Systematic Procedures

There may be differences in their preferred models, but the proponents of new models of the design process all agree that there is a need to improve on traditional ways of working in design.

There are several reasons for this concern to develop new design procedures. One is the increasing complexity of modern design. A great variety of new demands is increasingly being made on designers, such as the new materials and devices (e.g. electronics) that become available and the new problems that are presented to designers. Many of the products and machines to be designed today have never existed before, and so the designer’s previous experience may well be irrelevant and inadequate for these tasks. Therefore a new, more systematic approach is needed, it is argued.

A related part of the complexity of modern design is the need to develop team work, with many specialists collaborating in and contributing to the design. To help coordinate the team, it is necessary to have a clear, organized approach to design, so that specialists’ contributions are made at the right point in the process. Dividing the overall problem into subproblems in a systematic procedure also means that the design work itself can be subdivided and allocated to appropriate team members.

As well as being more complex, modern design work often has very high risks and costs associated with it. For example, many products are designed for mass manufacture, and the costs of setting up the manufacturing plant, buying in raw materials, and so on, are so high that the designer cannot afford to make mistakes: the design must be absolutely right before it goes into production. This means
that any new product must have been through a careful process of design. Other kinds of large, one-off designs, such as chemical process plants, or complex products such as aeroplanes, also have to have a very rigorous design process to try to ensure their safe operation and avoid the catastrophic consequences of failure.

Finally, there is a more general concern with trying to improve the efficiency of the design process. In some industries there is a pressing need to ensure that the lead-time necessary to design a new product is kept to a minimum. In all cases, it is desirable to try to avoid the mistakes and delays that often occur in conventional design procedures. The introduction of computers already offers one way of improving the efficiency of the design process, and is also in itself an influence towards more systematic ways of working.

**Design Methods**

One of the most significant aspects of this concern to improve the design process has been the development of new design methods. In a sense, any identifiable way of working, within the context of designing, can be considered to be a design method. The most common design method can be called the method of ‘design-by-drawing’. That is to say, most designers rely extensively on drawing as their main aid to designing.

Design methods can, therefore, be any procedures, techniques, aids or ‘tools’ for designing. They represent a number of distinct kinds of activities that the designer might use and combine into an overall design process. Although some design methods can be the conventional, normal procedures of design, such as drawing, there has been a substantial growth in new, unconventional procedures that are more usually grouped together under the name of ‘design methods’.

The main intention of these new methods is that they attempt to bring rational procedures into the design process. It sometimes seems that some of these new methods can become over-formalized, or can be merely fancy names for old, commonsense techniques. They can also appear to be too systematic to be useful in the rather messy and often hurried world of the design office. For these kinds of reasons, many designers are still mistrustful of the whole idea of ‘design methods’.
The counterarguments to that view are based on the reasons for adopting systematic procedures, outlined above. For instance, many modern design projects are too complex to be resolved satisfactorily by the old, conventional methods. There are also too many errors made with conventional ways of working, and they are not very useful where team work is necessary. Design methods try to overcome these kinds of problems, and, above all, they try to ensure that a better product results from the new design process. They can also be good practice methods for student designers, offering a training in certain ways of thinking and proceeding in design.

Some design methods are new inventions of rational procedures, some are adapted from operational research, decision theory, management sciences or other sources, and some are simply extensions or formalizations of the informal techniques that designers have always used. For example, the informal methods of looking up manufacturers’ catalogues or seeking advice from colleagues might be formalized into an ‘information search’ method; or informal procedures for saving costs by detailed redesigning of a component can be formalized into a ‘value analysis’ method. Different design methods have different purposes and are relevant to different aspects of and stages in the design process.

The new methods tend to have two principal features in common. One is that they formalize certain procedures of design, and the other is that they externalize design thinking. Formalization is a common feature of design methods because they attempt to avoid the occurrence of oversights, of overlooked factors in the design problem, of the kinds of errors that occur with informal methods. The process of formalizing a procedure also tends to widen the approach that is taken to a design problem and to widen the search for appropriate solutions; it encourages and enables you to think beyond the first solution that comes into your head.

This is also related to the other general aspect of design methods, that they externalize design thinking, i.e. they try to get your thoughts and thinking processes out of your head and into the charts and diagrams that commonly feature in design methods. This externalizing is a significant aid when dealing with complex problems, but it is also a necessary part of team work, i.e. providing means by which all the members of the team can see what is going on and can contribute to the design process. Getting a lot of systematic work out of your head and onto paper also means that your mind can be more free to pursue the kind of thinking at which it is best: intuitive and imaginative thinking.
Design methods therefore are not the enemy of creativity, imagination and intuition. Quite the contrary: they are perhaps more likely to lead to novel design solutions than the informal, internal and often incoherent thinking procedures of the conventional design process. Some design methods are, indeed, techniques specifically for aiding creative thought. In fact, the general body of design methods can be classified into two broad groups: creative methods and rational methods.

Creative Methods

There are several design methods which are intended to help stimulate creative thinking. In general, they work by trying to increase the flow of ideas, by removing the mental blocks that inhibit creativity or by widening the area in which a search for solutions is made.

Brainstorming

The most widely known creative method is brainstorming. This is a method for generating a large number of ideas, most of which will subsequently be discarded, but with perhaps a few novel ideas being identified as worth following up. It is normally conducted as a small group session of about four to eight people.

The group of people selected for a brainstorming session should be diverse. It should not just be experts or those knowledgeable in the problem area, but should include a wide range of expertise and even laypeople if they have some familiarity with the problem area. The group must be nonhierarchival, although one person does need to take an organizational lead.

The role of the group leader in a brainstorming session is to ensure that the format of the method is followed, and that it does not just degenerate into a round-table discussion. An important prior task for the leader is to formulate the problem statement used as a starting point. If the problem is stated too narrowly, then the range of ideas from the session may be rather limited. On the other hand, a very vague problem statement leads to equally vague ideas, which may be of no practical use. The problem can often be usefully formulated as a question, such as ‘How can we improve on X?’

In response to the initial problem statement, the group members are asked to spend a few minutes, in silence, writing down the first ideas that come into their heads. It is a good idea if each member has
a pile of small record cards on which to write these and subsequent ideas. The ideas should be expressed succinctly, and written one per card.

The next, and major, part of the session is for each member of the group, in turn, to read out one idea from his or her set. The most important rule here is that no criticism is allowed from any other member of the group. The usual responses to unconventional ideas, such as ‘That’s silly’ or ‘That will never work’, kill off spontaneity and creativity. At this stage, the feasibility or otherwise of any idea is not important; evaluation and selection will come later.

What each group member should do in response to every other person’s idea is to try to build on it, to take it a stage further, to use it as a stimulus for other ideas, or to combine it with his or her own ideas. For this reason, there should be a short pause after each idea is read out, to allow a moment for reflection and for writing down further new ideas. However, the session must not become too stilted; the atmosphere should be relaxed and free-wheeling. A brainstorming session should also be fun: humour is often an essential ingredient of creativity.

The group session should not last more than about 20–30 minutes, or should be wound up when no more new ideas are forthcoming. The group leader, or someone else, then collects all the cards and spends a separate period evaluating the ideas. A useful aid to this evaluation is to sort or classify the ideas into related groups; this in itself often suggests further ideas, or indicates the major types of idea that there appear to be. If principal solution areas and one or two novel ideas result from a brainstorming session then it will have been worthwhile.

Participating in a brainstorming session is rather like playing a party game; and like a party game it only works well when everyone sticks to the rules. In fact, all design methods only work best when they are followed with some rigour, and not in a sloppy or half-hearted fashion. The essential rules of brainstorming are:

- No criticism is allowed during the session.
- A large quantity of ideas is wanted.
- Seemingly crazy ideas are quite welcome.
- Keep all ideas short and snappy.
- Try to combine and improve on the ideas of others.
Example: container lock

This example shows how brainstorming can be applied to the task of creating a new solution to an old problem: the locking of containers (the large goods containers transported by lorries). The conventional solution is a padlock, but then the key for the padlock also has to be either transported together with the container (hence presenting an obvious security problem) or sent separately to the recipient (possibly getting lost). In practice, it seems that most container padlocks are ‘opened’ with a bolt-cutter, because no-one can find the key!

A short brainstorming session was held to generate ideas for solving this problem. The problem was stated as: ‘Provide a means of securing containers that is tamper-proof but easy to open.’ Within a few minutes, the following ideas were generated:

- incorporate an electronic code – fax the code to the recipient;
- combination lock;
- time lock;
- clasps welded together;
- a locked bolt that is easily cut to open it;
- padlocks with master keys retained by regular customers;
- giant stapler and staple-remover;
- ceramic bolt that can be smashed;
- glass bolt that sounds alarm when smashed;
- lorry driver swallows the key;
- a ‘puzzle’ lock that can only be opened by a very skilled person.

Some of these are fairly ‘obvious’ ideas, but getting them out of your head can sometimes seem to free the mental space for other ideas to come. Others are ‘crazy’ ideas, such as the lorry driver swallowing the key; in such a case, everyone knows where the key is, but has to wait a couple of days before it can be recovered! (Another sort of ‘time lock’, as the proposer explained!) There is also an example in the list of one idea building upon another: the ‘glass bolt that sounds an alarm when smashed’ was a response to the ‘ceramic bolt’ idea, but based also on fire alarm buttons that are activated by smashing the glass cover.
In reviewing this list of ideas several novel concepts come to mind, but perhaps most appealing is the simplicity of adapting what is already the unofficial but conventional solution: to cut the bolt off. A bolt could be made such that it was designed to be cut off. Made in two sections, the parts of the bolt would be pushed together to secure the container, and could only be opened by being cut. Colour coding and numbering each bolt would mean that it could not be replaced in transit, and if it was cut open then this would be obvious. Such simple but secure bolts would be cheaper than conventional padlocks. The ‘Oneseal’ disposable container lock was designed on these principles.

**Synectics**

Creative thinking often draws on analogical thinking, on the ability to see parallels or connections between apparently dissimilar topics. The role of humour is again relevant, since most jokes depend for their effect on the unexpected transfer or juxtaposition of concepts from one context to another, or what Koestler called the ‘bisociation’ of ideas. Bisociation plays a fundamental role in creativity.

The use of analogical thinking has been formalized in a creative design method known as ‘synectics’. Like brainstorming, synectics is a group activity in which criticism is ruled out, and the group members attempt to build, combine and develop ideas towards a creative solution to the set problem. Synectics is different from brainstorming in that the group tries to work collectively towards a particular solution, rather than generating a large number of ideas. A synectics session is much longer than brainstorming, and much more demanding. In a synectics session, the group is encouraged to use particular types of analogy, as follows:

**Direct analogies**

These are usually found by seeking a biological solution to a similar problem. For example, Brunel’s observation of a shipworm forming a tube for itself as it bored through timber is said to have led him to the idea of a caisson for underwater constructions; ‘Velcro’ fastening was designed on an analogy with plant burrs.

**Personal analogies**

The team members imagine what it would be like to use oneself as the system or component that is being designed. For example, what would it feel like to be a motorcar suspension unit; how would I operate if I were a computerized filing system?
Symbolic analogies
Here, poetic metaphors and similes are used to relate aspects of one thing with aspects of another. For example, the ‘friendliness’ of a computer, the ‘head’ and ‘claw’ of a hammer, a ‘tree’ of objectives, the ‘Greek key pattern’ of a housing layout.

Fantasy analogies
These are ‘impossible’ wishes for things to be achieved in some ‘magical’ way. For example, ‘What we really want is a doorkeeper who recognizes each system user’; ‘We need the bumps in the road to disappear beneath the wheels’.

A synectics session starts with the ‘problem as given’: the problem statement as presented by the client or company management. Analogies are then sought that help to ‘make the strange familiar’, i.e. expressing the problem in terms of some more familiar (but perhaps rather distant) analogy. This leads to a conceptualization of the ‘problem as understood’: the key factor or elements of the problem that need to be resolved, or perhaps a complete reformulation of the problem. The problem as understood is then used to guide the use of analogies again, but this time to ‘make the familiar strange’. Unusual, creative analogies are sought, which may lead to novel solution concepts. The analogies are used to open up lines of development which are pursued as hard and as imaginatively as possible by the group.

Example: forklift truck
A design team looking for new versions of a company’s forklift trucks focused on the problem area of using such trucks in warehouses for the stacking and removal of palletted goods. Conventional forklift trucks have to face head-on to the stacks in order to place and lift the pallets, and then be manoeuvred again within the aisle between the stacks in order to move to another location or to exit the warehouse. This means that the aisles have to be quite wide, using up warehouse space.

This example shows how synectics thinking can be used in the approach to such a problem. Direct analogies could be used to ‘make the strange familiar’, i.e. to familiarize the team with the new problem. For instance, analogies of the movement of snakes might be explored, leading to ‘the problem as understood’ being the need for a truck to twist sinuously in its manoeuvring. To ‘make the familiar strange’, the team might use personal and fantasy analogies of the kind: ‘If I was holding the pallet in my outstretched arms,
going along the aisle, I would like to be able to twist my upper body through ninety degrees (without moving my feet) to place the pallet in the rack.’ Symbolic analogies of rotating turrets and articulated skeletons could lead eventually to a new design concept of an articulated truck with forks mounted on a front section that could swivel through ninety degrees. The Translift ‘Benditruck’ was designed on these principles.

**Enlarging the search space**

A common form of mental block to creative thinking is to assume rather narrow boundaries within which a solution is sought. Many creativity techniques are aids to enlarging the ‘search space’.

**Transformation**

One such technique attempts to ‘transform’ the search for a solution from one area to another. This often involves applying verbs that will transform the problem in some way, such as

magnify, minify, modify, unify, subdue, subtract, add, divide, multiply, repeat, replace, relax, dissolve, thicken, soften, harden, roughen, flatten, rotate, rearrange, reverse, combine, separate, substitute, eliminate.

**Random input**

Creativity can be triggered by random inputs from whatever source. This can be applied as a deliberate technique, e.g. opening a dictionary or other book and choosing a word at random and using that to stimulate thought on the problem in hand. Or switch on a television set and use the first visual image as the random input stimulus.

**Why? Why? Why?**

Another way of extending the search space is to ask a string of questions ‘why?’ about the problem, such as ‘Why is this device necessary?’ ‘Why can’t it be eliminated?’, etc. Each answer is followed up, like a persistent child, with another ‘Why?’ until a dead end is reached or an unexpected answer prompts an idea for a solution. There may be several answers to any particular ‘Why?’, and these can be charted as a network of question-and-answer chains.

**Counter-planning**

This method is based on the concept of the dialectic, i.e. pitting an idea (the thesis) against its opposite (the antithesis) in order to generate a new idea (the synthesis). It can be used to challenge a conventional solution to a problem by proposing its deliberate opposite, and seeking a compromise. Alternatively, two completely
different solutions can be deliberately generated, with the intention of combining the best features of each into a new synthesis.

**The creative process**

The methods above are some techniques which have been found useful when it is necessary for a designer or design team to ‘turn on’ their creative thinking. But creative, original ideas can also seem to occur quite spontaneously, without the use of any such aids to creative thinking. Is there, therefore, a more general process of creative thinking which can be developed?

Psychologists have studied accounts of creative thinking from a wide range of scientists, artists and designers. In fact, as most people have also experienced, these highly creative individuals generally report that they experience a very sudden creative insight that suggests a solution to the problem they have been working on. There is a sudden ‘illumination’, just like the light-bulb flashing on that cartoonists use to suggest someone having a bright idea.

This creative ‘Ah-ha!’ experience often occurs when the individual is not expecting it, and after a period when they have been thinking about something else. This is rather like the common phenomenon of suddenly remembering a name or word that could not be recalled when it was wanted.

However, the sudden illumination of a bright idea does not usually occur without considerable background work on a problem. The illumination or key insight is also usually just the germ of an idea that needs a lot of further work to develop it into a proper, complete solution to the problem.

Similar kinds of thought sequence occur often enough in creative thinking for psychologists to suggest that there is a general pattern to it. This general pattern is the following sequence: recognition – preparation – incubation – illumination – verification.

- **Recognition** is the first realization or acknowledgement that ‘a problem’ exists.
- **Preparation** is the application of deliberate effort to understand the problem.
- **Incubation** is a period of leaving it to ‘mull over’ in the mind, allowing one’s subconscious to go to work.
- **Illumination** is the (often quite sudden) perception or formulation of the key idea.
- **Verification** is the hard work of developing and testing the idea.
This process is essentially one of work–relaxation–work, with the creative insight (if you are lucky enough to get one) occurring in a relaxation period. The hard work of preparation and verification is essential. Like most other kinds of creative activity, creative design is 1% inspiration and 99% perspiration!

The sudden illumination is often referred to as a ‘creative leap’, but it is perhaps not helpful to think of creative design as relying on a flying leap from the problem space into the solution space. The creative event in design is not so much a ‘leap’ from problem to solution as the building of a ‘bridge’ between the problem space and the solution space by the identification of a key solution concept. This concept is recognized by the designer as embodying a satisfactory match of relationships between problem and solution.

**Rational Methods**

More commonly regarded as ‘design methods’ than the creativity techniques are the rational methods which encourage a systematic approach to design. Nevertheless, these rational methods often have similar aims to the creative methods, such as widening the search space for potential solutions, or facilitating team work and group decision-making. So it is not necessarily true that rational methods are somehow the very opposite of creative methods.

Many designers are suspicious of rational methods, fearing that they are a ‘straitjacket’, or that they are stifling to creativity. This is a misunderstanding of the intentions of systematic design, which is meant to improve the quality of design decisions, and hence of the end product. Creative methods and rational methods are complementary aspects of a systematic approach to design. Rather than a straitjacket, they should be seen as a lifejacket, helping the designer, especially the student designer, to keep afloat.

Perhaps the simplest kind of rational method is the checklist. Everyone uses this method in daily life; for example, in the form of a shopping list, or list of things to remember to do. It externalizes what you have to do, so that you do not have to try to keep it all in your head, and so that you do not overlook something. It formalizes the process, by making a record of items which can be checked-off as they are collected or achieved until everything is complete. It also allows team work or participation by a wider group, e.g. all the family can contribute suggestions for the shopping list. It also
allows subdivision of the task (i.e. improving the efficiency of the process), such as allocating separate sections of the list to different members of the team. In these respects, it is a model for most of the rational design methods. In design terms, a checklist may be a list of questions to be asked in the initial stages of design, or a list of features to be incorporated in the design, or a list of constraints, standards, etc., that the final design must meet.

There is a wide range of rational design methods, covering all aspects of the design process from problem clarification to detail design. The next eight chapters present a selection of the most relevant and widely used methods, also covering the whole design process. The selected set is listed below, with the stage in the design process on the left, and the method relevant to this stage on the right.

<table>
<thead>
<tr>
<th>Identifying opportunities</th>
<th>User scenarios</th>
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</thead>
<tbody>
<tr>
<td>Aim: to identify and define an opportunity for a new or improved product.</td>
<td></td>
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<table>
<thead>
<tr>
<th>Clarifying objectives</th>
<th>Objectives tree</th>
</tr>
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<tbody>
<tr>
<td>Aim: to clarify design objectives and subobjectives, and the relationships between them.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Establishing functions</th>
<th>Function analysis</th>
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<tbody>
<tr>
<td>Aim: to establish the functions required, and the system boundary, of a new design.</td>
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<table>
<thead>
<tr>
<th>Setting requirements</th>
<th>Performance specification</th>
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<tbody>
<tr>
<td>Aim: to make an accurate specification of the performance required of a design solution.</td>
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<table>
<thead>
<tr>
<th>Determining characteristics</th>
<th>Quality function deployment</th>
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</thead>
<tbody>
<tr>
<td>Aim: to set targets to be achieved for the engineering characteristics of a product, such that they satisfy customer requirements.</td>
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<table>
<thead>
<tr>
<th>Generating alternatives</th>
<th>Morphological chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim: to generate the complete range of alternative design solutions for a product, and hence to widen the search for potential new solutions.</td>
<td></td>
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</table>
Evaluating alternatives

Aim: to compare the utility values of alternative design proposals, on the basis of performance against differentially weighted objectives.

Improving details

Value engineering

Aim: to increase or maintain the value of a product to its purchaser whilst reducing its cost to its producer.

As we shall discuss later, in Chapter 13, these eight stages of design, and their accompanying design methods, should not be assumed to constitute an invariate design process. However, Figure 4.1 suggests how they relate to each other and to the symmetrical problem–solution model developed in Chapter 3. For example, clarifying objectives (using the objectives tree method) is appropriate both for understanding the problem–solution relationship and for developing from the overall problem into subproblems.

Figure 4.1  Eight stages of the design process positioned within the symmetrical problem/solution model
This model of designing integrates the procedural aspects of design with the structural aspects of design problems. The procedural aspects are represented by the sequence of eight methods (anticlockwise, from the top), and the structural aspects are represented by the arrows showing the commutative relationship between problem and solution and the hierarchical relationships between problem/subproblems and between sub-solutions/solution.

In the following eight chapters, each of the methods included in the model is presented in a step-by-step procedure, followed by a number of short practical examples and a more complete worked example. The examples show that such methods are often adapted to suit the particular requirements of the task in hand. Although it is important not to follow any method in a slavish and unimaginative fashion, it is also important that an effort is made to follow the principles of the method with some rigour. No beneficial results can be expected from slipshod attempts at ‘method’.