THE CONCEPT OF MODELLING IN ARCHITECTURAL DESIGN

Professor T.W. Maver

ABACUS – University of Strathclyde – Glasgow, UK

1. Introduction

Design drawings were introduced into architecture about 5000 years ago. Prior to that time the design concept had been translated directly from the mind of the master builder into its physical form on site. It is possible to imagine how, at that time, the move towards an abstract model of the built form – perhaps drawn in the sand with a sharp stick – was resisted: the models would undoubtedly appear incomplete, ambiguous and clumsy.

Design drawings have, of course, become an established feature of architectural modelling. Curiously, however, little or no development of the modelling technique has taken place in the 5000 year period: to this day plans and elevations are the major vehicle for design decision-making in practice and in education.

Within the last two decades, there has been an increased interest in design methodology and in the models which might promote a more rational and explicit basis for the design activity. Not surprisingly, the early results appear "inadequate, ambiguous and clumsy". The 'first generation of design methods was characterised by a heavy reliance on formal mathematical models; the application of the models usually required an over-simplification of a particular sub-system within the total design problem (e.g. traffic flow in towns, movement of people in buildings), chosen on the basis of numerical amenability. Little or no attention was paid to the systemic nature of the design problem or to the formulation of the broad design objectives.

The ensuing disenchantment with such models led to a so-called 'second-generation' of design methods – altogether more pragmatic, personal and political. Unfortunately, the "enfant terrible" – intellectual rigour – went out with the bath water.

This paper suggests that a 'third generation' of design methods has now emerged which, on the basis of the small but growing amount of evidence from practice and education, promises to have a significantly greater impact on architecture than did the emergence of design drawings 5000 years ago.

Before elaborating on the third generation, it is worth re-affirming the basic concepts which underlie our design objectives.
2. Design Concepts

A useful definition of design is "making explicit proposals for a change from some existing state to some future state which more closely approximates to man and woman kinds concept of the ideal".

The necessary and sufficient conditions for the existence of an 'ideal state' have been identified byAckoff (1), Mason (2) and others from the writings of Singer (3):

i) adequate means (PLENTY): does the design method add to each individual's stock of resources?
ii) awareness of appropriate ways of selecting (KNOWLEDGE): does the design method provide each individual with knowledge as to how best to use the resources?
iii) goals which are consistent with the goals of others (GOOD): does the design method promote cooperation among individuals?
iv) capability to conceive of new goals (BEAUTY): does the design method provide for the renewal and refreshment of each individual?

In short, the design methodologist is concerned with 'enabling' and should 'act so as to increase an individual's chances of gaining what he wants'.

We know, of course, that the significant design problems are essentially 'wicked'. The characteristics of wicked design problems are considered to be:

i) the magnitude of the solution space: the number of alternative feasible solutions is so large as to be effectively infinite;
ii) the multi-variate nature of the design objectives: any design solution must be appraised on a large number of ill-defined, disparate and conflicting criteria;
iii) the temporal variation in objectives: relevant criteria will change throughout the life of the designed artifact or system.

The basis, then, for determining the progress of the development of explicit design methodologies - whether appropriate to new building or to a national strategy for electricity generation - could be the degree to which the four necessary and sufficient conditions of the ideal state are met and the degree to which the three wicked characteristics of design problems are tackled.

3. Third Generation Concepts

The concept underlying the third generation methods is simply one of explicit appraisal, as characterised in Figure 1.

The "designer" generates a design hypothesis which is 'tested' or 'appraised' on as many cost and performance attributes as are considered appropriate. The profile of cost/performance attributes is evaluated by the "designer" who then, on the basis of this information, iteratively modifies the design hypothesis.
The method has several important features:

i) the design hypothesis - which may have had its origin off the top of the designers head or as the outcome of a more explicit generative algorithm - can take a variety of forms - topographical, topological, functional, etc. - depending on the nature of the design problem;

ii) the cost/performance attributes, i.e. the output from the model - may take on a variety of expressions: e.g. numerical - measured on some physical scale or as percentage deviations from the norm of all hypothesised solutions, or analogue - perspective views, acoustic simulations, etc.

iii) the appraisal logic itself can be added to, as the relevance of additional criteria is recognised.

The crucial issue in the use of such a methodology is, however, the nature of the evaluative activity and how the outcome of the evaluation influences modifications of the design hypothesis. The recent review of numerical methods for evaluating multiple objective alternatives by Grant (4) reinforces the view that at the finish up, and by definition, design decision-making involves subjective value judgement. Having squarely acknowledged this fact it is important to state that subjective value judgement, by whomsoever, must be made from the best possible explicit and objective information base.

The causal relationships between, on the one hand the design variables, and on the other hand the cost/performance variables are exceedingly complex in all wicked problems and are ill-understood by professional designers, let alone by those who write the brief or by those who will be affected by the outcome of the decision-making process; the relative importance of each of the cost/performance attributes cannot sensibly be established in anyone's value system until the sensitivity, one to another, (Fig. 2) is established by iterative operation of the model.

4. Examples of Third Generation Models

The number and range of computer based explicit appraisal models is increasing rapidly (5). In this paper, the character of such models will be exemplified by reference to two sub-system applications and a 'total system' application.

4.1 The process sub-system

Figure 3 illustrates the form and content of the program AIR-Q (6) which is intended to simulate passenger movement within transport termini. Within the context of, say, an aircraft arrival and departure schedule, the user of the program constructs on the computer graphics terminal the network of activities (check-in, baggage reclaim, etc.) and the modal split on the routes between the activities. For each activity a level of provision (number of 'servers') is specified together with an appropriate distribution of serving time. The program simulates the arrival of passengers and, for small time increments throughout the simulation period, their progress through the process network. The status of the system at each time interval is held in file to allow the
FIGURE 3. Diagramatic structure of the AIR-Q simulation program
user to display the queue build up at any activity point for any period during the simulation run. The mode of use is as shown in Figure 2: the user, in an attempt to get the system into an economical balance, modifies his hypothesis on service provision by responding to the output of queue size, queue time, throughput etc.

4.2 The energy sub-system

As pressure grows to make less profligate use of our diminishing stock of irreplaceable energy resources, the need increases to model effectively the thermal behaviour of buildings. Figure 4 shows the form and content of the program ESP (7). Within the context of selected climatic data tapes, the user hypothesises a building layout and construction. The program logic, operating on an implicit enumeration technique of finite differences, models the dynamic thermal behaviour of the building. The user can hypothesise alternative temperature control regimes and intermittent plant operating strategies. The wide range of output measures, which are automatically plotted in any desired combination, assist the user in the search for the 'best' layout and construction.

4.3 The 'total' system

The sub-systems illustrated in Figures 3 and 4 do not, of course, behave independently. The number of passengers in any part of an air terminal will affect the environmental conditions; moreover, the chosen layout will concomitantly but diversely, affect the functioning of both sub-systems.

It is a feature of third generation design methods that the models representing disparate sub-systems can be 'nested' within a 'total' design model; the term 'total' is, of course, relative to the designers terms of reference.

Currently nearing completion is the development of the program BILD (8), the form and content of which is illustrated in Figure 5. The program allows the designer to develop his/her design hypothesis from the 'block outline' stage up to 'detailed design' stage by constructing on the computer screen the site, the envelope and room layout, the structure and the cladding. At every stage in the development of the hypothesis the program outputs measures of cost and performance at an accuracy compatible with the form of the input description. These measures include predictions of the operational behaviour of, for example, the process and energy sub-systems which can be considered in conjunction with the entire set of sub-system performances.

5. Claim

The evidence now being gathered from practice (9) supports the claim that third generation models, based on explicit appraisal, are effective in use. In the interests of intellectual rigour, however, we must match the models against the basic concepts of design as set out in Section 2.
FIGURE 5. Diagramatic structure of the BILD appraisal program, showing the different stages of representation and appraisal accessible by a series of menu.
Fig. 6 — Cost-performance profiles, plotted from the synoptic output, showing the history of the development of the four alternative design strategies.

Fig. 7 — Plan layout.

Fig. 8 — Plan layout with room labels: "These rooms are too far apart" and "A noisy room is next to a quiet room."
First, let us consider the three wicked characteristics of design:

i) magnitude of the solution space.
Over the last year, two new district general hospitals have been designed to the 'development control plan' stage - one by the Common Services Agency of the Scottish Home and Health Dept., the other by a private architectural practice. The design teams in both cases, by use of CAAD software, increased the search space approximately 10 fold. The direction of the search was influenced in large measure by the objective and explicit information base comprising numerical measures of cost and performance (Figure 6) supplemented by perspective views of the design alternatives (Figure 7).

ii) multi-variate nature of design objectives.
Throughout the search process, the balance between the elements of the cost/performance profile is explicit. Whereas traditionally the decision-making is sequenced in a strict hierarchy, access to the cost/performance profile allows, from the word go, simultaneous consideration of economic, spatial, functional and environmental criteria. Alternative design hypotheses on, for example, glazed area, can be causally related to disparate cost/performance attributes such as daylight levels, energy cost and view. Use of the software is thus rapidly expanding our knowledge of the results of design decisions (11).

iii) temporal variation in objectives.
Quite obviously computer software is no more able to predict the future than is a crystal ball. What explicit appraisal of, for example, the operation of an air terminal complex, can promote is the testing of the robustness of the design hypotheses against anticipated future scenarios: e.g. the introduction of jumbo jets, the incidence of fog, or the setting up of immigration checks on London/Glasgow journeys (12).

Claims made on the basis of the four necessary and sufficient conditions of the ideal state are, perhaps, more conjectural. But here goes:

i) PLENTY

The experience of one Local Authority, applying CAAD software to the existing stock of school buildings has been able to increase significantly the quantity and quality of useable space for educational purposes (13). Numerous applications of CAAD software to new building design and to existing building stock is reducing significantly the profligate utilisation of scarce energy resources (14).
ii) KNOWLEDGE

A vast volume of information is currently being built up on the causal relationships between design and cost/ performance variables. These relationships are available to all who seek to improve the logical basis of their design decision-making (11).

iii) GOOD

All the evidence emerging from reliable studies of the use of CAAD software indicates that the more information that is put at the disposal of a group of design decision-makers the more the group is likely to agree on the 'best' design. Indeed Cakin (15) has shown that in the promotion of concensus, quality of the information base is more important than design education.

iv) BEAUTY

Following from the work of Cakin, Aish (16) has shown that access not simply to the information which is output by an explicit appraisal model, but also to the model itself, will allow naive designers to conceive of new and 'better' solutions (Figure 8).

6. Future Implications

If the claim is allowed to stand it can be used as a basis for projecting future developments.

Some glimpses of the direction that model building might take have appeared. In one exciting experiment, several hours of TV time in California were given over to computer modelling of highway routes in part of the state. In the TV studio the operators of the computer model could superimpose alternative routes for a proposed highway on a land-use map drawn on the graphics screen; the computer output, for any particular route, information on construction cost, houses lost, agricultural land used, etc., etc., Viewers at home could phone in, during the program, to suggest alternatives which seemed to them to provide better balance of cost and performance. With advances in technology, proven as feasible in another context, it is possible to develop the scenario to the point where viewers can interact graphically with their own TV set and thereby enjoy fuller participating in design decision-making which will, after all, affect the quality of their lives.

At a more technologically modest level, recent work at Strathclyde has shown the ultimate feasibility of providing experiential appraisal of built form, both visually (Figure 9) and acoustically (Figure 10).
If support if forthcoming for these and other developments in model building, the implications for professional practice (and therefore education) are significant. These implications are now set down as three paradigms:

The plan is the process - the role of the professional design team is to develop and make generally available (for adoption and use) the processes (i.e. the models and methods) of design decision-making, rather than to develop products.

The process is design-in-use - design is a continuing activity; the processes (i.e. the models and methods) for decision-making should be as relevant to the modification, adaptation, and management or manufacture of the product as to its original specification.

Design-in-use is participatory - design decision-making is the province of those affected by design decision; the processes (i.e. the models and methods) must therefore be used by - and the value judgements made by - naive, as opposed to professional designers.

7. Acknowledgements

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8. References


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