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SUSTAINABLE INNOVATION MANAGEMENT MODEL BASED ON VALUE ENGINEERING METHOD

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Abstract: *The continuous improvement of a product or service by gradually adding new features, functionalities, or technical enhancements, thereby adding value and gradually improving the product's performance without radically changing the existing product, is a characteristic of any product on the market. The current research explains, analyzes, and applies a method of incremental innovation based on functional analysis to improve the key aspects of the product based on customer feedback. This study presents the design and conception phases of the product, proposes specific product functions that are sized technically and economically, conducts a systemic analysis of these functions, and applies hybrid techniques to resize them in optimizing these functions as perceived and demanded by potential customers.*

Key words*: value engineering method, incremental innovation, redesign management model*

1. INTRODUCTION

Incremental innovation involves gradually improving existing products, services, or processes [1]. It entails making small iterative changes over time to refine and optimize existing solutions rather than introducing radical or disruptive innovations [2]. Unlike radical innovation, which involves creating entirely new products, services, or business models, incremental innovation builds upon the existing system (aiming to add value) to enhance its features, functionality, or performance. The characteristic of this type of innovation is the incremental improvement based on the continuous refinement of the analyzed system [3, 4]. Incremental innovation can take various forms, such as: *feature enhancements* [5] - adding new features or improving existing features of a product or service to provide additional value to customers; *performance improvements* [6] - optimizing the performance of a product or service by making incremental modifications to enhance efficiency, speed, reliability, or quality (this could involve improving manufacturing processes, upgrading materials, or modernizing components); *cost reductions* [7] - identifying ways to reduce production costs without compromising quality (this could involve streamlining manufacturing processes, sourcing cheaper materials, or optimizing supply chains); *user experience enhancements* [8] - making progressive improvements to enhance the usability, accessibility, or overall user experience of a product or service (this may involve simplifying interfaces, improving ergonomics, or incorporating user feedback); *process optimizations* [9] - analyzing and refining internal processes to increase efficiency, productivity, and quality (this could involve implementing new tools, automating repetitive tasks, or reorganizing workflow).

Incremental innovation is often seen as a more sustainable and manageable approach to innovation. It leverages existing resources and knowledge while minimizing the risks associated with radical changes. It allows organizations to make continuous progress, respond to market demands, and remain competitive by iteratively improving their offerings.

The paper presents a complete process for implementing an incremental innovation method

- the value engineering method, in a new product - a knitted bag for women, which needs to be introduced to the market. The product is analyzed through its most essential functions, which are technically dimensioned (determining the weights of the product's functions in its overall utility) and economically (the weights of the function costs in the total product cost). Optimizing these utility and cost weights of the product's functions leads to resizing these functions through specific hybrid methods of analysis. The product is redesigned based on the optimization process of the product's function weights. The economic dimension of the new product is recalculated, and these cost weights are reassessed in the total Cost of the new product. The result of the value engineering method is a new knitted bag for women, whose functions are optimally dimensioned in terms of the weight of utility versus the weight of costs.

2. MATERIAL AND METHOD

Value analysis and value engineering [10, 11] are two methods used in managing and improving the production process and product development. They focus on identifying and eliminating inefficiencies, reducing costs, and increasing customer value [12]. However, there are some differences between the two concepts. Value analysis is a method of analyzing the costs and benefits of a product or service [13]. The primary goal of value analysis is to identify and eliminate any features, components, or processes that do not add final value to the product or service offered [14]. Value analysis focuses on cost reduction and eliminating unnecessary expenses without compromising the functionality or quality of the product. Value engineering involves redesigning the product by optimizing its functions analyzed during the value analysis phase.

The research organizational chart is presented in Figure 1.

The method used in the current research is classical and customer-centred, aiming to optimize the product functions in an iterative process (Figure 2.). Thus, this process includes the classic stages of the functional analysis method of the product, followed by a stage of re-conception of the product to incorporate the same optimized functions in terms of cost-weight ratios for each individual function utilized.

The novelty of the approach is that in the product redesign phase, the focus is not only on resizing the overrated functions (often by reducing costs) but also on proposing solutions for the underrated functions – by increasing the utility weights of the under-dimensioned functions faster than the weight increase of the cost function in the total Cost of the product.

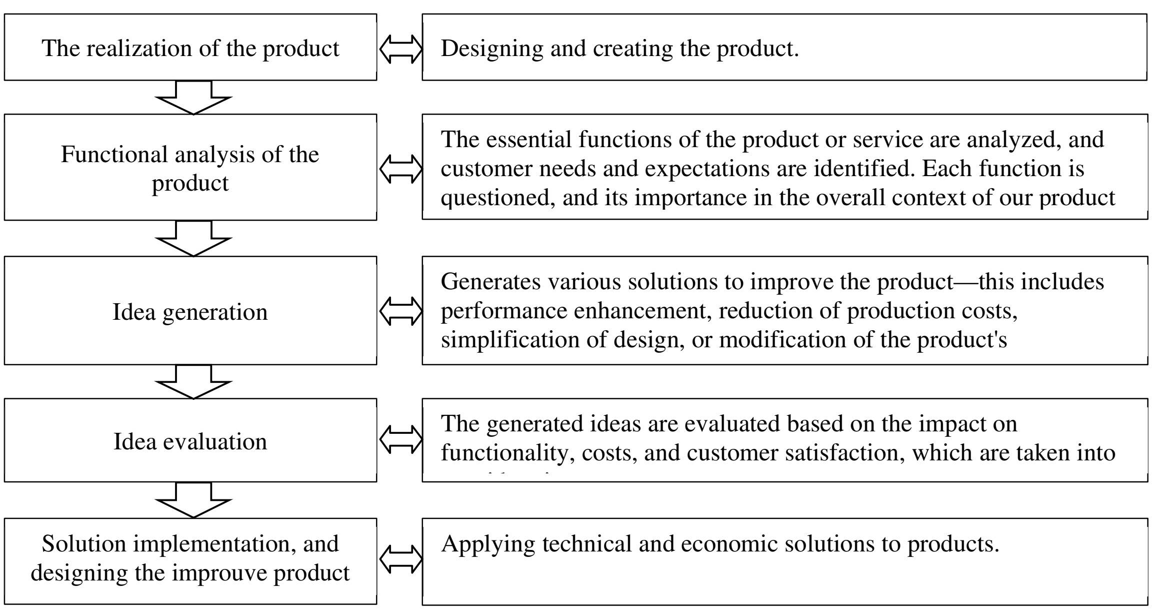


Fig. 1. The research organizational chart

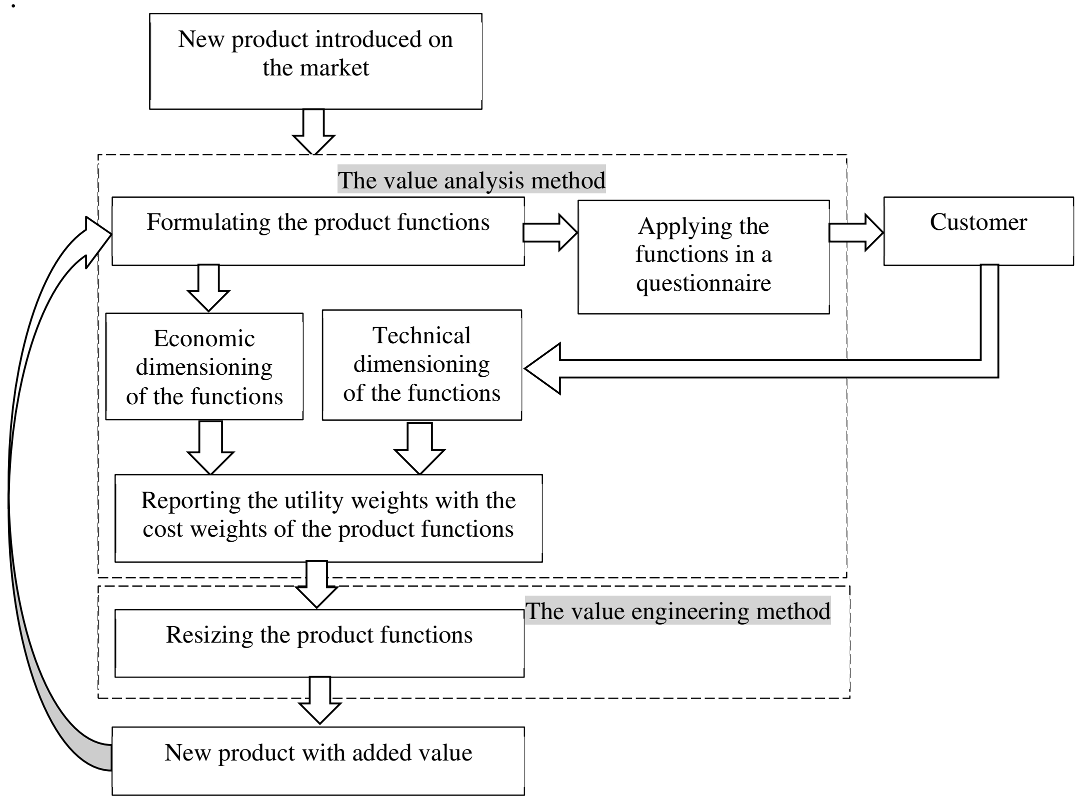


Fig. 2. Iterative process based on value analysis and engineering method

3. EXPERIMENTAL STUDY

3.1. The design phase of the initial product

The manufacturing stage of the knitted handbag for women includes the design and production process. In the design phase, Gerber AccuMark 2D software was used for pattern making (Figure 3).

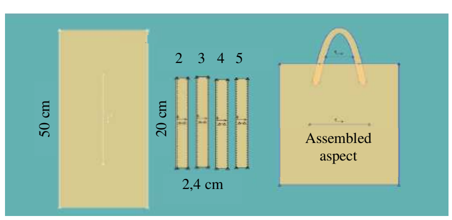
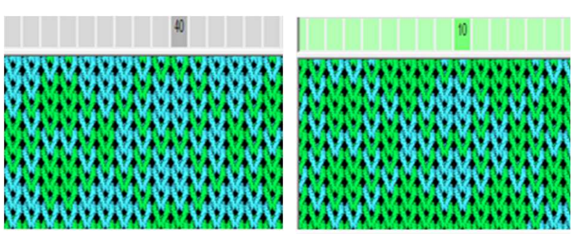


Fig. 3. The initial patterns of the handbag



(a) Exterior aspect (b) Interior aspect

Fig. 4. The aspect of knitting

The idea behind this product is *the double aspect* of the bag. On the exterior, there is one design, and on the interior, the same type of pattern but with inverted colors. This model allows its wearer to match it with various types of clothing and express their style at that moment. To change the bag's appearance, it is necessary to turn it inside out. This model is composed of 5 components:

- Component 1: is the body of the bag and is made of a Jacquard Net structure with a network on all its back fonts. I chose this structure because of its characteristics: complex patterns, versatility, durability, breathability and design reversibility (Figure 4).
- Components 2, 3, 4, and 5 are the handles of the bag, which are made using interlock knitting, providing more excellent stability compared to the chosen structure for the body of the bag. Components 2 and 4 will have the exterior color of the bag, while components 3 and 5 will have the interior color.

3.2. Choosing the raw materials

A blend of polyester and cotton is chosen to create a high-quality knitted bag for women. The combination of these two materials brings numerous benefits and characteristics - durability and strength, comfort and breathability, easy maintenance, variety of design and colors, and fade resistance - that will make the bag a remarkable accessory.

3.3. Creating programs for knitting the components

In the process of creating knitted panels, the knitting machine is selected, the desired fineness of the yarn is chosen, technical specifications are obtained (containing essential information about raw material consumption, panel shapes), yarn field allocation, technological parameters for knitting are established, the technical design is edited, the Sintral program is generated and tested, and then transmitted to the knitting machine.

3.4. Creating knitted panels

We will transfer the program to the Stoll Flat Knitting Machine Cms 502 HP E 2,5.2 to create the knitted panels. This machine allows the creation of jacquard patterns and various types of stitches by individually setting the needles.

The label is made by the provisions of Regulation (E.U.) No. 1007/2011 of the European Parliament and of the Council of 27 September 2011 on textile fiber names and related labelling and marking of the fiber composition of textile products. The main information includes care recommendations (*hand washing, normal rinsing, and gentle squeezing; do not iron; do not use bleach; chemical cleaning is not allowed; do not tumble dry*), the percentage of materials used, and the product's country of origin.

3.5. Product manufacturing

The technological process of manufacturing the knitted bag for women is presented in Table 1.

Table 1

Technological process for manufacturing the knitted bag for women.

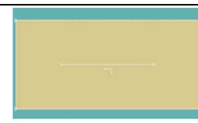
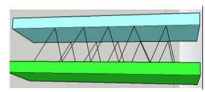
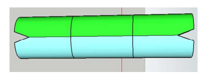
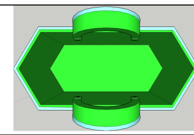
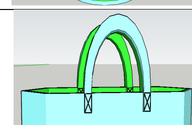
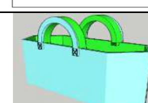
No.	Work phase	Work phase image	Equipment used
1	Knitting the components		CMS 502 HP knitting machine
2	Closing the stitches on the left and right edges		Circular knitting machine
3	Overlocking the edges of the handles (face-to-face)		Overlock machine
4	Turning the overlocked components inside out		Crochet hook
5	Attaching the handles to the bag		Manual
6	Sewing the ends of the handles onto the bag		Sewing machine
7	Adding the detachable label to the product		Manual
8	Final product		

Table 2

The definition of functions.

The function number	Function definition
F1	Bag volume
F2	Design
F3	Versatility in matching
F4	Ease of use
F5	Carries information
F6	Durability
F7	Weight capacity
F8	Psycho-sensory comfort

3.6. The process of incremental innovation management applied to the knitted bag product for women

Functional analysis of the product - The proposed functions for the women's knitted bag product are in accordance with its technical and aesthetic characteristics. We reduce the number of functions to the most important 8, which represents the product in its entirety, encompassing the technical, aesthetic, and psycho-sensory aspects (Table 2).

Determining the weight of function utility in the total utility **-** To establish the relative importance of function utilities within the product, we surveyed a sample of 29 users and potential customers of this product. The purpose of the survey was to collect the necessary data to calculate the weights of function utilities in the total utility of the knitted bag. Participants were asked to evaluate the importance of each utility for each function relative to the total utility of the product function, assigning a rating on a Likert scale ranging from 1 to 5 (a. 1 point, b. 2 points, c. 3 points, d. 4 points, e. 5 points).

The recorded results are synthetically presented in Table 3. The notations in this table are given by the following relationships:

$$sum_j = \sum_{i=1}^{29} n_{ij}\,, with\ \ j = \overline{1{,}8}$$

$$mean_j = \frac{\sum_{i=1}^{29} n_{ij}}{29}\ with\ \ j = \overline{1{,}8}$$

$$u\_w_j = \frac{\sum_{i=1}^{29} n_{ij}}{\sum_{j=1}^{8}\sum_{i=1}^{29} n_{ij}}\ with\ j = \overline{1{,}8}$$

which is the weight of utility j in the total utility of the product order: the descending order of the product functions as perceived by potential buyers.

$$utility_j = \frac{(mean_j - \min_i(n_{ji})}{(\max_i(n_{ji}) - \min_i(n_{ji}))}$$

The economic dimension functions - The economic dimension of functions consists of 2 stages: assigning cost weights to each function of the product "knitted women's bag" (Table 4) and, based on these weights, allocating costs with raw materials and labour for each function separately. The results are consolidated in Table 5. The parameter (c_w) calculated in Table 5 represents the weight of function costs in the total Cost of the product. The values in Table 4, representing the weights in the total product cost for each function separately, are determined by the technological expert and the economist responsible for the product's development.

Systemic analysis of functions - This analysis compares functions' utility-weight ratio to the product's total utility with the cost-weight ratio of functions to the total product cost. Ideally, this ratio is 1.

In Table 5, c_wi represents the cost weight of function I in the total Cost of the product.

Graphically, in the (u_w, c_w) coordinate system, the functions of the product, in the optimal case (when functions are optimally sized), are placed on a line inclined at a 45-degree angle. Over-sized functions (c_w > u_w) are located above the 45-degree line, under-sized functions (c_w < u_w) are located below this line, and correctly sized functions (c_w = u_w) are appropriately sized.

Table 3

Technical dimensioning

No.	F1	F2	F3	F4	F5	F6	F7	F8
sum_j	95	126	110	111	102	124	108	106
$mean_j$	3,28	4,34	3,79	3,83	3,52	4,28	3,72	3,66
u_w_j	10,8%	14,3%	12,5%	12,6%	11,6%	14,1%	12,2%	12,0%
order	8	1	4	3	7	2	5	6
utility	0,57	0,78	0,70	0,71	0,63	0,82	0,68	0,66

Table 4

Allocation of costs by functions as % of the total Cost

Subassembly / Function	F1	F2	F3	F4	F5	F6	F7	F8
Blue Thread from the body of the bag	20	10	10	0	0	30	20	10
Green Thread from the body of the bag	20	10	10	0	0	30	20	10
Handle made of blue thread	0	10	10	10	0	35	25	10
Handle made of green thread	0	10	10	10	0	35	25	10
Sewing thread	0	5	5	0	0	45	40	5
Label	0	10	0	5	85	0	0	0

Table 5

Weight in Costs of Product Functions.

No.	Subassembly	Total Material Cost	Labor Cost	Total cost lei/piece	F1	F2	F3	F4	F5	F6	F7	F8
1	Blue Thread from the body	0,143	6,5	3,393	0,68	0,34	0,34	0	0	1,02	0,68	0,34
2	Green Thread from the body	0,152		3,4026	0,68	0,34	0,34	0	0	1,02	0,68	0,34
3	Handle made of blue thread	0,035	2,5	2,535	0	0,25	0,25	0,25	0	0,89	0,63	0,25
4	Handle made of green thread	0,035	2,5	2,535	0	0,25	0,25	0,25	0	0,89	0,63	0,25
5	Sewing thread	0,035	3	3,035	0	0,15	0,15	0	0	1,37	1,21	0,15
6	Label	0,25	0,5	0,75	0	0,08	0	0,04	0,64	0	0	0
Total Cost		0,65	15	15,65	1,36	1,41	1,34	0,54	0,64	5,18	3,84	1,34
Weight in Cost (c_w) [%]		**4,16**	**95,84**	**100**	**8,68**	**9,03**	**8,55**	**3,48**	**4,07**	**33,1**	**24,5**	**8,55**

Table 6

Systemic analysis of functions.

No	Function	u_w	c_w	(u_w)2	u_w*c_w	c_w-u_w	(c_w-u_w)2
1	F1	10,77%	4,34%	1,16%	0,47%	-6,43%	0,41%
5	F5	11,56%	12,13%	1,34%	1,40%	0,57%	0,00%
8	F8	12,02%	15,06%	1,44%	1,81%	3,05%	0,09%
7	F7	12,24%	21,07%	1,50%	2,58%	8,82%	0,78%
3	F3	12,47%	10,72%	1,56%	1,34%	-1,75%	0,03%
4	F4	12,59%	15,37%	1,58%	1,93%	2,78%	0,08%
6	F6	14,06%	12,75%	1,98%	1,79%	-1,31%	0,02%
2	F2	14,29%	8,55%	2,04%	1,22%	-5,73%	0,33%
	TOTAL	100%	100%	12,60%	12,55%		1,7%

Table 7

Allocation of costs by functions as % of the total Cost after the redesign stage.

Subassembly / Function	F1	F2	F3	F4	F5	F6	F7	F8
Blue Thread from the body of the bag	10	15	15	5	10	10	10	25
Green Thread from the body of the bag	10	15	15	5	10	10	10	25
Handle made of blue thread	0	15	10	40	10	5	10	10
Handle made of green thread	0	15	10	40	10	5	10	10
The bottom part of the bag	20	10	0	10	10	20	20	10
Sewing thread	0	15	15	0	0	35	30	5
Label	0	0	0	5	95	0	0	0

Table 6 contains the parameters of utility weights and cost weights of the functions, as well as the mathematical calculation for determining the total deviation value.

$$S = \sum_{i=1}^{8} (c\_w_i - u\_w_i)^2 \qquad (1)$$

For $S \leq 0{,}01$, it is considered that the product is well-sized in terms of its primary functions. In Table 6, the functions are ordered in ascending order based on their utility weight.

Figure 5 presents the graph created using the data from Table 6. In this figure, the first value attached to the function name represents the utility weight, and the second represents the cost weight. The regression curve is also plotted, with a slope of 45,64 degrees with the abscissa, at a calculated value of the coefficient of

$$\alpha = arctg\left(\frac{\sum_{i=1}^{8} u_{w_i} * c_{w_i}}{\sum_{i=1}^{8}\left(u_{w_i}\right)^2}\right) = arctg\left(\frac{12,5}{12,6}\right) = 0,99$$

The total error value for the product functions' dimensioning compared to the optimal dimensioning (Equation 1) is S=0,017 > 0,01, which leads to the product's redesign.

The application of the value engineering method – product redesign is presented in the following. The first modification applied to the product is increasing the volume of the bag - an undersized function in the initial product. This solution falls within the technique of increasing the weight of the function's utility in the total utility of the product faster than the weight of the function's Cost in the total Cost of the product.

This decision to redesign the product led to the need to introduce a new component (the bottom part of the knitted women's bag) and to revise the matrix of cost weightings of functions in the total Cost of the product (Table 7). In Table 8, we have summarized the proposed changes to the weights in the final Cost of each function (the percentage values are reported in Tables 4 and Table 7). We can observe a decrease in the allocated values for functions F7 and F6 (which were identified as oversized during the value analysis phase) and an increase in the cost weights for functions F2, F3, and F8 (functions related to the aesthetics of the product and the psychosensory characteristics of the knitted women's bag). The costs and cost weights of the functions in the total Cost of the product have been recalculated (Table 9).

Considering the one carried out for the initial product, it has been decided that the technical sizing of the functions will still need to be reevaluated. The calculations are redone to determine the total functional value for the redesigned product (Table 10).

Figure 6 presents the projection of functions in the orthogonal coordinate system (utility weight (u_w), cost weight (c_w)). The value that validates the optimization model of utility weightings in the final utility compared to the cost weightings in the final Cost (equation 1) is $S = 0,0031\,{}^{0}/_{00} < 0,01\,{}^{0}/_{00}$.

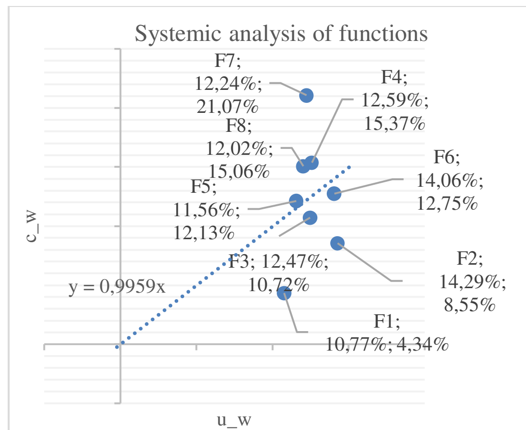


Fig. 5. Graphic representation of functions in the (u_w, c_w) coordinate system.

Table 8

Allocation of costs by functions as % of the total Cost before and after the redesign stage.

Function	F1	F2	F3	F4	F5	F6	F7	F8
Initial	7%	9%	8%	4%	14%	29%	22%	8%
After redesign	6%	12%	9%	15%	21%	12%	13%	12%

Table 9

The functions' costs and cost weights are in the product's total Cost.

No.	Subassembly	Material Cost	Labor Cost	Total Cost	F1	F2	F3	F4	F5	F6	F7	F8
1	Blue thread from the body of the bag	0,338	6,5	3,59	0,36	0,54	0,54	0,18	0,36	0,36	0,36	0.90
2	Green thread from the body of the bag	0,639		3,89	0,39	0,58	0,58	0,19	0,39	0,39	0,39	0.97
3	Handle made of blue thread	0,104	2,5	2,60	0,00	0,39	0,26	1,04	0,26	0,13	0,26	0.26
4	Handle made of green thread	0,098	2,5	2,60	0,00	0,39	0,26	1,04	0,26	0,13	0,26	0.26
5	The bottom part	0,237	3	3,24	0,65	0,32	0,00	0,32	0,32	0,65	0,65	0.32
6	Sewing thread	0,07	3	3,07	0,00	0,46	0,46	0,00	0,00	1,07	0,92	0.15
7	Label	0,25	0,5	0,75	0,00	0,00	0,00	0,04	0,71	0,00	0,00	0.00
Total Cost		1,736	18	19,74	1,40	2,69	2,10	2,82	2,30	2,73	2,84	2,87
Weight in Cost (c_w)		8.8%	91,2%	100%	7,1%	13,6%	10,6%	14,3%	11,7%	13,8%	14,4%	14,5%

Table 10

Systemic analysis of functions for product redesign.

No.	Function	u_w	c_w	(u_w)2	u_w*c_w	c_w-u_w	$(c\_w-u\_w)^2$
1	F1	10,77%	7,07%	1,16%	0,76%	-3,70%	0,14%
2	F5	11,56%	11,67%	1,34%	1,35%	0,11%	0,00%
3	F8	12,02%	14,52%	1,44%	1,75%	2,51%	0,06%
4	F7	12,24%	14,37%	1,50%	1,76%	2,13%	0,05%
5	F3	12,47%	10,65%	1,56%	1,33%	-1,82%	0,03%
6	F4	12,59%	14,27%	1,58%	1,80%	1,68%	0,03%
7	F6	14,06%	13,83%	1,98%	1,94%	-0,23%	0,00%
8	F2	14,29%	13,61%	2,04%	1,94%	-0,68%	0,00%
	TOTAL	100%	100%	12,598%	12,630%		0,31%

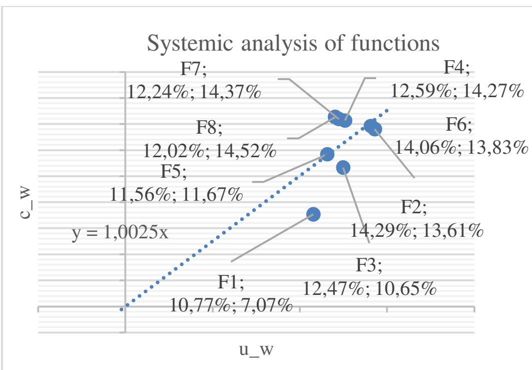


Fig. 6. Graphic representation of functions for redesigning product

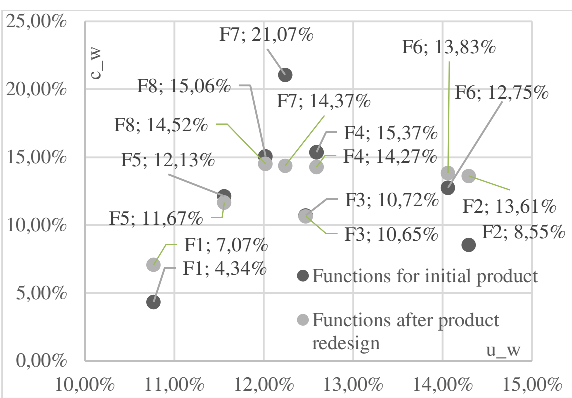


Fig. 7. Graphic representation of functions for product – initial and redesigned

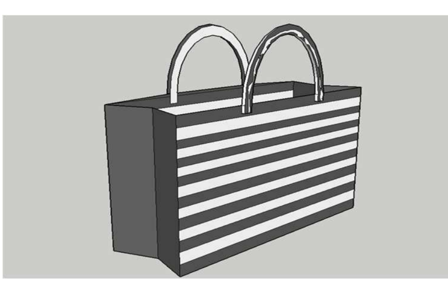


Fig. 8. The final product after the application of the value engineering method

Based on this analysis, it can be concluded that the knitted women's bag optimally supports all the analyzed functions from both the customer's and the manufacturer's perspective.

Figure 7 compares the weights of functions in Cost and utility calculated for the basic product and the redesigned one.

The product that will be launched on the market is presented in Figure 8.

4. RESULTS AND CONCLUSION

The current research proposes a quantitative method of incremental innovation focused on the customer to increase the added value of the product, the knitted handbag for women. The novelty elements used in this research involve the application of two different solutions from the classical ones (which are mainly characterized by reducing the weight of costs on functions in the total Cost of the product) for both the oversized and undersized functions. For the volume function of the bag (a function determined to be undersized), the utility weight of the volume function in the total utility of the product is increased by increasing it from 2000 cm^3 to 16000 cm^3 (30cm x 25cm x 16cm), with a cost increase with 31%, from 15,65 RON to 19,74 RON.

The second method used to resize the product is the modification of the cost weighting matrix in the total Cost of the product (during the economic design phase of the product), primarily driven by the introduction of a new component (the bottom part of the bag) in the product structure. Thus, functions F4 (ease of use), F7 (supported weight), and F8 (psycho-sensory comfort) are brought to approximately the same ratio of utility weights to cost weights (approximately 1). The volume function, F1, remains with a utility weight ratio higher than the cost weight ratio, while functions F2 (design), F6 (durability), and F3 (versatility) remain undersized but are pulled towards the optimal rightmost position (where the ratio of utility weight in the total weight and cost weight in the total Cost is 1) for product sizing.

The versatility of the value analysis and engineering method is remarkable. It creates added value to the product when it is launched on the market through an iterative decision-making process in a short time and with reduced financial effort. Another characteristic supporting the method's versatility is that hybrid decision solutions can be used for the technical and economic sizing of the functions of a new product on the market.

The limitations of the research arise from the value analysis stage in the second iteration step, as the technical sizing of the functions is not reevaluated, and no new functions are proposed for the redesigned product.

In conclusion, the value analysis and engineering method is a successful approach to managing incremental innovation for a new product on the market.

5. ACKNOWLEDGEMENTS

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Model de management de inovare sustenabilă bazat pe metoda de analiza și ingineria valorii

Procesul de îmbunătățire continuă a unui produs sau serviciu prin adăugarea treptată de noi caracteristici, funcționalități sau îmbunătățiri tehnice, astfel aducând valoare și îmbunătățind progresiv performanța produsului fără a schimba radical produsul existent, reprezintă o caracteristică a oricărui produs de pe piață. Cercetarea curentă explică, analizează și aplică o metodă de inovare incrementală bazată pe analiza funcțională pentru a îmbunătăți aspectele importante ale produsului, în baza feedback-ului clienților. Acest studiu prezintă fazele de proiectare și concepție ale produsului, propune funcții specifice ale produsului dimensionate tehnic și economic, efectuează o analiză sistemică a acestora și aplică tehnici hibride pentru a le redimensiona în procesul de optimizare așa cum sunt percepute și solicitate de potențialii clienți.

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