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22 Appraisal in the Building Design Process

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The design process is distinguished as an interactive and cyclic activity involving analysis, synthesis, appraisal, and decision, applicable at a number of stages in a sequential design morphology. The process takes place within a framework of a cost-benefit model and against a background of nonspecific and disparate objective functions. Taking spatial environment as illustrative of a decision area, the paper deals with the limitations of attempts to generate design syntheses and suggests that the designer's intuitive synthesis should be accepted as a first approximation, explicitly appraised on a variety of counts, modified, reappraised, modified again, and so on, until convergence on an optimum solution is achieved. Degree of attainment is measured in a number of cost and performance levels for which the designer can elicit the client's approbation. An example of such an appraisal is given. Finally, it is suggested that this mechanism may lead to mathematical formulation of the relationship between design and performance variables and the emergence of true performance specifications.

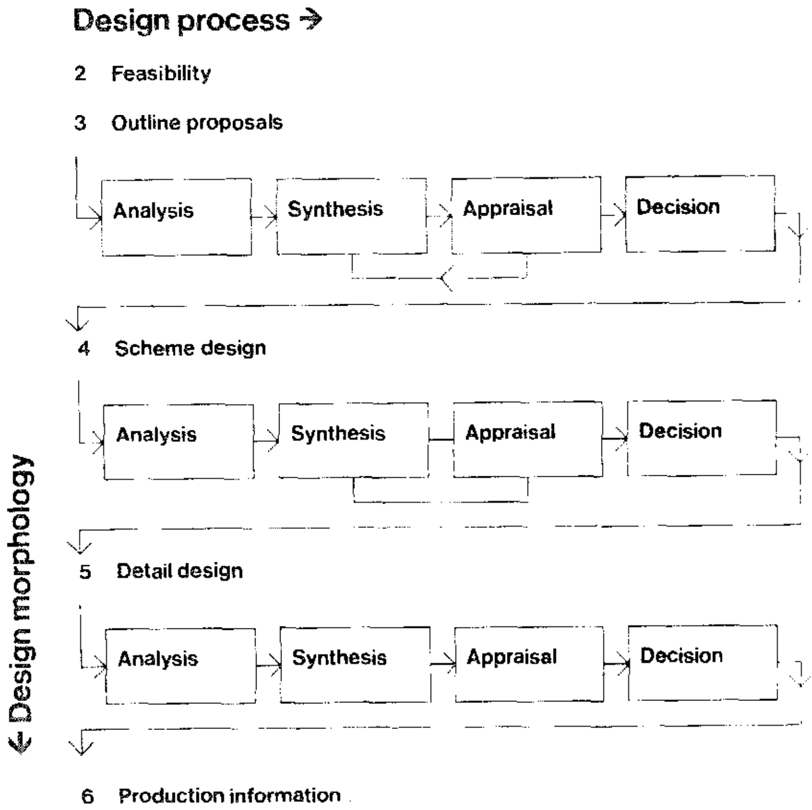
Decision-making in building design, as in many other fields of design and planning, is concerned with narrowing the field of search, in the universe of possible design solutions, for that design which optimizes the return on the client's investment.

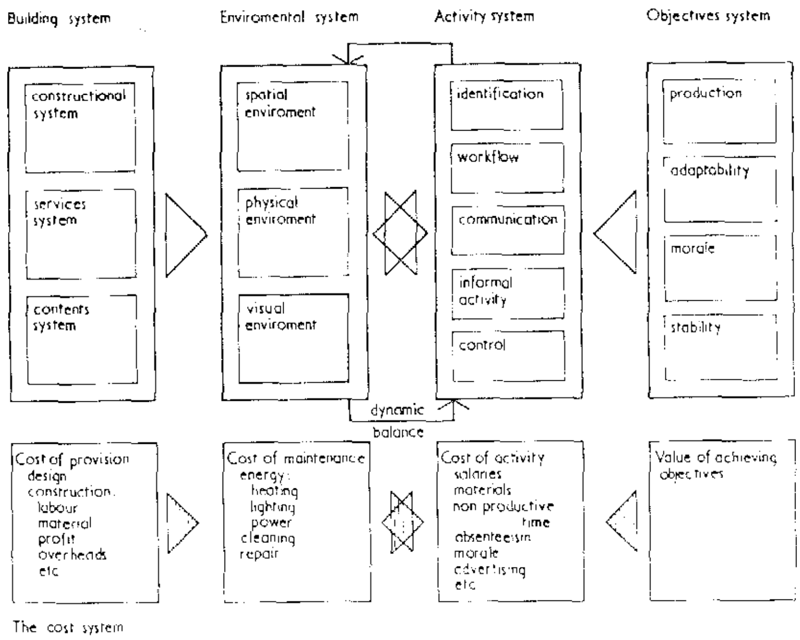
The first of the designer's difficulties is that the client is seldom, if ever, able to make an explicit statement of the objective function in terms of which the level of return can be measured; at best the client will be in a position to state what features of the built environment will promote the attainment of his objectives and what features will inhibit their attainment. The second of the designer's difficulties is that the universe of possible design solutions is constrained from the outset by the client's inability to make an investment of an amount which would allow optimum solutions.

The problem can thus be seen to be that of recognizing, weighting, correlating, and manipulating the host of interdependent variables which affect the built environment in a manner which is sufficiently rational and explicit to promote joint decision-making on those levels of performance which together comprise the optimum design solution.

1. Framework for design management

2. Conceptual cost-benefit model





This paper sets out to provide a decision-making mechanism, based on the iterative explicit appraisal of design syntheses, within a cost-benefit framework.

Framework For Design Decision-Making

A number of commentators have suggested frameworks for the management of design decision-making which, although differing in terminology, all embody the concept of vertical and horizontal dimensions. Markus, dealing with the management of architectural design, refers to the vertical dimension as the *design morphology* and describes it as "a chronological sequence advancing from the abstract and general to the concrete and particular."[1] The Royal Institute of British Architects' "Plan of Work" is in fact a building design morphology comprising the following stages:

1. Inception	7. Bills of quantities
2. Feasibility	8. Tender action
3. Outline proposals	9. Project planning
4. Scheme design	10. Operation on site
5. Detail design	11. Completion
6. Production information	12. Feedback

Stages 2–5 are concerned with "design" as we understand it and subsequent stages are concerned with implementing the design as accurately, cheaply, and quickly as possible (stages 6, 7–8, and 9–11, respectively). The characteristic of a morphology is that the stages are sequential and not iterative; return from a later stage to an earlier stage is recognized as failure in the management of the design activity.

The horizontal dimension, referred to by Markus as the *design process*, is, however, iterative and cyclic in character and comprises four steps, analysis, synthesis, appraisal, and decision, defined as follows:

Analysis. Clarification of goals, identification of problems, nature of difficulties, exploring relationships, producing order from random data.
Synthesis. Creation of part-solutions, combination of part-solutions.
Appraisal. Evaluation, application of checks and tests, application of criteria, constraints and limits, consistency testing.
Decision. Selection of "best" solution from a set, advancement to next morphological stage.

The total framework of the management of design thus comprises a vertical dimension of design morphology and a horizontal dimension of design process linked operationally as shown in Figure 1. It is of value to have not only a management framework, as already described, but also an objective framework. To embody the philosophy of cost-benefit in design decision-making, the Building Performance Research Unit has developed a conceptual model of the relationships between the building and the users. Figure 2 demonstrates the interaction between four conceptually separate systems. The building system gives rise to an environmental system just as the objectives system gives rise to the activity system. At the center of the diagram the animate/inanimate interface, the two-way arrow represents the fact that the environment modifies the activity at the same time as the activity modifies the environment.

For each of the four conceptual systems there are associated costs. It is in terms of these costs, or alternative measures of system provision and performance, that a design is optimized.

The Approach

Since spatial environment is a major decision-taking area in the design of all building types, it will be taken as a suitable vehicle for the development of the proposed approach. The *spatial environment* in buildings may be said to be the number, size, and type of individual spatial elements and the relative disposition of these elements in three dimensions within the building en-

1. Thomas A. Markus, "The Role of Building Performance Measurement and Appraisal in Design Method."

velope. More simply put, the spatial environment comprises the accommodation schedule and layout.

What then are the difficulties of a design team attempting to progress through the design morphology of the spatial environment in, say, a school? While the team may be able to elicit some statement from the education authorities with reference to the activity and objectives systems, this will be neither specific nor readily translatable into a cost function. The design process, therefore, must be one of obtaining at each stage of the morphology a balance between the cost investment on the inanimate variables and some measure of performance on the animate variables in a form sufficiently explicit to determine the degree of client approval.

Research workers in the United Kingdom concerned with spatial environment have, almost to a man, been brave enough to apply their efforts to the synthesis step in the design process. Some consideration of their methodology and results is necessary to the development of the arguments in this paper.

The earliest work was an attempt to apply the transportation technique of linear programming to the location of rooms in a building.[2] The objective function to be minimized was the product of number of journeys and journey distance. It is possible to formulate such a problem in linear programming terms only if the number and distance of journeys are considered between each room and a single fixed station; such a formulation optimizes the location of each room with respect to the fixed station but not with respect to each other.

To deal with the traffic patterns between every room in every location clearly is a mammoth problem, outside the bounds of formal mathematical analysis. Realizing this, Whitehead and Eldars developed a heuristic program which, using the number of "standard" journeys as a measure of association between spatial elements, placed the elements consecutively on a two-dimensional grid, as shown in Figure 3.[3] The first element to be placed was that with the highest association with all other elements; the second was that having the highest association with the first; the third was that having the highest association with the first and second, and so on. Each new element will take up a position somewhere on the periphery of the elements already placed; the exact location is that which yields the least sum of the products of the association and the distance between the new element and each of the elements already placed. This program will produce a layout and an envelope in two dimensions only.

Other research workers have employed variations on this theme. Beaumont, in what he describes as a $2 \times n$ hierarchical decomposition, starts by breaking the total space into two parts in a way that minimizes the association between the two; these are then placed on a grid.[4] Each part is itself broken into two and the subparts located. The hierarchical breakdown continues until the individual elements are themselves located. The advantage claimed for this method is that it more closely follows the intuitive design morphology of increasing specificity and allows interruption at each stage to manually adjust the partial solution. There is provision in Beaumont's program for taking daylight requirements into account by making inadmissible those layouts that do not permit a predetermined proportional disposition of external wall.

It is clear that the determination of an optimum layout on the basis of a single variable, say traffic movement, by formal mathematical analysis, e.g., linear

2. Lynn Mosley, "A Rational Design Theory for Planning Buildings based on the Analysis and Solution of Circulation Problems"; L. Bruce Archer, "Planning Accommodation for Hospitals and the Transportation Problem Technique."
3. Bertram Whitehead and Mohamed Z. Eldars, "The Planning of Single-Storey Layouts."
4. Michaël J. Beaumont, "Computer-Aided Techniques for Synthesis of Layout and Form with Respect to Circulation."

programming, is not feasible unless the problem is simplified by assumption beyond the bounds of realism. The alternative, a series of heuristic algorithms such as those proposed by Whitehead and Eldars, and Beaumont generate a solution, but the proximity of the solution to an optimum is dependent on the relevance of the heuristics adopted and is therefore impossible to judge. If it is desired to take account of additional variables, the relevance of the heuristics adopted becomes increasingly dubious, as does the complexity of the program, until a stage is reached when the solution generated may be further from a true optimum than a solution intuitively arrived at by the most simple-minded architect. The difficulty of putting forward valid heuristics, as has already been seen, is due to the lack of knowledge of the functional relationship between the variables and, if they are not all measured in cost terms, lack of knowledge of their relative importance.

The approach proposed here embodies the philosophy that if a number of variables are to be manipulated simultaneously, a design synthesis cannot be generated as effectively as by an architect using his intuition. It *is* possible, however, to get such a synthesis by using an intuitive synthesis as a first approximation and then explicitly appraising it in a way that promotes iterative modification towards an optimum solution. The iterative method of successive approximations is well tried in algebra, and there would appear to be no fundamental reason why it should not apply to the simulation of design solutions. It does depend, however, on two conditions: one is that all possible solutions should exist along the single dimension (of good-bad), the other is that each appraisal should be carried out in sufficient detail to suggest the appropriate modification for convergence on the optimum solution.

Souder's work on traffic movement in hospitals illustrates this approach for a single variable and provides a useful comparison with the approach of Whitehead and Eldars.[5] Using a performance criterion similar to that of Whitehead and Eldars (that is, a product of number of journeys and journey distance), Souder input a design solution and had the computer simulate the traffic movement associated with the solution. The output gave a level of performance, measured in total journey time, and gave details of the usage of lifts, stairs, and corridors. This secondary detailed output allowed conclusions about the best way of modifying the design for a better level of performance.

The drawbacks to Souder's program as it stands are threefold: (1) it deals with only one variable, (2) there is no way of telling when the synthesis/appraisal recycle has produced a near-optimum solution, and (3) while a level of performance is output, there is no comparable level of cost investment.

The proposed approach, then, is to develop a series of appraisal programs: a cost appraisal dealing with the cost of provision and maintenance of the inanimate side of the conceptual model and a performance appraisal for each of the variables on the animate side. At any stage of the design morphology, say scheme design, Figure 1, an intuitive synthesis is put forward and appraisals made. The designer then has, as primary output, a cost figure and a performance level for each variable; as secondary output he has sufficient detail of each appraisal to assist him in the modification of the synthesis if this should be considered desirable. The desirability of modifying the synthesis may be discussed with the client, since only the client is able to weigh intuitively the balance of performance levels on a variety of variables. This balancing cannot be done other than by reference to basic cost and performance criteria. The cost criterion may be simple enough, for example, the client's predetermined upper limit for capital and running costs. The performance criteria may be of quite disparate form, a statutory minimum (e.g., 2 percent daylight factor) or a recommended maximum (e.g., no more than 100 ft between classrooms and lavatories).

5. James J. Souder et al., *Planning for Hospitals: A Systems Approach Using Computer-Aided Techniques*.

There are some performance criteria, particularly those directly dependent on the spatial environment (for example, traffic movement) which are more difficult to state. For these cases it may be possible to use heuristic programming to generate a criterion, as in the total journey distance solution of Whitehead and Eldars.

In any event the design process, as envisaged, is concerned with proceeding round the synthesis/appraisal cycle until client and designer are satisfied that the cost investment results in performance levels which optimize the allocation of the client's resources. Even if the client is not consulted on every cycle, his approbation should be sought at the end of the cycling process and before progressing to the next stage of the morphology.

The Mechanism: An Example from the Design of Schools

In the school design problem the process would be as follows: On the basis of an analysis of the user requirements, the architect would put forward a design synthesis. This first approximation would then be subjected to a battery of appraisals. The appraisals on the inanimate side of the conceptual model would be in cost terms and the appraisals on the animate side would be in performance terms most appropriate to each variable. The cost appraisals might comprise the cost of provision of outside walls, internal partitions, floor area, service runs, as well as the cost of maintaining the fabric, plus heating and lighting. The performance appraisals might comprise the number of alternative curricula possible, the level of daylighting, the volume of traffic movement, the departmental propinquity, the integration of social and educational space, and the potential for growth.

The Building Performance Research Unit is at an early stage in the production of computer programs for design appraisal. The main effort is being centered on cost appraisal and those appraisals which have direct relevance to the spatial environment in schools. As an example it may be appropriate to take the difficult problem of flexibility with regard to curriculum change.

Data may be gathered to provide a frequency histogram of numbers of pupils engaged in the same activity for a variety of curricula. If these data are replotted with the number of pupils on the *y* axis and with the column width representing the number of periods (in a 40-period week) in which each number of pupils meet, the resulting format is as shown in Figure 4. Now assuming for the moment a building system with partitions fixed at points on a 3 foot module, there are a very large number of schedules of accommodation possible, some of which will satisfy both curriculum A and curriculum B. One such schedule (1) is the envelope of the two curriculums. An alternative solution, however, is to employ a building system incorporating demountable partitions in which case the schedule may be dramatically reduced (2). If a large number of different curriculums are under consideration, the sequential appraisals of schedule 1 and schedule 2 could be in terms of the number of curriculum structures which were, say, 90 percent satisfied. The parallel cost appraisals will of course exhibit a marked difference: for schedule 1 the space cost will be high and the partition cost low; for schedule 2 the space cost will be low and the partition cost high.

Now schedule 1 and schedule 2 would of course be embodied in two consecutive design syntheses of specificity appropriate to the stage reached in the design morphology. Whatever the stage might be, some information would be available regarding the acoustic properties of the boundaries. The parallel and simultaneous appraisal of these two syntheses with regard to acoustic environment would show a deterioration in performance level, and this could lead to a modified synthesis in which certain noise-producing classrooms are articulated from the others and scheduled separately. The subsequent appraisals would show a change in cost, a change in acoustic performance, and perhaps a change in departmental propinquity.

This simplified example illustrates how a series of simultaneous appraisals leads to synthesis modification and how the designer, in consultation with