DEVELOPMENT OF A GENERIC DESIGN DECISION PLANNER

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We have developed a design decision planner which is totally generic and independent of how the design process is modelled or organised and can be used to plan the design stages, their timing and to identify resources and information inputs required. This is the final outcome of the research project on controlling innovation in construction design (interim results were presented at ARCOM 1998).

An electronic data gathering tool (EDGT) was developed and used on three 'live' building projects (one of which was an Egan Demonstration) to capture design decisions as they took place and examine who took them, on what basis, using what information sources and under what constraints.

It is apparent that, at the system and sub-system level, the process of decision making follows a characteristic 'S' curve when plotted against normalised time and that more than 70% of decisions are generic although the sequence can vary from project to project. On a day-to-day basis design decision making is a highly iterative process not easily described by a single model.

Key words: design, modelling, process, planning, innovation.

INTRODUCTION

These are the final conclusions of a LINK-IDAC project (funded by EPSRC, DETR and industry collaborators) on Controlled Innovation in Construction Design.

This project was concerned with improving the design decision making process by gaining a greater understanding of how the decision making processes work in construction so that they can be monitored, controlled and, hopefully, improved. We are considering the decision making process, not the technical design issues, and therefore we need to understand who takes decisions, when, on what information, taking account of what constraints and considering what design options.

Our approach to this has been to develop a software based tool to record and monitor design decisions as they were made, apply the tool to a number of 'real' project design situations and evaluate the outcome in terms of what generic lessons we can learn (if any to help improve the design decision making process by offering guidance for a consistent approach to decision making.

The first step in the project was the development of a software tool (the Electronic Data Gathering Tool) which can be used by design teams to record decisions as they are made. The development and operation of this software tool has been described elsewhere (Morris et al, Sept. and Oct. 1998).

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This paper, therefore, contains the results of the use of this software tool on three 'live' construction projects (one retail development, one shopping centre refurbishment and one airport terminal building) and the generic conclusions we can draw from the close analysis of the design decision making processes in each case. These generic conclusions lead us then to proposing a step-by-step guide to planning and managing the design decision making process in construction.

MODELLING THE DESIGN PROCESS

It is frequently stated that construction is 'unique' because it is organised on a 'project' basis with a different team and different, project specific, supply chains for each construction project. This may be so but many of the lessons developed in manufacturing management over the last decades are applicable with advantage. Indeed, Egan (1998) expressly sets targets for the construction industry on the assumption that manufacturing management lessons can be applied. Experimental results (e.g. Darazentas et al, 1998) demonstrate that this is a reasonable assumption.

Design (including the briefing stage) is crucial to construction (every building is to some extent a prototype) so there have been a number of attempts to model the process (Cooper et al, 1997) which parallel quite closely the models for the product introduction process in automotive (Schoper 1997) and aerospace industries (Parnaby 1995) with 'gates' to help manage the process. These are good models in the sense that they provide an understanding of the main elements of the process but, from a management and control point of view, one that is not really an advance on the conventional RIBA stages (RIBA 1992). At the detail level, design takes place in a less linear form. The concepts of Suh (1990) and Albano and Suh (1994) are more appropriate as they treat 'design' as a continuous iteration between different domains (functional, physical and process).

Our experience is that this is a more accurate way of describing how design decisions are actually made so we have taken this 'model' as the philosophy to follow. It has another advantage in that it describes the design process without making any assumptions about how design is managed and what contractual relationships apply. In the context of the construction industry, its varied contractual formats and different key players (architects, consultants, contractors, quantity surveyors, clients) this is an important advantage when trying to analyse the decision making process.

DATA COLLECTION ON DESIGN DECISION MAKING

During the time scale of this research project it was possible to follow through, in detail, the design stages of three construction projects. All three were dissimilar (see Table 1 for details) but, as we shall see from the results, exhibited sufficient commonality in the type of decisions made to permit the formulation of a generic guide to design decision making (a design planner). This guide can be modified and refined as more design data becomes available. One of the project, the airport terminal building (London Gatwick South Terminal Extension), was identified as an 'Egan' demonstration project as it was carried out under the BAA 'partnership' principle.

In each case the software tool was loaded onto the system at the relevant design office and a designated member of the design team was responsible for recording and entering data onto the system as the design activity progressed.. Each of the people collecting data was involved in, or close to, the design decision making process.

Regular visits were made by Cranfield staff to monitor progress and download results for analysis. A great deal of prior effort was spent in simplifying the tool and adding features which the design teams could use for other purposes (QA records for example).

Table 1: Building details and construction planning outline for the case studies

Project type	Refurbishment/ Construction	Extension of existing facility	Construction
Building type	Retail	Airport building Retail/operational areas (sitting, transfers)	Supermarket
Location	Essex.	Gatwick Airport	Lincs.
Type of contract	JCT 80	BAA specific based on New Engineering Contract – multi-contractor version (with suppliers).	Design and Build.
Length of phase			
Planned Constr.	9 months.	22 months.	6 months.
Pre-Engineering.	Steel frame components fabricated off-site during contract.	Pre-formed service modules - piping, duct work, cables.	Steel frame (arrives on-site as a kit ready for construction). Windows – units made up railing features for boundary wall, all the soffits, eaves and facias for roof pre-fabricated, painted off-site.
Level of Innovation:			
Design	Medium	Medium	Medium
Materials	Low	Medium	Medium
Assembly	Low	High *	Medium
	* High – people on board, contributions to design, programme and cost implications, process mapping – selections made on basis of cost and programme after function.		

The data collection concentrated on ‘system level’ decisions (typically there will be 80 – 100 such decisions in a building) and in each case we wanted to know:

Who made the decision?

When it was made?

How it was made (designer acting alone or a group decision)?

What information sources were used (prior design information, client instruction, etc.)?

What constraints controlled the decisions?

What design options were considered?

From this we could get a very comprehensive picture of the decision making process as it took place. This, of course, took into account all the iterations which occurred and clearly demonstrated the appropriateness of the Albano and Suh approach to design characterisation.

Data was collected in the form of tables for each case study. The main table for each project consisted of 132 information fields and from 83 – 98 records, 1 for each system/sub-system level decision recorded.

DATA ANALYSIS

Matching Data

One of the most important data processing issues for this study was identifying which of the design decisions were ‘equivalent’ across the case studies. Some were quite easy to establish, for example, the choice of material for the frame. Others were far more difficult because each of the data collectors had their own style for phrasing the decisions that had been made.

For the purposes of establishing equivalence between design decisions across case studies, each of the data collectors was asked to match his decisions to the decisions made in the other case studies. This worked surprisingly well as all data collectors reinforced each others’ decision matching, with only a few discrepancies. Having overcome the problem of matching decisions, the second issue of design hierarchy had still to be addressed. The hierarchical nature of the decisions was only a problem with respect to processing the data. The three sets of data were matched as three pairs: Essex – Gatwick, Essex – Lincs and Gatwick – Lincs. Where, for example, one Essex decision was equivalent to three Gatwick decisions, two additional, identical, records were created for the Essex case study, with each of the three Gatwick decisions being matched to one of them.

Decisions Superseded

In both the Essex and the Gatwick case studies some decisions were superseded by later decisions. This is indicative of design iteration. The tool did not seek to investigate this phenomenon in detail, however, therefore a number of iterations may have occurred before some of the decisions were finalised. It is this finalised decision in most instances which the tool captures, which means that some iterations were not recorded.

The Design Period

For the purposes of producing normalised time graphs the ‘design period’ had to be defined. Originally, the design period was taken to run from inception to the date that the contract placed. Because of the different contractual arrangements for each project, BAA framework, design and build and a more traditional procurement route, this led to distortions in the data. Therefore we have defined the design period as 0 – representing the ‘inception of the project’ and 1 – representing the ‘date that the last system / sub-system level design decision was made’. The only exception is for Gatwick. Because work was performed on the Gatwick project as part of the internal decision making process of the client body, the design period for this case study is defined as 0 – representing the start of ‘feasibility’ and 1 - representing the ‘date that the last system / sub-system level design decision was made’.

DEDUCTIONS FROM THE DATA ANALYSIS

A very large volume of data was collected and analysed and it was possible to deduce a number of generic issues on construction design decision making including the issue of information flows and appropriate IT systems.

Most importantly though, we can make some credible assumptions about construction design decision making in general which leads to a generic, step-by-step guide to design decision planning.

DECISION COMMONALITY AND CHRONOLOGY

Matching equivalent decisions between projects allowed an assessment to be made of the amount of commonality that exists in the design decision making process. The generic content between each pair of case studies was found to be between 73% - 80%, at the system / sub-system level. This is an important finding as it contradicts the commonly held assumption of the uniqueness of each construction project. This statement is not without qualification, however, as the detail of each project is specific to each design, but the importance of the finding resides in the knowledge that whatever project is to be undertaken 73% - 80% of the *types* of decisions that have to be made are the same.

Fig. 1 shows the cumulative count of system/sub-system level design decisions made for each of the three projects. Each graph shows only the incidence of when a decision was made and makes no attempt to reconcile *what* decisions were made. The graphs all have the characteristic ‘S’ curve shape with very similar parameters. All three case studies had very slow starts, with less than 5% of the design decisions made by 20% of the total design period. Between the curves there are quite larger tolerances, for instance at approximately 50% of the design period the Essex project has made approximately 40% of the design decisions whereas the Lincs. project has made approximately 60% of the design decisions. Interestingly there are a number of crossing points which illustrate that a particular project does not always ‘lead the way’.

This suggests that although there is a large generic component of design decisions, there is also a large degree of variability in how and when these decisions are made. This suggests the possibility of establishing an approach to planning and monitoring construction design which ensures that designers consider all the decisions which have to be made, the timing and ordering of the decisions, whilst not prescribing a rigid route that does not allow for those aspects of the project which are indeed unique. This approach could incorporate Latham’s (1994) idea of clearly defined design responsibilities by assigning each decision to be made to a particular discipline. In its simplest form this would be a list of decisions to be made, the timing of the decision (and hence the order) and name of the person responsible for making the decision. This could be developed further by adding in the tasks which need to be performed to make that decision, the information to be gathered and the tools which should, or could, be used to support the decision making process. The decisions, which have been found to be generic, would provide a starting point, with project specific decisions identified by the design team. At the same time the design team would have to work out the timing, order and responsibility for each decision based on a mixture of experience and tools - Design Structure Matrix (DSM) for example. Monitoring progress against planned activity would provide a performance metric which could be used as a basis for discussion for project managers. A long-term consequence of using a tool developed on this basis is that individual designers may elect to follow the same decision pattern regularly to help them to control the process better. This would leave more time and energy to concentrate on the truly creative aspects of construction design, as the approach to design, not design itself, would become routine. This is one way in which a standardised approach to construction design could be achieved without inhibiting architectural freedom. This would lead to a better controlled design process, not ‘controlled design’. We therefore have confidence to establish structured guidance for design decision making.

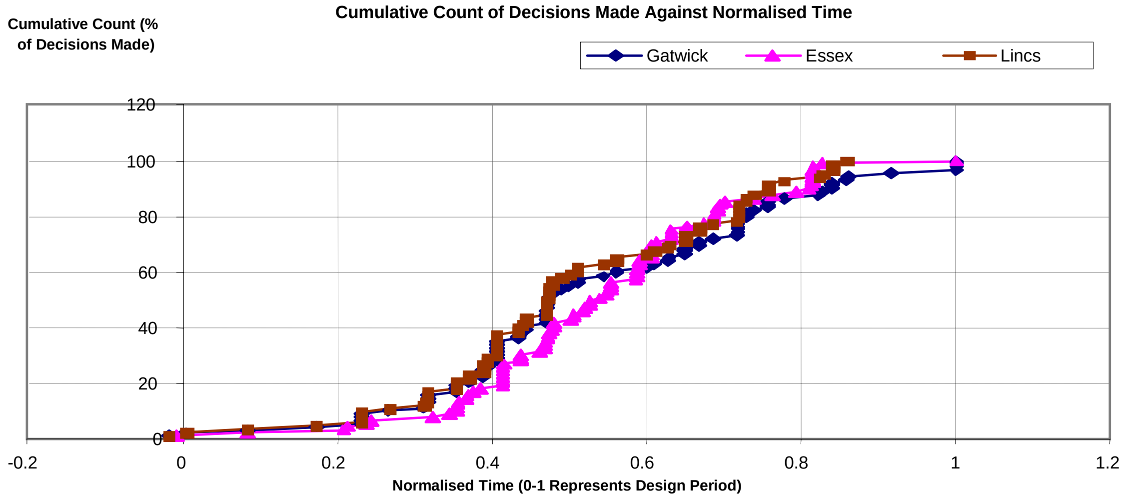

Figure 1: Cumulative count of decisions made against Normalised time (all three case studies)

A DESIGN DECISION PLANNER

Design is a highly iterative process so the actual design paths taken in a project are difficult to predict in detail and perhaps impossible to model in a generic way. But there are generic system level steps for which we can provide clear guidance, whatever the structure of the design team, the form of the design contract or the technical issues to be decided.

We can make four major, generic statements about construction design on the basis of this research project:

Irrespective of other factors and whatever the composition of the design team, the organisational set up or the type of contract, the process of design decision making follows a characteristic ‘S’ curve when plotted against time. The parameters of this curve only vary between narrow limits

More than 70% of the design decisions at the system and sub-system level are common although the sequence of decision making can vary from project to project.

The most common drivers for design decisions are functionality, cost and interface issues.

Design decision making on a ‘day-to-day’ basis is a highly iterative process not easily describable by structures, which have a consistent relationship to the established ‘macro’ models of the design process, which are used as high level abstractions to depict the main design output stages.

We can therefore develop a 5-stage ‘design decision planner’ (Rogerson et al, Sept. 1999) which is completely generic and which can be used to plan the design stages and their timing and identify the design resources needed and information inputs required. This planner can be used at different levels of sophistication and can be continually refined and made more accurate with use and as design decision records and databases are built up. Briefly, the decision planner operates by the user following through the 5 stages.

Identify the time-frame allowed for the design stage from initial client contact to design completion.

List the decisions to be made at system and sub-system level (typically 80-100 decisions for a building).

Produce a table of the number of decisions (not the actual decisions) against time in steps of 10% of allowable design time-frame.

Order the decisions in terms of the available skills, resources, information and constraints at the appropriate stages of decision/timetable.

Produce a final table of decisions/time-scale.

The key issue of ordering the design decisions can be done on the basis of experience or by more formal, structured methods such as Design Structure Matrix techniques (Austin 1999).

The complete design decision planner (available from Cranfield University) includes comprehensive guidance notes and a worked example. Guidance is given on the following issues:

Identification of Time-frame

This will be set by the client requirements/contractual situation. For the purposes of this design guide the time -frame should be considered as starting with first client contact which leads to significant design work by the design team (whether or not a contract with the client has been signed) ‘inception of the project’ and ending with ‘completion of design work). This end point may sometimes be difficult to define but approximates to the end of stage H in RIBA categorisation as all major system level decisions should have been made by this time. Subsequent design decisions and changes (which may continue well into the build stage) would be design ‘refinements’, process driven modifications or detail issues.

It is up to the design authority to define the time-frame and hence the actual decision making curve. This therefore provides the facility to plan to improve design productivity by shortening the planned timescale.

Listing Design Decisions

It is not necessary at this stage to consider who makes these decisions or on what basis of authorisation or approval. These issues only become significant when the ordering of the decision is to be defined.

Although each building is necessarily unique, it would be normal to need to list 80-100 decisions at the system or sub-system level.

Defining Timing of Decisions

Table 2 lists the number of design decisions which (expressed as a range) must be made by each 10% of the allowable design time-frame on a normalised basis. Using this table it is then possible to produce a table of number of decisions to be made against planned ‘real’ time for a given project. Note the ‘bunching’ of decisions over 0.3 - 0.6 of design time period. This clearly has resource implications.

Ordering of Decisions

The listed decisions (Step 2) must now be put in the correct order against the required timescale. In some cases the sequence is obvious but in others it is not so. Also, many decisions are not inter-dependent and the order in which decisions are made is not critical from a technical point of view.

For each project, the sequencing of design decisions is likely to be different. The form of contractual arrangement may well, of course, be relevant in this regard as will be the need to take into account issues such as CDM, safety and environmental impact on many decisions and their inter-dependencies.

Table 2: Number of decisions to be made for each 10% of design timescale

Normalised Time	Cumulative percentage of system level design decisions to be completed (lower boundary)	Cumulative percentage of system level design decisions to be made per interval
0 - 0.1	5% (2%)	5%
0.1 - 0.2	10% (4%)	5%
0.2 - 0.3	20% (7%)	10%
0.3 - 0.4	40% (20 %)	20%
0.4 - 0.5	60% (41%)	20%
0.5 - 0.6	80% (63%)	20%
0.6 - 0.7	90% (79%)	10%
0.7 - 0.8	96% (90%)	6%
0.8 - 0.9	98% (95%)	2%
0.9 - 1.0	100% (100%)	2%

Methods for Ordering the Decisions

Hierarchical: Design decisions can be ordered in a logical way using a simple decision tree. This can be used in the absence of information to make other choices, but is not likely to be ideal as it ignores the necessity for iterations as part of design development.

Experience Based: An alternative is to take an initial, hierarchical decision order and modify it in the light of experience and project-specific conditions. This, ultimately, relies on the building up of a database of design decisions using, perhaps, a simplified version of the EDGT.

Structured Analysis: A further refinement and, ultimately, more rigorous approach, is to use formal decision making techniques such as ADEPT (Austin et al, 1999).

CONCLUSIONS

Recognising that each construction project is ‘unique’ to some extent and that design is a very iterative process, we can see that trying to model the design process in great detail in a generic sense is not feasible. However, by recording and analysing the design decision making process in some detail using our EDGT does allow us to provide generic guidance to design decision making.

A simple-to-use 5-stage design decision planner allows design teams to plan and monitor the sequencing (including planning resource implications) of system level decisions (the 80 – 100 main design decisions) whatever the composition of the design team or the contractual arrangements. The planner can be continuously modified and refined on the basis of experience and use.

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