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Information technology (IT) and integration in the construction industry

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The focus of this paper is on the integration of design and construction activities. We argue that information technology (IT) can effectively promote integration in the construction industry. Recent advances in the field of IT, the increasingly global nature of the construction market and a renewed demand for quality and productivity in construction are making the issue of integration more critical than ever. Design and construction organizations can achieve integration of various construction activities by redesigning many of their organizational functions and processes and IT can facilitate redesigning of these processes. The dynamic nature of construction processes, interdependence of various participating entities and the need for teamwork, flexibility and a high degree of coordination suggest that IT has great potential in the construction industry. The construction industry can make effective use of *communication*, *data accessibility* and *common systems designed to process data*, the three major categories of IT capabilities to achieve integration. We contend that appropriate IT investment and management's commitment and ability to provide leadership under the changed atmosphere are crucial for the successful implementation of IT in the construction industry. The impact of IT on the design and construction organizations must be managed with an understanding of external and internal factors that affect business organizations. It is essential that an appropriate environment that establishes suitable reward recognition procedures, encourages team-work and creativity and stimulates decentralization of decision-making activities be created. Thus, IT implementation is not just a technical enhancement but a managerial decision that involves re-engineering of organizational functions and operations.

Keywords: Information technology, organization, integration, shared data resource, re-engineering.

Introduction

In the construction industry, information technology (IT) is creating new possibilities and, as a result, its advancement is placing new demands upon design and construction organizations. IT can no longer be viewed as an enhancement to traditional business procedures but rather as an innovative agent that enables new and different alternatives to organizing and operating business enterprises. As a consequence, business organizations are faced with opportunities as well as challenges.

Technological advancement, market expansion, global competition and a renewed demand for quality and productivity are making the issue of integration of various stages involved in the process of construction more critical than ever (Schimming, 1993). Traditionally fragmented construction organizations are searching for new ways to integrate both inter- and intraorganizational functions (Nam and Tatum, 1992). There is a need to identify the roles IT can play in this changing industry environment. Likewise, it is important to understand how the construction industry, in general and the organizations, in particular, would be impacted by IT. Formulation of organizational strategies and plans should be based on this comprehension.

Bröchner (1990) points out that various aspects of IT actually enhance the patterns of integration in the construction industry. Coordination, automated inspection, data translation, efficient transactions and elimination of intermediaries are seen as IT aspects that would have positive effects on patterns of integration such as geographic expansion, diversification or subcontracting and integration with materials supply and into real estate investment. Betts *et al.* (1991) argue that the real benefits

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of IT are yet to be realized in the construction industry. The main reason is that the management of IT in a fragmented industry requires careful and strategic planning at the industrial and organizational levels.

The objective of this paper is to explore the current and potential needs in the construction industry and to examine the corresponding IT capabilities for adoption by the design and construction organizations to satisfy those needs. The emphasis of the paper is on the IT capabilities that can be used to establish effective integration in the industry. We argue that design and construction organizations can benefit by redesigning many of their organizational functions and processes and that IT can be employed to assist in redesigning these processes. In this paper, we attempted to provide the managers and practitioners in the construction industry with useful ideas and thoughts for redesigning and reorganizing their business enterprises for effective integration of various construction activities by employing IT. We hope that the managers of design and construction organizations will find the review of IT capabilities presented and the recommendations (on how to utilize these capabilities) made in this paper useful. We believe that researchers will find the information and the assessment presented in this article not only interesting but also thought provoking. We feel that new research areas in this field will emerge from an understanding of how IT can positively impact on design and construction organizations.

The rest of the paper is organized as follows. In the next section, characteristics of the construction industry and how IT can influence or alter these characteristics are discussed. Prevalent market forces in the construction industry are identified and reviewed. We examine available and emerging IT capabilities that are being used or can be used in the construction industry. Next, a discussion of an IT application area, shared data resource, is presented. This specific application area is chosen to explore the implementation and organizational issues and to point out the problems and difficulties. The impacts and effects of IT application on design and construction organizations are discussed next. In the following section, challenges facing design and construction organizations in the wake of emerging IT capabilities are pointed out and the strategies to turn these challenges into opportunities are outlined. In the last section a summary of the main issues discussed in the paper is provided.

Characteristics of design and construction organizations

Design and construction organizations function in an atmosphere that is characterized by certain features that lend themselves to successful applications of IT. Some of these characteristics are outlined below. The corresponding potential IT advantage is also pointed out with each of these features.

1. Dynamic process: the work atmosphere is continually changing both at the project and at the organization level – automation and quick communication enabled by IT can be extremely helpful; analyses can be performed and decisions can be made quickly with the help of IT.
2. Process is based on the complex interrelationship among the various participating entities – IT can reduce the need for bureaucracy and hierarchy of interaction and can enhance integration of organizational activities.
3. Team-work is required to construct a facility successfully; organizations involved in the construction industry are project-oriented and *ad hoc* teams and/or networks can be very effective – IT can be employed as a facilitator to build teams overcoming the barriers of time and distance.
4. Operations in the construction industry are people intensive and cannot be completely automated or mechanized; the production-line concept is in general not appropriate in construction – IT will allow people to communicate in a flexible atmosphere by relieving them from routine work. IT can also be employed to coordinate the activities of many participants typically present in a construction project.
5. The solution of construction project problems are highly dependent upon the experience and judgements of professionals and also involves uncertainty – IT will be helpful in dealing with a high level of task uncertainty usually involved in design and construction operations; common systems such as knowledge-based expert systems and executive information systems will prove indispensable.

Existing market forces in the construction industry

The prediction that extensive use of IT would transform business organizations was first made by Leavitt and Whisler (1958) in their seminal work, 'Management in the 1980s'. IT, a term coined by them, was considered to be the main agent for change in business organizations. Their predictions about the organizations in the 1980s were found to be, for the most part, true (Applegate *et al.*, 1988). Leavitt and Whisler (1958) prophesied that increased IT capability would transform the nature of market forces, industries would have to set new norms

and performance standards and business organizations would have to reformulate their strategies.

We observe the same phenomenon in the construction industry. Emerging market forces are transforming the business atmosphere. Design and construction organizations are challenged with increased global competition. Large organizations are looking for ways to become diverse, while small ones are attempting larger-sized projects (Carlyle, 1990). The use of CAD (computer-aided design), 3-D graphic simulation and computer-based network scheduling is on the rise and these new practices require new standards, new specifications and new ways of interaction among various project participants (Navarrete and Ahmad, 1993). Renewed interest in design/build construction, CM/GC (construction manager/general contractor) contracting, alternate dispute resolution (ADR), total quality management (TQM) and partnering is evident in the industry. The existence of these market forces demands that IT be employed to respond to these forces.

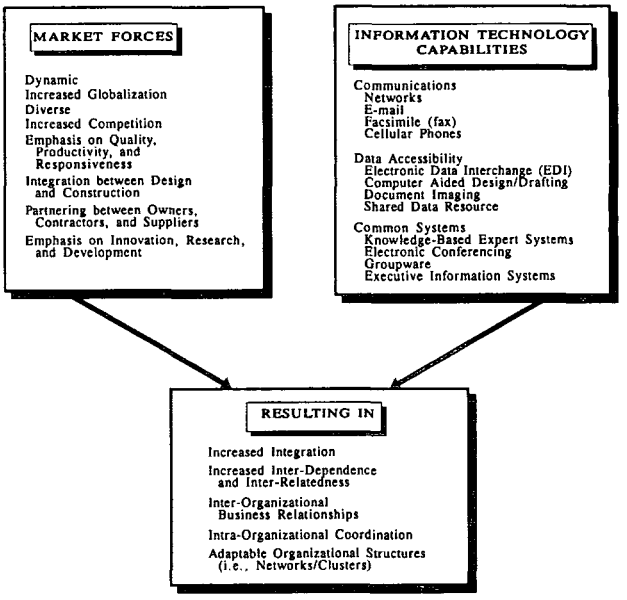

Figure 1 Effects of market forces and IT capabilities on design and construction organizations

IT capabilities

Current and emerging IT capabilities can be grouped into three broad categories: communications, data accessibility and common systems, as indicated in Figure 1. This grouping of IT capabilities is based on the usefulness of IT from a user perspective. In construction, *communications* or exchange of information is one of the most important functions. The success of this function depends to a large extent on the quality and *accessibility of data*, as well as on the efficiency and effectiveness of the *systems designed to process data.*

The industry is already experiencing a tremendous increase in the use of communication technologies in improving its operations. Recent advances in the area of data accessibility and sharing are encouraging (Edmister, 1993). Electronic data interchange (EDI), computer graphics and image processing (document imaging) are some of the current research topics, results of which may transform the infrastructure of design and construction organizations. At the higher level of management, the role of IT is to assist decision makers in various ways. These can take the forms of knowledge-based expert systems (KBES), decision support systems (DSS), electronic conferencing, groupware (software for use by a group, as opposed to by an individual, for consensus reaching or other group purposes) and executive information systems (EIS).

Incorporation of construction knowledge during the design stage (Howard and Rehak, 1989), application of bar code technology (Bell and McCullouch, 1988) and object-oriented database systems (Cohen and Levitt, 1991; Yau *et al.*, 1991) are some representative examples of integration effort. Several large design and construction organizations are investing in cutting edge technologies, such as, 3-D graphics simulation and integration of CAD and scheduling (Nevins and Zabilski, 1991). Utilization of recent communication technologies, such as, local area network (Chang and Chao 1992, *Engineering News Record*, 1993) and e-mail (Safayeni *et al.*, 1992) is gaining increasing acceptance among design/construction organizations. Fax machines and cellular phones are now commonplace in the construction industry.

The changing business environment and increased IT capabilities are translating into a more focused emphasis on integration. Increased global competition on one hand and availability of communication-tools on the other are resulting in increased opportunities for design and construction organizations for establishing joint ventures, partnering programmes and long-term relationships with clients and/or suppliers. Integrations between planning and design and design and construction are gaining increased attention from practitioners and researchers alike. This attention is focused upon increased productivity and improved quality of construction (Betts *et al.*, 1991).

Needs of design and construction organizations and available IT tools

Table 1 lists the critical needs of design and construction organizations with corresponding IT capabilities. Available tools under each broad category of the IT capabil-

ities are also identified in Table 1. It should be noted that the needs are primarily in the area of integration involving various functions of planning, design, procurement and construction.

Communication tools can help design and construction organizations to coordinate their activities better overcoming the barriers of time and distance. Training tools, such as multimedia, can help train workers. Mechanisms of remote supervision or self-supervision can also be established with the help of communication tools. There is a profound need for uniform and standard data in the construction industry. Without standard data it is difficult to establish an effective performance measurement system or an efficient quality assurance programme. Uniformity of procedures and standardization of data would greatly enhance the effectiveness of communication among the multiple construction organizations teaming up to build one constructed facility. This kind of uniformity can be achieved effectively through one specific IT application, shared data resource. However, the solution is not simple. In the following section, we discuss the issues related to development, implementation and utilization of shared data resource.

Shared data resource: an IT application-area and related issues

Each construction project is almost unique and there are large amounts of data generated during the project life cycle. There are a large number of project participants with different specialities that make construction a complex and fragmented industry. In this fragmented environment it is necessary for the various participants to share information pertaining to project concepts. Cooperation between the large number of project participants is essential in order to achieve the purpose of the project, to deliver a constructed facility. Communication, in many forms, is the means for information and data exchange between those different participants.

The sharing of information requires the deliberate and intentional exchange of messages through a physical medium comprising the communication channel. The traditional communication channel used in the construction industry contains symbolic messages consisting of text and graphics in paper medium. This communication channel has existed virtually unchanged for several centuries, in spite of its deficiencies, for one simple but subtle reason: the same channel is sufficient to establish communication with a variety of participants (Meyer, 1991). The participants typically share a natural language, such as English and a certain ability, acquired through learning, to translate graphic language into the medium of thought.

Computers in sharing data

The introduction of microcomputers in the early 1980s stimulated revolutionary change in the work environment and, somewhat inconspicuously, initiated evolutionary change to the communication channel. Tasks previously performed by manual methods were soon relegated to computer-assisted environments, especially those tasks associated with information processing. This transition contributed to gains in human efficiency, but also created additional fragmentation in the construction industry. The large number of and variation in computer environments is a significant problem (Howard *et al.*, 1992). For example, project documents can be written in a variety of word processing environments. Each package creates its own data file in a distinct format resulting in difficulties with exchanging documents electronically. This difficulty in data exchange can affect productivity negatively by communication inefficiency. Howard *et al.* (1989) argue that the introduction of computers to the

Table 1 Technology needs and IT applications in construction

Needs (1)	IT capabilities (2)	IT tools (3)
Integration Coordination Training Supervision	Communications	Voice mail/e-mail/fax Electronic network Document imaging Multimedia
Internal (project/company) and external (industry) standards Data capturing, storage, retrieving and transmitting	Data accessibility	Shared databases Electronic data interchange (EDI) Bar code 3-D graphics
Decision making Consensus reaching Technical analysis	Common systems	Knowledge-based systems Decision support systems Groupware Executive information systems

design process has changed the means of generating the paper, but has not fundamentally changed the methods of sharing data across organizational boundaries. Unlike human environments. Messages must be translated from one environment to another which raises the distinct possibility that each communication channel can be different.

Definition of shared data resource

Computer automation is often promoted as a cost-effective means to store, process and distribute project information. An integrated communication strategy requires a 'common' communication channel for exchanging data between project participants. A primary component of this channel is a shared data resource. Unfortunately, there is wide variation in the definition of this resource and subsequent implementation schemes. In this paper, shared data is defined as any data that are shared and flow between different organizations. In other words, the data created by one organization and used by another organization(s). An example of shared data in a construction project can be the bearing capacity of soil. This piece of data is shared between the geotechnical engineer who determined it and the structural engineer who uses it to design the structural systems. Contract documents, project drawings, change orders, other administrative paper forms and verbal instructions are other examples of data that the construction project participants share and exchange.

Benefits of shared data resource

The most important benefit of shared data resource is that it allows the automatic exchange of data between diverse systems of hardware and software with minimal effort in developing translators. Any implementation of the shared data resource idea requires the users to have a pre-processor to translate from their knowledge representation to the shared data resource representation and a post-processor to translate from the shared data resource representation to the users' knowledge representation. Using only two translators to get information from the shared data resource is a key issue and an important benefit of developing such a resource.

Information availability, accuracy and timeliness is a crucial factor in the decision-making process. Establishing a shared data resource, which contains information necessary to perform different construction tasks, can provide the participants' organizations with general guidelines of what their data needs are as well as the sources of these data. This knowledge will save the participants' time and increase their productivity as a result of minimizing errors typically generated in traditional communication channels, i.e. the paper medium.

Implementation of shared data resource

The implementation of this shared data resource can take several forms. For example, one can think about it as a database that contains all the information needed for the construction project for use by different project participants. But, this raises some important questions such as the following. How will this database be organized? Will it be a single database that contains all the information or will it be different small specialized distributed ones? Which alternative is more cost-effective? Which alternative is more feasible with respect to implementation? These questions can be summarized in one question: Which form is better? Is it the centralized database or the distributed database?

To answer the last question posed, one can compare the costs and benefits of centralization versus decentralization. Several factors may be included in this comparison such as the system's development cost, the system's flexibility and availability, the access privileges responsibility, the waiting time, the maintenance and updating costs, the failure rate and the access fees. In the case of the centralized database the following can be asked. Who will build the database? Where will this database be located? Who will be responsible for the accuracy of information? How can the accuracy of the data be checked? Who is liable for incorrect or incomplete information? What are the organizational aspects that should be considered?

Wright (1988) discussed the idea of integrated project information systems, which he defined as a dynamic repository for project-specific information that can be appropriately accessible to all project participants. He suggested solutions to many of the previous questions. He stated that 'the technologies for integrated project information systems may themselves be proprietary. Software packages and the host hardware may be commercial products. The provision of a project information service also can be a private or professional activity. The service can belong to and be operated by the owner if the owner regularly builds and operates facilities; it can be provided by the contractor or by a service bureau specializing in integrated project information system service. However, a number of public, generic technologies are needed to strengthen the service provided by and market for integrated project information systems.'

Another alternative for the shared-data resource is a common language or, in other words, a neutral format through which the information can be exchanged between different organizations. This common language can solve the problem of how different computer soft-

ware and hardware communicate. Initial Graphics Exchange Specifications (IGES) is an example of such a common language of interchange for CAD systems. Another example of a common standard is the Open Systems Interconnection (OSI) model of the International Standards Organization (*Engineering News Record*, 1986).

Impact upon the construction industry

Shared data resource will basically promote integration of operations and functions within and among various design and construction organizations. The availability and use of shared data resource would change traditional interdependence among them. A new type of interdependence, based on whether the resource is centralized or distributed and whether a common language exists or not would emerge. As a consequence, management processes, communication channels and organizational structures would have to be redefined and redesigned to fit within an atmosphere focused on integration and coordination. The challenge is, therefore, formulation of techniques and strategies for managing this new type of interdependence.

To comprehend the dynamics of a modern-day business organization a description in terms of its external environment and internal elements is very helpful. The external environment consists of two main parts:

1. Technological;
2. Socioeconomic.

According to Scott Morton (1991) there are five major internal (within the boundary of an organization) elements in a business organization. They are

1. Information technology;
2. Organizational structure;
3. Management processes;
4. Individuals and roles;
5. Business strategy.

External environment

The technological environment is being transformed by the significant advances made in recent years in the fields of computer hardware and software technology. These advances have enhanced IT capability. The external socioeconomic environment is dependent to a large extent upon governments and local economies. Clearly a significant transformation is ongoing in the construction industry regarding a globally evolving competitive economy (Russell and Casey, 1993). As indicated in Figure 1, design and construction organizations and their management processes might be transformed in a fundamental way due to these dynamics. The two components of the external environment are driven by each other. New socioeconomic forces are demanding enhanced IT capabilities and, in turn, improved IT capabilities are transforming the socioeconomic environment.

Internal elements

The forces pushing for integration of functions in the construction industry will have an influence on the internal elements of design and construction organizations, as well. Changes in one of these elements affect the others. Thus, changes in the nature and extent of information technology can transform structure, management processes, individual roles and strategy in a business organization.

Organizational structure

IT enhances communication, takes over most of the routine tasks and minimizes data handling problems. The magnitude and quality of organizational memory can be enhanced by IT. IT thus allows organizations to be as responsive as small firms and at the same time as diverse as large firms. IT can improve the quality and promptness of interconnections between organizational processes by leading to greater shrinkage of time and distance effects. New and different kinds of interconnections and interdependence among various organizational units and organizations will be required as a result of increased emphasis on integration enabled by IT. Electronic networks have the potential to give rise to networked organizations. In a networked design/construction environment effective integration of design and construction activities would be feasible. With the help of IT, vertical (sequential) and horizontal (parallel) work groups can be quickly formed on an *ad hoc* basis to solve problems, to administer programmes and to manage projects. The contractual relationships among various design/construction organizations must be redefined and reformulated for effective incorporation of IT in the construction industry. A common database shared by different project participants, for example, will require a different kind of interaction between design, construction and other activities.

Management processes

With the flexibility and *ad hoc* work patterns afforded by IT, design and construction organizations can become more effective and efficient in managing projects. New methods of planning, control and measurement systems need to be implemented to benefit from IT. Electronic network communication can provide large firms a competitive edge on smaller projects (*Engineering News Record*, 1993). Small firms, on the other hand, can have the same economy of scale as the large ones by direct

electronic linkage with manufacturers eliminating the need for wholesalers and retailers. Formation of *ad hoc* (temporary) groups or clusters would be a relatively simple task with IT. Establishment of long-term business relationships with clients and/or vendors can become cost-effective options for design/construction organizations.

Individuals and roles

As a result of IT, the importance of interdisciplinary knowledge and team-work will increase in the design and construction organizations. IT-enabled flexibility in these organizations will encourage team building. Individuals employed in design and construction organizations, functioning in an IT-enriched environment, will be required to have multiple interdisciplinary skills and expertise. IT enables multiple skills to be brought together at an arbitrary point in time and location. The dynamic nature and prompt problem-solving requirements of construction projects will be helped by this capability. It will be possible to form teams effectively and quickly as problems arise. It is imperative that the management of design and construction organizations need to reformulate their recruitment policy, performance appraisal procedure and their education and training activities to benefit from these IT capabilities.

Business strategy

IT will create increased opportunities for both vertical (sequential) and horizontal (parallel) integration in the construction industry. IT will enable the formation of virtual organizations or instant consortiums with minimal effort. Enhanced communication enabled by IT will make joint venturing and partnering truly effective in the construction industry. Contractual arrangements that promote integration such as design/build contracting, CM/GC (construction manager/general contractor) contracting, partnering, joint venturing, geographic expansion and diversification in the construction market will be facilitated by increasing IT utilization.

Challenges and strategies

As argued in the previous section, IT can foster effective integration of various activities performed before and during construction. However, implementation of IT tools to promote inter- and intraorganizational integration is not without difficulties. These difficulties must be anticipated and managed with diligence in order to maximize the effectiveness of IT application. For effective use of IT, certain steps must be taken to create an appropriate environment in organizations as well as in the industry. The characteristics of an appropriate environment include a suitable reward recognition procedure, establishment of an atmosphere that encourages team-work, decentralization of decision-making activities and maintenance of uniformity of data. Design and construction organizations should exploit the flexibility and freedom offered by IT and should encourage creativity of its employees.

Senior management should be willing to invest in IT and be capable of providing direction, support and leadership under the changed industrial and organizational atmosphere. Critical challenges exist and must be part of a focused strategy. In an integrated design and construction environment, enriched with IT applications, management of organizations must deal with increased role complexity, unclear lines of authority and multiple interdisciplinary teams. Individuals employed in these organizations should have flexible and changing nature of work assignments for effective implementation of IT. Adopting suitable performance measurement systems, devising a mechanism of self-supervision, providing adequate training and education to employees and encouraging creativity and innovation will constitute a major component of management's strategy in a design or construction organization that operates with IT capabilities. Benefit–cost analysis of IT investment should be based on a consideration of projected gain through re-engineering enabled by IT.

Management makes the ultimate difference; the degree of IT awareness by management, level of IT investment, extent of IT direction and leadership are all necessary ingredients for successful IT implementation. Managers of design and construction organizations should formulate a strategy to address the challenges originating from competitive market forces and increasing IT applications. Three broad areas where design and construction organizations can concentrate to formulate such a strategy are outlined below.

1. *Re-engineering:* as IT helps integrate various design and construction functions, it is important to determine what the needs are, tasks that are not necessary and what can be relegated to IT. The ability of architects and engineers to transform CAD data to bill of quantities and to share this information with contractors has the potential to bring fundamental changes in the traditional practice of bidding based on contractor take-offs. Industry norms as well as organizational procedures will have to be re-engineered as a result of these changes. Shared data resource, for example, requires different kind of relationships among the participants such as the owners, the engineers and the contractors. Answers to most of the questions raised regarding the implementation of shared data resource lie in re-engineering. Re-engineering is the process of redesigning organizational functions and operations (Hammer, 1990). Hammer (1990)

argues that investments in IT, that leave the existing processes intact are likely to deliver disappointing results. The essence of re-engineering lies in re-examining traditional assumptions about technology, people and organizational goals. Industry norms and traditions and organizational rules and procedures must be re-examined to determine their validity under the changed environment. Therefore, IT implementation should not be viewed as a mere technical enhancement but must be considered as a managerial decision that involves a complex organizational change. The traditional job design, work flow, reporting system, accounting procedures and control mechanisms are in need of being re-engineered on the basis of new possibilities created by IT. IT should be used not to automate old processes but to enable new ones.

2. *Decentralization of the power of decision making:* moving power to where work is performed. It will be employed to interconnect design, procurement and construction process segments with data and information. Again, as an example, shared data resource can effectively empower the middle management and operating core with decision-making authorities. Decisions would be made where the problem is, by those who are facing the problem. Properly developed shared data resource should have the effect of reducing vagueness from information and it should make the interpretation of data a relatively straightforward task. In the construction industry it means more decisions will be made on site thus making decisions more effective and timely. The availability of reliable and useful data through shared data resource is the key to make this happen.
3. *Development of integrated information processing systems:* collecting and storing data once and using or transmitting repeatedly. For example, cost, schedule and financial information can be generated from the same source of data. It should be noted that the degree of decentralization of decision-making activities is dependent on the extent of integration of information-processing systems. Sharing of same site data by multiple contractors (prime and/or sub) from an integrated source of information, for example, would greatly enhance the effectiveness of communication among the project participants.

Summary and conclusions

The infrastructure of business organizations is being redefined by IT capabilities. IT offers the potential to materialize much needed integration in the construction industry. Well-defined and easy to share data, effective inter- and intraorganizational networks and integrated information processing capability are fundamental to the kind of integration needed in the construction industry. Shared data resource, electronic network, knowledge-based systems and other IT capabilities can be effectively employed to promote integration and coordination of various design and construction functions. Increasing global competition and market forces demand integration in the construction industry. Incorporation of IT to respond to these market forces, however, is not a simple issue. Development and utilization of shared data resource, for example, necessitates that traditional organizational processes and procedures be re-engineered. To benefit from IT-induced re-engineering processes, design and construction organizations should reconsider their organizational structure, management processes, individual roles and business strategy. Design and construction professionals must realize that IT may change competitive climates, organizational rules and industry norms. They should anticipate and plan for these changes. Top management support for training and development, encouragement for creativity and innovation and the creation of an autonomous and flexible work environment are essential elements for the successful implementation of IT.

Advances in IT and the transformation of organizations are thus interdependent upon one another. Shared data resource, for example, can bring a number of changes in the way design and construction organizations operate. The availability of data from an integrated source will eliminate the need for traditional methods of data transfer and, hence, interdependence, among various design and construction organizations participating in the construction of a facility. This IT capability would eliminate many intermediate steps. Uniformity and reliability of data provided by shared data resource would facilitate decentralization of the decision-making process. Thus, the impacts of IT upon the internal elements of a design or construction organization can enhance increased integration in the industry. To realize effective integration, however, traditional functions and operations of management of design and construction organizations must be re-examined, redefined and, where appropriate, re-engineered.

It should be realized that IT is not the only answer to all the problems facing the construction industry. IT, however, can effectively promote integration. The ability of design and construction organizations to seize the opportunities IT can offer and to plan for the changes IT can bring will become one of the most important indicators of their success in this era of information. The impact of IT at the industry level will leave design and construction organizations without any choice but to respond to the industry demands for the incorporation of IT.

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