Automation and Robotics in Construction XI
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Information Technology in Support of Construction Site Automation and Robotics

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Abstract
Information technology and information management structures are now well established at all levels within manufacturing industry and supports the use of automated and robotic tools within the manufacturing process. Though the construction industry has adopted elements of IT there remains little penetration at the site level. This paper therefore considers some of the problems associated with the introduction and use of IT on site with particular reference to the impact on site automation and robotics.

1. INTRODUCTION

Though the construction industry was quick to take advantage of developments in information technology as applied to design, analysis, office automation and associated management functions, it has not to date given any real indication that it is able to assimilate information technology into the construction site environment. As a result it has failed to reflect the development of the 'shop floor' information systems now found in many areas of manufacturing industry.

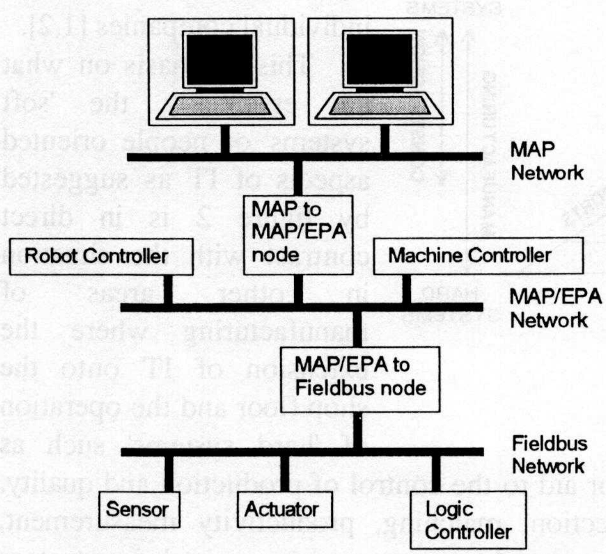

Figure 1. A communications hierarchy in manufacturing

In any manufacturing process; the flow, availability of, and access to information has a significant bearing on the way in which that process operates. Indeed, in conventional, factory based manufacturing environments the information structure adopted has tended to dictate the pattern of automation that has been adopted and has led to the development of a range of communication systems, as suggested by figure 1, operating at various levels throughout the manufacturing process to handle the associated data flows. Unlike the deterministic environment found in a factory, the generally non-deterministic environment of a construction site poses particular and special problems for the collection and distribution of process information and precludes the direct transfer of technologies developed in manufacturing industry. Indeed, a construction site may well be considered as unique among industries in that only that structure is imposed upon the 'production site' which is necessary to accommodate the work in progress.

The problems of introducing an appropriate information infrastructure for the collection, transmission and interpretation of process data onto a construction site are therefore associated with the nature of the site processes themselves. While IT applications in manufacturing are by their nature task and function specific, there is in general sufficient similarity between individual manufacturing environments to have supported the evolution and wide scale application across a range of industries of a variety of essentially common IT techniques and methodologies such as flow-lines, flexible manufacturing, computer integrated manufacturing and shop floor data collection. In particular, the continually changing task structure of a construction site presents particular problems to the definition of the communication network and the device gateways to accommodate a range of plant.

As was the case with the introduction of shop floor robots in manufacturing, the absence of an appropriate information infrastructure is a major obstacle to the large scale introduction of automated and robotic technologies into construction. This in-turn limits the effectiveness of many of the systems currently under investigation and development to a relatively few environments which can be structured to meet the needs of automated and robotic technologies.

2. IT IN CONSTRUCTION AND MANUFACTURING

As a result of its labour intensive nature relying on a transient and contract labour force the construction industry was one of the first major industries to use computers on a large scale in areas such as payroll and accounting and then into planning and management control. Despite the increasing use of computers for design and analysis, these areas still remain the major area of application for IT within the construction industry as a whole though there are wide variations between individual companies [1,2].

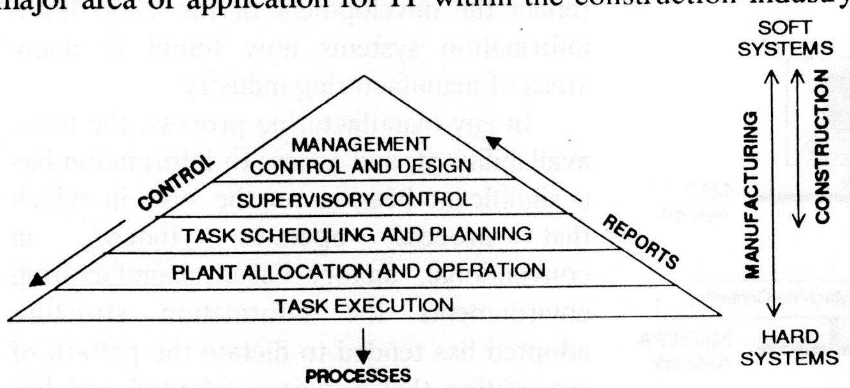

Figure 2: An information and systems hierarchy

This emphasis on what are essentially the 'soft systems' or people oriented aspects of IT as suggested by figure 2 is in direct contrast with the situation in other areas of manufacturing where the extension of IT onto the shop floor and the operation of 'hard systems' such as robots and CNC machine tools is seen as a major aid to the control of production and quality. The presence of systems for automatic inspection, matching, productivity measurement, despatch and delivery control, fault monitoring, materials usage, monitoring work in progress and energy consumption have all facilitated the introduction of automated and robotic technologies and the development of the concepts of flexible manufacturing [3,4].

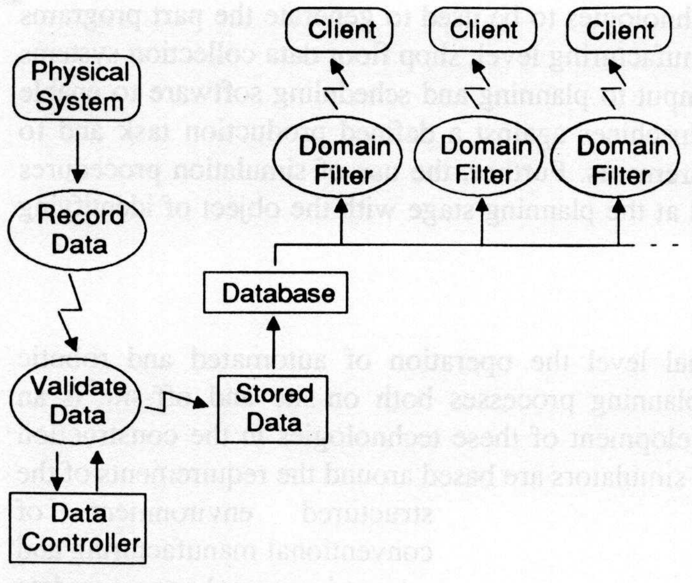

Figure 3. Site information structures

2.1. The Construction Industry

As has already been noted, the similarities between the construction industry and conventional manufacturing industry cease at the production level. While IT developments are inevitably task specific at this level, there is enough similarity between the requirements of the industries to support the evolution within the construction industry of computer based practices, procedures and methodologies based on those already in existence in manufacturing. In each case the form of implementation will be dictated by the nature of the processes involved and may well require the introduction of novel forms of communication link onto the construction site. These may serve to provide functions similar to those carried out by local area networks in a manufacturing environment but may well also require the incorporation of additional features such as the ability to carry speech or even vision.

The nature of the information process must also be considered specifically in relation to the operation of a construction site and the existence of a number of 'clients' such as automated plant, site robots, engineers, quantity surveyors and sub-contractors each requiring access to essentially the same data but at different levels and in different contexts. Figure 3 suggests a structure for one such system in which validated data is presented to the associated clients via a database and a series of 'domain filters' which isolate the required data elements for an individual client. These domain filters are established by the client and tailored to their needs and may well contain an element of data analysis and interpretation.

3. THE IT REQUIREMENTS OF AUTOMATED AND ROBOTIC SYSTEMS IN CONSTRUCTION

Figure 4 suggests one possible structure for an overall IT strategy for the construction industry based on the use of a shared data base. A number of the elements of this structure, represented by the shaded elements and the thick lines in the figure, are already in place but are not generally fully interconnected. Indeed, in some instances information is being entered onto systems on site while the same data is also being entered independently onto off-site systems as no form of communications link has been established.

Thus though computer based systems have had a significant impact on many areas of the construction industry, their use and integration, particularly at the site level, are not as yet at the point where they provide an effective support for the introduction of automated and robotic systems on site. This situation may be contrasted with that for conventional manufacturing where developments in computer integrated manufacturing (CIM) are linking the design process to the manufacturing technologies to be used to generate the part programs for the machine tools to be used. At the manufacturing level, shop floor data collection systems monitor work in progress and provide an input to planning and scheduling software to enable the efficient integration and utilisation of machines against a defined production task and to provide a tighter control of materials requirements. Further, the use of simulation procedures enables the operation to be studied in detail at the planning stage with the object of identifying possible areas of difficulty.

3.1. Simulation

The ability to simulate at a functional level the operation of automated and robotic processes in support of the design and planning processes both on-site and off-site is an essential requirement to the long term development of these technologies in the construction industry. Unfortunately, currently available simulators are based around the requirements of the structured environment of conventional manufacturing and cannot in general accommodate the specific needs of the construction industry in areas such as sensor modelling and the static and dynamic structural behaviour of the robots.

At the site level there is a need for a task and operational level simulation in support of the day to day planning function in order to enable the proper scheduling of plant. A particular problem in this respect is that of safety where there is a need to model not only the operation of the robot in relation to a defined task but also its interaction with the environment. This interaction must of necessity include the operation of any sensor framework used to define a safe operating zone for the robot and must include the ability to model not only the sensors themselves but also the related signal processing requirements [5].

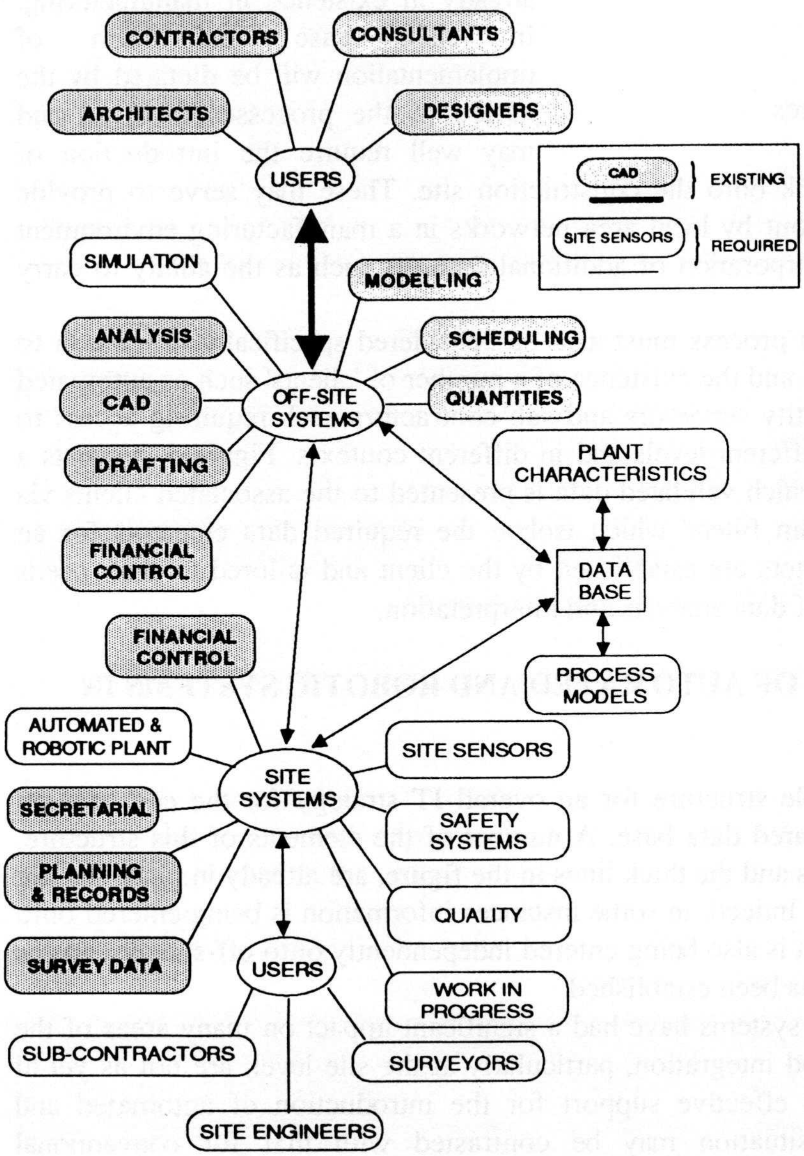

Figure 4. IT structures and organisation in construction

3.2. Modelling

Figure 4 associates both plant characteristics and process models with the central database where the information contained is accessible to both off-site and on-site users. The association of the functional characteristics of individual items of automated and robotic plant and equipment with models of individual processes such as the placement of reinforcement or the pouring of concrete would then facilitate planning at all levels.

3.3. Work in progress

The ability to monitor work in progress is a key feature of many automated manufacturing processes. Typical systems rely on the use of automated data entry by operators using techniques such as bar codes. With the exception of the United States where the 'LOGMARS' standard has been introduced by the Department of Defense [6], relatively little use has been made to date of such techniques for the recording of work in progress by the construction industry.

3.4. Quality

One of the problems in considering the quality aspects of automation and robotics in the construction industry is that of obtaining a suitable definition in an environment which in general involves a number of different collaborators each with different objectives and interests. As a result, quality as defined by one collaborator may be significantly different from and even in conflict with others in the group. For instance, using a value-based definition of quality [7] a contractor has no incentive to do other than that which is absolutely necessary to conform with the specification given by the designer and it is not generally in the contractor's interests to draw attention to errors in the specification.

In many instances, the financial benefits to a contractor of offering an improved quality of service are difficult to calculate and may even be negative. Improvements in quality are, by themselves, unlikely to be a sufficient reason for a contractor to invest time and money on equipment and training in this area. Since IT, and by implication automation and robotics technologies, represent such an investment, applications must be sought where there is an obvious financial incentive to be gained from deploying the technology.

3.5. Information flows and data integrity

One of the problems in designing any information system is that of ensuring the integrity of the available data. In particular, operation will be influenced by a number of possible problems associated with the flow of data on site including:

- Absence of appropriate data
- Incorrect or incomplete data
- Late arrival of data
- Too much data

In addition, the available data may be characterised in terms of a number of attributes each of which influences the way in which the data may be used. These attributes include:

Criticality	How important is the data to the operation?
Integrity	How reliable and trustworthy is the data?

Timing	**When must it be made available to the user or client?**
Relevance	**Who are the users or clients for the data?**

4. CONCLUSIONS

Consideration of conventional manufacturing industry has shown that for automated and robotic technologies to be successful they need to be supported by a structural and organisational hierarchy involving all levels of the organisation which enables the effective flow of information throughout the organisation. Based on the extensive use of the techniques of information technology such structures allow for the passing of information from the designer to production in a unified and coherent form and supports the use of computer numerically controlled machine tools and robots. Meanwhile, shop floor data collection systems provide a picture of the work in progress to support more efficient scheduling and use of resources. Already extensive in some industries, the scope of IT will further increase with the adoption of the techniques of concurrent engineering and computer support for collaborative working, increasing the flexibility of the design process. In areas such as quality, the adoption of information based systems for the control of machine tools including condition monitoring and in-process gauging together with the uniformity and consistency inherent to the operation of a machine tool have also had a significant impact.

Examination of the construction industry shows that to date the adoption of the techniques of IT is varied in the extreme with, in some cases, quite extensive use being made of certain functions off-site but with relatively little impact at site level. If automated and robotic technologies are to have any immediate future in support of the construction industry then it is necessary to critically examine the use of IT at the site level and, in particular, the necessary information structures to support the introduction of these technologies.

In doing so, the differences between the manufacturing and construction industries will need to be taken into account, not only in relation to their respective physical environments but also with regard to the different nature of the information structures required by virtue of the nature of the processes involved. In manufacturing, these processes can, in most instances, be considered as part of the product in that raw materials arrive, are operated on and leave the factory in a finished form. Although different processes may be applied at different stages, the manufacture of the finished product does not, in general, affect the processes in real time. In construction, as a structure 'grows' it places constraints on the construction methods and techniques that can be deployed. This additional complexity imposed by the nature of the construction process makes planning, analysis and scheduling more difficult and means that unexpected events can have far reaching consequences on the construction process.

REFERENCES

1. Construction Industry Computing Association, (1991), **Building on IT for Quality: A Survey of Information Technology, Trends and Needs in the Construction Industry**
2. N. Fisher & S. Yin, (1992), **Information Management in a Contractor**, Thomas Telford
3. J. Bessant, (1983), **Management and Manufacturing Innovation: the Case for Information Technology,** Information Technology in Manufacturing Processes: Case Studies in Technological Change, Rossendale, pp 14 - 30

4. J. Fleck, (1983), **Robotics in Manufacturing Organisations**, Information Technology in Manufacturing Processes: Case Studies in Technological Change, Rossendale, pp 44 - 56
5. LiLi Zhang, D.A. Bradley & D.W. Seward, (1993), **Safety Critical Systems for Robot Excavation**, 10th International Symposium on Automation and Robotics in Construction, Houston, pp 109 - 116
6. G. Stukhart & E.L. Cook, (1990), **Bar-Code Standardization in Industrial Construction**, Journal of Construction Engineering and Management, Vol 116, No 1, March, pp 417 - 431
7. D.A. Garvin, (1988), **Managing Quality**, The Free Press