# Architectural designers' values and the evaluation of their designs

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*Arising from a review of several design judgement studies, a tentative outline of the design process, using the framework of decision-making and value theory, is set out. This paper reports an experimental programme based upon that outline. The experiments entailed designers planning a school and, in conjunction with the design process, performing a judgement-analysis exercise to elicit their values. The plans are also evaluated subjectively with respect to the designers' values. Generally, the findings provide support for the tentative theory, and have several implications for design teaching, research and practice.*

In a previous paper[1] in which several empirical and theoretical studies of design judgement were reviewed, the present author set out a tentative outline of the design process using the framework of decision-making and value theory. This outline was as follows:

- Designers use a simplified model, conceptualization or internal representation of the design problem, which thereby becomes cognitively manageable. This representation may comprise a small set of strongly valued attributes which are relied upon to generate design conjectures.
- The attributes designers value may be understood as being weighted and ranked; design decisions imply such preference orderings.
- Designers may differ in the attributes they value and in their evaluations of the same attributes. These differences may be the result of selfimposed values, or of the explicit specification of certain objectives by the client or design organization.
- The differences between designers' value systems may account for the differences between their design proposals.
- The differences between designers' value systems may give rise to the following of different strategies.

Additionally, it was shown that designers' value systems may themselves be affected by the design process as the designer negotiates between his objectives and what he finds is possible.

This outline formed the basis of an experimental programme intended to test a number of hypotheses about the influence of designers' values on their designs and on their preferences between alternative designs. Architectural design was chosen as a focus for the study, as a good deal of design research is concerned with architecture. In general terms, the findings probably have relevance to other areas of design activity. The method adopted was to set up a series of three intensive design exercises in which individual designers undertook to design a sketch plan of a building over a period of about three hours. Before and after the design process, they performed a judgement-analysis exercise, recently devised by Thomas Saaty, intended to elicit their value judgements. The sketch plans, having been redrawn, were evaluated by the same experimental subjects. The evaluation phase made use, again, of Saaty's technique. Data from the experiments enabled the hypotheses derived from the outline given above to be tested.

The number of designers whom it was possible to include as experimental subjects was the result of a balance between attempting to study design in depth and ensuring that the numbers were not so few that their idiosyncracies obscured generalizable results. After pilot studies, three main experiments were conducted: one with qualified architects, one with graduate students of environmental design (architecture) and one with nonarchitects. Six subjects took part in each of the three experiments.

Experimental conditions were held as constant as was considered compatible with the intended purposes of the experiments, and with the practicality of groups of people taking part for a whole day or more. The students were all studying together, so the experiment took place in their communal design studio; similarly the nonarchitects all worked in a communal studio. The architects worked individually in their own studios. All the subjects used their own drawing equipment. Bearing in mind that these experiments were intended to study the subjective values of the participants, it was felt that the imposition of standard conditions might have had a deleterious effect on the design process. Conditions may be said to lie between the very high degree of experimental control used in certain psychological experiments and much less uniform conditions common in interview techniques. Differences between the experiments do warrant some caution in the comparisons of results between experiments.

The design task for the three experiments was to plan a two-form entry primary school. It was selected for several reasons. A brief, listing requirements, was considered to be realistic and neither too complex nor too trivial as a problem for an intensive design exercise. All subjects would have broad familiarity with the functioning of a school through personal experience. Finally, there are precedents in the use of school planning for design monitoring[2,3] which may increase the relevance of the experimental findings.

The subjects in the experiments were asked to prepare only a plan of the school, not elevations or sections. This was to simplify the design task, in view of the restricted time scale. It was also advantageous to those nonarchitects who might have lacked knowledge of drafting skills and conventions. Finally, it reduced the variety of attributes which the subjects had to consider.

Once prepared by the experimental subjects, the school plans were redrawn to a common scale, orientation and format before being evaluated. Redrawing was believed to be desirable in an experiment of this kind; it was done by Lowe[4] in his experiments in evaluation and recommended, though not done, by Cakin.[5] The advantages are that the sizes and orientations of the plans are readily comparable, individual presentation and drafting styles have no effect on the evaluations, and the quantity of information conveyed by each plan is the same.

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The disadvantages are that the amount of information given on each plan can be only as much as that provided by the original plan with the least information, the style of drawing is dependent on who does the redrawing and may convey some of his prejudices unintended by the designer and, linked to both these points, some of the designer's intentions may be eliminated. On balance, redrawing was considered essential. Limitations of the experimental timetable necessitated rapid redrawing, and a rather simple hand-drawn style was adopted throughout. There may be a case for using computer drafting systems in such experiments, though sometimes these impose their own restrictions, such as orthogonal geometry, which makes them less value-free than might be assumed.

## JUDGEMENT-ANALYSIS TECHNIQUES

The intention of using a judgement-analysis technique was to provide a means of eliciting verbally and numerically from the designers their valued attributes and the relationships between these attributes, so that comparisons could be made between each designers' proposals and his elicited subjective value judgements. It was also desired to find a means whereby designer's preferences between alternative designs could be elicited in a verbally and numerically precise way.

A psychological scaling method recently devised by Saaty[6] and known as prioritization was selected. Its choice was prompted through experience gained at the Department of Design Research, Royal College of Art. Its use forms part of a continuing exploration of such techniques in design research. Mallen and Goumain[7], Stansall[8] and Cornforth[9] have described experiments using the repertory grid technique and multidimensional scaling to study designers' judgements, and the present experiments may be considered a continuation of their earlier research.

Like similar techniques, Saaty's prioritization entails two processes: the elicitation of verbally stated attributes from the subject, followed by numerical scaling of the relationships between these attributes. In the evaluation of design proposals, numerical scaling of attributes is followed by scaling of plans with respect to each attribute.

The elicitation of attributes prior to scaling used two types of stimuli. In both cases the principle was that the attributes were elicited from the subjects; they are the attributes which the subjects themselves offer and use. In conjunction with the design process, the means of eliciting attributes involved the subjects being given a site plan for the school and briefing instructions about the school accommodation required. They were then read the following statement:

> Consider the implications of planning a two-form entry primary school, on the given site and to satisfy the given brief. What important attributes or qualities would you take into account in planning the school?

The architects, with whom the experiment was conducted with each individually, were asked to list six attributes. The student and nonarchitect groups had a brainstorming session and 20 to 30 attributes were elicited; then through discussion, each group was asked to condense these down to a basic list of six common attributes. The number of attributes, six, is in accordance with the widely recognized observation that the human mind is limited to seven, plus or minus two, factors for comparison at the same time[10], a point emphasized also by Saaty.

The second means of eliciting attributes, used in evaluating the school plans, is the method of triadic comparisons. The subjects were shown all possible combinations of three items (school plans) from the set of stimuli, and made similarity judgements among them. For each triad the subject has to separate out a pair that shares some common significant attribute, which makes them similar and differentiates them from the third item and to state the attribute. The maximum number of attributes which could be elicited in this way equals the number of triads which, when there are six plans, is 20; it is significant that the average number recorded was between six and seven, thus vindicating the decision to specify that number when the previous method of elicitation was used.

### Prioritization

Saaty's scaling method, prioritization, was used for establishing the designers' priorities among verbally elicited attributes. It was also used for establishing the designers' preferences between alternative designs, both for overall merit and with respect to individual attributes. Thus the same scaling technique was used in both the design and the evaluation phases of the experiments.

Prioritization is a means of deriving weights for a set of items according to their subjective importance. In conjunction with the design process, the subjects scaled the attributes elicited in terms of their relative importance to the success of the design. In evaluating the school plans, not only were the attributes scaled for their relative importance, but also the school plans were scaled for their relative degree of achievement of each attribute. Saaty's method enables the weights of attributes and the weights of plans with respect to each attribute to be combined using an additive utility model into an index of overall merit associated with each plan. This may be considered a form of *multi-attribute utility analysis*.

Saaty has described prioritization in great detail[6] of such a matrix to show that it expresses underlying properties of the judgements. First, the maximum eigenvalue of the and published many examples of practical applications[11-13], so only a brief account will be given here. The method involves the judge being presented with all possible combinations of two items from the set to be judged. For each pair, he uses a prespecified scale of 1 to 9 to decide the importance of each member of the pair. If they are of equal importance, this is denoted by each being given the value 1; if one is more important it is allocated a value on the remainder of the scale, ie 2 to 9, according to the degree of importance, while the other of the pair is allocated the reciprocal of that value. The integers and their reciprocals from each paired comparison are entered into a matrix.

Saaty has taken advantage of the special properties of such a matrix to show that it expresses underlying properties of the judgements. First, the maximum eigenvalue of the matrix gives a measure of the internal consistency of the judgements forming the entries. Second, he has shown that the normalized eigenvector associated with the maximum eigenvalue gives a weighting attached to each element implied by the judge's scaling. If perfect consistency among the judgements is assumed, the relative weights ascribed to items are given by normalizing the sums of each row of the matrix, or alternatively by normalizing the entries in any one column. The use of prioritization in conjunction with the attributes elicited from the designer, therefore, provides a measure of his priorities among attributes and of his consistency in weighting attributes.

In evaluation, the attributes used to differentiate between school plans may be weighted with respect to their relative importance in the success of the school. Also, prioritization may be used to assess the weights of the school plans with respect to each of the attributes. By the use of an additive utility model, these judgements may be combined using the formula:

$$I = \sum_{n=1}^{n} x_n y_n$$

where $I$ is an index of overall relative value of each plan, $x_n$ is the weight ascribed to attribute $n$ for its relative value to overall merit, and $y_n$ is the weight ascribed to the design for its relative value with respect to attribute $n$. Additionally, it is possible to use prioritization to obtain a weighting of overall merit of each plan by asking each subject to scale paired comparisons of school plans directly for overall merit, and these overall merit ratings can be compared with the index of combined partial judgements

Finally, in the evaluation of the plans, the triadic comparisons, which were used to elicit the attributes subjects were using to differentiate between designs, may also be used to find the groupings or clusterings of items inherent in those comparisons. Hierarchical cluster analysis enables a system of clustering representations to be constructed, which range from one in which each of the $n$ objects (plans) is represented as a separate cluster to one in which all $n$ objects are grouped together as a single cluster. The method described by Michon[14] was used, which itself is based on an algorithm proposed by Johnson.[15]

## EXPERIMENTAL METHOD

After pilot studies, a basic format for the experiments was decided upon. This format required the presentation of a site plan and briefing instructions to a set of six designers, all of approximately equal experience in design. The brief specified the accommodation to be provided, but no other detailed planning requirements. This was followed by the elicitation and prioritization of the designers' subjective valued attributes. Then each designer spent about three hours developing a school plan to satisfy the brief.

After design, prioritization of valued attributes was repeated. The six plans produced were redrawn. Each designer then evaluated all the six plans. Triadic comparisons were used to elicit the attributes being used in the evaluation to differentiate between plans. These attributes were scaled for their relative importance in school planning using prioritization. The plans were scaled for their relative degrees of fulfilment of each attribute using prioritization. The plans were also evaluated for overall merit using priorization.

Three such experiments were held, and each used experimental subjects of different levels of experience. The three were architects, students of environmental design (architecture) and nonarchitects.

The three experiments were not organized identically. The architects were seen individually by the experimenter. Each architect used his own valued attributes in the first elicitation and prioritization, and each was given the option of changing these attributes in the prioritization after design. For experimental control, each architect also had elicited from him and prioritized before and after design valued attributes for a holiday companion. In evaluation, the method of triadic comparisons was used to elicit the attributes each architect was using to differentiate between the school plans, and each architect evaluated the plans with respect to his own attributes.

### Brainstorming

The nonarchitects, conversely, met as a group and once the brief and site plan had been given out they used brainstorming to elicit attributes for school plan design. This was followed by a group discussion in which these attributes were combined or discarded, so that a basic list of six common attributes was agreed for the purposes of the experiment. These common attributes were used in prioritization before and after design, and in evaluation. The triadic comparisons were therefore used not to elicit attributes for evaluation but to see which of the six common attributes were actually being used to differentiate between plans by each subject.

The students of architecture also used brainstorming followed by discussion to agree their six common attributes. They repeat the process for attributes for a holiday companion. Both school plan attributes and holiday companion attributes were prioritized before and after design. As it had been found with the nonarchitects that in evaluation the weights ascribed after design
to attributes were almost identical to those ascribed after design, the third repeat of scaling common attributes in evaluation was dropped, and the weights ascribed after design were used in computing the indices of overall merit. Again the triadic comparisons were useful as a check on which attributes were being used to differentiate between plans by each subject.

Within each experiment, the data enable several hypotheses to be tested. These cover the changes in priorities and in the consistency with which priorities are expressed resulting from the design process, with a control to check that such changes are not arbitrary. Levels of concordance or agreement among priorities by a set of subjects both before and after design may be measured. Each designers' sketch plan may be compared with his verbally stated priorities. In evaluating the plans, levels of concordance between the weighting of attributes could be measured. Levels of concordance between the weighting of plans with respect to each attributed may also be measured. Finally, for each individual subject it is possible to compare the overall merit rating, the additive utility indices and the hierarchical cluster analysis of the evaluations of plans. Differences between the experiments do mean that not all these tests can be made in every experiment.

## RESULTS

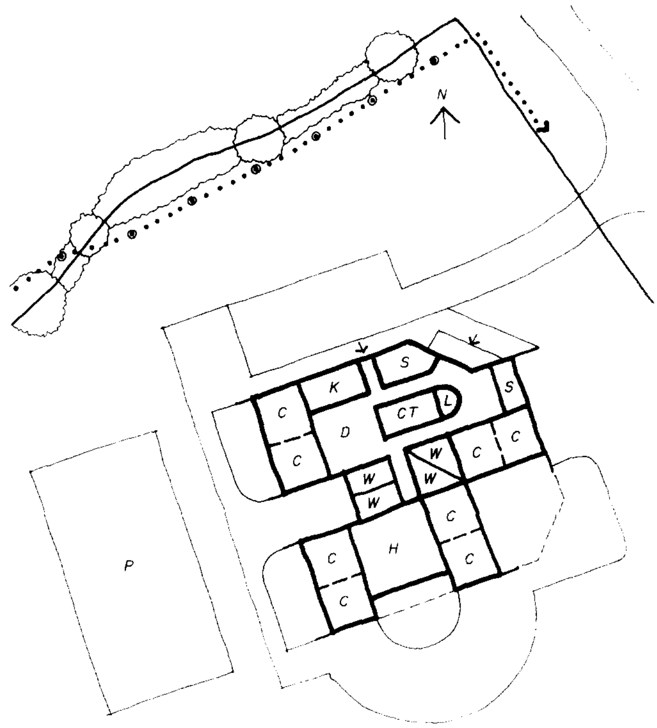
In the eliciting and scaling of attributes in conjunction with the design process, comparisons could be made between each designer's values and his design proposals. Figure 1 shows two of the architects' plans and the weighted priorities that were elicited from the two subjects. The dramatic differences between the plans may be explained by the differences in valued attributes.

Architect 1 has planned the classrooms in pairs according to age so that each pair can be opened up to create a space capable of offering a greater range of uses, and the juxtaposition of three of the four pairs next to the hall or dining room further increases the variety of potential uses. Circulation space is reduced to a minimum. His second attribute is also clearly demonstrated. The two pairs of classes for younger children are at right angles in the south east corner and create an intimate external courtyard, while the other two pairs face outwards to the playing fields. There is an obvious concern for inside/outside relationships, his third priority. With respect to orientation, classrooms have been kept off the north elevation, which is occupied only by service areas. Vehicular access to these service areas has been

| Weighting of attribute before design | Description of attribute | School plan |
|---|---|---|

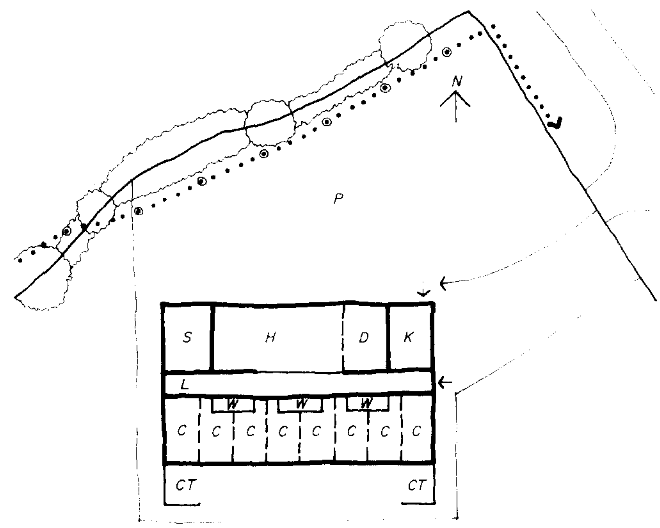
**Architect 1**

| | |
|---|---|
| 0.369 | Optimize use of scarce resources<br>• each space to offer alternative possible uses<br>• contiguous spaces jointly offering other alternatives<br>• waste eliminated<br>• internal circulation<br>• external vehicular access |
| 0.298 | Child's scale/identification<br>• recognizable/different spaces<br>• clarity of space organization<br>• group identity |
| 0.112 | Outside/inside relationships<br>• teaching extends outside<br>• openness |
| 0.074 | Flexibility<br>• short term: daily use/activities<br>• mid term: changing educational approaches<br>• long term: possible other uses (non-school?) |
| 0.074 | Orientation/aspect/shadowing |
| 0.074 | Access<br>• vehicles: car park (staff, visitors), deliveries<br>• pedestrians |




**Architect 2**

| | |
|---|---|
| 0.465 | Similarity of parts |
| 0.202 | Administration hierarchy not reflected in plan arrangement |
| 0.139 | Clear, easily understandable circulation |
| 0.115 | Flexibility |
| 0.047 | Light and airy (as opposed to cosy) |
| 0.033 | Simple structure/building system |




Key
C - Classroom
K - Kitchen
D - Dining room
L - Library
H - Assembly hall
W - W.C.s
S - Staff rooms
CT - Courtyard
P - Playground

*Figure 1. Designers values and their designs*

separated from pedestrian access. Flexibility is apparent only in the combining of pairs of classrooms.

The second plan illustrates the designer's intentions to achieve a school with little differentiation between one classroom and another, or between classrooms and other parts of the building. There is no obvious hierarchy in the plan, the administrative accommodation being tucked out of sight. Clear circulation around the building is achieved by means of a central spine corridor. Considerable flexibility is achieved by opening up the whole line of classrooms and by combining the hall and dining room, and opening these to the central corridor. One can well visualize a good deal of glazing giving light and air and a structural frame built on a simple grid layout.

These results, and the plans and attributes of other designer's, demonstrate quite clearly how the differences between designers' values may account for the differences between their design proposals.

Although the experiments presumed that designers' would use only a limited number of attributes, the subjects had no difficulty in offering a short list of priorities and in ascribing weights to them consistently using the scaling method. Together with evidence previously cited[1], the findings tend to support the belief that designers have an internally consistent simplified model, or representation, or value system, to guide and justify decision-making in the design process, and that the attributes designers' value may be understood as being weighted and ranked.

## Changes in ratings

After the design process, when the architects were asked if they wished to amend the attributes for school planning elicited before design, none wished to do so. Potential changes in each subject's rating of attributes for school planning, caused by the design process, were measured by calculating Spearman's rank correlation coefficient between each subject's set of ranks of attributes before and after design. To enable some kind of quantification, it was decided to consider that if the coefficient was greater than the statistically significant level for a probability of 0.05 then there had been no change to the ratings as a result of the design process.

For all six architects' pairs of rankings, there were no significant changes caused by the design process. Neither were there significant changes in the control part of the experiment where attributes for a holiday companion were scaled. In the experiment with students of architecture (who were each scaling the same set of six commonly agreed attributes), one of the students changed his rating of attributes significantly; and there were no significant changes in the rating of attributes for a holiday companion.

In the experiment with nonarchitects (who were each scaling the same set of commonly agreed attributes), four out of the six made significant changes in their rating of attributes as a result of the design process; and, while there was no control part of the experiment, when the subjects scaled attributes for a third time during the evaluation phase, it was found that there were no changes between the ratings after design and those during evaluation.

These results suggest that the architects had a fairly fixed view of their priorities and knew the major trade-offs they would make. Nonarchitects given a school to design may, on the other hand, be barely able to predict what trade-offs they will make, so the design process may result in them changing their priorities. Students of architecture may be somewhere between these two states.

A check was made to find whether there was any influence on the ratings according to the order in which they were scaled. This was done by calculating for each subject Spearman's rank correlation coefficient between the ratings of attributes for a school plan and those for a holiday companion, each set according to the alphabetical order in which they had been scaled by the subjects. There was no significant correlation, so there is no reason to believe that the order in which attributes are scaled has any effect on the ratings.

Improvements in the consistency with which attributes were scaled caused by the design process, were tested for by comparing the six subjects' set of consistency measures before and after design using the Mann-Whitney U-test. No significant changes were found. In the experiment with students of architecture and that with nonarchitects, the same results were found; there were no improvements in consistency caused by the design process. By implication, there is no improvement in consistency resulting from repeated use of prioritization.

Levels of agreement or concordance between subjects' ratings of attributes cannot be measured in the experiment with architects, since from each architect were elicited the attributes which he as an individual felt to be important. In the other two experiments, however, because the subjects scaled commonly agreed attributes, it is possible to measure such levels of agreement. In the experiment with students of architecture, Kendall's coefficient of concordance was calculated between the six subjects' sets of ranks of attributes; both before and after design the coefficients were significant at the 0.01 level. In the experiment with nonarchitects, the coefficient before design was significant at the 0.01 level, but (because four of the six subjects changed their ratings) after design the coefficient was not significant. These results were slightly surprising but may be explained by a theory put forward by March and Simon[16] that the decision-maker's organizational environment influences his value system. The homogeneous composition of a group of graduate students of architecture seems to have resulted in significant agreement about desirable attributes.

In the evaluation phases of the experiments, each subject's preference were expressed in three ways: by the additive utility model indices, by the overall merit rating, and by the hierarchical clusterings. From the similarity judgements, partial judgements and the overall merit ratings, it was possible to test how well the combination of partial judgements into an index correlated with the overall merit ratings, and how well each of these two measures corresponded with the hierarchical cluster analysis of the similarity judgements.

The three sets of judgements were compared graphically. Figure 2 shows these comparisons for each of the six architects. At the top of each subject's diagram is given the hierarchical cluster analysis in the form of a similarity tree or dendrogram. This shows the subjective clusterings derived from the similarity judgements. Below this, the additive utility model indices (dotted line) and the normalized eigenvectors given in overall evaluation (solid line) are plotted to the same scale, giving subjective evaluation profiles of the plans. As the figure indicates, the two profiles exhibit a high degree of correlation: subject *S*1 is highest, while *S*2 and *S*3 are somewhat lower. If the profiles are compared with the similarity trees, it can be seen that generally there is good correlation. Taking *S*1 as an example, it may be seen that his two least preferred plans, *C* and *F*, were clustered together and rated low. The three most highly rated plans, *A*, *B*, *E*, were also clustered together, and intermediate plan *D* was considered more similar to the three most preferred plans than to the other two. In contrast to *S*1 who separated out the two least preferred as being most similar, *S*3 separated out the two he most preferred, while *S*6 formed a cluster of the two most preferred and another cluster of the two least preferred.

In the experiment with nonarchitects, the above comparisons for their evaluations were rather less encouraging in that there was less correlation between the results of the three methods. There were two main causes. First, poor consistency in scaling attributes resulted in distortions in computing the indices. Second, and more important, the triadic comparisons revealed that not all six attributes had been used to differentiate between plans; particularly where a highly rated attribute had not been used, its own high rating distorted the indices.

In the experiment with students of architecture, the results of making the above comparisons were more

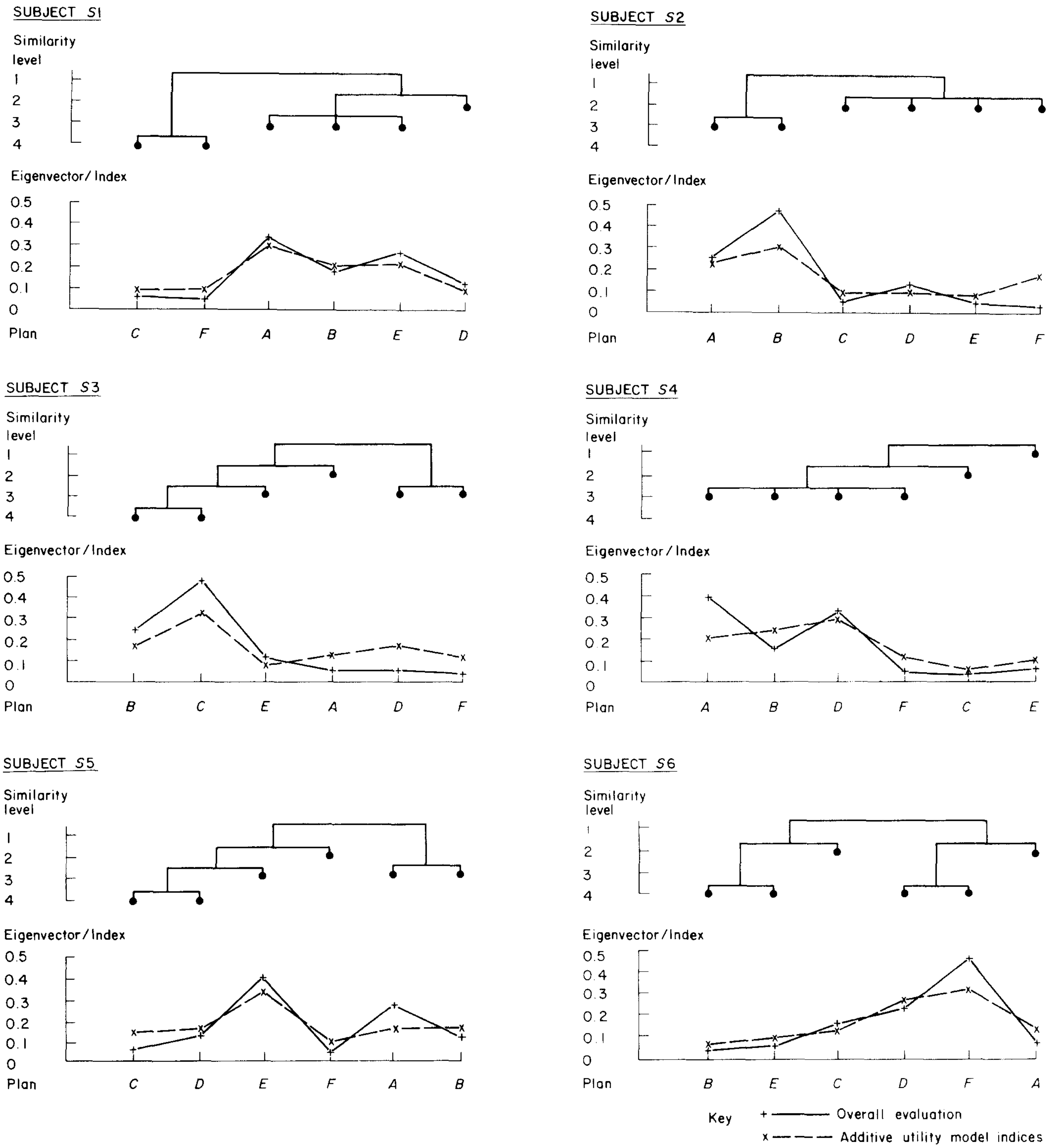



*Figure 2. Comparisons between each architect's similarity judgements of school plans and the weightings given in overall evaluation and in evaluation derived from additive utility model indices*

encouraging. In the case of one subject, he did not use the attribute he scaled most highly to differentiate between plans, and his consistency in scaling attributes was poor; both factors caused poor correlations. Better correlations were recorded for most of the other subjects.

## Concordance

Between the subjects' evaluations of designs, it was possible to test for concordance. Levels of agreement between the architects' evaluations of the school plans were measured using Kendall's coefficient of concordance. For the set of ratings for overall merit, the coefficient was found to be 0.149; for the set of indices, the coefficient was found to be 0.251. These results showed that there was no statistically significant agreement between the architects' evaluations. This is as would be expected; the architects valued different attributes and therefore do not agree in their evaluations of alternative design proposals.

In the experiment with nonarchitects, the same result was recorded; there was no significant agreement between the subjects' evaluations, either for overall merit or in the indices. In the experiment with students of architecture, a different result was recorded; concordance was statistically significant at 0.01 level both in overall merit ratings and indices. What is interesting about this result is that it is just as would be predicted by the original outline given in the introduction. Since the students of architecture were in agreement about priorities, it would be expected for them to be in agreement in their evaluations of design proposals, as indeed they are shown to be.

In the experiments with nonarchitects and students of architecture, the evaluations with respect to individual attributes could also be tested for concordance. For the nonarchitects, there was significant concordance between their evaluations with respect to two of the six attributes, but not for the other four. For the students, there was significant concordance at the 0.01 level between the evaluations with respect to each of the six attributes. The first of these results is a little disappointing, since it implies that in a few cases evaluators, even when evaluating plans with respect to the same attribute, have construed that attribute in a way not shared by all the evaluators.

Despite one or two slightly unexpected results, the data show clearly the way in which these techniques can be used to elicit designers' values and their evaluations of designs.

The findings illustrate the generative importance of a small set of strongly valued attributes in the conjecturing of design proposals. Differences between design proposals could be accounted for by differences between valued attributes. Weightings of attributes could be elicited consistently from the designers. The design process caused nondesigners to change their priorities as they negotiated a solution, though architects made no significant changes to their priorities in these experiments. The techniques were used also to illustrate in a precise way how preferences among alternatives reflect evaluators' priorities, and in particular that where designers have differed about the relative importance of attributes, they have also differed in their evaluations of alternatives, and that where there has been agreement about the relative importance of attributes, there has been agreement about the rating of designs.

## CONCLUSIONS

Design is a complex activity, and one which needs to be simplified in order to be understood and described. Many published accounts of the design process have emphasized the important role of value judgements in design. Value theory provides a framework for creating from such accounts a tentative outline for design. The present experiments have explored this outline by using Saaty's scaling method as a means to elicit and to analyse designers' judgements.

While these experiments have used relatively simple design problems and small numbers of subjects, the results provide strong evidence in support of the tentative theory. They underline the usefulness of value theory as one means to explain design. They stress the importance of the subjective structuring of design problems. The success with which the scaling method could be used to elicit this subjective structuring shows how frequently covert and implicit value judgements may be made the subject of critical examination.

Independent of the potential for practical application of Saaty's scaling method, the results have a number of implications for design. In teaching, alternative value systems should be explicitly discussed and compared, and awareness should be developed of the design implications of alternative value systems. For practice, if designers are to respond to clients' needs, it is essential for them to be briefed as precisely as possible, or to find out as much as possible, about their clients' values; or if designers' values remain unmodified by their clients' needs, then clients must choose designers whose values correspond to their own.

For research, there are several potential lines of development of these ideas: using judgement-analysis techniques in conjunction with quantitative evaluations provided by computer-aided building design systems, exploring the effect of specifying objectives or values on design proposals, and exploring whether and how a designer's value system is expressed in several different design problems. In experiments to monitor design processes, it seems essential to study strategies in the context of value systems and design proposals; if the differences between value systems have such obvious effects on designs, it is highly likely that they will also affect designers' strategies. One or more of these studies would seem to be an important next step for design research.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## REFERENCES


1 **Lera, S G** 'Empirical and theoretical studies of design judgement: a review' *Design Studies* Vol 2 No 1 (1981) pp 19-26

2 **Krauss, R I and Myer, J R** 'Design: a case history' in **Moore, G T (ed)** *Emerging methods in environmental design and planning* MIT Press, Cambridge, USA (1970)

3 **Willey, D S and Yeomans, D T** 'Monitoring graphic techniques in design' paper to CAD Conference, ICL (September 1974)

4 **Lowe, J B** 'The assessment of students' architectural design drawings' *Archit. Res. Teaching* No 2 (1972) pp 96-104

5 **Cakin, S** *Evaluation and participation in design* PhD Thesis, University of Strathclyde, UK (1976)

6 **Saaty, T L** 'A scaling method for priorities in hierarchical structures' *J. Math. Psychol.* Vol 15 No 3 (1977) pp 234-281

7 **Mallen, G L and Goumain, P** *The analysis of architectural design activity in the working environment* Rep. to Science Research Council, Dept of Design Research, Royal College of Art (1973)

8 **Stansall, P J** *A contribution toward the development of models of thought-processes underlying the design activity* MA thesis, Dept of Design Research, Royal College of Art, London (1973)

9 **Cornforth, C** *Towards the development of a model of the architectural design activity* MA thesis, Dept of Design Research, Royal College of Art, London (1976)

10 **Miller, G A** 'The magical number seven, plus or minus two' *Psychol. Rev.* Vol 63 No 2 (1956) pp 81-97

11 **Saaty, T L** 'Modelling unstructured decision problems – the theory of analytical hierarchies' *Math. Comput. Simulation* Vol 20 (1978) pp 147-158

12 **Saaty, T L** 'Applications of analytical hierarchies' *Math. Comput. Simulation* Vol 21 (1979) pp 1-20

13 **Saaty, T L and Erdener, E** 'A new approach to performance measurement: the analytic hierarchy process' *Design Methods Theories* Vol 13 No 2 (1979) pp 64-72

14 **Michon, J A** 'Multi-dimensional and hierarchical analysis of progress in learning' Fifth Ann. Symp. on Cognition, Carnegie-Mellon University, USA (1969)

15 **Johnson, S C** 'Hierarchical clustering schemes *Psychometrika* Vol 32 No 3 (1967) pp 241-255

16 **March, J G and Simon, H A** *Organisations* John Wiley and Sons, New York, USA (1958)