Reducing soldering defects in mobile phone manufacturing company: A DMAIC approach

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Abstract. A DMAIC (an effective tool) approach has been presented in this paper for reducing defects in soldering in an endeavor to approach six sigma quality level in a mobile phone manufacturing company. DMAIC helps expose and kill the root causes of defects in the process and thereby helps achieve higher customer satisfaction by means of improved quality. The case study was conducted in an electronics manufacturing industry engaged in an assembly of mobile phones. Post successful implementation of Six sigma - DMAIC in the assembly processes, ppm defectives dipped from 3800 to 200, which is a massive 94.74 percent reduction in ppm defectives.

Keywords: Six Sigma, Quality Control, DMAIC, Drag soldering, Defects, Mobile phone, Manufacturing, ppm

1. Introduction
Fierce competition these days, has made imperative for all the manufacturing industries to bring down their various types of waste. Minimizing wastes gives an industry unparalleled and distinctive edge over its rivals because it clearly shows how the former uses its diverse resources way more efficiently. Working on getting rid of these eight wastes of manufacturing viz. defects, over production, waiting time, non-utilized talent, transportation, inventory, motion and extra-processing are what turns a company into lean. Putting lean principles into action has its own rewards of making a company productive, profitable, better in terms of quality and hence achieve customer satisfaction.

Among these eight, one of the most unsought yet noteworthy waste materializes in the form of defects. This is where Six Sigma methodology comes to rescue and makes a company run lean by minimizing the ppm defectives. DMAIC stands for Define, Measure, Analyse, Improve and Control, and is a six-sigma tool used to define a problem onto a paper, scrutinize root causes of the defects and then control them by exercising manifold improvements in the process. In simpler words, DMAIC helps expose and kill the root causes of defects in the process and thereby helps achieve higher customer satisfaction by means of improved quality. Though it provides a sequence of well-oiled steps to check waste, a precise combination of approach, direction and tool is what you require for turning a project into success.
2. Literature Review
The DMAIC as an effective tool has attracted many researchers as an area of interest. The motive of this review is to highlight the significant improvements in the form of productivity and quality improvement. This section briefly discusses the implementations of six sigma – the DMAIC methodology and results achieved by various researchers.

Satyajit Mahato (2016) describes that Six Sigma is not limited to the manufacturing sector; it is also useful in a service industry. There was a reduction in default cases from 28.4% to 5.74%. Neha Gupta (2013) discussed quality improvement study applied to a yarn manufacturing firm based on six sigma methodology. The author specifically uses the DMAIC tool to streamline the processes and enhance productivity. Rahul (2014) investigated how the fast-changing economic conditions, such as global competition, product variety, customer demand for high-quality product etc., had a major impact on manufacturing industries. To achieve these needs, the author used various strategies, such as ISO 9000, TQM, Six Sigma based DMAIC tool. Amit Yadav (Oct 2016) highlighted how the DMAIC methodology helped in achieving quality level in the automobile part industry. Successful implementation of six sigma had resulted in a reduction of DPMO from 68181 to 9090.9, and hence increased the sigma level from 2.99 to 3.86 with superlative solution. Varsha Karandikar (2014) effectively deployed the DMAIC approach for tackling issues like process variation, rejection and rework at a filter manufacturing industry. Prominent root causes were identified through the Cause and Effect Diagram, FMEA etc.

Punyisa Kuendee (2017) had used seven QC tools for minimising delay in delivery problem. The cause and effect diagram was used to find out the root causes of this problem. Using the Pareto chart cleared that the coordination problem was a major cause. Rahul Singh (2014) discussed how an application of Six Sigma i.e. the DMAIC methodology provides a framework for better quality and productivity improvement in a manufacturing enterprise. Ibrahim Alhuraish (2015) highlighted the effective combination of Six Sigma and Lean manufacturing in various industries of France. Nilda Tri Putri (2018) used Lean Six Sigma tool for reducing quantity of defects produced by cement bags company by identifying the causes and root cause analysis of non-conformance products. P. A. Marques (2016) proposed an integration framework where the life cycle stages inherent to a Lean or Six Sigma project can be systematically linked to the applicable causes and sub-clauses of ISO 9001:2015. Sushil Kumar (2016) stated that a Six Sigma tool-Taguchi approach is applied for defect reduction; further for analysing various significant process parameters of the casting process at a foundry in automobile casting industry. After reviewing the above papers, it was concluded and understood that the DMAIC is a core part of Six Sigma quality initiative. It refers to a data-driven improvement cycle used for improving, optimizing and stabilizing business processes and designs.

3. Case Study Objective
In this paper, the author(s) conducted case study in an electronics manufacturing company that assembles mobile phones. A DMAIC has been presented in this work. This is the approach to reduce defects in soldering in a mobile phone manufacturing company. DMAIC is used to kill the root causes of defects in the process thus improves quality. The objectives of this study are as given below:

- The proposed study focuses on reducing market Annual Failure Rate (AFR) and thereby reducing customer complaints.
- The presented study shows how the DMAIC methodology helps in reducing soldering defects quantity.
- The study also helps in reducing soldering defects ppm from 3800 to 200.
4. Research Methodology

- Define: This phase is the basis for all succeeding stages as it determines the needs of customers. Specific roles and responsibilities are assigned to different members of the team. A project charter is prepared.
- Measure: All the processes that influence customers are highlighted and defects generated in the same are determined.
- Analyse: This phase compels the reader to a question- WHY? It leads to the root cause of the defects in the process. The objective of this phase is to understand what causes the defects to generate.
- Improve: The objective of this phase is to brainstorm, devise and implement methods to bring defects under control.
- Control: This phase ensures that the new process after implementation of changes has all of its key variables under acceptable range. This is achieved using various tools like control charts, statistical process control (SPC), check-sheets etc.

![Figure 1. DMAIC Process]

4.1. Define
During the VOC (Voice of Customer) analysis, it was found that almost 20 percent of the feature phones returned from the market due to the functional failure of LCD and camera. The cause of this problem was mainly bad processes followed during these drag soldering stages. The opportunity here was to create a standard process for soldering stages to help curb defects by 100%.

| S. No | Role              | Department                                      |
|-------|-------------------|-------------------------------------------------|
| 1     | Mentor            | Quality HOD                                     |
| 2     | Champion (Leader) | PQC In-charge                                   |
| 3     | Team Members      | Maintenance, Repair, Production, Process Engineering, Quality (Incoming, Process, Outgoing, Market), Reliability |
To make sure that the VOC was translated properly to the CTQ (Critical to Quality), a cross functional team (CFT) was raised which comprised members each from incoming quality, production, process quality, outgoing quality, process engineering, market quality, maintenance, repair and training department. A PFMEA (Process Failure Mode Effect Analysis) meeting was held with a goal of reducing the defects of drag soldering from 3800 ppm to 1000 ppm (approx.) in the phase 1 and then further to 200 ppm in the phase 2.

Table 2. DMAIC Parameters

| Phase | Objectives | Relevant Tools |
|-------|------------|----------------|
| Define | Define the end client Define its CTQ requirements Develop the high-level map of core processes involved | Project Charter CTQ Chart VOC Analysis |
| Measure | Measure the performance Map the magnitude of the problem | Data Aggregation Advance Excel |
| Analyze | Identify the root cause of the problems Prioritize opportunities to improve | Cause and Effect Diagram Histograms Pareto Chart |
| Improve | Innovative processes Develop and implement improvement plans | Brainstorming DOE (Design of experiment) FMEA (Process) |
| Control | Prepare Check sheets Control and standardize the improvements | Check sheets Control Charts Measurement System Analysis (MSA) |

4.2. Measure
This phase involved collecting and measuring performance data to estimate the process capability and sigma level of the current system. Raw data was collected from all the three shifts for a period of 12 weeks. Histograms showing trends of defectives were plotted against all the three shifts.
4.3. Analyse

The Analyse phase called for identifying and determining all factors that affected the process or procedure in the handling of the product from the beginning to the customer and lead to defects in LCD, LED, vibrato motor, mic, speaker, Bluetooth, camera etc.

For this purpose, GEMBA walks on the shop floor were conducted by team members shift-wise, line-wise, operator-wise. Various problems were identified and measured in the measure phase, leading to the non-conformance to the product were grouped in accordance with the 4M’s (Machine, method, material and man) efficiency and were found to be as follows:
4.3.1. Machine
- Improper or unsuited temperature was being used during the soldering stages. When/If the temperature at the bit end was lower than what was required, FPC’s tinning would take more time for melting than the conveyor speed, resulting in low quality soldering. In contrary to this, when the temperature was on the high end, it would result in the burning of an FPC.
- Calibration was yet another cause which led to unsuitable temperature of soldering.
- Unsuitable bits were being used for soldering. There was no specification regarding which soldering bit was best for point-soldered and drag-soldered.
- Temperature controlled soldering station was not adapted. In an absence of the TCSS, there was usually a temperature loss during soldering of large FPCs.

4.3.2. Method
- No jigs were being used at soldering stations. This resulted in an unwanted movement while the PCB getting disoriented when soldering iron was dragged over them.
- Tinning of soldering pads was skipped.
- Huge variation in work content at different stages led to line imbalance problem. This further resulted in a less cycle time for soldering at soldering stages.
- There was no standard cleaning and sorting method adapted to various stages on assembly line. This further led to mixing of good and not good components.

**Figure 5.** Cause and effect diagram analysis
• Low quality sponge was being used for cleaning of soldering bits. Further there was no instruction for method of cleaning and periodicity of cleaning at various soldering stages.
• Improper lighting (low luminous intensity) and magnifier were provided. There had been cases of improper lighting and hence low luminous intensity at the stages.
• Lack of soldering check stages on the assembly line.

4.3.3. Material
• Unsuit flux and soldering wire were being used.
• Damaged FPCs received from the vendor itself. There was no checkpoint of checking FPC damage while unpacking LCDs and cameras on assembly line before soldering.

4.3.4. Man
• The operators lacked proper skills and expertise required for soldering.
• The attrition rate among operators was high which led to recruitment and training of new operators. This again made the process vulnerable to various defects.
• There was unawareness of knowledge of identification of defects among operators. This can be again related to training of operators.

4.4. Improve
In this phase, different problems were found during the analyse phase, which were targeted and improved using various actions as listed below:
• The soldering temperature was increased to the range of 370-400 degree Celsius from 300-350 degree Celsius.
• Calibration was yet another cause which led to unsuitable temperature of soldering.
• As far as the use of soldering bits is concerned to all thin wired components like microphone, speaker, LED, Bluetooth wire and vibrator motor, round type bit was employed. For components with FPCs like camera and LCD, K series type bit was employed.
• To curb the issue of temperature loss during soldering of FPCs as in an LCD and camera, a normal soldering station was upgraded to electronics based on the TCSS embedded with a temperature sensor that keeps the tip temperature steady.
• PCB-specific jigs were designed and used for soldering. This resulted in the prevention of unwanted movement and the disorientation of the PCB when soldering iron was dragged over them.
• Another stage dedicated to tinning of solder pads was placed on assembly line whose sole work content was to supply PCBs to soldering stations after properly tinning their FPCs.

Figure 6. Soldering Defects’ Improvement Trend – Phase 1

![Soldering Defects' Improvement Trend - Phase 1](image-url)
Various Industrial Engineering tools like PMTS and ECRS were used to study the work content in order to distribute or eliminate them and hence bring cycle time within takt time.

The well proven 5S methodology was introduced, adapted and taught at various levels in an organization. Also, mandatory 5S audits were planned after every couple of days.

High quality brass and sponge were used for cleaning the soldering bits. Furthermore, there was no instruction in cleaning, method of cleaning and periodicity of cleaning at various soldering stages.

Luminous intensity was improved from 600-700 Lux to 800-900 Lux.

A dedicated stage for checking the defects of soldering like dry soldering, solder balls, solder bridges was seated just after the soldering stages on the assembly line. In addition to this, the stage was provided with a magnifying glass so as to have proper and zoomed visuals of the defects.

Now solder wire with flux 3.3% was made to be used.

A full-fledged check sheet was developed containing check points that would otherwise get skipped during sampling of the PCBs from a vendor.

A proper training and review program were developed for soldering operators.

Appreciation and awards were distributed for achieving milestones in soldering operation.

An in-house training school was established where training of soldering and in-depth knowledge of defects were imparted to assembly line workers.

4.5. Control
This phase required controlling or sustaining all the improvements in processes as adopted in the improvement phase. In other words, the purpose was to monitor the improvements that have been made and to assess the results that have been achieved through implemented kaizens. Moreover, a separate training school was developed, where operators are trained through the following activities:

- Soldering Manuals written in layman’s language provide detailed information on all processes related to soldering with illustrations.
- Bulletin boards carrying pictures of correct and incorrect ways of performing soldering were installed on walls.
- High power magnifiers were installed for assembly line workers for better understanding of defects.

![Soldering Defects' Improvement Trend - Phase 2](image)

Figure 7. Soldering Defects’ Improvement Trend – Phase 2
5. Conclusion
This paper explains the DMAIC tool in its entirety and uses the same to counter the problems of soldering. Based on the results of this paper it can be seen how the DMAIC tool was effectively used to eliminate waste by reducing soldering defects from 3800 ppm to 200 ppm with a purpose to approach a six-sigma quality level in soldering processes. No doubt Lean Six Sigma is a challenging yet effective tool and not limited to the type and size of the industry. Whether small or large scale, it can be used in any type of industry, be it medical, cement, automobile industry, etc. It is not a standalone tool and hence uses combination of various tools viz. DMAIC, PFMEA, Quality control, you name it which makes it a robust package for improving process and hence deliver customer satisfaction par excellence. Having said that it can be concluded that the implementation of six sigma calls consumes time, effort, money and ground-breaking improvements; however, it still is a process improvement tool worth giving a shot.

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