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Quality Control Practices Adopted in Electronic Device Supply Chain: A case study

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Abstract - *In the business era, when all the organizations are competing with each other on every aspect, it has become very important, not only to adapt with advanced technologies in manufacturing, material handling, sales and other Supply Chain processes, but also pay a huge amount of attention towards customer satisfaction. Two major factors that can bring a hike w.r.t customer satisfaction are cost and quality. This paper explores a specific dimension of improving quality of products and services that is Failure Analysis (FA). A failure inhibits a product to perform the function it was intended to do. Failure Analysis is a process of investigating such a failure. Basically, it analyses the failure modes by using optical, electrical, physical and chemical analysis techniques. Too often, jumping into statistical data analysis leads to flawed results and erroneous conclusions. Failure analysis is a key tool in answering those questions. This paper will cover the basics of FA and the process of carrying it out, and lastly will discuss about few case studies in detail and come up with a meta-analysis.*

Key Words: **Supply Chain processes, Customer satisfaction, Quality, Cost, Failure Analysis, Failure mode**

1.INTRODUCTION

Quality Control plays a very important role in the Supply Chain of any company. While most of the organizations focuses on efforts in improving the supply chain efficiency by looking at the supply chain process itself, there are very few organisations which realize that controlling the quality of products and services before it is delivered to the customer is of primary importance, as it can have a direct impact on the speed and efficiency. Quality control can be applied at various stages in a supply chain, i.e., manufacturing of products, assembly of components, and many other processes depending on the product.

One of these stages where quality check is a must is when the products are returned by the customers after purchase due to defects or unsatisfactory performance of the products. In such cases it is very essential to analyze the root cause of the failure and come up with a strategy which prevents any further returns made by customers on the same issue.

The objective of this paper is to analyze the Failure Analysis process for electronic products and thus have a broader view towards quality control in any organization, keeping in mind that the concept being so vast, can see various advancement with growing technology. This paper covers the existing methodologies used for quality assurance of the products and services.

2. LITERATURE REVIEW

In today's economy, the organizations are competing not only by business, but rather supply chain versus supply chain. Traditional ways of managing quality have been and will continue to be used to address many issues of supply chain integration. A systems-based approach to performance improvement is Supply Chain Quality Management, which integrates supply chain partners and leverages opportunities created by downstream and upstream linkages by focusing on creating value and achieving satisfaction of intermediate and final customers [1].

Although, there are several definitions of quality, it can be defined as meeting or exceeding customer expectations [2]. American Society for Quality defines quality as "A subjective term for which each sector or person has its own definition." In technical usage, quality can have two meanings:

1. the characteristics of products or services that have the abilities to satisfy the stated or implied needs;
2. Products or services free of deficiencies.

According to Joseph Juran [3], quality means "fitness for use" and according to Philip Crosby [4], it means "conformance to requirements."

Total quality management is a set of quality practices that seek to continuously improve quality in processes [5]. There exists a positive relationship between Quality management and Supply Chain Management. The Quality management improvements in reduction of process variations directly impact on supply chain performance measures. With continuous quality management improvements, defects, and therefore, process and production variations are returned. In turn, the cycle time is reduced and on-time delivery improves [6].

A quality improvement that leads to a reduction in defective units, and therefore a reduction in rework, creates a positive impact upon the supply chain as cycle times are reduced, schedules are met and customer response times also improve [7]. Lesser defective units in the system allow the remaining units to move faster through the supply chain, which is noted by improved cycle times. As companies are able to move product faster through the supply chain, the customers' demands and schedules can be met faster. This allows an improved synchronization and integration across the entire supply chain [8].

According to a survey, it was determined that FMEA (Failure Mode Effects and Analysis) is seldom used for Supplier risk assessment and is used as a proactive tool for SCRM (Supply Chain Risk Management) [9]. All potential failures are evaluated in terms of likelihood (O), severity (S) and detectability (D). A higher FMEA score implies higher risks on the products. The FMEA effectiveness can be significantly improved by identifying potential pitfalls, and raising awareness of those problems [10]. Applying a strategy that utilizes rules and controls can efficiently mitigate, or even avoid, all possible known harmful effects.

Risk assessment is determined via RPN (Risk Priority Number), which is calculated by multiplying the ranking values of O, S, and D and obtaining one categorization number for each possible cause of each failure using the following equation.

$$RPN = O*S*D$$

Texas Instruments, Inc. is a global semiconductor manufacturing and design company. It has Texas Instruments Failure Analysis Laboratory has developed a generalized routine for transistor FA (Failure Analysis) and is developing one for integrated microelectronics circuits [11].

Major theories have been developed with time to assure the quality of the products and processes in order to improve the supply chain performance. This paper brings together the various technologies to control quality across most stages of supply chain, and combine the concepts of FMEA and other techniques. It collates and analyses the Failure analysis process followed by Cisco Systems, Inc. and other successful MNCs.

3. TECHNOLOGY AND QUALITY

More companies are incorporating technology into their supply chain management systems today in order to stay competitive globally and remain on the cutting edge of a complex business world [12]. In recent years, consumers have become increasingly demanding, setting their expectations very high when it comes to quality and services. At the same time, supply chain managers have come to realize that the latest technology can help in ensuring them better accountability and visibility, allowing them to maintain strict control and stay ahead of the pack.

Table -1: Cisco's Quality Metrics

Metric Categories	Metric Name	Metric Definition
Customer Found Defects	CFD MTTR (days)	7 * (Avg Backlog over 13 weeks) / (Avg Disposal over 13 wks)
Service Requests	%Bug SR	# of SR that has at least one defected attached as a % of total number of SRs
Escalations	CAP Incoming	Number of cases incoming during this period
Hardware quality	IR (ppm)	(# of DOA units + # of Visual Defect units) * 1 million / (# of units shipped)
Preventive practices	% Static Analysis	Percentage of committed defects with Static Analysis done (52 Wks)
Internal Found Defects	IFD MTTR (days)	7 * (Avg Backlog over 13 weeks) / (Avg Disposal over 13 wks)
Hardware in-process	DFR & Schematic Review	Design for reliability

Technology in the present era has extensive capability when it comes to keeping a company's production on track, anticipating defects and repairing mistakes, and making modifications that guarantee top-quality product and service. Cisco's approach to quality management across the globe can be condensed into one phrase: "ensuring our customer success". In order to serve their customers well in terms of quality, the company consists of the team called- "Technology & Quality (T&Q)" in the Supply Chain Business Unit. T&Q involves adaptive, innovative and scalable supply chain services that optimizes customer requirements. To cover the broad spectrum of quality assurance, the team is divided into many departments:

A. CQT: COMPONENT QUALITY & TECHNOLOGY
B. PQE: PRODUCT QUALITY ENGINEERING
C. TQSG: TECHNOLOGY & QUALITY SYSTEMS GROUP
D. CQE: CUSTOMER QUALITY ENGINEERING

The team "Failure Analysis" comes under CQE department. This team is responsible for proactively finding out the issues which might occur in the products on the basis of customer provided-logs and previously occurred bugs and thus resolving the issues through various ways, for eg., software upgradation. This paper will have a detailed discussion on FA process in the later section.

4. FAILURE ANALYSIS (FA)

Failure Analysis is a process that supports the foundation of supply chain operations by proactively identifying the issues that can occur in a software or hardware product and thus, dig into the root-cause of the issue by duplicating and isolating the bugs. This paper discusses and analyses three used-cases on Failure analysis and Root-cause analysis, but before that it is important to understand some basic concepts regarding them [13].

Table -2: Failure Analysis Definitions

TERM	DEFINITION
Failure	The product no longer performs the function for which it was intended
Failure Mode	Effect by which a failure is observed
Failure Mechanism	The physical, thermodynamic, chemical or other process that results in failure.
Failure Model	Quantitative relationship between lifetime/probability of failure and loads
Load	Application or environmental condition needed (electrical, thermal, mechanical, chemical) to precipitate a failure mechanism.

4.1 Classificationof Failures

Failures can be broadly classified as :

1. Overstress: use conditions exceed strength of materials; often sudden and catastrophic
2. Wearout: accumulation of damage with extended usage or repeated stress

Figure 1 gives the details about the failure mechanism identification and Figure 2 provides the Failure analysis process of Electronics component

4.2 Root-Cause Analysis

Root-cause is the most basic sausal factor/s that, if corrected or removed, will prevent the recurrence of the situation. It's a methodology which should answer to the 'WHAT', 'HOW' and 'WHY' of a particular occurrence [16]. It's four main objectives are:

1. Verify that a failure occurred
2. Determine the symptom or the apparent way the part has failed (mode)
3. Determine the mechanism or root-cause of the failure
4. Recommend corrective and preventive action

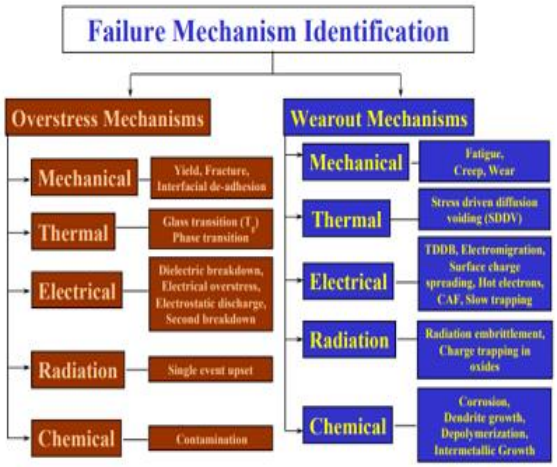

Fig -1: Failure Mechanism

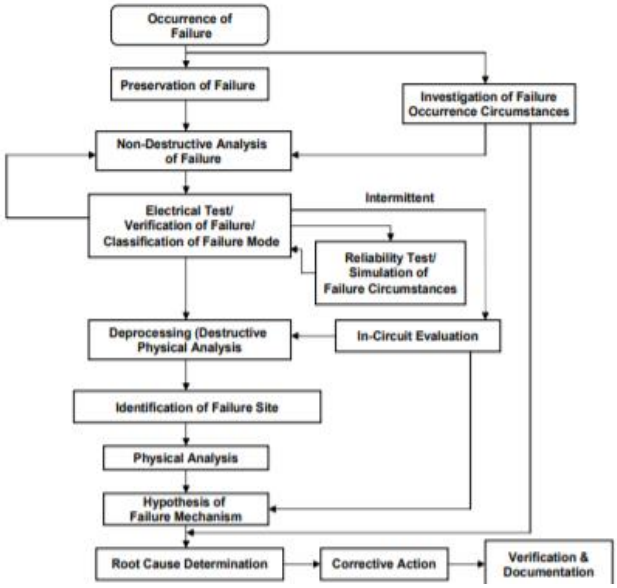

Fig -2: FA Process Flow of Electronics

5. FAILURE ANALYSIS PROCESS

Cisco Systems, Inc. follows a series of steps to carry out the failure analysis process, which are discussed below.

The first step in this is to inspect the part and review all the relevant data including description of the customer-reported issue looking for detail of symptoms, trouble-shooting steps, environment of unit location, devices connected to unit, system logs collected when issue occurred. Take a detailed description of the symptoms occurring in the product, the environmental conditions, and the frequency of occurrence

of the event. System logs are included in the Service Request (SR) by the customers or Technical Assistance Center (TAC).

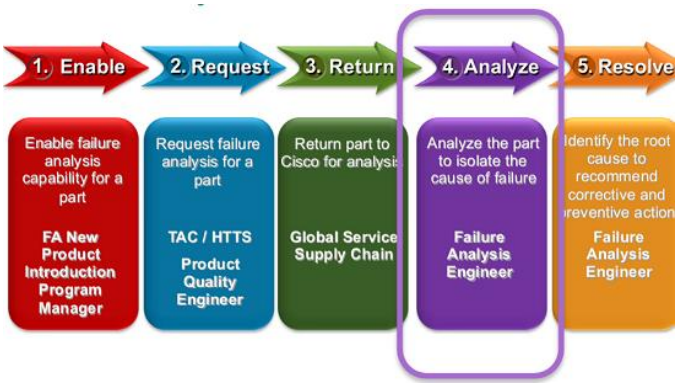

Fig -3 CISCO End to End FA Process

The system logs provide information about the parts of the product that experienced an issue. They can also help identify the connected devices and the status of those devices. If there are specific error messages generated by the system, additional information about the messages can be found in the Cisco tools, such as the 'Error Message Decoder'. If there isn't enough information about the case available, e-mail the FA case creator asking for it. Search for same customer issue in the FA case management system. Also, try to identify the issue using the serial no. to find if there were manufacturing issues.

Fig-4 Crushed Packaging

Fig -5 Unsealed packaging

The second step is the attempt to duplicate customer-reported issue which includes the following

- Create a test plan- Power up the system and check operational features, like LEDs, ROMMON, fans, power supplies, loading images through network/flash, ping test etc.
- Replicate customer conditions: Set up the system with customer's configuration and run Targeted tests targeting specific features and parts that are reported to be failing. Various other tests like Diagnostic test, Traffic test, EVDT test should be carried out depending on the product and the issues occurring.
- Perform non-destructive test : This is done to prevent the destruction of any evidence that might be causing the issue

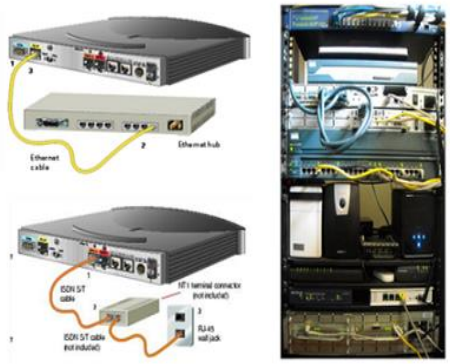

Fig -6 Customer's config for Target Test

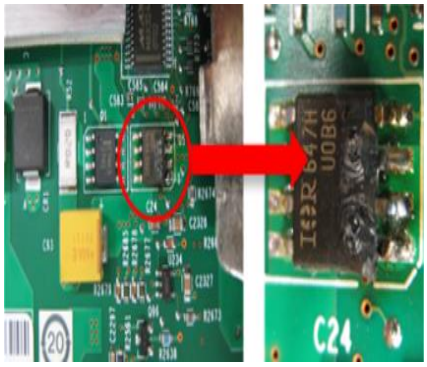

Fig -7 Burned component

The third step includes if successful in previous steps, attempt to isolate the cause of the issue. Once, the issue is consistently duplicated, the next step is to isolate the cause of the issue. The cause of an issue is a failing component or interface between components, which could have been introduced during design, manufacture, qualification or service of the part or components. Eg. Printed Circuit Board (PCB) Assemblies; Crystal Oscillators; Component solder connection failures, cable harness assemblies, etc. Visual Inspection of the component might help find the cause of the issue (fig 8).
The fourth step is to present the result of the tests to the Quality Improvement Team (QIT) and finally, close the FA case.

6. CASE STUDY

Case studies on failure analysis of electronic devices and components are described in the following table.

A. CASE STUDY NO.1

Case Description	
Symptom Code	Chassis
Problem Description	heard capacitors popping and saw sparks from the front of the switch
Case Status	Closed
Inspection & Review	
Part Inspection Summary	. Visual inspection -Failed . Found thermal event on power brick
Case Review Summary	Power supply issue -There are issues with removable power supplies.. - The LED lights are OFF. Tested it with a different power cable. - Power supply didn't turn on with the new power cable. Tested the switch with a different power source.
Fault Duplication and Isolation	
Fault Duplication Test Plan	1. Make sure Module/Unit is testable. 2. Review Case notes/Customer reported issue and Visual inspection. 3. Insert Module/Unit in to well-known chassis and Check the Power issue. If the failure event still could not duplicate, then perform Stress test. 4. Before Promoting module to Fault Isolation determine if the fault was successfully and repeatedly duplicated. 5. If the failure event still could not duplicate, Capture all Logs and attach to tool.
Fault Duplication Result	Cisco confidential
Fault Isolation Theory	Cisco Confidential
Closure Detailes	
Closure Code	Fault Isolated
Closure Description	- Visual inspection -Failed - Measurement location IBC found no output, but input work fine. - Issue narrow down to part IBC Power brick. - DC-DC converter location IBC burnt is cause of failure.

B. CASE STUDY NO. 2

Case Description	
Symptom Code	Chassis
Problem Description	A component is hitting a known bug X. This bug is primarily being seen by customer as their components are within the affected serial number range. If the device is experiencing the same symptoms of the bug X but it is outside of the affected serial number range, proceed with NBD RMA and EFA.
Case Status	Closed
Inspection & Review	
Part Inspection Summary	The unit passed inspection. Failure from customer is refer to bug X
Case Review Summary	Customer Requested Case Send to the next step for FD
Fault Duplication and Isolation	
Fault Duplication Test Plan	1. Review more detail in TAC. 2. Test diagnostic at ambient 25'C. 3. Test Diagnostic at 4 Corners (-5'C, +55'C) with voltage margin set. 4. Test Traffic layer2 at 4 Corners (-5'C, +55'C) with voltage margin set.
Fault Duplication Result	Cisco confidential
Is Fault Duplicated	No
Fault Isolation Theory	Cisco Confidential
Closure Detailes	
Closure Code	Cannot duplicate
Closure Description	Analysis result: Cannot duplicate Inspection summary: 1. The unit passed inspection. 2. Failure from customer is refer to bug X.

7. META-ANALYSIS

Thorough analysis of the three FA cases extracted from Cisco QMS tool gave us an insight about practical situations occurring in the process of failure analysis. Using the concepts of quality control and FMEA, Cisco has successfully developed a sequence of steps, following which one can identify the root-cause of the customer-reported issue and come up with a solution to overcome them.

In this paper we come across two very diverse form of issues and understand the approach of analysis. The first case study, FA case no. 1 is quite elaborate. In this case we observe that the customer reported 'popping of capacitors and sparks in the switch'. Through inspection and review we get to know that there exists some issue with removable power supplies. After following the necessary steps and successfully duplicating and isolating the cause of the issue, it is found that the device was unable to power up. The FA engineer comes to a conclusion that the DC-DC converter location IBC is burnt and is the cause of failure. And thus, the case is closed.

The second case study FA case no. 2 is about the customer facing repeated occurrence of the same known bug X in the product, but since it is outside the affected serial number range, one should proceed with NBD RMA. After following the fault duplication test plan, it was observed that the board completed all the tests successfully, including the 4'C test (Temperature-Voltage variations), and thus the issue could not be duplicated. This can happen sometimes when the logs submitted by the customer are improper. Hence the case was closed with CND.

With such variations in the reported issues and the severity of the case, the failure analysis follows the same series of steps. If the case is successfully fault duplicated, the FA engineer can proceed with the isolation and thus move forward towards the solution. But if, the fault is not duplicated, the product is sent for complete testing to DGI (Defective Goods Inventory), and if the product passes all the tests, it is considered a non-defective product and included in FGI (Finished Goods Inventory).

8. CONCLUSION

The success of modern supply chain lies in the efficiency of its different components. There have been plenty of research works that focused different aspects of supply chain such as raw material handling, processing, manufacturing, distribution and sales. However, these days 'after sale service' issues are of major concern for any firm to gain customer satisfaction and loyalty which has not been properly addressed by the researchers. This paper proposes an efficient way to deal with the issues encountered by the customers. Following the prescribed sequence of steps for failure analysis, one can successfully identify the cause of the customer-reported issue, analyze the root-cause, and hence resolve the bug from existing products as well as the new products.

The procedure carried out for Fault-duplication and Fault-isolation depends on the nature of issue and the product. Various tests like Diagnostic test, Traffic test, EVDT test, 4'Corner test , visual inspection test etc. are carried out in the process to dig into the root-cause, and once it is identified, removing it can prevent the recurrence of the situation.

Quality control through failure analysis has a major business impact on any organization. It helps create new bug IDs to address maximum issues, and thus avoids RMA, which reduces a huge amount of expenditure on customer satisfaction and finally results in Supply Chain Excellence.

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