Building Industry and the Agents of Change

BHARAT DAVE
Department of Architecture
Swiss Federal Institute of Technology
ETH-Hönggerberg
CH-8093 Zürich
Switzerland

ABSTRACT

The information technology and the changes it brings about are recent and evolving phenomena. In the absence of established historical perspectives, many previous studies have focused on the information technology issues that are of only immediate concern to the building industry and thus provide only limited perspectives. In this paper, we suggest that it is an appropriate time to look beyond the technological bottlenecks such as incompatibility of software or hardware, prohibitive resource investments, and others that are often cited as the reasons impeding applications of the information technology in the building industry.

With the new developments taking place in the information technology, the gradual and paced changes in the building industry organizations will be replaced by changes with a bigger scope and a higher momentum. These changes will not result in simply a new breed of professionals who become another discrete part of the web comprising the building industry; they will affect the very web defining the building industry. Additionally, the technological developments that will bring about such changes are presently being carried out by forces external to the building industry thus further obscuring their potential impacts. Five key information technology advances are submitted here as the agents of significant change in future: networks, groupware, robotics, flexible manufacturing, and microprocessor embedded building components. It is argued that the building industry needs to expand the debate about the role of the information technology by taking account of developments which presently lie outside its immediate and traditional concerns. The paper initiates this discussion and describes a number of likely impacts of the new technology on the educational, professional and organizational spheres in the building industry.
Key Words
building industry; information technology; key developments; structural changes

INTRODUCTION

The design, construction, and maintenance of built environment occupies significant human and material resources. In many developing countries, construction sector is the second biggest contributor to the gross national product (Miles, 1991). Similarly, it has been noted that in some developed countries more than 16 percent of the gross national product is devoted to the construction industry (Lahoud, 1991). While figures such as these highlight the significance of the construction industry to the national economies, it is also lamented that the construction industry is one of the slowest to integrate technological advances. More recently, the advances in the information technology have either enabled or forced substantial restructuring of organizations (Monk, 1989). In light of these observations, this paper attempts to anticipate significant changes that may be exerted upon the building industry by the advances in the information technologies.

Both the information technology and the changes it brings about are recent and evolving phenomena. In the absence of established historical perspectives, future projections are often indicative and tentative since the future events may not necessarily continue the preceding events in a smooth and continuous fashion. As a result, many previous studies have focused on the information technology issues that are of only immediate concern to the building industry and thus provide only limited perspectives. In our view, technological bottlenecks such as incompatibility of software or hardware, prohibitive resource investments, and others that are often cited as the reasons impeding applications of the information technology in the construction sector will be overcome; at the very least, they will become easier to manage than at present. Problems such as these affect not only the construction sector but other capital intensive industries like machine manufacturing as well. As a result, there is sufficient momentum and pressure to resolve these bottlenecks in the computer industry. The questions that we consider to be significant now are: once these 'technical' problems are solved, what then? What can we anticipate beyond this stage? Will it be sufficient to simply react to the new information infrastructure or should we actively select and plan for changes that will affect the skills and the roles of participants in the construction sector? Can we identify key information technologies that have the power to bring about more substantial changes than what we have seen so far? We initiate this discussion in the paper and describe some potential impacts of the unfolding information technology developments.

Scope and Organization of Paper

The construction industry spans many different activities of diverse scales such as roads, ports, buildings, and others. In this paper, the primary focus is on the design, construction, and maintenance of buildings although the issues raised here may be relevant to other sectors of the construction industry as well. The paper does not offer specific strategies for integration of the information technology in organizations; instead, the paper focuses on indentification of likely impacts of the technology in response to which organizational strategies need to be devised.

The paper is organized as follows. The first section briefly characterizes the past developments in the building industry and provides a frame of reference for the discussion that follows in the remainder of the paper. The second section discusses some often cited problems of information technology applications. The third section describes key emerging information technologies that signify substantial organizational changes in the building industry. The last section outlines possible impacts of the new technologies on the building industry.

PAST TRENDS IN THE BUILDING INDUSTRY

Studies on the building industry typically focus on aspects such as the roles and interactions of various professional groups in the design, construction and maintenance of buildings; on material resources, products and their utilization; and on the tools and skills necessary for designing and realizing efficient and 'better' solutions.

Over the centuries, the number of materials used in construction and our understanding of the properties of construction materials has increased (Stone, 1983). In contrast to a general decrease in the costs of materials, there has been an increase in the cost of labor. Better understanding of the properties of materials typically leads to more efficient and specialized construction techniques which, in turn, lead to higher labor costs. At the same time, the specialized knowledge that goes into the three major phases of conception, erection and maintenance of buildings also gives rise to specialized professions that deal with a narrow but highly focused component in one of these phases. These islands of specialized knowledge get loosely integrated for a particular project but, by and large, they carry on a separate existence. The exceptions to these forms of integration are some organizations that are founded on a collective pool of expertise that ranges over the entire life-cycle of buildings.

Due to the large number of participants and the diversity of skills involved in the building industry, many observers find the building sector very diffused and fragmented, unable to devise clear strategies for more efficient utilization of materials and other resources that are consumed by this sector. Additionally, any changes in the building industry are gradual and, quite often, arise from factors that initially may not have any relation to the building industry. For example, the plastics industry has cornered a substantial portion of the demand for finishing materials, a development which did not originally take place because of the stated needs of the building industry but rather due to the opportunist plastics manufacturers who were driven to expand their markets.

Based on these characterizations, the building industry can be summarized as comprising of a loosely organized set of professional groups. Whenever new technologies become available and applicable to some aspects of the building industry, either one of the existing professional groups reorganizes to take charge of the new technologies or a completely new professional group emerges that previously did not exist. A consequent of any such development is that the roles of participants in the building process are reshuffled; some of whom lose control and territory, some others gain a larger foothold. Due to the gradual absorption of such re-organizational forces, the building industry has not undergone so far any sharp or cataclysmic changes like the ones suffered by the textiles industry in the recent decades.

BOTTLENECKS OF INFORMATION TECHNOLOGY APPLICATION

With the introduction of the information technology, the gradual and paced changes in the building industry organizations will be replaced by changes with a bigger scope and a higher momentum. Before we identify key information technologies and their impacts, it is necessary to reorient the traditional preoccupations found in many studies on the applications of information technologies in the building industry. We do this by arguing that the typical bottlenecks credited with impeding the introduction or effective exploitation of the information technology in the building sector will gradually disappear. Most of the problems areas can be described in terms of the following four bottlenecks: user needs and customization, incompatibility issues, resource investments, and uncertainties.

User Needs and Customization

One often cited problem is that while the currently available software do many required tasks, such software typically need to be modified to adapt to the particular needs of various organizations. Such adaptations are costly in terms of time or skills required. In our view, these problems will gradually disappear in light of the current trends in software technology. Traditionally, software packages have been developed to address a set of related tasks and have been delivered as bundled code, ready-to-run by a 'model' user. It is being recognized now that many of these integrated packages incorporate features which an 'average' user does not need, and that while many users perform similar computations on similar data, the way in which they typically view and manipulate data is far from uniform. Instead of targeting a 'model' user with bundled software, more recent developments point to new software modules that can be selected as needed, customized and run by the user with little effort. Consequently, the users will be enabled to 'build' the software according to their own needs.

Incompatibility

In the rush to address specific tasks and markets, hardware and software developers created islands of information that can be bridged, if at all, by only tortuous bridges. Perhaps for an emerging technology, this is inevitable and this problem is likely to continue. Once the critical mass of users reaches a threshold, sufficient pressure is generated in the market and the information islands become better connected by way of either more transparent compatibility solutions or a few open standards that substitute myriads of closed proprietary solutions. As a result, the typical complaints about incompatibility of hardware and software will get resolved and disappear. The current emphasis on software applications as the crucial creators of information will also diminish as the new software technology focuses on developing ways of encapsulating manipulation protocols directly with the user created data thus making it possible to use data created with one application to be used by other programs. In the long run, application software will take the path of operating systems which have become more and more invisible.

Resource Investments

The amount of time it takes to become proficient and efficiently use the computing technology for most people is still substantially large. This is decreasing with better interface design and evaluation strategies as well as by modifiable software components. Similarly, capital investment which is required to employ computing technology is also declining. Hardware costs have kept falling while the processing power has been going up. Typical secondary resources such as space and energy consumption have also undergone substantial scaling down. These trends suggest that resource investments needed for employing the information technology will not be viewed as a major impediment in the future.

Uncertainties

Due to some of the problems cited above, many organizations typically hold back from investing in the information technology. This is quite understandable since decision makers in many of these organizations have not assimilated or appreciated benefits of the new technology as part of their long-term organizational goals. This tendency becomes more acute in the building industry which is primarily project-oriented, and long-term, assured activities or markets are difficult to identify. As a result, capital investments required for employing the information technology are undertaken with extreme conservatism. To confound the matters, hardware and software manufacturers seem to sprout and disappear, making potential investors in the information technology both nervous and uncertain. These uncertainties will diminish in scale; they will not go away until the computing industry delivers products that are perceived as easily and cheaply replaceable.

The major factors described above explain why so much effort has been directed at identifying (for example, Young, 1991; Betts, 1991) and solving these problems. Some of these efforts have led to concrete results; at present, much hope is pinned on the object-oriented computing paradigm to resolve many of the problems cited above. It is also our view that the attention paid to issues like what the technology should deliver and in which formats needs to be enlarged to include other issues like what we will do with all the information that will become accessible and what kind of changes result from applications of such technologies. It is useful to keep in mind that the problems cited above do not affect the building industry only; other time-sensitive sectors of economy such as banking and manufacturing are also affected by these problems. Thus there is sufficient pressure and momentum in general to attend to these problems with regard to the information technology. Once these problems are resolved- led by the people who have the interests and needs of the building industry at heart and by the people who see economic opportunities in other sectors of economies, we believe that organizations in the building industry will face structural changes. The advances made so far in the information technologies suggest only limited impacts on the building industry. In the following are described five emerging information technologies that need better appreciation in terms of not only what they enable but also in terms of how they can influence the very environments in which they will be put to use.

KEY INFORMATION TECHNOLOGY DEVELOPMENTS

The developments in the computing technology have been often characterized in terms of generations (Gaines, 1986); each succeeding generation incorporates more capabilities and enlarges its potential sphere of influence than the preceding generation. The structural changes that we anticipate in the building industry will clearly result from the next generation of information technology; the developments so far serve as the necessary or prerequisite components that enable the realization of the next generation. Here we focus on five, selected developments that will dominate the next generation of information technology: networks, groupware, robotics, flexible manufacturing, and microprocessor embedded components. These five developments have been selected for the following reasons. First, these technologies are being actively pursued and they are not only theoretical possibilities, thus we can expect their wider diffusion in the near future. Second, these technologies are being driven by greater benefits perceived in some other primary application areas, the building industry is likely to serve as the secondary target for these advances once the primary application areas have been saturated. As a result, their applications and potential impacts will be initially obscured and consequently need to be better understood. Third, much work has been invested in developing information technology solutions that fit into the traditional organizational structures and practices in the building industry. Developments such as expert systems and integrated databases are important but not included in the following discussion since the changes we anticipate will occur despite the degree to which such 'intelligent' systems are realized. We want to focus on the stage when information about material resources and their skillful utilization is replaced by information as a resource in the building industry.

Networks

Computer networks have been often likened (Malone, 1991) to the transportation arteries that propelled the Industrial Revolution. In their most basic functionality, networks connect a number of computers and enable exchange of information among them. Much effort is directed towards increasing the capability to carry diverse information, capacity, and speed of networks. As a result, distances shrink and separately functioning components, products and individuals obtain the possibility to function in an integrated fashion. The demand for developing better networks comes from diverse sectors of economy such as banking, defense, communication and entertainment services.

Groupware

With the possibilities offered by new network technology, the information technology that was typically directed towards serving the needs of an individual or a few people in physically proximate areas, is being refocused to larger groups of people who may be located over distances. The information technology specifically targeted for such contexts is being pursued under the rubric of groupware or computer supported cooperative work. The central idea behind groupware is to enable many individuals to apply simultaneously their individual skills in solving a problem using the computing resources. This technology will change not only the quality of decisions taken by decision-makers but also the knowledge and the way it is applied by decision-makers. The sequential decision flows and hierarchical organizations that partly resulted from the fact that the skills and material resources are often separated in time and place and hence need to be centrally coordinated, are giving way to more dynamic patterns of interaction. In areas like industrial manufacturing, it has long been evident that the increased specialization of tasks has severed increasingly complex and interdependent feedback loops between design and manufacture of products. Groupware technology is one response for efficient management of the increasing volume of information and offers a productive counterpoint to the increasing specialization trends in many disciplines.

Robots

Interest in developing robots for various tasks has been sustained despite the recognized complexities in their development. Many crucial areas upon which the development of robots hinge are being pursued separately such as the programmable logic controllers, sensor technology, computer vision, physically based modeling and visualizations. Many projects describe functional robots in a variety of construction related, labor intensive and potentially dangerous tasks (Lahoud, 1991). This technology will gradually make inroads in the manufacturing of building materials and products, and in building assembly, construction and maintenance tasks. Applications of robots is to be expected for both the on-site and off-site chores, operating in networked environments.

Flexible Manufacturing

Traditional manufacturing practices have developed around mass production lines with little or no variety among the components or products being produced. This leads to efficiency as well as economies of scale, reducing the final cost of products. With the advent of programmable numerical and logic controllers, the notion of flexible manufacturing is coming of age. This technology enables not only variations within one product line but also lets the same production line to be adjusted or modified for diverse products (Kaplinsky, 1984). This technology is presently being pursued in the production of mass consumer items like automobiles but its eventual applications in the production of prefabricated and variable building components is just a matter of time. This naturally leads to an possibly wider acceptance of experimental building techniques such the following.

Microprocessor Embedded Components

More and more objects around us are embedded with electronic microprocessors. Toasters, coffee-makers, ovens, washing machines, television and radio, automobile components, and many other products that entertain, educate, take over some of our chores and fulfil some tangible and intangible needs, are equipped with microprocessors. The development of such smart products is increasing, fueled by a number of related factors. The size of electronic components is shrinking; with smaller components, signals travel faster and thus more instructions can be completed in shorter amounts of time; diverse tasks can be programmed in smaller components. The technology of manufactured components and products with embedded microprocessors has gained a toehold in the building industry. Automated control systems for lighting, heating, air-conditioning, and security are becoming more common. Driven by a confluence of factors such as the developments in electronics, competitive pressures on the building product manufacturers, and globalization of concerns about depleting resources especially such as energy (Bevington, 1990), we will see increased applications of microprocessor embedded components in the building fabric.

IMPACTS

These developments will have a number of interrelated effects on the building industry. The benefits of flexibility and cheaper production costs for even smaller production quantities obtained in flexible manufacturing techniques will lead to a renewed interest in the systems and prefabricated component based building production. These changes together with microprocessor embedded components imply new burdens or opportunities for various participants in the building industry. Designers will need to become proficient with new products to fully explore the freedoms they gain by using the new products; contractors will need the requisite skills to build using the new products and correspondingly there will be a need for new maintenance professionals. Some of these tasks in construction and maintenance will be performed by robots that are partly autonomous and partly guided by human operators working together over high speed networks. The traditional hand-off project teams, in which a design team produces specifications that are handed-off to the structural, mechanical and services engineers, who hand-off their specifications to quantity surveyors and so on, will be replaced by on-line cooperative design teams. The emerging information technologies will consequently change the materials used in the building industry; how they are manufactured, used in construction and maintained subsequently; and how the professional teams are organized to deliberate, design and execute various tasks in the building industry.

Since the developments in the information technology are taking place in parallel but seemingly unconnected areas such as groupware and robotics, or flexible manufacturing and networks, diffusion and appreciation of such technology typically occurs in an incremental way. The impact of new technologies is initially often felt in disparate patches and hence it becomes necessary to try to discern the patterns of change if we are to not only react but also to take a proactive stance with regard to how best to utilize the new intellectual and material resources that become available. A number of authors (for example, Toffler, 1970) have articulated frameworks within which contemporary technological advances are described in terms of the historical context and their future trends. In the building industry, studies that address issues at a broader level are rather sparse although few authors (Coyne, 1992) have begun to address aspects of the introduction of computing technology and its impacts in the architectural offices.

To identify impacts of these technologies on the building industry at a broader level, we first employ the framework proposed by Kaplinsky in his study on automation (Kaplinsky, 1984) who describes the modern production process in terms of three spheres: design, manufacture and information coordination. Within each of these spheres, there are numerous activities which take place. Three forms of automation are proposed: intra-activity (in which automation substitutes human labor in one activity), intra-sphere (in which automation affects many activities within one sphere) and inter-sphere (in which automation propagates to all three spheres). It is shown that each form of automation tends to accelerate the organizational changes. The kinds of information technology applications in the building industry that we have seen so far reinforce Kaplinsky's argument that we have so far witnessed intra-activity and intra-sphere automation. The last form, inter-sphere automation, is still underway and its organizational impact is not yet well understood. In view of these observations, the following are some major impacts anticipated as a result of the information technology advances.

Information Technology Professional

The building industry has typically responded to the introduction of new knowledge and skills in design, construction and maintenance by admitting a new professional group among the existing participants in the building industry. To an extent, we are likely to see emergence of a new professional who provides expertise about the information technology to other professionals involved in the building team. This change, on the surface, is similar to the previous ones when new professional teams emerged, each of whom contributes and is responsible for an interdependent but discrete expertise in the entire building process. In addition, we anticipate a deeper change since the information technology not only introduces new personnel like system managers in the building team but also changes the organizational interdependence of professionals involved. The possibilities to manipulate, share, control and manage information in electronic forms need entirely new protocols within and among organizations. These changes suggest not only a new breed of professionals who become another discrete part of the web comprising the building industry; they will affect the very web defining the building industry.

Impacts on Education

Since the professional life in future will demand dealing with long-term uncertainties that arise out of rapid technological changes as well as being proficient and equipped to exploit the new technology, the educational strategies will have to incorporate these new realities. Unlike the sequential and staged decision-making processes that characterize the professional environment to which current educational methodologies strive to respond, it will become necessary to incorporate training that encourages simultaneous and more responsive decision-making in collaborative electronic environments. The other significant impact on the educational sphere concerns the scale and nature of skills required of the professionals in the building industry. With the diffusion of information technology in many industries, there occurs a lowering of the required skills threshold for a large number of people, a trend complemented with a significantly higher threshold of required skills for a smaller number of people (Kaplinsky, 1984). These trends will unfold also in the building industry; the professional, educational and national planning bodies need to find appropriate responses to these trends.

Professional Expertise and Teams

In the professional sphere, the new technologies will bring forth changes in not only how the professionals interact but also in what they contribute to the building projects. With the simultaneous on-line availability of expertise in any area, the expertise can become more transparent or opaque. Expertise can become transparent since it becomes easier to tap into geographically separated expertise via networks. Expertise can become opaque since computer programs often only produce and offer information as end-results of manipulations but not as visible manipulations that can be challenged or explained. The need to challenge, debate and defend in any kind of decision-making in the future becomes even more crucial when the legal and ethical aspects are considered in the light of electronic media.

The New Clients

The client who typically acts only as the source of capital for building projects will become more involved in the decision-making than has been the case in the past. This may happen since clients are getting just as technology-aware as the professionals who serve the clients. A secondary way in which clients will influence the building projects is by the generally increasing awareness and changing attitudes about the globally shrinking resources. This has already led to development of more performance-oriented products that are measured not only in terms of their immediate but also long term costs. Although it is acknowledged that undue attention is paid to the initial costs of the building projects, the attitude shifts that are generally visible now in the society will definitely spill over in the building industry.

Organizational Tendencies

The growth of knowledge and diffusion of technologies generally tend to encourage more mobile labor. For example, when the design tasks became separated from the manufacture tasks, the design teams could locate in places other than the actual project sites and thus extend their market boundaries. With the new technologies, the construction and maintenance teams in the building industry have the possibility to reorganize and take advantage of mobile labor and thereby increase their market reach. A related aspect of this development is that with the increasingly mobile labor and flexible markets, the need for coordination within organizations also increases. This will result in two opposing tendencies that will need to be balanced within organizations. On the one hand, there will a tendency to centralize since the organizations need to exercise more control as they become more diffuse. On the other hand, organizations will need to decentralize some tasks that were previously centralized since the people who can better control and carry out tasks may themselves be distributed throughout organizations.

SUMMARY

The changes in the building industry will occur at varying speeds in different countries. The professional organizations and the national planning agencies that can anticipate and plan for changes arising as a result of the applications of information technology will clearly benefit from these developments. The information technology keystones responsible for bringing about structural changes in the building industry are already in place. They are presently being pursued outside the immediate concerns of the building industry and it is well advised to look to those developments for preparing the building industry for their impacts.

References

Betts, M, Mathur, K, Ofori, G, and Lim, C (1991), The strategic use of information in the construction sector. In *Applications of information technology in construction* (ed JWS Maxwell). Thomas Telford Ltd, pp 25-38.

Bevington, R, and Rosenfeld, AH (1990), Energy for Buildings and Homes. *Scientific American*, September, pp 39-45.

Coyne, R (1992), The Impact of Computer Use on Design Practice. In *CAAD futures '91* (ed GN Schmitt). Vieweg, pp 413-424.

Gaines, BR, and Shaw, MLG (1986), The changing technologies underlying computer-aided design. *Environment and Planning B: Planning and Design*, Vol 13, August, pp 377-384.

Kaplinsky, R (1984), *AUTOMATION the technology and society*. Longman.

Lahoud, M, and Sarantopoulos, S (1991), Advanced robots in the building industry: the present and the future. In *Applications of information technology in construction* (ed JWS Maxwell). Thomas Telford Ltd, pp 281-293.

Malone, TW, and Rockart, JF (1991), Computers, Networks and the Corporation. *Scientific American*, September, pp 92-99.

Miles, D, and Neale, R (1991), *Building for tomorrow: international experience in construction industry development*. International Labour Organization.

Monk, P (1989), *Technological Change in the Information Economy*. Pinter.

Stone, PA (1983), *BUILDING ECONOMY Design, Production and Organization- A Synoptic View*. Pergamon Press.

Toffler, A (1970), *Future Shock*. Random House.

Young, B (1991), Application of information technology and its impact on the education and training needs for professionals in construction. In *Applications of information technology in construction* (ed JWS Maxwell). Thomas Telford Ltd, pp 119-130.