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Tom Heath

ON NOT GETTING IT WRONG: SCIENCE AND DESIGN IN ARCHITECTURE

Design seeks to stop things going as badly as they might otherwise do. That is not a *definition* of design. It is the beginning of an attempt to answer the question, «Why do we design?». What is the purpose or use of designing? Definitions are useful guides to understanding words, not always so useful in understanding life. JONES (1970, 1981) gives eleven different definitions of design which he attempts to summarise in a twelfth: «To initiate change in man-made things.» This definition does suggest some answers to our question: we are going to do something, necessarily in the future, perhaps some time off, and there is something new about it. There is another element common to several of the definitions Jones gives: the element of attempted foresight or planning. Instead of simply doing something, we are going to do it in anticipation, so to speak; we are going to simulate our proposed action before we actually do it. Now we would surely not go to all this trouble if we believed that success was inevitable. We do it because we fear that things will go wrong. Our intended action is likely to fail, and it is to avert that failure that we plan or design. Design seeks to stop things going badly.

Things go badly, by and large, because of human limitations. Mackie quotes G. J. Warnock to the effect that the human predicament is «inherently such that things are liable to go very badly». Mackie goes on to say:

> Among the factors which contribute to make things go badly in the natural course of events are various limitations —limited resources, limited information, limited intelligence, limited rationality, but above all, limited sympathies (MACKIE, 1977 : 108).

That is a statement which should be carved in stone in some prominent place in every design school. Leaving that aside, however, we notice that most of these limitations are human limitations. If we knew more, if we acted more wisely and generously, or even more cautiously, resources would not be a problem. These human limitations are all too familiar, but there is amongst designers a strong tradition of Utopianism which tends to make us ignore them. If the approach to design taken here seems a negative one, it is in part as a counter to that Utopian tradition which seems so positive and yet does so much harm.

Design therefore aims at removing human limitations. That is, our first proposition, that design seeks to prevent things going badly, turns out to imply that design seeks to remove the limitations of resources, of information, of intelligence, of rationality and of sympathy that operate in the normal course of events. Does that seem too sweeping a statement? No practising designer is likely to deny that design is concerned with removing limitations of resources. Readers of a journal such as this will not dispute that it is, or should be, concerned with removing limitations of informa-

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tion. It is widely accepted that designers should be concerned for the needs and aspirations of the users of their buildings, which involves sympathy as well as knowledge. Design clearly aims at overcoming these limitations. Yet important as they are, these human limitations are not central to design. They do not create the *need* for design. They do not determine its character as an activity. The need for design arises because of the limitations of our intelligence and rationality, which are narrow and absolute. What are these limitations? Let us consider them in the context of the limitations on design itself.

Design is subject to human limitations. Design resources are limited, particularly the fundamental resource of time. The designer cannot, and does not, get all the information which is necessary, or desirable. Designers are often and justly criticised for their failures of sympathy; it is the *leitmotif* of the environment —behaviour literature. Yet their most decisive limitation is the human limitation of rationality and intelligence. While rationality and intelligence are subject to a variety of limitations, the most important is the limitation of the processing capacity of our short-term memory. The «short-term memory» is jargon for what we ordinarily call our consciousness. The limitation of our short-term memory determines the number of things of which we can be conscious, that is, the number of things we can think about simultaneously. This number was identified by George R. Miller in a very famous paper «The magical number 7 Plus or Minus 2» (Miller, 1956, 1967). We cannot think of more than nine things at once; in practice, most of us cannot think of more than three or four. Many kinds of games and many everyday experiences depend on this fact, which is easily demonstrated by simple parlour experiments. Yet it seldom obtrudes into awareness, and its vital consequences are not widely understood or accepted.

Inadequate understanding of our limitations underlies a number of false theories of design. Holistic theories, theories of inspiration, theories of design as art, theories of genius, and the more recently fashionable phenomenological theories are all false. All these theories, which we may generally label «Romantic» have in common the notion that the designer sometimes conceives a solution whole, complete, all in one piece. If human beings could do this, design would be unnecessary. Design exists because our capacity to envisage the future, to cope with complexity, to cope with novelty, is so narrowly limited. Instead of saying «We will do this», the Utopian vision complete in our minds, we have to work it out. For the Utopian vision can consist of no more than nine, and probably no more than six, things. The complexity of the real world, its contradictions and conflicts, its ignorances, have been drastically edited. And what has been omitted, even in a little, familiar thing like a house, may be important. When the time comes to carry out the design serious conflicts which have not been considered will emerge. They have been edited out, but they will not stay out. Things will go badly wrong.

These false theories, in turn, prevent the effective use of science in designing. Indeed, it must be admitted that one reason for their popularity is that they provide an excuse for not learning some difficult subjects, and for not doing work which many designers are reluctant to do. Laziness should perhaps be included in our list of human limitations. However, such theories are also seriously and passionately held by many designers. Where this is so, the effective application of science is excluded. It is excluded in principle, because everything of significance is assumed to happen in what Chris Jones called the «black box» of the designer's mind (Jones, 1969). There is *no point of application* for scientific theory or knowledge. It may of course be proposed that scientific knowledge, once absorbed adds itself to the bubbling pot of the designers subconscious as one more spice which serves to produce the magically perfect design. In practice, we do not observe this to happen. Nor should we expect it to. For even accepting the Freudian theory of subconscious or unconscious thought —for which there is no empirical evidence whatever— still what is conceived in the unconscious must come out. And it must come out through the gate of consciousness, through the eye of the needle with its 7±2 limited capacity. So the effective use of science in designing can only be piecemeal, step by step; and it is just that piecemeal, step by step approach which Romantic theories reject.

Designers are reluctant to give up these false theories. Few designers are theoreticians, and, if truth be known, few are much influenced by theory. This makes theoreticians very cross. But if there is one theoretical point, on which a majority of practising designers are agreed, it is in holding some vague kind of romantic theory. Even Walter Gropius, whose humanity, practicality, and immense influence have cast him in the role of bogey-man for some recent writers, held fundamentally romantic views of design (Gropius, 1956; Herdeg, 1983). That is, despite the positivitism and pragmatism now imputed to him, he believed that design was at bottom a matter of intuition and of inspiration. What this means is that practising designers agree that there can be no explicit theory of design, no formal description based on and conforming to observation. Partly, this is because it is in fact very difficult to give such descriptions. Designers in practice do not want to be bothered by people with patently false notions of the way in which design can and should proceed. Especially they do not want to be bothered by such people attempting to tell them their business. Romantic theories keep off the busybodies. Romantic theories also sustain the Myth of the Romantic Artist, so useful in keeping bureaucrats and engineers at bay (Heath, 1984*a*). Finally, Romantic theories help with the centipede problem. No practising designer designs according to an explicit method. They do not want to think about it, lest, like the centipede in the fable, who was asked how he managed to control all those legs, they become paralysed. All of this has sad consequences for the application of science in architecture. It continues to be slower, more piecemeal and more haphazard than it should. For this, however, scientists and apologists of science are to some extent to blame.

Designers need these false theories of design in particular to defend themselves against much more widely held false theories of professional practice in general. Outstanding amongst these is what Schon has called the model of Technical Rationality. According to this theory,

> professional activity consists in instrumental problem solving made rigorous by the application of scientific theory and technique (Schon, 1983 : 21).

Schon traces the origins of this model from the positivism of Comte, through the German universities, to the universities of America, and into the conventional wisdom of all universities and all professions. Indeed, as Schon points out, superficial conformity to this model has become a criterion for professional status. Unfortunately this model is just wrong. The growing criticism and self criticism of the professions over the last two decades has focused on «the mismatch of traditional patterns of practice and knowledge, to features of the practice situation —complexity, uncertainty, instability, uniqueness, and value conflict» (SCHON, 1983 : 18). These are the realities with which the practising architect has to cope every day. In design practice, few decisions, and very few of the most important decisions, can be based on any well founded scientific theory or technique. This fact is also more apparent than it is in, let us say, medicine or engineering. Architects have therefore had to explain why it is that they do not do what they are «supposed» to do. They have had to advance an alternative model of their activity, in terms of which it could «make sense» to others. Romantic theories have served this purpose, even if they have not served it well.

In practice, design is not primarily instrumental. Instrumental problem solving implies that the goal is clearly defined. The problem is of a known class, and a solution can be reached by the application of established technique. Design is not like that. Design is concerned with setting or agreeing on goals as much as, or more than, with achieving them. Instrumental problem solving is approximated when there is a single function or a small number of functions to be optimised. The problem then lies in the means of achieving this. Even then, we only have an *approximation* to instrumental problem solving. There is always a limit to the number and scale of side effects which will be acceptable. In fact, as has been argued in detail elsewhere (HEATH, 1984*b*) design can only approach instrumental problem solving as a result of some very far-reaching social consensus on goals. In a fast-changing world such consensus is scarce and becoming scarcer. Design as instrumental problem solving is, we might say, an endangered species. The designers primary task is, as often as not, to secure some kind of agreement on what is wanted, or what ought to be done. Nor does this apply only to the broad disposition of the design; it applies at every level from the selection of paint colours to (dare one say it) the choice of structural system. The limitations on design, the constraints within which the designer has to work, are revealed as being much more social than physical.

Design can, therefore, seldom be rigorous. At every step the process is inflected by decisions about what ought to be the case, by agreements and deals between conflicting parties, by compromises with outside forces which cannot be controlled, or cannot be controlled in time for the work to proceed. The rationality of design is limited, as we have seen, by the limitations of our ability to reason. It is also limited by the rationality, or irrationality, of those designed for, and ultimately of the social situation at large. Where a significant portion of the decisions in a decision set or sequence are political and therefore, might have been otherwise, we cannot speak of rigour. This observation was originally made in connection with town planning (RITTELL and WEBBER, 1973 : 155-169) and was also soon extended in principle to architecture (HEATH, 1972 : 91-96; SIMON, 1973 : 181-200). The implications have since been worked out in some detail (HEATH, 1984*b*). The non-instrumental character of most design and its lack of rigour are both consequences of its nature as a social activity. It follows as already argued, that design does not and can never under any conceivable circumstances, fit the model of Technical Rationality. It is not a matter of our knowing too little; however much we may come to know, our knowledge cannot fit into design in that sort of way. We therefore need to give a new and better account of the way that scientific theory and technique can and do fit into design. We need this rather badly, if the real contribution which science can make to design is not to be lost.

Science is an invaluable aid to design, but it cannot constitute design. No theory about the world, and no set of observations designed to test any such theory, will in themselves produce a design. Design is concerned with producing something new; that «something» therefore does not yet exist to be observed or theorised about. Design is concerned with what *ought to be* the case, and this, as Hume pointed out in the eighteenth century, can never follow from what *is* the case. (If something is not, or cannot be the case it is idle to say that it ought to be, but that is a different matter). Existing solutions to practical problems which incorporate scientific theory may act as the starting point of a new design, but that is because they have, themselves, been designed, not because of the scientific theory which they incorporate. Theories of science as an activity, for example the hypothesis-test-hypothesis exit theory, may provide models for theories of design, but they do not constitute design, any more than they constitute science. You cannot have a theory of science before you have a science to theorise about, and you cannot have a theory of design before you have design to theorise about.

Yet we know that science *is* an invaluable aid. We really do not want buildings which fall down, or deflect or crack unduly. We really do not want buildings which leak, or are noisy, or are too hot or too cold. These problems cannot be passed over to engineers or technicians to solve after the event if they have not been solved in the preliminary design. Nor is qualitative understanding alone enough, as MAINSTONE (1975, 1983) has shown so entertainingly in connection with the failures of Santa Sophia in Istanbul. What applies to structures applies to heat exchange, sound penetration, wind pressure: designers do not only need to know how, but pretty accurately how much. But where does this fit into the design process? To answer that we need better models of design as an activity than we have been accustomed to use. ///

Design can be pictured as a process of «imaging» or imagining, representing, and testing, which is repeated until an acceptable, or «satisficing» proposal is obtained. This model is proposed by Zeisel in his book *Inquiry by Design* (ZEISEL, 1981); it is based on an extensive review of the literature and is consistent, though not identical, with other current models, for example, that given by HEATH (1984*b*, ch. 6.5). Zeisel developed this model to cope with the application problem in environment-behaviour research, and it is therefore peculiarly applicable to our present concern. «Imaging», Zeisel says «means forming a general, sometimes only fuzzy, mental picture of a part of the world». Just how this is done will not be discussed here; a detailed discussion can be found in HEATH (1984*b*, ch. 2.5) though much more empirical work is needed. In any case it is not very important, because this initial image, limited as it is by the capacity of our short term memory, exists only to be amended, added to, and generally improved.

This cannot happen in the short term memory alone. Therefore, it has to be represented: placed in what Newell and Simon have called the external memory (NEWELL and SIMON, 1972). Usually in the case of architectural design this presentation will take the form of a drawing —at this stage, a rough sketch. The presentation is then tested, that is, it is critically examined to see how well it fits what is known about the problem, whether its aesthetic implications are satisfactory or not, and so on. It is then rejected, modified or developed. All this can happen very rapidly; each line added to a sketch may represent a complete cycle. Depending on where the start has been made, a part of the problem may be expanded and added to, or an overall structure individuated and elaborated; and the two processes may alternate.

Zeisel pictures the development of this process as taking place through linked cycles: what he calls «a spiral metaphor». If it is proceeding well, it homes in on a «zone of acceptable responses». This phrase draws attention to the fact that in practice design cannot be optimised. This is true even if we disregard those factors, previously discussed, which are non-rational. Simon was the first to bring out the way in which most engineering design makes use of maxima and minima, boundary conditions, rather than optima (SIMON, 1969). He coined the term «satisficing» to describe designs which are acceptable in that they are within the boundary conditions specified. Given that for each sub-problem of a design problem there is a number of satisficing solutions Np then the total number of satisficing solutions for the whole design is of course Np_1 x Np_2 x Np_3 and so on. It can then be shown that the number of satisficing solutions in a given design problem is much more likely to be either infinite or zero than one (HEATH, 1984*b*). From the point of view of method, then, the object of the design process is to locate the boundaries of the zone of acceptable responses, or solution space, and a proposal which lies within them. The heuristic described in Zeisel's model is efficient because in it proposals or images are used to locate constraints or boundary conditions and are progressively adapted to the constraints as the work progresses. The constraints or boundary conditions are the «tests» which occur in each cycle.

What science can do is to provide some highly reliable tests. It may also serve other purposes. As Zeisel observes:

> information used in designing tends to be useful in two ways: as a heuristic catalyst for imaging and as a body of knowledge for testing (ZEISEL, 1981 : 6).

Despite this, it is difficult to think of cases in which scientific informations in its pure form is sufficiently concrete to act as a source of images. Only when it is embodied in technology, or more strictly in a «technology package» can scientific theory or knowledge act directly as a starting point for design. Be that as it may, the action of scientific theory and knowledge in testing proposals is intuitively obvious, and of great importance. Science gives us precise and reliable answers to the general test question, «if I do this, what will go wrong?» Such answers will be in such form as: «If you do that, the floor will deflect so much that loose objects will roll about» or «if you do that, 60% of people can be expected to complain of being too hot on 12 days a year». Strictly, locating the boundaries or constraints requires a further step: some sort of social consensus as to what is or is not acceptable. There is for example a social consensus that deformations sufficient to cause loose objects to roll about are quaint in Elizabethan inns, but represent failure in a modern office. This point is worth noting because it is often overlooked. We tend to learn the socially acceptable boundaries along with the methods of predicting performance. Thus the assumption creeps in that the design is somehow predictable from the facts. This is not so; theory and information can only tell us definitely what cannot be the case; that is, provide tests.

Such tests, applied at the right times and in the right order, help to ensure that things do not go too far wrong. It is important to make them at the right time. Design in practice is always a race against time: the resource of time is limited. This means that we must home in on the zone of acceptable responses as fast as possible. The way to do this is to apply tests as soon as they can effectively be applied; the longer we delay, the more work may be wasted. For the same reason we must apply tests in the right order. The most general tests should be applied first. General tests may be quite enough: we look at the order of cost before we attempt a detailed cost plan; we look at the approximate volume of building in relation to the site envelope before we prepare the sketch plan. Or at least we do if we are cautious.

The question then is what is the most efficient sequence? How can we design process? For this is what the question amounts to. It has been shown (HEATH, 1984*b*) that there is no general solution. However, it is possible to develop heuristic models. Design processed can be thought of as directed networks of decisions. They can be represented, after the event, in the form of precedence diagrams. What we can do after the event we can also, by taking thought, do before the event. That is, we can ask ourselves, what information and what previous decisions will I need to make decision x without too much risk of being wrong? Having determined that it depends on decisions m, n, o, p and facts f, g, h, we then ask the same question again of these prior decisions and so on. It is of course a great help to start with a very broad, rough model of the overall decision process. Invention of such models is one of the main tasks of design theory, and some progress has been made. Such models are no help with imaging, and very little help with presenting. What they can do is to improve the efficiency of testing. They also serve as tools for what SCHON (1983) calls «frame analysis». They represent the underlying conceptual framework which the designer is using, and this gives the possibility of choosing other, and more relevant frameworks. This however, goes far beyond the scope of the present paper, which has had the more modest aim of showing how and why science is important in not getting things wrong.

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