MAPPING THE DESIGN PROCESS DURING THE CONCEPTUAL PHASE OF BUILDING PROJECTS

SEBASTIAN MACMILLAN, JOHN STEELE, PAUL KIRBY AND ROBIN SPENCE
The Martin Centre, Department of Architecture, University of Cambridge, UK

and

SIMON AUSTIN
Department of Civil and Building Engineering, University of Loughborough, UK

Abstract:
This paper reports the outcome of a two-year research project that set out to provide a process map of the concept stage of building projects. From a literature review, comparison of current process maps, and through interviews and case study analyses, a tentative new framework for the concept stage was developed and tested. It comprises 12 activities in five phases. The framework formed the basis of a graphical method used to plot the activities of design teams in a series of workshop. This graphical method illustrates design iteration in a way which we believe has not been undertaken before, and the patterns it reveals are intuitively understood by design team members themselves, helping them reflect on their own design process. We have also constructed a prototype internet-based decision support tool for the concept stage of design. This is intended to be inherently flexible and supportive of non-linear routes through concept design, while also offering a structured approach, design tools to broaden the solution space or evaluate competing options, team management advice, and the recording of decision making. Initial testing of this tool showed it to be well-received, although it was criticised for focusing too much on the gates between activities and too little on the issues and decisions within each activity.

Keywords: building design, concept design, design process, process map, decision support.

INTRODUCTION

The concept phase of a design project is typically vibrant, dynamic and creative – and a time when decisions with fundamental and extensive effects on appearance, performance and costs are made. And it is the period when the designer can add the greatest value to a project. Yet it is often disorganised and poorly structured as a new team comes together for perhaps the first time, the brief needs to be refined, and uncertainties exist about project viability. This paper reports on the outcome of a two-year research project funded under the UK Engineering and Physical Sciences Research Council's Innovative Manufacturing Initiative to devise a process map intended to ensure decisions taken at this stage fully reflect the combined expertise of the project participants.

The project involved:

- A comprehensive literature review of some 200 publications dealing with concept design in various sectors including construction.
- A comparison between process maps from architecture and engineering.
- Interviews with designers from architectural and engineering disciplines about the design processes they follow during the early stages of design.

Drawing in these three sources, we defined a tentative new framework for the conceptual phase of building design projects –comprising 12 activities that occur in 5 phases. We used this framework as the basis for bar-charts on which we plotted the activities of seven design teams as they progressed through a concept design problem. Finally we constructed a prototype interactive web-based decision support tool and tested it with design teams.

LITERATURE REVIEW

The project began with a review of definitions of conceptual design and models of the design process from architectural and engineering writers such as Markus, Maver, French, Archer, Pugh & Morley, Pahl & Beitz, and Cross. In a previous paper (Macmillan, Steele, Austin, Kirby and Spence, 1999) we compared and contrasted the following process maps:
BAA Project Process (BAA, 1995), Salford Process Protocol (Kagioglou et al, 1998), RIBA Plan of Work (RIBA, 1969), MOD 'Working Document' (MOD, 1997), CIRIA 113 (Potter, 1995), BS: 7000 (BSI, 1989), Hubka (1982), Pahl & Beitz (1988), VDI 2222 (1973), French (1971).

In our comparison of the models we made the following general criticisms:

- most describe a sequence of phases which, typically, imply iteration within phases but not between one phase and another;
- most imply starting with an analysis of requirements before the generation of possible solutions (even though much design work involves the modification of existing solutions, not the invention of new ones);
- most set out only what should be undertaken, not why or how it should be done;
- most do not define what is to be done separately by different team members and what needs to be done in collaboration; and
- most limit their concerns to the problem requirements and their solution, and do not address the social aspects surrounding team-working, such as the selection and involvement of team members at various stages, the exchange of information, or the promotion of effective collaboration.

In considering how these models deal with the conceptual design phase, we noted that:

- All the models start by an analysis of requirements – none starts by taking an existing concept and modifying it to suit new needs;
- Few of the models explicitly encourage the generation of alternative concepts for evaluation – most imply convergence to one solution quite early in the process;
- None of the models makes explicit reference to means for generating alternative solutions, or to formal measurement, evaluation or assessment methods.

We concluded that none of the models succeeded in capturing ways to help a new design team overcome the stimulating but potentially chaotic period at the start of a project when team members have conflicting aims, priorities and expectations, and need to find ways to construct consensus, develop common goals and share problem-ownership.

The literature search provided 14 alternative definitions of concept design, and we also identified a wide range of published ‘design methods’ which we condensed down into a small set of simplified ‘team thinking tools’. These were embedded in the web-based decision support system described below.

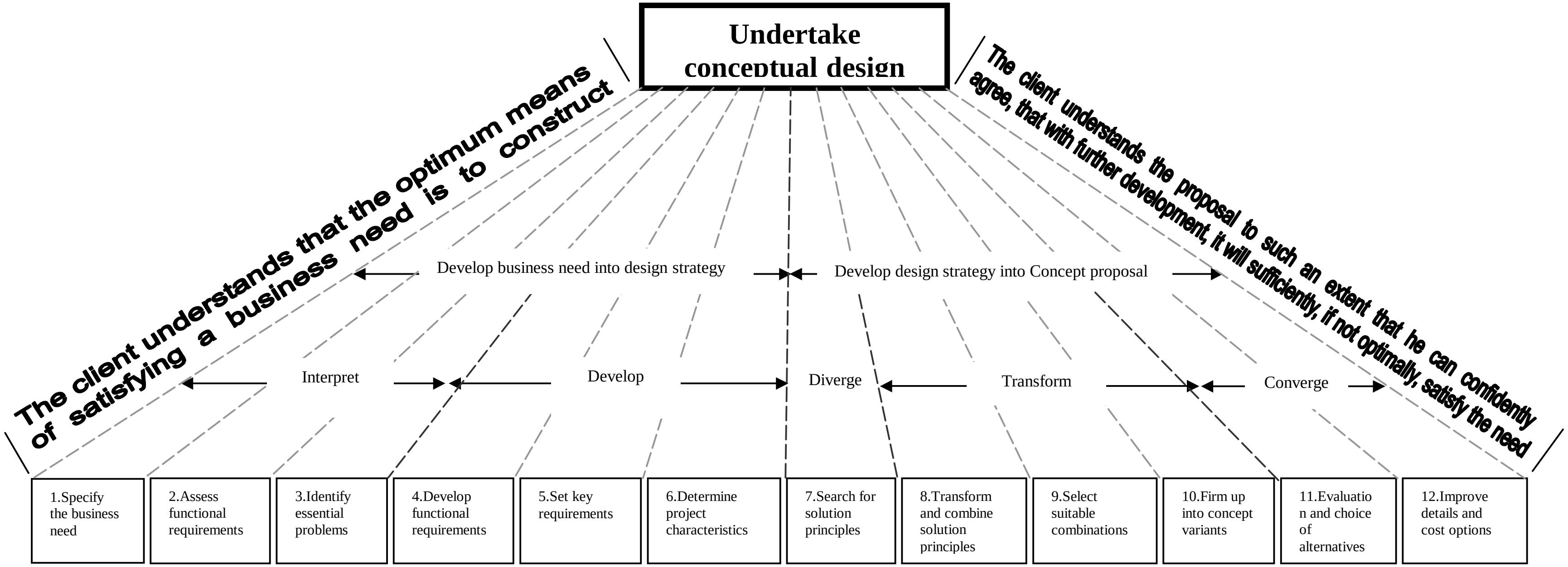


Figure 1 The conceptual design framework model

INTERVIEWS, AND OBSERVATIONS OF DESIGN MEETINGS

A study of the attitudes of practising designers towards concept design within AMEC and the other collaborating organisations was undertaken using questionnaires and interviews. A past project was the subject of these interviews, whose aim was to clarify the main issues and concerns at the concept design stage. In addition, design team meetings for a live design project were monitored, and post-meeting interviews were held with design team members. This primary data supplemented the literature search and, together formed the basis for a new paper-based framework for the concept stage of design. This comprises 12 activities in 5 phases, and is shown in Figure 1.

FIELD TRIALS OF THE FRAMEWORK

The framework for conceptual design was subjected to field trials in two design workshops. The first was held over two days in September 1998 and comprised three interdisciplinary teams of five designers working on a building re-cladding problem. The workshop acted both as training workshop for the main industrial collaborator in this research project – AMEC Design & Management – and as a means to test the framework. The framework proved valuable for classifying design activity and for tracking the strongly iterative nature of the design process. It was noticeable that one activity had been omitted from the framework – team management. Successful self-management by the team appeared to be a key factor of successful design team working.

A second workshop held in January 1999 also comprised three teams of five designers, this time drawn from all the collaborating organisations. Again three interdisciplinary teams were formed and their activities tracked. This time the monitoring data was supplemented by questionnaires about the design process framework and the teams' opinions of their performance. We found that designers perceive they have performed better as a team when they agree on, and subsequently follow, a design process, although (in our very limited sample size) there was no necessary correlation with the quality of design concept as assessed by independent judges. We also noted an interesting link between process and product – one team consciously chose to produce a kit of parts solution, and the team members then worked relatively independently. Another team's solution was more integrated, and this was reflected in their design process.

RECORDING DESIGN ACTIVITY IN GRAPHICAL FORMAT

A graphical format – a bar chart – was used to record the design activity at the workshops, which shows how the activities change over time. This has proved particular valuable to record the iterative behaviour of the design team. While design has always been recognised as a highly iterative procedure, we have begun to look for the patterns among the iterations and are moving to a way of recording the extent of the iterations.

Considerable effort in observation of the team and classification of its actions is required to construct this chart. We have experimented with self-monitoring, in which a member of the team is delegated to sample the team's activity at regular intervals. We have several reservations, methodologically, about doing this, not least the accuracy of the recording and the impact of the recording task on that person's contribution to the team's efforts. However, to explore these effects is beyond the scope of the present research. Our interactive decision support tool (discussed below) may enable activity sampling to be performed with little or no intervention.

By annotating the bar chart, as shown in Figure 2, we can very quickly provide an overview of the activities of the team and the drivers that lie behind the design process. From the two workshops we have built up a set of six similar annotated charts.

A final design workshop was held in February 2000 at Heathrow Airport at which seven members of a design team spent a day designing a pier of a £100m airport terminal. The project has yet to receive final approval so the workshop was still ‘off-line’, but it represents the closest we were able to get to working with a design team ‘on-line’. This event provided a seventh example of a pattern of progression through the twelve activities.

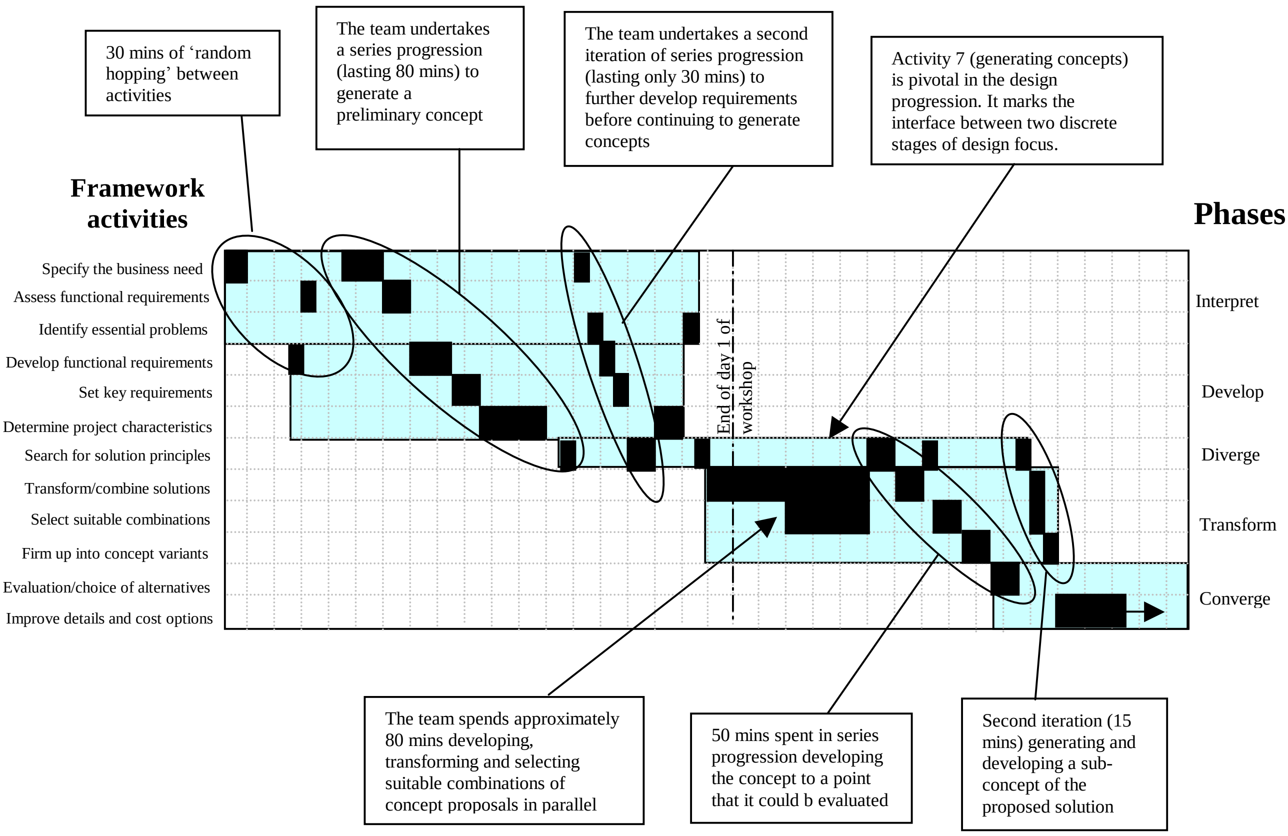


Figure 2: Pattern of progression for Team 1, Workshop 1

INTERPRETING THE PATTERNS OF PROGRESSION

Although we have annotated all seven design processes, space restrictions preclude reproduction of all of them. What conclusions can be drawn from them? The first thing we noticed was a clear tendency to step forward one activity at a time – but to step backwards across many activities in a single leap. We termed this ‘one step forward but three back’ (Steele, Macmillan, Austin, Kirby, and Spence, 2000).

Figure 2 also shows how this team, having gradually reached activity seven, the *search for solution principles*, went back to activity one but, having done so, quickly worked through each stage to get back to activity seven. Again we have speculated that the may be a difference between parallel (1) and series (2) focus, as illustrated in figure 3.

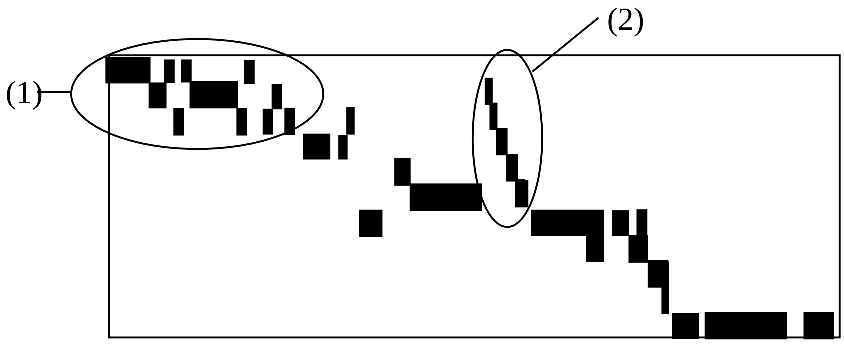


Figure 3: Parallel and series activities

Although we have emphasised the idea of step progression, we do have examples of a speculative leap to a design solution, as illustrated in Figure 4.

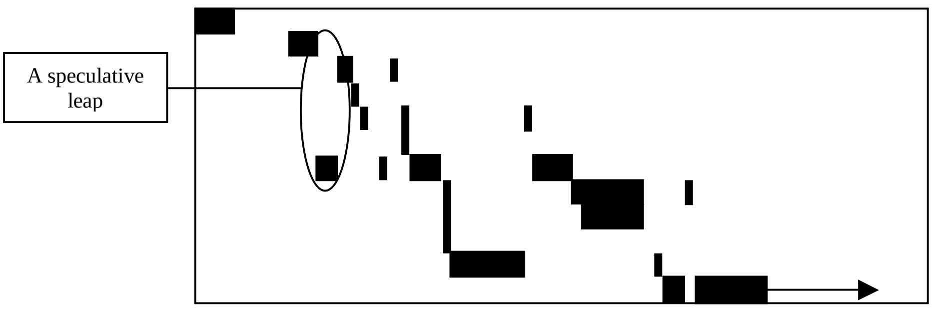


Figure 4: A speculative leap (team 6 in workshop 2)

We have also looked at gradients of the iterations, figure 5.

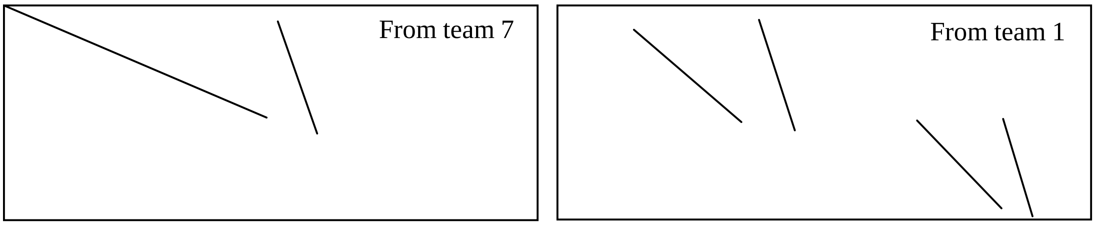


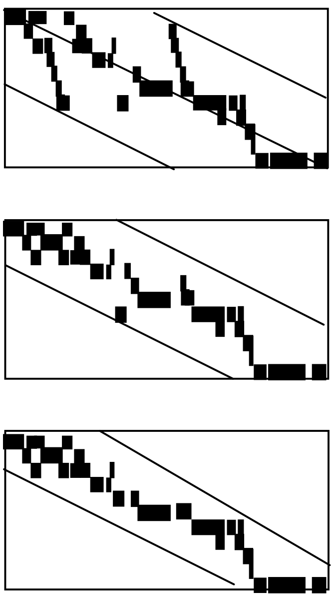
Figure 5: Gradients of iteration

Here we note that often the gradients are shallow for the first pass through a set of activities, and steeper the second time. This appears to be because there a learning process occurs as the team passes through the activities for the first time and the second iteration is therefore much more rapid. We do have examples of the converse, where the first pass is at a steep gradient, but is followed by a second shallower iteration. We do not know the precise cause, but believe this is because the team rushes ahead too rapidly and then has to go through a more reflective iteration. More detailed explanations of these patterns can be found in Steele, Austin, Macmillan, Kirby and Spence (2000a)

THE IMPLICATIONS FOR ARCHITECTURAL MANAGEMENT

Our study has been carried out primarily to understand rather than to control the design process. Nevertheless we are aware that the patterns of iteration could be used to help designers understand their own processes better. Designers have found our iterative patterns easy to understand and assimilate, and when faced with them are able to discuss and expand on the causes of iteration. (Unfortunately we were not able to do this in real time in the workshops as the graphs take some time to draw up.) We believe these patterns could help designers to become more self-reflective.

Besides encouraging self-reflection, a further use of these patterns could be to manage and steer the design process. What we might expect in design is that the degree of iterative behaviour would correlate with the experience of the team and the difficulty (or ill-structuredness) of the design problem. Figure 6 introduces the idea of ‘bandwidth’ in the progress through design activity. The first diagram illustrates how, with a new team and/or an ill-defined problem, high degrees of iterative behaviour – large bandwidth - may be expected. In the case of a well defined problem and an experienced team, bandwidth might be much lower. The middle diagram shows intermediate bandwidth. Potentially such bandwidths could be used in the management of design teams.



New team and/or ill defined problem, high levels of iteration expected – larger allowable bandwidth before questioning.

Problem type addressed before; iteration expected but knowledge is growing – smaller allowable bandwidth but iteration still expected to some extent.

Well defined problem faced by experienced team – tight bandwidth. However, iteration still expected, as all problems are unique to some degree.

Figure 6: the use of ‘bandwidth’ to assess design team activity

INTERNET BASED DECISION SUPPORT TOOL

The framework in figure 1 was developed into an interactive internet-based prototype design support tool, written in HTML (see figure 7). This language accords well with the richly iterative and often non-linear process which design typically follows. The tool is intended to encourage and stimulate inspirational concept design without imposing a rigid procedure. It can be entered at any of the five main phases - interpret, develop, diverge, transform, converge. Users are asked a challenging question at each activity stage – for example, “Is the team aware of the client’s priorities among competing objectives” which are intended to discover whether they feel confident of having completed a particular activity and are ready to move to another. Whatever their response they are at liberty to move to any other activity they choose. By default the system will guide them to the next activity.

Where the team lacks confidence to move forwards, the system offers assistance. The ‘team thinking tools’ embedded within the system can be called up. Based on the ‘design methods’ literature, these can help the team:

- to broaden the solution space through divergent search methods,
- to set priorities among competing objectives, and
- to evaluate options through ranking and weighting procedures.

In addition to offering guidance and tools, the system contains advice about team management issues – the negotiation of roles, rights and responsibilities. The system supports 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

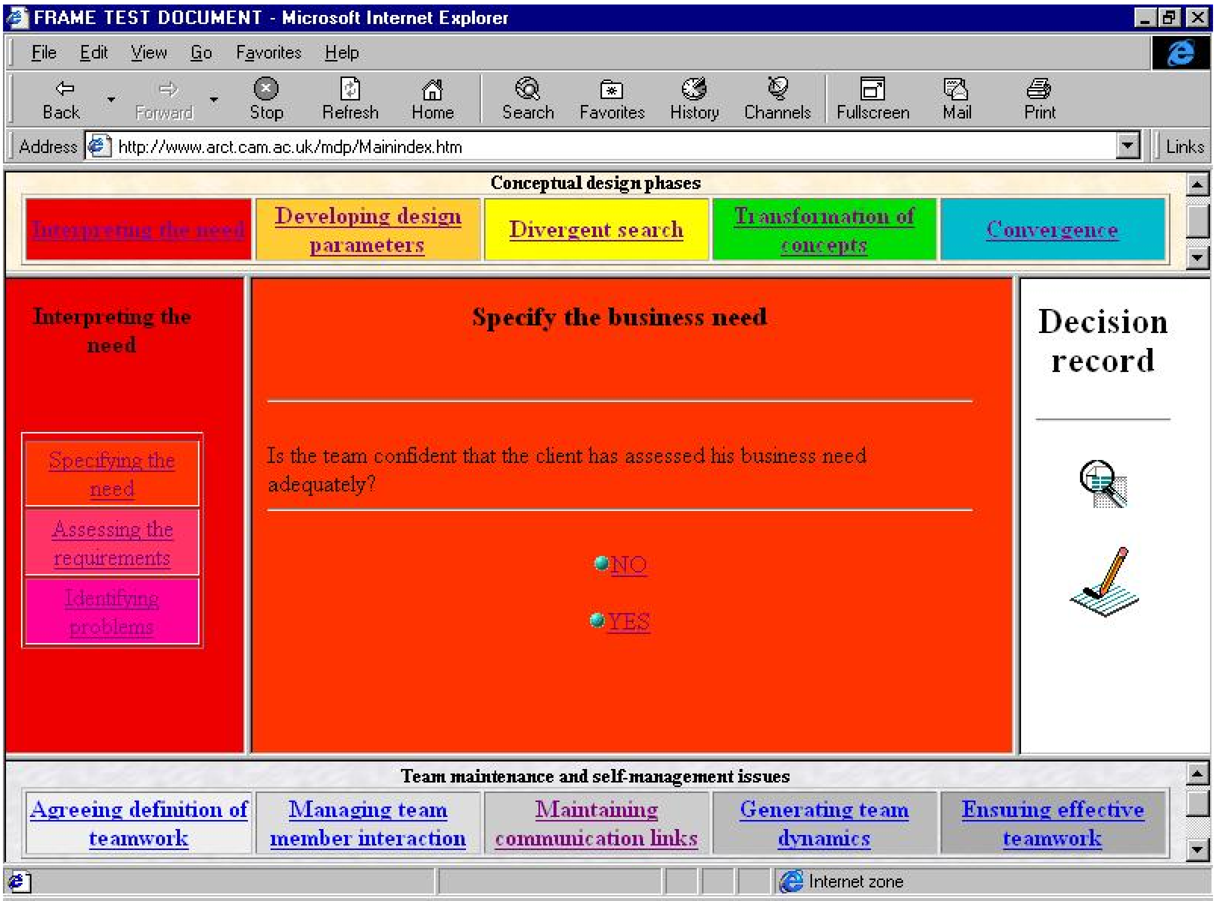


Figure 7: Opening page of the HTML model

This information is drawn from a previous project at Cambridge called Achieving Quality through Interdisciplinary Teamwork in Design which reviewed the management science literature on effective project teams and carried out three case studies – all of which led to the identification of good practice.

The final feature of the system is the possibility of recording decisions during each of the stages or activities. At the user's option, a record may be made of who took a decision, who else contributed, the justification or reasoning behind it, and the information sources used. Use of this facility results in a database of key project decisions and their rationale. The capture of this information, together with its storage and retrieval, have the potential to be extremely valuable both within the project, and to other similar projects. Such information could facilitate design reviews, provide an audit trail of decision making, and contribute to the management of knowledge within organisations. These facilities have not been fully implemented in the prototype, but they are not technically difficult.

The prototype was demonstrated to all the industrial collaborators in their respective offices during the autumn of 1999, and it was revised in the light of their feedback. It was demonstrated to the design team at the Heathrow workshop in February 2000 and was then made available to the team with a facilitator to run it on the team's behalf. On the whole, the prototype was well-received. However, this particular test indicated that, as it stands, the system focuses too much on the gates between each of the activities and too little on the issues and decisions within each activity. The team did undertake an evaluation of competing alternatives by ranking them, but the embedded 'team thinking tool' to do this was considered too cumbersome to use and was ignored. A more detailed explanation of the design tool and designers' responses to it can be found in Steele, Austin, Macmillan, Kirby and Spence (2000b)

Further testing in less condensed circumstances than a one-day design workshop is dependent of the take up and exploitation of the design tool by the industrial collaborators. We have made it available on a web-site at the Department of Architecture at Cambridge, from where it may be freely used provided its source is acknowledged. The address is: http://www.arct.cam.ac.uk/mdp, user name: *mdp*, password: *hmitditw*. The research team would welcome constructive feedback about it from anyone who attempts to use it – whether successfully or not. Feedback should be emailed to the first author of this paper using the address: sgm24@cam.ac.uk.

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