# Methodology for optimization of the quality costs


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## Abstract

While practicing the system for provision of quality according to ISO 9001 from the year 2000, in the rail-vehicle factory, it has been ascertained that there are increased costs due to the efforts for achieving the defined quality. Therefore, a methodology for optimization of the costs has been an object of a research.

Due to this aim, the following methods have been applied:

- The Pareto approach for detecting the operations where the largest percent of the irregularities in the working process appear, thus leading to costs caused by the losses;
- CE ( Cause and Effect ) diagram for discovering the causes which have contributed the increase of the costs;
- A method used to analyze the efficiency of working in shifts.

By the help of these methods, the factory losses in € have been determined on daily, weekly, monthly, as well as on yearly basis in the various operations for reconstruction of the rail-vehicles.

Again, by the implementation of this methodology, the defined quality can be effectuated with both increased efficiency and with smallest amount of costs in the working process.

## 1. Introduction

### About the need of methodology for analyzing the expenses

While practicing the system for provision of quality according to ISO 9001 from the year 2000, in the rail-vehicle factory, the need of consistent implementation of the standard operative procedures for all working processes became highly stressed in order the defined quality to be achieved, as well as to protect the customers from faulty products.

The factory management has set a target to them, aside from this goal, to achieve the defined quality with the smallest amount of costs during the working process.

Therefore, it was of essential importance to develop a methodology which would aid the detection of the working anomalies. Also, it could enlarge the possibilities of improving the efficiency in achieving the quality, as well as to avoid the preventable costs that are made on a daily, weekly, monthly, and yearly basis, accordingly.

During the literary coverage of the issue, we encountered very significant information upon which the methodology for optimization of the costs can be based.

## 2. Application of the Pareto approach for analyzing the claim for compensation

The Pareto approach *(Kume, H., 1995; Ishikawa, K., 1986; Chepujnoska, V., and Bien, D.D.,2000 )* has been applied in the working unit for freight cars, where a direct contact with the customers has been established. By analyzing the claims for compensation we can perceive the phase of reconstruction of the rail-vehicles where most of the working lapses appear. Due to this fact, an analysis on 50 freight cars has been conducted. The chart 1 displays the number of complaints per division in the working unit for freight cars expressed in €, the complaints percentage, as well as the cumulative percent of complaints.

According to the Pareto approach, it is notable that the largest number of claims for compensation appears in the blacksmith department, where 47, 7% out of the total number of complaints fall on this particular department.

The analysis of the problematic operations leads to analysis of the causes of the condition in order to eliminate the irregularities which, again, cause defects. The defects can be derived from several factors, such as: human, machine, methods of work, material, tools, etc.

After spending several month in analyzing the work in the blacksmith department during 2005 (Figure 1), we have concluded that the largest number of claims for compensation have appeared in February, September, and November.

The analysis of the costs that have evolved from the complaints on the repaired products in the blacksmith's department has been displayed in the Chart 2. Over 100% fruition in €

has been materialized when there are no complaints, the realistic accomplishments, and the losses due to the claims for compensation during the first six months of 2005. According to CE (Cause and Effect) approach, we should come to a realization about what causes the largest percent of loss (due to the claims for compensation) to appear in February (24, 7%) and in June (21, 5%).

**3. Implementation of the Ishikawa diagram for tracing the causes for the complaints**

In order to determine the causes for the losses that came out as a result from the claims for compensation, we have implemented the Ishikawa diagram (Figure 2) in the blacksmith's department. (*Ishikawa, K., 1985; Ishikawa, K., 1986; Chepujnoska, V., and Bien, D.D., 2000 )*

After the detailed analysis of the factors an sub-factors which can contribute the development of the defects, by the elimination principle, we have come to the following problems, events and acknowledgements:

- The interpersonal relations within the blacksmith's department are heavily violated. There are frequent disputes among the manager and the immediate executors of the tasks. Due to this condition, frequent interventions by the management are required.
- The claims for compensation of the ready-made products that come out from the Blacksmith's department are based, above all, on the input regenerated parts that do not meet the requirements, but are produced in the working unit for mechanical preparation, i.e. in the unit for mechanical treatment of metals.

After the analysis of the reasons for claims for compensation of products in the department of mechanical preparation of metals in the working unit of mechanical preparation (Figure 3), we have come to following acknowledgements:

- We noted that the welding torches were technically defective. Due to an age limit, the voltage has been irregularly maintained in a stable condition which is of great importance for welding. The intervention takes place in every four months.
- The working utensils, i.e. the lathes were in bad condition (dilapidated). In such condition the tools cannot provide both the required precision and the quality of processing. The intervention takes place in every four months.
- Both the lineal control and the final control do not perform their function adequately to the standard operative procedures.

## 4. Implementation of the Taguchi method for decreasing the costs due to quality variations

According to this method *(Taguchi, G. and Chowdhury, S. and Wu, Y., 2004*), every aberration from the defined values of the trait presents an cost, even when the aberrations are within the limits of tolerance (specification).

$$\mathbf{G(x) = K\ [S^2 + |\ (\bar{x} - D)\ |^2]}$$

$$\mathbf{A = K\ (3S)^2; \qquad K = A\ /\ (3S)^2}$$

**G (h) – Loss due to quality variations**

**K – Price coefficient**

**$S^2$ - Dispersion**

**S – Standard deviation**

**X – Median arithmetic value of the tested trait**

**D – Defined trait value as an aim**

**A – Cost of completion**

With a statistic observation of the process we can determine the variations which will further serve for calculation of the losses. We have applied this formula in the fabrication of cartridges that are **f 55/67x39** in diameter (Chart 3). They are used as a part of the press-button of the system used to stifle the oscillations of the rev base of the railway cars. The production of the cartridges on a daily base is 2000 pieces approximately. The sum of costs has been presented with the Taguchi's function of loss:

**X = 55, 044 mm.     S = 0,023mm.     A = 0, 20 €;     D = 55,00mm.**

**G(x) = 42[0, 023² + | (55,044 – 55, 00) | ²] = 0, 1 € per cartridge**

The possible loss for a daily fabrication of 2000 cartridges amounts 200€.

For a monthly fabrication, the costs of the possible loss amount 4.400€, while in a year long term the costs amount 52.800€.

This method offers a possibility for making savings based upon quality dispersion. Simultaneously, it allows us to take preventive measures, so there would not be any unnecessary costs or a defected product.

## 5. Rational organization of the work in shifts

From the literary acknowledgements that we have gained *(Garvin, A.D., 1987; Crosby, P., 1979; Deming, E.W., 2000)* we have come to an idea exploring the possibilities for more economical working, i.e. to provide the defined quality with smallest possible costs of working.

Thus, an analysis of the work in both shifts (during the year 2005) for drive shaft manufacturing has been conducted. The drive shafts are with the following dimensions: f-55; h=11mm with (-0, 19) mm tolerance. Also, they serve as brake rods of the railway cars.

From the view point of the factory, the optimal level of manufacturing costs is one that provides maximal positive differentiation between the selling price and the sum of manufacturing costs.

The factory produces three categories of drive shafts, depending on the type of railway cars they are to be built in. This has been presented in the Chart 4.

The contracts of the factory with Makedonski Zheleznici (Macedonian Railways) include manufacture and embedding of the three categories of drive shafts, with a weekly dynamics displayed in Chart 5.

The working process has been organized in two shifts, so the contract can be realized in whole.

We present this chart in a form of three equations with three unknown:

$$\mathbf{8A + 10B - S_H = 66 \qquad (1)}$$

**$3A + 4B – S_M = 26$ (2)**

**$6A + 5B – S_L = 43$ (3)**

***Note:*** *$S_H$, $S_M$, $S_L$ present surplus of the three categories of drive shafts that can be produced on daily basis.*

In order to find the optimal expenses *(Crosby, P., 1979; Roberts, N., 2000 )* so we could achieve the daily contractual dynamics, i.e. to determine how many days should be appointed for a first shift work, and how many for the second shift for optimizing the costs, we are solving the equations with a presumption that **$S_M = S_L = 0$.**

The results from the equations (2) and (3) are as follows:

**$3A + 4B – 0 = 26$ (2)**

**$6A + 5B – 0 = 43$ (3)**

**A = 4, 66 days and B = 3 days a week.**

By interchanging A and B in the costs per week we are coming out with sum of the costs per week that present a total of 1.667 €.

Presuming that $S_H = S_M = 0$ and by solving the equations (1) and (2) we are coming to the following results:

**$8A + 10B – 0 = 66$ (1)**

**$3A + 4B – 0 = 26$ (2)**

**A = 2 days and B = 5 days a week**

By interchanging A and B (days a week) in the costs per week, we get a sum of the weekly costs in total of 1.451 €.

Presuming that $S_H = S_L = 0$ and by solving the equations (1) and (3) we are coming to the following results:

**8A + 10B – 0 = 66 (1)**

**6A + 5B – 0 = 43 (3)**

**A = 5 days and B = 2, 60 days a week**

By interchanging A and B in the costs per week, we get a sum of the weekly costs in total of 1.665 €.

Presuming that the factory works exclusively in the first shift, i.e. A = 7 and $S_L = 0$, by solving the equation (3) we get the following result:

**6A + 5B – 0 = 43 (3)**

**B = 0, 20 days a week**

By interchanging A and B in the costs per week, we get a sum of the weekly costs in total of 1.650 €.

This method has helped us to acknowledge the fact that the sum of the minimal costs per week makes a total of 1.451 €. This can be attained with A = 2 and B = 5, i.e. two working days in the first shift and five working days in the second shift per week in order to maintain the weekly dynamics.

Nevertheless, if there are five working days in the first shift and 2,60 days in the second shift ( suiting organization of work in the factory), the sum of the costs per week would be equal to 1.665 €.

The difference between the optimal costs per week and the manner in which the work in the factory has been organized presents 214 € per week, i.e. 856 € per month. This is a display of a loss that can be corrected by the factory with a change of the organization of work.

The application of this method for optimization of the expenses (*Gyrna, M.F., 1998; Nandakumar, P. and Datar, M.S. and Akelia, R., 1993; Roberts, N., 2000 )* should help managers in organization of the processes with the smallest amount of costs.

**Chart 1: Number of claims for compensation (displayed in €) per department in a working unit for freight cars**

| Ordinal Number | Type of Department | Number of Claims for Compensation (displayed in €) | Percentage of Claims for Compensation (%) | Cumulative Percentage of Claims for Compensation (%) |
|---|---|---|---|---|
| 1 | Blacksmith's Department | 6.885 | 47,7 | 47,7 |
| 2 | Lower Engine Department | 2.459 | 17,0 | 64,7 |
| 3 | Upper Engine Department | 1.967 | 13,6 | 78,3 |
| 4 | Brakes Department | 1.803 | 12,6 | 90,9 |
| 5 | Carpenter's Department | 656 | 4,5 | 95,4 |
| 6 | Dye works Department | 328 | 2,2 | 97,6 |
| 7 | Round-slot Department | 328 | 2,2 | 100 |
| Total | | 14.426 | 100 | |

**Chart 2: Losses due to claims for compensation (displayed in €) in the first six months of 2005 in the Blacksmith's Department**

| Months | 100% Effectuation (displayed in €) | Realistic Effectuation (displayed in €) | Variation in Loss (displayed in €) | Percentage of Loss |
|---|---|---|---|---|
| 1 | 3.770 | 2.311 | 1.459 | 14,5 |
| 2 | 5.246 | 2.754 | 2.492 | 24,7 |
| 3 | 2.951 | 1.538 | 1.413 | 14,0 |
| 4 | 3.197 | 1.843 | 1.354 | 13,4 |
| 5 | 2.459 | 1.266 | 1.193 | 11,9 |
| 6 | 2.951 | 780 | 2.170 | 21,5 |
| Total | 20.574 | 10.492 | 10.082 | 100 |

**Chart 3: Metric values of the inner diameter of a cartridge F 55/67x39 with tolerance of (+0, 19) mm.**

| Number of measurements | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| X (mm) | 55,08 | 55,03 | 55,05 | 55,02 | 55,04 |
| Xi – X | 0,036 | 0,014 | 0,006 | 0,024 | 0,004 |

**Chart 4: Types of drive shafts depending on the degree of tolerance and upon what type of railway cars are implementing**

| Ordinal Number | Type of Drive Shafts | Dimensions | Tolerance ( mm ) | Implementation in railway cars speeding with k/h |
|---|---|---|---|---|
| 1 | First Class | F 55,h=11 | [0÷(-0,05)] | 160 |
| 2 | Second Class | F 55,h=11 | [(-0,06)÷(-0,1)] | 125 |
| 3 | Third Class | F 55,h=11 | [(-0,1)÷(-0,19)] | 80 |

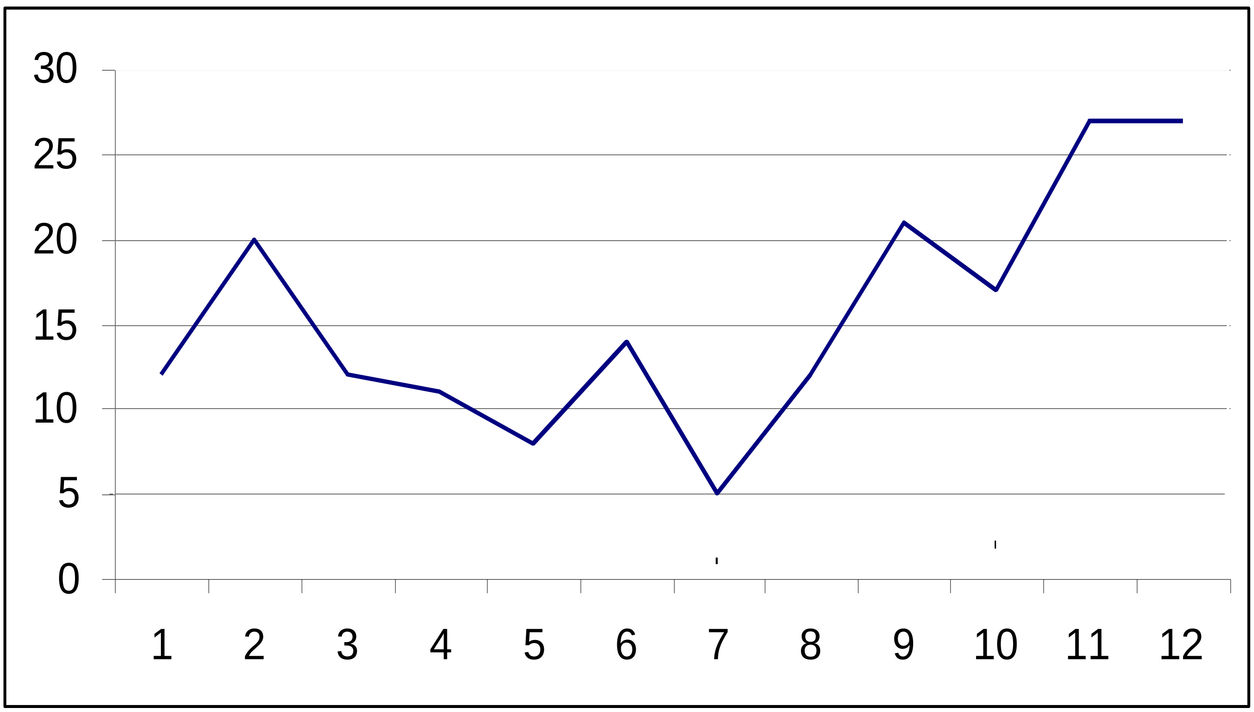
**Chart 5: Quantity of three cases of drive shafts manufactured in two shifts**

| | First Class Drive Shafts | Second Class Drive Shafts | Third Class Drive Shafts | Expenses per Day of Work ( displayed in € ) |
|---|---|---|---|---|
| First Shift A* | 8 | 3 | 6 | 230 |
| Second Shift B* | 10 | 4 | 5 | 198 |
| Orders per Week | 66 | 26 | 43 | |

* A – Working days a week in first shift, where **A ≤ 7**
**** B** - Working days a week in second shift, where **B ≤ 7**

**Figure 1: Chart displaying tendency of the number of claims for compensation in the Blacksmith's Department per months in 2005**

**Number of complaints**




**months**

Reference:


**[1] Kume, H. (June 1995)**
*Statistical Methods for Quality Improvement*
(Chapman & Hall)

**[2] Ishikawa, K. (1986)**
*Guide to Quality Control (Industrial Engineering & Technology)*
(Asian Productivity Organization; Second Revised Edition)

**[3] Chepujnoska, V. and Bjen, D. ( 2000 )**
*Using TQM to Achieve more Fficient Work: the Macedonian Experience*
(International Conference on Economic Aspects of Quality Management, Athens )

**[4] Taguchi, G. and Chowdhury, S. and Wu, Y. (November 8, 2004)**
*Taguguchi's Quality Engineering Handbook*
(Wiley-Interscience)

**[5] Ishikawa, K. (1985)**
*What Is Total Quality Control? "The Japanese Way"*
(Prentice Hall)

**[6] Crosby, B.P. (January 1, 1979)**
*Quality is free: The Art of Making Quality Certain*
(McGraw-hill Companies)

**[7] Deming, W.E. (August 11, 2000)**
*Out of the Crisis*
(The MIT Press; 1st Edition)

**[8] Gyrna, M.F. ( 1998 )**
*Quality Control Handbook*
(New York: McGraw-Hill . 4th ed.)

**[9] Nandakumar, P. and Datar, M.S. and Akella, R. ( 1993 )**

*Models for Measuring and Accounting for Cost of Conformance Quality*, pp. 1-16

(Management Science, vol.39, no.1 (January)

**[10] Garvin, A. D, ( 1987 )**
*Competing on the Eight Dimensions of Quality*, pp. 101-109
(Harvard Business Review (November-December)

**[11] Roberts. N. ( 2000 )**
*Total Quality Management and Profitability*
(International Conference on Economic Aspects of Quality Management, Skopje, Macedonia)