# Empirical and theoretical studies of design judgement: a review

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*This paper presents a review of some observation-based studies of the design activity and attempts two kinds of analysis of them. The first is to show some patterns of designer behaviour which appear to be common to most of the studies. The second is to show how observed behaviour is related to theoretical work on design. In particular the importance of judgement and evaluation in design is stressed. Using the framework of decision making and value theory, a tentative synthesis, compatible with both empirical and theoretical design studies, is proposed.*

Observation-based studies of the design process vary considerably in their time scales, methods of observation, and in the underlying framework within which they are conducted. Several early studies comprised simply observation and description; there was little underlying theory from which to develop and test hypotheses. More recently, and arising out of those early studies, design research has been characterized by the formulation of specific theories, and observations have been made to attempt to test such theories. Often researchers have looked to other disciplines for a framework within which to conduct their experiments; this has led to the characterization of design as, for example, 'problem solving' or 'decision making'. Because of the pervasive nature of the frameworks within which these studies have been undertaken and the highly specific nature of the techniques used, it is often difficult to see the relationships that exist between findings and to know whether and how they are compatible. Without such relationships being explicitly shown, further research cannot benefit fully from the growing body of knowledge about designing. Two authors have recently presented state-of-the-art reviews of current research. Gasparski[1] presents a tentative overview of the last three decades of design research, including both theoretical work and empirical studies. Gregory[2] tabulates and classifies 30 observation-based studies of designing and asserts that they constitute the prime material upon which development of knowledge about designing can be founded.

This present paper is an attempt to review some of the literature relating to the sketch-design process of individual designers. It is not an attempt to classify existing studies, but rather to present a coherent account of design which cites both theoretical and empirical work. Broadly, it shows the compatibility of several empirical studies with one another and with concurrent theoretical ideas about design. Because most of the studies cited are concerned with architecture, so this review tends to concentrate on architectural design.

The main argument to be proposed is that design may usefully be understood as a form of decision making. A typical design problem is introduced and analysed in terms of its dominant attributes and their relative values. Criticisms of the role of values and evaluation in design, and of the conscious deliberation of relative values, are themselves criticized. Existing descriptions of the design activity are cited, together with the analysis of the design problem exemplar, to demonstrate how value theory may provide a theoretical foundation for understanding design. Finally a specific technique, multi-attribute utility analysis, is shown to have potential as a basis for further exploration of the design process.

## TYPICAL DESIGN PROBLEM

Consider a typical example of the kind of design problem solved almost daily by most architects: the design of a domestic window. The design problem may be represented by a set of attributes.[3] Attributes are those qualities which it is hoped will be attributed to the final design. Attributes in design problems are commonly stated in the form of imperatives.[4] Typically, the window should:

- provide a good view to the outside
- allow sufficient daylight in the room
- allow adequate ventilation
- have a pleasing visual appearance
- not result in excessive heat gain or heat loss
- not exceed a certain cost

In designing the window, the designer specifies the decision variables, which might typically be:

- size
- proportion
- material of frame
- type of glazing

Faced with this type of problem, the designer knows that there are numerous alternatives each of which will result in different levels of fulfilment of the attributes. For example,

- a large window will give a good view, and good daylight, but it may be out of keeping with the room interior and the exterior; it may cause excessive heat gain and heat loss. Double glazing will reduce heat loss but will add to the capital cost. The large size may necessitate a costly material for the frame.

or

- a smaller window may be cheaper in capital cost, be more compatible visually both inside and out and not cause excessive heat loss and heat gain. But it may restrict the view, give little daylight in the room, and allow insufficient ventilation.

In designing the window the architect, whether explicitly or not, is making a value judgement about the relative importance of the attributes. Through his choice he is ascribing different weights to the attributes according to to the degree to which he values them. He may, for example

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choose a window in which all the attributes are represented approximately equally, or he may value a splendid view and, taking that as the major attribute, ascribe only low weights to the others.

The design process inexorably entails the designer making decisions, either alone or in collaboration with his client and/or consultants, either explicitly or more likely implicitly, about the attributes he believes to be important, and their relative weights. As Canter[5] has said

> The architect has to juggle the priorities.

The designer explores the problem and proposes solutions intended to satisfy the priorities he has decided on. During the process of exploration unforeseen critical interdependencies may become apparent as the designer learns more about the problem. Thus during the evaluation phases of the design process the designer may or may not find that his proposals reflect his priorities. If they do he may move on to another part of the problem. If they do not he may feel that his proposal nevertheless represents a good solution and adjust in his mind the original weightings to correspond with what he has proposed. What the designer wants depends upon what he finds he can have. This process has been described by Frischmuth and Allen[6] and has been termed 'solution by negotiation' in contrast to the 'solution by innovation' of Archer.[7]

There is no such thing as a right answer to this kind of problem. There are many answers and they demonstrate each of the attributes in varying degrees. What is recognized as a good answer is dependent upon value judgements. In evaluating proposals, preference will be shown for those which most closely reflect the priorities of the evaluator.

## CRITICS OF VALUE JUDGEMENTS IN DESIGN

The importance of values and evaluation in the design process seems self-evident. Surprisingly there is a school of thought which has sought to deny this:

> We believe that it is possible to define design in such a way that the rightness or wrongness of a building is clearly a question of fact, not a question of value. (Alexander and Poyner[8])

In developing a pattern language for design, Alexander decided to regard all human tendencies as worthy of fulfilment and conflicts as the occurrence of tendencies coming into opposition as a result of inadequate forms. Patterns would allow tendencies to coexist without conflict. In *A progress report on the pattern language* Duffy and Torrey[9] reaffirm the relationship of patterns to values:

> any approach based on the idea of the compromise of values or trade-offs is antithetical to the pattern language which attempts in each situation to achieve the best of all possible worlds by resolving all conflicts.

Daley[10] detected serious philosophical inconsistencies in Alexander's beliefs and suggested that, although he claimed to be observing conflicts which were brought on by inadequate forms, more often

> he seems to be defining conflict in terms of his own preconceived ideas about what constitutes bad form. (Daley[10])

She also noted that the question of observing tendencies in the environment could not be objective; tendencies might be undesirable and conflict among tendencies might coexist within the same person. Thus Alexander

> would have to decide which of the tendencies was worthy of fulfilment or facilitation by the environment, and that sort of decision, which would surely crop up repeatedly in any realistic assessment of human conditions, requires an appeal to values beyond Alexander's simplistic fiat that the sole criterion of 'rightness' in environment is the fulfilling of human tendencies. (Daley[10])

More recently March[11] has made a detailed examination of some of the unwritten assumptions and inaccuracies in Alexander's derivation of patterns.

First March shows that statements about conflicting tendencies

> are about values. Each can be rewritten 'X prefers . . .' and is therefore a statement about preferences. It is always possible to give such preferences a partial ordering and the design task can then no longer avoid the problem of evaluation. (March[11])

Second he shows that whereas Alexander puts forward, one solution (pattern), justified by an ostensibly scientific explanation, take it or leave it, this is an example of 'false precision' and that a more rational attitude leads to the selection of

> a solution from a range of possibilities and attempts to assess its relative value. (March[11])

Through his examination of the logic of design and the question of value, March is unequivocal that

> value theory is the essential foundation of any rational theory of design. (March[11])

## CRITICS OF WEIGHTING IN DESIGN

That attributes are weighted differently may seem to be self-evident, but there are those who have critized ranking and weighting procedures. Jones[12] characterizes attempts at weighting as absurd and, according to Grant,[13] Alexander and Manheim have also argued that consciously deliberated weights are not valid.

In support of his case, Jones notes that for numerical weights to be assigned, the data must be measurable on an interval or ratio scale. He also describes the problem of intransitive relationships in the process of ranking, and the requirement that the attributes have to be independent for weighting procedures to be valid theoretically.

Grant however makes the point that

> people must and do make decisions in multi-criterion situations, and act on them, whether or not the decision situation is theoretically well behaved and whether or not various criteria can be demonstrated to be factually independent. (Grant[13] but see also Wise[14])

Grant has described three options which those who do not believe in the validity of weighting procedures may follow to make essential judgements.

- Find the one most important attribute and decide on the basis of that attribute alone. This is of course a form of weighting albeit rather simplistic. The main implication of this method is that it involves hoping that all other attributes are satisfied at least to an acceptable degree. In any event, as he notes, this may be regarded as a form of weighting in which all attributes bar the main one are zero rated. Grant concludes that this approach is an inadequate response to a complex problem.
- Attempt to construct compelling graphic layouts from the partial judgements. Grant[13] describes two attempts to employ map-overlay techniques of decision criteria for highway locations. Each shaded overlay represents a decision criterion, and thus when all are overlaid the resulting shading indicates the optimum route. The technique has apparently been used by Alexander and

Manheim and by McHarg. According to Grant, McHarg simply combined the maps and thus built in an implicit equal weighting to each criterion. Grant asserts that Alexander and Manheim however did not merely overlay all the maps representing the decision criteria,

> they combined similarly patterned maps into one representative composite for each set of similar patterns. By so doing they assigned accidental weights of importance to each map or decision criterion and the accidentally assigned weights varied widely in magnitude. (Grant[13])

Grant goes on to quote an example in which he claims one map was weighted 62.5 times as heavily as another by graphic accident and without intelligent deliberation.

- Consider all criteria carefully, then sit back and let the matter incubate and an implicit intuitively derived decision may emerge. Grant asserts that even here

> It can be argued that the process of deliberating and aggregating weighted partial judgements is in fact a model of the process that one's mind must go through in arriving at an intuitive implicit gestalt decision, as a result of considering multiple criteria and then allowing an ensuing period of incubation. (Grant[13])

Just as Daley and March showed that critics of the notion of values and value judgements merely made the value judgements implicitly and then disguised them under the claim of factual objectivity, so Grant has shown that critics of weighting procedures in proposing alternatives have been known to make weighting decisions by default or implicitly without explicit recognition or deliberation.

## DESIGNERS' JUDGEMENT

> Le raisonnement, la critique, viendront à leur tour pour contrôler votre conception, car après avoir imaginé il faut que vous sachiez être les propres juges de votre imagination. (Guadet[15] *)

> In the design process judgement constitutes one of the integral creative components, in that it is the mechanism by which the relationship between intuitively imagined forms and intellectually apprehended data is continually assessed. For reasons stated earlier this aspect of judgement can be most conveniently considered in terms of 'decision making' because although, in theory, it would be possible for an architect to complete several different projects for any one building, and then 'judge' which is the best, in practice the process of selection can usually be effected most efficiently at embryonic stages in the course of the design, whereby only one final project is produced. (Collins[16])

Judgement, 'deciding the merits of', and evaluation, 'determining the value of', with the exceptions noted above, have been widely accepted in prescriptive and descriptive models of design. For example, many design methods were based on the three-phase cyclical process: analysis – synthesis – evaluation.

> One of the simplest and most common observations about designing and one upon which many writers agree, is that it includes the three essential stages of analysis, synthesis and evaluation . . . Most design theorists agree that it is usual to cycle many times through this sequence' (Jones[12])

More recently Hillier *et al*[17] have proposed a new paradigm for design. They argue that

> design problems are essentially pre-structured both by constraints and by the designer's own cognitive map. . . Design proceeds by conjecture-analysis rather than by analysis-synthesis.

Later they write of conjectures

> By and large they come from the pre-existing cognitive capability – knowledge of the instrumental sets, solution types and informal codes, and occasionally from right outside – an analogy perhaps, or a metaphor, or simply what is called inspiration.

And of analysis they write

> the purpose of analysis is primarily to test conjectures.

It is suggested that analysis is perhaps not the best term in this instance; 'testing conjectures' implies 'deciding the merits of' or 'determining the value of'. If this suggestion is accepted then the account by Hillier *et al* would be in close agreement with those quoted from Guadet and Collins at the beginning of this section. Design may be resolved broadly into imaginative and evaluative forces. Again therefore evaluation plays an essential role in design.

In descriptive models derived from observations of designers, there is both general recognition and detailed description of the role played by evaluation.

Lawson's results[18] are strongly supportive of the conjecture-evaluation paradigm in design. He studied strategies used in two-dimensional spatial layout problem-solving by architectural students and science-based (non-architectural) students. In comparing their strategies, he found that whereas the science-based students tended to search for underlying rules (analysis) and then propose a solution which satisfied those rules (synthesis), the designers proceeded by trying alternative configurations (conjecture) and testing whether they complied with the rules (evaluation). He described the former strategy as problem-focused, the latter as solution-focused.

From his monitoring of designers planning a bathroom layout, Eastman[19] drew a similar conclusion about generative and evaluative forces in design.

> Instead of generating abstract relationships and attributes, then deriving the appropriate object to be considered, the S's (subjects) always generated a design element and then determined its qualities.

Foz[20] monitored four subjects of varying degrees of design training during a two-hour architectural sketch-design problem. His findings support the same contention. He argues that the design activity proceeds as *ad hoc* responses to perceived misfits between a 'pre-solution model' evoked from memory and the program (design) requirements. Both Eastman and Foz applied an information-processing theory of cognition to help to provide explanations of their observation-based studies in terms of cognitive processes in design.

As Gasparski[1] has noted, in addition to observation-based studies as designers, a new and promising trend in design research is the effort to identify the internal representations used by designers.

Mallen and Goumain[21] citing psychologists Piaget and Bruner and other research in artificial intelligence and heuristic programming, posit the hypothesis that

> just as the child develops and uses internal representations of increasing sophistication to gain control over his environment, and as the master chess player uses a powerful representation to avoid exhaustive search in chess, then so does the designer develop and use internal representations of design problems to organise and control his progress through the design task.

They argue further that the internal representation is a dynamic plan of action for dealing with the problem. The model they propose is entitled SIMDAC (Simulation of Design Activity). It is intended

> to simulate the operation of internal representation processes.

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* 'Reasoning and criticism come in turn to control your ideas, because having used your imagination it is necessary to know how to exercise proper judgement of it' (author's translation).

In providing such a simulation

> The resulting computer model will be directly testable. That is, it will produce sequences of behaviour which will be comparable with sequences of real life design behaviour.

The fundamental mechanism of the model is the cybernetic feedback loop described by Miller *et al*[22] as a Test - Operate - Test - Exit, or TOTE, unit.

In parallel with the study by Mallen and Goumain, three research workers explored further the implications of the hypotheses proposed. Stansall[23] used Kelly's repertory grid technique to elicit the form of designers' internal representations. Henrion[24] observed designers in order to describe the nature of their plan of action in solving a design problem. Cornforth[25] combined these two approaches, using repertory grid technique and MDS (multi-dimensional scaling) analysis of the data to elicit designers' internal representations, and observing designers solving a sketch-design problem. He then attempted to compare the internal representation revealed by the MDS analysis with the plan of action, as observed in the designer's strategy. Stansall's subjects were first-year and final-year students of architecture. Using cluster analysis of the repertory grid data he found that the experienced architectural students revealed a greater number of separate clusters of constructs than did the inexperienced architectural students.

Henrion[24] monitored four subjects, two designers and two non-designers, arranging furniture in an office layout. His study of verbal protocols obtained from the designers dealt primarily with the way constraints operated. He studied how conflicting constraints were identified, before or during the process, and how they were resolved, partially resolved through compromise or not resolved but accepted. He presented some of his findings in the form of a graph of constraints identified and satisfied,

> intended to be a simple model of the subjects changing evaluation of the arrangements he generates in terms of the number of constraints it satisfies.

He characterized the design process as a series of modifications to the initial layout during which successive layouts satisfied increasing numbers of constraints. He concludes by stating that

> the design process was better modelled as a continuing attempt to increase the number of satisfied constraints, although it is clear that no solution exists which can satisfy them all. (Henrion[24])

Conforth[25] set up an experiment in which designers were monitored 'thinking aloud' while undertaking a sketch-design scheme, and in conjunction with the design process completed a repertory grid. Thus a verbal protocol could be transcribed and the results compared with a multi-dimensional scaling analysis of the repertory grid data. He characterized the sketch-design activity as a combination of a specification process and a search process. He offered evidence to support the hypothesis that search takes place in a hierarchy of problem spaces, and that the trend in the design process is to work from general simplified representations to more specific detailed representations. This is clearly apparent from the verbal protocol which Cornforth provides in the appendix. Right at the beginning of the design process the designer takes an overview of the problem and proposes an outline solution, which is then successively modified as new constraints are identified. He noted that constraints were identified in two ways: from memory and through perception of a misfit in a configuration. However the comparison between the plan of action and the internal representation proved to be of limited value:

> No structure could be found in the (MDS) configurations which corresponded to the detailed behaviour of the subjects.

Nevertheless considerable insight was gained into the design activity, and a number of observations made about the SIMDAC model. The experimental findings were in general agreement about SIMDAC, though some modifications were suggested. Cornforth, like Henrion, was unable to detect the relative importance of the constraints he idenfified in the protocols.

Elsewhere Baer[26] and Akin[27,28] have also conducted research into the design process within the framework of an information-processing theory of cognition. Akin's study of the architectural design process was conducted to propose a descriptive model of the design behaviour of architects. He provided evidence from protocol analyses of designer behaviour to support the existence of 11 different information-processing mechanisms in design, and explored three of them, 'design plans', 'transformation rules' and 'design symbols', in some detail. Among his many conclusions about design strategies and information-processing mechanisms, are several findings about designers' judgemental processes. On conflict resolution in design he notes

> conflicts are resolved either by remodifying the physical description or by modifying the problem criteria. (Akin[27])

He also provides evidence to support the conjecture-evaluation paradigm

> Often a few cues in the environment are sufficient to evoke a pre-compiled solution in the mind of the designer. (Akin[28])

Another important study of the designer's internal representation or conceptualization of a design problem is reported by Aish[29]. He used connectivity analysis in the design and evaluation of a control console layout. He took one attribute only, adjacency or interaction of elements, and compared, using connectivity analysis, the degree of complexity of interaction of elements specified by the client, achieved by a clustering algorithm, achieved by the designer's conceptualization (as elicited in a word-association test), and achieved in the designer's proposed console layout. One of the more important findings was that the designer's conceptualization achieved measurably less richness of interaction among elements than specified by the client, and that the designer's solution achieved measurably less richness of interaction than the designer's conceptualization.

In addition to the use of psychological measurement techniques for eliciting designers conceptualizations of problems, and the observation of designer behaviour to study information processing mechanisms in the design process, researchers have shown the benefits of interviewing designers about their own design processes, or of listening to and interpreting their accounts of their own design processes. Although such techniques imply subjective interpretations of the data by the researcher, the two following accounts both indicate the relative importance of constraints, an aspect of the design process which few of the previous accounts cited had been able to express.

Darke[30] interviewed a number of architects about their design process. She was able to provide strong support for the conjecture-analysis (or conjecture-evaluation) model of design. Furthermore she found a clear indication of architects' priorities from the interviews.

> It has been suggested in this paper that designers do *not* start with a full and explicit list of factors to be considered, with performance limits predetermined where possible. Rather they have to find a way of reducing the variety of potential solutions to the as yet imperfectly understood problem, to a class of solutions that

> is cognitively manageable. To do this they fix on a particular objective or small group of objectives, usually strongly valued and self-imposed, for reasons that rest on their subjective judgement rather than being reached by a process of logic. These major aims, called here *primary generators*, then give rise to a proposed solution or conjecture, which makes it possible to clarify the detailed requirements as the conjecture is tested to see how far they can be met. (Darke[30])

Where Darke reports on the designer's major aims as a small set of objectives, Grant suggests that the designer establishes priorities among his objectives in a way analogous to weighting and ranking procedures. He reports listening to a talk by an architect in which

> he described in his own approach a process in which the various opportunities and constraints of the site and of the client's needs and desires were weighed and ranked just as effectively as is done in the systematic procedures familiar now. His personal design process was one in which carefully thought out personal decisions were effectively integrated into overall judgements that led to a most worthwhile house. (Grant[13])

There is one other approach to understanding the design process which, although it does not seem to have been made the subject of research in architectural design, has been used with interesting results to study computer programmers. Weinberg[31] ran controlled experiments with computer programmers to find out how the specifying of different objectives or attributes would influence both the process and the product. Four programmers were given identical programming problems to solve, but two were asked for the program in as short a time as possible, the other pair that it should be as efficient in machine time as possible. The experiment was repeated with four other programmers. He found striking differences in the resulting programs, directly attributable to the different conceptions of the objectives; objectives not stressed were sacrificed to those stated explicitly. He found that the design processes varied too; different objectives caused different strategies to be followed by the programmers, particularly in their reaction to unanticipated difficulties. One of Weinberg's findings about computer programmers from his experiments is especially important in the context of design studies, for one of his conclusions was to suggest that a large proportion of the variation between programmers on any job can be attributed to a different conception of what is to be done; that is, programmers' differing values account in large part for the variations in their achievements.

To draw to a close this summary of accounts of designers' judgemental processes, mention should be made of some experiments which have been performed in the evaluation of designs. Many studies have been conducted under the heading 'architectural psychology' which attempt to establish user attitudes to buildings, and also to correlate the measurable performance of buildings with users' verbal responses. A number of techniques have been used in this research including Osgood's semantic differential (Canter[32], Canter and Wools[33], Wools[34]) and Kelly's repertory grid (Honikman[35]). This research generally has not been conducted to study the design process, although Abel's[36] 'Architrainer' was an attempt to teach students of architecture about their client's constructs using Kelly's repertory grid. However there are three studies in the evaluation of designs which are of direct relevance to the present review.

Lowe[37,38] obtained evaluations of seven redrawn student architectural design drawings. The evaluators were lecturers in schools of architecture. The designs were evaluated with respect to two criteria: 'functional planning' and 'effective use of daylight and sunlight'. Evaluations were made individually with respect to the first criterion, then after a discussion between a group of three assessors (to simulate a school of architecture jury) individually with respect to the second criterion. The method of ordinal paired comparisons was used for the evaluations so that inconsistencies could be measured. Lowe found that most assessors were able to maintain a consistent criterion of preference through the assessment session. In assessing the levels of agreement between the judgements he found that there was significant concordance between the judgements with respect to each of the two criteria.

Cakin[39] presented groups of people with five alternative design solutions for holiday chalets and asked them to put the designs in rank order of merit. The experimental subjects belonged to two categories: students of architecture and non-architects. The presentation of the schemes took forms: crude information (plans and elevations) and sophisticated information (plans, elevations and performance profiles). Cakin measured the concordance reached by the groups. He found that

- Groups of non-architects, given either crude or sophisticated information, exhibited significant concordance.
- Groups of architectural students, given sophisticated information, exhibited significant concordance.
- Groups of architectural students, given crude information, did not exhibit significant concordance.

Among his conclusions he suggests that

> One explanation for the differences found between the agreement levels and preferences of judges could be that each individual has a mental profile consisting of cost, performance and other attributes, each attribute having a different degree of importance. If the attributes he is presented with are the ones he thinks important then his judgement will largely be influenced by the profile rather than by the drawings. (Cakin[39])

Later he writes

> non-architects gave more consideration to the cost and performance measures of the schemes than the architects did. Architects seem to base their judgements on design drawings only. (Cakin[39])

These comments would certainly help to explain his results; the non-architects comparing primarily the given performance profiles would have an objective basis, the profile shapes, on which to make comparisons; the architects, not relying on the profile shapes and differing in the attributes to which they attach value, would therefore differ in their preferences.

Huber *et al*[40] obtained evaluations of 12 hypothetical hospital wards from 13 senior hospital staff members. The wards were described in terms of seven quantitative factors. Each subject marked each of the wards on a 1 - 100 scale. Huber *et al* used multi-attribute utility theory to interpret their results. They tried to fit the data to three forms of utility model and found that

> arguments supporting the use of addilog or multiplicative model forms were not particularly relevant in this experimental situation.

They concluded that a linear utility model was as useful as the other two to represent the value judgements of their subjects.

The evidence so far cited shows that even in the design of a modest window a decision implies a value judgement about the relative importance of attributes. Although some authors have criticized the conscious deliberation of value judgements, these views are shown to be invalid. Several authors are cited who emphasize the role of judge-

ment and of evaluation in the design process, and studies of designers provide empirical support for this contention; indeed Hillier *et al* create a kind of paradigm for design around the twin forces of conjecture and evaluation. Other authors have stressed that decisions are made with respect to a simplified representation, or have shown that the internal representation does not cope with the full complexity of the problem. One author has argued that designers fix on a small group of strongly valued objectives to generate their conjectures, and another that the designer establishes priorities among his objectives analogous to weighting and ranking procedures. This large body of evidence is strongly indicative of the need to refer to values in explanations of the design process. If value judgements play an essential role in the design process, then value theory may provide a basis for understanding decision making in design.

## VALUE THEORY

The link between values and their expression in decision making is well argued in value theory. Rescher, for example, in his *Introduction to value theory*[41] describes values as being manifested through decision making, in words and in deeds, and he notes the difficulty of defining value other than by reference to these manifestations. But by observing actions and words, values may be inferred. Having a value is different from having a goal but the two are linked in that one's goals are reflections of one's values, he argues; the fundamental role of a person's values is to determine the evaluation of his actions and thereby to support practical reasoning. Practical reasoning encompasses rational deliberation in the assessment of alternative courses of action; the comparative assessment of alternatives in the search for the optimal choice among competing mutually incompatible courses of action can be made only by recourse to value judgements. He argues further that in the logic of practical reasoning, values are an essential component and provide criteria for choosing among courses of action that are mutually exclusive in the context of finite resources.

Tribus[42] and Ozbekhan[43] have given similar accounts to that by Rescher explaining actions, decisions and outcomes, and their relationship to value judgements. For example, Ozbekhan writes

> (i) In order for man to act (rationally), a near or distant outcome must be visualised; (ii) such an outcome must be desirable; (iii) the desirability of an outcome can be judged in terms of its value, and the action leading to this outcome justified in terms of such value; (iv) if the actor has to choose among several outcomes, his preferences for one particular outcome must also be justified with respect to its value; (v) choice among outcomes enters into the action equation only when there are alternative valued outcomes available; (vi) the spectrum of alternative valued outcomes corresponds to the spectrum of options available. (Ozbekhan[43])

The organization of a person's values constitutes a value system (Bross[44], Rescher[41], Rokeach[45]). Rokeach describes the function of a value system as a general plan employed to resolve conflict and to make decisions. He writes

> Since a given situation will typically activate several values within a person's value system rather than just a single one it is unlikely that he will be able to behave in a manner that is equally compatible with all of them . . . A value system is a learned organization of principles and rules to help one choose between alternatives, resolve conflicts and make decisions.

This notion of a 'general plan' employed to make decisions is reminiscent of the 'internal representation' posited by Mallen and Goumain, as described above. Furthermore both seem to equate with the views of March and Simon[46] about decision making.

> Choice is always exercised with respect to a limited, approximate, simplified 'model' of the real situation.

Value theory, in addition to being a descriptive endeavour in philosophy and social science (Rokeach[45], Laszlo and Wilbur[47], Vickers[48]) has also been developed as a formal numerically based theory of decision making. The seminal work in this area was *The theory of games and economic behaviour* by Von Neumann and Morgenstern[49]. In it they set out the conditions for a theory of value. Subsequently Luce and Raiffa[50] gave a more general account of value theory and reformulated the set of axioms of rational behaviour.

From the theoretical issues which have been explored, techniques for decision making have been gathered together under the headings of decision theory and decision analysis. Behavioural decision theory is the study of the way decisions are made; Edwards[51,52] reviews the extensive research that has been conducted under this heading. The methods of decision analysis are systematic frameworks within which decisions may be made. Keeney and Raiffa[53] give an extensive account of formal techniques for making decisions with multiple objectives. Kaufman and Thomas[54] provide a collection of papers illustrating applications of these procedures in planning and management decision making.

The formal study of decision making using techniques and theories developed in decision theory has not found application in architectural design. An exception is the work of Derbyshire[55] who reports a study of indifference curves to represent the trade-offs made by architects and consultants between capital costs and running costs. However the view of design established in this survey indicates that more than two attributes may be taken into account, and furthermore that these attributes will be of both a qualitative and a quantitative nature. An alternative technique, multi-attribute utility analysis, seems more apposite to the view of architectural design established here. Grant[56,57] and Wise[14] have recently discussed the theory and potential of multi-attribute utility analysis in design, though neither presents empirical evidence or examples of its having been used to explore designers' judgement.

Multi-attribute utility analysis entails the following points:

- There is a set of alternative outcomes.
- There is a set of attributes.
- The outcomes demonstrate different degrees of fulfilment of the attributes.
- The decision maker has a preference ordering among the attributes; he can assess the relative weights attached to the attributes.
- The decision maker can assess the probability that any given alternative will fulfil an attribute.
- The decision maker selects the alternative which maximizes his utility function, that is, which in his subjective judge judgement fulfils those attributes which he most values.

It may be seen that this description corresponds to some accounts of design given above and in particular it corresponds closely to the example of a typical design problem:

- The set of alternatives are represented by the possible window designs.
- The various window designs result in different costs, lighting levels in the room, heat losses, and so on.
- The designer has a preference ordering among these attributes; he may value the view above all else or he may

consider each of the attributes mentioned to be of broadly equal importance, for example.

- In designing the window he bases his choice on achieving or fulfilling those attributes in proportion to the degree to which he values them.

Thus multi-attribute utility analysis may explain design decision making and may provide a suitable approach for studying design. According to this approach the designer may be considered to decompose the problem into the design variables and the attributes manifested by these variables. He assesses the subjective values or utilities of the attributes. He also assesses his expectation of the degree to which the choice of an alternative will fulfil a certain attribute. A folding back operation using the utilities and subjective probabilities of outcomes gives the subjective expected utility of each outcome. This subjective expected utility is the summation of the probabilities of alternative outcomes combined with the values attached to those outcomes. The designer's choice maximizes his expected utility.

## SUMMARY

This paper has sought to show that judgement is an essential component in the design process. In assessing the reasoning behind judgement in the design process it has been shown that such judgements may be accounted for by recourse to values. Value theory provides a basis for understanding decision making during the design process. Multi-attribute utility analysis provides a framework for studying design.

Using the framework of multi-attribute utility analysis together with descriptive accounts of design, a tentative outline of the design process may be proposed as follows:

- Designers use a simplified model, or 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 weighed 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 self-imposed values, or of the explicit specification of certain objectives by the client or the 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.

Although many of these points may, once stated, seem obvious, some observation-based studies of the design process have ignored these principles. In Foz's research[20], for example, there is a strong separation of the process from the product:

> In the analysis of the verbatim protocols and drawings I judged neither the designer's ability, nor the quality of his proposal. That is to say, I concentrated on how he/she experienced problem-solving rather than on the formal, logical properties of his product.

It seems probable that the detailed strategy which the designers followed might apply only because of their specific objectives. As Thomas and Carroll[58] have noted

> the typically implicit goal structure that the designer brings to the design situation will drastically alter his/her design activity and the product of that effort.

An important next step in design research would therefore seem to be to explore the designer's goal structure or value system to find out precisely what effect this has on the process and on the product. In passing it may be noted that one important principle to emerge clearly for the practice of design is for goals or values to be explicitly recognized and discussed, and concisely defined. Failure to do so may result in the designer designing for himself instead of for his client, or may prevent him from knowing what his objectives should be and thus prevent him from following an efficient strategy.

In a subsequent paper, I hope to show how the ideas put forward here generated an experimental programme. Designers' value systems were measured using a technique of judgement analysis, developed by Thomas Saaty[59], in conjunction with their preparing sketch designs. In this way their priorities, as elicited verbally and numerically, could be compared with their designs, in an attempt to show how their proposals could be accounted for by reference to their priorities.

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