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THE POTENTIAL OF VALUE ANALYSIS APPLICATION IN THE FURNITURE INDUSTRY – A CASE STUDY AT IKEA

Abstract: *Value analysis methodology uses a structured and methodical job plan contemplating several steps to ensure success in its application. This paper intends to perspective the potential of value analysis application, namely in the furniture industry. To draw conclusions of this potential a case study was developed at an IKEA factory in Portugal. To characterize the customer needs in a clear language and to quantify the value of a product (a bookcase) produced in this factory, a value analysis study was developed. Functional analysis is the most known and distinctive phase of value analysis and is, nowadays, an autonomous tool. With this functional analysis, the authors intend to describe the functions that the product performs, to provide a better knowledge of the product, to evaluate the degree of satisfaction of the product through its functional performance and to facilitate the search for alternative solutions. The results obtained allowed us to reach some important conclusions about the application of value analysis in this type of industry and can be an initial step to promote the use of this tool in this kind of industry.*

Keywords: *Value analysis; Furniture industry; Functional analysis; Bookcase; Customer needs; Value creation.*

1. Introduction

Markets globalization and the continuous innovation generated a redefinition of the value added chain. Value is one of the keywords most referred to a wide range of research and investigation topics as well as in the day-by-day of organizations. The competition is forcing companies to re-examine its range of products in order to provide a higher level of satisfaction to their customers without increase the costs. This need is based on a growing competitiveness and globalization of the markets and an increasingly essential innovation capacity. This value should be sustainable, seeking better resources application for the needs satisfaction and aiming not only to the economics but also to the environmental, social and other components. In order to attend the importance of products' value, Value Analysis (VA) methodology has been used, with success, in different production areas.

VA appeared in 1947 in the United States, from the work carried out by Lawrence Miles, executive of the purchasing department of the General Electric Company. Initially, VA was applied only in the reformulation of existing products. However, it soon became apparent that organizations could get higher benefits if VA were introduced into the product design phase, because redesign a product can involve large investments. Ho et al. (2000) and Mukhopadhyaya (2017) define VA as an organized and creative methodology that uses

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a functional approach and aims to increase the value of a product/service. VA provides a means to link, align, and maximize the efficiency of the value chain. It is a well-known structured method to increase value and support the selection of the most valuable solution (Romano et al., 2010). The tool has proven its potential to solve problems, not only regarding cost reduction and quality improvement (Chougule & Kallurkar, 2012; Singh & Ravanan, 2016), but also in process optimization and as a support for decision-making (Boulton et al., 2000). Applying effective methods to support the control of production execution VA plays a crucial role in the success of any manufacturing system (Zohooria et al., 2019) and permits the identification of a set of objectives and business improvement guidelines (Borgianni et al., 2010). Many companies, leaders in the respective sectors worldwide, such as Sony, Panasonic, Hewlett Packard, Nissan, Toyota, Ford, Boeing, BP, Fiat, Kmart Corp., Lockheed Martin, General Motors, Xerox, Motorola, Arthur Andersen, Mitsubishi, DuPont and others, achieved great benefits from the application of the method (Rich & Holweg, 2000).

The importance of the VA increases with the application in the conception phase, so it is necessary to expand the boundaries of the method utilization to every type of project or configuration models. The differentiation of a product can be defined by the constant seek in joining more and new values to the products. The authors intend to provide a better knowledge of VA and suggest possible ways of its application to increase surplus values in the organizations, namely the application of a functional analysis (FA) study in a specific product of furniture industry.

The authors did not find any references of its application in the furniture industry so it could be an innovative area to explore and potentiate the VA benefits, and following the same line of thought of Manea (2017), an opportunity to renew VA. Therefore the main objective of this work is to implement the functional analysis phase of VA methodology in a product (a bookcase) of furniture industry of IKEA.

To achieve the goal of this work, the rest of this paper is organized as follow. Section 2 describes the value analysis (VA) methodology and its job plan. Section 3 presents the case study at IKEA, for a specific bookcase. The focus of the case study is in the FA phase with the description and application of its several steps and its main results: to identify the functions that the product performs, to provide a better knowledge of the product, to evaluate the degree of satisfaction of the product through its functional performance, to facilitate the search for alternative solutions, and to quantify the value of the product. To finalize, in Section 4, some conclusions emphasize the principal benefits of the methodology application and future works are presented.

2. Value Analysis Methodology

VA uses a structured and methodical job plan with several phases. The most known and distinctive phase is the FA, nowadays an autonomous tool of VA. In the extent of our work we use the following job plan presented in Table 1 with the phases of the method indicating the responsibility or participation of the company management, operational departments, and the VA Team (Pires et al., 2007).

Table 1. VA Job Plan

Phases	Manage-ment	VA Team	Operatio-nal Depart-ments
Orientation	R		P
Information Search		P	P
Functional Analysis		R	P
Creativity		R	P
Evaluation		R	R
Development		R	P
Implementation	R		R

*Note: R – Responsibility; P - Participation

The phases of VA job plan are briefly described considering their objectives, key steps, and the authors' remarks, as following.

Orientation: preparation of VA application;

Objectives: Planning the project with the decision maker and evaluate the involvement of management.

Key Steps: Definition of the project; Definition of the objectives, constraints and relevant aspects to be taken into account; Selection of the project leader and formation of the VA Team; Planning of the necessary resources (human, physical, temporal, financial, etc.).

Remarks: This initial planning phase is critical to the success of practical application. It is important the support of the management.

Information Search: obtain all the necessary information;

Objectives: make the VA team "familiar" with the project and the problem; Get more and better information; Gain knowledge of the current situation.

Key Steps: Collect all relevant information, namely: Drawings and technical specifications; Materials; Suppliers and subcontractors; equipment, manufacturing operations, performance parameters; Human resources involved; Quantities sold, price, clients, market share; Internal information (quality problems, requirements of different departments, etc.); Products and competition status; Product strategy and marketing; Trends in technology associated with the product; Catalogs, norms, laws, regulations and bibliography relevant to the study in question; Obtain and structure all necessary costs (Development costs (research, design, testing, production, tool manufacturing) and Production costs (direct labor, raw materials, subsidiary materials, energy).

Remarks: The importance of an effective diagnostic in order to obtain an objective knowledge of the organization and the product in analysis, it is a relevant factor, for perspective possible actions and solutions derived from the method application (Pires, 2012).

Functional Analysis: identification, characterization, weighting, ranking and evaluation of the functions;

Objectives: FA is a way of expressing the user's needs in clear and precise language. With FA it is intended: Describe a product or service by the functions it performs in terms of purpose and not by the components or elements that constitute it; Know what the product does and not what it is; Characterize users' needs in clear and precise language; Assess the degree of satisfaction of a product through the evaluation of functional performance; Facilitate the search for alternative solutions to existing ones; Encourage creativity

Key Steps: Know the purpose of the product; Know the environment of the product; To form a multidisciplinary team; Know the main competitors; To master the rules for formulating the functional analysis

Remarks: Functional Analysis is the most distinctive and important phase of the method with five main steps: identification; characterization; weighting; ranking; evaluation. It consists in the full description of the purposes of the product; the definition of the desired levels of satisfaction for each function; the definition of the importance of each function in the total expected performance of the product, allowing the ordering of functions; and costing the functions in relation to the total cost of the product in order to allow an evaluation of the functions.

Creativity: generation of alternative ideas;

Objectives: Search and generate alternative solutions to perform the functions described in the previous phase; Stimulate and encourage creativity and innovation; In the creative phase the emphasis is on function. We should consider "what the product does" for the customer instead of "what is" in the mechanical sense of the term.

Key Steps: Promote free association of ideas; Apply creative techniques to solve problems and obstacles that may arise; Collect and record ideas.

Remarks: At this stage the AV team should already have a thorough knowledge of the product in order to allow the search for solutions that meet the detected needs. In this phase can be applied diverse techniques of creativity, such as: brainstorming, check-lists, analogies.

Evaluation: evaluation and selection of the alternative ideas;

Objectives: Evaluation criteria should be established, grouping compatible ideas and comparing solutions. Those with the greatest potential benefits should be selected and a development plan established.

Key Steps: Ideas are subject to an evaluation in which their advantages and disadvantages should be identified in the light of the current situation; The cost and value of each function are evaluated; The evaluation and selection of groups of ideas will be based on the concept of value.

Remarks: Assessment criteria, grouping compatible ideas and comparing solutions should be established. Ideas are subject to an evaluation in which their advantages and disadvantages should be identified in comparison to the current situation. In the evaluation and selection of ideas, those with the greatest potential benefits should be selected and a development plan established.

Development: development of the selected ideas;

Objectives: Prepare and characterize the solutions adopted.

Key Steps: Development of selected solutions, characterizing them and submitting them to a previous study; Plan the execution of the work, suggesting the division of the project into functional areas, facilitating the analysis by specialists.

Remarks: In some situations, the execution and testing of prototypes is essential for a preliminary study.

Implementation: implementation of VA project.

Objectives: Inform operational departments and start implementation; Track support activities and achieve effective results.

Key Steps: Start implementation; Involve management: Monitoring implementation activities; Inform the VA Team;

Remarks: It is important the involvement of the management in order to support the overcoming of unexpected problems.

3. Case study at IKEA

3.1. The Selection of the Product and the Process for the Study

IKEA is a multinational company that sells home furnishing products and is one of the major players in the furniture industry worldwide. The hugely successful company is known for its simple and affordable products. IKEA has been in business for decades and has hundreds of stores located around the world, including in North America, Europe, and Asia.

The present work was carried out at IKEA factory in Portugal more specifically in the EdgeBand & Drill area, with a production area of 21 000 m2 approximately (600 meters long by 35 meters wide) where 633 operators work. The EdgeBand & Drill area is dedicated to automatically produce sandwich-type wooden tables (tables, beds, and shelves). The components of the products are partially filled with "honeycomb" carton, implying that these components are of low weight, with stable structures, and permit the lower consumption of raw materials. This type of products has a competitive price and at the same time, quality and a modern design. The area under study, consists of three production lines (Line 1, Line 2 and Line Biesse) responsible for the placement of edge and drilling of elements BOF and melamine. The products can be bordered in five different colors Birch, Black-Brown, Black, White 2 and White 5. Despite the identical process sequence of the three lines the type of material operated there is different. The Line

1 is responsible for the placement of border and drilling of melamine, contrary to the other lines, Line 2 and Line Biesse, which only dedicate to the processing of BOF elements.

Due to the complexity of the production system of the whole area it was decided to start with an initial and gradual process. Thus, we compared the efficiency values of the lines to choose the line with less efficiency. Table 2 shows the values of the efficiency of the three lines that constitute the EdgeBand & Drill area.

Table 2. Performance measure comparison Efficiency on EdgeBand & Drill lines

Line	Efficiency %
EdgeBand & Drill - Line 1	56.17
EdgeBand & Drill - Line 2	51.32
EdgeBand & Drill - Biesse Line	**45.83**

Analyzing the previous data, the line that has the lowest efficiency percentage is the Biesse line (45.83%). This low efficiency is due to the high downtime of the line, high amounts of defective parts, the high costs associated with scrap pieces, lack of versatility of operators, waste of raw materials, and lack of organization. One of the possible causes is that this is the most recent line in the area, with new machines, new programming systems and different mechanisms of controls. So, it was decided to carry out the study on the current state of the production system in the production area Edgeband & Drill, specifically in the Biesse line.

The EdgeBand & Drill production process involves different stages that are carried out and controlled by six operators along the three production lines (115-meter extension) where all parts are transported by automatic mats. The process, presented in Figure 1, begins with the sending of pallets from the production area Frames & ColdPress through conveyors to the area of fringing and drilling. These pallets are arranged in an Inlet Buffer which, with the aid of an automatic horizontal conveyor, input conveyor, feeds the line with the parts that need to be produced.

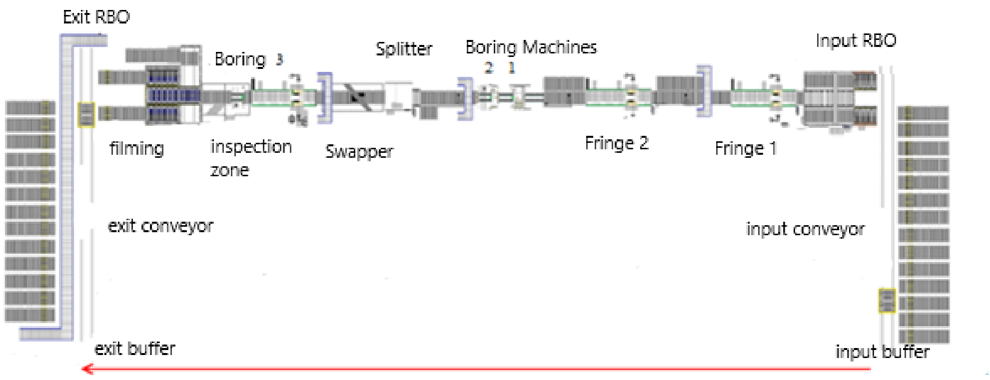

Figure 1. Layout of the Biesse Line with the identification of the different phases of the process and with the representation of the flow of materials.

Through an automated arm, RBO (Robot Biesse Operator), consisting of several suction cups the parts are removed from the automatic mats and placed in the center aisle of the line. The pieces are sent to the fringe machine 1, which is responsible for confining the finishing of the pieces (thinning, trimming and elimination of deburring), followed by the placement and gluing of borders on one side faces of the pieces. Then, by means of flapping cones the pieces are turned 90º in order to be sent by automatic mats to the fringe machine 2, whose function is to perform the laying and gluing of flange on the other side faces of the pieces.

After the edges are placed on the side faces of the parts, they are again turned through 90 ° (through cones) and transported to the borers 1 and 2 that pierce the pieces at different points (varying according to the reference) through various types of drills. These drills are capable of drilling horizontally and vertically, however, the upper and lower drilling of the parts is divided between the two drills since each drill cannot perform these two drills (upper and lower) at the same time.

After the drilling, the parts sent to the splitter machine, which has the function of cutting them in two equal parts. After cutting, the pieces inverted in the swapper so that the cut part has the ends facing outwards. If parts are to be produced that require lateral drilling, the pieces are processed in the boring machine 3, if this is not required, this machine is merely used for transport of parts.

The parts are then controlled in the inspection zone where the periodic controls are carried out, which define whether the part conforms to the specifications defined by the quality. Non-conforming parts considered rework is forward to a machine called repairer (responsible for repairing the parts), parts that do not have repair possible are scrap. In case the parts are within the specifications, they are sent to the Exit RBO, which is responsible for removing the parts from the line and stacking them on new pallets. These pallets are manually film by an operator and are then transport through the exit conveyor to the automatic mats that will ship the parts to the next lacquering area.

In this line are produced a large variety of products. In order to select the most important product for the company, an ABC analysis was performed in terms of the quantities produced. Table 3 shows the results of the ABC analysis for the quantity of products produced and the product chosen for performing the Value Analysis study was the Kallax bookcase SU 77 x 77, since it presents the highest percentage of production (14%).

Table 3. Analysis ABC for the quantity of produced products

Product	Number of produced products	Total %	Total accumulated %	Class
KALLAX SU 77x77	627 629	14.2	14.2	A
MICKE DK 105x50	491 234	11.1	25.3	A
LACK WS 110x26	459 382	10.4	35.7	A
KALLAX SU 77x147	398 857	9.0	44.7	A
KALLAX SU 42x147	339 619	7.7	52.3	A
LACK ST 55x55	301 504	6.8	59.2	A
MICKE DK 73x50	292 309	6.6	65.8	A
LACK CT 90x55	255 181	5.8	71.5	B
MICKE DK 120x50	247 251	5.6	77.1	B
MICKE add-on unit high	194 152	4.4	81.5	B
LACK WS 190x26	184 416	4.2	85.7	B
MICKE DK 142x50	182 835	4.1	89.8	B
KALLAX SU 147x147	136 042	3.1	92.9	C
MICKE drawer unit 35x75	132 918	3.0	95.9	C
LACK CT 118x78	90 568	2.1	97.9	C
LACK TV 149x55	82 067	1.9	99.8	C
LAPPLAND TV 183x147	9 894	0.2	100.0	C
Total	**4 425 858**	**1**	**100**	

3.2. Value Analysis Application

Having identified the problems some proposals for improvements to the production process of the Biesse line were presented. At this stage some Lean tools and Quality Management were used, namely the VA. In this paper it is presented some results of the VA application, more specifically the FA phase, with the intention to promote the potentialities of this type of tool in this kind of industry.

The present case study not includes the costs of product development (research, design, testing, production) and the production costs (materials, subsidiary materials, and energy) since the company does not provide these data. However, the final results of the production of each component of the Kallax bookcase product 77 x 77 were ceded by the company.

The components of the product are illustrated in the Figure 2 and consists in two laterals (part 1), two shelfs (part 2), one partition (part 3), and two top/bottom (part 4).

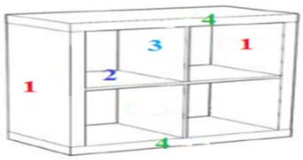

Figure 2. Kallax Bookcase

The dimensions of the product are detailed by its components in Table 4, in order to provide a better understanding of the product, a simple product but with a general utilization in different spaces, for different purposes and by different users.

Table 4. Dimensions of the bookcase

	Size (mm)		
Component	**Lenght**	**Widht**	**Thickness**
Partition	383	336	16
Shelf	688	386	16
Top/Bottom	765	392	37
Laterals	688	389	37

In order to characterize the customer's needs in a clear language and to quantify the value of a product (a bookcase) of the furniture industry, a FA study was developed. With this FA is intended to describe the functions that the product performs (identification), provide a better knowledge of the product (characterization), evaluate the degree of satisfaction of the product through its functional performance (weighting and ranking) and facilitate the search for alternative solutions (evaluation).

3.3. Functional Analysis – Main Results

In this section are presented the main results and conclusions of the functional analysis application phase. The steps of the functional analysis study applied to the product (bookcase) are also explained with their main objectives.

1st step - IDENTIFICATION: Description of the product functions. These functions are described by a verb and a noun according the VA methodology and are shown in Table 5.

In this step, it is intended to describe the functions that the product performs in terms of the customer's needs. The function needs for each function that was identified appears described below:

Be Functional: the product should be practical and useful, should allow the user easy access and its components should be removable.

Be Resistant: the product must have a strong structure to support heavy materials, shall be resistant to impact, moisture and sun.

Present Aesthetic: the product must have a pleasant color and design as well as a good and quality finishing.

Be Flexible: the product should be weightless, easy to carry and easy to assembly and disassembly

Adjust Environment: the product must be able to be used in different spaces (bedrooms, living rooms, kitchens, gardens).

Be Compact: the product should allow the user to save space allowing for a better use of space and should not obstruct the movement of persons.

Be Versatile: the product should enable the placement of storage boxes in the four partitions of the unit, each of which can assume different roles.

Table 5. Identification of the bookcase functions

Identification of the functions		
Verb	**Noun**	**Function**
Be	Functional	A
Be	Resistant	B
Present	Aesthetic	C
Be	Flexible	D
Adjust	Environment	E
Be	Compact	F
Be	Versatile	G

2nd step - CHARACTERIZATION: Definition of satisfaction levels for each function. Spex defines the level of satisfaction of the product defined by the VA team, and Sma defines the level of satisfaction required by the product users (Manea, D., 2017). The characterization of the bookcase functions it is represented in Figure 3.

Analyzing the Figure 3 is seen that the functions D (Be Flexible) and E (Adjust Environment) present a Spex value lower than the Sma value. For this reason these two functions should be improved in our VA application.

3rd step - WEIGHTING: Weighting of the product functions by comparison of two functions for every combination. The weighting matrix is shown in figure 4. In order to correctly order the product functions, it is crucial to define the importance of each function in the total expected product performance. The comparison criteria according the VA methodology by bilateral comparison of functions is as follows: 0 - Equally important – 1; Little more important; 2 - Most importantly; 3 - Much more important.

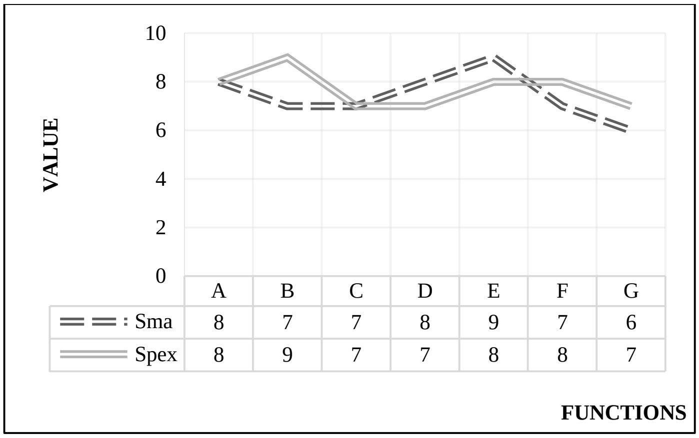

Figure 3. Matrix of the characterization of the bookcase functions

4th step - RANKING: Ranking of the product functions, by order of importance obtained from the results of the previous step, weighting step. As can be seen in the last column of Figure 4, the most important function is Be Resistant with 29.4% of the total importance and the least ones are Adjust Environment and Be Versatile with 5.9% of the total importance.

5th step - EVALUATION: Evaluation of the product functions versus cost, relating the costs of each item (product component) by the functions that performs or contributes for its performance. The results of this step are represented in Table 6 with the value of each function cost (F1 to F7), that are obtained by the sum of the expected costs for each component. As can be seen in the last line of Table 6, the most highest cost function is the function Be Resistant, with 28.6% of the total cost and the least one is the function Be Versatile, with 5.9% of the total cost.

Be Functional	Be Resistant	Pres. Aesthetic	Be Flexible	Adjust Environ.	Be Compact	Be Versatile			
	B	**C**	**D**	**E**	**F**	**G**	**TOTAL**	**%**	**Rank Nº**
A	A3	A1	A2	0	A2	0	8	23.5%	2
	B	B2	B3	B1	B2	B2	10	29.4%	1
		C	C2	C3	0	G2	5	14.7%	3
			D	D2	D1	D1	4	11.8%	4
				E	E2	0	2	5.9%	6
					F	F3	3	8.8%	5
						G	2	5.9%	7

Figure 4. Matrix of the weighting and ranking of the bookcase functions

Table 6. Matrix cost-function

			F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	
ITEMS	**TOTAL COST Euro**	**% TOTAL**	**Be Resistant**	**Be Functional**	**Pr. Aesthetics**	**Be Flexible**	**Be Compact**	**Adjust Envir.**	**Be Versatile**	**Total**
Top	**1.595 €**	**17.9%**	20%	25%	**0%**	25%	15%	**0%**	15%	**100%**
			0.319€	0.399€	**0€**	0.399€	0.239€	**0€**	0.239€	**1.595€**
Bottom	**1.595 €**	**17.9%**	45%	15%	**0%**	25%	15%	**0%**	**0%**	**100%**
			0.718€	0.239€	**0 €**	0.399€	0.239€	**0€**	**0€**	**1.595€**
Laterals	**2.645 €**	**29.7%**	20%	15%	25%	10%	15%	15%	**0%**	**100%**
			0.529€	0.397€	0.661 €	0.265€	0.397€	0.397€	**0€**	**2.645€**
Partition	**1.582 €**	**17.8%**	15%	25%	5%	25%	10%	5%	15%	**100%**
			0.237€	0.396€	0.079€	0.396€	0.158€	0.079€	0.237€	**1.582€**
Shelf	**1.476 €**	**16.6%**	50%	25%	5%	15%	**0%**	5%	**0%**	**100%**
			0.738€	0.369€	0.074€	0.221€	**0€**	0.074€	**0€**	**1.476€**
TOTAL	**8.893 €**	**100.0%**	**2.541€**	**1.799€**	**0.814€**	**1.679€**	**1.033€**	**0.550€**	**0.477€**	**8.893€**
			28.6%	**20.2%**	**9.2%**	**18.9%**	**11.6%**	**6.2%**	**5.4%**	**100%**

Now, already are calculated the values of each function importance and its costs associated, coming from Figure 4 (last column) and Table 6 (last line). In the Figure 5 can be seen the comparison between the cost and the importance of each function of the bookcase, leading to the main results of the FA study.

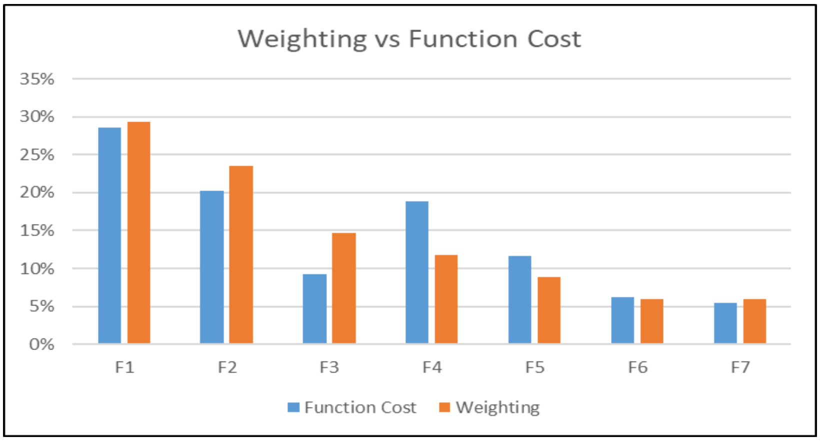

Figure 5. Comparison between the importance and the cost of the bookcase functions

Considering the steps of this study and its final quantitative results, illustrated in Figure 5, it is possible to emphasize that:

- Functions F4 (Be Flexible) and F6 (Adjust Environment) are functions in which its performance (Spex) is less that the users require (Sma), as seen in characterization step;
- Functions F4 (Be Flexible), F5 (Be Compact) and F6 (Adjust Environment) shall be intervened because their functions cost are higher than their importance (weighting);
- By analysis of the matrix cost-function we can see that the laterals and the partition are the components that most affects these three functions, so these are the main items where should be generated process alternatives.

These results are the basis to proceed with the next phase of VA methodology, creativity in order to generate of alternative ideas for the process. It means that the company should work in three possible ways to solve the deviation of the Functions F4, F5, and F6 already exposed. The first possibility is to improve the functions importance maintaining the cost; the second one is the opposite, maintain the importance and reduce the cost; and the third one is the combination of the previous ones.

4. Conclusions

In this paper, after an introduction to the principal goals of the work was done a literature review mainly focused in the benefits of VA application. Then, it was presented the case study at IKEA factory where the FA phase of VA was applied which allowed to identify the main product components and the functions to be improved. The main results of FA application suggest that the Functions F4 (Be Flexible), F5 (Be Compact) and F6 (Adjust Environment) shall be improved, and the laterals and the partition are the components that most affects these functions.

The results obtained with FA application and the benefits achieved by the VA team involved in this case study, promote the opportunity to go further with this study at IKEA. For future work it is intended to continue the VA application to the other phases and expand its application to other products and lines.

Therefore, as a short conclusion of this study and with the company motivation, can be said that it is launched an initial step to promote the use of VA methodology and its potentialities in the furniture industry.

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