An internet-based system to support interdisciplinary and inter-organisational collaborative conceptual design

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This paper builds on work presented at the last two CIBSE conferences, and describes the development of an Internet-based design tool to support interdisciplinary teams during the conceptual phase of the design process. Originally devised as a paper-based framework comprising five phases and twelve activities, the interactive internet-based version accords well with the richly iterative and often non-linear process which design typically follows. The tool is intended to encourage inspirational concept design without imposing a rigid procedure.

As well as offering alternative routes through concept design, the tool contains 'team thinking tools' to help designers widen the solution space, set priorities and evaluate options. In addition, drawing on management science literature about effective teamwork practices, it helps a team deal with social interactions. Also, at the user's option, the system can be used to capture, store and retrieve decisions made, and the reasoning behind them.

Overall the system, which exists as a working prototype, offers the combined prospects of decision support, an audit trail, and improved knowledge management. The prototype is available openly on the web, and constructive feedback from users is welcomed. At least one of the collaborating organisations is adapting the system to its individual needs and embedding it within its own operating procedures.

Introduction

Computer-aided tools are being increasingly used to support the design process. Most, however, are usable only in the latter stages of design and, even then, provide only limited support (Baya and Leifer 1996). Currently, no commercial computer-based design tool exists for, or has been developed with the sole intention of, supporting the interdisciplinary team during the conceptual design phase (Jensen 1999). This is a striking omission given that 80% of the final cost of a project (National Materials Advisory Board 1991) is fixed during this phase. Not only is this phase highly influential, but also the most informal, most complex, and least understood stage of the entire design process, and as such it is surely the activity which is most in need of computational support (Baya and Leifer 1996).

The Department of Architecture at Cambridge University has recognised this need and, through the collaboration of a number of construction industry firms, has developed a computer-based process-oriented tool to support the interdisciplinary team during conceptual design activity. For reasons described elsewhere (Macmillan, Steele, Austin, Kirby, Spence 1999a) the tool has been developed using the Internet-based HyperText Mark-up Language

(HTML) - a language that web browsers, such as Internet Explorer and Netscape Navigator, use to display web pages on the Internet. HTML was derived from a meta-language (a language used to describe languages in general) known as SGML (Standard Generalised Mark-up Language) and behaves much like any standard programming language (Tittel, Gaither, Hassinger, Erwin 1995). Although the Internet was originally conceived as a means of transferring and accessing large amounts of data quickly and easily, more recently both industry and academia have investigated the possibility of internet-based collaborative working (Ando, Kuboto, Kiriyama 1998, Nidamarthi Allen, Regalla, Sriram 1999). The reasons for this are several fold (adapted from Cowperthwaite 1999):

- It allows low cost computing and is currently utilised by the majority of organisations working within the design and construction industry, thus avoiding the need for introduction of additional technology.
- It is interactive and allows access to both images and textual information that stimulate and inform.
- It allows simple navigation around information held in many remote locations.
- It allows this information to be downloaded, manipulated and published easily.
- It has the potential to reach everyone, everywhere, constantly.

In response to a number of forces such as globalisation, increased specialisation, technological developments and growth of the Internet, design team activity is changing drastically (Ando *et al.*, 1998). Increasingly projects require collaboration between geographically distributed individuals (Steele, Murray 2000). The tool being devised is intended to support collaborative design activity over the Internet, while also providing access to geographically distributed resources (Nidamarthi *et al.*, 1999).

System basis

Following a literature survey, reviews of process models both within and beyond construction, interviews with designers about case histories, and observations of workshops where interdisciplinary teams of designers were observed during the concept phase of a design project, a preliminary framework for concept design (shown in figure 1) was devised (Macmillan *et al*., forthcoming [a]). This comprised: i) a standard framework describing five design phases that are generic from one project to the next; and ii) at the lowest level, a structured set of 12 generic design activities in which project specific tasks, knowledge, and data could be stored. The approach was intended to be flexible and adaptable, to accommodate different types of project, client, and design environment, while still offering a structure to which project specific sub-models can be connected.

Upon using this framework in a number of ‘Designing together’ workshops (Austin, Steele, Macmillan, Kirby, Spence, forthcoming; Steele, Macmillan, Austin, Kirby, Spence 1999) it became apparent that differing levels of dependency existed both within and across the phases and activities represented by the preliminary model (Austin *et al.*,1999b).

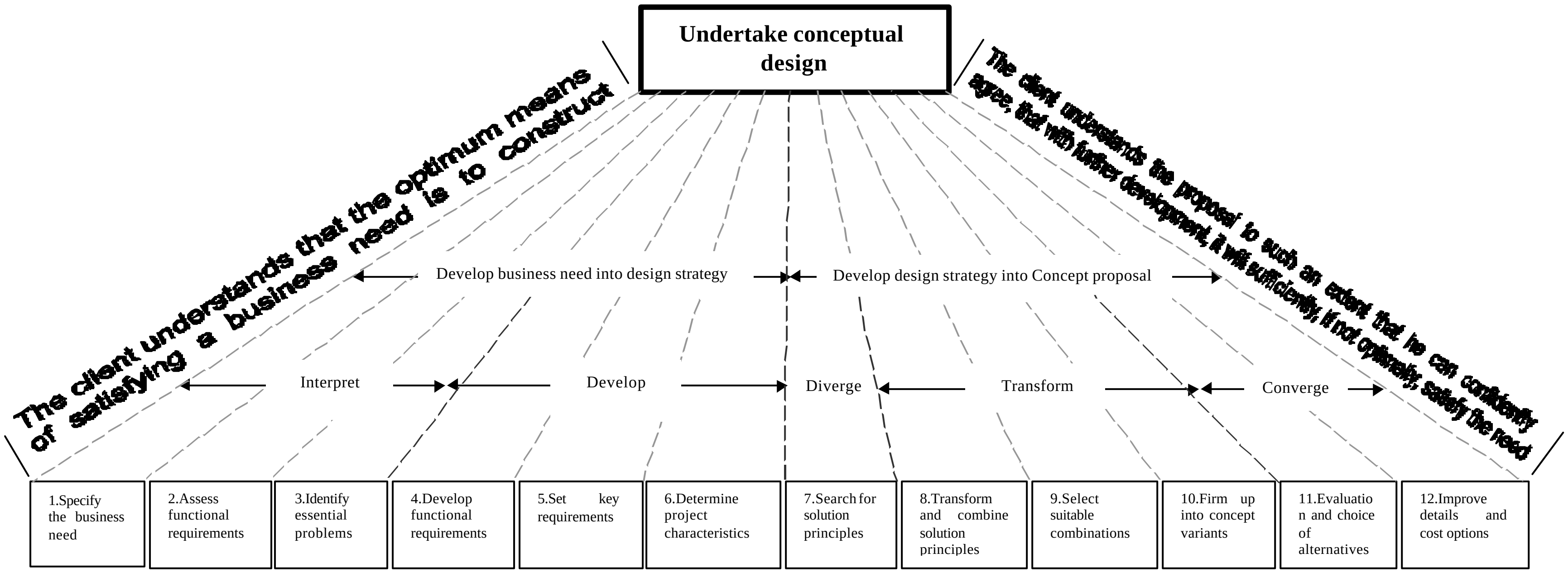

Figure 1 The preliminary conceptual design framework model

Iterations across the activities and phases of the design processes that were recorded during the workshops fitted within a higher level of iteration representing the entire conceptual design phase. In light of this finding the preliminary design framework model was developed into a more realistic representation of the conceptual design phase (figure 2). This formed the basis for implementation as a computer-based tool constructed by the first-named author using HTML.

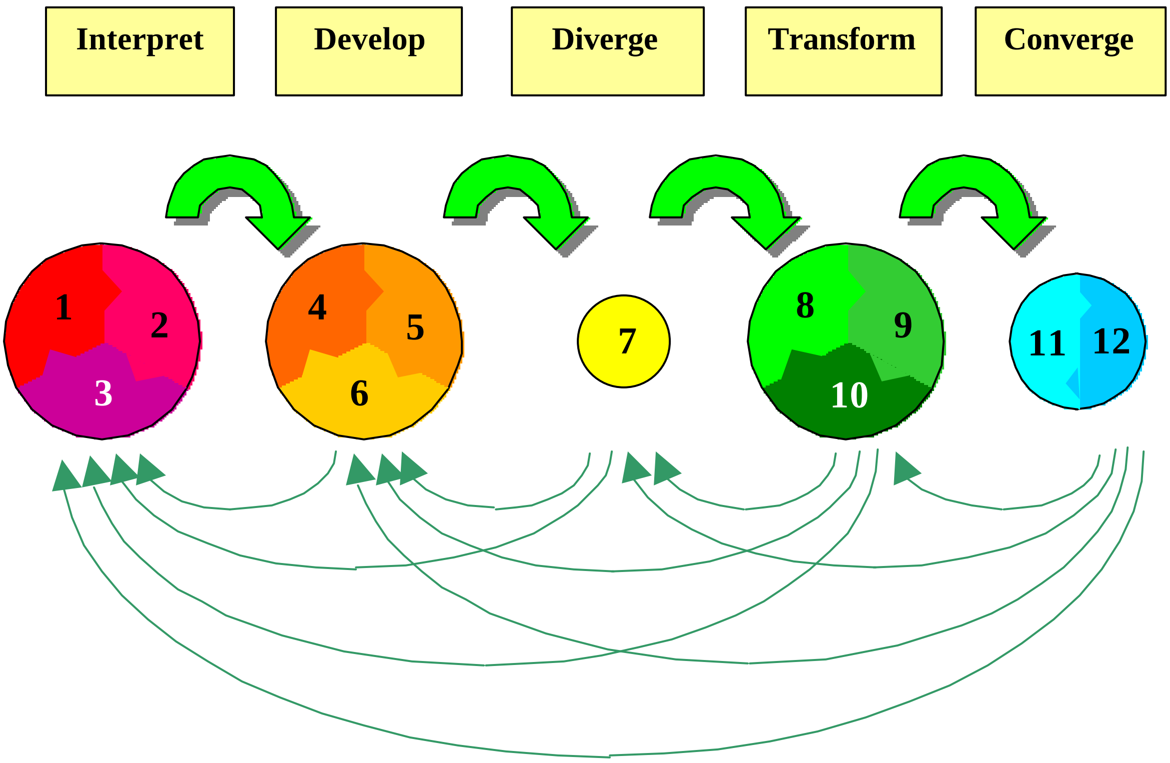

Figure 2 The revised conceptual design model

Characteristics of the system

Design is a dynamic, highly iterative and non-linear process, particularly at the early stages of a project. For any support system to be acceptable in practice it must be both flexible and responsive. As devised, the system attempts to be capable of aiding the process without imposing a procedure. It can be entered at any of the five main phases (interpret, develop, diverge, transform, converge). Provocative questions to the user (such as "Is the design team aware of the client's priorities among competing objectives") are intended to discover whether the team feel confident of having completed a particularly activity and are ready to move to another. Whatever response the team gives to such a question, they remain at liberty to move to any other of the 12 activities they choose. However, by default the system will guide them to the next activity in a stepwise progression. Once they reply that they are confident this next activity is complete, they will pass to the following one.

Where the team is not confident that it has completed an activity, the system offers assistance. This takes the form of a link to a set of 'Team Thinking Tools' embedded within the system. These are based on well-established design methods for:

1. widening the solution space through 'brainstorming' or the use of analogies
2. setting priorities among competing objectives

3. evaluation of options through ranking or weighting methods.

In addition to offering guidance and tools to the design team, the system has two further important components. The first of these is team management. A certain proportion of the time a team spends designing is used in social interaction - to negotiate roles and responsibilities. As such, the system attempts to support team interaction and collaboration in the following areas:

- Working as a team
- Maintaining interaction between members
- Effective communication
- Team dynamics
- Redirecting the team to maintain efficiency

The final feature of the system is the possibility of recording decisions during each of the stages or activities. The system allows, at the user's option, a record to be made of who took a decision, who else contributed, and other associated explanatory material, such as the justification or reasoning behind the decision. If this facility is used, a list of key decisions, who took them, when and why, will be available to the team in the future - and indeed to other teams within the collaborating organisations. Not only may the system help the users to avoid making unnecessary decision loops during the design activity, but capture, storage and retrieval of decisions during the process may also provide a means of performing follow-up reviews of the design process. In this sense the system offers the prospects of decision support, an audit trail, and improved knowledge management.

Visual layout of system

The ease with which a multi-layered system is navigated can contribute significantly to its acceptance in practice so visual layout has been considered in great detail during the development of the system. Navigation within the system requires certain facilities to be displayed continuously, irrespective of which activity the design team has reached, or is undertaking, within the overall process, while others relate to a specific activity and need only be viewed when required. The visual layout of the system, having been developed through an action research cycle (refer to Steele 1999, Oja and Smulyan 1989, Ebbutt 1985 for details) of demonstration, feedback and modification, has evolved into the five-frame split screen form shown in figure 3.

Frame 1: The five phases of conceptual design are displayed continuously. Clicking upon a phase, each of which is coloured differently to aid orientation once the users are deeper within the fabric of the system, allows the users to view the activities pertaining to it (displayed in frame 2).

Frame 2: The activities relating to the chosen design phase are displayed here. Each activity is a different shade of the phase colour. Clicking upon an activity introduces a question in frame 3.

Frame 3: This section of the screen is where questions, prompts, process advice, and when the team maintenance facility is used (see frame 4), team advice, are displayed. Negative responses to questions introduce prompts, while positive responses introduce the next question. The prompts provide advice, links to further information (within the system, on an external site), and details of any design tools that could be of assistance. However, the viewing of external sites and implementation of any electronic versions of design tools is accommodated in a floating screen that opens over the system structure. This ensures that navigation through any external site is undertaken independently of the design framework, thus keeping the multi-layered structure in tact throughout any outlying investigation.

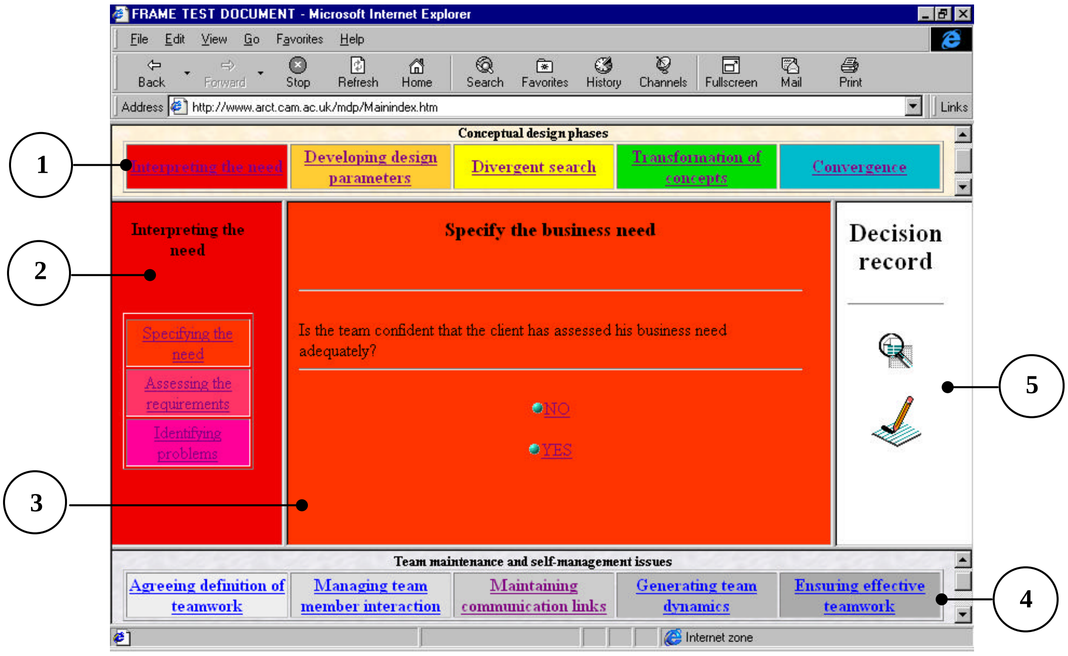

Figure 3 Screen layout of the support system

Frame 4: Frame 4 functions in the same manner as frame 1, but relates to the team maintenance issues. Upon choosing the appropriate issue, the related sub-issues are displayed in frame 2. Clicking upon a sub-issue introduces appropriate advice in frame 3.

Frame 5: This section of the screen provides access to both the decision recording, and viewing, screens. Once the appropriate mechanism is chosen the details are written into, and read from, a floating screen that opens over the system structure.

Preliminary evaluation: Demonstration feedback

Throughout the period of demonstration and development there has been a cyclic progression through the 'demonstration-idea-action' process. This has resulted in the systematic crystallisation of the support system into a prototype version, and allowed the intended end users to provide useful feedback with which to improve the system. The demonstrations also highlighted a number of perceived benefits that could result from its implementation (described elsewhere in CIRIA 1999):

- Improved integration:
  - promotes an integrated interdisciplinary approach.
  - provides an activity framework (passive; knowledge store).
  - provides a mechanism for co-ordinating and aligning organisational processes.

- Improved collaboration:
  - supports the social interaction which is critical to early stage design.
  - introduces a mechanism for the team to manage themselves.
  - provides a team-maintenance component to allow problems to be externalised and addressed.

- Improved process understanding:
  - promotes process (as well as product) negotiation.

- externalises the phase, activity, and type of thinking required by the team at any point during design activity.
- Allows the client to visualise and understand the reasoning behind iterative design progression.
- provides a contingency process for undertaking the conceptual design activities (dynamic: guidance mechanism).

Concluding remarks

This paper has described a decision support system for designers, developed in line with the needs of the envisaged end users. The basis of the system was the product of detailed investigations into current conceptual design practices in the UK construction industry. Its primary objective is to support the design team during the conceptual phase of building projects. It does this by focusing on the processes of design and not by prescribing solutions in the form of a product or a piece of technology. It allows the design team to understand and record their reasoning as they progress through the process. This is of key importance in improving the performance of the industry as a whole, for it is only by understanding how the final product is influenced by early design activity, that the design process can be adapted to take account of these issues on future projects.

Early testing of the system has been promising, with a number of construction companies showing genuine interest in the perceived benefits that it could offer. The system is about to be trialled on a large-scale design project involving the industrial collaborators on the project. It is intended that it will be adapted and embedded within one of the collaborating organisations to satisfy more fully their specific requirements and operating practices.

The prototype tool may be freely used, provided its source is acknowledged, from the project web site[4]. The research team would welcome constructive feedback about it from anyone who attempts to use it – whether successfully or not.

Acknowledgements

This work has been undertaken as part of a project entitled 'Mapping the Design Process during the conceptual phase of building projects'. The research is funded under research grant GR/L39292 by the EPSRC and industry (AMEC Design; BAA Plc., Hotchkiss Ductwork Ltd; Hutter, Jennings and Titchmarsh; Matthew Hall; and Pascall & Watson). Loughborough University is also contributing to the project.

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