Automation of the U.K. Construction Industry -
Current Status and Key Issues

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ABSTRACT

The current state of automation is revised with a view of establishing what developments need to take place to improve the competitiveness of the U.K. construction industry. In addressing automation, consideration is given to the whole subject of "Computer Integrated Construction".

1. INTRODUCTION

The construction industry represents a major part of the U.K. gross domestic product and improvements in its efficiency benefit all sectors of the U.K. economy. The U.K. construction industry has to compete in a world market which is highly competitive. To counteract the threat from the world wide competition the industry has to raise its productivity and quality of its products.

Traditionally, construction has been a craft industry. Today the construction-related industries are much closer to manufacturing industries, with considerable mechanisation and increasing automation being introduced. This has been paralleled by changes in the structure of these industries, and the management techniques employed. During recent decades these changes have been supported by the introduction of computers. The challenge now is for these industries to make the transformation and become information-centred, thus enabling further substantial gains in competitiveness to be realised.

Recognition of the fragmented nature of these industries resulted in early identification of the need for computer integration of the total "facility procurement" process. Since the late 1980's, the goal has been pursued by a number of major initiatives at National and European level with a major involvement from the U.K. Involvement from U.K. construction organisations has been significant in a number of European projects including ATLAS (Esprit), BRICC (Race), CIMsteel (Eureka), COMBI (Esprit), COMBINE (Joule), and Process Base (Esprit). A common thread to these projects has been the integration of the design and construction process through the use of Product Data Technology. Collectively, these initiatives are highly significant. When fully exploited, these results should enable construction to cross the boundaries to information-centred working.

As part of the U.K. Innovative Manufacturing Initiative (IMI)[1], launched in 1994, a number of research projects has been supported to address the design and construction processes with emphasis on business requirements. The aim is to enable the U.K. Construction industry to develop world class processes to deliver products and services to its clients which satisfy their complete business requirements. This programme of research targets "construction as a Manufacturing Process".

In recent years[2] progress has also been made in developing automated tools and systems in many applications and in some areas the technology has reached a mature stage for practical applications.

This paper explores how outputs from some of the recent R & D initiatives will impact on the competitiveness of the U.K. construction sector and in particular in the Large Scale Engineering Industries.

2. THE LARGE SCALE ENGINEERING INDUSTRIES

The term Large Scale Engineering (LSE) [3] is used to refer to that group of industries which form the wider construction industry. This includes Building, Civil Engineering, Process Plant, Offshore Oil and Gas, Power Plant and Supply, and Transport Infrastructure.

Considerable variation exists both within and between the identified industries. This variation is most strongly expressed in the degree of automation, and the organisational and contractual framework that is employed, but is also seen in the degree to which Information Technology is currently employed.

What is common to these industries is that their client (or customer) is the procurer of a major facility, and that facility is typically a one-off design. The overall procurement process can be characterised by a number of key stages including feasibility, overall design, detailed design, manufacture and construction, commissioning/handover and operation.

The subsequent maintenance, modification and eventual decommissioning of the facility are increasingly being seen as critical aspects of the extended procurement process (which thus addresses the full life-cycle of the facility). Many contractual frameworks are used for procurement including design-and-build and consultant-design-and-tender.

The business relationship between the client and the main contractor, and between the main contractor and his primary sub-contractors, may be one-off or ongoing. However all LSE projects are characterised by the large number of companies involved, multiple disciplines and skills, fragmentation of workforce by location and company, many project stages and concurrent activities and problems of co-ordination and clashes.

The measures of competitiveness are also universal - price, time, quality plus the economic and appropriate use of resources. The shared challenges that the U.K. LSE industries face are to reduce costs and increase productivity, shorten project timescales, satisfy the full life-cycle performance needs of the client, provide value for money for clients, improve the culture of the industry and the skill of the workforce, and to unlock the potential for growth in world markets.

A goal has been set for a 30% improvement in the real cost reduction of construction by the year 2000 [4]. If this target is to be achieved, the U.K. LSE industries need to develop, and to successfully apply, two complementary strategies: Firstly, to change the culture of the industry (away from conflict) to partnership and teamwork, with the client at heart. Secondly to centre operations on open digital information standards, allowing the realisation of computer integrated procurement.

The research projects referred to in the introduction have helped underline the requirement for the first strategy and have research the establishment of the second strategy. These strategies parallel changes in the manufacturing industries. The U.K. LSE industries need to adopt improved operational and integration methodologies drawn from research and from manufacturing sectors. Indeed, LSE as-a-whole needs to become more of a manufacturing process, and to give greater consideration to the full life-cycle of the facility.

3. THE ROLE OF PRODUCT DATA TECHNOLOGY IN PROCESS INTEGRATION

In their analyses of LSE industries[5], the research projects referred to in the introduction have identified similar informatics barriers to computer integration: varying levels of computerisation, applications software that do not meet the particular needs of the industry, inadequate staff training, and contractual/legal barriers to the exchange and sharing of information. Despite these barriers, the digital transfer of information between parties working on a given facility (i.e. the transfer of product data) is now happening in all LSE sectors. This practice is more common in those industries that are more structured and more computerised (such as Process Plant), than say the building sector. Increasingly, vendors of applications software are using the ability to "integrate" with other specific applications as a sales edge, even if this capability is only deployed within their client company.

Generally, the LSE research projects adopted a holistic approach to achieving computer integration which, in the majority of cases, recognised the potential enabling role of emerging Product Data Technology (PDT), with emphasis on open systems leading to International Standards for the exchange and sharing of product information. These standards will be based on ISO 10303 (STEP). Product Data Technology can be applied in design, analysis and construction process including the integration of plants, machines and robots within site operations.

4. THE CIMSTEEL PROJECT

By way of example of the impact of some of the collaborative research projects on improving the competitiveness of the Large Scale Engineering industries is the CIMsteel project.

CIMsteel(6) is a major Eureka project concerned with the Computer Integrated Manufacture of Constructional Steelwork. The vision of the project is to improve the competitiveness of the European Industry in world markets, to produce improved and economic steelwork structures, to improve design, manufacture and construction times, and to unlock potential for growth in the steelwork market. The project, which first started in 1988, is due to finish at the end of 1997 and has a total budget of over 60 million U.S. Dollars. It involves over 70 collaborating organisations in nine European countries plus a substantial number of associate collaborators - both software houses and clients.

The goals and objectives of CIMsteel are wide ranging:

- To raise awareness of the business advantage of "managing information for profit".
- To develop integration standards for the design, manufacturing and construction process.
- To exploit the opportunities provided by the new Eurocodes.
- To develop connection design procedure guides and implement these within the new world class software.
- To prepare best-practice guidelines for design for manufacture, design for construction, and automation for fabrication.
- To develop and demonstrate a cost-effective robotic welding system.
- To re-assess and re commend improvements to the business environment in which the industry operates.

CIMsteel is a typical LSE project in the extent that it focused on a particular industry sector, and is actively seeking to bring about direct industrial change within that sector. Thus it offers, on a limited scale, a vision on how the LSE industry might be moved to information-centred working.

From the inception of CIMsteel, the informatics aspects of the project were based on PDT. Computer integration has been explored through a series of demonstrator prototypes which (to date) have focused on data exchange between dissimilar applications software. CIMsteel is positioned as a user, not as a developer, of product data implementation technology. CIMsteel demonstrated a prototype involving STEP-based exchange between ten diverse applications in late 1994, and launched the CIMsteel Integration Standards (CIS) in September 1995.

The CIS are practical specifications(7) for implementing and industrial deployment of STEP-based steelwork modelling and prototyping. The CIS are open standards based on STEP file formats and implementation technology, using a product model that has been developed and refined within CIMsteel. Four data exchange protocols are provided in release one of the CIS covering Analysis, Member Design, Connection Design, and Detailing. CIS/1.0 is designed for building-type frames including residential, commercial and industrial structures. It will be followed by subsequent releases that extend its capabilities, and provide additional exchange protocols in the manufacturing and construction phases. The final stages of the CIMsteel project will explore further how the CIS can be extended into information sharing and information management.

To date the reaction of industry and software vendors to the CIS has been very encouraging and its industrial deployment is underway in major projects. Although CIMsteel is notionally directed at building type structures, considerable interest in the CIS has been generated from other LSE sectors such as Process Plant. The CIMsteel Project is providing a major input to the STEP application protocol (AP 230) which will eventually replace the CIS and thus ensure a long-term solution.

5. CONSTRUCTION AUTOMATION AND ROBOTICS

Automation of construction[8], equipment and tools is still in its early stages. Although progress has been made over the past ten years in developing good prototypes of "automated machines" and "robots", the industry has not been successful in progressing these products beyond the development stage.

This may be due to the fact that R & D was carried out without due regard to the integration of the end product with the design and construction operations. Unless the culture of the traditional parties in the design and construction process is changed progress will be slow in the implementation of new technology.

In order to introduce automation and robotics in the LSE construction industries, consideration should be given to the complexity of building and civil engineering sites which demand higher levels of adaptability from a wide range of plant and equipment systems. However the gradual introduction of flexible automated systems would make considerable impact on site operations.

6. CONSTRUCTION INDUSTRY NEEDS

In addressing automation, construction should be considered an integral part of an engineering project where a number of disciplines and operations are involved.

To improve the uptake of R & D results the industry needs to participate actively in developing:

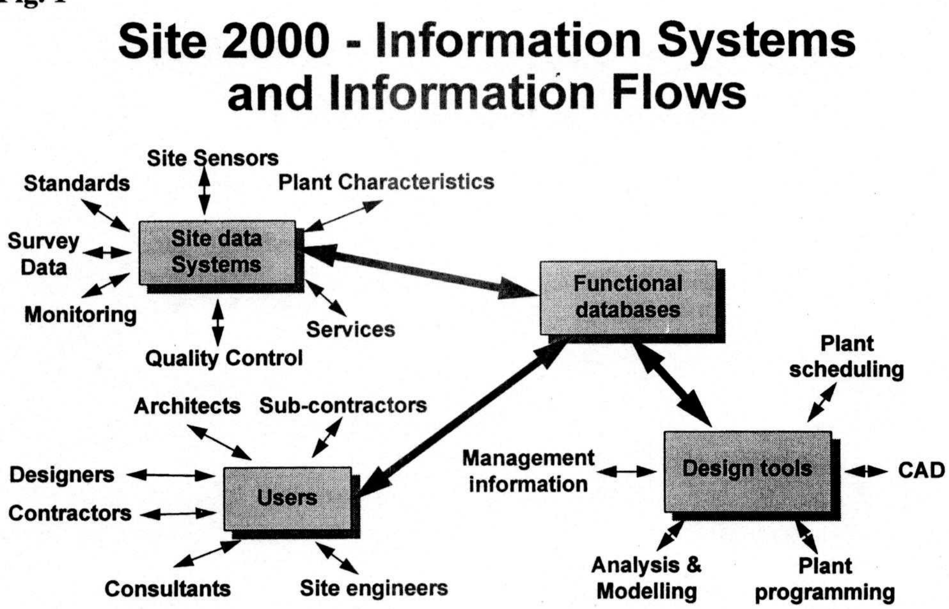
a) integrated project-wide database incorporating the whole life cycle and adopting open system approach
b) automated systems and robotics for off-site modular fabrication
c) computer simulation of construction methods, planning and scheduling

d) networks linking design offices, site operations and the supply chain
e) knowledge based systems for design and engineering decisions
f) industry-wide standards for communication flow
g) integration of design information and site operations including construction plants, robots and tools

7. SITE 2000 AND ISSUES OF DEPLOYMENT

Fig. 1 illustrates a scenario of how a fully integrated design and construction operation may be organised in the future - from tender stage to completion. This scenario would become a reality using largely current technology but the real barriers to implementations would involve issues of management, organisation and attitude.

Fig. 1



Automation of the construction process will be slow unless "automated systems" and "robots" are considered in the design process and as an integral part of complete Product and Process Technology systems

In the next few years automation and robotic application will be selective and influenced by economic and practical considerations and, of course, the type and nature of construction. However, in selective operations such as excavation, the wider application of robotics will be feasible. Equally, Inspection Robots will have a very useful and wide application to many types of structures. On the other hand, the universal introduction of "heavy robot plant to site", will be difficult indeed.

To accelerate the integration of the design and construction process including the use of automated systems in site operations, the following actions need to be considered:

- cultivate the concept of life cycle integration
- establish standards for communication and the flow of information
- develop "user-friendly" interfaces
- encourage the development of modularization concepts
- establish a number of test beds where the integration process of IT, machines and human resources should be demonstrated.

8. CONCLUDING REMARKS

The activities and the investment in R & D in the field of automation and robotics are far from being adequate for an industry with an output accounting for more than 10 percent of the annual gross domestic product.

There is an urgent need for a co-ordinated programme to develop a strong technological base, adopting an inter-disciplinary approach in the area of construction automation and robotics. This can only be achieved with the full support and involvement of industry, research and academic institutions.

R & D in automation and robotics are expensive and require substantial budgets especially during the implementation stages where prototype manufacturing and commissioning will use substantial resources. There is scope for pooling resources from various institutions and countries to collaborate in common aims and in particular in technological areas where skills gaps are apparent.

One of the biggest challenges for the introduction of automation and robotics to construction operations is the diversity of discipline the industry embraces. There is a need to reconsider construction operations to see how they can be tailored to automation and robotics, rather than simply making the robot mimic a human.

There is also a need for a co-ordinated effort to develop standards for robotics and automation processes and to address issues, such as safety considerations, training and education in this field.

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