Reduction of Scrap in an Electronic Assembly Line Using DMAIC Approach

Afzal Matathil[1], Ganapathi K. N.[2], Kalathil Ramachandran[3]

1- M. Sc. [Engg.] Student, 2-Asst.Professor,
Mechanical and Manufacturing Engineering, MSRSAS, Bangalore 560 058.
3-Manager-QA, Sanmina-SCI, Chennai

Abstract

In today's buyer's market; quality based competition is intensifying and enforces any manufacturing industry to produce better quality products with least cost. Quality with least cost is only possible by reducing the rejection rate especially at downstream customer. The study concentrates on the reduction of customer claimed scrap as it is capable of reducing the product profit and also the future business.

Quality is nothing but satisfying the customer needs and expectations on a continuous basis. The scope of this study is (1) Well designed products with functional perfection, (2) Meeting or exceeding customer expectation, (3) Excellence in service and (4) absolute empathy with customer. DMAIC methodology is used for this project, as it serves as a guideline for successfully identifying root cause of the selected problem and for understanding, implementing and evaluating solution/s.

The study brought more than 88% reduction of scrap cost within six months of work. The study brought many tangible and intangible benefits including increased future business. It is concluded from the study that the actual quality is lying with manufacturing process and any complicated problem can be solved by systematic application of DMAIC approach.

Key Words Six Sigma, Scrap Reduction, DMAIC, Communication Failure.

Abbreviations

CCM	Customer Complaint Management
CTQ	Critical to Quality
DMAIC	Define, Measure, Analyze, Improve, Control
EMS	Electronics Manufacturing Service
EMS	Electrical and Electronics Equipments
FMEA	Failure Mode Effective Analysis
MRB	Material Review Board
PCB	Printed Circuit Board
PDCA	Plan, Do, Check, Act
PPM	Parts Per Million
QC	Quality Control
QMS	Quality Management System
SIPOC	Supplier, Input, Process, Output, Control
SOP	Standard Operating Procedure.
TQM	Total Quality Management
VoC	Voice of Customer
WIP	Work In Process
WRM	Work Relationship Matrix
Zst	Sigma Short Term

1. INTRODUCTION

Scrap in an electronic assembly line is commonly referred as a type of electronic waste or simply E-waste. E waste is a term used to describe obsolete, broken or irreparable electronic devices. It may include electronic components, work in progress electronic assemblies or consumer end electronic products. With the increased concern about the negative impacts of E-waste, need to behave in a sustainable manner has become vital consideration for any electronic industry. Reduction of E-waste has attained increased attention ever before by the people and by the governments. Its negative impact on environment has been widely discussed all over the world. So, an industry has to adopt strategies that meet the need of the industry and its stakeholders while protecting the interest of our environment. Reduced life cycle of electrical and electronic equipments (EEE) is one of the reasons for increased E- waste generation. Products can become obsolete in a short time due to short life time or inadequate technology. These can be solved by improving product quality. Hence, now it has been accepted by any industry that primary solution for reduction of e-waste is improving quality in all aspects of the business; such as material quality, process quality, human resource quality, machine quality, etc and finally the end product quality.

Quality of the products can be improved by improving various factors affecting quality. Some of them are man, machine, method, measurement system, environment etc. These factors are critical for any electronic industry for ensuring product quality. Projects for quality improvement would provide other tangible and intangible benefits to the industry, such as increased reliability, better relationship with customer/supplier/other stake holders, reduced product cost, increased profit and many other benefits.

There are various approaches available for conducting a quality improvement/problem solving project. One of the prominent approaches is DMAIC. DMAIC approach act as guide line for conducting a project. It facilitates appropriate and effective utilization of quality and six sigma projects. This study conducted strictly on the guidelines of DMAIC approach. The study has five phases; Define, Measure, Analyze, Improve and Control. Various quality tools and six sigma tools were used in each phase of the project.

1.1 Place of Work

Sanmina- SCI is a global electronics manufacturing service (EMS) provider, headquartered in San Jose, California serves original equipment manufacturers in technology related industries such as communications and computer hardware. It has nearly 80 manufacturing sites around the world. Sanmina- SCI is the largest independent manufacturer of black panes.

2. PROBLEM DEFENITION

An electronic assembly line from the Sanmina-SCI is selected for the study based on scrap value. The selected assembly line scraps 0.6% of the total revenue. The selected line produces class-3 products goes for defense. The main contribution of scrap is from customer rejects which is in terms of 97%. The products cannot be reworked due to high quality requirements of customer. The scrap value creates much intangible loss to the customer apart from financial losses. The aim of the study is stated as "To reduce scrap rate from 9000 PPM to less than 1000 PPM in an electronic assembly line using DMAIC approach".

3. METHODOLOGY

- Literature survey on electronic production line and Assembly techniques and to understand DMAIC approach for problem solving by referring books , journals, quality system manuals and related documents.
- Collected scrap data and identified areas of improvement using QC tools like Pareto analyses, Process Mapping, SIPOC etc.
- Studied capability of current measuring system and quantified it using kappa analysis.
- Analyzed the current process and operating procedures to identify root cause for scrap generation using various six sigma tools like brain storming, cause and affect matrix, hypothesis testing etc.
- Implementation of viable solution/s by forming a cross functional team.
- Statistical testing of improvements have been done using hypothesis testing.
- Benefits through the study are validated and documents are modified with necessary changes for controlling the identified problem.

4. ANALYSIS

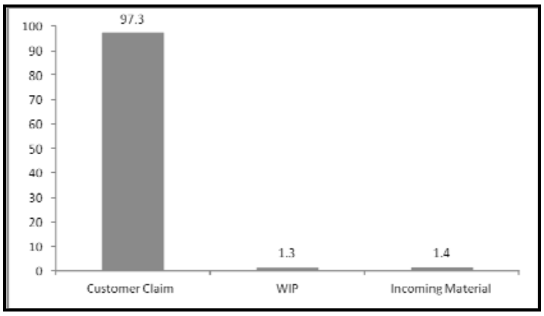

Fig. 1 Bar graph for scrap distribution

For better understanding of the scraps, more detailed data has been collected. From the first analysis, the calculated cost of scrap is 0.6% of the selected assembly line. And this overall cost can be subdivided as customer claim scrap, work in progress scrap and incoming material scrap. The scraps are valued in terms of cost and not in terms of numbers. The bar graph below shows distribution of scrap cost in the selected line in the three sub groups.

From the figure 1, bar graph above, it could be understood that 97% of total scrap cost is due to customer claim, 1.3% is contributed by WIP scrap and remaining 1.4% is caused by incoming material defects. Hence, as the most contributing group, this study concentrates on reduction of scrap generated through customer claim.

Focused study on customer claim scrap cost is conducted for better understanding of various issues contributing to it. The Pareto diagram been has been drawn after the focused analysis of customer claimed scraps.

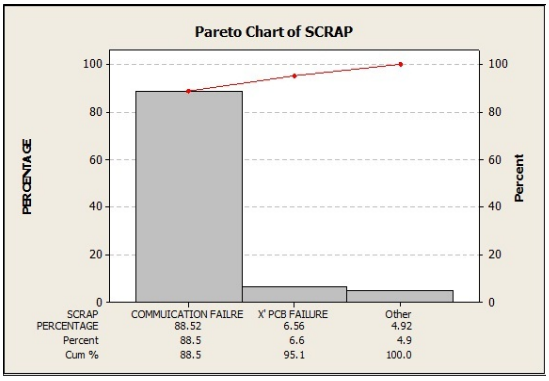

Fig. 2 Pareto on customer claimed scraps

The figure 2 reveals that 88.52% of the total scrap cost is due to communication failure. And 6.52% is due to CC PCB failure and remaining costs are due to various other factors. **Hence for this project, communication failure has been selected**. Resolving this problem would reduce 85% of the total scrap cost.

It has been understood that 'communication failure' is very severe for the product. As the product is entirely controlled by computer, communication failure literally stops entire operation of the product. It makes huge financial loss for the customer and stops important operations of the customer. As customer is defence, no rework was allowed and has to be scrapped directly. So, the whole product to be scrapped for the sake of communication failure and it's a huge financial burden for the company.

4.1 Kappa Analysis

To analyze the current measuring system capability, Kappa analysis has been conducted by putting three operators in place with 20 units randomly arranged. Each operator has to check each of the products. The analysis concluded that, each of the operators agrees with two others on each of the sample. It ensures that the measuring system is capable of repeated results and it reproduces the same result each time and every time. The table 1 below shows the results of the test.

Table. 2 Measurement system capability analysis

	Operator 1(1)	Operators 1(2)	Operator 2(1)	Operator 2(2)	Operator 3(1)	Operator 3(2)
1	Good	Good	Good	Good	Good	Good
2	Good	Good	Good	Good	Good	Good
3	Bad	Bad	Bad	Bad	Bad	Bad
4	Bad	Bad	Bad	Bad	Bad	Bad
5	Bad	Bad	Bad	Bad	Bad	Bad
6	Good	Good	Good	Good	Good	Good
7	Good	Good	Good	Good	Good	Good
8	Bad	Bad	Bad	Bad	Bad	Bad
9	Good	Good	Good	Good	Good	Good
10	Good	Good	Good	Good	Good	Good
11	Bad	Bad	Bad	Bad	Bad	Bad
12	Bad	Bad	Bad	Bad	Bad	Bad
13	Good	Good	Good	Good	Good	Good
14	Bad	Bad	Bad	Bad	Bad	Bad
15	Good	Good	Good	Good	Good	Good
16	Good	Good	Good	Good	Good	Good
17	Bad	Bad	Bad	Bad	Bad	Bad
18	Good	Good	Good	Good	Good	Good
19	Good	Good	Good	Good	Good	Good
20	Good	Good	Good	Good	Good	Good

The figure below shows measurement system agreement analysis report got from Minitab software. And the Cohen's kappa is calculated is 1.

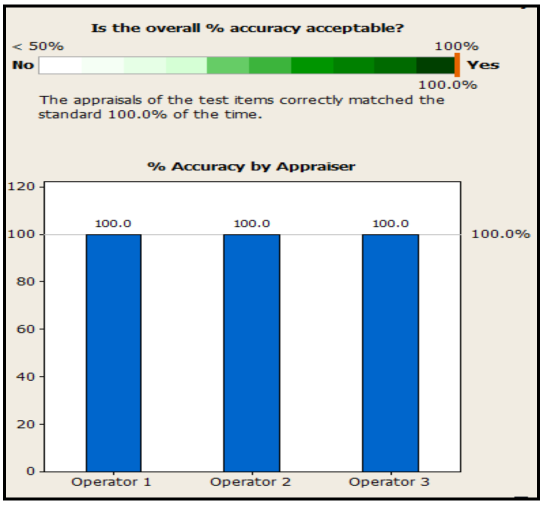

Fig. 3 Kappa analysis

From the above study it has been concluded that there is no loop hole in the process of determining the scrap.

4.2 Brainstorming Communication Failure

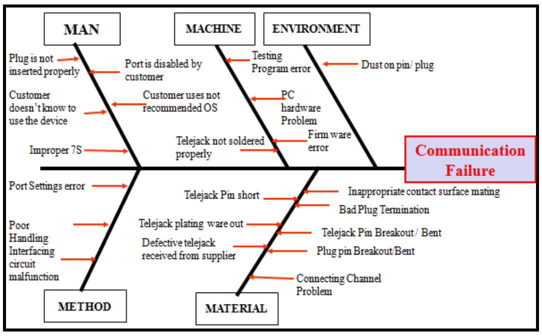

Fig. 4 Fish bone diagram

Brainstorming session had been conducted to understand possible causes for "communication failure". Brainstorming is done by the cross functional team participating production, testing, design, quality, process and finance departments. The figure below illustrates possible causes found in brainstorming session.

4.3 Action Plan Communication Failure

An Action plan has been formed after the brainstorming session. Some causes has been marked as "not a cause" during the initial judgment in the post-brainstorming session. 18 causes have been identified as possible causes and planned an action plan for finding the vital few. The table below shows the action plan and the results. It can be noticed from the table that 2 out of 18 have identified as vital or "existing". Remaining 16 has been identified as "not existing". The vital few identified are "Telejack Pin short" and "Inappropriate contact surface mating".

Table. 3 Action plan Communication failure

Sl. no.	Cause	Recommended Action	Status	Judgement
1	Plug is not inserted properly	check with properly inserted plug	Verified	Not existing
2	Telejack not soldered properly	check the defective boards	Verified	Not existing
3	Testing program error	check the fixture program	Verified	Not existing
4	Testing Skipped	Check the historical data	Verified	Not existing
5	Customer uses non- compatible OS	customer uses compatible OS	Verified	Not existing
6	Telejack Pin Short	Check continuity	Verified	Exisitng
7	PC hardware problem	check with tested PC	Verified	Not existing
8	Firmware Error	Check Firmware of defective units	Verified	Not existing
9	Dust on Pin/Plug	Visual Inspection	Verified	Not existing
10	Interfacing Circuit Malfunction	check defective units interfacing circuit	Verified	Not existing
11	Port Settings error	Check Settings of defective units	Verified	Not existing
12	Bad Plug Termination	Visual Inspection	Verified	Not existing
13	Inappropropriate contact surface mating	Check the signal continuity	Verified	Exisitng
14	Telejack Pin Plating ware out	Visual Inspection	Verified	Not existing
15	Defective Telejack Received from Supplier	Full lot test for 3 lots	Verified	Not existing
16	Connecting Channel Problem	check wih tested channels	Verified	Not existing
17	Telejack Pin Break out/ Bent	Visual Inspection	Verified	Not existing
18	Plug pin Break out/Bent	Visual Inspection	Verified	Not existing

4.4 FMEA

Table. 4 FMEA before

Component	Potential Failure Mode	Potential Failure Effects	Severity (S)	Frequency	Ocuurence (O)	Current Process Controls	Detection (D)	RPN (S x O x D)
Product X	Communication Failure	Telejack Contamination	7	> 1 in 8	8	No Control	10	560
		Telejack Short	7	>1 in 10	7	No Control	10	490
	Device is not functioning	CC Board Failure	7	> 1 in 2000	4	Could be detected at FCT	5	140
	Battery has to be scrapped	Battery Lookout	4	> 1 in 10000	3	Customer	10	120

FMEA is the acronym for Failure Mode Effective Analysis. It is a tool to identify means that a product/process can fail. The RPN is the acronym for Risk Priority Number. It has been identified that there are two failure modes for "communication failure"; inappropriate contact surface mating and telejack pins short. The RPN number for the failure modes are calculated and finalized by the CFT, that, 560 and 490 respectively. The table below shows FMEA for "communication failure".

4.5 Further Analysis

The vital few causes have been further examined to find out the root cause. It has found that "telejack pin short" and "inappropriate contact surface mating" are the immediate causes for communication failure. And by observing the contact strings/pins of telejack it has been understood that “inappropriate contact surface mating” is occurred due to corrosion. The figure below shows corrosion observed on telejack pins.

Fig. 5 Telejack pin corrosion

The action plan has been formed to find out the actual cause for the corrosion. The action plan and findings are listed on table below, and the study is explained later.

Table. 5 Action plan Further analysis

Action Plan	Results
Microscopic testing of defective telejack (50 samples)	Found corrosion
Microscopic testing of new telejack from supplier (50 samples)	Found OK
Microscopic inspection of telejack of new products (50 samples)	Found flux inside telejack
Salt spray testing on wave soldered telejack by external testing centre (3 samples)	Found corrosion after salt spray test
Salt spray testing on new telejack by external testing centre (3 samples)	Found OK after salt spray test

The causes for corrosion have been studied thoroughly for finding the underlying reason. Through the microscopic inspection, it has been found that during the wave soldering process, flux is getting penetrated into the telejack. Absence of flux in the new telejack and presence in the ‘wave soldered telejack’ conformed the result. And it has been assumed that this causes the corrosion and also for the ‘telejack pin short’.

For concluding the findings, salt spray test from external agency has been done. The result showed that ‘red corrosion’ on flux penetrated or wave soldered telejack and ‘no corrosion’ on new telejack.

4.6 Temporary Corrective Action

Temporary corrective action had been identified and implemented for reducing flux penetration inside the telejack. Those are,

- Cleaning process before the wave soldering process using IPL and a brush.
- Pasting scotch tap on telejack contact strings before wave soldering.
- Removing scotch tap off telejack contact strings after wave soldering.
- Cleaning the pins after the wave soldering process.
- Microscopic inspection of telejack after wave soldering process.

The temporary corrective action added 3 head counts to the line, it also added 4 minutes to the cycle time of the product. The corrective action has found successful and verified by the microscopic inspection as well as by salt spray test.

4.7 Brainstorming Flux Penetration inside the Telejack

Further brainstorming session has been conducted to find out the possible causes for “Flux penetration inside the telejack”. Production, NPD, process, purchase, and Quality representatives have been attended the session. The figure below illustrates possible causes for “Flux penetration inside the telejack”.

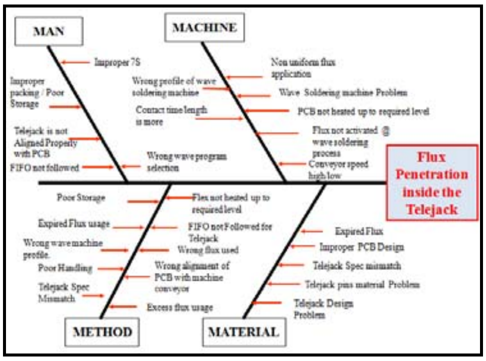

Fig. 6 Fish bone diagram Flux penetration inside the telejack

4.8 Action plan flux penetration inside the telejack

Action plan formed after the brainstorming session is illustrated in table below. Each identified causes had been examined under detailed study to find out its existence and non-existence. Some of the causes found out in the brainstorming session had been ruled out in the initial judgment. Remaining causes has gone through further examination. The table below shows action plan formed after the post brainstorming session and its results. The vital few causes are highlighted in the action plan.

Table. 6 Action plan Flux penetrates inside telejack

Sl.N	Cause	Recommended Action	Status	Judgement
1	Telejack is not Aligned Properly with PCB	Check the defective boards	verified	Not Existing
2	Wave Soldering machine problem	Two proportion test by putting telejack on different	Verified.	Not Existing
3	Expired Flux	Check historical data	verified.	Not Existing
4	Telejack Design Problem	Need to check the design of telejeack	Verified. Need further analysis	Existing: There are open areas in the telejack. Flux may be entering through open areas of telejack
5	Flex not heated up to required level	Check the program	Verified	Not Existing
6	Inappropriate flux	Check with optimised flux of water base flux	Verified with alternate flux	Existing: Resulted in fillet issues and test pad not soldered, so the solution can not be implemented
7	Wrong wave machine profile	Check the profile (temperature at different level)	Verified. Wave solder profile is under spec.	Not Existing
8	Telejack Spec mismatch	Check the dimensions	verified	Not Existing
9	Flux is not activated	Check the historical data/ and current process	Verified. Preheat temperature is under spec.	Not Existing
10	Non uniform flux application	Test with flexometer	verified	Not Existing
11	Wrong alignment of PCB to the machine conveyor	Check the thickness of flux on each sides of PCB	Verified	Existing, Trailing edge has more flux accumulation compared to leading
11	Flux not heated as per the spec.	Check temperature specifications/ historical data	check the temperature specified and measured data	Not Existing
12	FIFO not followed for Telejack	Check with supplier	verified	Not Existing
13	PCB is not heated up to required level at preheat	Check the historical data and with new board	56 C (23 to 84 C)	Not Existing
14	Conveyor speed is high/low	Verify the conveyor speed	1.56m/sec (1.2-2	Not Existing
15	Contact time or length is more	Verify the historical data and with new board	1.2 sec,(1-1.5) 0.52 min(0.4 to 0.8/	Not Existing

4.9 Why-Why Analysis

The why- why analysis below illustrates how “clearance hole” eventually caused in the communication failure.

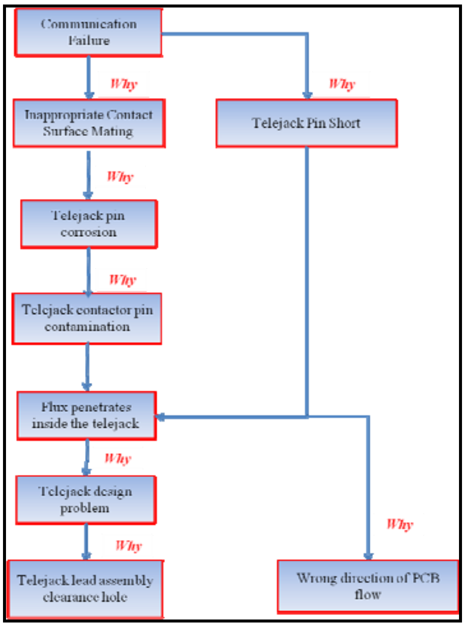

Fig. 7 Why-why analysis

The root cause had been confirmed after covering each telejack leads by a stiffener and by checking each with microscope for the flux penetration after the wave soldering process. Found that the flux penetration has been completely eliminated for the sample of 100. So, from the detailed analysis, it has been concluded that root cause for the communication failure are "Telejack Lead Assembly Clearance Hole" and "Wrong direction of PCB flow"

5. PROBLEM SOLVING

Problem solving includes identification of feasible solution, implementation of identified solution and finally evaluating effects of implemented solution. The problem solving steps are explained in this chapter.

5.1 Solution Identification

Defect	Cause	Root Cause	Solution	Solution Mode	Permanent/ Temporary
Communication Failure	Flux penetrates inside the telejack	Telejack assembly clearance hole	Telejack design change	Prevention	Permanent
		Wrong direction of PCB flow	Reversing PCB flow	Prevention	Permanent
		No detection at factory	Microscopic inspection	Detection	Temporary (3 months)

Table 7 Identified solutions

Solutions for eliminating communication failure have been identified. Below table shows identified solutions and its explanations.

5.2 Telejack Design Change

The clearance hole has been defined and specified on the telejack specification sheet. A new design of telejack has been proposed for designer approval. The diagram below shows current and proposed design of telejack.

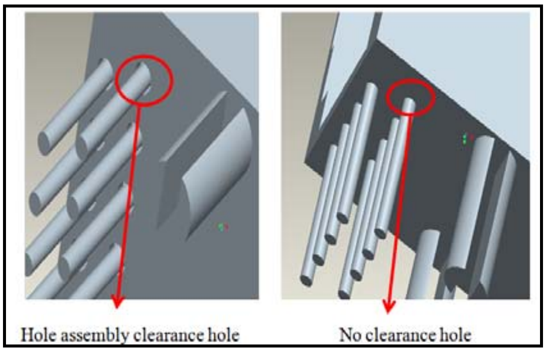

Fig. 8 Telejack design old and proposed

As the new proposed design send to the design team situated at U.S.A, The proposed design has been approved with minor modification. The approved design has square leads instead of circular shape with diameter reduction of 0.1 mm. The figure below shows actual photos of old and new telejack.

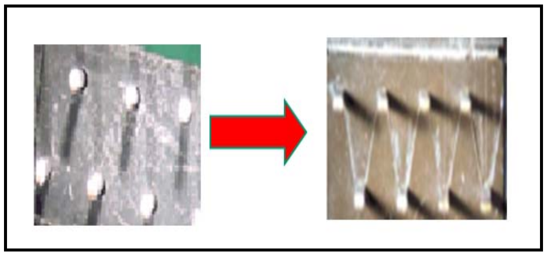

Fig. 9 Telejack old and new

- Pin clearance hole has been specified and defined in the telejack data sheet. As per the new drawing, no clearance hole allowed.
- Circular shaped pins are modified into square.
- The diameter of the pin has been modified from 0.9mm diameter into 0.89 diagonal lengths.

5.3 Change in the Board Flow Direction

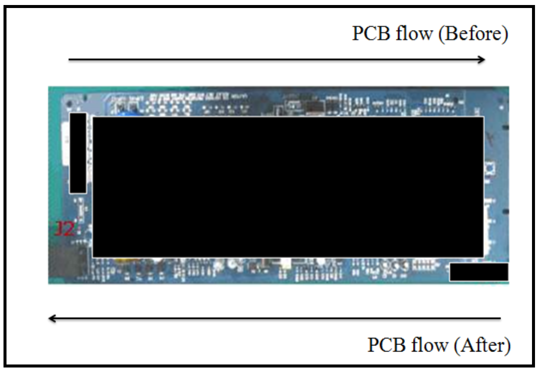

Fig. 10 PCB direction before and after

To avoid flux accumulation at pins of telejack pins, flow of board has been reversed and now the telejack is on the leading edge. The figure below shows PCB flow before and after. The telejack is marked as 'J2' in the figure. Instructions are added on WI and an alert has been provided in the line.

5.4 Microscopic Inspection

A permanent workstation for microscopic inspection of telejack has been added. It would help to verify the flux penetration into the contact strings of telejack. The operator has been trained to do the inspection, and has to paste a sticker upon inspection. The sticker has to remove the sticker and to mark on the check list. Any problem found should be informed to line supervisor and quality. The work station will be "on" for three months, and will be discarded upon customer feedback.

6. RESULT AND DISCUSSIONS

Project results have to be validated and discussed before closing. There are six sigma tools helps to validate the results of project. Validation of the study is very important to verify the results of the project. The improvements are measured by using six sigma tools. The validation of the study is explained below.

6.1 FMEA after the Study

FMEA is the acronym for Failure Mode Effective Analysis. It is tool to identify means that a product/process can fail. It can also be used for defining process improvements and controls. The tables below show FMEA before and after for the scrap. It could be noted that, the RPN for the failure mode "communication failure" has been reduced to zero after the project. As severity remains the same before and after the project, frequency and detection has been improved.

Component	Potential Failure Mode	Potential Failure Effects	Seriarity (S)	Frequency	Ocuurence (O)	Current Process Controls	Detection (D)	RPN After (S x O x D)	RPN Before
Product X	Communication Faillure	Inappropriate Contact Surface Mating	7	0 in 50	1	Microscopic inspection	1	7	560
		Telejack Short	7	0 in 50	1	Microscopic inspection	1	7	490
	Device is not functioning	CC Board Failure	7	> 1 in 2000	4	Could be detected at FCT	5	140	140
	Battery has to be scrapped	Battery Leakout	4	> 1 in 10000	3	Customer	10	120	120

Table. 8 FMEA after

6.2 Two-Proportion Test

For ensuring/ validating the results statistically, 2-propotion test has been done. The test is conducted by running 200 products with 100 of it with each old and new telejack. Each product has been checked through microscope for identifying flux penetration. The components found as flux penetration are marked as "fail". And the components with no flux penetration are marked as "pass". The test is conducted on the same machine and the result would be useful to ensure the improvement made through improved design.

The hypotheses made are,

H0 (Null hypothesis) = p1=p2 (There is no significant impact on communication failure by telejack design change).

Ha (Alternate hypothesis) = p1≠p2 (There is a significant impact on communication failure by telejack design change).

Where, p1 is the failure proportion of old telejack and p2 is the failure proportion of new or improved telejack.

The test has been conducted and found that 97 out of 100 old telejack have been failed after the wave soldering; in other words the flux penetration is found. And with new or improved telejack, the failure was 0 out of 100. The test is conducted at the significance level of 0.05. Below are the observations or inputs for the test.

- p1= 0.97 (Sample proportion of failure with old telejack).
- q1 = 0.03 (Sample proportion of success with old telejack).
- n1= 100 (Sample size of testing old telejack).
- p2= 0 (Sample proportion of failure with new telejack).
- q2= 1.0 (Sample proportion of success with old telejack).
- n2=100 (Sample size of testing new telejack).
- Alpha = 0.05 (Level of significance for testing this hypothesis).

After putting these inputs to the Minitab Software, 2-Propotion test has been conducted. The figure below shows screen shot of result from Minitab software.

Test and CI for Two Proportions

```
Sample   X    N  Sample p
1       97  100  0.970000
2        0  100  0.000000


Difference = p (1) - p (2)
Estimate for difference:  0.97
95% CI for difference:  (0.936566, 1)
Test for difference = 0 (vs not = 0):  Z = 56.86  P-Value = 0.000


* NOTE * The normal approximation may be inaccurate for small samples.

Fisher's exact test: P-Value = 0.000
```

Fig. 11 2-Propotion test

The null hypothesis (H0) has been rejected and accepted alternate hypothesis (Ha) based on the observations made from result as explained below,

- 0 lies outside the confidence interval for difference (0.936566,1)
- Z calculated (56.86) is greater than the Z table (1.96)
- P value is less than 0.05

So, null hypothesis has been rejected and accepted alternate hypothesis. It could be concluded that "There is a significant impact/reduction on communication failure through telejack design change".

6.3 PPM Level

PPM level of scrap has been reduced drastically from 9223 PPM to 1058 PPM against the target of 1000 PPM. The graph below shows the improvement.

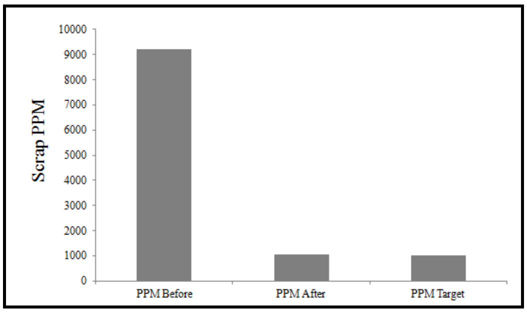

Fig. 12 PPM Before and after

6.4 Zst Level

Zst had been improved from 4.61 to 5.2 against the target of 5.21. The graph below shows the improvement.

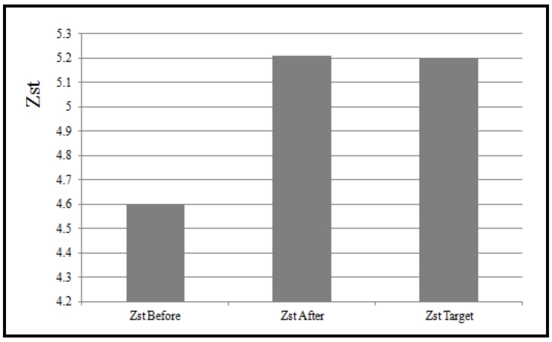

Fig. 13 Zst Before and after

6.5 Cost Benefit Analysis

Cost Benefit analysis measures cost benefit achieved by the project. The study incurred cost for its implementation and brings cost benefit to the company. Costs associated with study implementation are,

- Training cost.
- Manpower Cost.
- System and development cost.
- Cost of change (material and machine)
- Costs saved through the implementation are,
- Scrap material cost.
- Scrap transportation cost.
- Manpower cost.
- Production cost.

The total cost saved by study is estimated as Rs.2327000 / Annum.

6.6 Intangible Benefits

There are many intangible benefits company relish after the completion of the projects, as intangible benefits are cannot be measured it cannot be identified as well. Some of the identified intangible benefits are listed below

- Increased product profit.
- Increased product reliability.
- Increased customer satisfaction.
- Increased employee satisfaction.
- Reduced unscheduled customer visit.
- Better customer relationship.
- Reduced breakdowns at customer.

7. CONCLUSIONS

DMAIC approach helped successful completion of the study with clearly defining study road map. The Sanmina-SCI had very good system and procedure for defining the scrap. But the company lacks in data collection and effort for reduction. The study brought out the importance of data collection of scrap by the quality team and importance of defining the scrap in terms of quality. The study was successful with 88% reduction in total scrap cost. Cost saving through the study is estimated as Rs.23. 27 lakhs p.a. The company has to focus on continual improvement for further reduction of scrap. It is concluded from the study that the actual quality is lying with manufacturing process and any complicated problem can be solved by systematic application of DMAIC approach.

8. REFERENCES

[1] Hemant Urdhawareshe, (2000) "*The Six Sigma Approach"*, Quality & Productivity Journal, Vol 01, 3rd Quarter, pp 1-6.

[2] Julo Ponce, Adam Karahoca (2009), *Data Mining and Knowledge Discovery in Real Life Applications*. Austria; I-Tech.

[3] James R. Evans, James W, Dean JR(2006), *Total Quality Management Management, Organization and Strategy,* USA; South-Western College Pub.

[4] Arash Shahim (1997), "*Customer Complaints Management and Empowerment",* 4th International Management Conference, Germany,

[5] Ibrahim A. Rawabdeh, (2005), *"A model for the assessment of waste in job shop environments" International Journal of Operations & Production Management,* Vol. 25, pp 800-822.,

[6] Jung-Lang Cheng, (2008) *"Implementing six sigma via TQM improvement an empirical study in Taiwan"*, The TQM journal, Vol.20, pp 182-195.

[7] Margaret P. Bates and Paul S. Philips, (1999). *"sustainable waste management in the food and drink industry'*, British Food Journal , Vol. 101 No.8, 1999, pp 580-589.

[8] Thomas Pyzdek (2003), *"The six sigma handbook a complete guide for green belts, black belts, and managers at all levels"*. USA McGraw-Hill.