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Using Six Sigma to analyse Customer Satisfaction at the product design and development stage

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Abstract

The need for the products to be first manufactured according to the specifications is becoming a reality due to a situation that exists in the current markets. This is achieved by applying the six-sigma tool. This study is done in a multinational company that manufactures auto parts and aims to analyze the Key Performance Indicator (KPI) Customer Satisfaction (CS) in the design and development stages of the product to always obtain the optimum result, 100%. From the KPI CS data the sigma was calculated using the Define, Measure, Analyze, Improve, Design and Verify (DMADV) methodology. Using the range of values that CS can have to achieve the desired result, the six-sigma tool was applied. From the six-sigma tool, the value of the standard deviation for the results obtained is within the expected. Maximum limits were imposed to work comfortably within the six-sigma. If there is an alert for non-compliance with these limits, corrective and preventive measures can be taken so that there is no recurrence of the problem. When a control limit has been imposed and, even if corrective and preventive actions have been taken, the six sigma parameters are still working. Finally, using the CS calculation formula, the desired Quality Control and Time To Market results were obtained for the range of values within the six sigma with the appropriate control limits. With this study, the company was able to identify where the recurrence of the problems is happening. Knowing the cause of the problems it allows changes or improvements in the processes.

Keywords: Six Sigma; Key Performance Indicator; Define, Measure, Analyse, Improve, Design and Verify; Customer Satisfaction.

1. Introduction

At a time when the industry is becoming more competitive, dynamic, interactive and constantly evolving, adapting to this new reality is a necessity for companies to be able to stay within the business area. Globalization and the provision of services are forcing companies to rapidly innovate their management techniques. Nowadays companies

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are not only product-oriented as they take into account the needs and satisfaction of customers who are increasingly demanding in quality and speed and also price sensitive, forcing companies to efficient and sustainable management of the product cycle life.

Product Lifecycle Management (PLM) not only helps in product organization, development and design, but also manages product costs and sales.

Sustainable product life cycle management is not only fundamental, but also requires improvements in management and design processes.

Achieving these improvements requires the use of continuous improvement tools [1]. More and more companies use specifically the six sigma tool that aims to systematically improve processes until their variation elimination. The improvements in the processes go through their standardization, that is, there are no variations. The standardization of the processes leads to the elimination of defects and failures, having a direct impact on the quality of the product which, in turn, manifests itself in customer satisfaction. As such, the production costs of the product will decrease and the profit margin will be higher. All of this makes the product life cycle more efficient and sustainable.

The paper's structure is divided into 4 sections: the first corresponds to this Introduction; Section 2 corresponds to a literature review concerning Six Sigma; Section 3 presents the case study and, finally, Section 4, the conclusions of this work.

2. Literature review

Six Sigma is a methodology has the aim to reduce the variation in the processes [2-3], reduce the manufacturing costs and improve the customer satisfaction [3-9].

Six Sigma means six times sigma or six times the standard deviation, σ, of the reference value, μ, $(\mu-6\sigma;\ \mu+6\sigma)$ [10] which represents 3.4 parts per million opportunities (DPMO) and 99.99966% of the products are within the customer specifications [11].

Six Sigma is accepted in the companies for quality improvement. If it is used just as a statistical tool to solve complex problems then it won't be successful [12] because, Six Sigma sets the target that needs to be achieved [11].

In this context, Six Sigma uses scientific methods like DMAIC and DMADV to solve problems [4]. DMAIC (Define, Measure, Analyze, Improve and Control) is a method used by Six Sigma in the existing processes unlike the DMADV (Define, Measure, Analyze, Design and Verify) method which is used in new products and/or processes [13].

Six Sigma is a methodology that needs the support of top management to be successful. This way all the employees understand the importance of quality for the company creating the motivation needed for the Six Sigma's projects [14-15].

Although the use of Six Sigma improves the revenue of the company in the production series over the long term, the usage of six sigma tools in projects of new products must be used carefully and only should be used in critical projects otherwise could increase significantly the costs of the project [16].

In this paper it's intended to show how Six Sigma can improve the Customer Satisfaction Key Performance Indicator.

3. Case Study

The case study was carried out in the headquarters of an auto parts company. Due to the work being done at headquarters, it is necessary to analyze the data under study at a global level, considering all the companies in the group. Data collection was done through existing documentation.

3.1 Phases of the projects

The New Product Life Cycle Management projects are divided into several phases. The phases are as follows:

- Gate 0 - Sales;

- Gate 1 - Kick-off;
- Gate 2 - Design Release;
- Gate 3 - Process Release;
- Gate 4 - Pre-Series;
- Gate 5 - Series Release;
- Gate 6 - Handover.

For the purpose of this work, only the gates 2 and 3 will be focused.

3.1.1 Gate 2 and Gate 3 sub phases

It is in Gate 2 that the design and development of the product are done. The Bill of Process and the product specifications, created in Gate 2, will be inputs of Gate 3. At the end of Gate 2 a meeting is held where the project managers and other functions' managers decide if the project in question goes to the next phase, Gate 3.

The Gate 3 is departmental dependent. Due to this departmental interconnection the risk of delays increases. This is where the documents related to all manufacturing processes are made.

3.1.2 Customer Satisfaction CS KPI

The Company does a monthly review of Project Status. In this analysis, it is used the Customer Satisfaction KPI.

The CS Indicator is the sum of 30% of Quality Control (QC) and 70% of Time To Market (TTM). The QC is calculated by counting the Quality Claims 'OK' divided by the Total 'OK' and 'NOK' by Quality Claims. The TTM is calculated by counting the 'OK' from Risk to delay parts to events divided by the total of 'OK' and 'NOK' from Risk to delay parts to events & SOP (Standard Operations Procedures). In a Project there is a Quality Claim, two Risk to delay parts to events & SOP.

The CS indicator is calculated as equation 1:

$$\mathrm{CS} = \frac{\mathrm{QC} \times 0{,}3 + \mathrm{TTM} \times 0{,}7}{100} \quad (1)$$

Quality Control indicator is calculated by equation 2:

$$\mathrm{QC} = \frac{\text{OK Quality } \mathit{Claims}}{\text{Total Quality Claims}} \quad (2)$$

And Time To Market is calculated by equation 3:

$$\mathrm{TTM} = \frac{\text{OK Risk to delay parts to the event}}{\text{Total Risk to delay parts to event \& SOP}} \quad (3)$$

3.1.3 Interval of results

The CS KPI gives percentage results, but the analysis of the CS KPI is done in a qualitative manner. This analysis considers the following value ranges:

- Green (Good) $99{,}00\% \leq \mathrm{CS} \leq 100{,}00\%$
- Yellow (Regular) $95{,}00\% \leq \mathrm{CS} < 99{,}00\%$
- Red (Bad) $\mathrm{CS} < 95{,}00$

3.1.4 Customer Satisfaction Indicator Results

Table 1 and Table 2 shows the results of the CS KPI after applying for 2017.

Table 1 – Gate 2 CS KPI ‘s Results for 2017

Month	CS
Jan	100,00 %
Feb	100,00 %
Mar	97,81 %
Apr	98,33 %
May	100,00 %
Jun	95,63 %
Jul	100,00 %
Aug	100,00 %
Sep	100,00%
Oct	94,09 %
Nov	94,00 %
Dec	86,43 %

Table 2 – Gate 3 CS KPI ‘s Results for 2017

Month	CS
Jan	100,00 %
Feb	100,00 %
Mar	93,64 %
Apr	91,46 %
May	95,83 %
Jun	93,93 %
Jul	91,00 %
Aug	93,70 %
Sep	92,61 %
Oct	84,05 %
Nov	82,05 %
Dec	85,00 %

Due to the complexity of Gate 3, the results are lower than those for Gate 2. Due to acquisitions of new companies and their inclusion into the Group’s project management model, the last quarter of 2017 presents lower results in both gates in relation to the rest of the year.

3.2 Study of the Gaussian distribution

From the Gaussian distribution results are values that are between the defined limits.

As a general rule, the study of the Gaussian distribution is done on both sides of the curve as shown in Figure 1, two tailed Z test. In this case, as the objective, the indicator has an average of 100% so that it can only have lower values. In Figure 2 the shape of the one-tailed Z test can be seen.

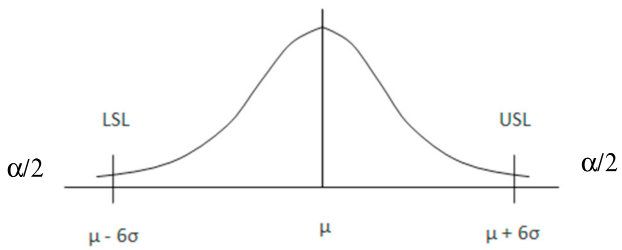

Figure 1 – Two tailed Z test

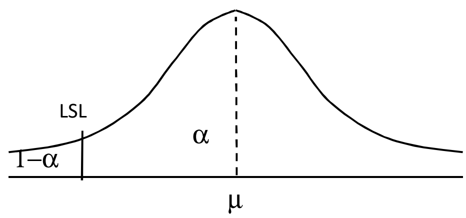

Figure 2 – One-tailed Z test

Z value can be calculated by equation 4:

$$Z = \frac{LSL - \mu}{\sigma} \quad (4)$$

3.2.1 Results from the one-tailed Z test for the indicator

The mean and standard deviation for the indicator for Gate 2 and 3 were calculated. The results can be seen in Table 3.

Table 3 - Results of CS mean and standard deviation

Gate	μ	σ
Gate 2	0,9719	0,0395
Gate 3	0,9194	0,056

The minimum gauge for both Gates was found. These minimums are identified in Table 4.

Table 4 - CS minimum results

Gate	LSL
Gate 2	86,43%
Gate 3	82,05%

With the results of Table 3 and 4 the Z was calculated for both gates, obtaining the results expressed in table 5.

Table 5 - Results from Z to CS

Gate	Z
Gate 2	-1,766
Gate 3	-2,72

3.2.2 Application of the six-sigma tool

Subsequent to the study of the Gaussian distribution in the CS KPI, the standard deviation for the optimal solution was calculated. For this purpose, the mean is 100%, $\mu = 1$, the minimum limit is 99%, $LSL = 0.99$, and $Z = 6$. The range of values shows the optimal result. After applying the formula (equation 4), we obtain $\sigma = 0.00167$, the maximum value of the standard deviation that the indicator can reach so that it is within the parameters of the six-sigma.

3.2.3 Control Limits

To be certain that the minimum limit is not reached are imposed control limits.

When shortening the interval, it is known that before reaching this minimum limit an alert will be given. If this alert is given, then corrective actions are implemented and in this way, one does not work outside these specific limits (maximum and minimum).

From the experience, it is known that a process cannot vary more than 1,5σ and then, the LSL = 4,5σ. Using the formula (equation 4), you get a result equal to 0.992485 or in percentage terms 99.2485%.

3.2.4 Limits of QC and TMR

From 1.2.3 it is known that the CS KPI should be greater than 0.992485. Having the CS formula two variables (QC and TTM) it is necessary to know how the KPI can vary. To simplify the CS formula, you get equation 5:

$$\mathrm{CS} = 0{,}3\ \mathrm{QC} + 0{,}7\ \mathrm{TTM} \tag{5}$$

After applying to CS the minimum value:

$$0{,}992485 = 0{,}3\ \mathrm{QC} + 0{,}7\ \mathrm{TTM}$$

Thus,

$$\begin{cases} 0{,}992485 = 0{,}3\ \mathrm{QC} + 0{,}7 & ,\mathrm{TTM} = 1 \\ 0{,}992485 = 0{,}3 + 0{,}7\ \mathrm{TTM} & ,\mathrm{QC} = 1 \end{cases} \Leftrightarrow \begin{cases} \mathrm{QC} = 0{,}97495 \\ \mathrm{TTM} = 0{,}98926 \end{cases} \begin{matrix} (6) \\ (7) \end{matrix}$$

In (6) if the Quality Control formula is applied and if the Total Quality Claims is considered equal to 100 you get a result equal to 98 'Ok' or 2 'NOK'.

In (7) if the Time To Market formula is applied and if we consider the Total Risk to delay parts to event & SOP equal to 200, sum of 100 Risk to delay parts to event and 100 Risk to accomplish SOP, we obtain a result equal to 99 'Ok' or 1 'NOK'.

The combined result with Quality Control and Time to Market was calculated and the QC obtained a result of 1 'NOK' for a total of 100 Quality Claims, and the TTM obtained a maximum of 1 'NOK' for a total of 200 Risk to delay parts to event & SOP. The Table 6 shows the comparison between the actual data and the data after the analysis with the Six Sigma tool. As can be seen, there is a significant reduction in the number of Quality Claims and Risk to delay parts to event & SOP for both Gates.

Table 6 – Comparison between the actual data and the data after the analysis with 6 σ

Nº Projects	**Real Data**	**After analyze with 6σ**
Nº Projects – Gate 2	100	100
Quality Claims – Gate 2	3,66	2 or 1
Risk to delay parts to event & SOP – Gate 2	4,71	0 or 1
Quality Claims – Gate 3	7,48	2 or 1
Risk to delay parts to event & SOP – Gate 3	1,29	0 or 1

4. Conclusions

The results of the CS indicator for the year 2017 were quite low, especially in gate 3. This is due to the complexity of gate 3 as evidenced by the summary of Table 3. Not only gate 3 is dependent on several departments as it is at this stage all processes related to the manufacturing and control processes will be created.

From the study of the Gaussian distribution we obtained a score of -2 and -3 sigma for gates 2 and 3 respectively. After the application of the six-sigma tool and the control limits a combination of results for QC and TTM was obtained. This combination of results revealed that for a maximum of one year there may be 2 complaints or a risk of delay. Another possible outcome is a complaint and a delay. All calculated values had the premise on the number of projects equal to 100. The results obtained are optimal since it would mean that the CS indicator would be within the desired range of values.

The Quality and Projects department reviews the design and production claims as a whole. The department reported that most complaints are process related (e.g. missing fasteners). The indicators used by the department are the number of complaints, the Parts Per Million (PPM) and Incidents per Billion (IpB).

If the six-sigma were implemented, the number of complaints would considerably lower and, consequently, the IpB. The PPM would also lower because as there are fewer complaints then there would also be fewer rejected parts.

Indirectly the implementation of six sigma would mean that there would be greater control of manufacturing and control processes.

To improve the CS indicator, it is proposed that the PFMEA and DFMEA be carefully developed so that when they go into the Pre-Series there are no problems related to quality.

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