Improving equipment reliability through the implementation of Root Cause Analysis (RCA)

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Jose Baptista, Development Manager for Reliability at Quant, identifies how RCA can be defined as a structured process that uncovers the underlying physical, human, and organizational causes of any undesirable event.

The root cause analysis or simply RCA, the acronym by which it is commonly known, is an indispensable methodology for the industrial maintenance to get out of the damaging reactive mode.

To better understand what the reactive mode is; consider the situation where the maintenance crew is occupied full-time to repair equipment that randomly breaks.

In this way, the maintenance team is always overloaded; working under the constant pressure of having to repair equipment to put the plant back in operation, another term commonly used to describe this situation is "only work to put out fires." In this work model the maintenance costs are high, fairly unpredictable. There is constant tension between operations and maintenance because the maintenance is always seen as the great villain that prevents the operation to meet its production program and, moreover, accounts for a significant portion of operating costs.

What prevents the successful implementation of RCA, despite the fact that companies are becoming increasingly aware of benefits of RCA? We have to ask, "Why doesn't RCA work?"

RCA methodology

The RCA process adopted worldwide by Quant in the industrial maintenance customer sites consists of the following steps:

- Define the problem
- If necessary, perform the Failure Analysis
- Identify possible causes
- Check real cause(s)
- Propose solution to the problem
- Implement the solution
- Monitor the results

Step 1: Define the problem

Albert Einstein has said that if he had only one hour to save the world, he would spend fifty five minutes to define the problem and five minutes to solve it. The quote illustrates how important it is to define the problem in finding its solution. First, it is important to understand that any problem or undesired event can be defined as the difference between the current situation and the goal (Eckert, 2005). A common practice in defining the problem, which ultimately hinder their subsequent analysis and solution, is that some people write a real novel describing the problem and, in most cases, end up defining not only a problem, but various problems in the same description.

We need to understand that different people or groups will have different views on the same problem (Eckert, 2005). One way to circumvent this difficulty and arrive at a consensus definition is to make the following simple questions

- What is the problem?
- When did this happen?
- Where did it happen?
- What goal has been impacted by the problem?

These questions must be answered in short sentences; one object and one defect.

Step 2: Failure Analysis (if necessary)

The failure analysis is a detailed inspection of the damaged components to determine what was the mechanism or failure mode responsible for the failure. The information "how" the component failed is an important data for determining the root cause. Figure 1 illustrates an example of analysis. There are five mechanisms that lead to a component failure:

- Overload: The application of a single load (mechanical or electrical) leads the component to deform or fracture as the load is applied
- Fatigue: Floating load over a relatively long period of time causes this type of failure and, in most cases, leaves clues
- Corrosion-influenced failure: Corrosion substantially reduces the design strength of metals
- Corrosion: The failure results is the wearing away of metals due to a chemical reaction
- Wear: Several mechanisms result in the loss of material by mechanical removal

Step 3: Identify the possible causes

One of the methods used to identify possible causes of the problem is the causal tree. The causal tree starts by determining the so-called main event, which is the problem or undesired event being analyzed. This block is extremely important because it determines the rest of the sequence analysis. In sequence, it is necessary to determine what factors may contribute to the occurrence of the main event and the possible interrelations between them.

The relationship between the main event and its factors is the immediate cause-effect relationship. The second level is the possible immediate causes of it. Thereafter, for each possible cause it should immediately be related to its possible causes, each immediate cause becomes an effect.

And the diagram will be expanded to as many levels as needed, as shown below.

In a causal tree, the main event is the accident itself and it is placed at the top or at left hand side as in the below example. The next step is to provide the causes for the top event, followed by the causes for those secondary causes, and continuing on until the endpoints are reached. These endpoints are the possible root causes.

In determining the roots, to facilitate understanding of the event, the roots can be divided into the following categories (Latino & Latino, 2006): physical, human and organizational (or latent) roots

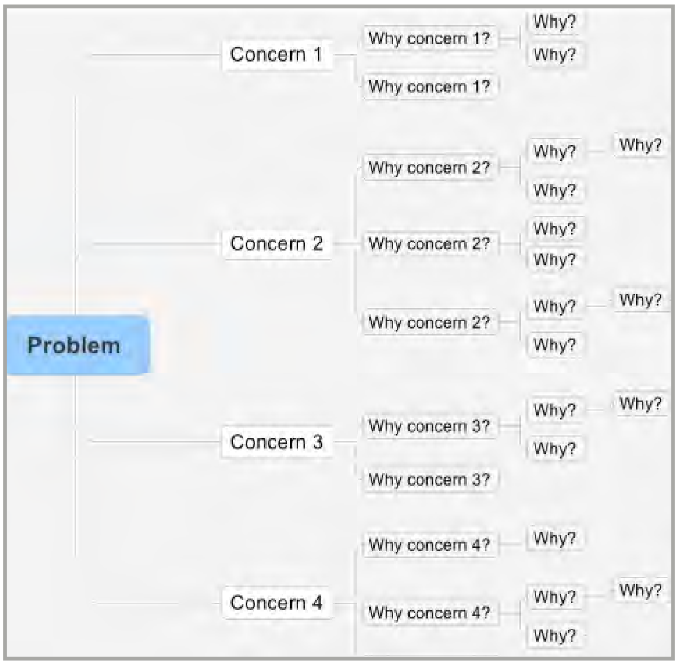


Figure 1: Example of Causal tree.

The physical roots are the immediate consequences of the event; roots are tangible or damaged components, for example. The human roots are the human actions that caused the physical roots or damage to components / materials, and finally the latent or organizational roots are the motivation for the action has been taken.

Physical roots are the physical reasons why the parts failed:
- Overload i.e. operation error, accident
- Fatigue i.e. thermally induced, mechanically induced, imbalance, misalignment, resonance, material
- Corrosion i.e. wrong material, process chemicals, environment, spills
- Wear i.e. lubrication, contamination, misalignment, excessive loading

Human roots can be understood as human decision-making errors that will cause the roots of the physical event. They are errors of action or omission, which means, someone did something they should not have done or failed to do something they should do. Examples:
- Memory i.e. forgetting a task
- Selection i.e. ordering wrong component, making wrong choice
- Discrimination i.e. poor information
- Test or operation error i.e. ‘knew’ the rest of the procedure
- Situational blindness i.e. acceptance of problems

When the conclusion of an analysis is simply human error, there is a strong indication that the analysis was incomplete. Human error just says that something was not done correctly and that there were people involved. Human error is a general conclusion that does not allow any specific action to prevent recurrence of the problem. Once the specific cause of the problem was found, organizations choose disciplinary actions as the only alternative and keep thus a vicious circle.

Organizations often blame employees for problems and seem to believe that this will set an example for all employees and discourage them to commit the same mistakes. In fact, the underlying message might be that: “If you identify a problem or are involved with a problem which is preventing us from achieving our goals, it is better not to reveal because you can be punished.”

Organizational or latent roots can be understood as organizational systems which people use to make decisions. When systems are flawed, the decisions made from them will result in errors. Some examples of organizational roots:
- Lack of employee engagement;
- Management complacency;
- Failure of communication;
- Task perceived as undesired;
- Lack of procedures, technical documentation and formal training;
- Missing or incomplete specifications;
- Incorrect incentive;
- Use of incorrect tools or worn;
- Priorities incorrect;
- Lack of access to information.

The following illustration describes the hierarchical order of root levels and implications of corrective actions:

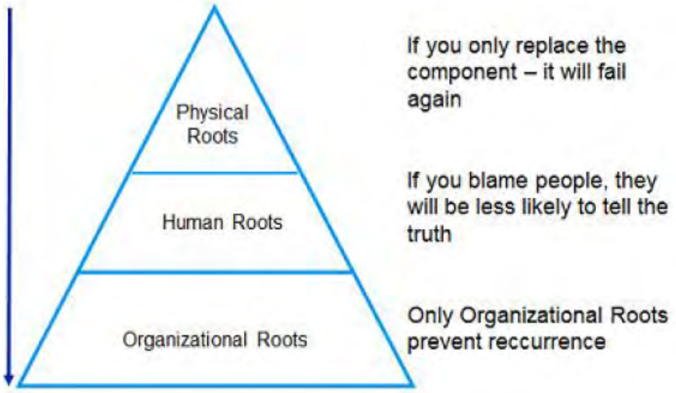


Figure 2: The three root levels.

Step 4: Check real cause(s)

In this step the possible causes are evaluated and the proof is sought through the data collected, as mentioned in the previous step.

The real causes of the event can be achieved by discarding the hypotheses that cannot be proved. “When you eliminate the impossible, whatever remains, no matter how improbable, must be the truth.” (Doyle, 1902)

Step 5: Propose solution to the problem

At this phase, the process identifies possible solutions for each individual cause found in the analysis mentioned above. It is important to verify that each solution prevents recurrence of the problem and does not create new problems. The ease of solution implementation and the required investment (cost / benefit analysis) should also be assessed.

Steps 6 and 7: Implementation of the solution and follow up

The whole process developed up to this point will be totally useless if the implementation of the solution does not take place. It is suggested that:
- A complete plan must be prepared with all the planned actions
- This plan must set deadlines, resources and responsible persons for all actions
- Do not plan many actions simultaneously or assign a single responsible
- An action properly implemented is more valuable than ten actions in the plan
- Expand the cause and expand the fix

The process of root cause analysis aims at complete elimination of the problem preventing its recurrence. Recurrence at any time, demonstrates that the process was ineffective for one of the possible causes:
- Errors in determining the root cause
- Errors in the determination of actions to eliminate the root cause
- Errors in determining the parameters for monitoring the results

Resistance to the implementation of Root Cause Analysis

To achieve success through the use of Root Cause Analysis, you must be prepared to overcome the possible obstacles. Here is a list of some of the arguments that people often use to justify their attitude (Latino, 2006):
- It is a bureaucratic process that takes a long time
- It is an expensive process
- It's just a "flavor of the month"
- It is a way to find and punish the guilty
- Only applies to really serious and important events
- It is a tool only for reliability engineers
- We've tried other times and it did not work
- We have enough quality programs

These arguments, however, are easily refuted. For example, those who think that root cause analysis will take a lot of time, need to be reminded that if they do not have time for analysis, they will need to get more time and resources to handle the continual repetition of undesired events.

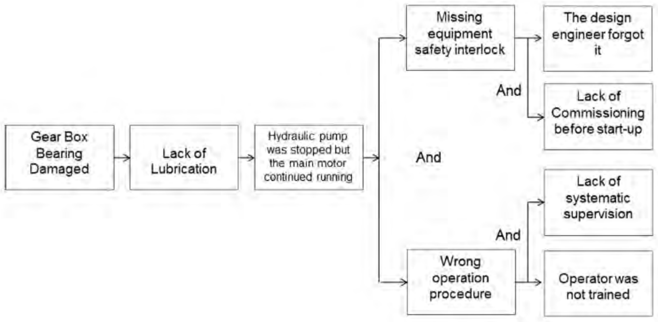
Example: RCA methodology application

Case example one: In a tire manufacturing plant there is an internal mixer equipped with two counter-rotating rotors in a large housing that shear the rubber charge along with the additives. The rotors were driven by a 2000 HP electrical motor / gearbox. In this case, the internal mixer of the tire plant had its automation system (PLC and software) replaced (upgraded) during a plant planned shutdown (holidays), after five years of continuous operation. As scheduled, it returned to operation on a Monday morning and operated continuously during that whole week until Saturday night, when it was supposed to stop for the weekend (the mentioned plant always stopped from Saturday night to Sunday night). At the moment when the equipment was stopped by the operator, an explosive sound was heard and some smoke comes out from the 2000 HP gearbox.

Problem: The internal mixer 2000HP gearbox bearings were damaged

Results from investigations that followed the event:
- It was the first time failure for the equipment
- The gearbox bearings were damaged due to lack of lubrication. The lubrication pump was stopped and the main motor continued operating
- The operator used to stop the equipment by stopping the auxiliary equipment (hydraulic pump, fans, cooling water pump) instead of normal stop (main motor). He claimed that he operated the equipment this way for more than five years.
- The engineer who made the PLC software conversion forgot to include the equipment safety interlocks.
- The equipment safety interlock wasn't tested during the equipment commissioning.

Casual tree:



Root causes:

- Physical roots: the damaged bearings
- Human roots: the operator didn't stop the equipment correctly and the design engineer didn't include the interlock avoiding the motor to continue running if the lubrication pump is not
- Organizational roots: missing or inadequate qualification of operators, missing or inadequate commissioning of new / refurbished equipment, the area operations supervision was deficient

Problem solution:

- The problem was solved by the replacement of damaged bearings and the inclusion of an equipment safety interlock to avoid the main

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internal mixer motor to continue running if the lubrication pump is not
- The internal mixer operations procedure was revised and all operators were trained

Extend the cause and fix:

To keep a failure from reoccurring is good, but the true value of RCA is to leverage the overall plant results. So it was checked where else in the plant similar problem could take place due to unknowledgeable and therefore wrong operation.

Case example two:

How RCA positively affected overall plant effectiveness

At an electronics industry in an Eastern European country, the availability of production lines was being seriously affected by frequent equipment breakdowns. Maintenance staff was overwhelmed and totally involved only in corrective maintenance, in other words "just working to put out fires" and the plant operations team was increasingly dissatisfied because they were not able to meet production schedules. The vicious circle was established; equipment broke, the production schedule was not met, the plant manager complained, operations team blamed maintenance and the maintenance worked even more without obtaining a result of their actions.

The following plan was established to overcome the situation: first the root cause of failures was to be discovered to prevent recurrence. Therefore, for every new failure the question should be:
"Why did it failed?" And then there are two options:
(1) the cause of failure can be identified
(2) the cause of failure cannot be identified: for this second option necessarily, it is needed
to apply the RCA.

Addressing each equipment breakdown this way, we begin to understand what is actually contributing to the poor production technical availability. However, this is not enough to achieve our goals of reducing failures because we need to be proactive, in other words, the failures need to be prevented from occurring or the impact of occurrence must be minimized, and for this we have the preventive maintenance plans. The below figure 5 shows a process flow explaining the plan to minimize the equipment failures, moving maintenance from reactive to proactive. The plan was put into practice, after training of the involved teams (maintenance, operations, process engineers, etc.), and after thirty weeks of dedicated team work, occurred a drastic reduction in the frequency of failures, increasing the operational availability of the two main production lines.

The end results

The RCA implementation is the first step towards a world-class reliability environment; it is extremely cost effective and greatly improves the reliability of the facilities, by improving standards of operation, maintenance and design, and helping to identify weaknesses in the organization. Some of the benefits of its implementation:
- A detailed understanding of what issues can be occurring on the plant
- Issues can be separated and clarified so the RCA is performed on the actual issues instead of perceived issues
- Identification of all root causes to the problem are exposed, giving a clear understanding of what is happening
- The root causes can be ranked in order of contribution and importance
- Recurring problems can be prevented; increasing availability, decreasing required maintenance costs and freeing up personnel to work on proactive improvements
- A failure database can be built up over a period of time
- Objective results are produced based on facts rather than personal opinion
- The analysis is documented for future review

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