The Development of an Interactive Simulation of Site Information Technology Systems in Relation to Construction Automation

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Abstract

Though the construction industry was one of the first to adopt aspects of Information Technology (IT) in areas such as drafting and design, its introduction at the site level remains sparse. One of the reasons for this is believed to be the suspicions that exist in the industry as a whole as to the possible IT formats and their likely impact on working practices. The use of a simulation linking the site activities to the IT infrastructure provides a means of providing an assessment of these impacts and of evaluating the effects of moving to an IT based approach to site operation and management.

1 Introduction

Experience from conventional manufacturing industry suggests that in order to achieve the full benefit from the introduction of automated and robotic technologies, the operation of these technologies needs to be properly integrated within the overall operating structure and strategy of the manufacturing and production process. It is also clear that this integration is typically achieved through the use of some form of hierarchical Information Technology (IT) structure such as that suggested by figure 1. Within the construction industry, though there has been extensive use of IT in the design and planning stages of a construction project, relatively little use is as yet made at the site level, particularly in relation to site automation and the use of robotic technologies.

In order to provide the IT systems that would bridge the gap between the development of automated and robotic systems and their large scale application on a construction site there is a need to improve the understanding of the flow of data both within the site and across the site boundaries. The availability of a formal information infrastructure on site can also be identified as having benefits in areas other than that of automation and, in particular, on quality [1,2,3,4,5]. In order to benefit from the introduction of IT construction companies must ultimately be able to:-

- Justify the introduction of identified IT systems through improvements in areas such as quality, productivity and efficiency and show associated cost benefits.
- Ease the acceptance of the introduction of IT by making any proposed changes incremental to current practices.

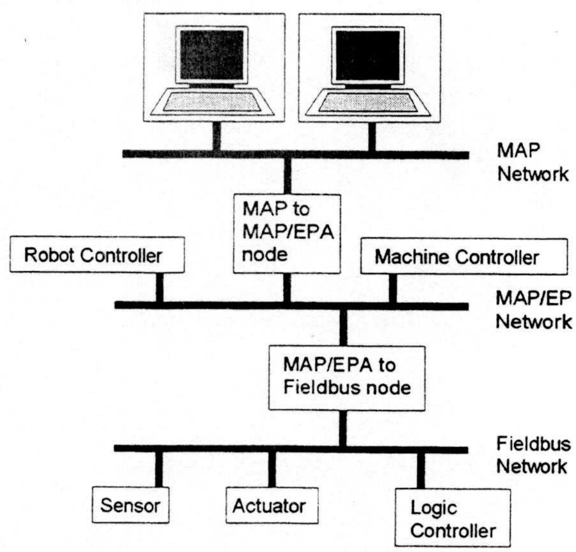

Figure 1: *A typical IT hierarchy within manufacturing*

The achievement of these objectives requires an increased understanding within the industry of the nature and flow of information on site. One of the ways of providing this understanding is through the modelling and simulation of the flow of information within the construction site and the ways in which the access to and use of this information is influenced by the IT structures deployed. The model could then be used to understand the ways in which the introduction of different levels and forms of IT would impact upon the organisation and operation of the site [6].

The paper therefore discusses the development of an interactive model of site IT in relation to construction site management and organisation with particular reference to quality and the introduction of automated and robotic systems into the construction process.

2 Barriers to the adoption of on-site IT

Attitudes as to the usefulness of IT tend to be very polarised within the construction industry. In the UK in particular, this split is broadly along the lines of builders versus engineers with individuals often claiming that while IT may be useful for engineers, it has little to offer to builders. This perception is based upon what IT is *seen* to be used for and not what it *could* be used for, often giving rise to the argument that the IT industry does not understand construction. It is clear therefore that there are significant cultural and contractual problems, many of which are perhaps unique to the construction industry, which present significant barriers to the further integration of IT, particularly in the provision of support for automation. Particular problem areas include the following.

2.1 The perception of IT

The perception of IT as being technology driven and not application based is a significant factor governing its acceptance or otherwise. Too often people perceive that the promises of the IT community are not achieved in reality, resulting in a prejudice against its introduction and use. In fact, the failure to meet the promises is in many cases due to an incorrect understanding of user requirements and a failure to properly take account of the environment in which the systems is to be used. Table 1 sets out some of the factors which can and do influence the perception of an IT system.

2.2 The prototype nature of construction

The one-off nature of many construction projects makes it difficult to generalise the benefits of a particular application of IT across a range of sites. In addition, the number of independent organisations usually involved on-site presents significant inter and intra-project communication problems. These are often exacerbated by the traditional contractual arrangement, which puts control of the project in the hands of the client/architect, or client/consultant, and not in the hands of the partnership responsible for spending most of the money - the contractor/sub-contractor. This presents practical problems for the introduction of any IT system in improving quality, since it would almost inevitably have to cross inter-company boundaries.

The promise of IT	Prospective benefits	Reality
Better decision making and control.	Faster response to unexpected situations.	Failure to deliver.
Visibility in the representation of information.	Increased profitability through appropriate use of information.	Costs greater than benefits.
Improved co-ordination.	Development of tools to enhance future performance.	Islands of IT **NOT** full integration.
Continuity of information.	Improvements in quality.	Information bottlenecks.
Networking.		Inconsistent and incomplete data sets.
		Reliance on tacit, and hence uncodified, knowledge, particularly true for craft based industries.

Requirements for success
Organisational change to take account of the introduction of IT.
Owners gain control of the system.

Table 1: *The promises, prospects and realities of IT*

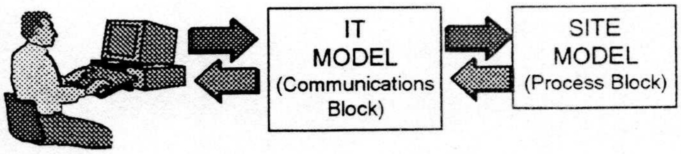

Figure 2: *Organisation of the interactive simulation*

2.3 Working practices

The introduction of an IT system for project control requires co-operation between the main contractor and the client, architect and consultants. However, it remains common practice for contractors to exploit errors in project documents to increase their profitability. Contractors may therefore see project-wide IT embracing quality matters as being detrimental to their own profitability and hence resist its adoption. For this situation to change requires a shift toward a more co-operative system of working which in turn implies a change in the contractual arrangements as is perhaps beginning to be seen in the increasing move to design-and-build contracts.

2.4 The nature of the site

On a purely practical level, a construction site does not have the degree of structure assumed to exist by IT applications in other environments. In a manufacturing environment protection from the elements, the provision of power, permanent routes\lines of sight, suitable locations for sensors and so forth can all be assumed to exist. On a construction site these need to be explicitly provided and changed as a project progresses. As a consequence, systems designed for use in manufacturing environments face serious physical problems if they are to be used on site. Indeed, it is probably far more sensible to assume that any site based IT system will require a new and novel approach to the solution of these and other related problems if it is to be successful.

3 Model Development

In discussions and interviews it was generally found that members of a site team had difficulty in visualising the benefits and likely impact of the introduction of various levels of IT onto their site. This is, at least in part, due to a lack of familiarity with the technology but also because the major preoccupation on a construction site tends to be with providing the solution to problems and not with the enabling technology.

In order to break out of this bottleneck it is necessary to demonstrate the beneficial effects of site-based IT without becoming too involved in the details of the implementation. As existing simulation and modelling tools were found not to provide the required flexibility or the capacity to handle conflicts and dependencies in relation to IT, a model of a construction site which was simplistic enough to be understood by the non-specialist, yet capable of representing the essential characteristics of a site IT system, was therefore developed as the basis of a computer simulation by which different forms of IT implementation on site could be evaluated.

3.1 Model configuration

As the major element of the investigation was that of identifying how IT would impact on the organisation and operation of the site it was essential that the model used would be able to reproduce conditions on-site where IT might be deployed. Interviews with site personnel suggested that the major areas of applicability were associated with the ability to record and monitor events such as the arrival on site of material or equipment and exception handling. Thus, a site engineer might use the system to provide them with notification of the occurrence of an event, enabling them to respond more effectively to that event. than would otherwise be the case.

Consideration of current modelling packages suggested that they were unsuited to the handling of dependencies such as the need to re-allocate task in response to changes in weather conditions or to handling exemptions. It was also felt that in order to properly evaluate the impact and use of IT an interactive model involving site personnel in the decision making process was necessary and a decision was therefore made to construct a model incorporating features for user interaction together with the handling of exemptions and dependencies.

The model as developed has the structure suggested by figure 2, with operational and management decisions being made by the user in response to the information provided by the program. Evaluation of the user actions then serves to draw attention to the effects of changes in the IT structure on the decision making process.

The site model itself is composed of two sections, the *process block* and the *communication block*. The process block represents construction operations as discrete, interdependent events controlled by a schedule and competing for the available resources. The process block also maintains an internal representation of the site being modelled and simulates the occurrence of problems such as machine breakdowns.

Information about the internal state of the model is then passed to the user by the communication block, the

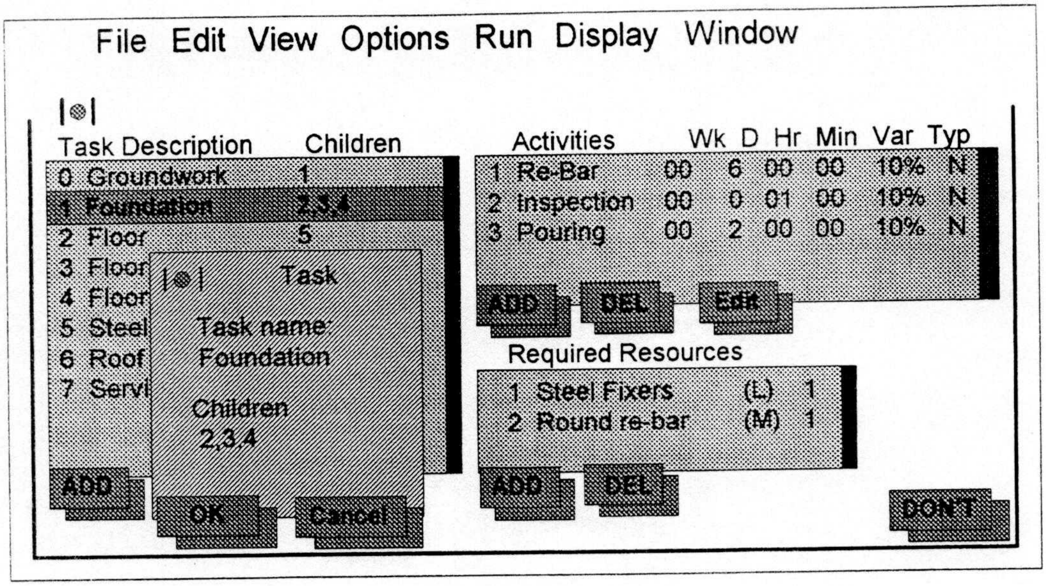

Figure 3: *Process block editor*

output of which is structured according to the particular levels and form of site IT deployed by introducing delays, errors, uncertainties or omissions in the information it displays.

By running the same model with different simulated levels of IT the user then can assess the effect of different IT provisions in terms of their ability to control the simulated site. Even a very simplistic model can therefore give a qualitative "feel" for the effect on site management and operation that different levels of IT provision and use. However, if desired, the model could be developed to a level of detail high enough to provide quantitative measurements for comparing the effectiveness of different IT strategies on site management and production quality.

3.2 Model structure

Using the model, site operations are represented as a number of inter-depended *tasks* each of which is composed of a set of *activities* which are required to be completed in order. In addition, each task may have associated with it a number of *children* representing task which cannot proceed until their parent task is completed satisfactorily. Each of these individual tasks has a specified "location" on the simulated site and their activities require resources, one of which can be attention from the site engineer, for instance to carry out an inspection before a child task can be allowed to proceed. Figure 3 shows the process block editor screen showing some typical defined relationships. The user of the simulation takes the part of the engineer and "moves" around the site attending to and dealing with requests or problems as they or arise in response to the information with which they are presented.

When the simulation is running, the user is presented with information on simulation time, messages about events occurring on the site as in figure 4 and also has access to other screens and controls for interacting with the model, for instance to indicate a response to messages. The level and form of access is however determined by the choices made as to the level and form of IT being used. At any time therefore the user only has access to those options and information that they would be likely to have access to on a real site equipped with the specified level of IT.

The program allows different levels of IT provision to be simulated by the selection of different communications, data processing and data collection options. These options can even be changed during a simulation run to highlight their effect.

Thus, in the example represented by figures 5, both the engineer and the foremen are equipped with two way radios and can therefore communicate directly across the site. This means that in the if an event arises requiring the presence of the site engineer, for instance to carry out an inspection, they can be informed directly of this by the foreman when, depending on their current location, there will be a delay related to the time required for them to reach the location where they are needed. However, if this situation was changed so that the foremen did not have radios or portable telephones then the only way for them to contact the engineer would be to send someone to find them and for the engineer then to come and "speak" to

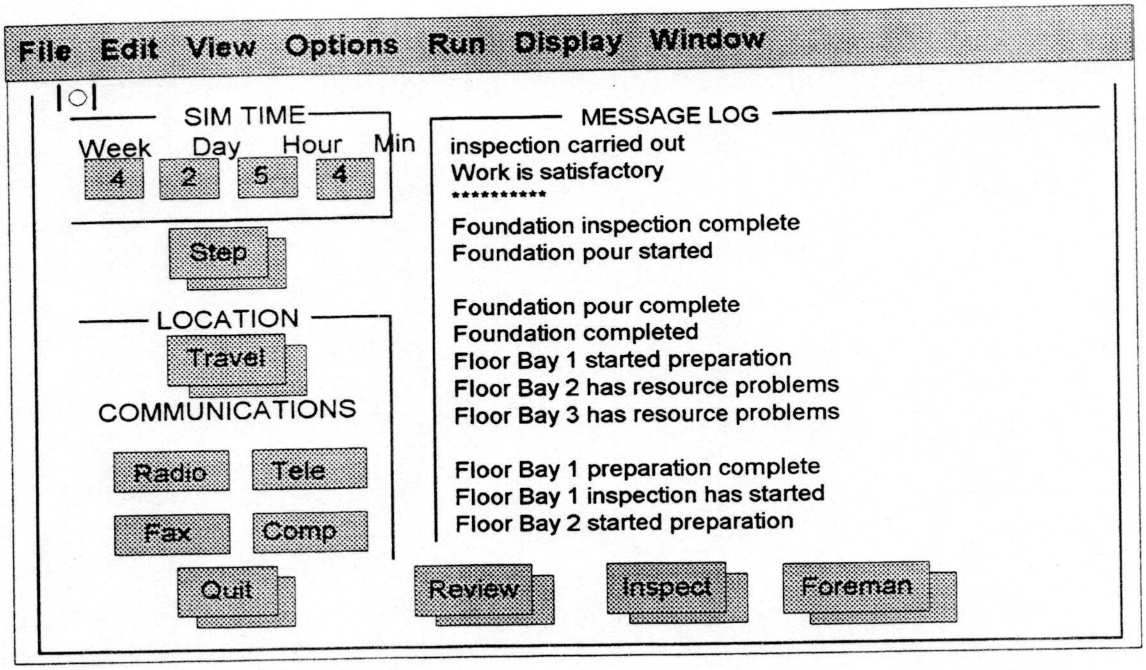

Figure 4: *Simulation - Information screen*

them, introducing extra delays into the decision making process.

Similarly, the data structures present on site will significantly influence the way in which the site operates. Thus in the example presented in figure 6 the site has an automatic reporting and paging system which can be used by the site engineer to monitor specifically identified activities and events such as the delivery of material onto site and to be automatically informed of this by the pager system. In this case, the site is also shown as being directly linked to the project data base held at head office, supporting the direct transfer of computer based material.

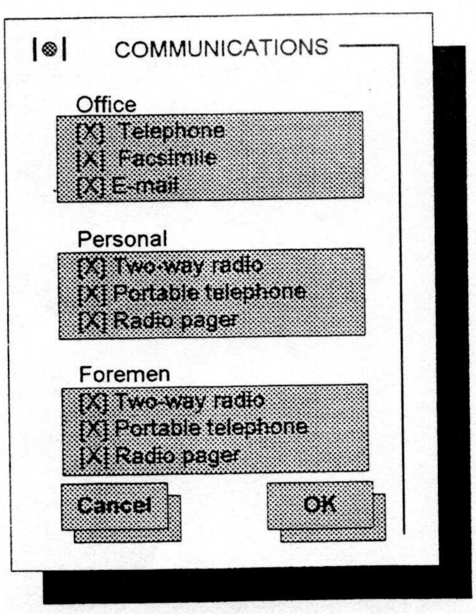

Figure 5: *Communications options*

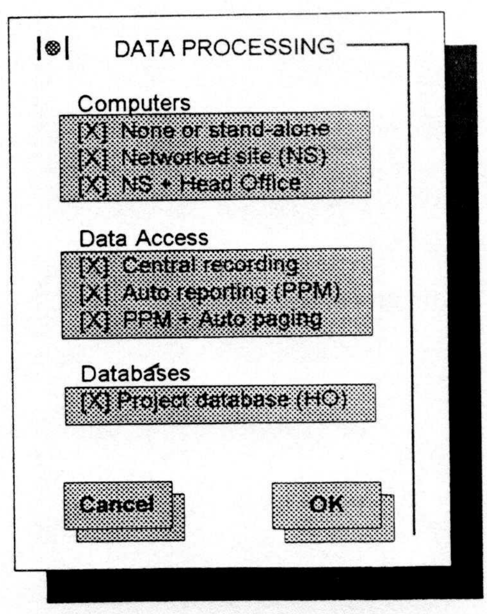

Figure 6: *Data processing options*

5 Conclusions

The introduction of IT onto a construction site offers many opportunities for performance enhancement and improvement in areas such as quality and productivity and is a necessary factory in support of the introduction of significant levels of robotics and automation into the construction process. However, to both acceptable and effective, the introduction of site IT must be needs driven and not technology led and must be structured to take account of the special features and needs of the construction industry.

The use of the simulation system described in the paper has increased the level of insight into the ways in which IT could be used on a construction site and has provided effective feedback as to the way in which such systems could be used by site engineers. Additional development of the simulation, perhaps by linking it to some form of visualisation systems, would further enhance the ability to analyse the performance of IT structures leading to the development of formal specifications for systems adapted to the requirements of the industry.

The experience gained by the research and the construction of the simulation has also had a direct benefit on other areas of construction related research, particularly in relation to the operational management on site of automated and robotic plant.

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