# THE APPLICATION OF KNOWLEDGE BASED ELECTRONIC PROTOYPING TO A PROJECT PROCESS AT CONCEPT PHASE

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## ABSTRACT

This paper describes the results of a research project concerned with integrating a building project model developed using object-oriented Knowledge-Based (KB) techniques with an existing project process. The initial product modelling work was the result of an earlier research project aimed at proving how the manufacturing concept of electronic prototyping could be used in construction. The integration of the model within the project process is discussed in the short term but the paper concludes by demonstrating the longer term implications for construction of information technology adopting a more central role.

## INTRODUCTION

During the last three years, four major European research projects have developed information technology systems for use in the construction industry (1st European Conference on Product Modelling for the Building Industry, Dresden 1994). There has, however, been little evidence of these systems becoming an integral part of everyday construction practice.

The dilemma of integrating IT solutions into commercial practice became apparent to this research team in the closing stages of a research project operating within a major client of the construction industry. The project was aimed at developing knowledge based applications in the construction environment. The techniques now required validation through field testing.

Literature reviews revealed that the concept of using generative technologies such as this are considered at a strategic level. Fisher (1993) considered that given,

"the technological advances and the economic pressures (outlined in this paper), the world wide construction industry will, during the 1990's rapidly move to the point where it becomes increasingly a manufacturing industry."

Since then the issue of construction as a manufacturing process has been sharply focused upon because of the perceived benefits of this approach. In particular, the

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opportunity of delivering better value for money to the regular purchaser of construction goods through the reduction of man-hours per unit of construction. A key aspect of the manufacturing culture is the ability to prototype products either as physical mock ups or as electronic models. They have adopted a high profile use of information technology to facilitate their processes. This is in contrast to the construction industry where the role of IT is limited to "an enhancement to traditional business procedures" ( Irtishad U. Ahmad et al 1994). These authors go onto argue that IT should be regarded as a catalyst for business process re-engineering where IT takes a more central role.

It is, however, early days in this research field and whilst the technological development is driving forward with some speed, the industry is struggling to understand and accept the challenge that this innovation demands. Enormous change within the industry and the way it operates will be required if the innovation is to be successful. It is the soft issues surrounding the technology that need to be considered.

This presented a challenge to the research team to undertake a tactical level project to investigate the application of the previously developed techniques within a client's project process. The aim of the new project was to research and overcome barriers to the implementation of the techniques into commercial practice.

It is the intention of this paper to give some background of the original research to familiarise readers with the techniques developed[5], outline the methodology used in developing the application strategy and discuss the implications of integrating the KB techniques into the project process and the project organisation.

## THE KNOWLEDGE BASED SYSTEM

### Technology

A key technique identified from other industries (aerospace and automotive) was Knowledge-Based Engineering (KBE). A substantial time saving was made by selecting commercially-available software (ICAD Generative Technology from Concentra) running on a SUN/Solaris platform

### Project Aims

The aims of the first project were to improve both the quality and conciseness of the brief from the client to all those involved on a new construction project. It was agreed to test the techniques and to prove that the technology could be transferred. In particular, the use of object-oriented technologies was seen as pivotal in constructing components and generating models (Papantonopoulos et al, 1994b). At all times, future re-use of objects was to be born in mind, and the goal was for

[5] Developed during a research project for BAA plc (formerly the British Airports Authority).

each object to be kept generic. Where possible, it was intended to concentrate on linking between available systems, for example in the use of Model Visualisation Devices. The group would be given the freedom to explore new methods, and to act as a focus group for technological improvement.

### Prototyping & the Construction Industry

Manufacturing has been using physical prototypes, both scale models and full size, for many years. Comparison of the process between manufacturing and construction reveals a close similarity up to the prototype stage, but in construction we call these products finished buildings. Construction rarely has the opportunity to learn from the process, with most buildings commissioned on a design-to-order basis.

Manufacturing has seen the benefits of using electronic prototypes, or digital mockups. This project was set up to promote the same ideas in construction. One of the demonstration systems produced was a planning configuration tool for airport remote satellite buildings, which are used to provide high quality access to aircraft where directly linked piers are not feasible. Principal drivers are the number and mix of different aircraft stand types, which in turn generate passenger traffic flows. The model allowed planners to configure apron geometry, move loading bridges and at any point to generate a satellite building complete with escalators, ramps, lifts, etc. knowing that the overall geometry was consistent with the client's encapsulated design knowledge.

A system was also developed for cabin baggage screening. This is one of the few detail design areas where BAA retains the expertise in-house. Systems inputs such as bags per hour, belt speed, screening process times etc. generate geometry for use in a larger building configuration model, to establish impact on space planning.

## RESEARCH METHODOLOGY

The original concept was that KB techniques should be developed to help the client optimise design during the early project phases of inception, feasibility and concept. The implications of this were not clear and what became evident was the need to find areas on the existing project process which could be facilitated in the short term whilst the longer term implications of process re-engineering around the concept of object orientated work would need additional investigation. A corporate decision was taken to adopt a top down strategic approach similar to that used by Boeing's Phoenix project described by Barlow et al (1995), the principle aim being to achieve consensus and buy-in early in the project process.

To integrate KB techniques within the existing development phase, it was necessary to develop a detailed understanding of the work within the phases, the manner in which it is achieved and by whom. A systems approach was used to analyse the project process and the project organisation. This approach, developed by Checkland (1987), allows the focus to dwell on the individual processes and their inputs and outputs. Subsequent work by Newcombe et al (1990) used this systems theory to define construction organisations. Using this approach would therefore enable a common methodology for both the project process and the project organisation.

The objective of the research was to determine the existing project process and organisation models within the client organisation, identify key sub processes and examine which could be facilitated by the use of KB techniques. Likewise the organisation model would be examined to identify the changes required.

## THE PROJECT PROCESS MODEL

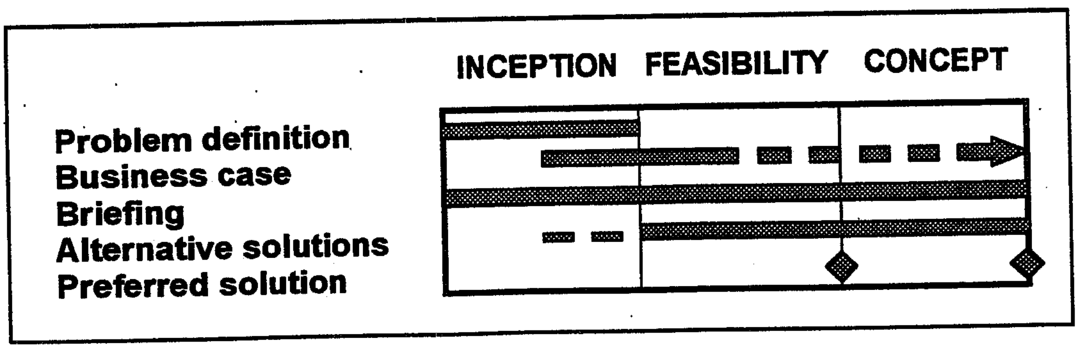
### Process Analysis

The research team based their project process model on some existing mapping work carried out by the client who had mapped the activities to be found within each stage of the project process. Taking those activities for the development phase a number of key sub processes could be identified from which the final model was derived.

The advantage of using the model is that it sets clear boundaries to the work within each phase. It also demonstrates the links between the key processes. The important caveat is that the delineation it assumes oversimplifies and mechanises processes which are in reality developmental and iterative in nature.

### Key Processes

The analysis revealed 5 major processes. Some of them are defined and carried out at unique points of time . Others are ongoing throughout the three phases and are developed incrementally as the level of detailed information increases through the project. The major processes are shown below:



*Problem Definition*

This is the foundation stone of the project. There may be a number of triggers within the business environment which will lead the client to initiate a project. The main task at this point is to gather information about the problem and the environment within which it operates.

*Business Case*

This is the first key analysis of the project process where specific numerical data is required in order to establish the scope of project that the business can support. The calculation of rate of return for the project which is the core of the process is determined by each client . Most intend to adopt a whole life approach in this work but unless the client is a frequent construction purchaser it can often be difficult to establish the required input data. The output from the process is a rate of return that the project is required to make if it is to remain viable. This process is sometimes reiterated throughout the project process to determine whether factors have changed that would make the project untenable.

*Briefing process*

This is an ongoing skill through all phases of the development process. Its purpose is to define the client's requirements for the project. It is a fundamental process in that the success of the project as a whole can be directly attributed to it (O'Reilly 1987; Green S.D., 1995). It is seen as an evolving picture with increasing levels of detail at each stage. The written document resulting from the briefing process is the link between project phases since it is the output from one phase and the input to the next. It has three purposes:

formulation of the clients needs
communication of these needs to the project team
is a record of the conceptual development of the project

*Generation of alternative solutions*

This process spans two phases of development. Firstly during feasibility when alternative process solutions are being generated and secondly during concept when construction alternatives are being sought. In both phases the work is critical since the choice of a preferred solution must depend upon the quality of the options available.

The critical activity in generating construction solutions is the move from the functional and process configuration of the building to the physical model which comply with both the process requirements of the business activity, the physical constraints and the less tangible elements of quality and aesthetics.

### *Choice of preferred solution*

This is often not a formal process except where clients are frequent procurers of construction and have formalised their methodology. Some clients have adopted value management techniques as part of this process.

## THE ORGANISATION MODEL

In determining the activities of the project process the client had also defined who was responsible for carrying out the activities. The organisational model was developed to show not only who did which task but to identify the location of each individual. Furthermore it was also necessary to understand where these individuals were placed within the departmental hierarchies.

### Key Features of the Organisation Model

The model shows the client team consisting of three key figures. Firstly the project sponsor who is the prime mover behind establishing the need for the project and will be responsible for the maximising the value that the project brings to the core business. The remaining two are the development manager and project manager who have interlocking roles whose balance varies through the process. Initially the development manager will shoulder the main responsibility for establishing the business case and the early aspects of the briefing process. As the project bias moves towards construction the project managers role becomes more dominant.

The model reveals that whilst the responsibility and ownership of the project resides with these key personnel during the development phase of the project there is a high degree of out sourcing of various aspects of work. Clear lines of communication are vital. The transfer of project information in an accurate and timely manner is impeded by the number of people involved. Team building in system terms allows the creation of "short circuits" within a communication line which assist in this.

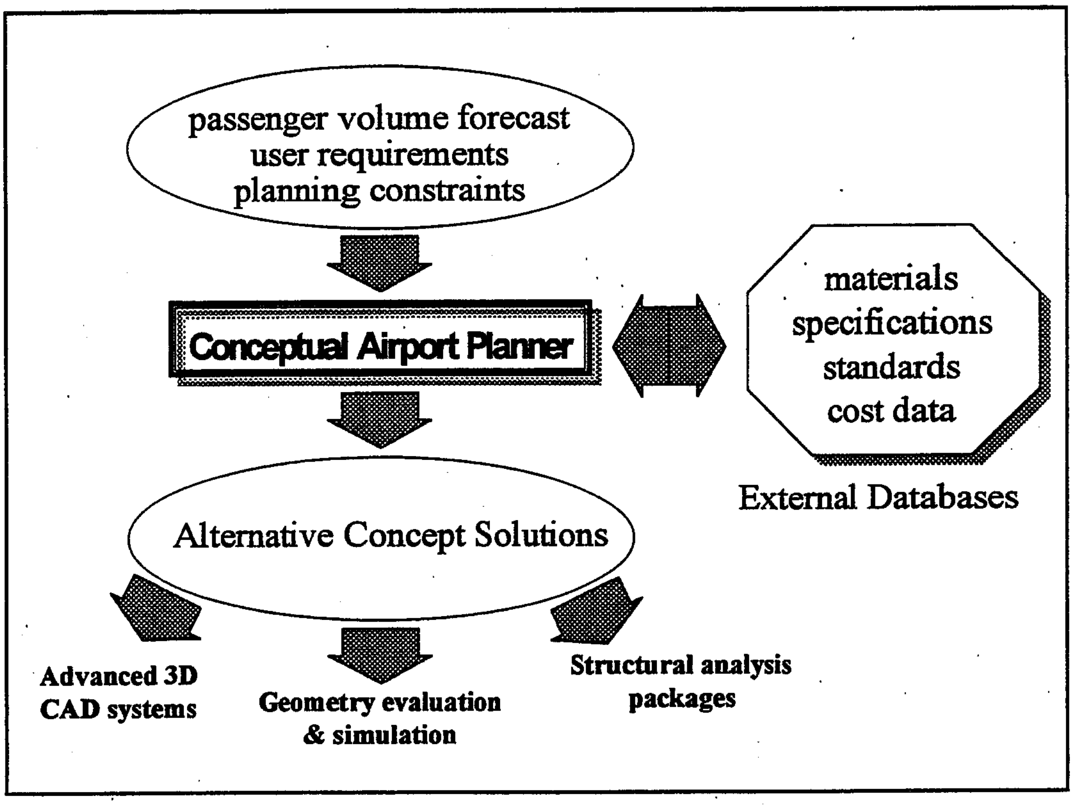
## IMPLEMENTATION OF KB TECHNIQUES IN THE SHORT TERM

### Strategy

To capitalise on the technology at the earliest opportunity it was decided to seek potential uses for KB techniques which would require little or no change to the project and process models. To this end the key processes were assessed for suitability and the "generation of alternative solutions" was chosen because it could make use of a key characteristic of the techniques, which is to allow changes to be implemented quickly and the model to be flexed.

## Generation of Alternative Solutions

Frequently on projects, at either feasibility or concept, the choice offered by the alternative solutions is artificially restricted by the constraints of time and imagination. By using the KB system, a wide range of changes and their impact can be tested and assessed.




A specific example of this philosophy was the development of a generic multi-storey car parking model where variables in terms of capacity and footprint could be used to evaluate the impact of the structural massing. The ability to execute these changes and assess the results within minutes enhanced the quality of the final recommended options; this work was carried out in parallel with the traditional design process, so that the capability of the system to generate large numbers of alternative schemes was immediately apparent. The KBE software acts as a control mechanism on the planning function ensuring that the resulting layout provides sufficient space to comply with the previously gained knowledge about what works and is successful in that type and use of construction.

A number of additional advantages to using the technology were identified.

## Additional Advantages

Firstly if the construction solutions are linked to a suitable cost modelling package then the cost implications of key changes can be quickly assimilated.

Secondly, the generation of 3D electronic solutions allows visualisation techniques to be employed through the use of other rendering packages which allow non-construction clients to "see" their project and determine the most appropriate solution.

Research is now underway in both these areas to develop the necessary linkages for data exchange. The use of 3D visualisation rendering techniques has become a key option during project development since the technology to allow this was more easily achieved.

## Organisation Implications

The use of the KB system to develop alternative solutions required the inclusion of KB experts within the project organisation. It was thought appropriate to retain central control of the new technology and for that reason a policy of locating the KB team within the planning group was taken. In effect this meant that the concept modelling would be offered for certain projects only.

## Support Issues

The implications of using knowledge based engineering in this way are far reaching. Although the process model needs little amendment to facilitate the use of KB techniques, there are, however, support issues which need to be tackled.

Primarily this is the development of suitable generic objects together with their attributes to allow speedy generation of individual project models from limited amounts of key data. If the project specific model cannot be developed accurately and fast there is a time lag on the project process which is unacceptable. The client has chosen to develop both the generic objects and their rule base direct with the software developers. When the ability to model is made available careful selection will be required of suitable project for its use. There may be a threshold of size and complexity of project below which it is not beneficial to use electronic prototyping in this way.

This type of implementation will disturb the existing project process and organisational models very little since it is in essence only seeking to facilitate work currently done within the existing models. It was realised that to develop the true electronic prototyping approach used in manufacturing would require in depth investigation into the implications for the construction industry and its modus operandi.

## BUSINESS PROCESS RE-ENGINEERING

### Long term changes

In applying the technology in the manner described previously the team believe that the potential for real step change within the industry is thwarted. The concept of electronic protoyping needs to be taken to its full extent in the same way that manufacturing industry would not begin production without first testing every aspect of the product through a detailed development programme. Whilst the construction industry cannot afford the luxury of a full development programme the use of object-orientated models can reduce much of the risk inherent in construction.

This project, sponsored by a client, concentrated on the concept development of the construction product paying particular attention to the client's needs to harness their core business experience and aesthetic requirements. The need to communicate these drove the project towards visualisation and virtual reality as mediums for improving their concepts and increasing customer satisfaction. The ultimate outcome could be the creation of an electronic brief centred on a 3D model as an interface with a full range of multi-media data.

The technology is capable of far more, particularly if the early concept work has been developed in an object-orientated medium. The concept thus developed could then be used through the design phase of the structure to ensure buildability and accuracy. This is the bottom-up approach used by Boeing where KB technology was used to manage the design process resulting in a very high degree of component compatibility.

Whilst the client's approach requires little remodelling of their processes, this latter application demands greater re-engineering and involves the integration of the external project team e.g. designers and specialist trade contractors. This area is currently being addressed through a number of research projects based at Reading University and managed through the Advanced Construction Engineering centre within the Department of Construction Management and Engineering. At its heart is the principle that for construction to benefit as a manufacturing process the application of IT must be moved to a central role within the project process and the necessary organisation model must be determined to facilitate this.

## CONCLUSIONS

Historically, individual software packages have been used during a construction project on an ad hoc basis. Few attempts have been made to improve the project process through the strategic implementation of carefully selected and researched software packages.

The research has shown that generative technology can be successfully used within construction. Furthermore with the appropriate support, the technology can be used by owner/operators with large construction portfolios. It provides them with a tool to generate innovative construction solutions as part of their development process. In time as a current research bears fruit the ability to include cost modelling and visualisation within the technology will further assist owner/ operators.

Initially with minor amendments to project process and organisational models the technology can be used effectively. There are, however, far greater opportunities for this work to impact on the construction process as a whole if the use of the technology was moved from the peripheral position it now holds, facilitating one key process, to the central role of the project data record and model generator.

The benefits of this approach are that it would provide a central integrating tool for information technology used on the project process. It would mean major changes to the way in which the construction industry would operate. This change would need to be managed carefully to achieve successful integration and the necessary role changes that would be required.

## FURTHER RESEARCH

If the use of knowledge based engineering is to be adopted and its full benefits received by the construction industry then further research is required in a number of area. Firstly, within the technology itself. New software packages continue to redress areas of weakness and the benefits need to be continually addressed and the software tested.

Also links to other software need to be developed and more will become apparent as experience is gained from using the technology. The boundaries of KB techniques will also be challenged. Through setting up the centre at Reading, the team will be particularly active in this area and is keen to work in trans-national collaborative projects.

Secondly, the use of KBE techniques need to be tested in live project environments. It is important to test and challenge the robustness of the technology and to ensure it can deliver in a beneficial way whilst interacting with the chaotic project environment. In addition, it is only through strategic evaluation of performance within live projects that the tangible benefits from implementing the technology can be measured.

Consideration of construction as a manufacturing process is another key area. Whilst research has shown areas of similarity and has focused on elements of the construction production process that could be executed in a similar fashion, it has not attempted to consider the implications of such changes at either a strategic or tactical level for the construction industry.

Given that this research will identify the changes that are needed to allow the construction industry to benefit from this approach, the changes themselves need careful management. The construction industry will need to fully understand and identify the implications of these changes because step changes of the sort to which this work must ultimately lead are notoriously difficult to achieve. It is a real possibility, that the failure of the construction industry to capitalise on these issues could render the industry vulnerable to encroachment from other manufacturers.

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