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ANALYSIS OF SIGMA LEVEL TO REDUCE THE COST IN AN AUTOMOTIVE INDUSTRY

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ABSTRACT
The quality is becoming an increasingly important factor for any business, once a quality product is a more competitive product. This paper aims to draw the sigma level profile that a process reaches a year by analyzing the capacity. This generates a forecast of failure and costs allowing therefore a better production management. The study was applied to fault data in the electric glass mechanism of cars of dealers. The expected average cost of company in maintenance decreases by about 70% if the production process is maintained at a level of at least three of sigma quality.

INTRODUCTION
According to [1], the company should see the quality as an important point in its development. Consumers are drawn more and more for products that have differential in the market and the difference is only achieved through good quality policy [2].

Processes are workflows of a company, be it a producer of goods or services. We know that every company starts its processes through customer entries as deadlines and specifications and ends with the outputs that are the completed products [3]. It is necessary to perform control of the process because in this moment that is there are the possible products out of specification, as explained to [4].

The Six Sigma program contemplates the prospects of production quality as well as restructuring of processes that will directly influence costs, according to studies of [5] and [6].The fundamental argument for positive financial impacts of Six Sigma adoption is that it provides new capabilities within the firm through the learning, control and adaptation.

This paper analyzes data from a network of dealerships. The main objective is to model failures in the operating mechanism of automotive electric glass during the warranty period offered to the customer. Through the process capability, it will be possible to identify the sigma level of quality and from this analysis, it propose improvements reducing repair costs.

MATERIALS AND METHODS
Identification of the Problem
Second [7], the problem addresses to the types of defects occurring in the automotive sector, specifically in the production area. A mechanism for lifting the glass and keep it aligned using a helical gear with system of cables and pulleys that operate via an electric motor.

This study is due to the high number of defects occurring in the electric glass mechanism as cable break, break the pulleys, gear locking and burn electric motor on customer vehicles. This customer, when realizes that there is something wrong, they report the dealership.

A stratification of the data help classify them as the failure mode that shows the description of the defect according to the client and the effect of failure that is the technical opinion submitted by the concessionaires assurance team [8].

Further study of the strata through Pareto diagram, enables point the most common type of defect and one that generates more impact both in costs as in the image of the product. Figure 1 shows a Pareto diagram of the failure modes considering a first level of strata.

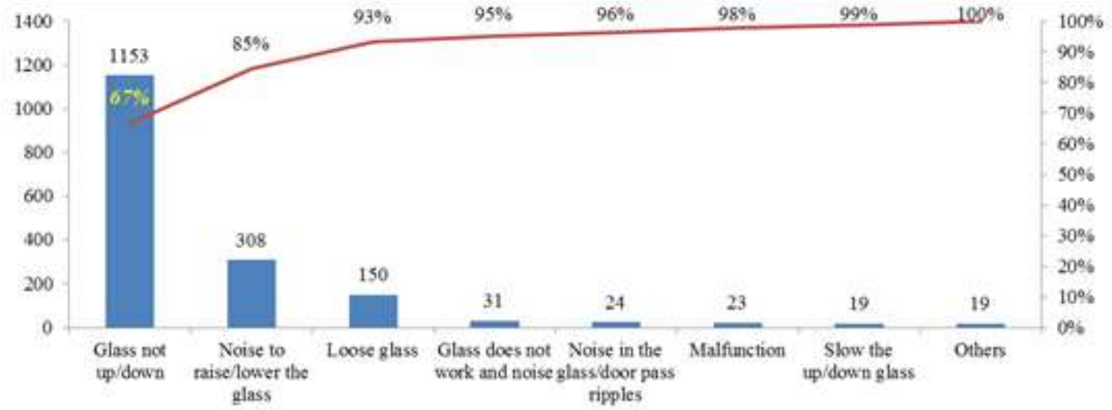

Figure 1. Pareto Diagram – Failure Mode – First level

In Figure 1, it is observed that the glass failure modes not rise and descend represents 12.5% of the problems and has an impact of approximately 67% compared to other defects. The failure mode closest, which is the noise for rise and fall glass, has an impact of only 18%.

From the most important failure mode was possible to build the Pareto diagram stratified presented in Figure 2. It can be seen that the most constant failure is the cable breaking, which has 893 cases within the customer complaints.

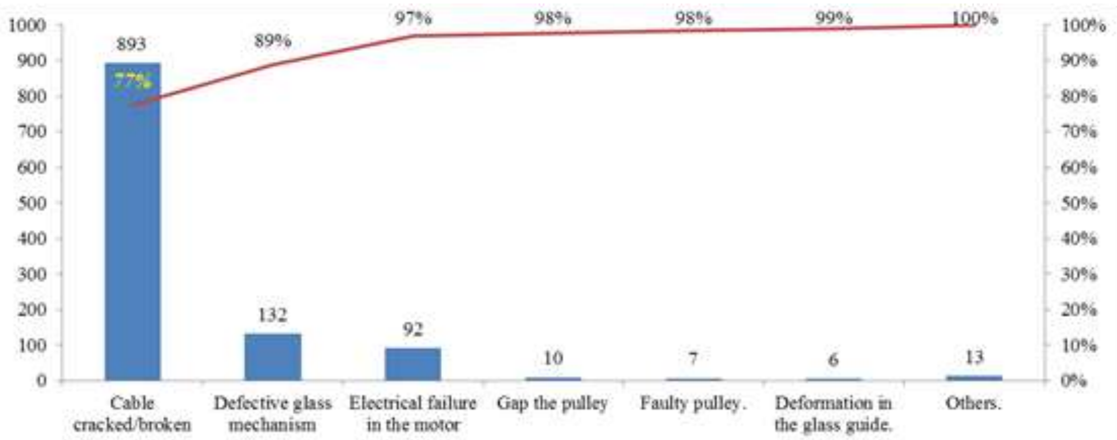

Figure 2. Pareto Diagram – Failure Mode – First second

The effect of the broken cable represent approximately 14% of the strata, this generates a 77.5% impact taking into account only the glass failure mode not move up.

Chi-Square Goodness of Fit Test

The goodness of fit of a statistical model describes if it fits or not a set of observations. Measures of goodness of fit normally summarize the discrepancy between observed values and the values expected under the model in question.

The test is applied when you have one variable from a single population. [9] defined then it is used to determine whether sample data are consistent with a hypothesized distribution predetermined.

Pearson's chi-squared test uses a measure of goodness of fit which is the sum of differences between observed and expected outcome frequencies (that is, counts of observations) each squared and divided by the expectation [10] as Equation (1):

$$X_o^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \qquad (1)$$

where:
Oi = an observed frequency (i.e. count) for bin i
Ei = an expected (theoretical) frequency for bin i, asserted by the null hypothesis.

The resulting value can be compared to the chi-squared distribution to determine the goodness of fit. In order to determine the degrees of freedom of the chi-squared distribution, one takes the total number of observed frequencies and subtracts the number of estimated parameters. The test statistic follows, approximately, a chi-square distribution with (k − c) degrees of freedom where k is the number of non-empty cells and c is the number of estimated parameters (including location and scale parameters and shape parameters) for the distribution [11].

Box-Cox Transformation
According to [12], when the normal distribution does not fit the data, often applies the Box-Cox transformation to obtain normality.

The most important results of the study [13] on the observations x1, x2, ...xn considered normally distributed with constant variance and expected values of linear models was to define the following exponential transformation represented by the Equation (2) of the variable x to x (λ) [14, 15]:

$$x^{(\lambda)} = \begin{cases} \frac{x^{\lambda}-1}{\lambda} & (\lambda \neq 0) \\ \log x & (\lambda = 0) \end{cases} \qquad (2)$$

As the analysis of variance is unaffected, Equation (2) can be simplified by the Equation (3).

$$x^{(\lambda)} = \begin{cases} x^{\lambda} & (\lambda \neq 0) \\ \log x & (\lambda = 0) \end{cases} \qquad (3)$$

For [13], this transformation is defined only by variables that have positive values (x> 0), and the parameter λ is the element that defines the transformation and it often results in normal.

Sigma Level
For [16], Six Sigma is a disciplined and quantitative management strategy, which aims to significantly improve the performances and profitability of companies by improving the quality of products and processes, as well as the increasing satisfaction of customers and consumers.

The idea behind this approach is simple: reduce variation, defects, errors or failures to a rate close to zero. It is important to emphasize that Six Sigma, unlike many previous programs, does not the improvement of operations in isolation, but rather focus on the improvement of all the process.

The Six Sigma terminology comes from the statistical representation of the level of variability of a process, or adequacy of the process to a specification. Sigma (σ) is the letter used to represent standard deviation of a distribution and the smaller the standard deviation of a process, more standard deviations will be accepted within specification [17].

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The projects are conducted by teams led by experts of Six Sigma (Black Belts or Green Belts), based on DMAIC methods (Define, Measure, Analyze, Improve, Control). The DMAIC method according to [18] is used as the standard approach for conducting projects Six Sigma performance improvement of products and processes.
The Table 1 presents a relation between sigma level and number of defects per million opportunities.

Table 1. Sigma Level, Adapted from [19]

Sigma Level	DPMO (defects per million opportunities)	Cost of non-quality
6	3,4	< 10 % of sales
5	233	10-15% of sales
4	6210	15-20% of sales
3	66807	20-30% of sales
2	308537	30-40% of sales
1	697672	-

A rough way to determine the sigma level is by Equations (4) and (5) according [20]:

$$\text{Sigma Level} \approx 3 * P_{PK} + 1{,}5 \quad (4)$$

$$\text{Sigma Level} \approx 0{,}8406 + \sqrt{29{,}37 - 2{,}22 * \ln(DPMC)} \quad (5)$$

RESULTS AND DISCUSSION

The Figure 3 shows the years and months manufacture of vehicle and the amount that failed within this period. It is observed a peak in 2010, specifically in October reaching 136 vehicles with defective on electric glass mechanism.

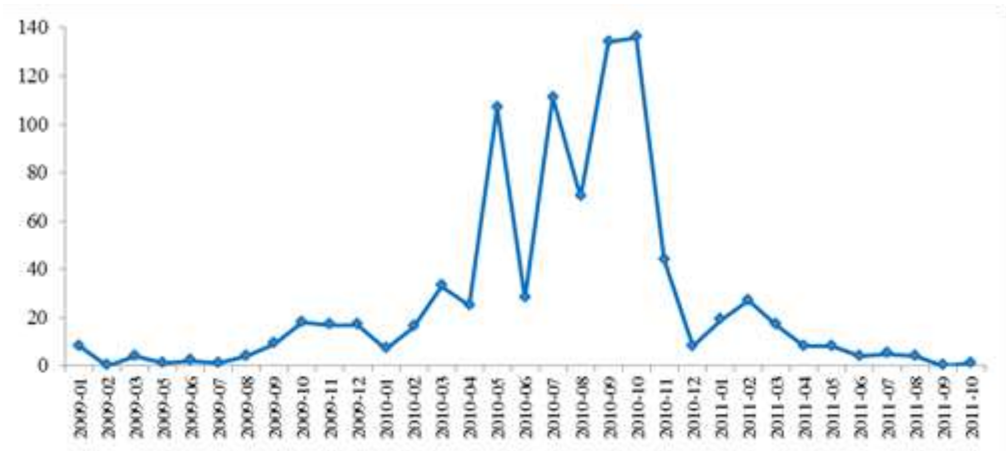

Figure 3- Number of Manufactured Vehicles versus Number of Defects

Through the average proportion of defects per period, it was possible to estimate an upper limit of 1% specification. With this, we carried out a process capability analysis using MiniTab® statistic software, Figure 4.

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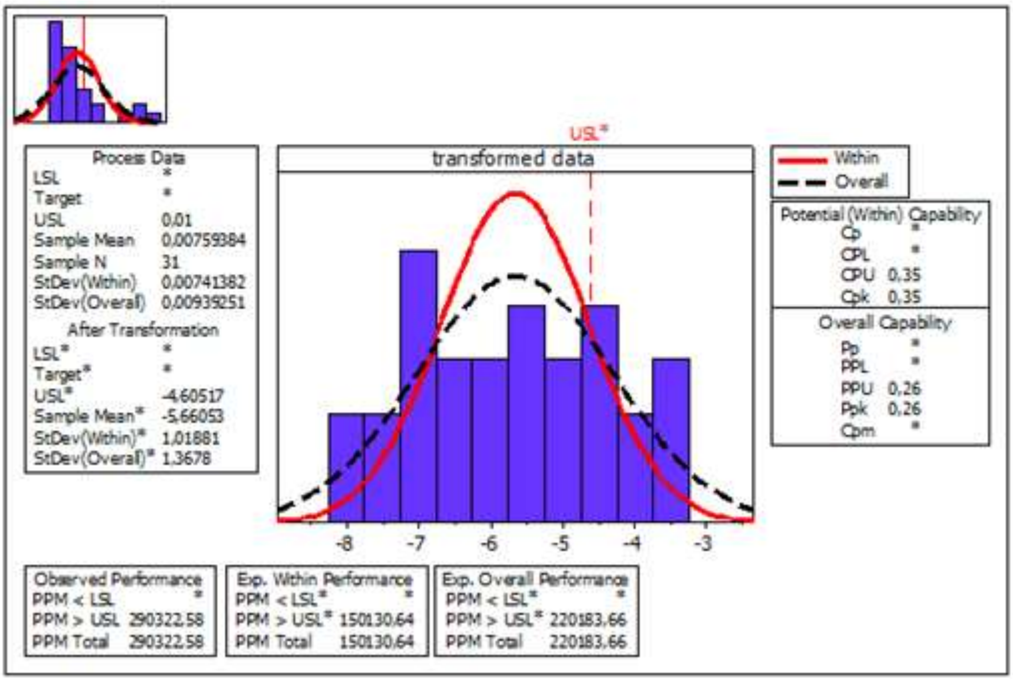

Figure 4- Capability of Process

The Figure 4 shows the PPK and CPK values found for the process, through value of CPK was observed that the process is unable [21].

Using Equation (4) it is possible to calculate the sigma level at which the company is operating. Sigma Level about of 2.28.

It is noted que the company is in the sigma level of about 2.28 with 308.537 defects per million opportunities, which compromises 30 until 40% of the cost.

The year 2010 presented an atypical behavior that is why; analysis of process capability will be made again for the other years.

In Figure 5, it is observed that the values CPK and PPK increased, this is resulted in an increase in sigma level to 3.09.That is, 66,807 defects per million opportunities, it implies a lower part of the cost, 20 to 30%.

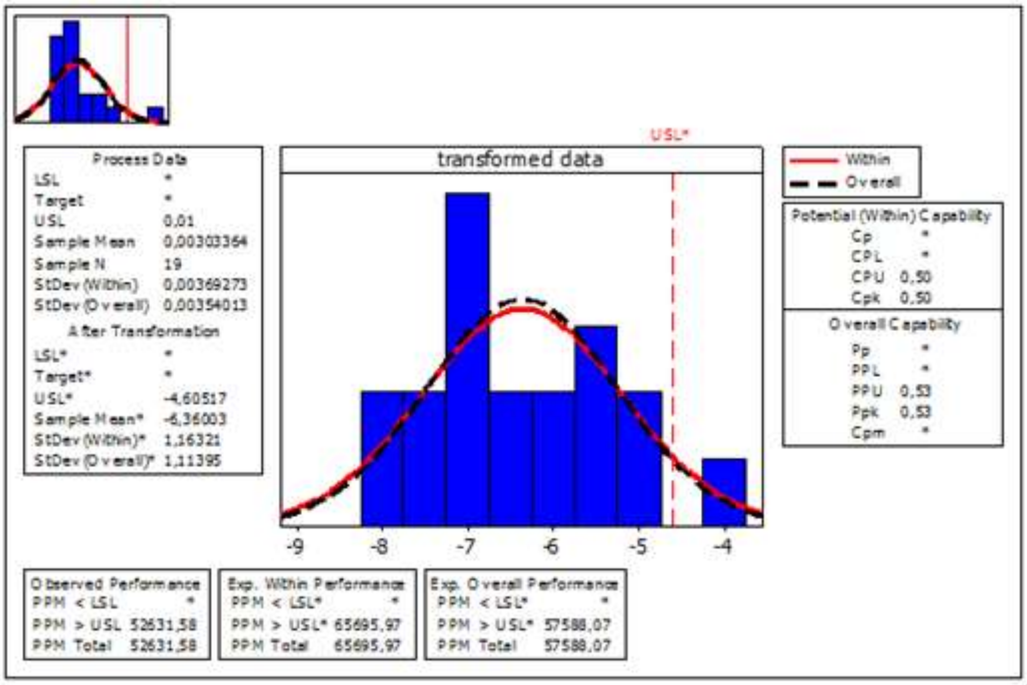

Figure 5- Capability of Process–year 2009 and 2011

If the analysis of cost is made for the whole period, we have an average cost of repairs € 1,645.73 per month. However, with only the years 2009 and 2011, the average cost is of € 495.79 per month. This shows that if the company keep the sigma level of process in 3.09 for all periods, it would reduce approximately 70% of the spent costs on repairs.

CONCLUSION

This article presented a failure analysis sequence aimed to find what the biggest flaw related to the electric glass mechanism based on quality tools. Through a sequence chart having as variable the number of occurrences of the most important defect in relation to the vehicle's manufacturing period. It was observed that vehicles manufactured in 2010 generated a negative impact on the process level sigma and consequently, an increase of average cost of repairs.

The sigma level was obtained by analyzing the capability considering two cases: first, using all period, and the second case, removed the critical year 2010. Thus, it was found that the process operates at its normal level at 3.09 sigma, and criticality in 2.28 sigma.

From the cost analysis it was identified a need for improvement in the process, because in a significant drop in the sigma level, causes a 70% increase in the cost of non-quality.

It is suggested a monitoring of defects in order to detect any possible upward trend. So can be planned preventives actions that would avoid criticality situation.

Thus, not only the component assembly process under study, but as the company would keep its sigma level, increasing opportunity of becoming more competitive.

Know the sigma level profile the process it became possible to predict failures and cost. This will assist in the company's production management.

To maintain a particular level sigma in the process, the use of a quality management methodology is needed. As limitation of the research, this analysis cannot be made for lack resource of enterprise that had a significant drop in sales due to the economic crisis.

The implementation and development of DMAIC is a good suggestion for future works.

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