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REDESIGNING A JAW CRUSHER USING VALUE ANALYSIS
Part I

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ABSTRACT

Value Analysis (VA) is a method that provides an operating technique using a creative and organized approach. It is managed by a group, each of them selected according their expertise in specific subjects and coordinated by a Value Analysis expert.

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 it can be concluded at the end of this paper.

KEYWORDS: value analysis, value, optimum variant

1. Value Analysis applied to the design of a Jaw Crusher

Firstly, an example of Value Analysis is presented, applied to the redesign of a jaw crusher used for primary crushing of a wide variety of materials in the mining, iron steel and pit quarry industries.

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.

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

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

The VA group activity is managed in seven stages:

- formation and functional analysis,
- creativeness,
- evaluation and selection of the proposals,
- the creative phase,
- development of the selected proposals,
- presentation of the selected proposals, set in order of priority,
- implementation phase.

2. Establishing the list of functions and dimensions

“When functions have been identified, clarified, understood and specified, the greatest help would come from the answer to the questions:

- Which, under our conditions of quantities, manufacture, etc. is the lowest cost that would provide that function?
- What approach and method would secure it for that cost?
- The great danger comes in the form or a proper and practical – sounding question:
- How have we accomplished it in the past and how much did that cost?”

The three questions are at the beginning of the Third Chapter “Evaluate the Function” of the “Techniques of Value Analysis and engineering” by Lawrence D. Miles.

The process of evaluating functions typically is as follows:

- Individualize separate functions.
- Understand them completely.
- Creatively establish other unobvious means for accomplishing each function. Concentrate intense energies on means that are likely to be much lower in cost. Think searchingly, penetratingly, and courageously.

- Assign approximate cost.
- Add the values of the various required functions to arrive at a value for the larger overall functions. Where functions are not interacting, add arithmetically.

Table 1 presents the list of functions of the jaw crusher.

Table 1. *List of functions*

Symbol	Functions	Type of function	Technical dimension of function		
			Name	UM	Value
F_1	Ensuring milling	FS	blast degree	-	3 - 12
F_2	Ensuring protection of machinery	FC	moment, force	daN*m daN	200 100
F_3	Ensuring adjustment	FC	length	mm	10 - 25
F_4	Supports the assembly	FS	weight	daN	20000
F_5	Aesthetics	FE	colour, form,	-	7
F_6	Supplies working energy	FS	moment	daN*m	100
F_7	Ensuring uniformity of the movement	FS	revolution pulsation	rot/min rad/sec	
F_8	Capability of work	FC	volume	m^3	2
F_9	Wear resistance	FC	eroded material	g/year	
F_{10}	Part evacuation	FS	debit	m^3/h	1 - 2

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

3. Establishing the levels of importance of the functions

Table 2 presents the value weighting of the functions.

The following percentage values of the functions value weighting result:

X_{F1} = 25 %, X_{F2} = 10.7 %, X_{F3} = 7.1 %, X_{F4} = 17.8 %, X_{F5} = 3.5 %, X_{F6} = 21.4 %, X_{F7} = 14.2 %.

The product value is equal to the sum of the functions levels and is equal to 28.

Photo 1 and figure 1 show the studied jaw crusher.

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

Functions	F_1	F_2	F_3	F_4	F_5	F_6	F_7	Total
Number of points	7	3	2	5	1	6	4	*28*
Ratio	0.25	0.107	0.071	0.178	0.035	0.214	0.142	*1*
*Percentage %	***25***	***10.71***	***7.14***	***17.85***	***3.571***	***21.42***	***14.28***	*100*

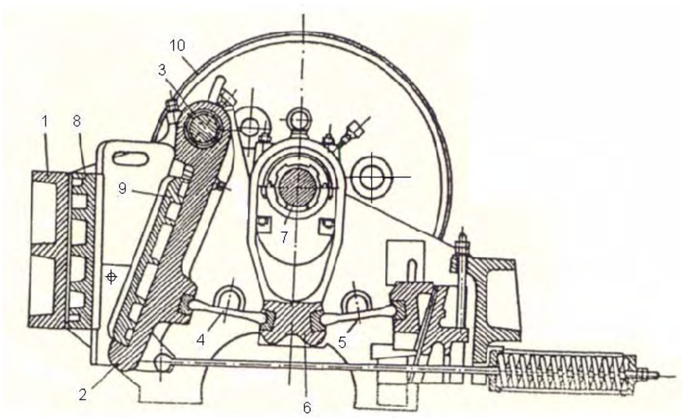

Fig. 1 *– Jaw crusher:*
1 – fixed crushing jaw; 2 – moveable crushing jaw (moving jaw);
3 – axle; 4, 5 – toggle; 6 – pitman; 7 – eccentric shaft; 8, 9 – wearing parts; 10 – flywheel.

4. Economic dimensioning of the functions

Costs were assigned to the various functions by means of the function-cost matrix shown in table 3.

The percentage values of the functions participation in the total cost are:

Y_{F1} = 22.29 %,Y_{F2} = 9,43 %, Y_{F3} = 5.26 %, Y_{F4} = 18,29%, Y_{F5} =4.00 %, Y_{F6} = 22.98%, Y_{F7} = 17.72%.

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

No.	Parts	Functions							Cost/ part**
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	
1	Fixed crushing jaw	450	45			5			500
2	Walls		95			5			100
3	Axle			50					50
4	Eccentric shaft	390	20	200	800	10	20	200	1640
5	Pitman	5		5		5	80		95
6	Belting	5	65	5		5	60		140
7	Flywheel	*300*				*20*	*250*	*750*	*1320*
...									
n		800	600	200	800	300	1600	600	4900
Total cost		1950	825	460	1600	350	2010	1550	8.745
Ratio		0.223	0.0943	0.0526	0.183	0.04	0.2298	0.1772	1
Cost of functions %		***22.29***	***9.43***	***5.26***	***18.29***	***4.00***	***22.98***	***17.72***	100

5. Comparison of the functions value and cost weightings

The value – cost 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 achievement.

6. Diagrams

Further on the construction of the diagrams is presented.

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 parameters have the following computed values: a = 0.9981, α = 44.96°, S = 27.7, S' = 0.

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

1) In figure 2 the diagram of the functions value weighting,
2) In figure 3 the diagram of the functions cost weighting,
3) In figure 4 the diagram of the functions value and cost weighting,
4) In figure 5 the diagram of the comparison of the functional values and costs weighting.

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

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

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

No.	Computational elements	Functions							Total value
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	
1	X_i	***25***	***10.71***	***7.142***	***17.85***	***3.57***	***21.42***	***14.28***	100
2	Y_i	***22.29***	***9.43***	***5.26***	***18.29***	***4.00***	***22.98***	***17.72***	99.97
3	$(X_i)^2$	625	114.8	51.02	318.88	12.755	459.18	204.0	1785.7
4	$X_i * Y_i$	555	101.04	37.571	326.61	14.293	492.43	253.1	1780.1
5	$(Y_i - a*X_i)^2$	7.4044	1.5637	3.4608	0.2393	0.1952	2.6213	12.10	27.591
6	S' *	136.05	26.796	26.576	-17.47	-3.156	-69.39	-99.41	0

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

- 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 functions whose achievement requires disproportionate material or work costs.

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 F6, F1, F4 and F7.

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 F6, F1, F4 and F7) 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 F7 and F6 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 F6 and F7 have disproportionate costs (22.99 %, 17.72 %) in relation to their respective contributions to value (21.4 %, 14.28 %).

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.

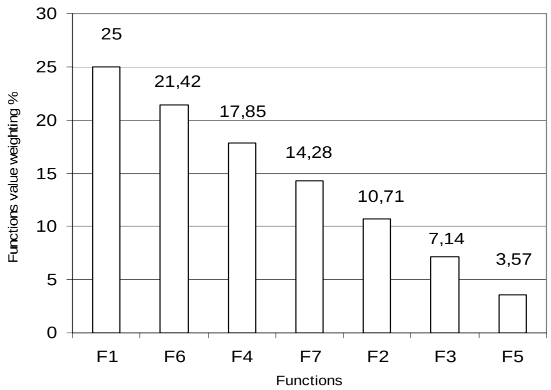

***Fig.2**. Diagram of the value weighting functions.*

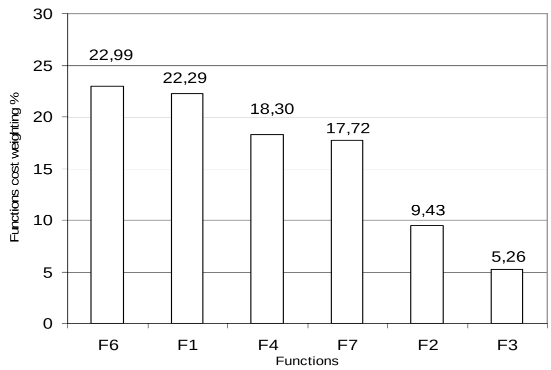

***Fig.3**. Diagram of the cost weighting functions.*

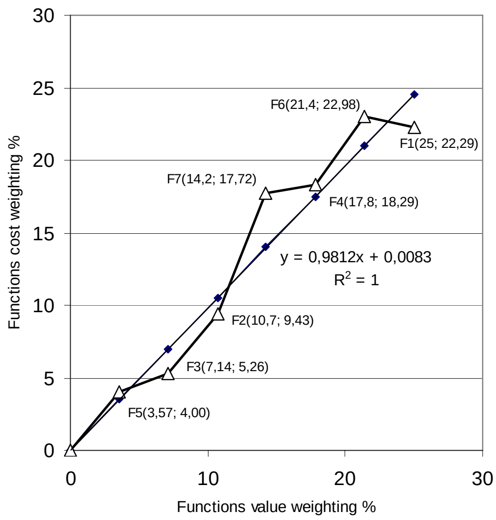

***Fig. 4**. Value and cost weightings of the functions.*

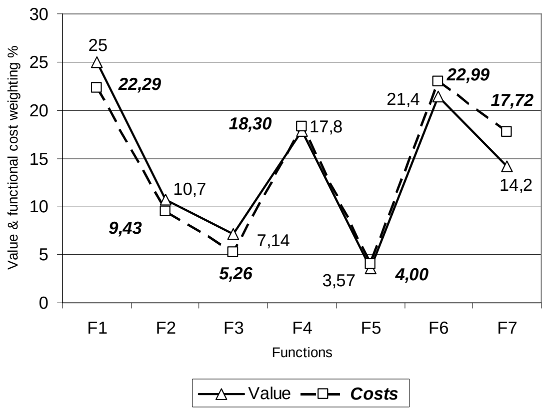

***Fig.5**. Comparison of value weighting (x---) and functional costs (y- - -).*

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 and 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 increases 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 of 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 with the in view of reducing their costs, followed by the re-plotting of the regression line, etc.

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

7. 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, as they are 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 have to focus on reducing the achievement costs of these functions.

Although interesting and revealing, this modality of critical evaluation entails however the disadvantage of using a scoring 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.

Out of these ones, the following should be mentioned:

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

8. Critical evaluation of the functions

The critical evaluation of the functions aims at identifying the deficient functions, which by their contribution to 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.

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