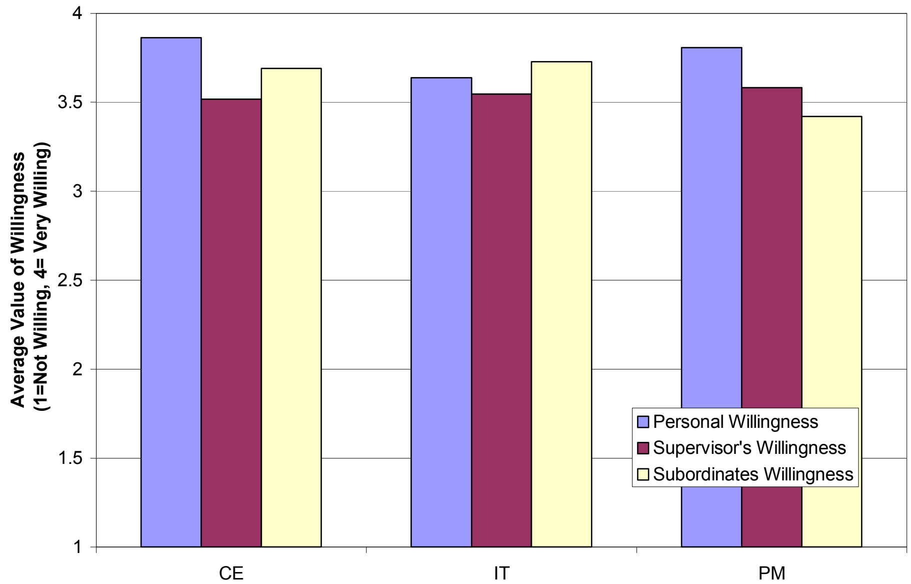

Figure 2. Corporate Executives, Project Managers, and Information Technologists Willingness to Implement Information Technology

subordinates. Information technology personnel consider willingness among all groups relatively the same. These results suggest that organizations create strong training and education for information technology implementation at the senior executive and project personnel levels. This is consistent with observations made by the researcher. Note that all responses represent a positive attitude toward implementing information technology.

Top 3 system technology investment priorities

Respondents were asked to identify their unit's technology investment priorities. A list of possible priorities was provided. This list included:

- 3D
- Data Warehouse
- Engineering Applications
- Web
- Data Management
- Other

Each respondent was asked to identify, in order of importance, his or her top three investment priorities. Figure 3 below illustrates the number of responses for 1st, 2nd, and 3rd priorities for each technology. Additionally, Figure 3 illustrates the total number of responses for each technology. These results demonstrate that the respondents' overall investment priority is in the area of Data Management. Data management includes technologies such as electronic data management systems.

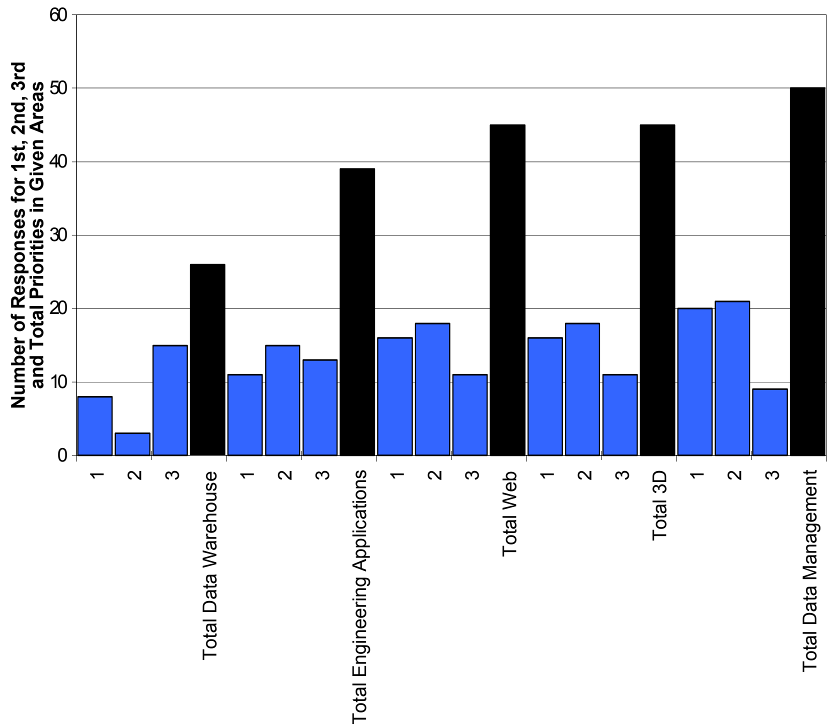

Figure 3. Overall Investment Priorities

Survey data demonstrates that contractors consider 3D applications as their #2 investment priority. Data warehousing and Web applications are #3 technology priorities. Data management and 3D applications are productivity type applications, which may explain contractor emphasis. Data warehousing and Web applications are less developed technologies that are currently being investigated and developed as data storage and data dissemination aspects of FIAPP.

Owners consider Web applications and 3D as their #2 and #3 investment priorities respectively. Investment priorities were analyzed according to corporate executive's, project manager's and information technologist's input (Figure 4). Corporate executives consider data management and web technologies as their primary investment priorities. Project managers have no clear priority but are somewhat split on investment priorities across data management, web, engineering applications and 3D technologies. IT personnel are also split on priorities across data management, engineering applications, data warehousing technologies. These priorities fall along functional requirements of the different areas.

This data suggests that there are no clear investment priorities among functional areas within organizations. Lack of a clearly defined organizational strategy may lead to excessive technology costs, delayed implementation, and a dilution of integration efforts.

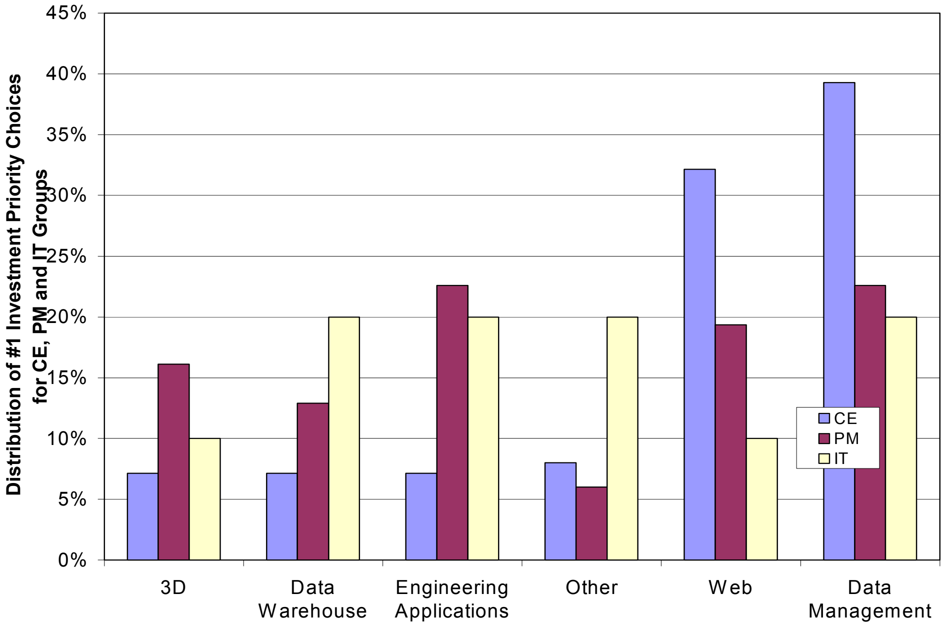

Figure 4. #1 Investment Priority for Corporate Executives, Project Managers and Information Technologists

Future technology spending

Respondents were requested to provide estimates of their organization's future information technology investment. Figure 5 illustrates spending levels for the next 5 years for IT investment. There is not a significant difference of expected spending levels among contractors and owners. The trend in figure 5 illustrates that contractor trends in investment lag owner trends. Owners are showing a tendency to reduce investments while contractors are still increasing their investment levels.

The low to moderate anticipated increase indicates that companies acknowledge the importance of continued technology investments but do not yet see benefits of large increases in spending. This is particularly true when combined with the low impact companies see IT having on return on investment (ROI) and value as noted in other parts of this paper.

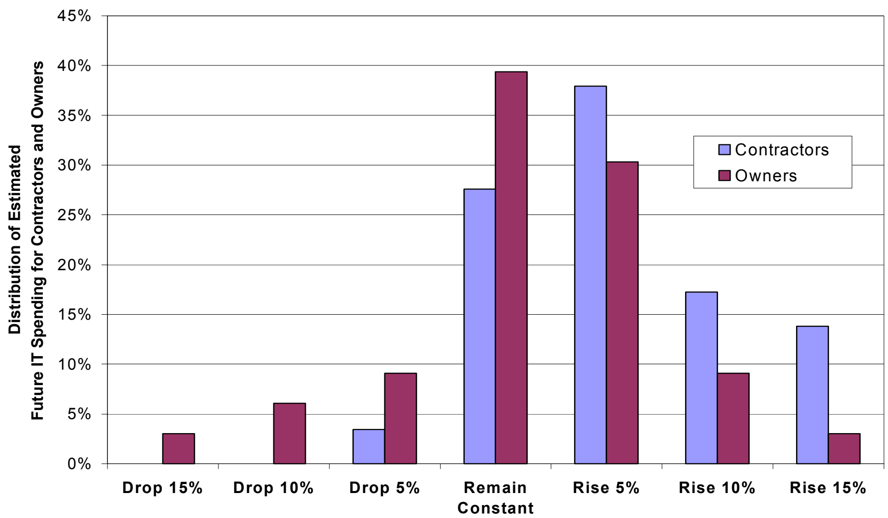

Figure 5. Expected Future IT Investment (next 5 years)

Barriers to implementing information technology in project execution

Survey participants were asked to rate barriers to integration and automation. Figure 6 illustrates overall average scores for barriers.

The primary barrier for implementing integration and automation among both contractor and owner organizations was cost. The perception that cost is an overriding barrier is reinforced when combined with survey data on performance that identifies reduced rework and return on investment as having very low positive impact on project and organizational performance. Combining the fact that value is a highly ranked barrier, it becomes evident that organizations do not currently view FIAPP efforts as cost effective investments. This suggests a requirement for further investigation of cost-benefits of FIAPP, and improved optimization models for investment and implementation.

Figure 7 illustrates the percentage of respondents scoring a value of 3 or higher for each barrier type presented. This analysis demonstrates a difference between two categories, which may have similar average values. In this case it is clear that cost has the highest percentage of high barrier responses (3-4). This reinforces the statement that cost is the primary barrier to fully integrated and automated project processes.

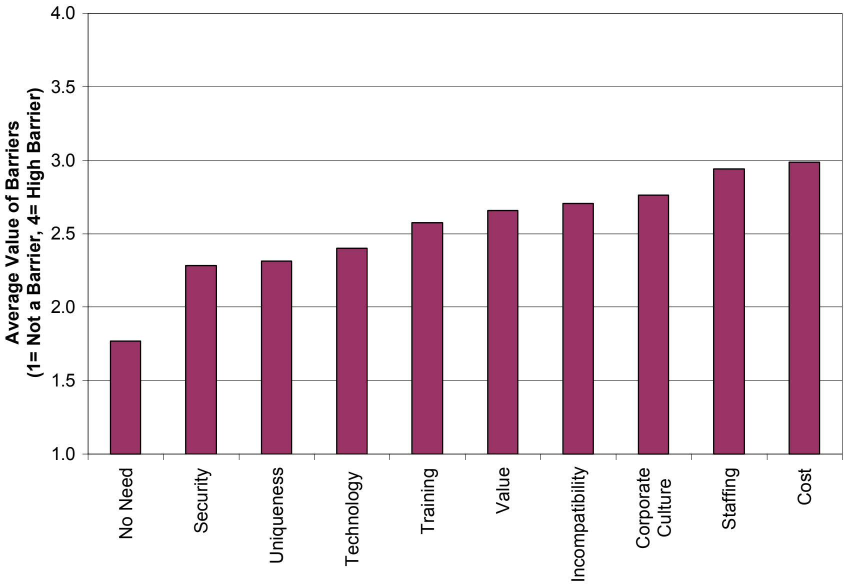

Figure 6. Overall Average Barriers

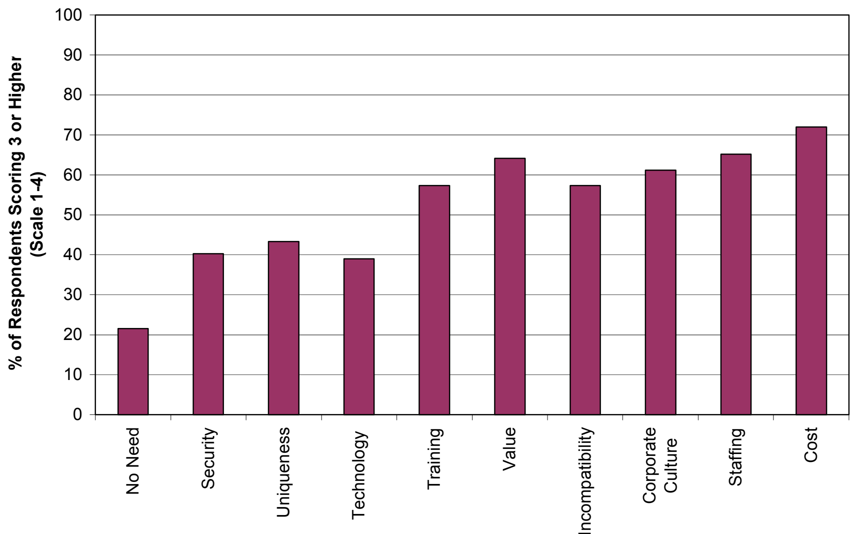

Figure 7. Percent of Respondents Scoring 3 or Higher on Barrier Survey

The overall averages in Figure 6 illustrate a similar importance for corporate culture, incompatibility, value, and training as barriers to FIAPP. However, Figure 7 illustrates that corporate culture and value received a larger percentage of scores 3 or higher than incompatibility and training. These findings when viewed with others in this report represent two evolving themes. First, cost and value as large barriers indicate companies' current lack of confidence that FIAPP investments provide appropriate returns. Secondly, the importance of staffing and corporate culture are consistent with industry observations where companies note that culture is a much greater barrier to implementation of information technology systems than technology. These findings suggest that while the importance of technology-based issues in FIAPP must not be overlooked, equivalent emphasis should be placed on business and organizational issues of implementing FIAPP.

Impact of information technology job performance and overall company performance

Participants were asked to comment on the impact of information technology on both an organizational unit's job performance as well as overall company performance. Although there are no significant differences in the categories of impact on performance, the trend is that members consider the non-measurable aspects such as organization and collaboration (unit job performance) and project delivery and customer service (overall performance) have the greatest impact. Quantifiable measures such as cost, budget, and rework (unit job performance) and ROI and competition (overall performance) are considered to have less of an impact. This suggests that further investigation be made on quantitative impacts of integration and automation. It also reinforces the importance of continued FIAPP study and dissemination of information among member organizations.

One common theme culled from the industry survey, discussions with industry representatives, and the author's involvement in IT related FIAPP research for the past 5 years is misalignment of social architecture of organizations with the IT implementation efforts. Focus on social architecture and new models of IT implementation is a central theme of ongoing research by the authors and is addressed below.

EXISTING TECHNOLOGICAL CULTURE OF AEC/EPC ORGANIZATIONS

Current methods of delivering projects in the AEC industry have not significantly changed in the past 50 years (Halverson, 1993). Although dramatic change is required to meet market, owner, and competitive needs, many barriers to change, particularly in the area of technology implementation, continue to thwart organizational initiatives for improving performance (Mitropoulos and Tatum, 2000). Additionally, failure to adequately address social architecture when embracing change is well documented (Bennis and Nanus, 1997, Young, 1996, Yuktavetya, 1999, Ford et al., 2000). Hence, social architecture is a primary issue requiring continued investigation (Ford et al., 2000, Songer, 1999).

The underlying theoretical framework for this investigation into social architecture is the organizational dynamic concept that an organization's successful implementation of technology, and the management thereof, depends on how knowledge is represented and distributed within the social architecture of the organization. Three relationships that affect organizational dynamics within this social architecture include:

- Changes in technology alter the nature of tasks and vice versa;
- Changes in tasks to be done affect the people and vice versa;
- Changes in people change the organization and vice versa (Sutton and Sutton, 1990).

However, current literature and case study investigations by the authors indicate that very little alignment or even acknowledgement of the above relationships exist within the AEC community. Identifying and understanding social architecture barriers to implementing IT within AEC organizations provides a foundation for change within associated social architectures.

ORGANIZATIONAL BARRIERS OF IT IMPLEMENTATION

Since the implementation of modern information technology is changing the workplace and the nature of work itself, alternative social structures guided by these information technologies are needed. Barriers include the basic components of most organizations.

Firstly, cultural aspects of the organizations, which rely upon methods to change individual or group values, attitudes, or role perceptions in the organization are not addressed (Holzner and Marx, 1979). Kipnis has noted that new technology tends to create work that isolates people from each other in the community, and encourages passive modes of adaptation. Kipnis further states that isolated and passive individuals tend to be powerless and less able to resist unwelcome influence (Kipnis, 1990).

Secondly, operational aspects, which address cognitive information on new practices or services, are often omitted. According to Hammer, new technologies enter the organization and members of the organization are expected carry on with business as usual, not taking into account that they not only have to learn new technologies, but also determine how the new technology affects their normal output. The biggest misconception is that the technology automatically enhances already routine tasks as opposed to changing them completely (Hammer, 1990, Hammer and Champy, 1994).

Finally, policy aspects, which rely on the redistribution of power, redefinition of rewards, and manipulation of resources in order to influence behavioral change are often overlooked. Most organizations use bureaucratic and hierarchical controls to maintain satisfactory levels of employee performance (Kipnis, 1990). The result is that employees tend to become dependent and submissive to their superiors, where they experience a very short time perspective and low feelings of responsibility about their work (Argyris, 1971).

These three aspects focus on the barriers of most organizations' inability to implement information technologies successfully and sustainably. They are based on how individuals need to engage in an interpretive process that informs their attitudes toward competing social practices. These social practices, governed by cultural, operational, and political components of the organization create new meanings that aim to increase the organizational operational capacities and reduce the complexity resulting from the transfer of technology (Simpson, 1989, Young, 1996).

IT MODELS FOR INTEGRATED, COLLABORATIVE WORK ENVIRONMENTS

It is unlikely that two primary conventions of the building industry will change their purpose significantly in the future. First, graphical representations of the project will continue to be created, though the type of representation may change over time, such as from two-dimensional paper drawings to three-dimensional computer models to a virtual reality representation and beyond. Second, communication will continue to be a necessary action between all the parties involved in a project. The manner in which this communication occurs may be unlike any that can be dreamed of today, but the need for communication in order to design and construct a building will remain.

Assuming these conventions remain constant, we must look towards IT models that foster an integrated, collaborative work environment and enhance, rather than threaten, graphical representations and communication. Eastman (1999) proposes that the goal is “to develop an electronic representation of a building, in a form capable of supporting all major activities throughout the building lifecycle.” This addresses the graphical representation needs and is consistent with the Construction Industry Institute (CII) and their goals with FIAPP, an IT driven response from the AEC/EPC industry to meet new market and owner demands.

Current construction IT research leaves out many informal portions of communication when modeling processes and instead dumps them into the "black box". Researchers generally are not looking at how information is processed or manipulated, but rather just model the information that is formally processed (Crook et al., 1996). With this incomplete picture, the communication needs of the industry may not have a neat solution. Simply providing electronic methods of information transfer such as email or voicemail does not appear to satisfy all the needs of the different parties. Electronic communication can be misconstrued and misinterpreted without the benefit of face-to-face contact to build trust and confidence (Hallowell, 1999). Consequently, there may not be an IT model that truly supports an integrated, collaborative work environment and it may be necessary to combine both technological and face-to-face communication methods instead.

MODELS OF ORGANIZATION ENCOURAGING INTEGRATION AND COLLABORATION – A PROPOSAL FOR CHANGE

Developing effective social architectures requires organizations and their members to account for numerous interrelationships that exist both internal and external to the organization. As mentioned earlier, changes in technology have lasting effects on the tasks to be done, the people, and the organization as a whole. Compounding this situation are barriers to information-sharing and knowledge creation throughout the organization. Cultural, operational, and policy components were mentioned here, but it is safe to say that this list is not conclusive and could certainly contain countless combinations of components mentioned and others that will possibly emerge.

Current social architectures do not support the transfer of new technology in the organization (Young, 1996, Yuktavetya, 1999). Overcoming barriers and simultaneously adding value to how people in the architecture view their contributions, performance, and overall wellness in the organization is a primary factor for transforming current social structures into ones that will permit the open and free creation of information and knowledge for appropriately recognizing technology impacts on all components of the organization (Richards and Young, 1996, Young, 1996).

There are several approaches that provide a solid foundation for members of the organization and give a viable means to participate in information sharing and knowledge creation, which encourages integration and collaboration. Wheatley suggests that members of the organization set out to build new relationships with other members of the organization and enhance those that are already in existence (Wheatley, 1992). She further suggests, as do Nonaka and Takeuchi, that knowledge is a function of the people and wellness of the organization (Wheatley, 1992, Nonaka and Takeuchi, 1995), meaning that knowledge, beginning at the individual level, can easily transcend group levels and eventually, the organizational level. As suggested here, the approach that will drive our model is one that fully integrates information technology as a means for showing how new relationships and knowledge creation can transform the social architecture into one that not only recognizes technology's impact on the organization, but also prepares to quickly integrate the effects of these changes throughout the organization.

REFERENCES

Argyris, C. (1971) *Management Science,* **17,** B-275-292.

Bennis, W. and Nanus, B. (1997) *Leaders: Strategies for Taking Charge,* HarperCollins, Inc., New York, NY.

Crook, D., Rooke, J. and Seymour, D. (1996) In *CIB-W78'96 Conference*(Ed, Turk, Z.) Bled, Slovenia.

Eastman, C. M. (1999) *Building Product Models: Computer Environments Supporting Design and Construction,* CRC Press, Boca Raton, FL.

Ford, D. N., Voyer, J. J. and Wilkinson, J. M. G. (2000) *Journal of Management in Engineering,* **16,** 72-83.

Hallowell, E. M. (1999) *Harvard Business Review,* **Jan/Feb,** 58.

Halverson, S. (1993) In *Surety Magazine*.

Hammer, M. (1990) *Harvard Business Review,* **July/Aug,** 104-112.

Hammer, M. and Champy, J. (1994) *Reengineering the Corporation: A Manifesto for Business Revolution,* HarperCollins Publishers, Inc., New York.

Holzner, B. and Marx, J. (1979) *Knowledge Application: The Knowledge System in Society,*

Allyn and Bacon, Inc., Boston, MA.

Kipnis, D. (1990) *Technology and Power,* Springer-Verlag, New York, NY.

Mitropoulos, P. and Tatum, C. B. (2000) *Journal of Management in Engineering,* **16,** 48-58.

Nonaka, I. and Takeuchi, H. (1995) *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation,* Oxford University Press, New York, NY.

Richards, L. D. and Young, R. K. (1996) *Systems Research,* **13,** 363-370.

Simpson, L. (1989) *Technology, Time, and the Conversations of Modernity,* Routledge, New York, NY.

Songer, A. D. (1999),Construction Industry Institute, Austin, TX.

Songer, A. D., Diekmann, J., Hendrickson, W. and Flushing, D. (2000) *Journal of Construction Engineering and Management,* **126,** 185-190.

Sutton, D. and Sutton, M. (1990) *Management and Development,* **21,** 122-132.

Wheatley, M. J. (1992) *Leadership and the New Science: Learning about Organization from an Orderly Universe,* Berret-Koehler Publisher, San Francisco, CA.

Young, R. K. (1996),Old Dominion University, Norfolk, VA.

Yuktavetya, O. (1999),Old Dominion University, Norfolk, VA.