THEORETICAL ASPECTS OF APPLICATION OF ENGINEERING VALUE ANALYSIS TO EVALUATION OF DESIGN PRODUCTS

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Abstract: Te subject of the paper is to treat of some theoretical aspects of application of engineering value analysis to evaluation of design products. It describes only hypothesis of opportunity of compilation between economical and heuristic methods for obtaining of complete and objective evaluation of design products. There will be given only theoretical proposition. Description of the experiments and results will be given later, in other report.

Keywords: ANALISYS, HEURISTIC METHODS, HYPOTHESIS, EVALUATION, DESIGN PRODUCTS

1. Introduction

Engineering value analysis, also known as value analysis, is a method for systematic and comprehensive study of various products, material or virtual, to increase the effectiveness of the use of necessary resources for their implementation. Its essence is generally lies in identifying and critical analysis of the functions that perform investigational products, cost estimates for implementing each of these functions and offer new creative methods, resulting in ensuring implementation only useful features products at the lowest possible cost and highest quality. [2]

The philosophy of the method can be generalized as follows: in the products have to set only what actually care about consumers and to eliminate or avoid all unnecessary, making them more expensive.

In value analysis product of design or improvement is considered and evaluated as a complex of services or functions that it performs or should perform to meet specific user needs, rather than as a physical object with a material-spatial structure. This is achieved through a functional approach to research and thorough analysis of the functional structure. [2]

Main starting point is the assessment to be carried out according to the question: how using the functions, the products meet specific needs.

The main objective is to achieve implementation of the function of products with the highest quality at the lowest cost possible for a given stage of development of science and technology. [2]

It's recommended to apply value analysis primarily to activities, supporting the development of the global concept of creating a new product still in design phase to achieve the necessary quality parameters in the most economical way. [2]

Value analysis is a highly effective group heuristic method, requires integrated participation of specialists from various professions and disciplines. Exclude the possibility to be applied individual. With its use systematically detect and allow different nature and complexity problems. It's not limited only to the existing solution, but extends the scope of searches in all possible directions. In the application of the value analysis is recommended to be used methods like Algorithm for solving inventive tasks, Brainstorming, Synectica, Morphological analysis, etc. [2]

2. Application areas of value analysis

Value analysis can be used both in designing new products and the improvement of existing ones. Exactly this universality makes it especially effective in the evaluation of design products.

The most important aims and tasks at designing and improvement from value analysis point of view are:
- achieving the optimum correlation between consumer characteristics on the one hand, and the cost of design, manufacture and operation of a new product from another;
- increasing the quality and reliability;
- reduction or elimination of the rejects;
- replacement of expensive materials;
- lowering the cost price of production. [2]

3. Basic principles and working rules of the value analysis

For effective implementation of the value analysis has to observe to the following important principles:
1. Correspondence between the degree of importance of the functions for consumers and the rate of the cost of their realization.

By defining the cost, functions that are different in nature, become comparable among themselves. Depending on the rate of the cost of their implementation and their degree of importance to consumers can judge the effectiveness of the means by which they are realized.
2. Comparing the costs of the realization the functions of the analyzed product with those of standards-analogues.

The aspiration for ensure the implementation of the useful functions of the products at the lowest possible cost can be achieved only if there is knowledge of the limits within which this could be achieved.
3. Use of group heuristic methods to solve problems.

With help of the group heuristic methods can be removed a much of the psychological barriers. [2]

4. Theoretical formulation for the application of value analysis in the evaluation of design products

The aim of investigation of design products with value analysis is finding the precise answers to questions such as:
1. What are the technical characteristics of the test product?
2. What is its main use?
3. What is its cost price?
4. Is it possible other methods to realize the functional and technical requirements for the product be applied?
5. How much will cost the new decision?
6. Which quality parameters will be improved? [2]

The answer of these questions is gives in different work stages. Particularly important is the ability to peculiar "dialogue" with the analyzed products at every stage. This assists the participants in the analysis and leads to effective results. [2]

Characteristic of the application of value analysis is the use of functional, systematic and organized approach to work, most often distinguish between six basic steps. Their number can vary in the range 4÷10 depending on the particular investigation. There is no clear boundary between each stage, because there is no need such separation. Most often the sequence of work is as follows:
1. Selection a product for analysis.
2. Gather information for the selected product.

3. Analysis on the function of the product and costs of their implementation.
4. Elaboration of the alternatives.
5. Assessment of ideas and choice of optimal solution.
6. Presentation of the proposal and preparation for its implementation.

Although the first and second stages are preparatory, they are particularly important since here is asking the exact parameters of the investigation, selecting a product or its structural parts subject to examination by the value analysis, formed teams to determine the objectives and timeframe for the development. [2]

Because of the possibility of reaching a wide variety of aims through the application of value analysis, imposed several restrictive conditions when choosing a product for analysis. One of the most important is the priority problems. To facilitate the selection is advisable to apply the Pareto principle (or ABC analysis). It is a very valuable support tool, because its priorities can be determined very easily. This is making with *"law of the vital few"* and *"trivial many"*, lie in the Pareto-analysis. [1, 4]

In the most general form of the Pareto principle read that a group or several separate small parts are most important, which corresponds to the relative importance of weight in this group. [1, 4, 5]

The essence of the ABC-analysis consists in dividing the whole into three categories, assuming that the relative importance (in terms of contribution to the outcome) does not match their relative numbers. Using the ABC analysis can classify the priorities of importance in the following proportionality:
- A – most important, 15%;
- B – less important, 20%;
- C – at least important, 65% (Figure 1) [5]

relative importance (share allocation)		
65%	20%	15%
class A	class B	class C
15%	20%	65%
relatively weight in general allocation		

Figure 1. Share allocation in accordance with ABC-analysis

The main stage of the application of value analysis is the third, because it reached the final result. Here the most important is:
- identify the functions of the products and their components;
- analysis of the usefulness and importance of each function;
- determination and analysis of the implementation costs of different functions. [2]

In addition to establishing the actual condition in the above aspects, are given basic cost structures and relationships between them (Figure 2).
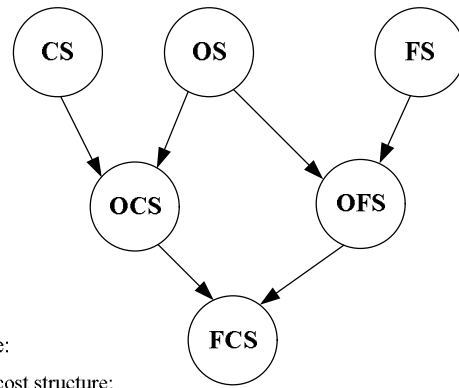
where:

CS - cost structure;

OS - object stucture;

OCS - object-cost structure;

FS - functional structure;

OFS - object-functional structure;

FCS - functional-cost structure.

Figure 2. Scheme of the relationships between cost structures

The aim is to develop a refined functional-value model, which most fully correspond to the requirements, associated with the level of quality and cost of production and exploitation. Based on this model in the next stages are look for suitable technical solutions for material bearer of the functions, which can be successfully implemented those requirements. [2]

For functional analysis is very important to make clear and precise identification of the functions. This is realized by searching an answer to the question *"Why are being produced the products"* rather than *"From what"*. It needs to be found the optimal ratio of form-function-use. [2]

In the basis of the method stands term *"function"*. It is treated as useful or other action which products made toward customers in their use accordingly its intended use. These actions are a manifestation of consumer properties of products and their constituent parts. The complex of functions are delimit on basic, additional, supportive and technical. Their identification is realized through a short and precise verbal description and by determining the dimensions of the functions that appear quantitative and qualitative requirements to implementation. [2]

To facilitate the identification of functions can be applied the task of optimization of functional. From mathematics is known that many of the functions of addition and multiplication form a so-called linear space of functions. It is also called the space of continuous functions. [3]

Functional is a figure of the linear space of functions in its corresponding field, or in other words, a function, that compares the argument of function complex number. In functional analysis mainly is used linear functional. They are of the form:

$$I(f) = \int_a^b f(x)dx,$$

where (a, b) is a linear space of functions.

Each task of optimization of the functional suggests existence of two objects - admissible multitude X and target functional I. Optimization can be two-way:
- for minimization;
- for maximization.

The particular task consists in the searching for such a function $x^* \in X$ for which the inequality is satisfied:

I(x*)≤I(x) in each $x \in X$ at minimization;

I(x*)≥I(x) in each $x \in X$ at maximization.

In general, the task of optimizing the specified functional of the multitude X may have the following solutions:
1. there is no decision;
2. there is only one decision;
3. there is more than one decision.

The realization of any of these decisions depends on the specific nature of the particular functional and the structure of multitude in which it minimizes or maximizes. [3]

To facilitate functional analysis are developed the schemes of functional levels and the functional structure of the products or so-called FAST-SAFE diagram. By this diagram is followed the road to the implementation of the basic function of each product. This diagram is also known as the "tree of functions". Figure 3 shows an example of FAST-SAFE diagram. [2]
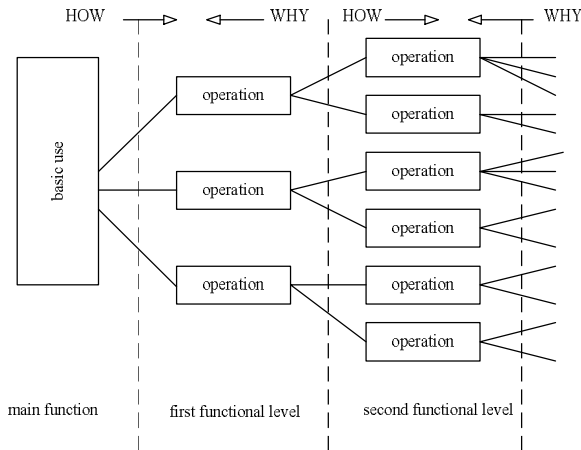

Figure 3. FAST-SAFE diagram

The functional level represent the ability of function to answer the key questions "*Why*" it is necessary and "*How*" satisfying this necessity. Thus are defining the links between functions of various hierarchical levels. [2]

The analysis of functional levels of one product serves as an effective check-up on the rationality of the concept of its creation without continuous examination of the role and importance of its individual parts. The task is establishment the function of the parts in order to implement the main function of the product. In that way determines the degree of their necessity. [2]

The determination the costs of individual functions allow to determine where the breach of the principle of proportionality between the value of a function and its importance to the user (Figure 4).

$$\frac{\Phi_i}{C_i} = const$$

Φ_i - weight of the function;
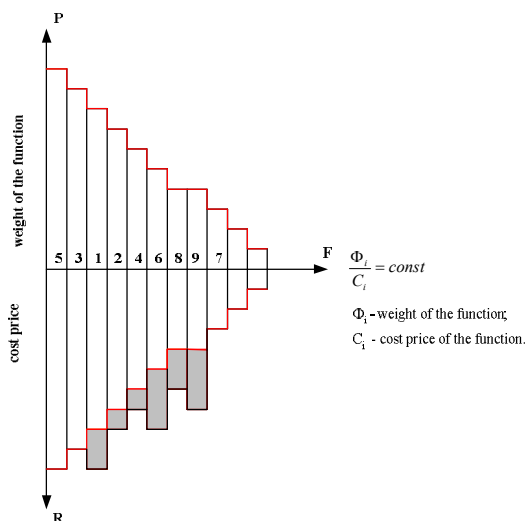C_i - cost price of the function.

Figure 4. Correlation weight-cost price of functions

In the practice of value analysis is use three ways to draw a scheme of the functional structure of the products.
1. *Descending*. Starting from the basic function as gradually extracted derived from lower levels.
2. *Ascending*. Based on the decomposition of the product of its component parts, each of them defines her functions. From them consecutively achieve to function at a higher level.
3. *Integral*. Here have to observe the following basic requirements:
   - to examine carefully the product from the consumer's point of view, and as a result from this, to identify the main and supportive functions;
   - to define all the functions for the first functional level of the product and on this basis to reveal the functions of the second level, using the descending method;
   - to divide the product of its components, for each of them to define the functions, then continues with ascending method.

With help of this functional structure are systematizing following:
- makes a clear picture of what is expected of each product and of its individual parts;
- clearly and conciseness shows the problems, which favors for their immediate solution;
- identified sectors in which there are alternative solutions and create conditions for their systematic research. [2]

It is recommended that the arrangement of functions according to their importance to be realized by analyzing the usefulness and importance, as well as their components by splitting them into basic, additional and targeted. It is better to apply the preference ranking by binary assessments and dichotomies matrices (Table 1).

Table 1

№ by order	Function Description	1	2	3	...	...	...	n	Σ
1		■	1	0	1	1	1	0	4
2		0	■	0	0	1	0	1	2
3		1	1	■	0	0	0	0	2
•		0	1	1	■	1	1	1	5
•		0	0	1	0	■	0	0	1
•		0	1	1	0	1	■	0	3
n		1	0	1	0	1	1	■	4

Overall problem, liable to solve, is define as result of the done analytical work. Follows organized searching for alternatives, which is a creative stage in the work. It was here that have to find new solutions to ensure the objectives of development. [2]

There are two different approaches in the search for new solutions:
1. Detailed study of existing expertise in the area in order to implement effective ready solutions for cheaper and better quality of implementation of the functions of the products. This is achieved primarily by making a comparative analysis in which the test product is compared with others, performing the same or similar functions.
2. Using the group heuristic methods for creative problem-solving. Characteristic of these methods is that activated creativity of participants in the process. As a result arise many new ideas that have to be registered.

On the next, fifth stage is made the valuation of the ideas, and became the selection of the optimal solution. The stage is also called research and is a continuation of previous creative work as

the creative process does not end with the rise of new ideas, but begins with it. [2]

Here the most important is:
- systematization of the proposal variants;
- analysis and evaluation of the variants to elimination inexpedient;
- formation of variant solutions with necessary documentation;
- complex technical-economical valuation of particular variant;
- arrangement of variants to facilitate the selection of the most effective and perspective solution between them;
- selection of optimal variant. [2]

One of the most essential moments of action at this stage is to define the criteria for evaluating proposals and selecting the best variant solution.

The basic rules of work are:
1. to apply all appropriate to the event criteria that could be used in the evaluation of ideas. It is preferable to apply those, that in quantitative and qualitative attitude represent what is the difference in effectiveness of the proposed ideas;
2. different ideas to be evaluated with one and the same criteria. The sequence of work is as follows: all ideas are evaluated by one of the criteria before proceeding to the next;
3. selected evaluation criteria to rise in order to importance, to facilitate the identification of best solutions.

For the aims of value analysis is recommended the use of obligatory and desirable criteria for evaluating ideas. [2]

Requirements of the obligatory criteria have to necessarily be done to achieve the aims of development. There is most important to be realized the full complex of useful functions in the optimum for each dimensions of realization. [2]

In desirable criteria is not necessarily the overall implementation of their requirements. But they also have an important role in obtaining a real assessment. These criteria apply some economic indicators and manufacturing limitations. [2]

The resaving results from the evaluation of ideas are the basis for next action by the evaluators, which decides on any proposed idea. Possible actions:
- to throw of inexpedient ideas;
- keep as backup. These are ides which have rationality, but generally do not cover the requirements of evaluation criteria. They can be used for future analysis.
- to use the idea in selecting the optimal solution. These are the ideas for which the opinion of specialists is that represent the interest in terms of analysis.

All this have to be consistent with the relativity of the concept of "optimal solution". For optimal is accept a decision, which in the most fully degree response to the specific requirements, laid in formulating the aim of the research.

The optimal variant is accompanied by explanatory notes and a full set of documents. It is also advisable to develop a list of recommendations for implementing the proposed ideas. [2]

5. Conclusion

Value analysis is a highly effective group heuristic method for solving problems of various kinds and in various fields and spheres of activity. The main aim of its application to design products is that they are designed and manufactured so as to fulfill their functional purpose of highest quality at the lowest outlay, possible at certain stage of development of science and technology.

Value analysis is a method that allows the successful application of concepts and principles from other scientific fields. This is particularly important as the designer products are the result of an integrative process, combining the efforts of specialists from different fields.

The combination of functional and systemic approach to value analysis, and the possibility of using different heuristic methods are a prerequisite for its universality.

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