ECONOMIC EFFICIENCY OF QUALITY

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***ABSTRACT*:** For every organization a well developed and certified by international standards quality system represents a real chance on the market.
The economic efficiency is the main indicator which qualifies a company as being profitable or going off-business. Therefore the expenses are aimed towards the increasing of quality and of incomes both for the suppliers and for beneficiary, since the quality influence on efficiency is different for the categories above.
The quality cost is given by the resource consumption done for achieving the product technical and quality level.
The product quality is achieved in the production process but is reflected in its consumption. Therefore, the paper distinguishes the *production quality* – reflecting the manufacturing process – from the *product quality* – representing the output seen from the beneficiary point of view.

***KEY WORDS*:** quality management, product quality, quality cost, competitiveness

1. QUALITY MANAGEMENT

An indicator of work productivity is

$$W = (\sum q_i k_i)/T, \quad (1)$$

where : W – work productivity indicator; q_i – the quantity of products with certain quality; k_i – the quality coefficient; T – labor expenses.

The influence of quality on economy is different for the supplier and for beneficiary:

- For the supplier it leads to: savings for the expenses with materials, scrap reduction, reduction of expenses for warranty replacements, etc.; currency savings, by buying materials and machine parts from the own nation, etc.;
- For the beneficiary it leads to: savings due to fewer maintenance and repairing operations, which decreases also the operation stoppage periods, leading to increased productivity, etc.; currency savings by buying products from the own nation.

2. QUALITY COSTS

Quality cost is given by the entire resource consumption done for achieving product's technical and quality level.

According to the ISO 9000 standards, the quality costs represent the costs done for achieving the proposed quality, ensuring the needed confidence in the product and the losses suffered when the proposed quality is not achieved.

The quality costs represent also an important quality capitalization instrument, for quality relevant processes and activities optimization, a potential source for increasing the company profit.

The product quality cost of a company may be established by taking into consideration the following expense categories: costs for preventing the defects and ensuring quality; costs for quality evaluation; costs regarding losses caused by low quality.

Figure 1 presents the route to total quality cost.

A point of view on classifying the quality related costs is found in the methodology of General Electric Company, regarding the cost management, integrated by Masser in a cost system called “Quality Cost Analysis”. Within this system Masser has defined 3 quality cost categories: prevention costs, evaluation costs and failure costs (noncompliance) [4].

Since the cost quality management is typical for the manufacturer, we will consider the cost quality classification for this stage in the product life: prevention costs, related to noncompliance prevention; evaluation costs, materialized in costs with checking, inspections, tests, audits, etc.; internal failure costs, done by the manufacturers for scraps, fixes and other noncompliance problems; external failure costs, done by the beneficiary in the exploitation period for noncompliance fixes.

By adding up these partial costs we get the total quality cost.

The evolution mode for quality costs is presented in figure 2.

Total product quality cost is composed of three groups of costs: failure prevention and quality insurance cost representing prevention actions (increasing the self-control and chain control); main control cost (fix points control, mobile control and final control); loss cost due to noncompliance (replacing the parts from the technical assistance service, their return costs etc.).

Total quality cost is given by relation [1]:

$C_G = C_{pa} + C_c + C_d + C_p$, (2)

where: C_G – total quality cost; C_{pa} – failure prevention and quality insurance cost; C_c – total quality control cost; C_d – beneficiary product service and maintenance cost; C_p – low quality cost.

3. ECONOMIC EFFICIENCY INDICATORS

Economic efficiency is the main indicator which splits every company in profitable and bankrupt.

Quality efficiency can be established both for suppliers and for beneficiaries [1]:

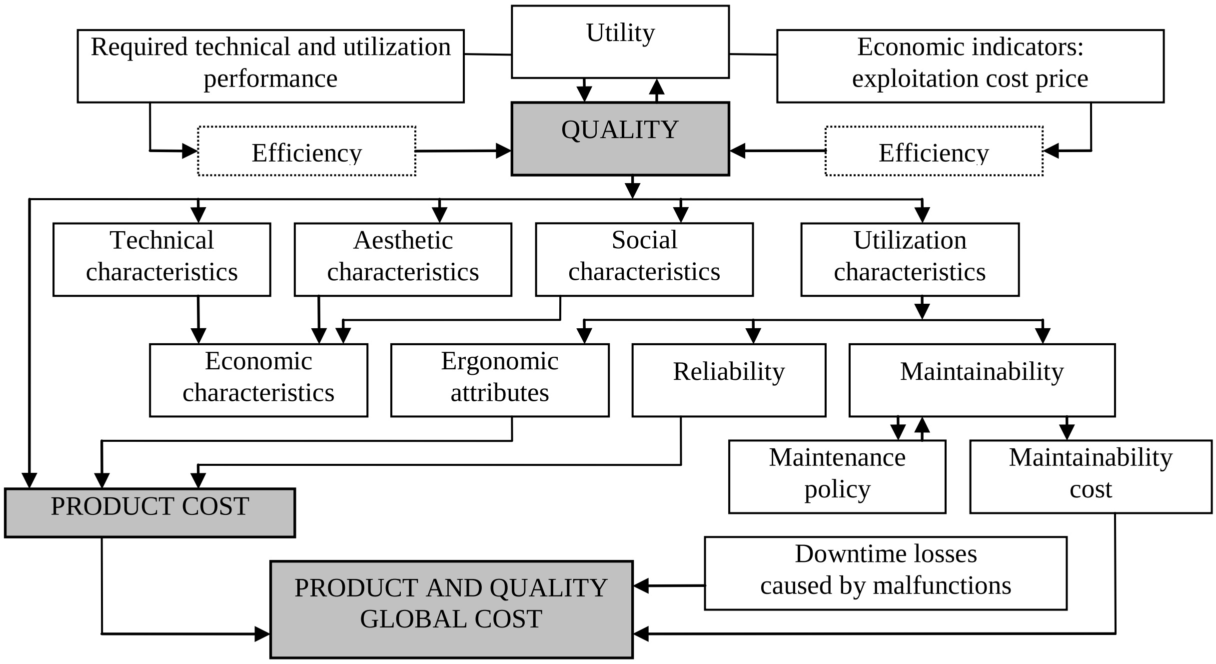


Fig. 1. Route for determining total quality cost

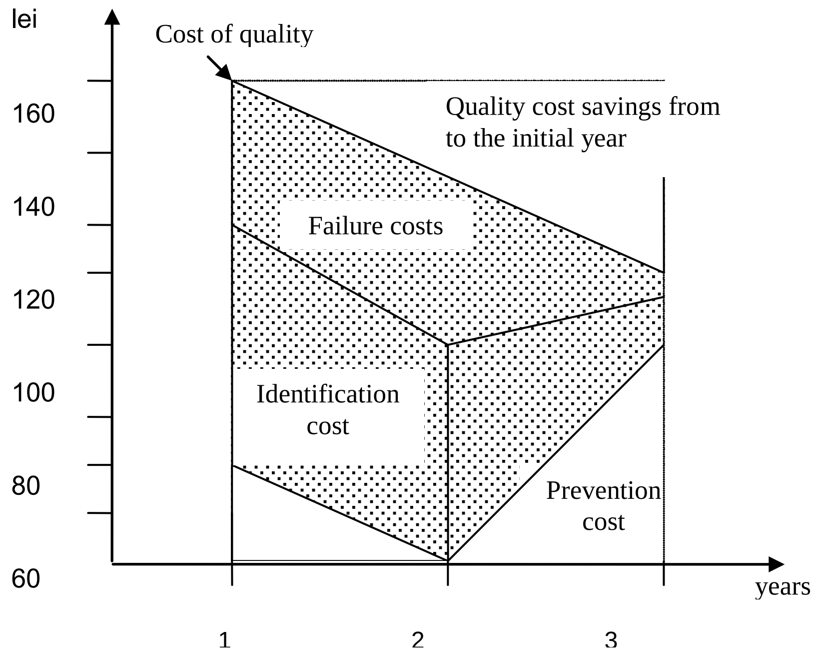


Fig. 2. Quality cost evolution

- *Total economic efficiency coefficient is given by the relation:*

$E_g=E_t/C_{tcp}=[E_{vn}+\Delta Q(1-C_n/1000)+E_v c_{rv}(1-C_n/1000)+E_r(1-C_n/1000)]/C_{tcp}$ (3)

where: E_g – total economic efficiency coefficient; E_t – total equivalent result in net income; C_{tcp} – manufacturer total quality cost; E_{vn} – the result of direct net income, given by quality increase; ΔQ – production growth given by quality increase; C_n – normed costs for 1000 lei production; E_v – currency savings; c_{rv} – commercial exchange for lei – currency return; E_r – savings from scraps and fixes losses related to a previous period.

- *Prevention and quality insurance cost recovery duration* of the net income is:

$D = C_{pa} / E_{vn}$ (4)

- *Resource specific consumption* for quality increase is calculated with the relation:

$C_s = C_{tcp} / E_t$ (5)

- *Net income growth* done for quality increase is:

$\Delta V_n = q_1(p_1 - c_1) - q_1(p_0 - c_0)$ (6)

where: ΔV_n – net income growth given done for quality increase; q_1 – yearly production capacity of the product, after quality increase; p_0, p_1 – product price before and after quality increase; c_0, c_1 – product cost before and after quality increase.

Economic effects of the quality increase when the product price doesn't change:

- for product (individual)

$\Delta Q_p = q_1 p_o(k_1 - k_0)$, (7)

where: ΔQ_p – production value growth per product

- for company

$\Delta Q_p = \sum q_1 p_o k_1 - \Delta q_1 p_o k_0$, (8)

where: ΔQ_p – production value growth per product; k_0, k_1 – product quality level before and after quality increase.

Obviously, for beneficiaries, the efficiency and cost structure have another interpretation.

Analyzing the service costs from using the bought products (product functional analysis), the beneficiary may realize that the cheapest product is not the most efficient.

The expenses done by the beneficiary during the product life for buying, operation and maintenance are strongly influenced by its quality.

4. ECONOMIC QUALITY OPTIMIZATION

Every company tries to get profit as much as possible and also to make quality products for the market. However these are two antagonistic requirements. Every unjustified quality increase leads to lower profit. Balancing the two requirements can be done by process optimization. Normally, the optimization is different for the supplier and for the beneficiary since their interests are antagonistic. Since the supplier wants the product's quality to be as close as possible to acceptability limit and to last a while to the lower limit, the beneficiary would like a high quality product which to last as much as possible.

The supplier process optimization is underlined by the expense curves for quality increase and respectively by the failure fixing curve (fig. 3).

The area of minimum resulting curve is the optimum area for the product expenses.

For the beneficiary, the graph is presented by figure 4.

For the beneficiary, this graph is also a solution for choosing the supplier when there are multiple manufacturers for the same product.

A higher complexity method of choosing the equipment with maximum advantage for the beneficiary will be described in the case study.

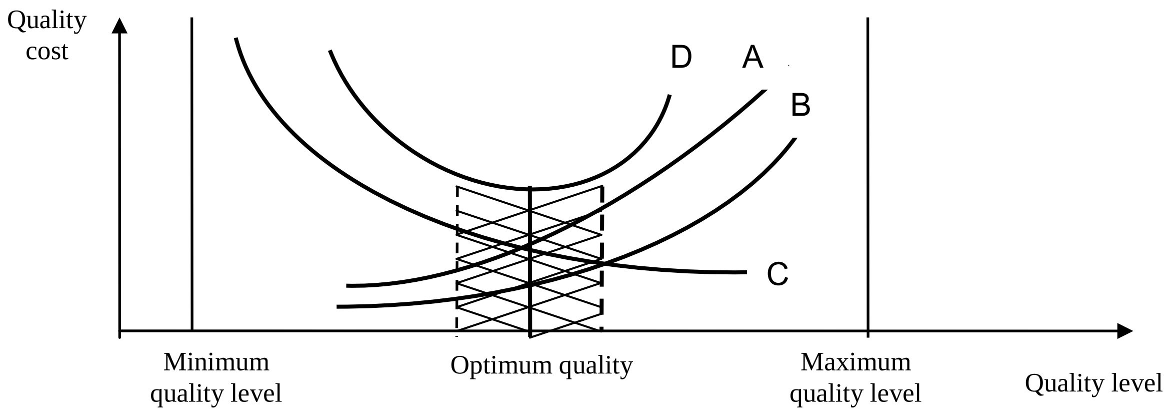


Fig. 3. Supplier quality optimization graph
A – Quality insurance cost curve; B – Quality control expenses curve; C – low quality fixing expense curve; D – resulting curve.

5. THE QUALITY – COMPETITIVENESS RELATION

The competitiveness basically represents the ability of a product to compete on the market.

The factors that support the competitiveness are: *technical factors, financial factors, maintenance factors, commercial factors*

A significant image of the competitiveness factors display method is given by the graph from figure 5.

We observe the various factors display levels. The first three are placed on consecutive levels. The technical level (4) is found twice on the diagram, which is normal since the technical quality should be found both at company level (on the external ring) and at service level (internal ring).

6. CASE STUDY: OPTIMUM METHOD FOR CHOOSING THE INSTALLATIONS IN CASE OF MULTIPLE OFFERS

Continuous improvements the construction companies bring to the installations they manufacture lead to various performances, even for the same type of equipment. Choosing the most efficient installation is even more different if different construction installations are used for the same operation [2] For example, there are various machines used for basic mincing of solid materials: jaw

crushers; gyratory (conical) crushers; cylinder crushers; hammer crushers.
The variety of these installations is high, and to show the differences we will present a comparison between the weights of the crushers which can process a block of 1 m^3 material, done by the French company Dragon.

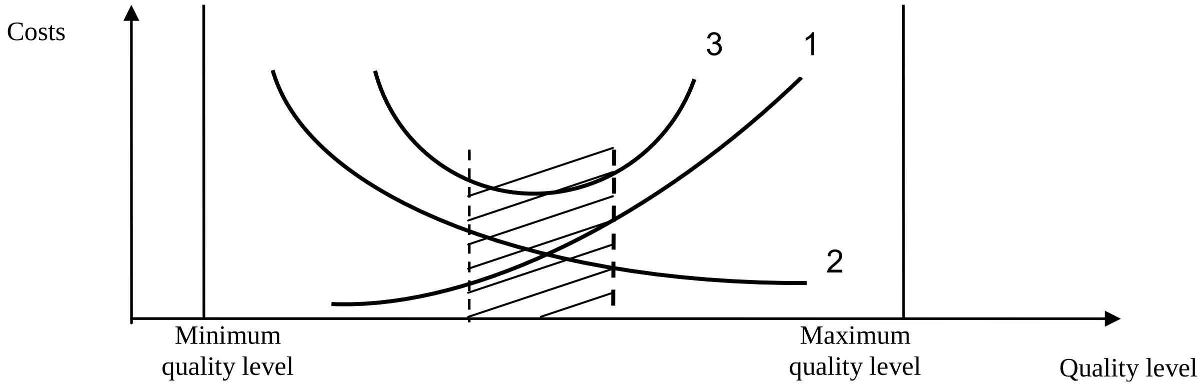
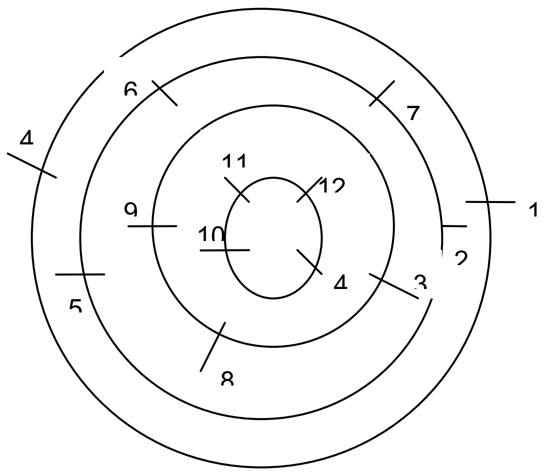


Fig. 4. Beneficiary optimization graph
1 – product acquisition expenses curve; 2 – product life maintenance expenses curve; 3 – resulting curve.



1 – technical factors
2 – commercial factors
3 – financial factors
4 – technical level
5 – promptitude
6 – delivery time
7 – distribution method
8 – price
9 – payment method
10 – tehnical support service (service)
11 – spare parts
12 – personal training

Fig. 5. Competitiveness factors display

The order of installations used for basic mincing of solid materials is shown in table 1.

Table 1. The installations used for basic mincing of solid materials

No.	Installation used for basic mincing of solid materials	Weight [t]	Order by weight
1	Crusher with 1 cylinder and jaw	15	*1*
2	Crusher with fixed hammers and 1 rotor	25	*2*
3	Jaw crusher with simple joint	43	*3*
4	Crusher with joint hammers and 2 rotors	54	*4*
5	Jaw crusher with double joint	60	*5*
6	Geared cylinder crusher	72	*6*
7	Gyratory crusher	120	*7*

Some crushers have similar performances. The research shows machines with higher output, some with lower power consumption, others with higher mincing degree etc. The question is how to pick the most efficient installation ?

A direct comparison of the performance of the considered installation might be the most relevant but is hard to use, while a comparison of the values of various parameters leads to a clearer overview on the installation characteristics even if it seems more abstract.

To exemplify we will consider crushers with different manufacture whose technical performances are presented by table 4 [3, 5, 6]. The criteria of choosing the presented installations was the output. There were analyzed 165 various crushers of some companies, shown in table 2.

Table 2. List of companies from various countries with analyzed crushers

No	Country	Construction company
1	Germany	Hazemag, Humboldt-Wedag, Krupp, Westfälische Maschinenbau
2	France	Babbittless, Dragon, Richier
3	Czech rep.	Skoda
4	Romania	Independenţa Sibiu, Progresul Brăila
5	Russia	Uralmaşzavod, Volgtemmaş
6	Sweden	Svedala Arbrå

7	Poland	Macrum Bydgoszcz

In table 4, in case of an interval of values (for output and power consumption), the coefficients were calculated using values close to a general value (close to an average, the table shows the values used with bold).

The criteria used were shown by table 3.

Table 3. List of used criteria

No.	Indicator	UM	Notation
1	Mincing degree: input material size / output size		i
2	Installed power / output coefficient	[kWh/t]	N/Q
3	Output / installation weight coefficient	[t/kg]	Q/M
4	Installed power / installation weight coefficient	[kWh/kg]	N/M
5	Particle size range	[g/t]	u
6	Wearing / product tone coefficient		
7	Installation price / output coefficient	[euro (USD)/t]	
8	Installation price / installation weight coefficient	[euro (USD)/kg]	

To make the analysis we need to determine the decision position vector of every coefficient. This analysis shows that:

- *the mincing degree* has to be as high as possible, so the decision position vector is positive;
- *the N/Q coefficient*, obviously the operation engine power needs to be as low as possible while the output as high as possible, so the decision position vector is negative;
- *the Q/M coefficient*, considering that the output has to be as high as possible, so the decision position vector is positive;
- *the N/M coefficient*, obviously the power consumption has to be as low as possible, so the decision position vector is negative;
- *the particle size range*, has to be as much narrow as possible among the needed size, so the decision position vector is negative;
- *the wearing coefficient*, obviously the wearing has to be as low as possible which lowers the maintenance costs and downtime of the installation or even the entire technologic line served by the machine. Therefore, the decision position vector is negative.

To use these coefficients we will consider the value 1,0 for the positive position of the decision vector (maximum or minimum, as it was stated when the coefficients were analyzed), 0,5 when neutral (average value) and 0 for the negative position of the vector (opposite situation to which was stated when the coefficients were analyzed). The installations with similar performance were given same scores.

Using the data from table 4 and following the stated norms for the coefficients, we got the values presented by table 5. Analyzing table 5 we notice that the impact crusher with 1 rotor gets the highest score and therefore it represents the best acquisition. It is seconded by three crushers (jaw crusher with double joint, gyratory crusher for average products and impact crusher with 2 rotors). In this situation, the decisive element will be the price indicators. The order of importance coefficients is given by table 6.

Table 6. Order of importance coefficients

Criteria	4	2 and 6	1 and 3	5
CI	0.444	0.388	0.333	0.277

We notice that the scale of these coefficients is: installed power / installation weight; installed power / output and wearing; mincing degree and output / machine weight, while the last (among the partly known) is the particle size range.

Based on this scale of values, the manager may take the best decision.

7. CONCLUSIONS AND SUGGESTIONS

Quality management became one of the most important activities in management. Quality attracts clients, brings profit, enters new markets and makes the company grow.

The suggested method of classifying a group of installations for the same purpose, might be applied for any kind of installation with the same destination and similar performances, i.e. a group of hammer crushers (with joint hammers or impact, with one or two rotors) or for different types of centrifugals (3 columns, slug discharge pulse plateau, gravity discharge, etc.)

8. REFERENCES

[**1**]. **Baron T., Isac-Maniu Al., Tovissi L., Niculescu D., Baron C., Antonescu V., Roman I.,** *Quality and reliability (in romanian)***,** vol. 1, Editura Tehnică, Bucureşti, 1988, p. 27-29; 46; 60-74, 278-287; 88-90; 491-496; 485-489

[2]. Iordache Gh., *Quality engineering. Reliability (in romanian)*, Editura Matrix Rom, Bucureşti, 2007, p. 41-52

[**3**]. **Iordache Gh., Ene Gh., Rasidescu M.,** *Installations for the construction industry (in romanian)*, Editura Tehnică, Bucureşti, 1987, p. 159; 315; 260; 42; 65; 75; 76

[4]. Kelada J., *La gestion intégrale de la qualité. Pour une qualité totale*. Edition Quafec, Québec, 1990

[**5**]. **Renert M.,** *Chemical installations calculation and building (in romanian),* vol. II, edition II, Ed. Didactică şi Pedagogică, Bucureşti, 1971, p. 365-368; 481-505

[6]. *** Prospects of crusher production companies

Table 4. Crusher types characteristics

Type	Hopper size [m]	Speed [rot/min.]	Output [t/h]	Power [kW]	Weight [kg]	Input size [m]	Output size [m]	i	u	N/Q [kWh/t]	Q/M [t/kg]	N/M [kWh/kg]
Simple joint crusher	1,40x1,07	150	150-**180**	110-**160**	82 500	0,7x0.7	0,125	5,6	6-10	0,888	0,00218	0,00194
Double joint crusher	0,9x1,2	170	165-**195**	100	69000	1,0x0,7	0,13-0,16	5,4	-	0,513	0,00282	0,00145
Cylinder crusher	-	83,6	104	85	43 400	0,080	0-0,02	4,0	16-40	0,817	0,00239	0,00196
Conical crusher for coarse crushing	0,5x2,05 (2 guri)	180	**150**-250	75	46000	0,4x1,0	0,065	15	5-30	0,500	0,00326	0,00163
Conical crusher for average crushing	0,36x1,45	330	**125**-300	92	35 000	0,25x0,80	0,025-0,050	80-32	-	0,736	0,00357	0,00263
Hammer crusher with 1 rotor	1,0x1,6	480	**180**-240	**184**-220	40000	0,6x0,6	0-0,25	24	-	0,978	0,00450	0,00460
Hammer crusher with 2 rotors	1,72x2,0	200-350	**180**-220	2x147	67 000	-	-	-	-	1,633	0,00268	0,00439
Impact crusher with 1 rotor	0,90x1,36	-	220	160	21700	0,6x0,6	$7x10^{-4}$	850	15	0,727	0,01010	0,00737
Impact crusher with 2 rotors	0,95x1,36		180	2x200	28000	0,6x0,6	$7X10^{-4}$	850	15	2,222	0,00643	0,14280

Table 5. Quality coefficients

Criteria no.	Number of decisions: DT = 9									Total positive decisions DP	Importance coefficients CI = DP/DT
	Jaw crushers		Gyratory (conical) crushers		Cylinder crushers	Hammer crushers					
						joint		fixed (impact)			
	simple joint	double joint	coarse crushing	average crushing		1 rotor	2 rotors	1 rotor	2 rotors		
1	0	0	0	0,5	-	0,5	-	1,0	1,0	**3,0**	**0,333**
2	-	1,0	0,5	1,0	0,5	-	0	0,5	0	**3,5**	**0,388**
3	0	-	0	-	0,5	0,5	0	1,0	1,0	**3,0**	**0,333**
4	1,0	1,0	-	1,0	-	0,5	0,5	0	0	**4,0**	**0,444**
5	0	1,0	0,5	-	0,5	0,5	-	-	-	**2,5**	**0,277**
6	1,0	-	-	0,5	0	-	-	1,0	1,0	**3,5**	**0,388**
Total	2,0	3,0	1,0	3,0	1,5	2,0	0,5	3,5	3,0		