Statistical Quality Study of the Parts Produced in an Automobile Industry: A Daimler India Case Study

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Abstract. Every manufacturing industry considers defect-free production in this competitive era. Though it is practically impossible to improve the rate of defect minimization, statistical tools can be used. In this case study, we take data from Daimler India, an automobile part manufacturing industry specialized in manufacturing OEM tools like chassis, oil filter nipple, and so on, and study how many defects are made during the day. The defect-causing process was eliminated after using statistical quality control tools such as np charts and cumulative sum charts, resulting in higher production quality.

Keywords. Control charts, np chart, cumulative sum charts, process quality control, non-conformities, control limits, parts acceptance.

1. Introduction

This research article is centered on the automotive business, an original equipment manufacturing (OEM) organization specializing in stamping metallic pieces, sub-assemblies, welded assemblies, chassis, and, more recently, precision parts. This research intends to investigate and analyze the statistical quality control applied to one-piece reference parts utilizing variable control charts for the parts that the plant produces and inspects. They use both manual and automated methods to inspect the quality of the finished product.

A procedure may be monitored, managed, and advanced the usage of statistical procedure manage. When random causes only influence a process, one speaks of a stable state of statistical control. When systematic influences influence a process, it is said to be statistically uncontrolled. The characteristic of a steady-state process is that they often obey random distributions because the statistical process is constantly subjected to regular variation. The data distribution will vary if a process is out of control. Statistical process control is a top-down tool mainly used as part of a quality improvement policy by the higher management of many industries. On paper, Statistical process control has the following characteristics:

- Statistical process control identifies a process by analyzing data from samples.
- The goal of statistical process control is to track a process’s performance across time.
- Another purpose of Statistical process control is to bring a process back to its optimal state.

As an effective Statistical process control tool, the control chart analyses the stability of a process and identifies unstable elements. In today’s high-tech era, some products have unusually short life cycles and can be manufactured at an early stage. Greater globalization and manufacturing capacity
boost the competitiveness of automotive factories. Quality in the automotive industry is determined by how satisfied customers are with the products and services. It is a method for increasing capability by reducing variability in the product, delivery, process, material, attitude, and equipment.

As previously stated, the industry is primarily an Original Equipment Manufacturer (OEM) specializing in, among other things, stamping metallic components, subassemblies, welded assemblies, and chassis. Many objects are rejected due to tolerance differences, and the quality of the objects is monitored using Statistical Quality Control tools. This paper aims to reduce the number of ways to detect errors during an inspection, improve production quality consistency, lay the groundwork for attainable specifications, identify bottlenecks and difficulty spots, and determine manufacturing process capability. [1]

2. Concepts & signs of progress
2.1. Concepts
2.1.1. NP control chart-based process control

![Diagram of np Chart]

**Figure 1.** Using an np Chart.

A mechanism for monitoring and controlling the processes is proposed. For error inspection, the proposed method employs a control np chart and a binomial capacity analysis. An np chart is a type of attribute control chart frequently used with data collected in subsets of the same size that vary over time based on the number of harmful objects created. The process’s attribute (or characteristic) is always expressed as a yes/no, or pass/fail situation (Figure 1). An np chart would be used to display the incomplete accident reports from a daily sample of five. NP charts are used to determine whether a process is stable and predictable and track the outcomes of various process improvement theories.
2.1.2. CUSUM control chart-based process control

The author conducted a thorough literature search and discovered that CUSUM-primarily based manipulate charts were used for fault detection and prediction in engineering applications. The proposed method successfully applied the incipient prognosis of fault states of gadgets used in the vehicle sector based on practical information about historical faults. The most important advantage of the tabular CUSUM chart is that it is far more sensitive to minor adjustments than different manipulate charts, particularly when comparing different manipulate charts (Figure 2).

2.2. Understanding the literature

In the research done in [2], researchers used a statistical analysis of the process data, the P-control chart, to identify abnormal process variability and take immediate action. The proposed statistical process control technique based on the P-control chart can control the process and improve the quality through data acquisition and statistical analysis, as shown in the application example. Using Statistical Process Control, the suggested P chart-based process control approach can assist businesses in improving the quality of their products. (Bo Yang, 2020).

The research in [3] is about the cumulative sum-based approach for monitoring conditions and detecting fault diagnosis of wind turbines (WTs) using Supervisory Control & Data Acquisition for the data work. The method is used to monitor the state of a WT in real-time utilizing temperature-related Supervisory Control & Data Acquisition data. (Dao, 2021).

The research in [4] develops two and three adaptive sample size control schemes based on the Max chart to simultaneously monitor the mean and standard deviation of the process since the main disadvantage of the Max chart is that it is a single chart that is variably controlled. A single statistical graph is required; the design and operation of adaptive sample size schemes for this graph proved

![CUSUM Chart Diagram]

**Figure 2. Using a CUSUM Chart.**
simpler than the standard X and S graphs. The most dramatic improvement occurred when the two-
state scheme was compared to the graphs of the non-adaptive X and S joints (Huang, 2014). This
article uses an exponentially weighted average chart to illustrate integrated optimization techniques
that solve maintenance and quality control techniques. (Mahmoud, 2020) [5]. The research in [6]
discusses the perks, using np reduces the cost factor compared with other traditional charts. Towards
the end, they concluded that adequate and accurate implementation of np charts in a real-time
industrial scenario could prove to be beneficial in reducing cost and time to a great extent. (Ming Ha
Lee, 2020).

The findings in [7] state that the quality of any product in an industry can be described and evaluated
mainly based on the following:
1. Features
2. Reliability
3. Durability
4. Performance
5. Conformance to Standards.
The quality of design and conformance is also an important aspect that should be kept in mind while
analyzing quality control in manufacturing industries. (Montgomery, 2009) [7].

According to the literature review and case studies conducted in [8], Economic, social, cultural, and
technological factors) indicate that the company is subject to solid external influences; these external
forces impact Toyota’s organizational culture (Toyota Way), response to customers, responsibility,
and the inability to accept that Toyota is no longer a Japanese company and is managed by the
Toyota family. Executives, employee issues, and training, to name a few because they have had a
significant impact on Toyota’s failure or success. (Oyinkepreye Bebetidoh, 2015) [8].

Statistical Process Control run charts are utilized to the utmost full potential and validity during a
Quality Index project conducted by [9]. When utilized properly, a STATISTICAL PROCESS
CONTROL chart serves as a statistical tool for analyzing a process’s performance and a resource for
alerting the team about which interventions are likely to be beneficial and worth executing on a
bigger scale. (Patrick W. Brady, 2018) [9].

The article [10] they concluded that Most of the processes are within the control range, but the
sample shows a rapid decline over time, and it is mentioned that the process parameter vibration
alarm is not in a state of statistical control. (Patrik Flegner, 2020) [10].

The Weighted cumulative sum chart has potential uses for monitoring processes with different
arithmetic means because any researcher/industry worker can dynamically adjust weights based on
observations. Compared to other weighting functions, the wcom (et) - based weighting function can
take full advantage of the sample size and observed number. (Qin Zhoua, 2014) [11].

The study’s primary aim in [12] is to show how a systematic strategy to use Statistical Process
Control across the many phases of production of a specific “X” item in a plant to improve its
manufacturing processes may be applied. This strategy, which employs control charts, provides for
detecting faults in the company’s manufacturing process. Using the model made it possible to bring
what had been taught and learned in theory into reality and develop knowledge and learning by
overcoming the problems and challenges experienced at each phase of the Statistical Process Control
application (Radu Godina, 2016).

In [13], the researchers hybridized the np chart and synthetic chart to produce a Syn-np chart. While
the np control chart pointed out that np control charts are widely used to monitor non-compliance
percentage processes in manufacturing to determine quality characteristics, they found that Syn np
charts are more effective than standard NP control charts. (S. Haridy, 2011)

The paper presents the design algorithm optimizes the charting parameters of each np chart element
cumulative sum chart element and the detection power allocation between the two elements, resulting
in the best overall performance. As a result, it would be helpful to search for the optimal values of n
and h of an np- cumulative sum scheme for such applications as a future project. (Salah Haridy,
2013) [14].
The study aimed to analyze the production process of buff sausages in the food manufacturing business using statistical control charts. All of the sample points are inside the two-sigma control boundaries, as shown in the range chart. (Shrestha, 2020) [15].

The primary purpose of [16] The authors evaluated and compared the performance of the Variable sampling Interval (VSI) np control chart with average time to signal (ATS) properties. After knowing the process parameters, they evaluated them, and the results showed that the performance of the VSI np table was slightly different when testing the number of samples in Phase 1, and it was minimal. (Shu Wu, 2019)

If a quality improvement program focuses on lowering variability in product performance characteristics over time, the quality control system should use the PSD improvement data to detect process mean shifts immediately. The - X -LC chart operates well even in cases with a slight process mean shift due to the employment of the time-varying, i.e., When the Shewhart-X-NLC chart is used without taking into account the learning curve, it has essentially little detection ability (Wang, n.d.) [17].

The findings in [18] this paper presents an optimal algorithm for designing the np control chart. The document states that the optimization algorithm can be applied to concentrated samples, which are more suitable for manufacturers with large production. They concluded by stating that the optimization design is much smaller than any traditional np chart generated. (Wu, 2000)

The locational np chart is proposed in [19], which uses a two-lever inspection system to determine process status. Position information for a non-compliant unit in a sample is examined during the second level inspection Position np chart overcomes both np table errors by default, which is close to the value established for a given sample size. It gives the QA engineer more control over the design of an NP diagram and allows them to get a near minimal sum of false positives and non-compliant costs (WU, 2004) [19].

In [20], the cumulative sum chart is used and put forward in four different scenarios to keep the quality under control and manage small process changes reasonably. It showed that the Shewhart control chart combined with the cumulative sum chart could prove to be highly useful, especially for the managers of the organization who aim to keep the production process and maintenance department under perfect control in terms of quality and standards. (Y. Li1, 2017)

The study in [21] examines the impact of changes in production and control chart factors on the optimal maintenance plan, which provides an integrated model of manufacturing policy, maintenance strategy, and quality control. They also provide a quality control guide that uses a statistical non-compliance checklist to select an appropriate maintenance plan. (Zied Hajej, 2021).

3. Methodology

Figure 3 below depicts the methodology implemented in this research using the data obtained from the authorities.
3.1. Data collection

The data collection brings together data from all relevant sources to solve the research problem, test the hypothesis and evaluate the results. The data were collected to use various items from DAIMLER INDIA PVT LTD. Data were collected daily, with more than 200 samples per day, depending on production status, equipment status, and staff status. During the data collection, the data collected the day before was checked twice to rule out checking errors as far as possible. The data collected are shown in Table 1.

Quantitative data collection methods are used based on mathematical calculations and can be presented in different formats. Examples of quantitative data collection and analysis approaches include regression, mean, mode, and median methods. Open-ended systems, focus groups, observation, games or role play, case studies, and other qualitative data collection methods are used to ensure more profound understanding.

Table 1. Depicting the data of parts inspected and rejected on a particular day.

| Part Name          | Oil Filter Nipple | Circular Oblong | Chassis Brackets | Axe Bush | Centre Bolt Plate |
|--------------------|-------------------|-----------------|------------------|----------|-------------------|
|                    | Inspect ed        | Accept ed       | Inspect ed       | Accept ed | Inspect ed        | Accept ed |
| Time Slot          |                    |                 | Inspect ed       | Accept ed | Inspect ed        | Accept ed |
| 8-9 AM             | 215                | 213             | 639              | 630       | 29                | 29        | 58                | 58        | 33                | 33        |
| 9-10 AM            | 202                | 199             | 620              | 610       | 21                | 20        | 63                | 62        | 35                | 39        |
| 10-11 AM           | 212                | 211             | 641              | 630       | 35                | 34        | 66                | 66        | 34                | 34        |
| 11-12 AM           | 206                | 214             | 618              | 615       | 22                | 22        | 51                | 51        | 30                | 30        |
| 12-01 PM           | 233                | 221             | 626              | 620       | 26                | 25        | 55                | 24        | 40                | 40        |
| 01-02 PM           | 211                | 205             | 636              | 630       | 25                | 24        | 67                | 67        | 35                | 35        |
| 02-03 PM           | 226                | 221             | 631              | 628       | 38                | 37        | 69                | 69        | 32                | 32        |
| 03-04 PM           | 234                | 201             | 629              | 620       | 31                | 30        | 57                | 57        | 31                | 31        |
| 04-05 PM           | 222                | 211             | 630              | 629       | 27                | 26        | 60                | 59        | 36                | 36        |
| 05-06 PM           | 231                | 210             | 604              | 599       | 23                | 22        | 54                | 54        | 37                | 37        |
| 06-07 PM           | 208                | 207             | 602              | 598       | 37                | 36        | 59                | 59        | 38                | 38        |
| 07-08 PM           | 204                | 197             | 603              | 595       | 33                | 32        | 64                | 64        | 35                | 35        |
### 3.2. Data stratification

Classifying data, people, and objects into discrete groups or levels is known as stratification. It is a method for analyzing data that are utilized in conjunction with other technologies. The meaning of data can be challenging to see when data from several sources or classifications have been thrown together. One of the seven core quality tools, this data collecting, and analysis technique separates the data to see patterns. Typically, data is stratified in four ways. Who, what, where, and when are the four factors? Two elements are taken into account in this vehicle company’s study to check their method.

### 3.3. Data identification using NP chart

Stratification is the process of categorizing data, people, and objects into discrete groups or tiers. It is a technique for analyzing data that works in tandem with other technologies. When data from multiple sources or categories are thrown together, the significance of the data can be challenging to discern. One of the seven core quality tools, this data collection, and analysis approach isolates the data to see patterns. Data is typically stratified in four ways. The four factors are who, what, where, and when. This automobile company’s study considers two factors in order to validate its strategy.

Components that have been inspected vs. parts that have been accepted and time slots are the two variables. There were seventeen samples with three sample sizes recorded at different time windows in the data collection. MS-OFFICE 2017 edition was used to plot the charts and do the calculations in this research.

For np chart:

\[
p = \frac{\text{Rejected parts}}{\text{Inspected parts}}
\]

\[
p' = \frac{\sum(\text{Rejected parts})}{\text{Inspected Parts}}
\]

\[
\sigma = \sqrt{p' \times (1 - p') / \text{Inspected parts}}^{[5]}
\]

\[
\text{UCL} = p + 3\sigma
\]

\[
\text{LCL} = p - 3\sigma
\]

### 3.4. CUSUM chart designing to know precise defect causing point

The primary purpose of the CUSUM control chart is to keep the process online. The “cumulative sum” for this type of graph is the sum of the deviations from the target of the results of individual samples or mean values of subgroups. The CUSUM control chart illustrates these cumulative deviations over time and shows when the process is “out of control” or, in this case, clearly deviating from the target.

For Cumulative Sum chart:

\[
\text{Mean (µ)} = \frac{\text{Accepted samples (Xi)}}{\text{Total number of Time slots}}
\]

\[
\text{LCL} = \mu - 3\sigma
\]

\[
\text{UCL} = \mu + 3\sigma
\]

\[
H = 5\sigma
\]

\[
\mu_1 = \mu + n\sigma
\]

\[
K = \frac{(\mu_1 - \mu)}{2}
\]

\[
C_i^* = \max [0, \mu + (\mu + K) + C_{i-1}]
\]

\[
C_i = \max [0, (\mu - K) - \mu_1 + C_{i-1}]
\]

### 3.5. Removing & Segregating the defect causing point

Manufacturing flaws can occur themselves in quite a few methods in manufacturing, main to product recollects everywhere in the world. The automobile enterprise suffers from the identical defective
problem. Human or operator adjustments in manufacturing settings, composition percent adjustments, fabric distribution, and environmental elements should all be reasons for those production failures.

Manufacturing flaws can occur themselves in quite a few methods in manufacturing, main to product recollects everywhere in the world. The automobile enterprise suffers from the identical defective problem. As a result, the manipulate chart has ended up our crucial tool for reinforcing the enterprise’s pleasant methods. Table 1 suggests the results. Data stratification is the method of showing all the records acquired from the enterprise in a tabular format. There are quite a few elements produced there; however, it was checked out that the oil clear-out nipple for pleasant manipulates purposes during the research.

4. Results & Discussions

After taking the data of all the products manufactured on a particular day, only a singular product, i.e., oil filter nipple (Table 2), was considered for further calculation. The reason was simple to have a simplified answer within a given time frame, and the procedure to calculate the result for each procedure is the same only.

As stated in the literature review, to detect the defect in any production and remove it, control charts are one of the best tools, and for that exact purpose, np charts and cumulative sum charts were used here.

| Time Slot   | No of Parts Inspected | No. of Parts Accepted |
|-------------|-----------------------|-----------------------|
| 12-01 AM    | 200                   | 196                   |
| 9-10 AM     | 202                   | 199                   |
| 07-08 PM    | 204                   | 197                   |
| 11-12 PM    | 206                   | 214                   |
| 06-07 PM    | 208                   | 207                   |
| 01-02 PM    | 211                   | 205                   |
| 10-11 AM    | 212                   | 211                   |
| 09-10 PM    | 213                   | 207                   |
| 08-09 PM    | 215                   | 213                   |
| 10-11 PM    | 217                   | 215                   |
| 04-05 PM    | 222                   | 211                   |
| 08-09 PM    | 224                   | 221                   |
| 02-03 PM    | 226                   | 221                   |
| 11-12 AM    | 229                   | 220                   |
| 05-06 PM    | 231                   | 210                   |
| 12-01 PM    | 233                   | 221                   |
| 03-04 PM    | 234                   | 201                   |

After collecting the data, data stratification was done, designing a scatter diagram (Figure 4). This scatter diagram gave us an idea of how much variation was between the total number of parts inspected and the total number of parts inspected. The result, as shown in the figure, is quite clear that the variation was somewhat more significant as only 24% of the total parts produced were closer to the line proving that the precision of production versus acceptance is relatively low, and that is undoubtedly a factor that needs to be considered. Moreover, in the day, nearly 134 products were defective out of produced 3695 products.
Table 3. Depicting the data of oil filter nipples inspected on a particular day with the lowest and highest slots.

| Time Slot | No of Parts Inspected |
|-----------|-----------------------|
| 8-9 AM    | 215                   |
| 9-10 AM   | 202                   |
| 10-11 AM  | 212                   |
| 11-12 PM  | 206                   |
| 12-01 PM  | 233                   |
| 01-02 PM  | 211                   |
| 02-03 PM  | 226                   |
| 03-04 PM  | 234                   |
| 04-05 PM  | 222                   |
| 05-06 PM  | 231                   |
| 06-07 PM  | 208                   |
| 07-08 PM  | 204                   |
| 08-09 PM  | 224                   |
| 09-10 PM  | 213                   |
| 10-11 PM  | 217                   |
| 11-12 AM  | 229                   |
| 12-01 AM  | 200                   |

Then moving ahead to get an idea of at what time the production was at peak and when it was lowest frequency chart (Figure 5) was designed, another factor behind designing it was that most of the times it happens that when the production capacity is at peak chances are high that defects are produced at that particular time rather than focussing on the shift where fewer parts were produced. With this, the data stratification gets over. Then major work begins that is to find out defect causing shifts initially np chart is taken into consideration, the reason being np charts are the charts that show the points which are above the upper control limits and below lower control limit in a single go, and that gives us a rough idea of which process to keep and which not in order to improve the quality of production.
Figures 5. Depiction of the frequency distribution chart of the oil filter nipple.

Here for the np chart calculation, first, the ratio of total rejected part and inspected part was calculated (refer to table 4), and then its sum gave us p bar, which was further used for sigma calculation (standard deviation) the value of p came to be 0.036265.

Then standard deviation was calculated for each shift individually with the formula:

$$\sigma = \sqrt{p \cdot (1-p)} / \sqrt{\text{Inspected parts}}$$

Moreover, as one can see, the value came out to be either 0.012 or 0.013, the value of 3σ was calculated. This 3σ helps calculate the control limits of the particular process now for calculating the control limits’ p, i.e., the ratio of accepted parts and inspected parts need to be calculated individually and also this ‘p’ acts as the mean Control limit or only control limit in the process, moving ahead after calculating CL the upper control limit is calculated with the formula p+3σ for all process individually. The lower control limit is calculated by p-3σ now in np charts value should always be positive; therefore, the values of lower control limit were negative was converted by default to 0. From the calculated table, one can notice that the process that was highest among the LCL is highlighted in red, and the process with the highest UCL was highlighted in the yellow mark.

After this, the np chart was designed using Microsoft Excel (Figure 6), and after creating it, the idea of which process is out of control was not visible as every process was confined accurately within the prescribed upper and lower control limits.

Table 4. Depicting the Np chart calculation along with the process that had negative p-3σ (marked in red) and process that has highest p-3σ (marked in yellow)

| Time Slots  | Inspected Parts | Accepted Parts |Rejected Parts| σ    | 3σ     | p     | p+3σ  | p-3σ  | p-3σ  |
|-------------|----------------|----------------|--------------|------|--------|-------|-------|-------|-------|
| 8-9 AM      | 215            | 213            | 2            | 0.013| 0.038  | 0.009 | 0.047 | 0.000 | -0.029|
| 9-10 AM     | 202            | 199            | 3            | 0.013| 0.039  | 0.015 | 0.054 | 0.000 | -0.024|
| 10-11 AM    | 212            | 211            | 1            | 0.013| 0.038  | 0.005 | 0.043 | 0.000 | -0.034|
| 11-12 PM    | 214            | 206            | 8            | 0.013| 0.038  | 0.037 | 0.076 | 0.000 | -0.001|
| 12-1 PM     | 233            | 221            | 12           | 0.012| 0.037  | 0.052 | 0.088 | 0.015 | -0.015|
| 1-2 PM      | 211            | 205            | 6            | 0.013| 0.038  | 0.028 | 0.067 | 0.000 | -0.010|
| 2-3 PM      | 226            | 221            | 5            | 0.012| 0.037  | 0.022 | 0.059 | 0.000 | -0.015|
To get the exact picture, a cumulative sum chart or CUSUM chart was taken into consideration; CUSUM chart is generally used to detect the defects through small shifts, the primary mechanism behind it is that it utilizes the cumulative sum of deviations from a target then it plots the same for individual measurements so that the point or shift where the defect is there can be identified and can be separated to enhance the quality of produced goods. For that, initially, the mean of accepted samples was calculated that came around 209.5 (Table 5) that also acts as the control limit (CL), now the next thing is to subtract the calculated mean with the accepted sample data of each shift individually and then for Cumulative Index the first value is calculated by subtracting accepted samples with control limit after that the cumulative sum of the accepted sample minus mean is calculated. Based on the findings, the data is tabulated, and then the cumulative sum chart is constructed (Figure 7) with accepted sample and upper control limit, lower limit, and control limit.

Figure 6. The NP chart of oil filter nipple
Table 5. Depicting the calculated CUSUM chart calculations with processes that need to be eliminated

| Time Slots | Accepted Samples (XI) | XI-209.5 | CI  | CL       | UCL       | LCL       |
|------------|-----------------------|----------|-----|----------|-----------|-----------|
| 8-9 AM     | 213                   | 3.5      | 4.1 | 209.5    | 212.5     | 206.5     |
| 9-10 AM    | 199                   | -10.5    | -7.0| 209.5    | 212.5     | 206.5     |
| 10-11 AM   | 211                   | 1.5      | -5.5| 209.5    | 212.5     | 206.5     |
| 11-12 PM   | 206                   | -3.5     | -9.0| 209.5    | 212.5     | 206.5     |
| 12-1 PM    | 221                   | 11.5     | 2.5 | 209.5    | 212.5     | 206.5     |
| 1-2 PM     | 205                   | -4.5     | -2.0| 209.5    | 212.5     | 206.5     |
| 2-3 PM     | 221                   | 11.5     | 9.5 | 209.5    | 212.5     | 206.5     |
| 3-4 PM     | 201                   | -8.5     | 1.0 | 209.5    | 212.5     | 206.5     |
| 4-5 PM     | 211                   | 1.5      | 2.5 | 209.5    | 212.5     | 206.5     |
| 5-6 PM     | 211                   | 0.5      | 3.0 | 209.5    | 212.5     | 206.5     |
| 6-7 PM     | 207                   | -2.5     | 0.5 | 209.5    | 212.5     | 206.5     |
| 7-8 PM     | 197                   | -12.5    | -12.0| 209.5    | 212.5     | 206.5     |
| 8-9 PM     | 221                   | 11.5     | -0.5| 209.5    | 212.5     | 206.5     |
| 9-10 PM    | 207                   | -2.5     | -3.0| 209.5    | 212.5     | 206.5     |
| 10-11 PM   | 215                   | 5.5      | 2.5 | 209.5    | 212.5     | 206.5     |
| 11-12 AM   | 220                   | 10.5     | 13.0| 209.5    | 212.5     | 206.5     |
| 12-1 AM    | 196                   | -13.5    | -0.5| 209.5    | 212.5     | 206.5     |
| TOTAL      | 3561                  | -0.5     |     |          |           |           |

Mean (µ) = 209.5 = CL; σ = 1; UCL = µ + 3σ = 212.5; LCL = µ - 3σ = 206.5

Figure 7. The CUSUM chart of oil filter nipple
The values of shifts that lie outside the upper control limit are highlighted in yellow, and those below the lower control limit are highlighted in red. That process is removed, and then again, the cumulative sum chart is designed with modified data (Figure 8); the modified data is taken after removing the out-of-control limits (Table 6). Now the same procedure that includes calculating the mean that came around 208.7 and then subtracting the calculated mean with the accepted samples and then calculating the cumulative frequency and then calculating the upper control limits and lower control limits for individual shifts and then tabulating it and then finally designing a modified cumulative sum chart is done. It is applied once again to check whether the process is within the limit or not. The findings found that all the processes were within the control limits and that the process now was defect-free.

Table 6. Depicting the modified cumulative sum chart calculations

| Time Slots  | Accepted (XI) | XI-208.7 | CI  | CL  | UCL | LCL  |
|-------------|---------------|----------|-----|-----|-----|------|
| 10-11 AM    | 211           | 2.3      | 3.0 | 208.7| 211.7| 205.7|
| 11-12 PM    | 206           | -2.7     | 0.3 | 208.7| 211.7| 205.7|
| 4-5 PM      | 211           | 2.3      | 2.6 | 208.7| 211.7| 205.7|
| 5-6 PM      | 210           | 1.3      | 3.9 | 208.7| 211.7| 205.7|
| 6-7 PM      | 207           | -1.7     | 2.2 | 208.7| 211.7| 205.7|
| 9-10 PM     | 207           | -1.7     | 0.5 | 208.7| 211.7| 205.7|
| TOTAL       | 1252          | 1043.3   |     | 208.7|     |      |

Mean(µ)= 208.7
CL= 208.7
UCL=µ+3σ= 211.67
LCL=µ-3σ= 205.7

Figure 8. The modified CUSUM chart of oil filter nipple.

By chance, if the control limit had exceeded this process, this procedure would have continued until all the processes were within the control limits.

Now since all the out of control process shifts were separated, these given shifts are the process that would provide quality products with 100% defect-free and that if the out of control limits would have
been forecasted in the np control chart itself, then the cumulative chart would not have been used extensively moreover in place of np chart, p chart could also have been used to detect non-conforming units, but then it would have just shown the proportion of non-conforming units rather than an actual process where non-conformities are happening.

5. Conclusion
The primary aim of this research is to remove the defect causing shifts after identifying it, and that was achieved completely using various statistical quality control tools like Np charts and cumulative sum charts. Moreover, this research analyzes only a single factor, i.e., Oil filter nipple, to get a rough idea of how effective the control charts are. The same can be applied to all the products manufactured in the industry for more precise and accurate results. Though one can argue that the np chart failed to confine the results due to which cumulative sum chart was considered, the cumulative sum chart required specific iterations and time to confine to an optimal result. That can be considered a disadvantage here, but that thing can be solved with more advancements and more accurate computerized methods in the future. Apart from that, one can doubt why the exponentially weighed Average chart (EWMA) was not used to detect the non-conformities in small shifts; EWMA cannot predict Cumulative Sum charts precisely. Also, the Shewhart chart has the same disadvantage: it cannot detect small shifts, and here the actual non-conformities were detected only through small shifts. Shewhart charts are way too high sensitive to significant process shifts and add to it the probability of precisely detecting small shifts non-conformities is relatively tiny, so cumulative sum chart was taken into consideration. Also, one must note that from a future perspective cumulative sum chart with computerized methods will be used more regularly than today as it provides instant and accurate results, and with the recent advancements in Cumulative sum charts like V- mask Cumulative sum chart, it obtains a more accurate, and new advancements like combining the Shewhart chart with cumulative sum chart to provide the advantages of both and providing better results will surely help to use cumulative sum charts more extensively indeed aims to increase the quality of production in the long run. [22-28]

Conflict of Interest
The authors declare no conflict of interest. Due permission was taken from the concerned authorities of Diamler India.

Contributions
TP, and SKr: conceptualization, methodology, software, and formal analysis. UC: validation, supervision, project administration. TP, and SKr: investigation. TP, SKr, and UC: resources and data curation. TP, SKr, and UC: writing—original draft preparation. TP, SKr, and UC: writing—review and editing and visualization. All authors have read and agreed to the published version of the manuscript.

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