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Case Study

Impact of Quality Control Tools for improving Manufacturing Performance

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I N F O

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A B S T R A C T

The purpose of this study is to elaborate on the use of two out of seven QC tools of the quality management system to reduce rejection during operational and production stages in a car manufacturing company in northern India. After observing the process, it has been found that the tilting effort defect was causing major rejection, i.e., 26% rejection rates were observed. An eight-step methodology has been adopted to overcome the procedure of reducing quality rejection by defining the problem and removing the root cause of the problem using quality control tools, viz. the Pareto chart and run chart. Locking control of 2 nuts used in the steering wheel was achieved by the root cause analysis technique. Descriptive statistics (before and after root cause analysis) have been calculated, and validation of overall improvement is done by a two-tailed paired-sample t-test. With reduction in rejection, annual savings of 84000 rupees per annum have been made (rework cast savings of 7000 rupees per month). Finally, standard operating procedure has been prepared so that it becomes error-proof.

Keywords: QC Tools, Rejection, Pareto Chart and Cost Saving

Introduction

The continuous improvement approach aims at quality improvement through effective leadership and collective efforts of a team of experts from different departments of the organisation. Quality control tools are used in every stage of production, from product development to customer support (Keller, 2005).[1] The quality improvement cycle, namely the PDCA cycle, helps to know the utilisation of quality tools at different stages of production and assembly (Paliska et al., 2007).[2] In production and manufacturing processes, quality control tools are employed to get maximum output from labour and continuous improvement of the manufacturing system (Sokovic et al., 2007).[3] Quality tools help to predict optimum production schedules and reduce scrap by analysing the root cause of the problem (Jabnoun, 2002).[4] Process capability, variation in the process and the root cause of the problem are measured with the help of QC tools (Ercan, 1987).[5] Figure 1 shows the use of quality tools in the PDCA cycle of continuous improvement.

Growing competition in the global market has captured the need for continuous evaluation of manufacturing system processes. Organisations are searching for a competitive edge due to growing customer desires and needs. QC tools evaluate and measure the performance of the process to improve the quality by incremental changes and support decision-making (Besterfield et al., 2003).[6] Increased market share, productivity improvement and customer loyalty are different benefits of implementing quality control tools in the manufacturing industry (Gitlow and Levine, 2009).[7] This study attempts to achieve the following objectives:

- To implement QC tools in manufacturing operations.
- To assess the important benefits of practical implementation of QC tools.
- To standardise the operating procedure of processes.

The rest of the chapter is as follows. The second section includes an exhaustive literature review, the third section includes detailed implementing steps of QC tools in the form of results and discussion, and finally, the conclusion, practical implications and limitations are presented.

Literature Review

The output of the processes can be brought to statistical stability by engineering and management interventions (Montgomery, 2005).[8] The quality management system is maintained by managing and monitoring the quality tools in manufacturing system processes. Seven tools are used to monitor quality, including check sheets, flow charts, cause and effect diagrams, scatter diagrams, histograms, control charts and Pareto charts (Ott et al., 2000).[9] In order to ensure small improvement activities in the PDCA cycle, the quality insurance management procedure has to be followed step by step to achieve high customer satisfaction (Kitchenham and Pfleeger, 1996).[10] Figure 2 shows the process of achieving total quality management in an organisation.

In controlling the quality of a product, three elements should be properly explained as follows:

- Clear defining of quality goals.
- Status of implementation of tools and techniques of continuous quality improvement.
- Measures should be defined to take actions on poor quality defects (Parnas, 1994).[11]

There is a dynamic development of the process improvement approach of manufacturing companies, and this approach integrates ways of achieving quality, quality management systems and the mechanism of TQM (Feigenbaum, 1983).[12] Figure 3 shows the standard procedure of preventing defects in TQM.

Quality tools are implemented by manufacturing organisations to meet the long-term objectives. Strategies are planned to overcome the quality- or defect-related issues. Monitoring- and evaluation-related issues are also talked about by QC tools. Action and thinking companies should think of a process which is to be included in quality management systems (Patel et al. 2001).[13] The aim of such tools is to eliminate waste and human error, resulting in quality rejection. Each process is monitored by a quality management system through quality control techniques. Monitoring and analysis of the root cause of defects is done using QC tools in a systematic manner. Information gathering about emerging deficiencies is also the aim of the quality management system (Hwang and Lin, 1987).[14] Before shipment of product to customer, inspection has to be done to remove the defective products. Monitoring and controlling the processes is also the main function of the quality management system through the use of a statistical control chart (Lee et al., 2000).[15] QC tools are the scientific methods for analysing the manufacturing data. Based on data, measures are taken to reduce defects for improving the customer relationship and capability of the process (Wyckoff, 1984).[16]

Results and Discussion

Step 1: Selection of Problem (Theme)

From the rejection data for the month of December 2023 of XYZ company of Northern India, it has been found that the tilting effort of the steering column was high, i.e., 16 to 28 kgfm (preoperational 78% of vehicles were found to have a high tilting effort), and was causing rejection rates of 26%. A core committee, including managers and assistant managers of different departments, has been established to overcome the technical defect. Figure 4 showing titling effort of the steering column manufactured.

The selection of the critical process is done on the basis of the following points:

- Establish the place of improvement (steering wheel of the car).
- Make sure the issue name shows what is to be done and its purpose (reduction of tilting effort).
- Express things in terms of results rather than in terms of methods (hypothesis testing).
- Do not confuse solutions with problems (corrective actions).
- Express things clearly: Use “action” verbs (standard operating procedure).

The theme/concern must meet the following conditions:

- Highly necessary and required by all.
- Difficult but possible.
- Related to the division and department’s policy and objectives/targets.
- Be common to all group members.
- Allow the group’s level of practice/skills to improve.

Step 2: Justification of the problem

In this step, justification of the problem has been done by taking a reading of tilting effort by using a digital push-pull meter. Figure 5 shows the trend graph, occurrence and severity of the problem.

Further, Descriptive statistic has been calculated using SPSS software which signifies high deviation from mean as shown in Table 1.

While selecting the targets and problems for this study, the following points are looked into:

- Produce benefits outweighing the costs and efforts required to achieve them.
- Be important enough to create motivation.
- Be attainable (to avoid discouragement).
- Be verifiable – to see whether they have been attained or not.
- Be accepted and believed in by all parties involved.
- Their link with other departments must have been carefully considered.

Step 3: Understanding of current situation

The reasons for the high tilting effort have been checked at every stage of manufacturing and in the finished product. The following stages have been checked:

- Before mounting the column in CCB, the tilting effort is found within specification.
- After pre-tightening of the right bolt of the column on the CCB, the steering effort was found to be within specification.
- After tightening of two bolts on CCB, steering tilting effort was shooting up above specification.

For understanding the question in hand, the following points are taken into account.

- The search for possible causes is not the actual analysis but the first step in analysis.
- A maximum number of opinions must be obtained when searching for causes.
- If on-site experience or testing to select causes is possible, test and confirm their degree of influence.
- Repeat "Why?" at least five times when searching for root causes.
- Select the corrective actions and classify them in order of feasibility, impact on other processes, safety, cost, effect, delay, etc.
- Do not attempt to find all possible causes; the important thing is action.

Step 4: Observation of Symptoms and Variations

Various symptoms of the tilting effort have been observed in this step. The assembly sequence has been followed. The process of observation has been shown in Table 2.

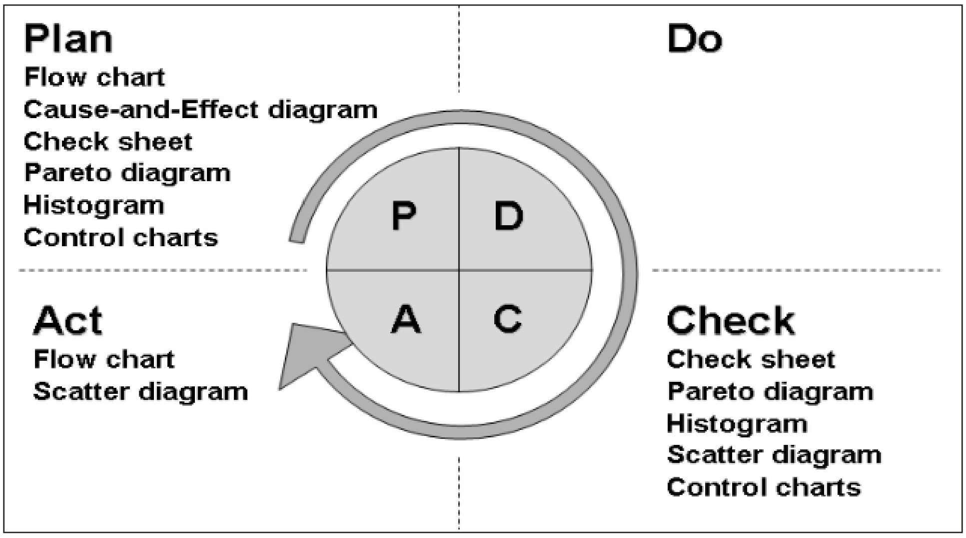

Figure 1.Use of quality tools in PDCA cycle of continuous improvement (Source: Booker, 2003)[17]

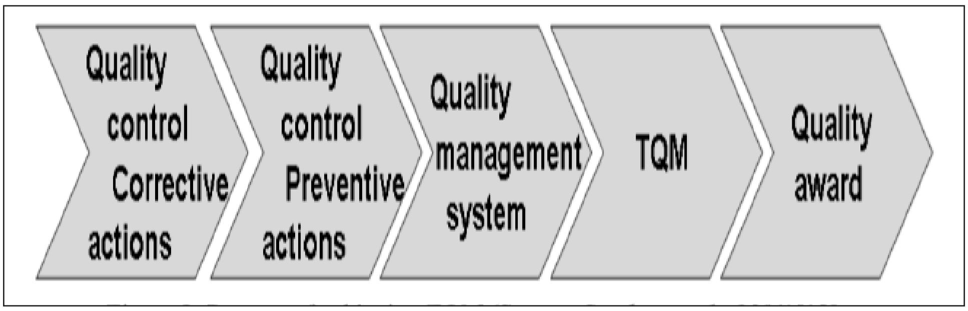

Figure 2.Process of achieving TQM (Source: Stephen et al., 2001)[18]

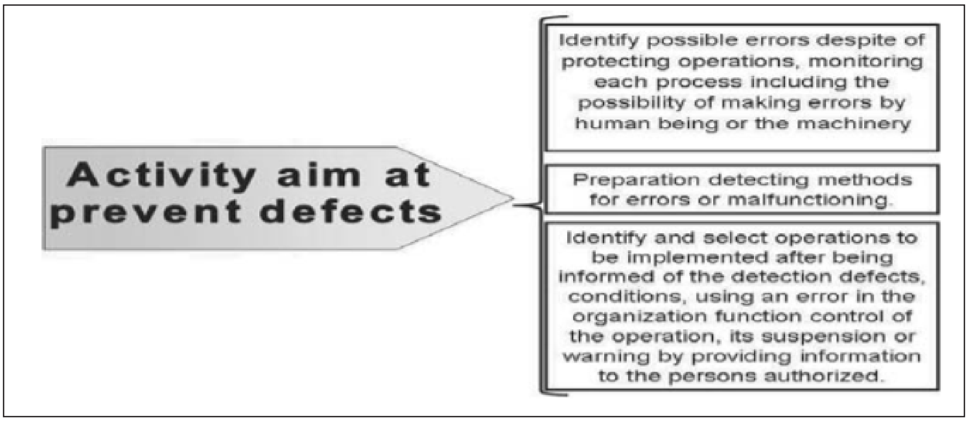

Figure 3.Process of preventing Defects (Source: Dudek-Burlikowska and Szewieczek, 2008)[19]

Figure 4.Tilting of steering column

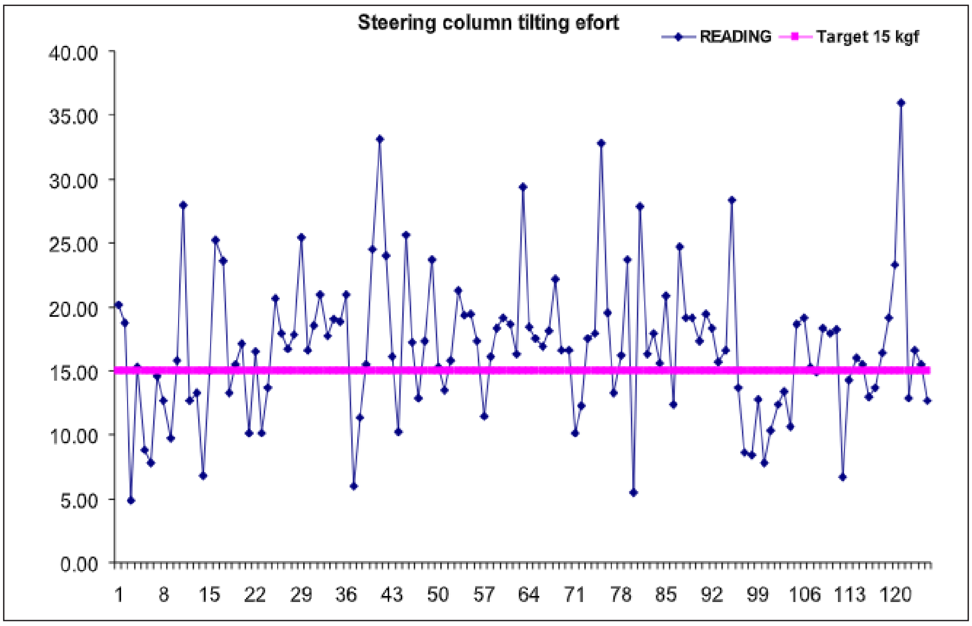

Figure 5.Trend of tilting effort

Table 1.Descriptive statistics for tilting effort

Descriptive statistics- Before	
Mean digital push pull meter	16.84864
Standard Error	0.498816319
Median	16.6
Mode	19.17
Standard Deviation	5.576935993
Sample Variance	31.10221507
Kurtosis	1.282910755
Skewness	0.63284792
Range	31.14
Minimum	4.86
Maximum	36
Sum	2106.08
Count	125

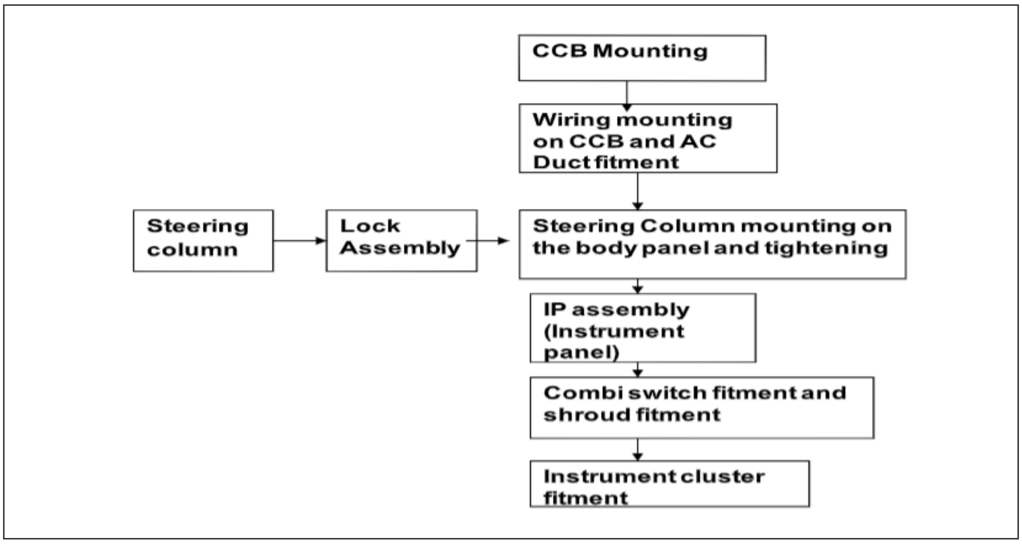

Figure 6.Process Observation Procedure 1

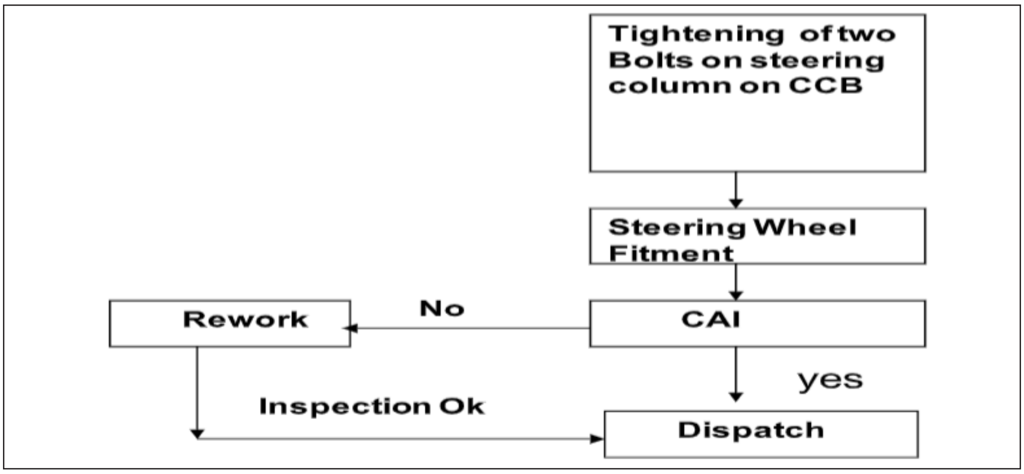

Figure 7.Process Observation Procedure 2

Figure 8.After placing Steering column on dash panel right side bolt of CCB is pre

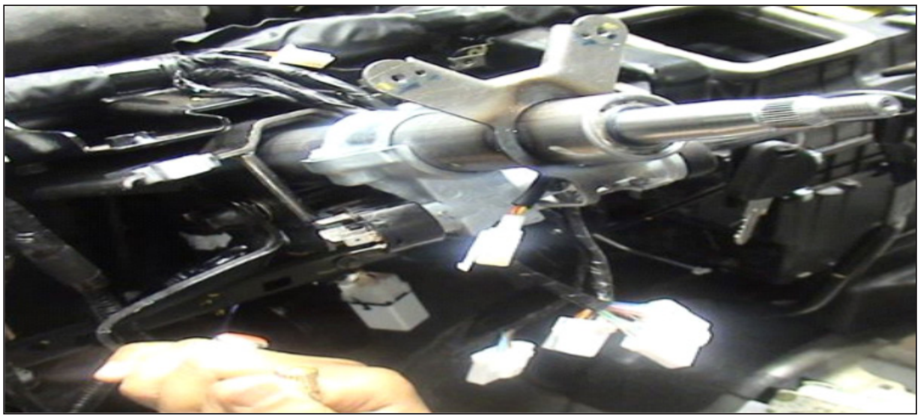

Figure 9.Steering lever opened for product left side bolt (Open condition)

Table 2.Observation of assembly sequence

<table>
<tr><th colspan="3">Existing</th></tr>
<tr><th>Sr. No</th><th>Process</th><th>Stage</th></tr>
<tr><td>1</td><td>Place the column in position</td><td rowspan="5">1</td></tr>
<tr><td>2</td><td>Tighten four nuts on the fire wall to clamp lower end of the column</td></tr>
<tr><td>3</td><td>Open the tilt lever</td></tr>
<tr><td>4</td><td>Assemble the connector of Wiring Harness</td></tr>
<tr><td>5</td><td>Assemble AC Ducts, Fuse Box etc</td></tr>
<tr><td>6</td><td>Tighten the bolts of tilt bracket (Upper End)</td><td>2</td></tr>
</table>

Further, variations have been observed at production and assembly level for different processes as shows in Table 3.

Step 5: Identification of Root Cause

The brainstorming has been done to identify the cause of the tilting effort observed in the steering assembly. Figure 10 shows the root cause of the problem.

- Not locking 2 bolts on CCB without opening the lock lever of the steering column.
- Verification of the following dimensions in the steering column. Flatness of injection casting w.r.t. bracket. (Not mentioned in drawing.) Flatness and parallelism of CCB bracket. (Not mentioned in drawing).
- Verification of the following dimensions in the steering column. Dim. 387 ± 1 mm, Angle 33 deg. Dim. 54 and Dim. 106 ± 0.5 mm.
- Co-ordinates of CCB mounting bracket.
- Gap between outer bracket and inner bracket of steering column in unlock condition.

- Co-ordinates of CCB mounting bracket after assembly in body.
- Co-ordinates of the dash panel to the steering mounting bracket.

Step 6: Testing of Hypothesis and corrective actions taken

The t-test has been applied to justify the significance of the root cause of the problem.

Testing of Hypothesis (T-test method)

A t-test can be used to test whether there is a difference between two population or process means. It is a useful method to test a root cause hypothesis when the X factor represents two categories.

So we are using the T-test for the process mean, as shown in Table 5.

Statement

H0- After the process change, the process mean is not shifted (mean = 17.15).

Ha – There is a significant difference in process mean (mean <= 17.15).

The actions taken are based on the following points:

- Consider various probable actions
- Ensure that probable action selected does not create side effects.
- Before implementation, decide on the role of each member and a schedule.
- Assign each corrective action a priority and stick to it.
- Involve the operators.
- Do things yourself; the approach will be all the more concrete!
- More than half of the corrective actions will require changes to be made: tests and checks are extremely important when implementing corrective actions.
- Confirm the effect using the same method and same observer.
- The use of colour, limits, graphics, and instructions at the place where the corrective measure is to be applied are effective means of drawing attention to it.

Step 7: Data collection after implementing corrective actions

Descriptive statistics have been calculated after implementing corrective actions, which show that the mean and standard deviation are low as compared to before the data. Table 8 shows the descriptive statistics (after improvement).

Table 3.Observation of Variations

Sr no	Trials	1	2	3	4	5	6	7	8	9	10
1	Keeping body Mounting bolt tight (Dash panel) -10 nos										
	a) In loose condition of CCB mtg. Bolt , Effort Found	9.2	10.6	10	9.6	8.7	9.3	10.1	9.4	10.5	8.3
	b) After Tightening only left bolt on CCB , Effort Found	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
	c) After tighten right Bolt on CCB effort found	18.6	>20	>20	>20	>20	>20	>20	>20	>20	>20
2	Putting 1 mm plain washer Below CCB , behind the two Mtg bolt - 10 nos										
	Effort found after tightening	14.6	16.7	15.8	13.9	18.7	14.1	15.5			
		14.6	16.7	15.8	13.9	18.7	14.1	15.5			

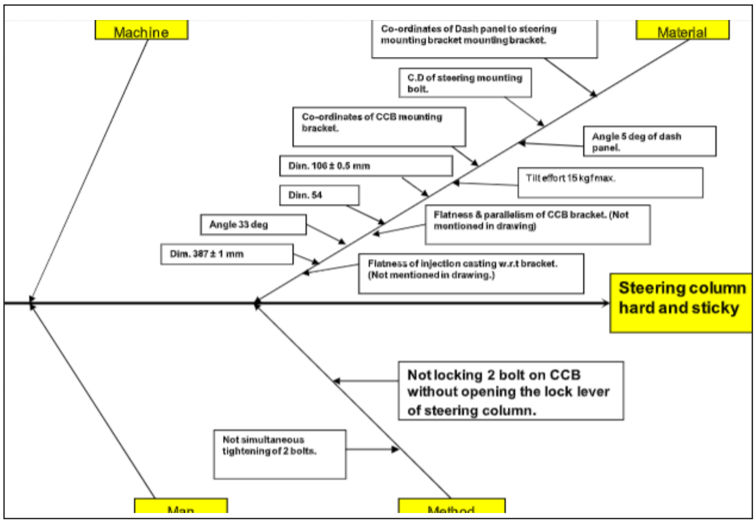

Figure 10.Root cause of the variation in tilting effort

Table 4.shows the root cause of the problem

No	Probable Cause	Testing and Observations	Conclusion
1	Not Locking 2 bolts on CCB without opening the lock lever of steering column.	Locking of 2 bolts on CCB without opening the lock lever of steering Column, result was found as follows. After action implementation 75 nos of vehicles are checked. Total Preoperational 12 % vehicles found tilting effort more than 15 kgfm.	Hypothesis valid. 55 % improvement is observed with change of process.
2.	Verification of following dimensions in steering column. 1.Dim. 387 ± 1 mm 2.Angle 33 deg 3.Dim 54 4.Dim. 106 ± 0.5 mm	All dimensions are observed within range.	Hypothesis invalid.
3.	Co-ordinates of CCB mounting bracket	Co-ordinates of CCB mounting bracket as per CMM report is ok. Acceptance fixture Gauge is available (Supplier Visit is completed as per plan.)	Hypothesis invalid
4.	Co-ordinates of Dash panel to steering mounting bracket mounting bracket	All coordinates are observed within range.	Hypothesis invalid.

Table 5.T-Test

Before	
Mean	17.15
Standard Deviation	5.59
After	
Mean	11.65
Standard Deviation	2.36

Table 6.Preventive and Corrective Actions Taken to reduce problem

Root Cause	Action Plan
Not Locking 2 bolts on CCB without opening the lock lever of steering column.	1. Locking 2 bolts on CCB without opening the lock lever of steering Column. We are monitoring this action for two month. 2. SOP to be displayed on line indicating Locking 2 bolts on CCB without opening the lock lever of steering column.

Table 7.Corrective Actions Taken

Modified Process		
Sr.No	**Process**	**Stage**
1	Place the column in position	1
2	Lock lever kept in closed condition (in upward direction) during pre tightening of bolt. Pre tighten the two bolts in CCB.	
3	Tighten the 4 bolts in dash panel.	
4	(lock lever position is in close condition) Tighten the two bolts in CCB	2
5	Open the lock lever if required.	2

Table 8.Descriptive statistics after implementing corrective actions

Descriptive statistics- After	
Mean	11.1226087
Standard Error	0.247565941
Median	10.6
Mode	11.2
Standard Deviation	2.654848952
Sample Variance	7.04822296
Kurtosis	1.505019624
Skewness	-0.087601712
Range	17.41
Minimum	0.24
Maximum	17.65
Sum	1279.1
Count	115

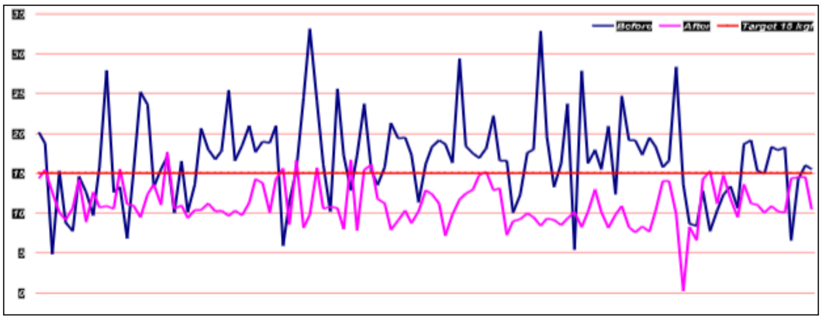

Figure 11.Carry out full scale implementation – Run Charts Before and After

Two-sample T for after vs before

	N	Mean	StDev	SE Mean
after	75	11.65	2.36	0.27
before	75	17.15	5.59	0.65

Difference = mu after - mu before

Estimate for difference: -5.495

95% upper bound for difference: -4.336

T-Test of difference = 0 (vs <): T-Value = -7.85, P-Value = 0.000, DF = 148

Both use Pooled StDev = 4.29.

Conclusion

P is less than 0.05; hence, reject Ho.

Step 8: Standardisation

The standardisation of the process is done by following procedure:

Updation of Documents

- SOP (standard operating procedure) is modified.
- Process audit checklistmodified.

Training

- Operators at in-house assembly stages are trained for modified SOPs.
- Train people on new/modified SOP
- Train people to modify / develop SOS

Additional Audit/Check

- As the process audit checklist checking is carried out.
- Daily verification of process by Manufacturing Quality Assurance.
- Carry out additional audits/checks to ensure adherence to the new system and monitor results achieved.

Conclusions and Limitations

Results of the investigation demonstrated that QC tools help to predict the optimal solution by root cause analysis. By making small changes, large output can be ascertained. The illustration of 2 QC tools, viz. the Pareto chart and run chart, in specific condition for the process has been done. Results indicate a 26% reduction in rejection (tilting effort problem) with the net savings of 84000 rupees per annum having been achieved. After the root cause analysis process is standardised to make it error-proof. The negative statement of the hypothesis is rejection in the t-test, which signifies there is a significant difference in the process means of improvement before and after implementing QC tools. Process modification is done based on brainstorming operation by taking corrective actions. Modification is done without changing the design attributes, which may cause method variance. Moreover, selection of the manufacturing industry has been done on convenience sampling.

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