Appraisal in design

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Computer-based design appraisal models can be seen in systems terms with the design hypothesis as input, the resulting cost and performance profile as output and the design modification as feedback. This paper discusses the main elements of such a model (representation, measurement and evaluation) and exemplifies the application. The paper ends with proposals for future work – notably the coupling of computer models with telecommunication systems and the development of 'experimental' appraisal.

Design is the activity of making explicit proposals for a change from some existing state to some future state which more closely approximates to mankind's concept of the ideal. As such it embraces a wide spectrum of human endeavour: the outcomes of design activity are part and parcel of our everyday life and are determinants, for better or worse, of our man-made future. In common with all complex human functions the activity of design is ill-understood: it involves the most rational and systematic process of human thought and also the most intuitive and conjectural leaps within the human mind.

The design professions are many and varied; they include the engineering professions (mechanical, civil, electrical, electronic, aeronautical, nuclear, naval architecture, chemical, environmental), the architecture profession and the industrial design profession. The educational systems from which these professionals emerge, and the institutes of which they are members are unique, disparate and, sadly, often competitive. Design then, unlike medicine, has as yet no unifying educational or professional corpus; there is a view, however, at least within the Design Research Society, that from a developing understanding of mode Uning concepts within the design activity a unified view of design may emerge.

Modelling has a long and interesting history; to Bronowski\(^1\) the single most significant step in the ascent of man was the creation of cave paintings — the first bold attempt to model, for the young men of the community, a future reality as yet outside their experience. In the context of design, model development has taken place at varying rates: the classic example of the successful application of advanced modelling techniques is of course the design of lunar modules; in other fields of design endeavour, some of which are at the core of our everyday existence, the concept seems to be moribund.

It is instructive, by way of example, to consider architectural design. If the architectural historians are correct, modelling found its way into architectural design around the year 2800 BC. Prior to that time the architect or master builder stood on site and directly translated the design concept from his mind's eye into full-scale, three-dimensional reality. By dint of drawing plans and elevations in the sand with a sharp stick, the first models in architectural design, the master builder opened his concepts to critical appraisal and greatly accelerated his productivity.

Curiously, the plan and elevation — virtually undeveloped — continued to be the core model in architectural design over the next 5000 years. Only in the last decade have we seen significant development in architectural modelling; it is the progress during this decade which will be reviewed in the remaining sections of this paper.

APPRAISAL IN SYSTEMS TERMS

Central to the concept of appraisal is the development of a model of the operational behaviour and formal characteristics of the proposed artifact. The model may be thought of as a system: the system inputs are in effect the design hypotheses and the system outputs are the predictions of the operational behaviour and formal characteristics of the design under a particular set of context variables (Figure 1).

This systems view of design appraisal recognizes that the activity of design decision-making is not wholly contained within the technological sphere but may well have functional, economic, social and aesthetic implications for society at large. Successful computer applications to limited technical problems abound, of course: it is very useful to input to the computer a set of beam loadings and to have it output a minimum depth of beam. However, the pressing problems of ecological pollution, dwindling energy and material resources, urban deprivation, etc. facing society today, demand a more systemic view of design, a view that will recognize the aspirations and value judgments of all those who will be affected by the design decisions.

Development of systemic computer-based design appraisal models is in its infancy but advancing rapidly in most fields of design endeavour. Nowhere more so than in the fields of architecture, building science and urban planning. In the course of designing a building the architect is concerned to satisfy as best he can a wide range of disparate and sometimes conflicting objectives: the building must be structurally sound, environmentally comfortable, efficient for its purpose, aesthetically pleasing and economical to acquire and run. The brief he is given is unlikely to be explicit as to the acceptable level of any of these criteria (except perhaps to impose an upper limit on capital cost). The architect then engages in an iterative, open ended, multi-variate search process during which the directions of search and the final outcome depend in large measure upon his own implicit and subjective value judgements.

The philosophy underlying the current generation of CAD appraisal models is not one of simplifying the problem in order to make it univariate and free of subjective value judgement; rather it is one of recognizing the complexity of the problem — the fact that it is multivariate (and multiperson) and of providing as rich an information base as possible about the predicted performance of hypothesized solutions on which explicit value judgements can justifiably be made.

COMPUTER AIDED APPRAISAL

Developing the systems model of Figure 1, the CAD activity can be presented as in Figure 2. The designer generates a design hypothesis which is input into the computer (representation); the computer software models the behaviour of the hypothesized design and...
Figure 1. The design activity in systems terms

outputs measures of cost and performance on a number of relevant criteria (measurements); the designer (perhaps in conjunction with the client body) exercises his (or their) value judgement (evaluation) and decides on appropriate changes to the design hypothesis (modification).

- **Representation** Representation of the design hypothesis will require to take a form appropriate to the appraisal measures which the software is designed to carry out. It may be simply alphanumerical, or, increasingly commonly, topographic (eg a building plan, bridge elevation, printed circuit layout, mechanical linkage); it is the interface between the designer's mental model and the computer based model and, as such, is the focus of the man-machine exchange.

- **Measurement** The software model of the operation and form of the design artifact which exists within the computer must be capable of interpreting the input representation and of applying known algorithms which model aspects of the design's character and behaviour. Output measures of cost and performance may be wholly descriptive (eg building plan area, maximum bridge span, number of circuit modes, lengths of linkage arms), wholly predictive (eg capital cost of plan layout, deflection profile of the bridge span, resistance between two circuit nodes, angular velocity of a linkage arm) or an appropriate mix of descriptive and predictive measures. Additionally, it may be advantageous to have the software effect a visual transformation on the input representation, to output addition views of the design hypothesis (eg a 3D perspective of the building plan or bridge).

- **Evaluation** Profiles of the cost and performance characteristics which are output by the computer, supplemented by subjective or other views, form the information base on which the designer acts. Evaluation of a profile of measures on disparate and possibly conflicting criteria can be undertaken only by the application of value judgements relating to the perceived needs of the client/user body and of society at large. Introduction of CAD models does not obviate the need for evaluative decisions. Indeed, by making the information base explicit, CAD models throw into sharp focus the subjective aspects of the design decision-making activity. In some instances, the brief for the design problem may express certain upper and lower limits of acceptability for some or all of the cost/performance characteristics, against which the profile may be judged. Increasingly, however, it is recognised that such a priori constraints cannot be set sensibly in ignorance of the causal inter-

relationships between the elements of the cost/performance profile. For example, the requirement to achieve a minimum of 2 percent daylight factor in a school plan may result in an unacceptably high energy cost for heating. In effect, if a priori cost/performance specification is a meaningful concept, agreement on its form is likely only to emerge from extensive and controlled explorations using the CAD model.

- **Modification** Any design hypothesis embodies a unique set of design variables. For example a plan layout has a particular floor area, shape of envelope, topological relation of spaces, etc. Each design variable contributes, to a greater or lesser extent, to the behaviour of the design as a whole and hence to the cost/performance profile. If, from the evaluation of the profile, it is considered that, for example, the level of daylighting in some rooms is unacceptably low, the designer must decide in respect to which design variable the overall design hypothesis must be modified. Improvement in this aspect of performance may be achieved by modification of any one of several design variables; moreover, a change in any particular design variable is likely to affect not only daylighting but many (if not all) of the other cost/performance characteristics. The nature of the causal relationships between each and every design variable and each and every cost/performance variable is, unfortunately, known a priori, but must emerge in the process of iterative use of the CAD model.

It will be seen, then, that if the representation and measurement modules of the design system can be set up and made available, the processes of evaluation and modification take place dynamically within the design activity as determinants of, and in response to, the pattern of explorative search. This mode of working puts a premium on ease of communication with the computer.

**COMPUTER-AIDED APPRAISAL IN ACTION**

The emerging new generation of computer-based appraisal models is already having a dramatic impact on design practice, on design education and on the client/user bodies affected by design decisions. The impact stems from the fact that the new models, as opposed to paper-based plans and elevations for example, are predicated rather than descriptive, dynamic rather than static, explicit rather than implicit. The following subsections aim to exemplify current applications and to identify implications for the quality of design decision-making in the context of architectural design.

![Figure 2. Model of CAD activity](image-url)
Professional Practice

- The search for good solutions. Figure 2 represented the designer’s iterative search for a solution in which an appropriate balance is struck within the range of cost and performance criteria. Figure 3 exemplifies the character of the input to and output from a typical computer-based architectural appraisal model. In practice, access to such a model is known to increase the search for a good solution by approximately ten fold. Not only is the search coverage extended, it is also more purposefully directed, with the architect able to compare the quality of any one solution against the quality of all previous solutions.

- Design team working. A great deal of design time is lost as design hypotheses are passed to and fro between the architect and specialist members of the design team. Quite frequently the scheme on which the architect has lavished time and effort is found by one or other of the specialists to be infeasible. With access to explicit appraisal techniques it is possible to check a wide range of criteria simultaneously from the outset of the design activity. Moreover, it is entirely practical for each member of the design team to have access to, and operate on, the common design model whether or not they share a design office. The models, then, provide a strong integrating force in design team working.

- Design insights. Apart from the use of appraisal programs to search for an optimal solution to a particular design brief, the programs can be used in a research and development context to provide insights into how design decisions affect cost and performance attributes. Typically, the designer would select an existing building as the vehicle for his study, then, keeping all other design variables constant, systematically vary one design factor while monitoring the cost/performance output from the program. In this manner the architect can establish sets of causal relationships which provide powerful insights into the design activity.

- Objective and subjective judgements. Contrary to the fears of many architectural practitioners, the use of CAAD techniques focuses increased attention on subjective value judgements, rather than cost. As the measurable attributes of design alternatives are made more explicit the necessary value judgements are forced to the surface of the design activity and, thereby, themselves become more explicit.

- General. If CAAD techniques such as those described here are to be developed to their full potential, it will necessitate a diversion of professional effort away from the design of individual buildings in favour of a commitment to designing better design methods and models.

Education

Students currently in Schools of Architecture will be at the peak of their careers around the year 2000. Pressure on the schools to provide an education and training which will stand the student in good stead between now and then is considerable. In at least one school,4 importance is placed within the course on the concept of modelling, i.e. the development and use of models of the operational behaviour and aesthetic character of design proposals which will allow prediction of how real buildings will perform in the real world. The belief, supported by a growing quantity and quality of evidence, is that access to and use of explicit models of the future built reality promotes:

- retention of studio project work as the core synthesis discipline within the education environment.
- an appropriate degree of independence from the prevailing corpus of factual, but highly perishable, information on materials, constructive detail, etc.

![Diagram](image)

Figure 3. (a) PHASE: floor plan shown in relation to site boundaries (b) PHASE: synoptic output (c) PHASE: efficiency of boilerhouse location output by program (d) PHASE: outdoor temperatures in selected departments output by program
of the analysis procedure. Over the weekend the tutors considered the submissions and agreed a common brief for all students.

Synthesis: armed with an accommodation schedule and 'target' costs the students were given a week to generate, by conventional means, one or more 'outline proposals' as to the form of the hotel.

Appraisal: the computer program GOALT is an integrated appraisal model intended for use at the outline proposals/scheme design stages. Students were able to input their design hypotheses by digitizing their layout drawings and choosing from a file of constructional elements. Output from the program provided a check of accommodation areas, predictions of environmental conditions and a prediction of how any particular scheme compared, in capital and running costs, with the 'target' figures of the brief.

Typically, students would interactively explore alternative geometries using a standard construction then begin to 'fine-tune' the scheme in terms of constructional decisions (figure 4). It was also possible to produce automatically perspective views of any scheme at a scale appropriate for immediate photomontage on photographic prints of the site.

Submissions had to include the conventional plans and elevations, a clear account of the process of search and trade-offs which had led to the final scheme. Conclusions drawn by the tutors from the presentation and debrief sessions were as follows:

- deploying a methodology to generate a functionally appropriate brief (in this case one based on maximum profitability subject to planning and administrative constraints), rather than accepting one 'ready made', greatly increased the students' motivation to meet the brief requirements.
- ready access to an iterative appraisal methodology motivated almost all students to explore a wider range of alternatives than would otherwise have been the case.
- different students benefited from the rigour of the methodology in different ways: those considered 'weak' in design started with a mundane scheme which was close to the requirements of the brief and then used the appraisal program to become progressively more innovative within the envelope of feasibility; those considered 'articulate' in design started with an innovative scheme which broke the requirements of the brief and then 'tightened up' to meet the brief while preserving the innovative concepts.
- the outcome, in all but one case, was a 'better' design than would have been expected from a conventional project. The single exception was a student openly hostile to any form of design methodology.
- the intermediate and final 'irit sessions' were more structured and helpful to the students and properly differentiated between objective fact and subjective value judgements.

User Participation

There is growing evidence of dissatisfaction on the part of the users of buildings. Two inter-related reasons for this dissatisfaction can be advanced:

- lack of a reliable language interface between the user
and the architect which might make user need less liable to misinterpretation
- embodiment in the design solution of subjective value judgements which are essentially those of the architect rather than those of the users.

Recognition of the problem has led increasing numbers of (usually young) architects to involve themselves more intimately with the user community in an effort to more fully and more accurately interpret user needs and values. This approach represents an attempt to bring the interface between architect and user to an earlier point in time and to blur and deformalize the communication process.

An alternative, and largely unexplored, approach is to postpone the user/architect interface by allowing the user community to penetrate deeply into the design activity to the point where needs and values are made explicit in spatial terms.

It is suggested — and some evidence is presented later in this subsection — that computer models make this alternative approach not only feasible but preferable to the "barefoot architect" approach. The characteristics of computer-based appraisal models which are relevant to this claim are as follows:

- the models are, in effect learning aids which promote the rapid development of insights into the way in which design decisions affect cost/performance attributes.
- the cost/performance profile resulting from the final user-generated design hypothesis provides an explicit performance specification, embodying the user's value judgements, on which the executive architect can sensibly operate.

The suite of programs known as PARTIAL has three modules which allow user participation in design to be studied. Using PARTIAL 1, the architect is able to:

- select the schedule of accommodation and its associated 'space budget'.
- define the geometry of any 'fixed elements', such as would be required in the case of building conversion. If there are any fixed parts of the design these can be input by the architect using PARTIAL 1 and will subsequently appear on the screen of the computer terminal when the participant uses the PARTIAL 2 program.
- select which performance measures will be used by the program to present appraisal information to the participant about the design.
- select tutorial and advice options used by the program to comment on the participant's design.

After the architect has finished using PARTIAL 1 to create the control file which describes the design problem, the participant can use PARTIAL 2 to build up the design on the screen of the computer terminal. The participant uses the graphic manipulation commands to select, place and shape the rooms, walls, doors, windows, and partitions. The participant visually reads his drawing on the screen.

In a corresponding way the computer 'reads' the drawing by making a numeric description of the design as a data file.

Each design can be evaluated according to the experienced user's own criteria by using the subjective visual and spatial information from the plan. The computer, on the other hand, can evaluate his design with objective measures of performance such as indices of capital cost, energy cost, daylighting and planning efficiency. These measures are displayed in an unambiguous manner.

Using the graphic manipulation commands the participant can modify the design. He or she can add, shape, reposition or remove the rooms and the cladding elements. The computer redraws the modified design and always presents to the participant a tidy and accurate representation of the current design. The computer can also re-evaluate the design after such a modification so that the participant can see if he has improved both the objective as well as the subjective qualities of his solution. The participant can continue the iterative process of modification and evaluation until a design evolves with what he considers to be the appropriate mixture of subjective qualities and objective properties (Figure 5).

PARTIAL 3 allows a record to be kept over time of the participant's design activity; this record can be subsequently interrogated by the researcher to establish the sequence of design actions and decisions.

The major conclusions and implications which emerge from an experiment in which nursery school headteachers were given the opportunity, individually and in groups, to design an 80-place nursery school, are as follows:

- Nursery school headteachers are capable of formulating design objectives and producing layout schemes which are considered to incorporate successfully the majority of their initial design objectives. These designs are considered by the participants themselves to be more acceptable than comparable architect-produced designs.
- Participants evaluate their own individual design more highly than other participants' individual designs. However, they are capable of cooperating to produce a collective nursery school design which is not only an improvement in building performance and space allocation terms upon the design from which it evolves, but is also evaluated more highly than the participants' individual designs.

![Figure 5. Appropriate design reached](image-url)
Further support for the feasibility of this type of involvement comes from the finding that not only do architects evaluate the participants’ designs as highly as those of the architects, but also they considered the group solutions to be an improvement over the individual solutions upon which they were based.

FUTURE DIRECTIONS

In the introductory section, this paper drew a parallel between the genesis, some 5000 years ago, of architectural drawings and the genesis, 10 years ago, of computer-based appraisal models. Whereas architectural plans and elevations, as models, have developed very little over 50 centuries, the development of computer-based models, if we can extrapolate from events over the last decade, promises to be rapid and dramatic.

One direction of necessary research effort lies in the matter of developing multi-criteria merit scores to facilitate the comparison, over a number of disparately dimensioned attributes, of alternative design solutions. Attempts have been made in the design methodology literature to summarize the possibilities: ordinal methods, weighted criteria methods, weighted average methods and vector space methods. None of these has the appeal of a method (which I shall call ‘normative averaging’) which sums, over all measurable attributes the normalised deviation of each from the mean, gathered over an increasing portfolio of design solutions.

It is in the nature of things, however, that some attributes (eg ‘style’ as referred to by Ackoff) will, at any point in time, defy enumeration. So be it. The issue then is to arrange to make the models accessible in a meaningful form to those who should exercise, in each specific case, the appropriate value judgements over multi-criteria spectrum. This implies:

- harnessing of the telecommunication media to the design models, perhaps as exemplified in Figure 6, and
- a move towards models which allow experiential appraisal of the ‘qualities’ of the designed artifact (eg acoustic quality, as exemplified in Figure 7).

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REFERENCES