Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

ENHANCEMENT OF VALUE ANALYSIS USING THE THEORY OF TECHNICAL SYSTEMS

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Abstract: *The purpose of the paper is to improve the method of value analysis. Value analysis has been for decades one of the major methodological tools for initiating design innovations of existing or proposed technical products pursuant to their functional-cost analysis. Developmental milestones of this method and a brief description of the latest version are given. Some weak points in the published methodology have been found. Our opinion is that they can be eliminated or reduced by using the theory of technical systems, particularly by the systematic product design specification of the product lifecycle properties of the analyzed product.*
Key words: *Analysis, Value, Product, Specification*

1. INTRODUCTION

Value analysis (VA) is a method aimed at achieving the optimal value of an existing product (either designed or real). Value is traditionally and mostly considered here as a ratio of product functions and costs. Major developmental milestones of VA are shown in Tab. 1.

<table>
<tr><th>Miles (1971)</th><th>Miles (1989)</th><th>ČSN EN 12973 (2000) and Dostal et al. (2009)</th></tr>
<tr><td>1 – Orientation</td><td rowspan="2">1 – Information</td><td rowspan="2">0 – Preliminary phase
1 – Project definition
2 – Planning
3 – Capture of data about studies</td></tr>
<tr><td rowspan="2">2 – Information</td></tr>
<tr><td>2 – Analysis</td><td>4 – Functional analysis, Analysis of cost</td></tr>
<tr><td>3 – Creative thinking</td><td>3 – Creativity</td><td>5 – Making of subject for new solutions</td></tr>
<tr><td>4 – Analysis
5 – Planning</td><td>4 – Judgment</td><td>6 – Evaluation of ideas about solutions</td></tr>
<tr><td>6 – Realization</td><td rowspan="3">5 – Developm. planning</td><td>7 – Development of global proposals</td></tr>
<tr><td rowspan="2">7 – Summary</td><td>8 – Presentation of proposal</td></tr>
<tr><td>9 - Implementation</td></tr>
</table>

Tab. 1. Examples of developmental phases of the working steps of the value analysis

The paper stems from the latest developmental version of VA according to ČSN EN 12973 (CSN, 2000) interpreted in (Dostal et al., 2009). Thus a brief description and analysis of VA in terms of aspects related to designing technical products/systems (TS) is introduced first. Some weak points in the published methodology have been revealed. Our opinion is that they can be eliminated or reduced by using the theory of technical systems, particularly by using the systematic product design specification on the product lifecycle properties. Thus the content of the theory of technical systems (TTS) (Hubka & Eder 1984) is briefly described. The proposed improvements of the VA working steps and our future plans close the paper.

2. REVIEW OF THE CURRENT STATE OF VALUE ANALYSIS

The specific objectives of VA are the identification of groups of functions of the analyzed (proposed or realized) TS with the inconvenient value *V*. Value is understood (Dostal et al., 2009) as:

$$V = \frac{F}{C} \tag{1}$$

F - degree of fulfilment of the required functions
C - costs required to achieve these functions

Function in this case is defined as “defining or determining activities, operations or abilities of the solved object, which ensure a certain need by the aspect of the needs”. (Dostal et al., 2009).

However, analysis of the documents shows that the working steps of VA methodology concentrate almost entirely on analysing functions that are realized in the design of an analyzed TS. No longer explicitly find out which other properties the TS should provide for ensuring the above (very generally defined) mentioned needs, i.e. including those needs which are not realized in the analysed TS in the form corresponding to ‘groups of functions’.

However, the functions realized as ‘groups of functions’ generally focus primarily on operational functions (Dostal et al., 2009), (Miles, 1971). This is because functions corresponding to other needs (in the operation phase and in other phases of the TS lifecycle, e.g. manufacturability, appearance, etc.) are usually reflected in the structure of a TS as separate ‘groups of functions’ (wheels for transport, an aesthetic cover, etc.) only if they cannot be ensured by the design (adjustment) of basic operational or other necessary TS ‘groups of functions’. A related shortcoming is, in our opinion, that in the definition of ‘function’ F (1) it is hard to include the significant time and term ‘needs’ (i.e. aspects) placed on the ‘groups of functions’ of the analysed TS with the aim of innovating it.

Identifying the functions of a TS is furthermore left almost exclusively up to the knowledge and experience of the VA team. Similarly, the identification of needs is left up to the VA team, as is the appropriate content of the specifications of the properties required of the analysed TS (Dostal et al., 2009).

Another identified shortcoming is that, although the costs C (1) are defined as “costs spent on achieving a certain function” (i.e. ‘groups of functions’ of an analyzed TS), general methodical instructions and published Case Studies (Dostal et al., 2009), (Miles, 1971) lead to focusing almost exclusively on production costs. To sum up, although VA is described as a systematic methodology (Miles, 1971), (ČSN, 2000), (Dostal et al., 2009), only the basic working steps are in fact systematically defined (Tab. 1.) and sometimes only their partial steps.

3. THEORY OF TECHNICAL SYSTEMS

The Theory of Technical Systems (TTS) is part of the scientific discipline of Engineering Design Science (EDS) (Hubka & Eder 1992, Hosnedl & Eder 2008).

The essential element of TTS is the model of a general transformation system. The model contains a transformation process with a transformed object (operand) and the elements needed for its transformation (operators). By using this model a systematically structured model of the phases of a TS lifecycle can be created. This TS lifecycle model is formed of a chain of interrelated transformation systems. The TS lifecycle model is the basis for a systematic taxonomy of the TS properties. This sorting of properties can then be used for example for a comprehensive systematic specification of TS property requirements of all the aspects of its lifecycle and for evaluating their performance.

4. RESULTS

The working steps of the latest developmental version of VA in accordance with ČSN EN 12973 (CSN, 2000) (Tab. 1. col. right), with the proposed uses of the systematic specification of property requirements of the analyzed TS, are briefly characterized in the following paragraphs.

After completing the necessary managerial tasks (steps 0, 1 and 2), a systematic specification of property requirements of the analyzed TS is carried out at the end of step 3. The identified and quantified requirements are systematically organized in accordance with the classes of TS properties mentioned above. Requirements sorted in this way may be efficiently compared with the properties of the analyzed TS, and with competing TS. Then they can be evaluated, including identifying the strengths and weaknesses and associated risks of the evaluated TS.

In step 4, the realized 'groups of functions' (in TTS 'construction organs') are first identified in the analyzed TS. Then the functions are assigned to them (in TTS the functions are: main, assistant and induced). Then, the analysis needed to determine the 'value' V (1) is carried out for the identified construction organs. Thus the critical construction organs with inconvenient value V are determined.

However, the TS must satisfy a range of other desired properties set out in the specification of requirements, which are not explicitly provided by any of the identified (i.e., realized) construction organs. If these 'other' properties are not satisfied (which will be evident from the outputs of the previous step 3) then conceptual and specific design innovations of existing construction organs or other induced functions realized by new construction organs must be provided (in the following steps 5 and 6). Theoretically, it may occur that some existing construction organs do not correspond to any of the desired properties. Then these construction organs are unnecessary and can be removed from the analyzed TS (in the following step 5). Suggestions for innovations of the analyzed TS now objectively result from the systematic specification of requirements, not only from the function-value analysis of 'groups of functions' in the existing TS.

The content of step 5 is now the conceptual design (variants) of the innovations to the analyzed TS, not only focusing on the identified 'critical' construction organs, but on the whole TS focusing on all 'critical properties' identified in step 3. By using the systematic specification of property requirements of the analyzed TS, the systematic creative methods of EDS can now be used to their full advantage. In step 6, the proposed concept variants of the innovations are generally evaluated using the systematic requirements specification. The key strengths and weaknesses of the variants are also objectively found, revealing the optimum variants of the solution and identifying their properties and if necessary their construction organs. The next step focuses on making improvements to these variants.

One or more optimal variants of the solution are concretized and improved in step 7. The solution is again evaluated according to the systematic requirements specification and the final optimal solution is selected from them. The final solution is systematically documented, presented and archived in step 8, which in turn creates conditions for the realization of step 9.

5. CONCLUSION

By implementing into VA methodology a systematic specification of property requirements of the analyzed and innovated TS and evaluating them using the theory of technical systems, the VA team acquires a more effective tool because it can use systematically structured properties of the TS (including the functions of the TS) and their evaluation. This means that the VA team need not proceed only by rigid instructions, either intuitively or empirically. Using a systematic specification of properties also significantly contributes to the better design of innovated solutions, better evaluation of proposed or existing solutions and for their better documentation, archiving and presentation. This in turn leads to higher design quality and to better competitiveness of the innovated TS.
In our further research work, we will focus on the validation of the proposed improvements to the VA methodology and its further improvements, particularly by more appropriately defining the still ambiguous and very imprecise definition and term 'functionality' of the product and its relation to the quality of TS, and to the costs and time demands of the TS.

6. ACKNOWLEDGEMENTS

This paper includes results from Project No. 402/08/H051 Optimizing of multidisciplinary designing and modelling of production systems subsidised by the Grant Agency of the Czech Republic.

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