A DYNAMIC FRAMEWORK FOR PROJECT DECISION SUPPORT - DEVELOPING "SOFT" INTERFACES FOR THE MANAGEMENT OF CONSTRUCTION PROJECTS.

W. D. McGeorge
S. E. Chen
M. J. Ostwald

The University of Newcastle
New South Wales, Australia.

Abstract

Construction is an information intensive industry involving many different participants (or actors). The fragmentation of functions and barriers to the effective communication of information from amongst participants has been a major obstacle to productivity and quality in the industry. The development of computer technology offers the technical means to improve the integration between different participants and functions.

The paper describes a dynamic framework for project decision support which take into account the participants and the stages of the project life cycle. This conceptual framework has been adopted in formulating a strategic approach in managing project buildability, and is being extended into post occupancy functions. An essential part of the strategy is the development of user-oriented interfaces linking managers and decision makers to an arsenal of relevant technology which remains largely invisible.

This approach emphasises the development of "soft" technology which takes into account management needs generated by the project process. Project participants and decisions makers are thus able to directly exploit the potential of computer-based integration of project information while maintaining their own specialist roles and functions.

1 INTRODUCTION

The construction industry, like many other manufacturing industries, involves a wide range of different activities and specialist participants from the design and pre-design stages of projects through to the construction and maintenance of the completed product. Each of the different activities generates and/or uses information and the different participants need to engage in an effective communication network so that relevant information flows are not impeded. In reality, the fragmentation and barriers to effective flows of information between participants has been a major obstacle to productivity and quality in the industry (Mathur and McGeorge, 1993; RCBI, etc).

Most manufacturing industries are geared to long production runs which allow a relatively high investment in refinement of the design and production processes of each product. The building industry however, is characterised by projects which are almost all unique and highly complex. There is also generally an inverse relationship between production and coordination costs. This amplifies the imperative for developing improving coordination and integration and presents a major challenge for managers in the construction industry.

The development of computer technology in the building industry has largely resulted in improvements within the specialist functions. Arguably, this has exacerbated the separations between specialist functions. At the same time, the technology also offers the technical means to promote coordination and integration between different participants and functions. The development of "hard" technology which largely results in improvements in specific functions needs to be matched by the ability of managers to maintain and improve coordination and integration across these functions.

This paper describes the development of an organisational decision support system (ODSS) for managing construction projects, which would operate in an iterative and recursive decision making environment comprising a large, and in many cases, compartmentalised, groups of actors and decision takers. The ODSS is a system "...designed to coordinate and disseminate decision making across functional areas and hierarchical levels such that decisions are congruent with organisational goals" (Carter et al., 1992). This is proposed as an example of "soft" technology which provides user-oriented interfaces and takes into account the challenges of managing technological innovation.

2. BACKGROUND

Although this paper is primarily concerned with the design and development of an ODSS per se, it is worthwhile reviewing at this point the research context within which our prototype ODSS was conceived. The research project's objectives are to derive, validate and implement quantitative measurements of buildability in public sector projects for the New South Works Public Works Department. Part of the implementation strategy is the design of the prototype ODSSs which is described in this paper (Chen and London, 1994).

The definition of buildability adopted for this research project is "the extent to which decisions, made during the whole building procurement process, ultimately facilitate the ease of construction and the quality of the completed project" (Chen, McGeorge and Varnam, 1991).

This definition embodies two important principles:

a) buildability performance is driven by the quality of relevant project decisions

b) buildability performance extends beyond just the ease of construction. The trade-offs manifested in terms of the quality of the completed project need also to be taken into account in evaluating buildability.

Buildability is thus regarded as a project attribute which is within the influence of those who shape the whole project process, that is the project decision makers. The compartmentalisation of functions in the project process causes barriers to information flow to project decision makers. This degrades the quality of decisions which may ultimately result in buildability problems.

The primary generator for the prototype organisational decision support system described in this paper has been the proposition that participants in the life cycle of a building project need to be able, in a conceptual sense, to locate their position in a three dimensional framework which relates to the intersections of the dimensions of time, other participants and factors influencing decision making (which in the context of our research is the factor of 'buildability'). This conceptual model is illustrated in Figure 1.

We acknowledge the diversity of the participants involved in the building life cycle and the difficulty which this presents in designing a decision support system which can accommodate their conflicting demands. Mather and McGeorge (1993) claim for example that there are more than 60 professional groups involved in the building procurement process. The adoption of a '"soft" technology approach allows different participants in the system to exploit the potential of computer interrogation of electronic stored information whilst still maintaining their own roles and identities. Our application of soft technology has been to design a user-friendly graphical interface which allows participants to share a common pictorial representation of the complex set of relationships which are involved in the building life cycle.

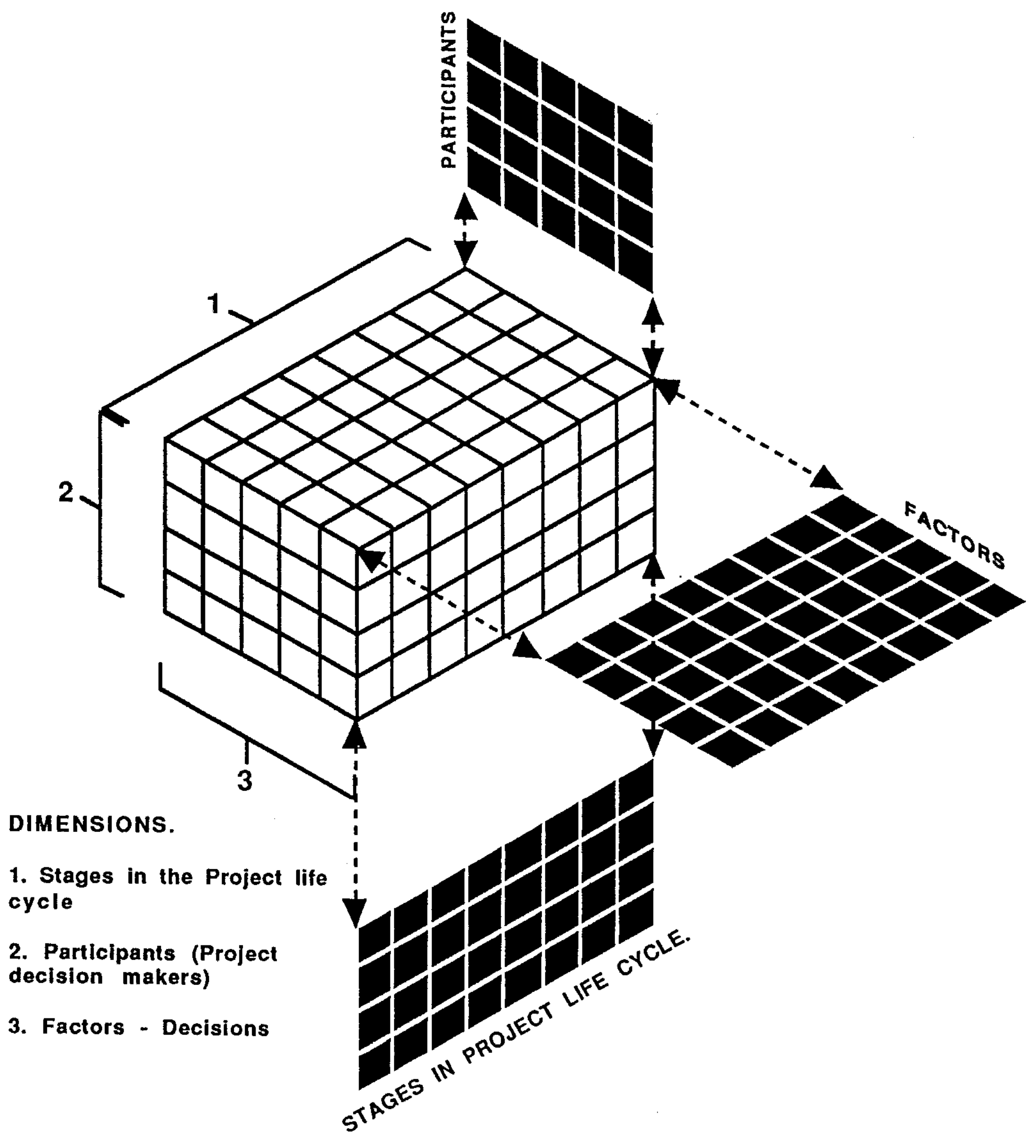

Figure 1 - 3 D Conceptual Model

It is perhaps worth noting at this point, the successful introduction by the legal profession in Australia of computer generated graphics to create pictorial representations of evidence. This approach has been used to effect in legal cases involving complex monitory transactions which have occurred over a period of time and have involved a large number of companies located in many different countries. In some cases it has been found that the costs of providing computer monitors to each of the jurors together the software development costs have been more than offset by savings due to a reduction in court time or even in some instances the abandonment of the trial due to defendants changing a plea from innocent to guilty when the clarity of the prosecution's evidence was demonstrated using a graphical representation of evidence. This recent use of soft technology demonstrates quite strikingly the power of pictorial and graphical representations of complex relationships in assisting decision makers (in this case jurors) to arrive at a collective decision. It is this innate human ability to conceptualise abstract relationships though pictorial representations in the form of cognitive maps which we are attempting to harness in our prototype organisation decision support system

The primary purpose of our ODSS is to provide an example, although not necessarily an exemplar, of a decision support system which will enable the implementation of buildability related decisions in a large , complex state authority. We believe however that there could be a considerable number of additional benefits accruing to the organisation (in our case New South Wales Public Works) as a consequence of introducing a buildability ODSS. Although many of these side-benefits or bi-products have yet to be identified, it can be hypothesised that the control and consistency of decision making which a buildability ODSS might achieve would be adaptable to a wider spectrum of building procurement decisions. Experience in other fields indicates that ODSSs help to unify and integrate an organisation and contribute significantly to improved interpersonal communications and inter group coordination (Carter et al.,1992).

3 CONCEPTUALISING THE ODSS

Conceptually we view our buildability ODSSs as a 'cybernetic system'. This has been described by Athey (1982) as "a system which is affected by environmental shifts but has means through feedback control to continue to meet system objectives. Additionally the system objectives are not rigidly fixed but are adaptable to changing conditions and responsive to new understanding." An important aspect, as far as we are concerned, is that these systems gain from experience and thus exhibit new learning. In Athey's view, all social systems, which in our case is a ODSS system, should function as a cybernetic system.

The problem of identifying appropriate components in a cybernetic system is particularly challenging given that our system is attempting to model the building life cycle which can encompass a time frame of some 60 years.

One of the difficulties in designing the ODSS is to decide whether to design the system in response to current organisational structures, patterns, responsibilities, interactions etc. or whether to design a system which is capable of adapting to changes in organisational structures, for example the abolition of a department or the formation of a new department. The converse of this approach is to attempt to persuade an organisation to modify its organisational structure to fit a predetermined ODSSs in order to achieve a apparently more elegant solution. We have taken the view that by declaring our system as cybernetic in nature and by focusing on the functions of the system rather than the organisational structure, that we have adopted a sound fundamental approach.

Thus the fundamental functions of our buildability ODSS are

a) issues identification - generating the decision which need to be addressed within a buildability management plan

b) information access - identifying the sources of information, build in data filters and processors

c) decision support tools and procedures - establishing performance goals, application of appropriate decision rules, identification of possible solutions, evaluation of solutions through simulation and compliance testing

d) communication and coordination - decision tracking and updating, compilation of the integrated project description (Chen, McGeorge and Ostwald, 1993).

4 DEVELOPMENT OF THE ODSS

As previously stated the ODSS presents as a graphical user interface which mediates between a variety of users, operating as a project team, and an existing array of information sources. The form this mediation takes, between the users and the data, is through a sequence of screens which prompt time specific actions and possible criteria for undertaking these actions, or decisions, based upon data gathered. This program fills the important interface between difficult to access data forms and the diverse backgrounds, skills and abilities of the project team (See Figure 2). The overall aim of the prototype decision support system is to assist initially in the recording of the decisions during the project life cycle and, eventually, to use this body of knowledge to inform decisions made in future projects.

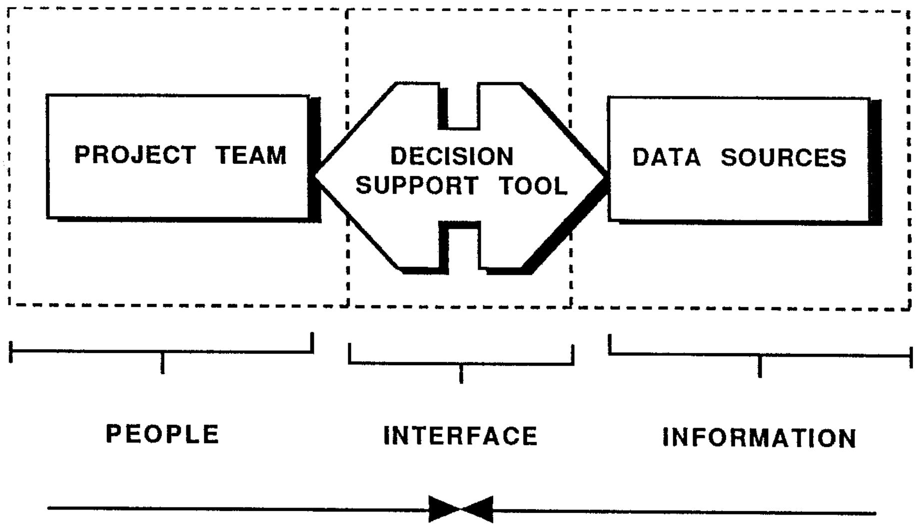

Figure 2. The ODSS as an interface.

The ODSS facilitates a sequence of parallel dependent users linked to a central decision log and to a diverse range of external data sources. In order to accommodate this tripartite relationship a conceptual structure was required that would combine the three areas, factors, participants and time in such a way that they were able to interact seamlessly. The conceptual structure that had been developed in order to support research into buildability provided a key three dimensional abstraction from which the user interface could be explicated.

The program is conceptually structured about three dimensions of the construction industry; participants, factors and time. Time is represented by a horizontal bar which gradually changes tone from left to right marked the stages of the building life cycle. All other operations in the program are linked to the time line. The decision factors are the most complex features of the interface; as a result they fill the screen from top to bottom and occupy an iterative sequence that loops from top to bottom of the screen and then back. The third dimension is the participants. As the interface has to suit particular users, who would normally be fulfilling one role only, the third dimension is a sequence of layers beneath the screen - each is which is barely visible like a stack of cards. Although only the top most level is active, a series of buttons provides access to each of the participants layers. In theory the users may watch other members of the project team as they make and record their decision although they may only work interactively with the other users by permission. (See Figure 3) The combined interface allows the user to determine those participants who are active in the process at any specific time. Each participant is then able to interact with the decision making process and the factors affecting each stage of the project.

Once the conceptual framework had been translated into a graphical user interface the interactive components of the program were designed.

The ODSS uses three operational devices or fields. Conceptually these fields are the interface, the user support mechanism, and the log of all actions (decisions).

The first field is the interface between the user, data and decision support tools. In this field the active and passive participants are identified, the activities or decisions are flagged, external databases are accessed and decisions are made. This field is the basis for the interface and is the most detailed level of the program. It is the combined elements within this first field that form the cognitive map.

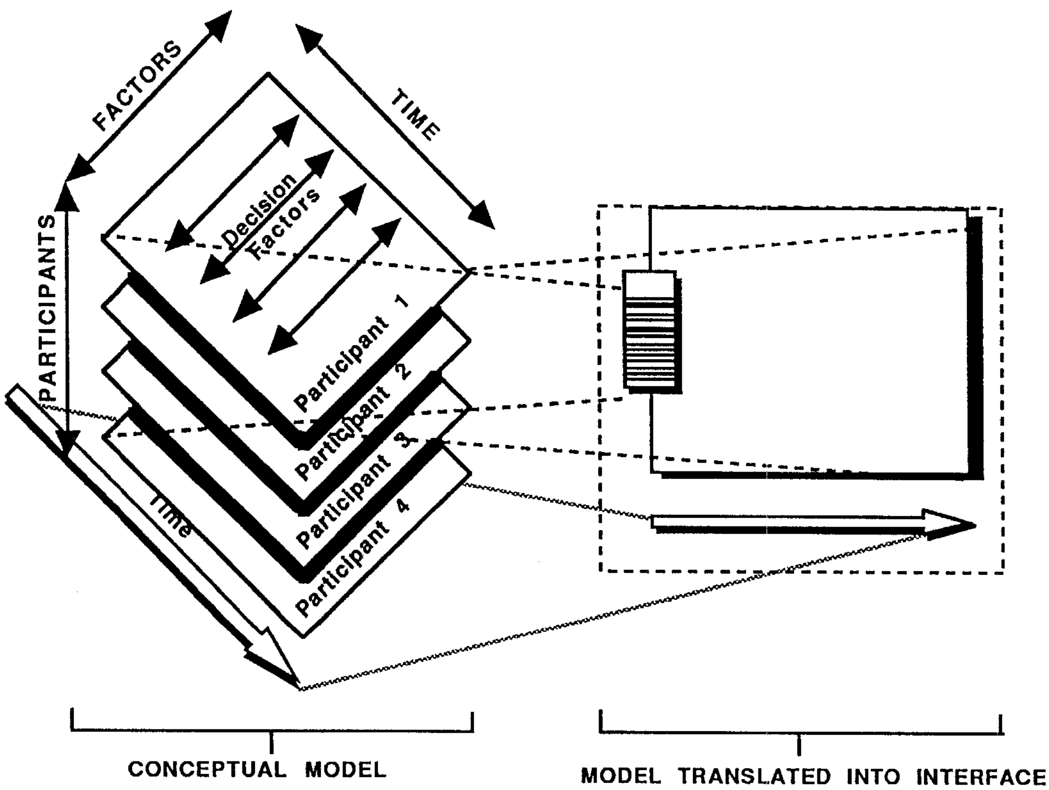

Figure 3. The Conceptual Model translated into an Interface.

The second field is active at all times. This field provides continuous interactive support for the users. At each stage of the iterative sequence of events the second field prompts the user with the options available and the manner in which these options will be recorded. This field acts as a combined help screen and a program control device. Certain non-intuitive controls are contained within this field, as to are exit routes to more detailed help screens and background information on the program. These additional help screens and the background information devices are essentially static and non-interactive; they provide a more detailed description of the program, how it operates, how it was programmed and the manner in which it should be used. Despite this material, the program is fundamentally driven by the uppermost layer of the support field. By prompting the user at all stages on the suggested path or options the user is lead through the decision making sequence. The prompting does not provide answers. Rather it provokes a pattern of thought processes which will assist in the decision making action. The second field informs the users reading of the cognitive map and provides directions such that in time the user will be able to navigate through the system in ways defined by themselves rather than in the suggested manner. The cognitive map remains but its cartography may be explored differently by different users.

The third field is, in the long term, the most powerful. This field records the decisions made during the building life cycle, from pre-construction to post-completion periods. In the Decision Log field all decisions are graphically charted against the time the decision was made, the person who made the decision and those other participants who have vetted, or noted the decision. (See Figure 4)

In terms of the overall prototype interface and the most important fields are the first two. The third is potentially the most powerful project diagnostic tool in the long term but the effectiveness of this feature is reliant on the ease of use of the interface itself.

The two main fields in the graphical user interface are designed to provide a mouse driven, and occasionally keyboard defined, sequence of events. By pointing at various on-screen items, as prompted by the second field, the user is able to open and close menu's, choose actions, or forms of data interrogation.

4.1 PROGRAMMING THE PROTOTYPE INTERFACE.

A dummy demonstration model of the prototype interface, was programmed using Authorware, a visual programming system suitable, simultaneously, for both Macintosh and Windows environments. Cross platform capability and the initial ease of programming were major considerations in the choice of software for the prototype.

Elements on screen in each of the three fields were designed using a sequence of Boolean rules, such that the specific status of any menu, or icon, was reliant on the options chosen previously (particular participant or project stage) and the position of the mouse. In this manner the menus interactively responded to both the previous actions of the user as well as to the location of the user's mouse and certain keystrokes. Thus if the user clicked on any one menu, the program would check the status of previous menus and the decision log to determine the data it would display. In addition lists on menus were displayed in one of three status forms. Any menu item was either active, passive, or inactive. Active menu items were part of the prevailing sequence of decision protocols currently being used. Passive menu items are those which are not in use in the current sequence but are available for divergent searches and multiple simultaneous actions paths. Inactive menu items are those which are unavailable; such items are usually locked, (the user does not have direct control of this decision of body of data) off-line (the data or sub program is disconnected or in use by more users than the system can cater for), or specific to previous decisions that have been recorded and noted by all the project team. Eventually, when the prototype is developed it will be possible to unlock such menu items but only certain users will have the ability to make such decisions at any time and each of the other project team members will be warned instantly as past decisions are amended.

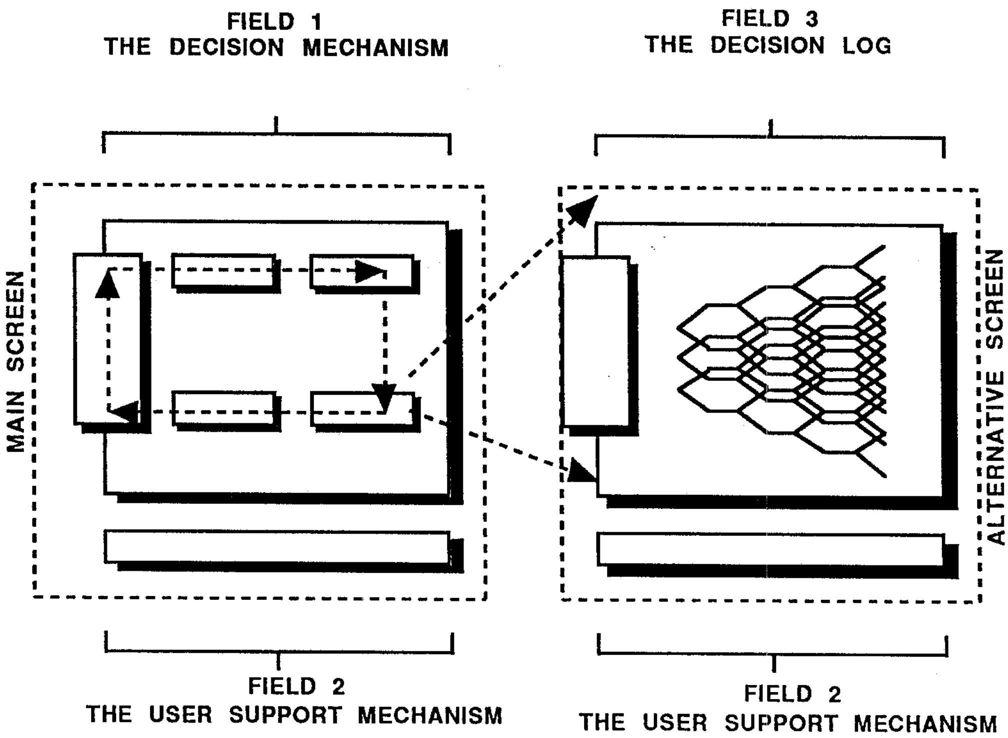

Figure 4. Three operational Fields.

The programming codes thus check not only the display in each menu but also the status of any menu item. The on-screen representation of either the text or its icon is controlled by a series of sub-programs or 'sprites' set within a 'score' of on-screen objects and their status.

When planning the prototype software it was recognised that the programming language and the programmers themselves were limited in a number of ways. With these limitations in mind, as well as severe time constraints to produce the prototype, it was decided to restrict the capacity of the program. As the most intensive programming stages were those relating to time it was decided to limit the time sequence of the prototype to a single stage in the project life-cycle. Thus the programs time activated decisions would not be available in the prototype.

The second restriction placed initially on the program by the development team was that the prototype would only be active for those decisions made by the Project Manager participant. Other links were pre-designed into the program but not written at the testing stage. This restriction placed on the prototype grew from a lack of computational power and the difficulty in cross checking even the most simplified decision making process in a limited time.

Final testing of the prototype program identified a number of problems in the software chosen. In particular as each and every menu choice involved the processing of many hundreds of lines of hybrid programming language through the filters of the Authorware program itself and then the Windows or Macintosh operating system the speed of the program was considerably slower than anticipated. The rate of data display, particularly from data log, via network to the user was extremely slow. The speed itself, while not markedly problematic for the prototype, would have to be considered in more detail before the program could progress any further. When actions taken on screen in the program do not instantly occur, the perceptual lag in time is damaging for the effectiveness of the interface. When the interface aims to be as seamless and perceptually 'thin' as possible any interference to this process is damaging for the overall useability of the program. The final version of the program will have to be rewritten as a 'native' program, in two versions to suit both computer platforms in use. The authoring shell, Authorware, while theoretically capable of meeting the needs of the program was more limited in practice; limited either through the diversity of work stations it would have to operate on or through its particular programming language. Authorware proved to be an effective prototyping tool but after more detailed testing will no doubt be less efficient for the final program. Despite this it should be noted that Authorware is not specifically designed for this use, rather it is more commonly used as a programming shell for computer aided learning systems. Authorware was chosen to model the graphical environment and a few of the functions of the final program; for this specific purpose the program served very well. The final working version of the ODSS will require not only a higher level programming language but also a greater understanding of the "black box mechanisms" at work in the decision making processes.

While speed was the most obvious difficulty with the prototype program the decision log also was seen to be in need of a different system of graphical inter-activity. Although the main program retained a degree of intuitive "feel" the decision log was less readily accessible to those without an understanding of the entire program and its longer term goals.

Despite these problems the ease of use of the program, and the manner in which it would allow users to communicate and record decisions processes, was seen, by the potential users, as highly beneficial. The users, at the first demonstration of the prototype, repeatedly expressed an interest more in the programs ability to link the project team closely and to provide a mechanism for communication and quality assurance. Curiously these are side effects which attest to the programs versatility as an interface. That the users were able to see ways in which the program could function, which were outside of the original charter of the software development group, is notable. Such outcomes of the test environment are consequential as despite the greater aims of the prototype one constant concern was that the program would not present a transparent interface between the many project participants and the databases already available.

5 CONCLUSIONS

Computer innovations have generally focused on automating individual functions or sets of functions (eg CAD/scheduling, project programming, estimating). Improvements in these have arguably strengthen some of the separations between specialist functions and at the same time increased the potential gains of better coordination and integration. There is a strong argument for innovations in soft technology such as is described in this paper which would promote these improvements (in coordination and integration) thus harnessing the full power of "hard" developments.

This paper has advocated, amongst other things, the use of cognitive maps as a means of breaking down the compartmentalisation which currently exists in the procurement and operation of buildings. This approach presents technical difficulties, which have been discussed in this paper. It also perhaps presents ethical problems, in terms of the potential to manipulate the players in the system, which are yet to be explored. The example quoted of the application of this approach in a legal context where lay people have been able to assimilate difficult technical information through what, is in essence, a computer generated cognitive map is perhaps a pointer to future directions for the increased use of this form of soft technology.

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