Model for Integrated Value Engineering

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Abstract – **The approaches of target costing and value engineering support product development processes in identifying target costs from a customer perspective and in improving the value cost ratio of a product. This research introduces the approach of Integrated Value Engineering, which combines both approaches in one model. In the Model for Integrated Value Engineering the three levels components, functions and requirements of a product are modeled in a matrix and target costs from requirements and current costs of components are assigned to each other on all three levels. This allows a holistic comparison of the current costs with customer based target costs and easily highlights potentials for cost reduction or adding value. The approach is evaluated by an academic and an industrial case study.**

Keywords – **Value engineering, target costing, integrated model, multiple-domain-matrix**

I. INTRODUCTION

A. Motivation

Nowadays new products should offer high quality and functionality for the customer for same or lower prices as predecessor products. A rising number of competitors due to global connected markets aggravate the challenge for product development projects to sell high customer value for low costs.

The methods value analysis and value engineering support in finding cost reduction potentials and adding value. Value analysis focuses on reducing costs of an existing product, while value engineering goes further. It is based on functional values and aims to increase the ratio between the costs and the value of product for the customer. Value engineering is also applicable for the development of new products and will be discussed further in this contribution [1, 2].

B. Value engineering

The approach of value engineering includes several steps. Reference [1] introduces these basic steps: He first separates the components of a product and identifies the functions which are fulfilled by each component. Afterwards the values for the customer of each identified function and the costs of the components are determined, e.g. using the target costing approach. Based on this information ways for reducing costs without reducing value or of adding value without adding costs are identified and the alternatives evaluated. The best ones are selected to improve the product. Even if these steps might differ in the approaches proposed by literature the basic idea of value engineering stays the same: Identification of the products' components and of the functions served by these components. With the costs for the components and the value of the functions potentials for improvement can be identified and optimized in new product development processes or adaption processes of existing products [2-5].

C. Target costing

Another method for managing costs is target costing. The strategy of target costing is that the major percentage of the products lifecycle cost are determined in the development phase [5, 6]. So target costing defines and manages cost targets for the development and production phase. Therefore it begins with a marketing research and identifies customer expectations of products in terms of functionality, quality and price. The price deduced from the market is reduced by the expected profit a company wants to earn with the product. The result gives the target cost for development and production of the product. Consequently a product is only developed if the target cost can be reached [6, 7].

D. Problem statement and objectives

Target costing and value engineering are complementary approaches and can both support companies in improving products, the first in identifying targets and the second in achieving these targets [4, 6]. However, both methodologies introduce a high number of calculation steps and tables to gain the aimed insights in the target costs or value cost ratio. For example the target price of the product has to be separated on the different components and be compared with actual costs, or components have to be allocated to functions and costs recalculated for functional comparison [1, 2, 4].

Therefore this contribution introduces a matrix based approach combining target costing and value engineering, defined as Model for Integrated Value Engineering with the objective to map the main information in one model. Besides the advantage of facilitating system understanding and including the approach of target costing and value engineering in one model the comparison between target cost and actual cost can be easily performed on a requirements-, functional and on a components level. This fosters a solution neutral comparison of target and current costs of a product.

II. RESEARCH METHODOLOGY

The Model for Integrated Value Engineering evolves from the approaches of target costing and value engineering. As a result, the basis for the paper at hand is a literature review on both approaches in relevant journal publications or reference books. As target costing and value engineering lack an integrated model this paper features a Multiple-Domain-Matrix (MDM) to provide a fundament for the integrated value engineering. The MDM is used in the field of systems engineering. It supports the handling of complex systems understanding through a comprehensive model [8].

With that fundament section III presents the Model for Integrated Value Engineering, which is evaluated in terms of internal validity and operability through a case study from academia (section IV). Moreover, another case study in an industrial application of gas engines was performed to evaluate the developed approach. Due to confidentiality agreement with the case study providing manufacturing firm, this paper has to focus on the case study from academia.

III. MODEL FOR INTEGRATED VALUE ENGEINEERING

The Model for Integrated Value Engineering combines value engineering and target costing to an integrated approach with a MDM as fundamental representation of the product in its center. The MDM_{RFC} covers the three essential domains; requirements (R), functions (F) and components (C), which represent the main levels of a product development process, according to [9, 10].

Besides, this MDM_{RFC} provides information about the interdependencies between the three domains in terms of the mapping of requirements on functions as well as of functions on components. The MDM_{RFC} as a fundament is extended by the corresponding cost information in accordance to the approach of target costing. This requires a sequence of eight steps, which are described in the following paragraph. The first three steps (A-C) derive the MDM_{RFC} (Fig. 1) from information on the requirements, functions and components of a product.

	Requirements	Functions	Components
Requirements			
Functions	fulfills		
Components		fulfills	

Fig. 1. MDM_{RFC} of a product.

A. *Identification of requirements*

The first step foresees the identification of relevant requirements of a product, which evolve from market and customer demands. These requirements "represent an unambiguous agreement" on the performance of a product [9]. Finally, the requirements are captured in the nodes of the requirements matrix in the MDM_{RFC}. For existing products the relevant requirements might be available through requirements lists [10, 11].

B. *Definition of functions*

In the next step the relevant functions of the product are defined, which might be supported by corresponding functional models of the product [11]. Functions fulfill specific requirements and bridge the gap between the physical components of a product and its requirements [9].

C. *Identification of components*

This step focuses on the identification of physical components based on the derived functions of the product. Thereby, a component is required to fulfill at least one function of the product.

Fig. 1 summarizes the results of the first three steps of the Model for Integrated Value Engineering. Components and equally functions and requirements are included in the MDM_{RFC} as nodes. The matrix provides the fundament for the next steps (D and E), in which target costs for requirements and current costs of components were assigned to the corresponding nodes in the matrix.

D. *Assessing target costs for requirements*

The target costs for the product are defined similarly to the target costing approach based on customer needs, market prices, estimated development and production costs of the product. Cost targets of the product are distributed to the identified requirements (A). A preference matrix supports the distribution of target costs to requirements as long as there is no explicit data available [11].

E. *Assessing the current costs of components*

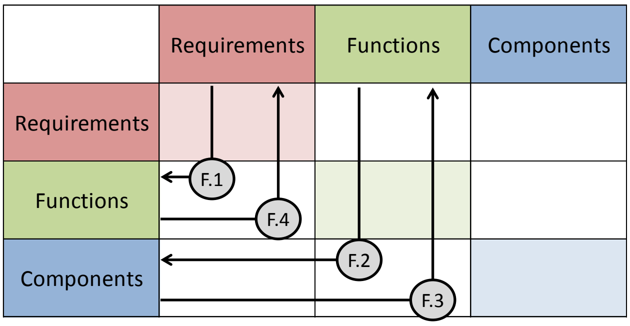
The overall costs of the components are calculated from experience in teams or from further sources like the analysis of predecessor products or competitors with methods like benchmarking. For existing products, the overall costs of components are assessed by a cost calculation, which considers the relevant categories of costs (e.g. manufacturing costs, life cycle costs …) [5].

The two preceding steps (D and E) are modeled through two additional columns at the MDM_{RFC}. The next steps build on the acquired and documented information of the integrated model by a deduction of correlations between requirements, functions and components (step F), a comparison of the target and actual costs (step G) to enable the identification of potentials in terms of costs and values (step H).

F. Deduction of correlations

With the nodes of the three domains (incl. MDM_{RFC}) and the target costs for the requirements and the current costs for the components four calculation steps have to be proceeded to deduce all costs for the comparison between target and current costs (see Fig. 2). The target costs of the requirements have to be distributed to determine the target costs of the functions (Step F.1) and thereby the target costs of the functions can be used to calculate the target costs of the components (F.2). In the same manner the current costs of the components are distributed on the functions to determine current costs of the functions (F.3) and the current costs of the functions are distributed on the requirements (F.4).

Step F.1 is now exemplary for the other steps discussed in detail: The correlation between requirements and functions is defined as function fulfills requirement. For the deduction of the detailed values for the edges between the certain function and requirement nodes several methods can be used. For example the values can be estimated, or functions can be directly matched to one requirement. An additional weighting of the relationship will increase the quality of the matrix. More accurate results are achieved with a pairwise comparison and a preference matrix [11].



F.1	Distributing target costs of requirements on functions	Normalization in columns
F.2	Distributing target costs of functions on components	Normalization in columns
F.3	Distributing current costs of components on functions	Normalization in lines
F.4	Distributing current costs of functions on requirements	Normalization in lines

Fig. 2. Steps for the deduction of correlations.

For the calculation of the target cost value of functions (F.1) it is important that every column has a sum of 100% which means every requirement is completely fulfilled at least by one function completely or by several functions partly. The normalization to one ensures that the target cost of each requirement will be distributed completely. For the calculation in the other direction in terms of assigning the current costs of functions to requirements (F.4), the values in the matrix have to be normalized in every line. This ensures that the current costs of a function will be distributed based on the values in the line of the requirements.

The correlation between functions and components is defined as component fulfills function. The deduction of the values for the edges between the certain component and function nodes (F.2 and F.3) can be done similarly to the deduction of values for edges between functions and requirements.

With the correlations in the matrices the cost values can be divided by multiplication of the initial value with the allocated normalized values of the column (F.1 and F.4) or of the line (F.2 and F.3).

G. Comparison of target and current costs

Based on the cost values of the three levels requirements, functions and components a target to current cost comparison can be drawn. It is suggested to calculate the difference between target and current costs on the levels of components and functions with absolute and relative values [5]. Negative values indicate components, functions or requirements which are too expensive or add not enough value from a customer perspective. The relative values underline the need of cost reduction or adding value in the certain case and show improvement potentials whereas the absolute values directly show the cost value to be reduced.

A benefit in comparison to the already existing value engineering approach is the possibility to compare target and current costs on all three levels in the model. The comparison on the component level mainly supports the reduction of costs of components which are too expensive. The comparison on the function level is not depending on already existing solutions and will support the adding of value and an extensive scope of cost reduction. On the level of requirements a comparison between current and target cost can identify unbalanced objectives in the product development process. For example a requirement, which is much more expensive as its target price reflects the problem of over-engineering on this requirement.

H. Improving details

For the implementation of the determined improvement potentials similar methods as in standard product development processes can be used. The benefit of using the Model for Integrated Value Engineering is that the methods don't have to be applied on the entire product. It is sufficient to improve the selected components or functions with consideration of their interfaces (e.g. engineering change propagation). The different methods for improving a product won't be discussed in this contribution as the focus lies on the procedure to identify improvement potentials.

Fig. 3 summarizes the eight steps of the Model for Integrated Value Engineering as essential contribution of this paper.

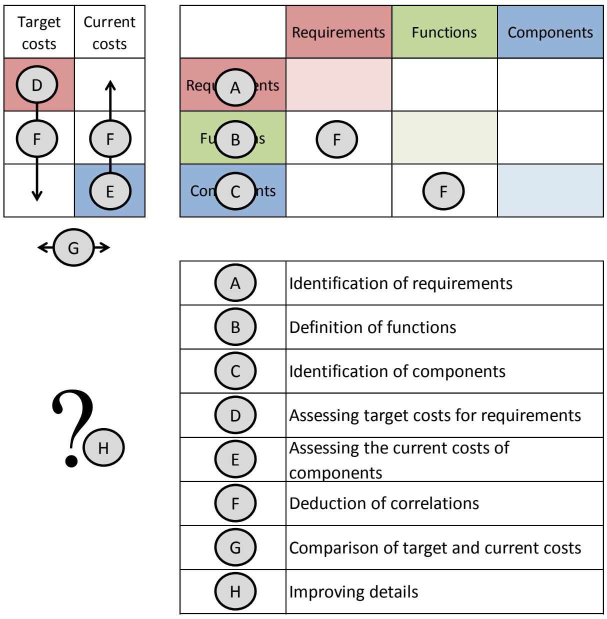


Fig. 3. Model for Integrated Value Engineering.

IV. CASE STUDY

This section presents the application of the integrated value engineering approach to a generic case study, as the data for the industrial case study cannot be used in detail due to the confidentiality agreement. The example shows the structure of a simple technical product, which consists of three different components (C.1, C.2 and C.3). These components fulfill four functions (F.1, F.2, F.3 and F.4), which realize three requirements (R.1, R.2 and R.3).

The summary of this information represents the MDM_{RFC} and illustrates the result of the first three steps (A-C) of integrated value engineering. According to the approach of target costing, the target costs for the requirements are derived from a market analysis. As a result, the target cost for the requirements R.1 (100 €), R.2 (150 €) and R3 (67 €) are summarized in Fig. 4 (step D). Moreover, the current costs of the components C.1 (121 €), C.2 (91 €) and C.3 (117 €) are derived from a cost analysis (step E).

Based on that information the next step (F) is performed in order to deduce the relevant correlations which allow a comparison of current and target costs on all three levels of a product; requirement, function and component (step G). Fig. 4 illustrates the outcome of those four calculations performed at step F within the two columns on the left side.

The comparison reveals (step G) that the current costs of R.3 reach its targets, while the current costs of R.1 are higher than its target. In contrast R.2 is outperformed by the current product. Within the functional level, the comparison shows that the current costs of F.2 and F.3 are lower than their targets. F.1 and F.4 do not have such a performance in the current product and do not meet their targets. Finally, the comparison on the component level reveals that C.3 is not meeting its targets, while C.2 is in target and C.1 is even outperforming its target.

The last step (H) of the integrated value engineering approach builds on the comparison and deduces potentials for the product utilizing the differences in the figures for current and target costs within the three levels. Thereby, the higher costs of R.1 is an indicator for over-engineering. Due to the significant difference between the current and the target cost for F.1, this function should be investigated in terms of the used technologies. Such a substantial cut in costs is difficult to achieve with an evolutionary change of the implementation of the function. Furthermore, the comparison on a component level reveals that C.3 is not meeting the target costs, which is an indicator for an inadequate technical implementation of the corresponding component.

Fig. 5 shows the matrix of an internal combustion engine. The example had been used to successfully evaluate the applicability of the integrated value engineering approach for industrial problems. It cannot be discussed in detail, due to confidentiality.

current costs	target costs	MDM	R.1	R.2	R.3	F.1	F.2	F.3	F.4	C.1	C.2	C.3
152 €	100 €	R.1										
87 €	150 €	R.2										
67 €	67 €	R.3										
94 €	33 €	F.1	0,3	0,0	0,0							
80 €	137 €	F.2	0,2	0,4	0,8							
78 €	95 €	F.3	0,3	0,4	0,2							
55 €	52 €	F.4	0,2	0,2	0,0							
121 €	176 €	C.1				0,0	1,0	0,3	0,2			
91 €	91 €	C.2				0,4	0,0	0,5	0,6			
117 €	50 €	C.3				0,6	0,0	0,2	0,2			

Fig. 4. Integrated value engineering approach applied on a generic case study.

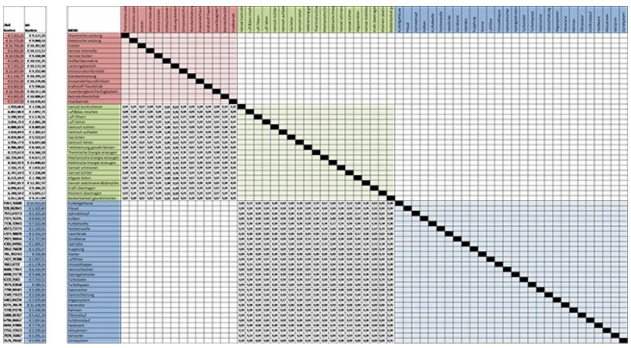


Fig. 5. Integrated value engineering approach applied on an industrial case study.

V. CONCLUSION AND OUTLOOK

A. Conclusion

The Model for Integrated Value Engineering combines the approaches of value engineering and target costing to an integrated model with a MDM as representation of the product in its center. Based on the essential domains of a product; requirements, functions and components, this approach uses the assessment of target costs for requirements and current costs of components to draw a comparison of costs within the different domains of a product. This comparison is enabled through the integrated character of the model, which allows the deduction of correlations between the different domains. As a result, the actual costs of components can be analyzed against their target costs, while the same comparison can be performed based on the requirements and functions of a product as well. Therefore integrated value engineering provides one integrated model for the analysis and synthesis in terms of target costing and value engineering. Moreover this model covers all the relevant data, so that various model transformations are not required.

The approach of integrated value engineering allows a systematic comparison of products through benchmarking or other comparative methods. As the relevant data is captured in the integrated model, a comparison with predecessor products or competitors just involves an analysis of the actual costs of the particular products. Thereby, the comparison is not restricted to components, as the integrated model allows a comparison in all three domains (requirements, functions and components).

The representation of the MDM_{RFC} in the center of the integrated value engineering approach enables further calculations of indirect dependencies. This reveals dependencies of costs based on the three domains in the MDM_{RFC}. Furthermore, the dependencies between requirements and components can be calculated using the mapping of requirements to functions and functions to components.

B. Outlook

A next step for future work is the validation of the approach by using case studies from other industrial applications. Thereby, the authors focus on the additional features of integrated value engineering as well. These features cover benchmarking or the deduction of indirect dependencies within the MDM_{RFC} to derive further information of the system, which exceed the direct acquired data.

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