THE ITERATIVE PROCESS OF VALUE ANALYSIS

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ABSTRACT: The paper presents a complete study of VALUE ANALYSIS applied concretely to a selected piece of equipment. The phases and ITERATIVE operation of the Value Analysis method are presented.

Value Analysis combines both ENGINEERING and ECONOMICS without, however, placing neither ENGINEERING or ECONOMICS first. They both are similarly important, as can be concluded by the end of this paper.

Value Analysis (VA) is a method that provides an operating technique using a creative and organized approach.

Keywords: value analysis, value, optimum variant

VALUE ANALYSIS APPLIED TO THE DESIGN OF A MIXER FOR MOULDING AND CORE SAND PREPARATION

Value Analysis (VA) is a method that provides an operating technique using a crative and organized approach.

It is managed by a group, each of them selected by their expertise in specific subjects and coordinated by a Value Analysis expert.

The VA group activity is managed in seven stages:

1- information and functional analysis,
2- creativeness,
3- evaluation and selection of the proposals,
4- the creative phase,
5- development of the selected proposals,
6- presentation of the selected proposals, set in order by priority,
7- implementation phase.

An example of Value Analysis is presented, applied to the redesign of a mixer for moulding sand preparation.

Next the establishing mode of the optimum constructive solution is presented from the technical and economic viewpoint for a part participating in a function of over-dimensioned cost.

ESTABLISHING THE LIST OF TECHNICAL FUNCTIONS AND DIMENSIONS

Table 1 presents the list of functions of the mixer.

Tab.1: List of functions.

Symbol	Function	Type of function	Technical dimension of function		
			Name	UM	Value
A	Loosening and homogenizing	*FS	force	daN	1000
B	Includes components	FS	volume	m^3	0.4
C	Ensures adjustment	FC	height	mm	10 – 25
D	Part feed	FS	flow rate	m^3/h	0.4 – 4
E	*Supports the assembly*	*FS*	*force*	*daN*	*10000*
F	Part evacuation	FS	flow rate	m^3/h	0.4 – 4
G	Supplies working energy	FS	torque	daN*m	1000
H	Transforms electric energy into mechanical work	FS	mechanical work	J	-
I	Wear resistance	FC	worn material	g/year	-
J	Ergonomics	FE	-	-	-

*FS: Service function; FC: Constraint function; FE: Estimation function.

ESTABLISHING THE LEVELS OF IMPORTANCE OF THE FUNCTIONS

Table 2 presents the value weighting of the functions.

Tab.:2 Value weighting of the functions (* - X coordinate).

Functions	A	G	H	B	I	F	E	Total
Number of points	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*28*
Ratio	*0,25*	*0,21*	*0,179*	*0,14*	*0,11*	*0,07*	*0,04*	*1*
*Percentage %	***25***	***21,4***	***17,9***	***14,3***	***10,7***	***7,14***	***3,57***	*100*

Step 1

The product value is equal to the sum of the functions levels and is equal to 28. The following percentage values of the functions value weighting result: X_A = 25 %, X_G = 21.4 %, X_H = 17.9 %, X_B = 14.3 %, X_I = 10.7%, X_F = 7.14 %, X_E = 3,57 %.

Figure 1 shows the studied mixer.

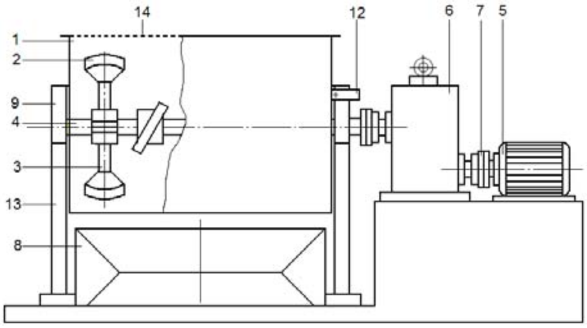


Fig.1: Blade mixer: 1 – tank; 2 – blades; 3 – blade supports; 4 – shaft; 5 – electric motor; 6 – reducing gear; 7 – coupling; 8 – flute; 9 – bearing; 12 – stopper; 13 – frame; 14 – protection grate.

ECONOMIC DIMENSIONING OF THE FUNCTIONS

Costs were assigned to the various functions by means of the functions – costs matrix shown in table 3.

Tab.3: Distribution of costs on functions (*Y coordinate, ** monetary units).

No.	Parts	F u n c t i o n s							Cost part**
		A	G	H	B	I	F	E	
1	Motor	*12*				*90*			*102*
2	Reducing gear	*40*				*90*	*90*	*20*	*240*
3	Tank	*10*	*60*	*10*	*10*			*5*	*95*
4	Blades	*30*						*15*	*45*
5	*Bearing*			*280*				*15*	*295*
…	...	*1170*	*980*	*300*	*750*	*510*	*310*	*203*	*4223*
Total cost		*1262*	*1040*	*590*	*760*	*690*	*400*	*258*	*5000*
Ratio		*0,25*	*0,21*	*0,12*	*0,15*	*0,14*	*0,08*	*0,05*	*1*
Cost of functions %		***25,2***	***20,8***	***11,8***	***15,2***	***13,8***	***8***	***5,16***	*100*

Step 1

The percentage values of the functions participation in the total cost are:
Y_A = 25,2 %, Y_G = 20,8 %, Y_H = 11.8 %, Y_B = 15.2 %, Y_I = 13.8 %, Y_F = 8 %, Y_E = 5.16 %.

COMPARISON OF THE FUNCTIONS VALUE AND COST WEIGHTINGS

The value – costs relationship needs to identify:

- The functions that are very expensive in relation to the others,

- The functions that are too expensive in relation to their contribution to the value of the product,

- The functions that are too expensive in relation to the existing technical possibilities of production.

DIAGRAMS

The construction of the diagrams is presented at last.

Based on the values for coordinates x_i and y_i presented in table 4 the diagrams of figures 2, 3, 4 and 5 are plotted. The calculus is made with the smallest squares method.

Tab.4: Computational elements for plotting the diagrams.*$S'=2*a*(X_i)^2-2*X_i*Y_i$

No.	Elements of calculus	Functions A	G	H	B	I	F	E	Total value
1	X_i	***25***	***21,4***	***17,9***	***14,3***	***10,7***	***7,14***	***3,57***	100
2	Y_i	***25,2***	***20,8***	***11,8***	***15,2***	***13,8***	***8***	***5,16***	100
3	$(X_i)^2$	*625*	*459*	*319*	*204*	*115*	*51*	*12,8*	*1786*
4	$X_i * Y_i$	*631*	*446*	*211*	*217*	*148*	*57,1*	*18,4*	*1728*
5	$(Y_i - a*X_i)^2$	*1,1*	*0*	*30*	*1,89*	*11,8*	*1,18*	*2,9*	*48,89*
6	S' *	*-52,4*	*-2,74*	*196*	*-39,3*	*-73,5*	*-15,5*	*-12,2*	*0*

Step 1

The parameters have the following computed values: a = 0.976, $\alpha = 44.31^o$, S = 60.95 and S'= 0.

Table 4 provides the necessary values for constructing the following types of diagrams:

- Diagram of the functions value weighting (fig.2),
- Diagram of the functions cost weighting (fig.3),
- Diagram of the functions value and cost weighting (fig.4),
- Diagram comparing the functional values and costs weighting (fig.5).

Figure 2 shows the ranking of the functions by their value.

Figure 3 shows the ranking of the functions by their functional cost.

The diagram allows significant comparisons of the functions total costs, and within the total costs, of the work and material costs:

- The very expensive functions with the highest weighting in the total cost of the product,

- The secondary functions that are very expensive in relation to the objective functions, or even more expensive than these, The diagram reveals a Pareto type distribution, meaning that 20 - 30% of the total number of functions, include 70 - 80% of the total costs of the functions. These functions are A and G.

In the case of such a distribution, the first functions in the order of costs, representing 20 - 30% of the total number of functions (in the above example functions A, B and G) are considered to be very expensive functions.

The real situation is represented by the shape of the straight line in figure 4, plotted by means of the smallest squares method, and showing disproportions in the distribution of costs and in the contribution of the various functions to the value of the product.

An analysis of the diagram of figure 4 shows that functions I and E are located above the regression line, indicating high costs, not justifiable in relation to the value.

The disproportions are highlighted also in the diagram of figure 5, where it can be noticed that functions I and E have disproportionate costs (13.8%, 5.16%) in relation to their respective contributions to value (10,7%, 3,6).

These aspects allow the assumption that these functions are deficient, hence the solutions to be identified are to focus on those assemblies, parts, materials and technological operations that contribute, within the general structure of the product, to the achievement of these functions.

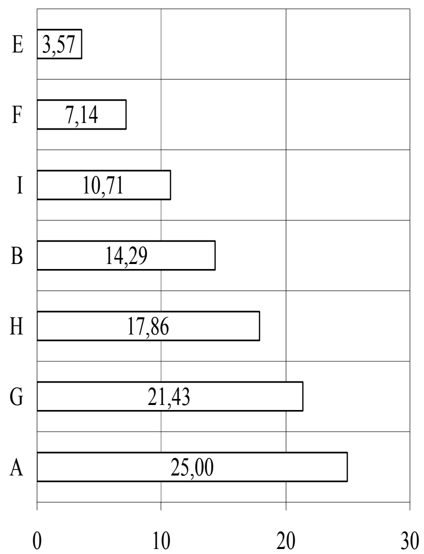


Fig.2: Diagram of the functions value weighting. Step 1.

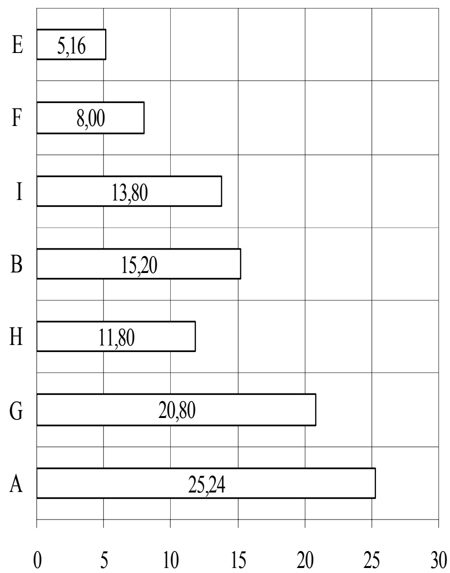


Fig.3: Diagram of the functions cost weighting. Step 1.

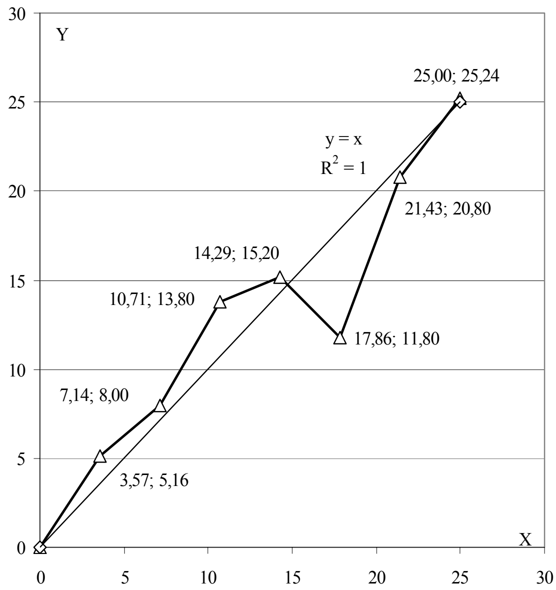


Fig.4: Value and cost weightings of the functions. Step 1.

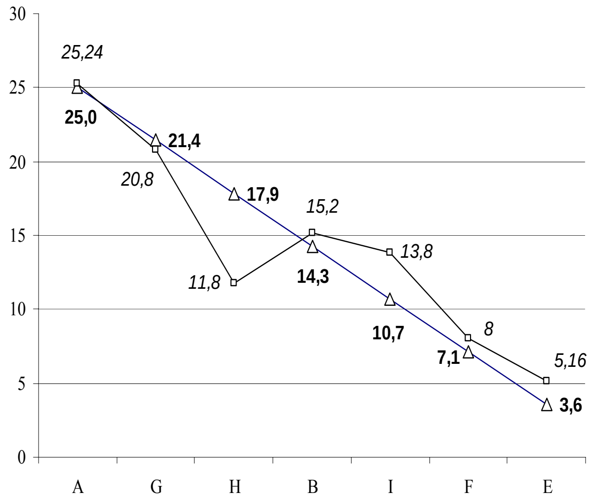


Fig.5: Comparison of values weighting (x---) and functional costs (y-- --). Step 1.

CRITERION OF VALUE ANALYSIS

A basic criterion of Value Analysis is obtaining a minimum value for S'.

In order to diminish estimator S' the points need to be aligned as perfectly as possible along the straight line $y = a * x$, with a tilt of 45^o.

Firstly, in order to diminish costs those functions will be redesigned that are located above the straight line.

For the points below the line the problems is more complicated. By diminishing the cost of the functions above the straight line, it may change its tilt and the points initially located below the line may appear above it. It is also evident, that by diminishing the cost of certain functions the total costs of the product decreases, the weighting of the functions that were not modified increasing implicitly. This is another cause for some points relocating from below the straight line to above it, without, however, any modification occurring in the absolute value of the costs of these functions.

Secondly, the minimization of S' needs to be understood in the sense of growth the value/cost ratio as much as possible, and not in the sense of imposing S'=0.

Thirdly, Value Analysis also admits the increase of the costs of some functions, provided their value increases at a faster rate than the costs.

Practically, the criterion of minimization of S' leads most often to cascading Value Analysis studies, the optimisation of the constructive solution being thus an iterative process.

At first the functions above the regression straight line are analyzed and their costs reduced, then the regression line is re-plotted and the functions relocated above it are noted; these functions too are analyzed in view of reducing their costs, followed by the re-plotting of the regression line, … etc., etc. Hence the constructive solution is improved from one iteration to the other.

CONCLUSION CONCERNING THE EXISTING SOLUTION

One of the causes of the disproportions is the distribution of costs on functions for that no certain values are available in all cases, they being the result of approximate averages.

Other causes may appear from answers to the following question:

- Which are the most conclusive criteria and means of critical evaluation for identifying the deficient functions?

The main criterion is the economic one.

This comparison typically yields the conclusion that some functions cost too much in relation to their contribution to the product value and are over dimensioned from the economic viewpoint, the study of solutions having to focus on reducing the achievement costs of these functions.

Interesting and revealing, this modality of critical evaluation entails however the disadvantage of using a scores system for establishing the levels of contribution of the functions to the product value, which is, in essence a subjective operation, that cannot prevent certain assessment errors.

In literature also other modalities for the critical evaluation of functions from the economic dimensions viewpoint are recommended, with more or less limited applicability.

Of these the following should be mentioned:

- Comparison of the achievement costs of the product functions to the same functions of similar products,
- Theoretical computation based evaluation of the costs of a function.

CRITICAL EVALUATION OF THE FUNCTIONS

The critical evaluation of the functions aims at identifying the deficient functions, which, by their contribution the product functionality and by their constructive and technological achievement have a negative influence on the value/cost ratio.

By identifying the deficient functions the directions of re-conception of the existing product are determined, with a focus on solutions for the constructive and technological achievement of these functions. The critical evaluation of the functions is carried out by the following methods:

- the utility criterion,
- the technical dimension criterion,
- the economic dimension criterion.

EVALUATION BY THE UTILITY CRITERION

The starting point in relation to this criterion is the close examination of the list of functions, in order to identify potentially useless or partially useless functions.

Useless service functions can be identified by relating to user requirements, while useless technical functions result from relating to functionality requirements.

A service function is useless if it is not required by any of the product users (if it does not satisfy any real necessity), and is partially useless if it is required only by a small part of the users.

A technical function is useless if it can be established that it does not condition any service function, and hence does not contribute, from the technical viewpoint, to the product functionality, in its studied constructive concept.

If existing and identified, from the utility aspect deficient functions entail useless achievement costs, which can be eliminated by product re-conception.

EVALUATION BY THE TECHNICAL DIMENSION CRITERION

The quality of a product is given by the level of its achieved performances. The higher this level, the greater quality and value will be.

In certain cases, however, exceeding certain performance limits leads to costly over quality that does not improve product value.

It is thus possible that certain technical dimensions of product functions exceed the real necessities, meaning that there exists the possibility of technically over dimensioned functions.

In addition to over dimensioning, the critical evaluation of the functions by this criterion allows highlighting also of possible over dimensioning of certain functions.

Identifying solutions for the re-dimensioning of these over dimensioned functions will contribute to improving product value.

Hence functional analysis is followed by the constructive and technological analysis of the product.

EVALUATION BY THE ECONOMIC DIMENSION CRITERION

The economic dimension or the cost of the function represents the main criterion for the critical evaluation of functions.

These evaluating aim at identifying those functions, the too costly technical solutions of achievement of which affect the total manufacturing cost of the analyzed product.

A correctly completed critical evaluation will directly lead to the identification of what can be called the deficient functions of the analyzed product, that is of those functions that include useless costs.

The deficient functions from the economic viewpoint appear as:

- very expensive functions in relation to the others,
- too expensive functions in relation to the existing technical possibilities of achievement.

Evaluation by the criterion of economic dimension can be achieved in several ways, presented below:

1) - comparison of costs per function, by means of the diagram presented in figure 3. This diagram allows comparisons of:

- the costs of the functions and comparisons of the total cost and the cost of each function,
- work and material costs, highlighting the very expensive costs, with the highest weighting in the total cost of the product,
- functions the achievement of which requires disproportionate costs, of either work or material,

2) - comparison to the functions of other products. Other products refer to:

- products of the same typo-dimensional range or family, manufactured by that company,
- products similar to the analyzed one, manufactured by other companies,
- products with other destinations, but having some functions similar to those of the analyzed product.

The aim is to identify potential too expensive functions in relation to the existing achieved technical solutions, existing and tested in other products.

It is recommended to relate to the simplest existing technical solutions, that ensure the achievement of the respective functions at minimum costs.

3) - theoretical evaluation of the costs of the function. Such an evaluation is possible when a function is determined by a single part or by a small number of parts. Evaluation is carried out in relation to material consumption.

STUDY OF THE SOLUTIONS

Based on the conclusions resulting from the critical evaluation of the functions, the study of the solutions will focus on identifying re-conception solutions of the product, in view of reducing its costs and improving its value.

This is possible by constructive and technological modifications of the parts, sub-assemblies and assemblies, according to the identified deficient functions.

ESTABLISHING THE FUNCTIONAL-TECHNOLOGICAL FORM OF THE PARTS IN VIEW OF COST REDUCTION

An analysis from the technical and economic viewpoint will be carried out in order to select a technically optimum variant for one of the parts: the bearing. Five constructive variants of bearings will be studied and eventually the most cost effective and the most competitive one from the technical and economic viewpoint will selected.

Prior to the actual study a number of basic ideas of creative engineering will be presented in short.

Figure 6 presents the workshop drawing of a support made from welded semi-products.

The figures 6, 7b and 8b presents the welded variant.

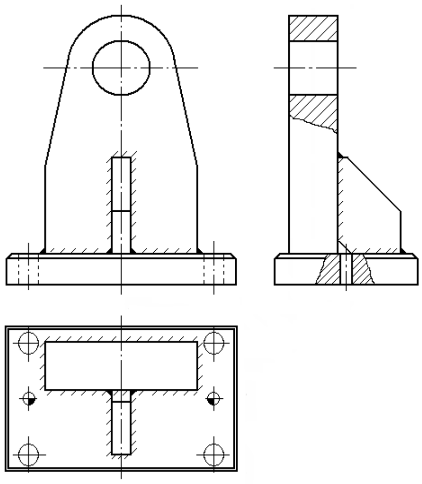
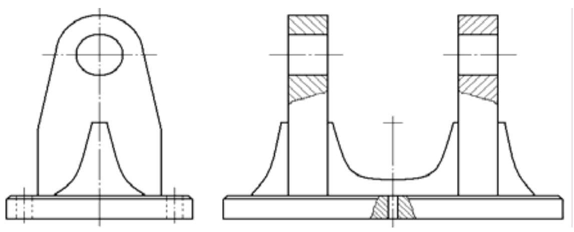
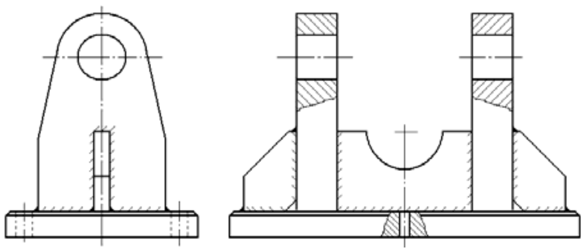


Fig.6: Workshop drawing of a support achieved from welded semi-products.



a – cast semi-product



b – welded semi-product

Figure 7 – Support made from two semi-products.

In the example of figure 8 it can be observed a support made from welded semi-products.

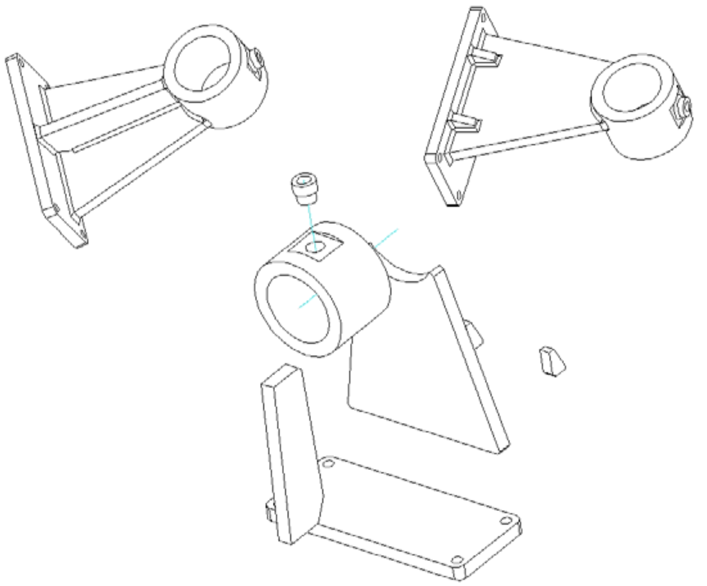


Figure 8 – Support made from welded semi-products

THE ANALYSIS OF THE CONSTRUCTIVE VARIANTS

The analysis of the constructive variants for the support (bearing) of figures 6, 7, 8, 9 and 10 is presented on.

Figure 8 shows one constructive – technological variants of the support (bearing): welded semi-product made of five modules, figure 9 – cast semi-product and figure 10 a complex bearing.

The constructive variant of figure 9 obtained from a cast semi-product ensures the best functional characteristics, if the technical conditions for heat treatment are provided. It has, however, the disadvantage that it allows only one solution for reconditioning: build-up welding and re-machining to the initial functional dimensions. The difficulty in this case is applying a heat treatment subsequent to reconditioning.

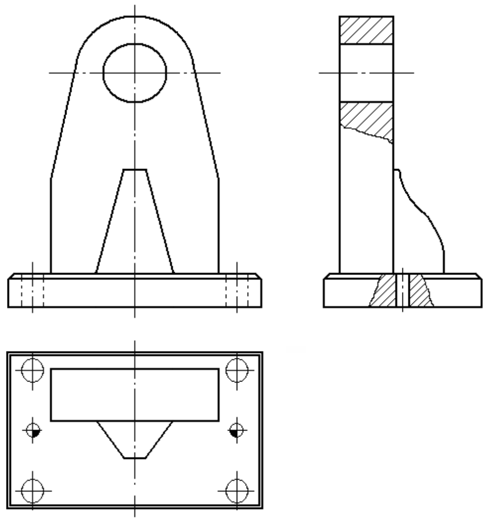


Figure 9 – Cast support (bearing).

Table 5 presents the denoting by 9 assessment criteria of the analyzed constructive variants of a support (bearing).

Tab.5: Synthetic table with the analyzed constructive variants.

No.	Analysis criteria	Figure				
		6	7b	8b	9	10
		welded 3 modules	double welded + cast	welded 5 modules	cast	complex
	variant	initial			final	
1	Functional characteristics	6	6	6	6	6
2	Semi-product	5	4	2	6	2
3	Mechanical machining	4	3	3	6	4
4	Mounting	4	4	4	4	6
5	Repair	5	5	5	5	5
6	Rigidity	4	4	4	6	4
7	Ergonomics	6	6	6	6	6
8	Aesthetics	6	6	6	6	6
9	Cost	5	4	4	6	2
	TOTAL	45	42	40	*51*	41

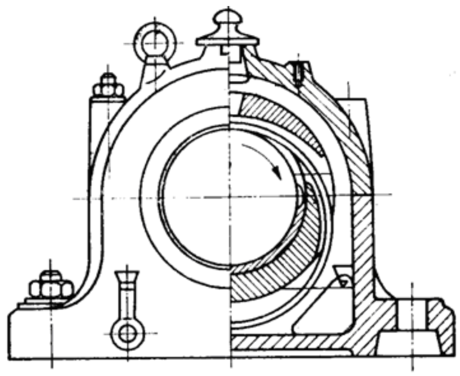


Figure 10 – Complex bearing.

The cast variant of figure 9 has obtained the highest score, and will thus be selected as the constructive solution within the assembly of the mixer.

The cost of the final variant of figure 9 presented in table 6 (step 2 of the Value Analysis – study) is of 215 monetary units and has a weighting of 3.22% of the final cost as compared to the initial situation of 295 monetary units with a weighting of 5.16% presented in table 3 (partial) (step 1 of the Value Analysis study).

Tab.6: Cost distribution on functions (partial) (*Y coordinate, ** monetary units).

No.	Parts	Functions							Cost part**
		A	G	H	B	I	F	E	
5	*Bearing*			200				15	*215*
…		1170	980	300	750	510	310	100	4120
Total cost		*1262*	*1040*	*510*	*760*	*690*	*400*	*155*	*4817*
Ratio		*0,26*	*0,22*	*0,11*	*0,15*	*0,14*	*0,08*	*0,03*	*1*
Cost of functions %		***26,2***	***21,6***	***10,6***	***15,8***	***14,3***	***8,3***	***3,22***	*100*

The final situation – step 2 of the VA study

Tab.3: (partial) – Cost distribution on functions (partial) (*Y coordinate, ** monetary units).

5	*Bearing*			*280*				*15*	*295*
…		*1170*	*980*	*300*	*750*	*510*	*310*	*203*	*4223*
Total cost			*1262*	*1040*	*590*	*760*	*690*	*400*	*258*
Ratio		*0,25*	*0,21*	*0,12*	*0,15*	*0,14*	*0,08*	*0,05*	*1*
Cost of functions %		***25,2***	***20,8***	***11,8***	***15,2***	***13,8***	***8***	***5,16***	*100*

Initial situation – step 1 of the VA study

By introducing the new data into table 7 the diagrams of figures 11, 12 and 13 are plotted.

These diagrams will be compared to those of figures 2, 3 and 4.

Tab.7: Computational elements for plotting the diagrams.* $S' = 2*a*(X_i)^2 - 2*X_i*Y_i$

No.	Elements of calculus	Functions							Total value
		A	G	H	B	I	F	E	
1	X_i	***25***	***21,4***	***17,9***	***14,3***	***10,7***	***7,14***	***3,57***	100
2	Y_i	***26,2***	***21,6***	***10,6***	***15,8***	***14,3***	***8,3***	***3,22***	100
3	$(X_i)^2$	625	459	319	204	115	51	12,8	1786
4	$X_i * Y_i$	655	463	189	225	153	59,3	11,5	1756
5	$(Y_i - a*X_i)^2$	2,59	0,26	48,7	2,98	14,3	1,63	0,09	70,56
6	S' *	-80,5	-22	249	-49,3	-81,1	-18,3	2,11	0

Step 2

The parameters have the following computed values: a = 0.973, $\alpha = 44.23^{o}$, S = 43.7, S' = 0.

It can be noticed that S and S' have smaller values than in the initial variant.

Table 7 provides the necessary values for the plotting of the following types of diagrams:

- the diagram of the value weighting of the functions (figure 11 – identical with figure 2); this diagram has not changes, as the value of the system and of the functions has remained the same,
- the diagram of the cost weighting of the functions (figure 12); the diagram of figure 12 presents the functions cost weighting,
- the diagram of the value and cost weightings of the functions (figure 13); figure 13 presents comparatively the old variant, step 1 and the new one, step 2.

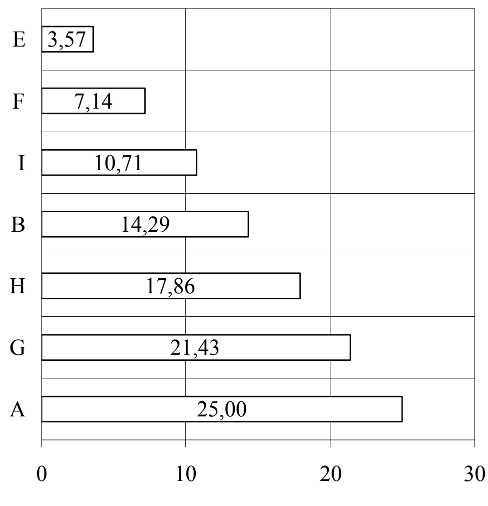


Figure 11 – Diagram of the functions value weighting. Step 2.

Only the costs are represented in order to not overload the diagram and to observe the decrease of the value of cost of function E, from 5.16 % to 3.22 %.

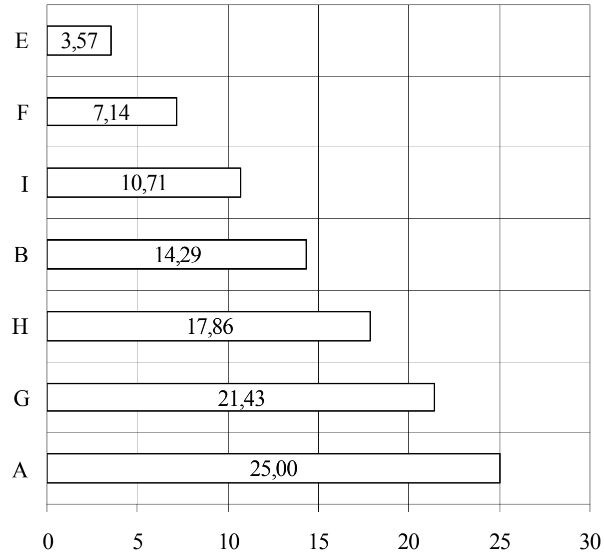


Figure 12 – Diagram of the functions cost weighting. Step 2.

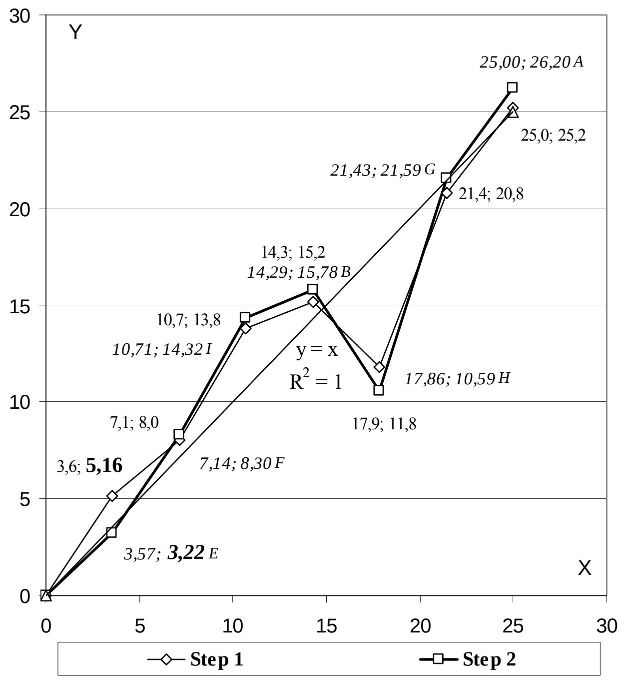


Figure 13 – Value and cost weightings of the functions in step 1 and step 2.

At the moment, in the second step the calculation shall be made as fallows:,

- others functions can bee situated above the regression straight line,

- these are analyzed and their costs reduced, then the regression line is re-plotted and the functions relocated above it are noted; these functions too are analyzed in view of reducing their costs, followed by the re-plotting of the regression line, … etc., etc.

Hence the constructive solution is improved from one iteration to the other.

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