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APPLICATIONS AND EFFECTS OF EMERGING AUTOMATED AND INFORMATION TECHNOLOGY IN CONSTRUCTION

Amaury A. Caballero
Department of Construction Management, Florida International University, Miami, Florida

ABSTRACT

The wide implementation of information technology in construction has proved to be a difficult task due to the characteristics of the construction industry. Field-oriented industries like construction, with frequently reconfigured operations and often-severe environmental conditions, have been slower to adopt new information and automation technology. The principal causes that promote this situation may be summarized to be, among other the complexity of building process, distinctive nature of projects, dispersion of construction activities, divided authority, work environment, and long service life. In spite of these conditions, the introduction of the new techniques is inevitable because of three characteristics that are also present in the construction work: dirty environment, hard working conditions, and dangerous working places. The paper condenses the results from a study developed for the State of Florida Department of Education, in which the use of these new technologies is analyzed.

KEYWORDS

Information Technology, Construction, Computers, Robotics

1. INTRODUCTION

The construction industry is faced with a monumental challenge. While the rest of the manufacturing world has made steady progress in the fields of automation and robotics, construction has lagged behind. Among the reasons for this lag, it is important to highlight that while the manufacturing industry is generally a stable, repetitive act that can be placed in controlled environments, construction mostly exist in an ever changing, challenging environment.

The objective of the paper is to present the obtained results during a research realized in the Department of Construction Management at Florida International University under the auspices of the Building Construction Industry Advisory Committee (BCIAC) and funded by a grant from the State of Florida Department of Education (John, 1990). The main goal of the study was to analyze the existing and emerging technologies and the new relationships between the involved parties as a consequence of their introduction. The following questions were addressed:

- The concepts of Automation and Information Technologies in construction.
- The building construction process integration.
- The new computer-based relations in the construction industry.
- The characteristics of robotics applications in construction.

The study was developed using the available published material related to the introduction of new technology in the construction industry, including case studies. The results presented at the end of the paper were fully extracted from the conclusions obtained in the cited study. The main body of the study contains all the employed references, which are not necessarily included in this paper.

2. FLOW OF INFORMATION ON A CONSTRUCTION PROJECT

In a very simplified way, the flow of information on the construction site may be represented as shown on Figure 1 (Leslie and Mckay, 1993):

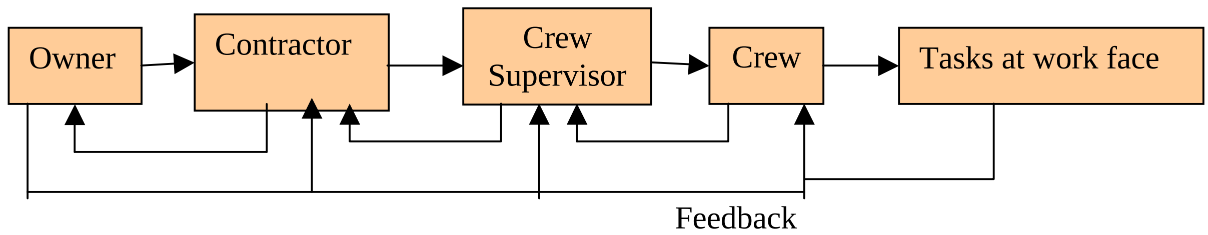

Figure 1: Flow of information on the Construction site

Communication of any kind involves a complex process strongly influenced by those who generate and transmit it. In addition, the informal communication, which usually occurs, may have a marked effect on productivity. If the construction process is analyzed from the beginning, the problem becomes more complicated. Traditionally, the building delivery process has been managed as a series of discrete activities that are supposed to be controlled from the project team. This situation is represented on figure 2 (Leslie and Mckay, 1993):

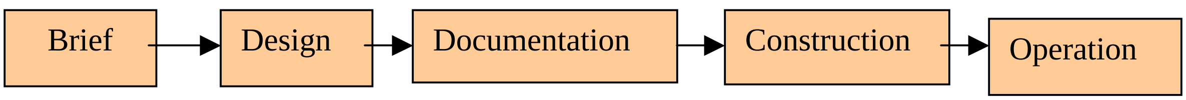

Figure 2: Traditional Fragmented Project Description

The information produced by each stage is described by the following:

- Design information: drawings, material schedules, specifications, simulations and calculations.
- Execution information: contracts and change orders, government codes and regulations.
- Business information: cost, schedule, resource and quality models.
- Construction information: resource and work method plans.
- Operating information: operating manuals and as-built drawings.

In traditional construction, this information is usually not integrated. The applied terms and standards are different and are frequently developed and owned by different organizations. In order to overcome the difficulties presented by the poor organization of information in construction projects, it is necessary to move to what is called the Computer Integrated Construction (CIC). This involves the "application of computers to better manage information and knowledge in their various forms with the goal of totally integrating the managing, planning, design, construction and operation of facilities." (Leslie, 1993). The CIC is part of a more general branch called Information Technology (IT).

In order to effectively use the IT the users need the following:

- A clear definition and architecture to organize, classify, and manage the required information.
- Tools for modeling the processes associated with the construction.

3. INFORMATION TECHNOLOGY (IT) APPLICATION

With the purpose of successfully applying the information technology to any system, including construction projects, it is necessary to focus the attention on five perspectives (Steven, 1999): architecture; performance; infrastructure; context; and risks.

The major driving forces for information and automated systems applications in construction are as follows:

- Extensive lack of skilled workers and a growing average age of the staff.
- Demands for effective humanization of nearly all construction works.
- Increased requirements on the quality of the work execution.
- A need for works in dangerous and inaccessible areas of operation.
- An increase in performance and reduction of costs for improvement in economy.
- The competition on international markets of construction machinery.

Among the major barriers may be encountered:

- Difficulties in standards introduction due to the interaction between large numbers of bodies.
- The benefits of installing the new technology may be relatively low unless every participant in the grouping has it and uses it.
- The degree of support exhibited by top management.
- Problems related to the technology installation on-site.
- The different educational and cultural backgrounds of the people involved in the construction.

4. THE CREATION OF A MODEL OR COMPUTER-BASED DESCRIPTION OF CONSTRUCTION PROJECTS

The success of Computer Integrated Manufacturing (CIM) is springboard in considering the possibility of a wider application of communication, computers and automated machines in construction. Field oriented industries, like construction, have been slower to adopt these technologies. In the previous paragraphs, some of the more important barriers for this application were enumerated. All of this could be summarized in one general conclusion: *The lack of coherent strategy for the integration of these technologies within a company is the basic constraint of their effective use within the organization*.

A main task of automation in the construction industry should be to increase the possibilities of information interchange, not only between locations or companies, but also between computer-applications in one system.

Figure 3 shows the traditional relationships between owner-designer-contractor. This model could be viewed somewhat like representing adversarial positions, with the project construction people on one side and the design people on the other, with the owner in the middle like a referee. In a modern approach, with concepts as partnering and construction management risk, the building process becomes much more collaborative. Among the changes that IT has introduced in the traditional relationships between designers and constructors is the possibility of working like a team, which has the ability to communicate faster, so decisions can be made quickly. It is difficult to estimate what it will represent to a contractor to have a piece of information today versus tomorrow.

The basic change with the new technology is that the process can be changed interactively and accordingly to the needs. In other words, the feedback is made more efficient. It is very important for the different parties to sit down at the early stages of the project and work trough all the issues, like setting which office standards will apply to the project documents.

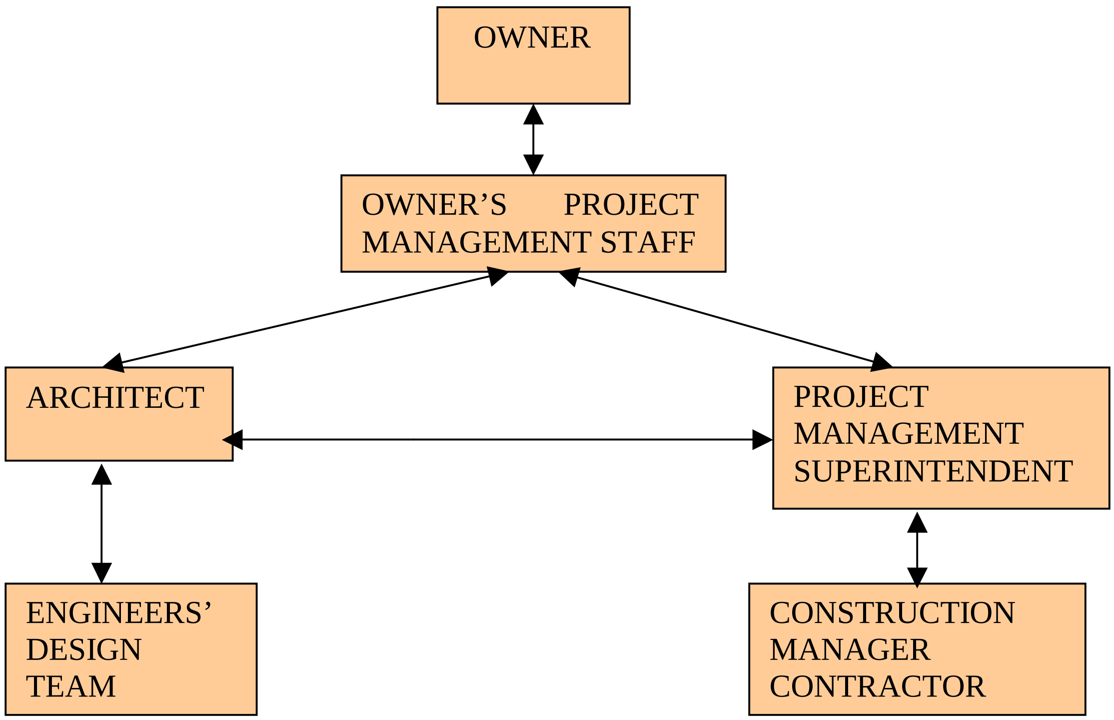

Figure 3: Classical Owner-Designer-Contractor Relationships Representation

A more actualized model shall comply at least with three conditions:

- All the parties will work on the product from the early stages up to the production stage like a team. The previously separated design information and construction process planning stages have to be combined and integrated as a big construction system.

- The process will be changed interactively and accordingly to the needs.

- It is necessary to have standards accepted by the whole industry.

The model for the interchange of information among the different parties participating in the construction process can be graphically represented as shown on Figure 4. The data model has to exhaustively define the building through its entire life cycle. The data will include graphic representation in four dimensions, technical and cost calculations, scheduling, etc. The goal is to form a software bridge between mathematical coding - the language that computers read - and the characters and pictures that human can see and understand.

5. RESULTS OF THE STUDY

The wide implementation of Information Technology in construction has proved to be a difficult task due to the inherent characteristics of the construction industry. In spite of these conditions, the introduction of the new techniques is inevitable because of three traits that also are present in the consdruction work:

- Dirty environment
- Difficult working conditions
- Dangerous work sites

Nowadays most participants in a building project perform their activities aided by computers. In contrast, the communication between participants is carried out in the majority of the projects with conventional media (for example through drawings, specifications, etc.). Human beings carry out the process of interpreting and understanding the exchanged information. In order to improve this situation, it becomes mandatory to support this exchange of information-by-information systems. This implies the use of models for representing the different participants in the construction process and standards to exchange the model's data.

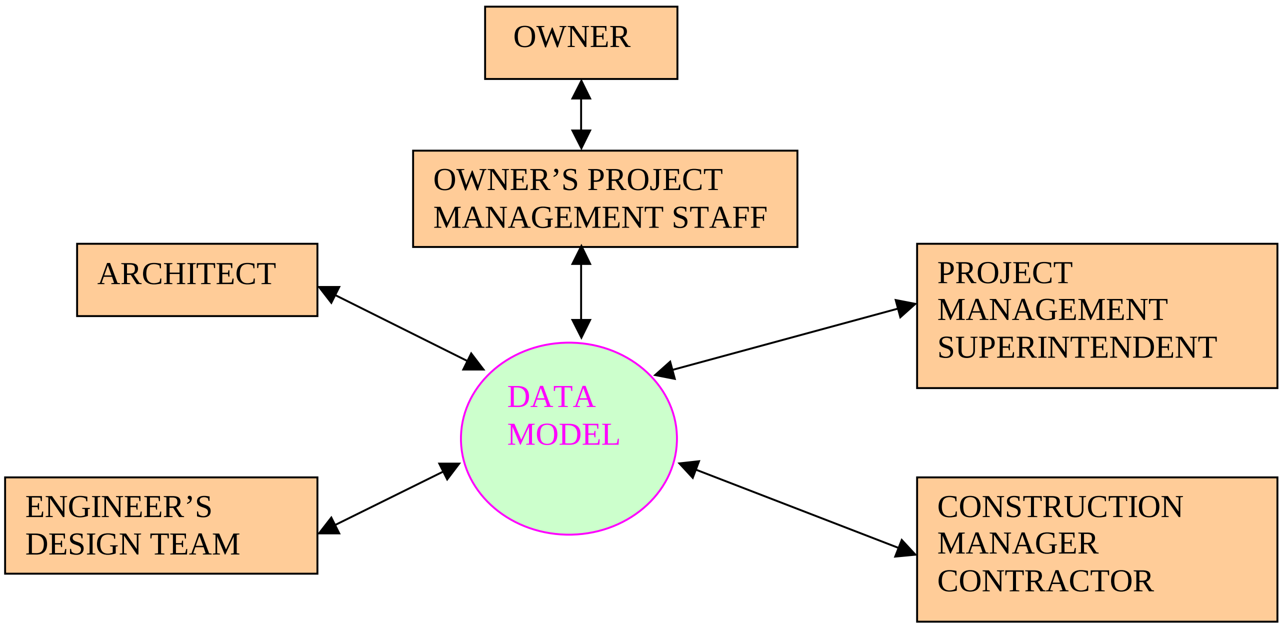

Figure 4: Possible Owner-Designer-Contractor Flow of Information Representation

As was stated by several authors, the central problem of coordination during the construction process arises from the fact that the basic relationship between the parties to a construction project has the character of an <u>interdependent autonomy</u>. *There is a lack of match between the technical interdependence of the work and the organizational independence of those who control the work.* The main barrier for the complete introduction of the technologies of information and computers in the construction industry is the lack of coherent strategy for the integration of these technologies within a company or a project.

There exists a high number of coordination of activities, which construction project managers not always can identify. These activities are numerous and miscellaneous in nature. They neither could identify specific customdrs nor specific inputs/outputs of their processes and claimed that the customers of a construction project manager are so numerous because he (she) has to work with every participant of the project and every outsider connected with the project, each having unique needs. It may be that the informal character and intangibility of construction coordination have made it very difficult for the practitioners to establish a model of the process itself.

The general means used for solving tasks in the construction industry are not suitable for open-systems communications and it is necessary to introduce software permitting this high-level computer communication. This will be possible when the reasoning behind the design and construction choices is made explicit in communication. To realize this, application needs information with more explicitly defined meaning, which is related with information at a higher semantic level.

A way of solving the differences between designers and pre-casters is the creation of open systems of interchangeable elements, which could be supplied by different producers and could be used in any type of design conforming to the basic rules.

There exist two tendencies in the product modeling in the construction industry. One is the creation of standards like ISO 10303 STEP, and the other is to use companies that act as application service providers or management service providers.

In recent years, Artificial Intelligence (AI) and Expert Systems have received enormous exposure. At the present time, AI is a practical technique that presents a wide range of applications in construction.

The previous separated design information and construction process planning are combined and integrated as a big construction system. That conceptual progress is considered as the trigger of construction automation.

To achieve the consolidation period in the construction automation, it is necessary to focus the efforts in four main directions: *Integration, Pre-fabrication, Robots and Automated Machines, ,and More Investment.*

From the analysis of different case studies, it becomes clear that there exists a wide tendency towards the integration of diverse managerial functions: engineering, contract administration, quality control, accounting, commercial transactions, and reporting. Unfortunately, no satisfactory general solution has emerged so far due to the complexity of the interactions and the differences in the methods used by diverse groups on different projects. At this moment, one of the effects of IT has been to fragment the construction industry, because different organizations are at different stage of IT implementation and simply cannot “talk” to each other. The reason is that the software architecture has thus far been designed in an ad hoc fashion primarily to perform individual business functions, such as scheduling, cost estimation, purchasing, inventory management, or financial accounting. In many construction companies such function-oriented applications gave rise to an unmanageable maze of system components, and data could not be easily transmitted to other partners. For solving this situation, interfaces have to be developed to link the various applications. This problem becomes more complicated by the fact that, once instituted, function-oriented structures could not be transformed into process-oriented structures; as a result, companies sacrificed flexibility and th% ability to introduce changes. This phenomenon, which is characterized by a high degree of internal integration with very loose or non-existent connections, has been called by Hannus “islands of automation”.

Currently, the construction industry has found more application off-site than on-site. The off-site automation is basically directed towards the creation and use of intelligent databases and data mining techniques, INTERNET-based project management, 4-D CAD technology and electronic commerce in construction. Among the changes that IT has introduced in the traditional relationships between designers and constructors is the possibility of working like a team, which has the ability to communicate faster, so decisions can be made quickly. Now that most construction firms are relying on computers and communication technology to perform office functions and project work, these systems are influencing how the different parties in the construction process work together. The connectivity afforded by digital tools makes possible new levels of coordination and management control in single-project associations, more formal joint ventures, and permanent partnership created by mergers or acquisitions.

The basic change with the new technology is that the process can be changed interactively and accordingly to the needs. In other words, the feedback is made more efficient. It is very important for the different parties to sit down at the early stages of the project and work trough all the issues, like setting which office standards will apply to the project documents.

In the process of automating the information in the construction process, it becomes very important that all participants match the same tools: Microsoft Office, AutoCAD, 3-d studio, Internet compatible E-mail, and file transfer protocol (FTP). The entire team needs to have comprehensive, universal standards that are flexible enough for all team members to participate. Another significant coordination issue is keeping the team’s software in synch throughout a multiyear project development cycle.

In the near future it is expected that rather than cutting procurement costs by putting pressure on their suppliers, construction companies’ IT departments must devote resources to integrate CAD, enterprise resource planning, project scheduling, and other systems to reduce job-cycle.

The following conclusions can be drawn with respect to robotization of building construction activities:

1. The number of elements to be positioned should be minimized. This can be achieved by using large pre-fabricated comprehensive assemblies. Small elements - planks, boards, tiles, and bricks - should not be used in

robotized activities, except when pre-assembled in the factory into the largest possible (within the constraints of weight, size, and maneuverability) components.

2. The components should be designed in such a way that their configuration will eliminate the need for temporary support and bracing during the erection.

3. Special fixtures should be built into the components and the receiving structure, which will facilitate their grasping, orientation, positioning and connecting.

4. Connections between components should be made as simple as possible.

5. Finishes should be selected, whenever possible, from the group most amiable to robotics, namely the group which involves finishing of continuous surfaces.

6. Finishes should be made as homogeneous as possible, i.e.. of such technological content that no task will require multiple robot activities for its execution. If a task requires two activities (e.g. spreading and smoothing), they should be technologically designed in such a way that a robot will be able to execute them in immediate succession (or at least from the same station) with two effectors mounted on the same arm.

7. There should be an easy access for robot manipulators to all work locations.

The automation of Construction works will require some changes in the composition of the labor force involved in them. Workers in charge of robotized construction tasks must be able to teach the robots, start them, monitor their work, and cope with various malfunctions of robots and its materials feeding system. Such workers, or technicians, will need an entirely different educational background and training than workers employed in those tasks in a traditional way. An appropriate training program for the management and the technical personnel will therefore have to be designed and carried out before the actual implementation.

The robotic application has a very meager success in the construction industry. This can be explained by the following main reasons:

- Insufficient development of construction robot prototypes.
- Insufficient attention in building design to the constraints of robotized construction.
- Insufficient economic justification for robotics in building.
- Difficult managerial environment.

From a general point of view, a success in robotic application in construction will be possible if the following conditions are met:

1. The robot has to be construction friendly. All features of operation, movement, material feeding and transfer and their adaptation to the particular conditions of a construction site, must be taken into account in the development.

2. The building design should be "robot friendly". Attention must be paid to the selection of an appropriate building technology to simplify ill-structured (for the robot) building tasks.

3. Better results in robots applications will be obtained in high-precision tasks such as coating build surfaces: painting, fireproofing, and plastering. Also in sophisticated tasks involved in the intelligent application of sensors, and interpretation of the results, such as, non-destructive quality control tasks or particularly hazardous or dirty work.

The managerial involvement is essential in:

- The choice of projects appropriate for robot application.
- Long range planning of the site for robotized construction in terms of material supply of economically feasible building sites.

- Careful planning of the site for robotized construction in terms of material supply, unobstructed robot movements and robot’s transfers.
- Enforcement of procedures suitable for robot operation and maintenance.

When all these features are addressed, robots will have available a promising future in construction.

6. CONCLUSIONS

The study presents the major problems encountered for the total construction process integration. The major driving forces and barriers for the ITC systems application in construction have been analyzed. The analysis has taken place after an intense literature review. When possible, application examples have been presented for sustaining the results of the study. Also new trends for development have been presented.

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