

ENGINEERING DESIGN METHODS

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Abstract: *A related part of the complexity of modern design has been the development of new design methods. This paper reviews the field of design methods, describes methods that help to stimulate creative design thinking such as brainstorming, synectics and enlarging the search space and introduces the most relevant and widely used rational methods that covering the whole design process. The eight methods included are: user scenarios, objectives tree, function analysis, performance specification, quality function deployment, morphological chart, weighted objectives and value engineering.*

Key words: *engineering design methods, creative methods, rational methods.*

1. INTRODUCTION

There is a 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. One of the most significant aspects of this concern to improve the design process has been the development of new design methods. The main intention of these new methods is that they attempt to bring rational procedures into 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. Other general aspect of design methods is that they externalize design thinking, i.e. they try to get thoughts and thinking processes out of 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.

Design methods 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.

2. CREATIVE METHODS

Since creative thinking is an extremely important part of the design process, some design methods are devoted to stimulate creativity in design process. The most well-known and practiced creative methods are brainstorming, synectics, and enlarging the search space/removing mental blocks.

2.1. Brainstorming

The brainstorming method aims to stimulate a group of people to produce many ideas quickly [1]. This method increases the quantity of the ideas that it may also foster the quality of the ideas generated. This argument is supported by the definition which describes that this method as an activity for generating a large number of ideas, most of which will subsequently be discarded [2]. From this perspective, it can be concluded that brainstorming method aims to quickly elucidate as much ideas as possible to avoid overlooking valuable ones.

The brainstorming method provides the design process with a variety of perspectives that couldnot be gained through conventional methods. This method could be applied simply and directly

and at any stage of the design process, unless the design process is stabilized. The brainstorming activity might also be used to generate information instead of ideas [1].

2.2. Synectics

In synectics, the aim is to direct the spontaneous activity of the brain and the nervous system towards the exploration and transformation of design problems. Synectics is identified as the formalization of analogical thinking [2]. Similar to brainstorming, synectics is a group activity, through which the members of the group try to generate and combine ideas to develop a creative solution to a certain problem. This method differs from brainstorming in that the group tries to generate ideas together on a particular design problem, instead of trying to generate as much ideas as possible. In addition, a synectics session takes much longer than a brainstorming session. In conclusion, the synectics method provides unusual and creative solutions for a design problem, however it involves certain risks and disadvantages.

2.3. Enlarging the Search Space

The aim of this method is expanding the solution areas of the design problem with certain techniques. This method is identified as removing mental blocks which aims to find new directions of search when the apparent search space has yielded no wholly acceptable solution [1]. Four techniques is suggested in practicing this method as (1) transformation through which the search for a solution is transformed from one solution area to another, (2) random input which is used to facilitate creativity by providing random inputs from any source, (3) why? why? why? by which the search space is extended through asking why? questions about the problem, (4) counter-planning which is used to challenge an existing solution to a problem by suggesting its opposite [2]. This method is rather applicable when the search area for a complex problem is limited to generate any solutions.

3. RATIONAL METHODS

The creative phase is the most important stage of the design process in search of novelty through the design activity. However, the design activity also requires certain methods that bring a systematic approach to the whole design process. Hence, rational methods aim to enhance the quality of both the design decisions and the product. This method also encourages teamwork, by which the tasks could be divided into minor tasks to be achieved by a team. The checklist illustrates the systematic approach to a set of tasks, whereas the design activity entails complicated methods or a set of methods to be systemized.

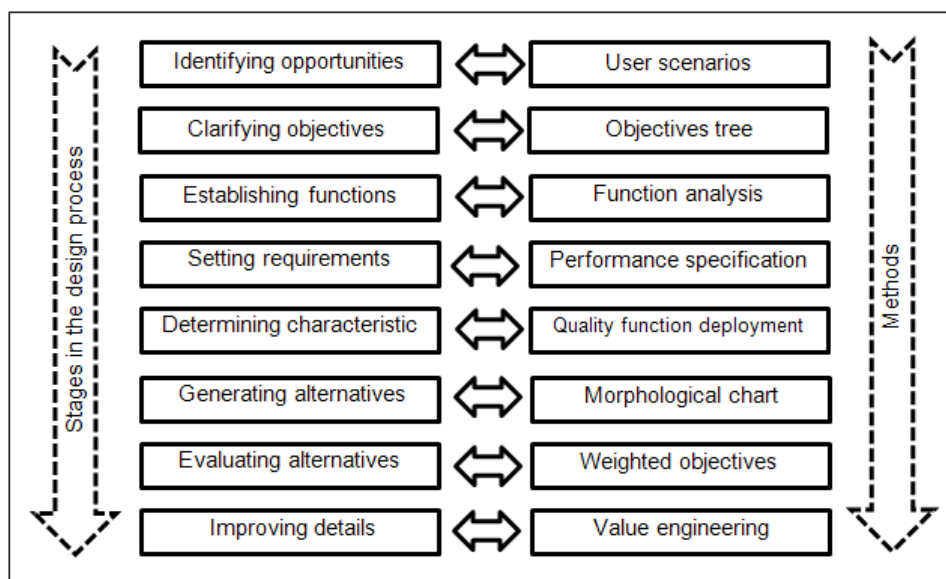


Fig. 1. Stages of the design process

There is a wide range of rational design methods, covering all aspects of the design process from problem clarification to detail design. Fig. 1 represent the most relevant and widely used methods,

also covering the whole design process with the stage in the design process on the left, and the method relevant to this stage on the right.

3.1. The User scenarios method

Many products do not work well in use because the presence of the user is not strongly represented during design. A user-centered approach is often referred to as universal or inclusive design – meaning designing to include everyone. Regarding this, the user scenarios method provides a useful starting point and focus for the design process by taking the users point of view, and identifying opportunities for creating new products that aim at satisfying users need [2].

The practice of this method entails a five-step-process to be carried out including (1) deciding which users (or users) point(s) of view to adopt and the variations to the user trip or trips (using the product or service in a deliberate way and noting reactions), (2) observing experienced and inexperienced users in action, (3) questioning users about their experiences, (4) creating relevant users personas and scenarios; persona is a well-defined but hypothetical user, and scenario is a storyline about their use of the product or service, (5) defining the preliminary goal, context, constraints and criteria for a new product opportunity which are the key steps in formulating a good brief for a new product design.

3.2. The Objectives tree method

This method refers to the important step of the design process where the objectives of the design activity are clarified. The aim of the objectives tree method is to clarify design objectives and sub-objectives, and the relationships between them [2]. While practicing this method, three main steps should be followed. Initially, a list of design objectives is prepared utilizing a variety of sources such as the design brief, expectations of the client, arguments of the design team and so on. In the latter step, the listed objectives and sub-objectives are grouped in a hierarchical order. Eventually, an illustrative tree of objectives is drawn representing the hierarchical relationships and linkages between all objectives.

The objectives tree method helps the design team achieve a clear and helpful statement of objectives, which represents the set of objectives and the outline of the path that would be followed in order to achieve those objectives. The output of this method also helps the design team and their clients agree on the stated objectives.

3.3. The Function Analysis Method

To adequately meet the stated objectives of the design activity, instead of solutions, essential functions of a solution should be established. This attempt defines the level of the design problem, i.e. whether a problem should need a radical design change or a design improvement. Regarding this, the function analysis method aims to establish the functions required, and the system boundary, or a new design [3].

The function analysis method entails five main steps to be carried out, which are (1) expressing the overall function of the design activity in terms of transforming process inputs into outputs, (2) dividing the overall function of the design activity into a set of essential sub-functions, (3) illustrating the interactions between sub-functions in a block diagram, (4) drawing the system boundary that defines the functional limits of the design solution, and (5) searching for suitable components to meet the sub-functions and the interactions among them.

The function analysis method draws the outline of the essential functions that the output of the design activity would be expected to satisfy. Therefore, the design team is enabled to develop alternative solutions that meet these predefined functions.

3.4. The Performance Specification Method

Although identifying the objectives and functions of the design activity clarifies the requirements of a design solution, they are not identified in exact limits. For that reason, certain boundaries should be set to the solution space for the design team to search for solutions. The aim of the performance specification method is to make an accurate specification of performance required of a design solution [2].

The procedure of this method is in four phases that comprise (1) considering the different extents (the level of generality) that the solution might cover in an applicable manner, (2) deciding on the extent to study in, (3) apart from any solutions, identifying the required performance characteristics, and (4) precisely specifying specific performance requirements for each characteristics.

The performance specification method helps the design team determine and specify the design problem in order to establish the study space and means of adequately resolving the problem for the designers. This method identifies the necessary performance that the solution should achieve instead of physical components of the product. The performance specification method could also be used in the later phases of the design process in evaluating the arrived solutions whether they exist within the specified boundaries of the specified performance.

3.5. The Quality Function Deployment Method

Understanding the needs and expectations of customers, in terms of product attributes, is essential to meet them with appropriate characteristics of the design solution. The quality function deployment (QFD) method aiming to set targets to be achieved for the engineering characteristics of a product, such that they satisfy customer requirements [2].

Seven major steps in executing the QFD method are important as (1) identifying customer preferences in terms of product attributes, (2) classifying the attributes in terms of importance, (3) assessing the attributes of the competing products, (4) drawing a matrix of product attributes counter to design characteristics, (5) identifying the relationships between product attributes and design characteristics, (6) identifying the possible interactions between design characteristics, and (7) specify necessary figures to be achieved to ascertain the design characteristics.

The QFD method suggests that the voice of the customer is the most valuable factor in the commercial success of a product [2]. Thus, the QFD method is based on in-depth understanding of the customer and the determining design characteristics in the light of its findings. QFD method is such an excessively comprehensive method that it could be utilized in multiple stages of the design process.

3.6. The Morphological Chart Method

Considering all of the phases of the design process, generating alternatives stage stands to be the most essential and central one, through which novel solutions or re-orderings of existing solutions to a design problem is generated in different levels of novelty. In this essential phase of the design process, the 'morphological chart method' provides designers with "the complete range of elements, components, or sub-solutions that can be combined together to make a solution" [2].

Cross [2] suggests that the morphological chart method would be classified as a rational method, while according to Jones [1], this method is essential to search for creative ideas, therefore might stand to be a creative method.

The practice of 'morphological chart method' aims to widen the area of search for solutions to a design problem [1]. The aim of this method appears similar to that of enlarging the search space method, while the use of morphological charts differs in its use in the exploration of unbounded and undefined problems [1]. Cross [2] signifies the aim of this method as to generate the complete range of alternative design solutions for a product, and hence to widen the search for potential new solutions.

Jones [1] identifies the 'morphological chart method' to develop in three main steps, which are (1) definition of the functions that any satisfactory design should be able to perform, (2) listing a broad range of sub-solutions on a chart, and (3) selection of an satisfactory set of sub-solutions that meets the set of functions.

Facilitating creative thinking by morphological charts prevents the design team to overlook novel solutions to the design problem. Furthermore, this method has the advantage of concluding a matrix in a short time if the set of functions are identified properly at the initial stage of the activity.

3.7. The Weighted Objectives Method

Subsequent to the generation of alternatives, these alternative solutions need to be evaluated in order to choose the solution which best fits the statement of objectives that the design solution has initially meant to achieve. However, particular characteristics of different solutions might match different aspects in the design objectives. Therefore, the weighted objectives method provides the evaluation and comparison among alternative solutions by differently weighing the initial design objectives.

The main aim of the weighted objectives method is to compare the utility values of alternative design proposals, on the basis of performance against differentially weighted objectives [2]. The practice of this method entails a five-step-process to be carried out including (1) listing the initial design objectives, (2) identifying numerical rankings to the objectives and ordering them, (3) giving comparative weightings to the objectives, (4) determining certain performance parameters or utility

scores for all objectives, and (5) analyzing and comparing the comparative utility values of the alternative solutions, multiplying each parameter score by its weighted value and arriving to the alternative solution having the highest sum value.

The weighted objectives method appears to be the most rational method reviewed in this section. Since the evaluation method is merely based on the assignment of quantitative measures to the qualitative aspects of a design solution, the numerical output of this method might not represent the best selection.

3.8. The Value Engineering Method

The design process is also applicable for improving the value of an existing product, while the same effort could be devoted to increasing the 'value' of a novel design solution by improving the details of the design. Cross [2] classifies the 'value' that a product might have as (1) the value of a product to its purchaser; the extent that the purchaser perceives a product as worthy, and (2) the cost of a product to its producer; the extent that the producer reduces the design, manufacturing and delivery costs of a product. Therefore, the value engineering method seeks to improve a product by reducing cost or increasing value, or usually to achieve both.

The aim of the value engineering method' is to increase or maintain the value of a product to its purchaser while reducing its cost to its producer. Five main phases must be followed through this process including (1) making a list of the components of the product and determining the function of each component, (2) identifying the values of determined functions, (3) specifying the costs of the components, (4) investigating solutions for improving the value of the product without increasing the cost or reducing the cost of the product with no change in the value, and (5) assessing and selecting the alternative improvements. Also, operation of the value engineering method necessitates the participation of members of different departments, such as design, marketing, production, and so on.

The improving details phase of the process of design is necessary for improving the value or reducing the cost of both an existing product and an eventually arrived design solution. Therefore, the value engineering method appears to be essential to improve the quality of the output of the design process and eventually the product.

4. SYMMARY

The goal of engineering design methods is to stimulate creative thinking and introduces the rational methods. Different design method have different purpose and are relevant to different aspects of and stages in the design process.

Using engineering design methods helps designer perform certain tasks by reducing the possibility of errors that often occur in conventional design procedures and enables to propose a hypothesis and validate if it is true or false. Also they greatly improves the design of everyday products by providing designers with a systematic, though not rigid, series of steps.

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