A DISCIPLINED APPROACH ON CAUSAL ANALYSIS

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ABSTRACT

Now, more than ever, companies want to deliver products and services better, faster, and cheaper. At the same time, in the high-technology environment of the twenty-first century, nearly all organizations have found themselves building increasingly complex products and services. Today, a single company usually does not develop all the components that compose a product or service. More commonly, some components are built in-house and some are acquired; then all the components are integrated into the final product or service. Organizations must be able to manage and control this complex development and maintenance process. The problems these organizations address today involve enterprise-wide solutions that require an integrated approach. Effective management of organizational assets is critical to business success. In essence, these organizations are product and service developers that need a way to manage the Causal Analysis and Resolution in order to identify and analyze the causes of defects and other problems and to take the necessary actions to remove the causes and prevent the occurrence of those types of defects and problems in the future.

1.0 INTRODUCTION

In the current marketplace, there are many approaches, practices, models, standards, methodologies, and guidelines that can help an organization improve the way it does business. However, most available improvement approaches focus on a specific
part of the business through corrective actions rather than proactive measures and do not take a systemic approach to the problems that most organizations are facing.

2.0 LITERATURE REVIEW

Lots of studies were performed in the area of root cause analysis and many defect tracking mechanism were handled in this area as part of the improvement. The following were the observation found from the past studies done in the area of root cause analysis.

1. Defects were identified
2. Cause were identified
3. Necessary actions were triggered to fix the causes than defects
4. Same type of defects was not repeated due to consistent process follow up.

Root cause analysis which is also called as Causal Analysis may also be performed on problems unrelated to defects. For example, causal analysis may be used to improve quality attributes such as cycle time. Improvement proposals, simulations, dynamic systems models, engineering analyses, new business directives, or other items may initiate such analysis. It is observed during the past studies qualitative approach was being implemented across the business and projects.

3.0 SCOPE OF WORK AND OBJECTIVE

Apart from the qualitative approaches followed in the work I intended to evolve the following aspects as part of my study:

1. A systematic and disciplined approach is built that gives the step by step approach that can be understood by any person in the organization.
2. A Quantitative approach is introduced that speaks in terms of numbers rather than subjective alone.
3. Various thought processes are also dealt by comparing the various standards that are available in the industries and market.
4. The Critical to quality characteristics for improving the defect prevention are being monitored and controlled using various useful metrics.
5. Continual Improvement is ensured by implementing the process improvement model.
6. Defect prediction model is being used in order to predict the defects occurrence that triggers the proactive measures and prevents the reactive measures.
4.0 RESEARCH METHODOLOGY

4.1 DATA COLLECTION MECHANISM AND METHODOLOGY

4.1.1 Process:

Root cause analysis also called as Causal Analysis had been implemented using the organizational standard process assets library. All the guidelines, procedures, checklists and templates used for data collection and causal analysis follows the organizational standard set of processes that adheres to ISO 9001:2000, CMMI v1.2 ML 5 and ISO 27001:2005 etc.

4.1.2 Tools

Defect tracking tool is one of the better option considered where across the organization consolidated reports could be generated that helps in arriving the expected results through analysis.

4.1.3 Interview:

The root causes have been identified by interviewing various project managers, project leaders and relevant stake holders. The interview had been triggered via in person, mails and over the calls. Nearly 20 potential candidates had been identified and the observation has been recorded.

4.1.4 Brainstorming mechanism:

Apart from the interview process necessary discussion namely the brainstorming activities were held including the representatives from the Business team, Project team, Quality team and other support units.

4.2 PRIMARY DATA:

Raw data were collected mainly from the Defect Tracking tool and those data can be listed as follows.

4.2.1 Project id

Project Id is a unique attributes form which the defects are arising.

4.2.2 Project name

The project Name refers to the identifier from where the defects belong to.
4.2.3 Project type

This refers to the type of project like Development Project, Maintenance Project and Support project

4.2.4 Methodology

This identifier includes the nature of project like Software Methodology, Object Oriented methodology, SAP approach oriented and ITSM methodology.

4.2.5 Project manager

The project Manager is the key accountable person who is responsible for the success of the project.

4.2.6 Project leader

The project leader is the most responsible person who plays a significant role in deciding the projects progress towards the success for the project and mainly on the root cause analysis.

Timely Defect prevention activity need to be triggered by the Project Leader.

4.2.7 Phase of detection

The phase in which a particular defect is detected. The phases includes the following
a. Analysis
b. Construction
c. Design

4.2.8 Inspection / Review item

The artifacts or type of document which is subject for review or inspection that forms the source of defect identification is dealt in this section. It relevant artifact or document includes the following:

a. Detailed Design Document
b. Integration Test Cases
c. Software Requirement Specification
d. Source Code
e. System Test Cases
f. Unit Test Cases
4.2.9 Severity (h/m/l)

The severity of defects can be classified as follows:

a. Critical
b. High
c. Low
d. Medium

4.2.10 Type

The type of defect can be categorized as follows:

a. Computation
b. Configuration
c. Data
d. Documentation
e. Interface
f. Logic
g. Others
h. Standards
i. System
j. User Interface

4.2.11 Phase of origin

The phases where the defects can be originated could be distinguished as given below.

a. Analysis
b. Construction
c. Design
d. Grand Total

4.2.12 Defect category

The defect category is one another important measure or factor that contributes during the management and prediction of defects that are useful for a proactive approach.

a. Architecture (Physical/Logical)
b. Compatibility
c. Computational
d. Data Model / Database Design
   e. Data Validation
   f. Design Non Conformance
   g. Error / Exception handling
   h. Incomplete Requirement
   i. Incorrect Requirement
   j. Initialization
   k. Input / Output
   l. Installation / Configuration
   m. Logical
   n. Missing requirement
   o. Module/Package/Class/API Design
   p. Not Meeting Coding Standards
   q. Not Meeting Documentation Standards
   r. Not meeting the standard
   s. Test Cases / Test Scripts
   t. User Documentation / Help Design
   u. User Interface
   v. User Interface Presentation

4.2.13 Follow-up action proposed

The action that is recommended so as to achieve a particular cause of the defect in such a way to achieve the defect prevention mechanism.

4.2.14 Follow-up action status

Status of a particular action item that has been identified as a proposed followup action item. This helps a particular action item to track to closure.

a. Initiated
b. Closed
c. Resolved
d. Onhold
4.2.15 Verification of follow-up action status

This is one such measure that conveys the message whether the proposed follow-up action item is verified and closed so that the implementation can be considered as successful one. The real success comes when the same type of defect should not occur in future.

The status could be as follows:

a. Verified and closed
b. Rejected

4.3 SECONDARY DATA

Secondary data are the data that are arrived due to combination of primary metrics or could be the condition that it depends on the primary data. Those data are listed as given below.

4.3.1 Cause-wise distribution of defects

Formula

For each pre-defined cause – (defects attributed to the cause / total defects) * 100.

4.3.2 Defect detection rate in inspection

Formula

Total no of defects detected in inspection / Actual Size (For each category of work product)

The Actual Size is size of work product that was inspected

Category of work products are – Plans, Technical Documents and Code

4.3.3 Delivered defect density

Formula

(D1 + D2 + … + Dn) / (S1 + S2 + … + Sn)

Where

n = work request for which acceptance test completed in a month

D1, D2, …, Dn are the defects reported for each work request during acceptance testing and / or use

S1, S2, …, Sn is Actual Size of individual work request where size is terms of changed LOC
4.3.4 Delivered defects

**Formula**

\[(\text{Number of work requests delivered with defects} / \text{Number of work requests delivered}) \times 100\]

4.3.5 Phase-wise defect detection rate

**Formula**

Total no of defects detected in a phase / Actual Size (for each category of defects)

The Actual Size is size of document for phases prior to construction and source code size after construction upto acceptance testing

4.3.6 Defect removal efficiency (phase-wise and cumulative)

**Formula**

Phase-wise Defect Removal Efficiency

For phase I, DRE = (No. of defects found in phase I / Total no. of defects attributed to phase I) * 100

Where

Total no. of defects attributed to phase I = No. of defects found in phase I + No. of defects attributed to phase I in subsequent phases

Cumulative Defect Removal Efficiency

\[(\text{DBD} / (\text{DBD} + \text{DAD})) \times 100\]

DBD - Number of defects found before delivery
DAD - Number of defects found after delivery

4.3.7 Pre-release defect density

**Formula**

\[(D_1 + D_2 + \ldots + D_n) / (S_1 + S_2 + \ldots + S_n)\]

Where

n = work request delivered in a month
D1, D2, …, Dn are the defects reported for each work request prior to delivery. This includes defects detected in the code review and testing.
S1, S2, …, Sn is Actual Size of individual work request where size is terms of changed LOC
4.3.8 Review efficiency

Formula

\[
\left( \frac{\text{Total Defects Detected in Review}}{\text{Total Defects Detected in Review} + \text{Total Defects Detected in Testing}} \right) \times 100
\]

The term Review includes both Review and Inspections

4.3.9 REWORK DUE TO DEFECTS

Formula

\[
\left( \frac{\text{Total Rework due to Defects}}{\text{Total Actual Effort}} \right) \times 100
\]

5.0 SUMMARY OF THE RESEARCH WORK

5.1 ROOT CAUSE ANALYSIS - A SYSTEMATIC AND DISCIPLINED APPROACH

In essence, these organizations are product and service developers that need a way to manage the Causal Analysis and Resolution in order to identify and analyze the causes of defects and other problems and to take the necessary actions to remove the causes and prevent the occurrence of those types of defects and problems in the future.

5.2 CAUSAL ANALYSIS IN COMPARISON WITH OTHER QUALITY STANDARDS

5.2.1 Causal analysis vs ISO series

Clause 8.5.2 - Corrective action

The organization shall take action to eliminate the causes of nonconformities in order to prevent recurrence. Corrective actions shall be appropriate to the effects of the nonconformities encountered.

Clause 8.5.3 Preventive action

The organization shall determine action to eliminate the causes of potential nonconformities in order to prevent their occurrence. Preventive actions shall be appropriate to the effects of the potential problems.

5.2.2 Causal analysis vs CMMI series

The purpose of Causal Analysis and Resolution is to identify causes of defects and other problems and take action to prevent them from occurring in the future.
5.2.3 Causal analysis vs six sigma

Process:
A process can be described as a transformation of set of inputs into desired outputs.

The desired output differs from the expected output and hence the nonconforming condition is called as Defects or defectives.

The Root cause of defects is because of variations.

Variations

There are two types of variations
a. Variations due to Chance Causes
b. Variations due to Special Causes

Properties of Variations due to Chance Causes
a. Inherent to the process
b. Occurs randomly
c. Process adjustments cannot eliminate these variations
d. Elimination requires fundamental changes in process
e. For a given process this variation is inevitable
f. Predictable, as it can be described by statistical distributions

Properties of Variations due to Special Causes
a. Due to specific identifiable causes
b. Irregular occurrence
c. Unpredictable
d. Can be avoided by correcting/adjusting process parameters / process inputs Variations in the process are controlled by the Statistical Process Control.
5.3 DEFINITIONS RELATED TO CAUSAL ANALYSIS AND RESOLUTION

5.3.1 Quality

Quality can be defined as a set of inherent characteristics that meet the customer requirements.

5.3.2 Defect

Defect refers to a failure to comply with requirements.

5.3.3 Correction

A correction is any action that is taken to eliminate a nonconformity. However, corrections do not address causes.

5.3.4 Corrective actions vs preventive actions

<table>
<thead>
<tr>
<th>S.No</th>
<th>CORRECTIVE ACTIONS</th>
<th>PREVENTIVE ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>To remove the causes of an existing Nonconformity</td>
<td>To remove the causes of potential Nonconformities</td>
</tr>
<tr>
<td>2.</td>
<td>Designed to prevent the recurrence of Nonconformities</td>
<td>Designed to prevent the occurrence of Nonconformities</td>
</tr>
<tr>
<td>3.</td>
<td>Address actual problems</td>
<td>Addresses potential problems</td>
</tr>
<tr>
<td>4.</td>
<td>Can be thought of as a problem solving Process</td>
<td>Can be thought of as a risk analysis process</td>
</tr>
</tbody>
</table>

• Taking of measurements and arrangement of those measurements to reveal the pattern and to allow predictions on performance.

• End product is resultant of combination of Methods + People + Material + Environment + Equipment

• Comparing Actual performance Vs Target

• Identifying Gap in performance

• Taking necessary corrective actions
5.4 STRATEGIC APPROACH

The strategic approach includes the following steps namely.

5.4.1 STEP 1: IDENTIFY AND COLLECT THE DEFECTS

5.4.2 STEP 2: PRIORITIZE THE DEFECTS

5.4.3 STEP 3: IDENTIFY THE ROOT CAUSES

5.4.4 STEP 4: IDENTIFY THE POTENTIAL ROOT CAUSE

5.4.5 STEP 5: STRATEGIC PLAN OF ACTION

5.4.1 STEP 1: IDENTIFY AND COLLECT THE DEFECTS

To perform a unit level Causal Analysis for the defects as outcome of Review and Testing Process. Defect Data had been collected from Review and Testing activities as obtained from Defect tracking Tool.

5.4.2 STEP 2: PRIORITIZE THE DEFECTS

Using the Pie chart it is found that maximum number of defects are from System Testing and Reviews.

![Defects Type](image)

Figure 1 Defects Type

5.4.3 STEP 3: IDENTIFY THE ROOT CAUSES

Concerned PMs, PLs and Key Stakeholders were involved in this activity to generate various root causes for the Defects that were identified as part of Review and Testing activities.
5.4.4 STEP 4: CYCLE 1 – IDENTIFY THE POTENTIAL ROOT CAUSE

The Potential Root Causes have been extracted from the List of all applicable Root Causes using the Ishikawa Tool.
Figure 4 Cause and Effect Diagram for Process related sub causes

Figure 5 Cause and Effect Diagram for management related sub causes
Figure 6 Cause and Effect Diagram for training related sub causes

Figure 7 Cause and Effect Diagram for resources related sub causes
Figure 8 Cause and Effect Diagram for requirements related sub causes

Figure 9 Cause and Effect Diagram for design related sub causes
Figure 10 Cause and Effect Diagram for coding related sub causes

Figure 11 Cause and Effect Diagram for testing related sub causes
5.4.5 CYCLE 2 – EVOLUTION OF POTENTIAL ROOT CAUSES

All the identified potential root cause had undergone one more cycle of review. Based on the formal evaluation method more critical potential causes that adhere to impact of the Quality are identified.

Figure 12 Cause and Effect Diagram for process related sub causes
Figure 13 Cause and Effect Diagram for management related sub causes

Figure 14 Cause and Effect Diagram for resources related sub causes
Figure 15 Cause and Effect Diagram for requirements related sub causes

Figure 16 Cause and Effect Diagram for design related sub causes
Figure 17 Cause and Effect Diagram for coding related sub causes

Figure 18 Cause and Effect Diagram for testing related sub causes
5.4.6 STEP 5: STRATEGIC PLAN OF ACTION

Plan of Action has been devised in such a way that all the Potential Root Causes need to be fixed and closed strategically.

Table 1 Strategy for achieving Potential Root Causes

<table>
<thead>
<tr>
<th>S.No</th>
<th>Causes Category</th>
<th>Potential Root Causes</th>
<th>Strategic Planning</th>
<th>Execution</th>
<th>Verification</th>
<th>Evidence</th>
<th>Measures</th>
<th>Responsibility</th>
<th>Target Date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Management</td>
<td>Lack of Management Commitment</td>
<td>Including the Senior Management during the project reviews</td>
<td>Representatives from senior management taking part in project review</td>
<td>Involvement of Senior Management Commitment can be checked by following means</td>
<td>Monitor the Meeting Attendance Sheet, Maintenances</td>
<td>Reviews Effectiveness during Project Review, GMR etc.</td>
<td>SMJ</td>
<td>31-Jul-09</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Requirements</td>
<td>Insufficient time for Requirements Review</td>
<td>During the Project Planning timeframe should be taken for providing more effort for Requirements Review</td>
<td>More Effort is spent on Revising the Requirements</td>
<td>Whether necessary Effort is spent on Requirements Review</td>
<td>Project Plan - VSS, Review Report for test case, Defect Log.</td>
<td>Defect Removal Efficiency, Review Efficiency</td>
<td>SV</td>
<td>31-Jul-09</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Design</td>
<td>Insufficient time for Design Review</td>
<td>During the Project Planning timeframe should be taken for providing more effort for Design Review</td>
<td>More Effort is spent on Revising the Design</td>
<td>Whether necessary Effort is spent on Design Review can be checked by following means</td>
<td>Project Plan - VSS, Review Report for test case, Defect Log.</td>
<td>Defect Removal Efficiency, Review Efficiency</td>
<td>SMJ</td>
<td>31-Jul-09</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Coding</td>
<td>Insufficient time for Code Review</td>
<td>During the Project Planning timeframe should be taken for providing more effort for Code Review</td>
<td>More Effort is spent on Revising the Code</td>
<td>Whether necessary Effort is spent on Code Review can be checked by following means</td>
<td>Project Plan - VSS, Review Report for test case, Defect Log.</td>
<td>Defect Removal Efficiency, Review Efficiency</td>
<td>SV</td>
<td>31-Jul-09</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Process</td>
<td>No Tollegate check provided during any deliverables</td>
<td>Instruction for project team to implement the Tollegate checks systematically in all the phases or milestones</td>
<td>Implementing the Tollegate checklist systematically before any deliverable can be checked</td>
<td>During PPMA and Audits usage of Tollegate check list before any deliverable or release can be checked</td>
<td>Implementation of Tollegate Checklist can be evidenced by the following means</td>
<td>Defect Detection Efficiency</td>
<td>FS</td>
<td>31-Jul-09</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Resources</td>
<td>Lack of Motivation</td>
<td>Constant Monitoring of Associate in all possible means</td>
<td>Training related to technical and management are executed among the associates</td>
<td>During PPMA, Audits, Project Review Meetings</td>
<td>Training Evidence - Attendance Sheet, Feedback form</td>
<td>Associate Effectiveness before, during and after the training</td>
<td>SMJ</td>
<td>31-Jul-09</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Testing</td>
<td>Insufficient time for Test Code Review</td>
<td>During the Project Planning timeframe should be taken for providing more effort for test case review</td>
<td>More Effort is spent on Revising the test case that brings down the concerned defect occurrence</td>
<td>Whether necessary Effort is spent on test case review can be checked by following means</td>
<td>Project Plan - VSS, Review Report for test case, Defect Log.</td>
<td>Defect Removal Efficiency, Review Efficiency</td>
<td>FS</td>
<td>31-Jul-09</td>
<td></td>
</tr>
</tbody>
</table>

5.5 WHAT IS DIFFERENT IN MY AREA OF RESEARCH?

Like other studies I had conducted a systematic and regressive analysis and utmost care was taken during the Defect data collection, prioritizing, identifying the root causes. In addition to this the study were extended to drill down to the potential root
causes that are actually the real causes. Not stopping at upper level but to an extent of proceeding to the core level. Also an disciplined process improvement model is used in order to achieve the consistent and progressive continual improvement.

**5.6 EVOLUTION OF CAUSAL ANALYSIS IMPROVEMENT MODEL**

Causal Analysis Improvement model is built with the past data for generating the pattern, current data for understanding the present system and the relevant metrics to identify a path to direct the process improvement. This brings out the necessary quantification in the system apart from qualitative.

Causal Analysis Improvement model consists of the following elements:

1. Strategic Planning
2. Execution
3. Verification
4. Evidence
5. Measures

Please refer the table 1 and it would represent the model expectations.

This cycle will be repeated till all the root causes will be identified and the model will take care of the prevention measures because of which the continual improvement will be ensured.

**6.0 CONCLUSION**

Causal Analysis Improvement model that contributes to the Quantitative approach improves quality and productivity by preventing the introduction of defects into the products or service. Reliance on detecting defects after they have been introduced is not cost effective. It is more effective to prevent defects from being introduced by integrating causal analysis and resolution activities into each stage of the project or business.

The types of defects and other problems encountered are analyzed to identify any trends. Based on an understanding of the defined and quantified process and how it is implemented, the root causes of the defects and the future implications of the defects are determined. The Causal Analysis Improvement model monitors and control the entire system by Strategic Planning, Execution, Verification, Evidence and Measures.
Causal Analysis Improvement model plays a critical role for communicating lessons learned obtained from defects and problems previously encountered on other projects or business or in earlier stages or tasks.

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