AN INTEGRATIVE APPROACH TO ROOT CAUSE ANALYSIS

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Abstract - The integrative nature of using problem solving and root cause analysis is often misunderstood. This leads to facilitation of investigations which often do not eliminate future and recurring failures. It is crucial to understand the various types of causes and how they interact to form the root cause of an incident, in order to the investigation to ensure that all corrective actions are identified and implemented. Specific techniques only guide the investigator to a specific cause and a specific prevention measure, which is not integrative and holistic in nature. Harnessing an integrative approach, and knowing when to use which technique, will ensure a successful RCA.

The term, Root Cause Analysis (RCA), is probably one of the most common terms in the world of Asset Management and Reliability Engineering. Its application is widely used in basic fault finding, detailed failure investigations and continuous improvement in the engineering and operations improvement sphere, although it can be used just as effectively in any other engineering practice.

Several acknowledged methodologies exist, all with the end goal of identifying the root cause of failures and thereby eliminating recurrences. In understanding the various methods, when to use them, as well as the different types of causes and how they interact, RCA can be transformed to a powerful tool to be used in any problem solving scenario. This will in turn lead to a consolidated view to manage risk and contribute to better operational stability and reliability.

Contextualising Root Cause Analysis

Although RCA is mainly used in cases after a failure or incident has occurred (in other words, as a reactive tool), the value of an effective RCA as part of a Reliability Centred Maintenance (RCM) approach should not be excluded.

RCM is a collective term referring to a structured process that is followed in setting out strategies for assets to ensure that each will fulfil its intended function throughout its life cycle. These strategies include maintenance plans, operating philosophies, renewal plans etc. In this context, a properly conducted RCA can provide crucial input in the asset strategy relating to understanding failure modes, consequences of failure, degradation mechanisms and anticipated life cycle.

RCA also contextualises risk and how to manage these risks, as it looks wider than just the technical aspects and encompasses a multi-disciplinary solution. An RCA can thus be conducted pro-actively before an undesirable event occurs, to ensure that controls are in place to be preventive and more predictive.

It is critical to understand, that there is a fundamental difference between RCA and fault finding, as per **TABLE 1**. RCA seeks to understand the entire spectrum of problems or potential obstacles by means of reviewing the entire package of available information. Fault finding is where the error is searched for and corrected in order to continue normal operations. Fault finding is thus an input into an RCA and not an RCA in itself. The causes identified in the fault finding will form part of the RCA solution.

TABLE 1: Root Cause Analysis versus Fault Finding

ROOT CAUSE ANALYSIS	FAULT FINDING
• Finding entire spectrum of reasons for an incident.	• Finding the technical reason for an incident.
• Always has more than one cause.	• Usually limited to a single item.
• Usually latent, systemic and procedural in nature.	• In most cases it is physical in nature.
• Diverse and multi-disciplinary orientated.	• Most often technically orientated.
• Wider knowledge is needed, such as legal, procedural, human resources etc.	• Specialised, technical knowledge is usually needed to resolve the issue.

Overview of the Most Common Methods

To facilitate a successful RCA, it is important to understand the various techniques that can be used, as well as the advantages and limitations to each tool. **TABLE 2** is a high level summary of the most common methods.

TABLE 2: Overview of the Most Common Root Cause Analysis Methods

METHOD	BRIEF OVERVIEW
5 Why	• Ask the question "why?" 5 times. • Usually limited to technical causes. • Often does not take contributing causes into consideration. • It is very direct and to the point.
Barrier Analysis	• Identifies barriers to be in place to prevent incidents. • Barriers are evaluated to see where it failed or were ineffective. • Often does not identify missing barriers - expert knowledge required. • A good tool to validate findings & recommendations.
Causal Factor Tree	• Align the sequence of events with the conditions that caused it. • Link events & conditions (with evidence) line to represent the incident. • Identifies the root cause, as well as causal factors.
Fault Tree Analysis	• Identifies all faults and causes that could lead to the incident. • Logically groups items to indicate the integrated nature of causes. • Clearly indicates the sequential effect of the various causes.
Fishbone / Ishikawa Diagram	• Group all causes into categories (i.e. people, process & procedures) • Group causes into sub-causes and evaluate the causes against proof. • Can be used effectively with any other technique.
Failure Mode & Effect Analysis (FMEA)	• Identify all the potential failures & preventive actions. • Evaluate if all preventive actions were implemented and followed. • This usually translates to maintenance strategies. • Good starting point & end point to every investigation.
Kepner-Tregoe©	• Evaluate the situation by comparing it to similar systems / equipment. • List the differences and changes to derive a root cause • Highly factual method that works well where impartiality is crucial.

Pareto Analysis	• List all potential causes and rank causes according to probability • The top 20% of causes will have the most severe consequences. • Works well when there are complex issues with several causes / roots.

In some instances it may be beneficial to use a combination of techniques in order to address all failures successfully, provided that each method is used and applied correctly. Refer to paragraph 5 for practical examples.

Classification of Causes

It is crucial to understand the various types of causes and how they interact to form the root cause of an incident. This guides the investigation to ensure that all corrective actions are identified and implemented. **TABLE 3** explains the various types of causes that are usually present in an investigation.

TABLE 3: Explanation of the Various Types of Causes

CAUSE	BRIEF OVERVIEW
Root Cause	• Most basic cause which can be corrected to prevent recurrences.
Direct Cause	• Primary cause (usually technical) leading to an incident (usually technical).
Contributing Cause	• Not a self-sufficient cause but usually contributes to the severity of an incident.
Physical Cause	• Causes with tangible roots and is often visible after the incident.
Human Cause	• Refers to human actions, for instance tasks that were executed / not executed.
Latent Cause	• Underlying reasons that explains procedural / human causes.

Typical Steps in a Root Cause Analysis

The typical steps in executing a successful RCA are discussed in the various sections below. These steps are not dependent on a specific method, but are based on experience and consolidated lessons learnt.

1. The Problem Statement

A good problem statement can form the backbone of an investigation. Often an external person needs to facilitate an RCA, hence developing a good problem statement plays a vital role in aligning people, guiding the direction of the investigation and to setting the scene for a team to reach a solution.

The problem statement needs to be as specific as possible in terms of date, time, location and conditions during which the incident has occurred. Set the boundary of the investigation and clearly include / exclude items that will not form part of this investigation. It is advised to keep this problem statement visible at a physical location as well as to refer back to this statement whenever the team needs clarification. It also assists to place the correct focus on the investigation. This often plays a critical role when distinguishing between fact and fiction at the initial phases of the investigation.

The role of a competent facilitator is crucial as the facilitator needs to build a focussed team dynamic and get the buy-in from all the parties involved from the starting point. If this fails to happen, the RCA may not be successful as all the findings need to be signed off by the entire team. The facilitator thus acts as a change agent, while also conducting the investigation.

2. Understand the History & Impact of Failures

In this aspect, the equipment / system is evaluated in its entirety where all the history is collected in an attempt to compile a sequence of events. The main focus is on evaluating the original design and comparing it to the current operating and maintenance philosophies. Furthermore, this step ensures that any open actions from previous investigations are closed out and resolved fully.

This often guides the investigation to assess whether the fundamentals are correctly in place and whether there have been deviations and changes from the design intent. It also assists the facilitator in identifying areas where more detailed information for the RCA may be required.

It is also important to ensure that the function of the equipment / system / process is understood well. There is merit in explaining the process / equipment in broad terms by mentioning the basic working conditions, flow rates, pressures, product in the system, etc.

Be diligent in listing the potential conditions that could lead to failures and evaluate whether these conditions arose during the incident. At times, a criticality matrix can also be used effectively to distinguish between the root causes from the causes that impacted on the severity of an incident. This also aids the facilitator in removing personal bias during the investigation.

3. Data Gathering & Multi-Disciplinary Interpretation

Position the multi-disciplinary team members to take the lead in gathering data according to areas of expertise. Allow these members to voice over the prominent findings individually, as well as to indicate the importance of these findings and how they relate to the failure.

Sometimes arguments amongst the team members can be beneficial at this point in time, but it is important to lay down ground rules and to remind the team that the investigation is to solve a problem; not to blame people for the incident having occurred. If agreement cannot be reached, note down the issues in a visible place and revisit these obstacles as soon as facts become available.

Be factual and evaluate statements that are made during the investigation against concrete proof. The facilitator should, at all times, remain neutral. A good tool to use is to ask probing, clarifying questions and / or to guide the focus back to the problem statement. Ensure that the facts / conditions leading to failure are well understood and that they make sense logically.

4. **Sequence of Events**

Start the sequence from the closest similar occurrence in the investigation in question. In severe cases you might have to revert to history if the incident is truly first in its nature.

The facilitator plays the strongest role in this step. Often individuals in a team will look at a failure from a single, biased point of view. The facilitator reconstruct the incident chronologically, putting a multi-disciplinary picture together, based on facts only. The sequence of events need to be as accurate as possible and all facts and proven theories must be captured.

An accurate, well-developed sequence of events sets the scene for common understanding of the scenario in the team set up. Often once this integrated storyline is played back to the team, the root cause immediately stands out to the team as a whole. As a minimum, it contains traces of all of the associated root causes of the incident and starts to guide the team in thinking of all the real causes, compared to the perceived causes.

5. **Generating Potential Causes & Mechanism of Operation**

All potential causes have to be listed - even causes that are improbable and blatantly non-factual. In most instances, the person who raised such an item will eliminate it himself when the factual evaluation of causes commences. The value of including these items is in building credibility and buy-in through allowing everyone to contribute and feel that their opinions were evaluated.

For every cause the entire mechanism of failure needs to be explained and captured as it would have happened. These mechanisms also need to align with the agreed sequence of event and has to be substantiated with facts. This will aid in building the entire, integrated RCA and ensure that all causes are correctly identified and addressed.

When it is evident that a potential cause is not probable, the detail as to why this was eliminated from the investigation also needs to be captured, as this step validates the thought process through the investigation to assure quality of an RCA. The remaining potential causes, provided that they can be factually substantiated, also need to be aligned with the sequence of events.

An example of such an evaluation of causes is follows:

> "A dip in the plant air supply (listed potential cause) could have resulted in solenoid activation, causing the firewater system to be activated, without sending an alarm to the control panel (the mechanism of the failure). It was eliminated as a root cause due to the fact that the solenoid was found to be in a working order after the incident and no fluctuation in plant air supply was observed at any time."

6. Formal RCA Review per Defined Method

At this point in the investigation, the majority of work will have been completed and there should be mutual consensus on the sequence of events, as well as the potential causes. The initial list of causes will have been filtered and validated. Based on the nature of the identified causes, the information presented and the complexity of the incident, the facilitator should then choose the most appropriate RCA technique for the formal evaluation.

The facilitator should then ensure alignment of the investigation team by briefly explaining the method that will be followed. This will establish credibility such that the RCA is a well thought through process. Evaluate the potential causes against the chosen method and either eliminate them or list them as another type of cause, such as contributing etc. Include the reasoning behind every validation.

For instance, the 5 why method might be effective in drilling down to the root cause in a very technical incident, but it might fall short in addressing latent or human causes if the facilitator is not properly trained.

Another example is where frequent and several types of failures are observed across an entire plant. In this instance it would have been better to evaluate all the multi-disciplinary team data and to develop a Pareto analysis. This hotspot will then give an indication of the top 20% of failures that accumulates to 80% of losses (whether it be production loss or downtime). This will already start to converge the findings. Building a causal factor tree and then updating the FMEA (which translate to the maintenance strategy) can then assess all of the failures, the risks associated with failure and the preventive actions to be put in place.

There might be instances where there are many related causes, but identifying the single most probable cause is still uncertain. In these instances, weight the relevant causes against each other to assess the probability of the failure occurring, as per the example:

> "If the switch in the control room was activated, it would have activated the firewater system without sending an alarm to the panel, as this switch is not linked to a panel alarm. The event of this occurring, however, is highly unlikely, as this is of a 'sunken in' type and has to be pressed with deliberate action. It is possible that this switch could have been pressed in error, due to not understanding its purpose, but based on the probability of failure, the most probable cause is that this switch was faulty."

If, at this point, the root cause is still unclear, refer back to the problem statement and sequence of events. In most instances, the reason why a root cause cannot be established is that information has been omitted or is not factual. It may happen that interviews need to be conducted independently with additional people in support of facts that have been provided.

Prior to closing out the investigation, validate your findings using an RCA method that has not been used in the formal evaluation, as this bring further assurance that the correct causes have been identified.

7. Classify the Causes

Unpack all of the causes, preferably by discipline or area as it will assist in ensuring that the next steps to resolve these causes will also be executed. All other aspects that could have been of consequence need to be listed and classified per **TABLE 3** as well.

8. Generate & Document Solutions / Recommendations

An incident investigation cannot be complete or successful if solutions and recommendations are not executed. For every listed cause, there needs to be at least one recommendation for practical implementation, together with a responsible person and due date. Barrier Analysis serves as an effective tool to verify the measures to be taken to prevent incidents from occurring. If all succeeding next steps are not executed, recurrences will almost certainly occur. Often reviewing prescribed open next steps in an investigation is a good starting point for recurring incidents.

Closing

The critical success factors to an RCA lies in the strength and competency of the facilitator in to convene an investigation team, to extract information from this team, to evaluate this information according to the correct RCA method (or combination of methods) and to update preventive measures for the entire spectrum of causes. In essence, success in eliminating failures / incidents lies in the integration between the various steps in an RCA together with the correct tools and techniques. This will in turn improve the bottom line, which directly translates to cost saving, larger profit margins and continuous improvement.

Keywords

Asset Management	Condition	Preventive
Change	Design	Proactive
CMRP	Downtime	Process Improvement
Condition	Failure	Quality
Corrective	Failure Modes	RCA
Cost Savings	Lessons Learnt	Reliability
Critical	Maintenance	Root Cause