IMPLEMENTING VALUE ANALYSIS IN DESIGNING OF SINGLE ROLL CRUSHER

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Abstract: Implementation of Value Analysis in designing of industrial equipment is a demonstrated need for a long time in highly developed industries. Beneficial results of applying this creative, functional and very practical multidisciplinary approach can see at all the products that surround us in everyday life.

The paper presents a complete study of Value Analysis applied concretely to a selected part of one single roll crusher. The phases and iterative operation of the Value Analysis method are presented.

Keywords: value analysis, optimum variant, single roll crusher

1. Value analysis applied to the design of a single roll crusher

Value Analysis is a method that provides an operating technique using a creative 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 paper presents a complete study of Value Analysis applied specifically to one equipment, a single roll crusher shown in figure 1, with one finality: re-design one selected part and establishing the optimum constructive solution from the technical and economic viewpoint for this part participating in two functions with a high cost: function F3 *ensure adjustment* and function F9 *ensure kinematic chain protects*.

Table 1 presents the list of functions of the single roll crusher [2, 3].

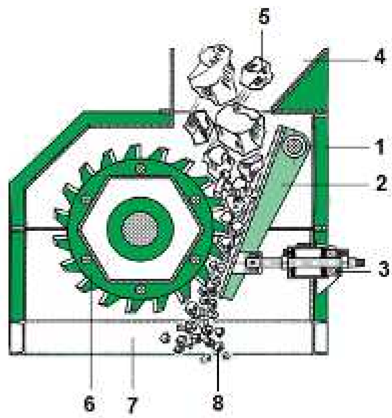

Figure 1. The single roll crusher
1 – framework; 2 – mobile jaw; 3 – damper cylinder; 4 –funnel power; 5 – shredded material; 6 – cylinder crushing spurs; 7 –outlet; 8 – crushed material [1]

Table 2 presents the value weighting of functions.

Table 1. List of functions *FS: Service function; **FC: Constraint function; ***FE: Estimation function

Symbol	Function	Type of function	Technical dimension of function		
			Name	UM	Value
F1	Ensure crushing	FS*	force	daN	1000
F2	Includes components	FS	volume	m^3	0.4
F3	*Ensure adjustment*	FC**	height	mm	10 – 25
F4	Ensure material supply	FS	flow rate	m^3/h	0.4 – 4
F5	Supports the assembly	FS	force	daN	10000
F6	Ensure material removal	FS	flow rate	m^3/h	0.4 – 4
F7	Supplies working energy	FS	torque	daN·m	1000
F8	Transforms electric energy into mechanical work	FS	mechanical work	J	-
F9	*Ensure kinematic chain protects*	FC	force	daN	1000
F10	Ensure user safety	FC			
F11	Provide user interface	FE***	-	-	-

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

The percentages of value weighting of functions are presented in the last row of the table 2 and the product value is equal to the sum of the functions levels and is equal to 66.

Table 2. Value weighting of the functions (* - X coordinate). Step 1

Functions	F1	F2	***F3***	F4	F5	F6	F7	F8	***F9***	F10	F11	Total
No. of points	11	10	9	8	7	6	5	4	3	2	1	66
Ratio	0.16	0.15	0.13	0.12	0.10	0.09	0.07	0.061	0.045	0.03	0.015	1
*Percentage %	16.7	15.2	***13.6***	12.1	10.6	9.09	7.58	6.06	***4.55***	3.03	1.52	100

2. Economic dimensioning of the functions – step I

The cost of physical components of the single roll crusher is supplied to the function or functions which take part, shown in table 3, the functions – costs matrix. The costs are approximated in the first step for the constructive variant presented in figure 1.

The percentages of the cost weighting of functions are presented in the last row of the table 3.

3. Diagrams

The percentage values of the value and cost weighting of functions from the last row of tables 2 and 3 are introduced in table 4, where calculations are made using the method of least squares (MLS). The parameters have the following computed values: a = 0.97, $\alpha = 44^o$, S = 24.8 and S' = 0. Based on the values for coordinates x_i and y_i presented in table 4 the diagrams of figures 2, 3 and 4 are drawing.

Table 3. The functions – costs matrix. (*Y coordinate, ** monetary units). Step 1

		Functions											Cost
No.	Parts	F1	F2	***F3***	F4	F5	F6	F7	F8	***F9***	F10	F11	part**
1	Framework	*10*	*235*	*5*	*50*	*20*	*50*				*75*	*25*	470
2	Mobile jaw	*500*		*250*			*10*			*30*	*20*	*30*	840
3	Damper cylinder	*20*		*200*			*10*			*10*	*20*	*20*	280
...	...	*300*	*560*	*405*	*500*	*450*	*345*	*455*	*390*	*340*	*105*	*25*	3875
Totalcost		830	795	860	550	470	415	455	390	380	220	100	5465
Ratio		0,15	0.145	0.157	0.101	0.086	0.076	0.083	0.071	0.069	0.04	0.018	1
Cost of functions %		*15,2*	*14.5*	***15.7***	*10.1*	*8.6*	*7.59*	*8.33*	*7.14*	***6.95***	*4.03*	*1.83*	*100*

Table 4. Computational elements for plotting the diagrams. Step 1. $*S = \Sigma(Y_i - a\times X_i)^2$; $**S'=\Sigma(2\times a\times (X_i)^2 - 2\times X_i\times Y_i)$

		Functions											Total
No.	MLS	F1	F2	***F3***	F4	F5	F6	F7	F8	***F9***	F10	F11	value
1	X_i	***16.7***	***15.2***	***13.6***	***12.1***	***10.6***	***9.09***	***7.58***	***6.06***	***4.55***	***3.03***	***1.52***	100
2	Y_i	***15.2***	***14.5***	***15.7***	***10.1***	***8.6***	***7.59***	***8.33***	***7.14***	***6.95***	***4.03***	***1.83***	100
3	$(X_i)^2$	277.8	229.6	186	146.9	112.5	82.64	57.39	36.73	20.66	9.182	2.296	1162
4	$X_i\times Y_i$	253.1	220.4	214.6	122	91.21	69.03	63.07	43.25	31.60	12.19	2.772	1123
5	S*	0.863	0.011	6.504	2.746	2.741	1.433	1.000	1.627	6.543	1.19	0.133	24.8
6	S'**	30.96	3.156	-69.5	40.17	35.12	21.76	-15.1	-15.4	-23.2	-6.63	-1.10	0

The diagram of the value weighting of functions (figure 2), showing the ranking of the functions by their value, the diagram of the cost weighting of functions (figure 3), showing the ranking of the functions by their functional cost and the diagram of the value and cost weighting of functions (figure 4), showing the comparison between the percentages of value and cost weighting of functions. This diagram is the most important part, is actually one modelling of the Value Analysis approach applied to optimize the single roll crusher of economically and technically viewpoint.

The diagram of figure 3 reveals a Pareto type distribution, meaning that 20 - 30% of the total number of functions includes 70 - 80% of the total costs of the functions. These functions are F1, F2, F3 and F4 [4].

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 functions to the value of the single roll crusher.

An analysis of the diagram of figure 4 showing that the functions F9, F7 and F3 are located above the regression line, indicating high costs, not justifiable in relation to the value.

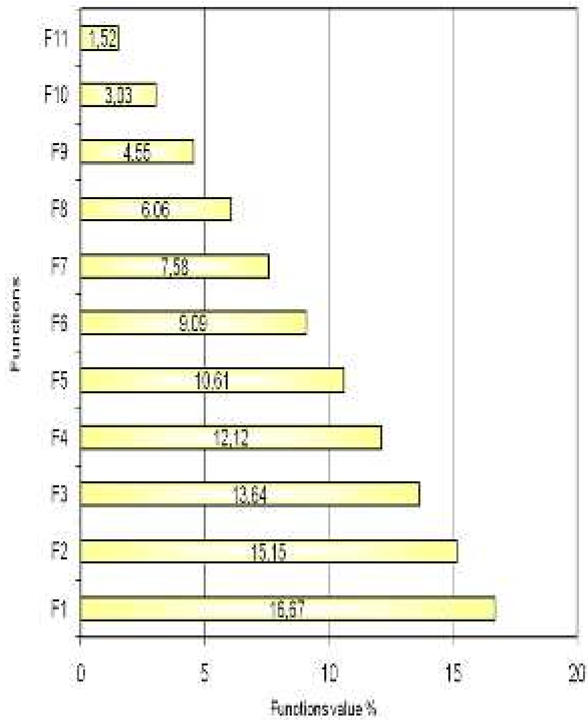

Figure 2. Diagram of the value weighting of functions. Step 1

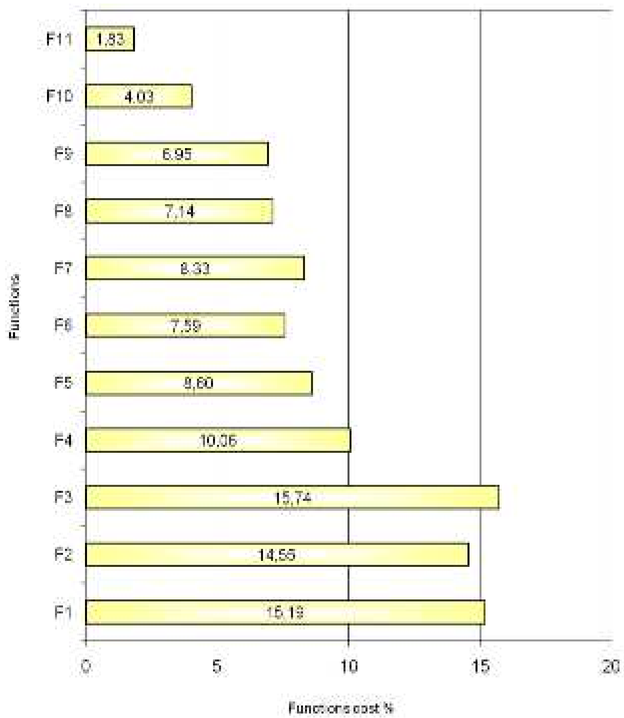

Figure 3. Diagram of the cost weighting of functions. Step 1

To reduce the cost of the functions F9, F7 and F3 will be used in phase 3 of the Value Analysis study (phase of creativity, the search the ideas and the solutions) the morphological analysis presented in table 5.

This study will be made only for two functions: F3 *ensure adjustment* and F9 *ensure kinematic chain protects*. The number of variants that can design with the technical solutions of this morphology, for these two functions is $F3_i \times F9_i = 180$.

For these two functions, structural variants are still in large numbers, to find new technical solutions, can use several methods of sorting one new technical variant like: screening matrix, morphological analysis through sequence, morphological analysis by listing ordered, morphological analysis by sampling, examined criteria, multi-criteria analysis.

An analysis from the technical and economic viewpoint will be carried out in order to select a technically optimum variant for one of the mechanism: the mechanism to adjust the jaw opening and for kinematic chain protection.

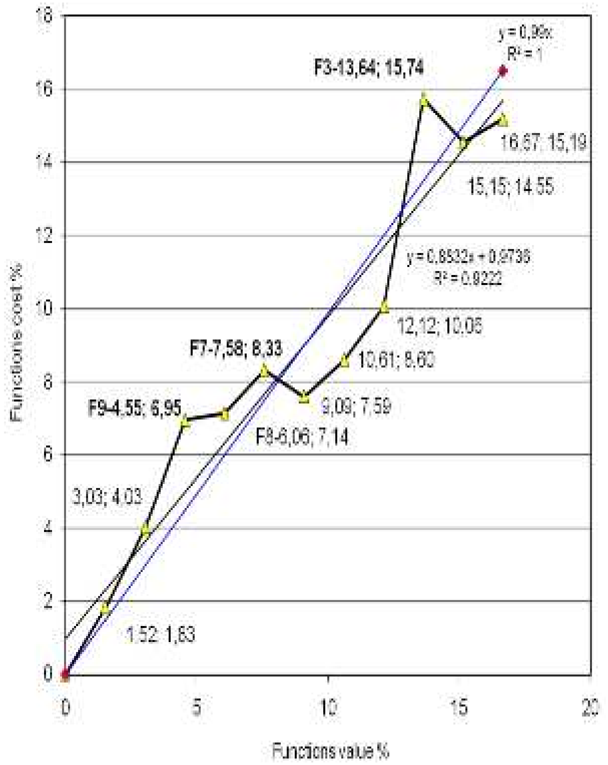

Figure 4. Value and cost weightings of functions. Step 1

4. The analysis of the constructive variants

The analysis of the constructive variants for the mechanism to adjust the jaw opening and for kinematic chain protection is presented on.

Table 6 presents the denoting by 9 assessment criteria of the analyzed constructive variants of the mechanism to adjust the jaw opening and for kinematic chain protection.

Table 5. Morphological analysis

Functions	Possible variants
F3 – Ensure adjustment	$F3_1$ – manual adjusting leverage, $F3_2$ – manual adjusting with screw mechanism, $F3_3$ – manual adjusting with screw mechanism and metal spring, $F3_4$ – spatial cam mechanism with manual adjustment, $F3_5$ – spatial cam mechanism with pneumatic adjustment, $F3_6$ – spatial cam mechanism with hydraulic adjustment, $F3_7$ – manual adjusting with vertical wedge and screw mechanism, $F3_8$ – manual adjustment with horizontal wedge and right-left screw, $F3_9$ – adjustment with pneumatic/ hydraulic cylinder, $F3_{11}$ – adjustment with hydraulic plunger, $F3_{12}$ – pneumatic adjusting leverage, $F3_{13}$ – hydraulic adjusting leverage, $F3_{14}$ – manual adjusting with gear and rack, $F3_{15}$ – pneumatic/ hydraulic adjusting with gear and rack, $F3_{17}$ – combined adjustment, $F3_{18}$ – adjustment with hydraulic jaw toggle, USA Patent no.4,927,089 $F3_{19}$ – adjustment with rigid lever
F9 – Ensure kinematic chain protects	$F9_1$ – protection with levers and flexible elements, rubber, $F9_2$ – protection with levers and flexible elements, metal spring, $F9_3$ – protection with pneumatic cylinder, $F9_4$ – protection with hydraulic cylinder, $F9_5$ – combined protection, $F9_6$ – protection with hydraulic jaw toggle, USA Patent no.4,927,089, $F9_7$ – protection with screw and metal spring, $F9_8$ – without protection, $F9_9$ – protective elastic membrane chamber

Table 6. Synthetic table with the analyzed constructive variants

No.	Analysis criteria	Type of mechanism		
		*$F3_{10}$ + $F9_4$	**$F3_3$ + $F9_7$	***$F3_1$ + $F9_9$
1	Functional characteristics	3	3	3
2	Mounting	3	3	2
3	Repair	1	3	2
4	Rigidity	2	2	3
5	Ergonomics	3	2	3
6	Aesthetics	2	2	3
7	Possibilities for adjusting	3	2	3
8	Degree of protection	2	2	3
9	Cost	1	3	3
	TOTAL	20	22	25

*$F3_{10}$ + $F9_4$ → $F3_{10}$ – adjustment with hydraulic cylinder + $F9_4$ – protection with hydraulic cylinder,
**$F3_3$ + $F9_7$ → $F3_3$ – manual adjusting with screw mechanism and metal spring + $F9_7$ – protection with screw and metal spring,
***$F3_1$ + $F9_9$ → $F3_1$– manual adjusting leverage + $F9_9$ – protective elastic membrane chamber.

5. Economic dimensioning of the functions – step II

The score obtained by the $F3_1$ + $F9_9$ variant is less than the $F3_{10}$ + $F9_4$ and $F3_3$ + $F9_7$ variants and choose the variant $F3_1$ + $F9_9$.

The cost of physical components of the single roll crusher is supplied to the function or functions which take part, shown in table 7, the functions – costs matrix for step 2.

By introducing the new data into table 8 the diagrams of figures 5 and 6 are plotted.

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

The parameters have the following computed values: a = 0.97, $\alpha = 44.2^o$, S = 11.5, S' = 0.

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

Table 8 provides the necessary values for plotting the following types of diagrams:

- the diagram of the value weighting of the functions is 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 5); the diagram of figure 5 presents the functions cost weighting;
- the diagram of the value and cost weightings of the functions (figure 6); figure 6 presents the value and cost weightings of the functions in step 2.

Table 7. The functions – costs matrix. (*Y coordinate, ** monetary units). Step 2

No.	Parts	Functions											Cost part**
		F1	F2	*F3*	F4	F5	F6	F7	F8	*F9*	F10	F11	
1	Framework	*10*	*235*	*5*	*50*	*20*	*50*				*75*	*25*	470
2	Mobile jaw	*500*		*210*			*10*			*20*	*20*	*30*	790
3	Damper cylinder	*20*		*180*			*10*			*5*	*20*	*20*	255
...													
		300	*560*	*325*	*500*	*450*	*345*	*455*	*390*	*250*	*105*	*25*	3705
Total cost		830	795	720	550	470	415	455	390	275	220	100	5220
Ratio		0,15	0.152	0.138	0.105	0.09	0.08	0.087	0.075	0.053	0.042	0.019	1
Cost of functions %		15,9	15.2	13.8	10.5	*9*	*7.95*	*8.72*	*7.47*	*5.27*	*4.21*	*1.92*	100

Table 8. Computational elements for plotting the diagrams. Step 2. $*S = \Sigma(Y_i - a\times X_i)^2$; $**S'=\Sigma(2\times a\times (X_i)^2 - 2\times X_i\times Y_i)$

No.	MLS	Functions											Total value
		F1	F2	*F3*	F4	F5	F6	F7	F8	*F9*	F10	F11	
1	X_i	***16.7***	***15.2***	***13.6***	***12.1***	***10.6***	***9.09***	***7.58***	***6.06***	***4.55***	***3.03***	***1.52***	100
2	Y_i	***15.9***	***15.2***	***13.8***	***10.5***	***9***	***7.95***	***8.72***	***7.47***	***5.27***	***4.21***	***1.92***	100
3	$(X_i)^2$	277.8	229.6	186	146.9	112.5	82.64	57.39	36.73	20.66	9.182	2.296	1162
4	X_i*Y_i	265	230.8	188.1	127.7	95.5	72.27	66.03	45.28	23.94	12.77	2.903	1130
5	S*	0.1	0.237	0.275	1.582	1.732	0.802	1.809	2.478	0.714	1.602	0.195	11.5
6	S'**	10.55	-14.7	-14.3	30.49	27.92	16.28	-20.3	-19.0	-7.68	-7.67	-1.33	0

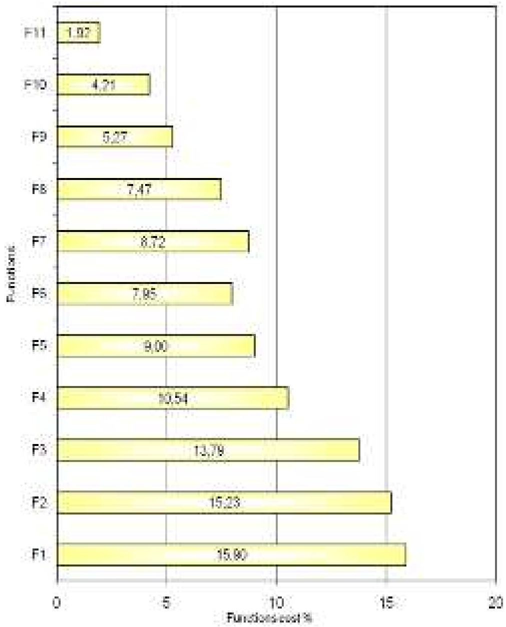

Figure 5. Diagram of the cost weighting of functions in step 2

In this diagram is observed the cost of functions in step II of Value Analysis study.

a. F3 from 15.74 %, in first step of Value Analysis study (figure 3) to 13.79 % in second step of Value Analysis study (figure 5),

b. F9 from 6.97 %, in first step of Value Analysis study (figure 3) to 5.27 % in second step of Value Analysis study (figure 5) [5, 6].

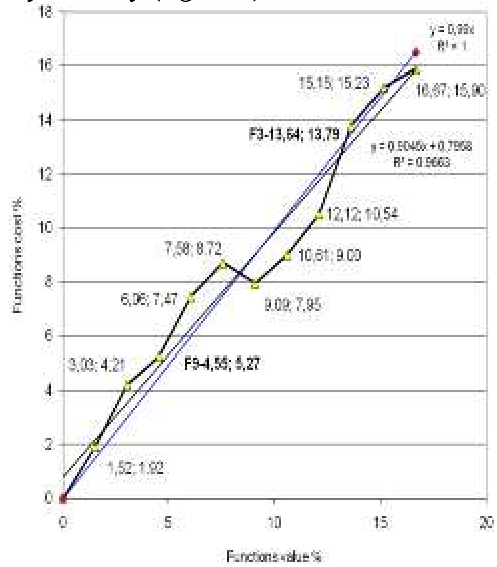

Figure 6. Value and cost weightings of functions in step 2.

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.

6. Conclusions

In two steps of Value Analysis study one mechanism of single roll crusher who contributes at the function F3 (*supports the assembly*) and at the function F9 (*Ensure kinematic chain protects*), was redesign and optimized:

1. from engineering viewpoint: from variant *$F3_{10}$ + $F9_4$ → $F3_{10}$ – adjustment with hydraulic cylinder + $F9_4$ – protection with hydraulic cylinder, to the variant **$F3_3$ + $F9_7$ → $F3_3$ – manual adjusting with screw mechanism and metal spring + $F9_7$ – protection with screw and metal spring,

and finally to the variant ***$F3_1$ + $F9_9$ → $F3_1$– manual adjusting leverage + $F9_9$ – protective elastic membrane chamber.

2. from the economic viewpoint (figure 7):

a. the cost of function F3 decrease from 15.74 %, in the first step of Value Analysis study to 13.79 % in the second step of Value Analysis study (decrease with 14.1%).

b. the cost of function F9 decrease from 6.95 %, in the first step of Value Analysis study to 5.27% in the second step of Value Analysis study (decrease with 32%).

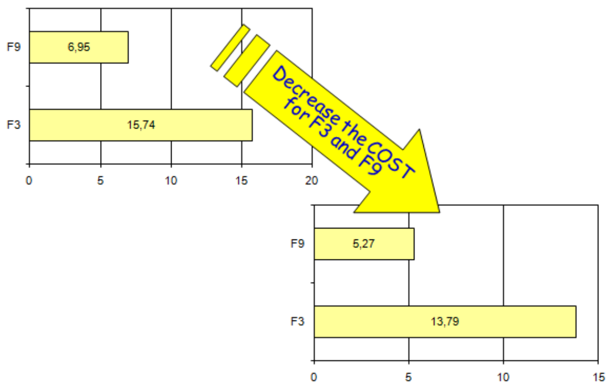

Figure 7. Value Analysis from economic viewpoint

3. in the third step of Value Analysis study are analyzed other functions above the regression straight line 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.

4. in the third step of Value Analysis study are analyzed other functions above the regression straight line 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.

At the end of the Value Analysis study the points are aligned as perfectly as possible along the straight line $y = a \times x$, with a tilt of 45°, this is the optimal situation, the values weighting of functions and the functions cost weighting are equal, the final interest in Value Analysis study.

References

1. *** (2011) Aubema Company documentation
2. Bejan, V. (1991) *Technology, manufacture and repair of technological equipment, vol.I and II*, OID ICM, Bucharest, Romania
3. Michel, J. (2001) *Management par la Valeur, création de Valeur, chaîne de Valeur, ... Parle-t-on de la même Valeur? - Proposition d'un cadre conceptuel pour la valeur généralisée et contribution au développement de la Valorique*. La Valeur, no. 90, p 2-7, Available from http://michel.jean.free.fr/public/ JM338.html
4. Brun, G., Constantineau, F. (2001) *La management par la valeur: Un nouveau style de management*. AFNOR Pratique, Paris, ISBN 2-12-465051-3
5. Miles, L.D. (1989) *Techniques of Value Analysis and Engineering*. Available from: http://wendt.library.wisc.edu/ miles /milesbook.html, Accessed: 07/01/2011
6. Kenneth, C. (2002) *Value Analysis and function analysis system technique*. Available from: http://www.npd-solutions.com/va.html, Accessed: 07/01/2011