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MAPPING THE EARLY STAGES OF THE DESIGN PROCESS - A COMPARISON BETWEEN ENGINEERING AND CONSTRUCTION

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1 Introduction

The conceptual stage of a construction project is a vibrant, dynamic and creative period. Ideas are generated rapidly about the nature of the project, the requirements and desires, and potential solutions. But this period can also be disorganised and even chaotic; there are many uncertainties about the project, and the risks are high. Design team members may be unfamiliar to each other and unaccustomed to one anothers' ways of working. Maps of the design process are intended to obviate the need for the design team to re-invent the process each time, and to contribute to a working environment in which good design can flourish.

Several process maps already exist for construction. One of the best known in the UK is the Plan of Work published over 30 years ago by the Royal Institute of British Architects, and whose terminology continues to be used throughout the industry. Recently other maps of the process have begun to emerge, some from industry, others from academic institutions. Neither the RIBA Plan of Work, nor more recent maps, give in-depth support to the concept phase.

At the Department of Architecture at Cambridge University we are working with a number of construction industry firms (AMEC Design, BAA, Hotchkiss Ductwork Ltd, Hutter, Jennings & Titchmarsh, Matthew Hall, Pascall & Watson) on *Mapping the design process during the conceptual phase of building projects*. The project runs from April 1998 to March 2000 and is funded by the UK Engineering and Physical Sciences Research Council. Loughborough University is also involved in the project. It focuses on two areas: i) the collation, evaluation and potential transfer of established mapping methods and design techniques at the concept stage from engineering and other industries to construction; and ii) the refinement, testing and exploitation of these design techniques by construction industry designers.

2 Research Aims

We began by collecting examples of process maps which concern the early (or concept) stage of design, from both construction and engineering. (We had intended also to obtain maps from the aerospace, automotive and petrochemical industries, but this has proved difficult in practice.) In this paper we present a comparison of the process maps collected so far from engineering and building design. We compare both the overall processes, and the conceptual phases in particular. We also present an outline of our own newly-developed map of the sub-phases of conceptual design in construction. Subsequently we intend to test the adequacy and the value of this model in the construction industry.

3 Maps of the overall design process

Figure 1 compares ten maps of the design process from construction and engineering. Each model i) describes a sequence of phases which, typically, imply iteration within phases but not between one phase and another; ii) shows progression from broad outline to elaboration of detail; iii) implies 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); and iv) has comparable, though not identical, terminology.

BAA Project Process (1995)	Inception	Feasibility	Concept design	Co-ordinated design	Production information			
Salford Process Protocol (1998)	Demonstrate the need	Conception of need	Outline feasibility	Substantive feasibility & outline financial authority	Outline conceptual design	Full conceptual design	Co-ordinated design, procurement & full financial authority	Production information
RIBA Plan of Work (1969)	Inception	Feasibility	Outline proposals	Scheme design	Detail design	Production information		
MOD 'Working Document' (1997)	Inception	Definition & qualification	Concept design	Detail design				
CIRIA 113 (1995)		Feasibility and briefing	Scheme design	Production information				
BS: 7000 (1989)		Feasibility	Concept design	Embodiment design	Detail design	Design for manufacture		
Hubka (1982)		Elaboration of assigned problem	Conceptual design	Laying out	Elaboration			
Pahl & Beitz (1988)		Planning and Clarification of the task	Conceptual design	Embodiment design	Detail design			
VDI 2222 (1973)		Planning	Conceptual design	Embodiment design	Detail design			
French (1971)		Analysis of the problem	Concept design	Embodiment of schemes	Detailing			

Figure 1. Comparison of full phase models of design

Typically, although there are exceptions, the maps i) set out only what should be undertaken, not why or how it should be done; ii) do not define what is to be done separately by different team members and what needs to be done in collaboration; and iii) limit their concerns to the problem requirements and their solution. They 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. Also, the building design models include an initial feasibility phase – which engineering models seem to exclude.

4 The conceptual design phase

Figure 2 compares existing models of the conceptual design phase. Here we note the following: i) All the models start by an analysis of requirements – none starts by taking an existing concept and modifying it to suit new needs; ii) Few of the models explicitly encourage the generation of alternative concepts for evaluation – most imply convergence to one solution quite early in the process; iii) Engineering models subdivide the concept phase into a number of sub-phases to be undertaken sequentially; in contrast, building design models do not have the sub-phases mapped; and iv) No reference is made about how to generate concepts - none of the models makes explicit reference to techniques for stimulating a wider solution space, or to formal measurement, evaluation or assessment methods.

BAA Project Process (1995)		Concept design studies			
Salford Process Protocol (1998)	Prepare outline concept designs				
RIBA Plan of Work (1969)	Outline proposals				
MOD 'Working Document' (1997)		Specify functional needs	Generate and prepare design options	Select design options for development	Develop and cost options

<table>
<tr><td>Markus and Maver (1970)</td><td colspan="4"></td><td colspan="7">Analysis</td><td colspan="6">Synthesis</td><td colspan="2">Evaluation</td><td></td></tr>
<tr><td rowspan="2">Hubka (1982)</td><td colspan="5" rowspan="2"></td><td colspan="6">Establish Function Structures</td><td colspan="6">Establish Concept</td><td colspan="3" rowspan="2"></td></tr>
<tr><td>Establish function structure</td><td>Establish technical process</td><td>Apply technical systems and establish boundaries</td><td colspan="2">Establish groupings of functions</td><td>Establish functional structure and represent</td><td>Establish inputs and modes of action</td><td>Establish classes of function carriers</td><td colspan="3">Combine function carriers and examine relationships</td><td>Establish basic arrange-ment</td></tr>
<tr><td>Pahl & Beitz (1988)</td><td colspan="3"></td><td colspan="2">Identify essential problems</td><td colspan="6">Establish function structures</td><td colspan="2">Search for solution principles</td><td>Combine solution principles</td><td colspan="2">Select suitable combin -ations</td><td>Firm into concept variants</td><td colspan="2">Evaluate against technical and economic criteria</td><td></td></tr>
<tr><td>Cross (1989)</td><td colspan="2"></td><td colspan="3">Clarifying objectives</td><td colspan="2">Establishing functions</td><td>Setting requireme-nts</td><td colspan="3">Determining characteristics</td><td colspan="6">Generating alternatives</td><td colspan="2">Evaluating alternatives</td><td>Improv -ing details</td></tr>
<tr><td rowspan="2">Jones (1992)</td><td colspan="11"></td><td colspan="2">Divergence</td><td colspan="2">Transformation</td><td colspan="4">Convergence</td><td rowspan="2"></td></tr>
<tr><td colspan="5"></td><td colspan="2">Design situation explored</td><td colspan="3">Problem structure perceived and transformed</td><td colspan="4">Boundaries located, sub-solutions described and conflicts identified</td><td colspan="2">Sub-solutions combined into alternative designs</td><td colspan="3">Alternative designs evaluated and final design selected</td></tr>
<tr><td>Prelimin ary research model</td><td>Spe-cify the need</td><td colspan="3">Assess the require-ments</td><td>Identify essentia -l proble-ms</td><td colspan="2">Develop the requirements</td><td colspan="2">Set key requirements</td><td colspan="2">Determine project characteristics</td><td colspan="2">Search for solutions</td><td>Trans-form & combine solutions</td><td colspan="2">Select suitable combinati-ons</td><td colspan="2">Firm into concept variants</td><td>Evaluat -ion and choice of alternat -ives</td><td>Improv -e details & cost options</td></tr>
</table>

Figure 2. Comparison of conceptual design phase models

Additionally, none of the models of the building design process succeeds 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 shared goals, objectives and problem-ownership.

From our analyses of existing maps of the design process, we have devised a 12-phase model, shown as the last row in Figure 2. This exists also as a simpler 5-phase description and at a deeper level, some 40 phases. We are now beginning to test this with practising designers, initially in controlled workshop sessions, and subsequently on live projects.

5 Conclusions

Initial testing of our model suggests: i) the exchange of information is rapid, dynamic and unpredictable during the conceptual design phase; and there is little benefit in trying to model it at this early stage, although it becomes more valuable to model it subsequently; ii) while locating information and providing deliverables are important to all phases of design, the concept stage is largely concerned with making decisions and reaching agreement - this needs to be reflected in maps of this part of the process; iii)as well as addressing formal issues such as identification of decision points and key design drivers, this phase should also address social interaction, collaboration and communication; and iv) the sub-phases do not simply follow sequentially, but instead are highly iterative.

For these reasons we are proposing that our map of the conceptual phase needs to be flexible - in the form of a contingency model which allows the user to follow various alternative pathways through it depending on the needs of a particular project and its design team.With low cost computing now readily available, we believe that such a model can usefully be built using HTML or a similar approach. This would allow the design team to choose the order in which they address the sub-phases and positively encourages iteration.

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