



Reliability Center, Inc.
www.Reliability.com
804-458-0645
info@reliability.com

Chapter One: Root Cause Analysis: Performance for Bottom-Line Results- 3rd Edition

Robert J. Latino, EVP Strategic Development, RCI &
Kenneth C. Latino, President, Practical Reliability Group

Introduction to the PROACT® Root Cause Analysis (RCA) Work Process

Effective RCA can arguably be one of the most valuable tools to any organization. This is especially true for large asset intensive companies. There are many issues that arise and if there is not a plan in place to deal with these issues then the facility can become very reactive.

The challenge with effective RCA, is when do we apply the resources to identify the root causes of a problem? There are simply too many issues that arise to effectively solve every one. Therefore, a more intelligent approach must be taken to select the right issues to resolve.

Let's take a simple example. Let's assume that we have two centrifugal pumps. One of the pumps is a charge pump that is critical to the operation of the unit it serves. The other is a water pump that is spared and is not deemed in a critical service. Which problem do we analyze if we are experiencing problems with both of these pumps and there are limited resources to address the root causes? The critical charge pump of course.

We often see organizations struggle with which failures to analyze using RCA. Very often, analysis work is limited to regulatory issues like safety and environmental events. Many times, equipment or process related issues are simply corrected and the process is started back up without knowing the cause. Without identifying and addressing the various root causes, the problem is likely to recur. It seems that without some sort of outside pressure to perform an analysis it simply does not happen. Therefore, a strategy should be employed to direct personnel on what and when to do RCA.

As we stated, there are many issues that occur on a daily basis at a large asset intensive facility. When these issues occur they are deemed very important and must be addressed. We need some way to separate the emotion of the "failure-of-the-day" to what is truly important to the success of the facility. Therefore, we need to determine what the perspectives, objectives and measures are for the organization. For example, perhaps your plant has a mandate to improve profitability without the expenditure of additional capital. How would you go about doing that? You need a strategy to determine what you are going to do and how you are going to measure it.

We work in a lot of facilities where they are measuring many things related to their operation. Many organizations develop the metrics that they feel are important to measure as they progress into a maintenance and Reliability initiative. We often hear about Mean-Time-Between-Failure (MTBF), Mean-Time-to-Restore (MTTR) and many others. Measuring performance for the sake of measuring is not especially useful unless the measurements are directly related to the performance of the organization and action is taken to make the needed improvements when the measures are going in a negative direction.

Therefore, we must first think about what goals or objectives we are trying to accomplish before we can determine what measures we need to monitor. An effective methodology for determining your company's objectives is to create a strategy map. A strategy map takes all of the objectives of the company and puts them into various perspectives. The perspectives can vary from company to company but for the area of asset management there are four main perspectives:

1. Corporate Assets
2. Work Practices
3. Knowledge and
4. Experience

Within each of the four perspectives, a number of individual objectives are defined. For instance, within the Corporate perspective we look at objectives that directly relate to goals defined within the company. These are typically related to the fiscal performance of the business but can also relate critical operational issues like environmental and safety performance. Other objectives related to the corporate perspective might be customer satisfaction issues like on-time deliveries, quality of the product and many others. However, in the area of asset management we typically focus on those areas that relate to financial, safety and environmental performance as it relates to the utilization of assets.

Below is a table of typical perspectives and objectives related to asset management:

1. Corporate Perspective
 - a. Increase Return on Investment (ROI)
 - b. Improve Safety and Environmental Conditions
 - c. Reduction of Controllable Lost Profit
 - d. Reduction of Maintenance Expenses
 - e. Increase Revenue from Assets
 - f. Reduce Production Unit Costs
 - g. Increase Asset Utilization
 - h. Minimize Safety and Environmental Incidents
2. Asset Perspective
 - a. Minimize Unscheduled Equipment Downtime
 - b. Improve System Availability
 - c. Reduce Scheduled Maintenance Downtime
 - d. Reduce Unscheduled Repairs
 - e. Reduce Non-Equipment Related Downtime
 - f. Increase Equipment Reliability
 - g. Reduce Equipment Failure Time
3. Work Practices Perspective
 - a. Reduce Repair Time
 - b. Reduce Maintenance Material Inefficiencies
 - c. Improve Labor Efficiency
 - d. Improve Material Purchasing
 - e. Perform Predictive Maintenance
 - f. Optimize Time-Based Maintenance
 - g. Optimize Work Processes
 - h. Perform Reliability Studies
 - i. Perform Criticality and Risk Assessments

4. Improve Maintenance Planning and Scheduling
 - a. Knowledge and Experience Perspective
 - b. Improve Historical Equipment Data Collection
 - c. Improve Operations Communications
 - d. Train Maintenance and Operations Personnel

Once the perspectives and objectives are fully defined we need to determine the relationship of lower level objectives to upper level objectives. Below is an example of a sample strategy map with the objective relationships defined for the corporate perspective.

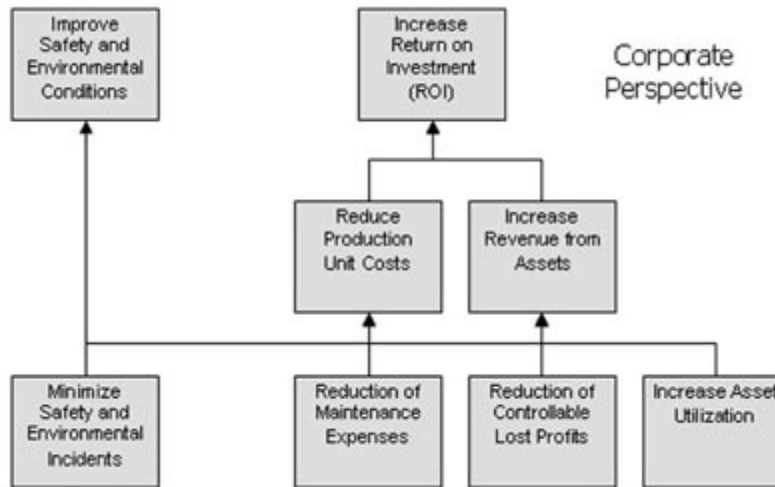


Figure 1.1: Sample Corporate Perspective Strategy Map

Strategy maps are an effective visual vehicle for demonstrating how every person in the organization can affect the performance of the overall business. For instance, when a technician is performing vibration analysis in the field they can see how the application of that skill will improve equipment reliability. This will ultimately contribute to the corporate goals of achieving higher returns on the capital they have employed.

Let's return to the concept of metrics and Key Performance Indicators (KPI's). Tom Peters once said, "You can't improve what you cannot measure". If you think about it for a minute it makes a lot of sense. We have been exposed to KPI's since we were very young. From the moment we are born we are weighed and measured and then we are compared to standards to see what percentile we are in. As we grow and get into school we are exposed to another set of KPI's, the infamous report card. The report card allows us to compare our performance against our peers or to some standard. An example that many people can certainly relate to is the use of a scale to measure the progress of a diet. We probably would not be very successful if we did not know where we started and what progress we were making week-by-week.

We all need a "scoreboard" to help us determine where we started and where we are at any given time. This certainly applies to measuring the performance of a maintenance and reliability organization. We need to know how many events occur on a given month, on a specific class of equipment, etc. Not until we know what KPI's will effectively measure our maintenance and reliability objectives can we begin to establish which opportunities will afford the greatest returns.

With all of that said, we would like to provide a word of caution. Be very careful to diversify your KPI selections. While a report card in school is a good measurement of a student's performance, it still does not provide a complete picture of the individual student. It is only one data point! Some students perform better on written tests while other students excel in other ways. We need to be careful to make sure that we employ a set

of KPI's that most accurately represents our performance. That means having many different metrics that look at different areas of performance so we can get a complete picture.

So let's take a look at a few common Reliability KPI's that can be employed to give us an understanding of our overall asset performance.

MTBF (Mean-Time-Between-Failure)

This is a common metric that has been used for many years to establish the average time between failures. Although it can be calculated in different ways, it is primarily looking at the total runtime of an asset(s) and dividing by the total number of failures for that asset(s).

Total Runtime / Number of Events = MTBF

Equation 1.1 Sample MTBF Calculation

This is a good metric because it is easy for people to understand and relate to and is common throughout industry.

Number of Events

This metric will simply measure the volume of events that occur on a variety of dimensions. Those dimensions are typically process units, equipment classes (e.g. pumps), equipment types (e.g. centrifugal pumps), manufacturer, and a host of others. This metric is closely related to MTBF as it is the denominator for the calculation. It can also be an accurate reflection of a facility's maintenance and reliability performance.

Maintenance Cost

This metric simply measures the number of maintenance dollars that are expended on rectifying the consequence of an event. This is typically the sum of labor and material cost (including contractor costs). This metric is also employed across many different dimensions like equipment, areas, manufacturers, etc. This metric is a better business metric as it shows some of the financial consequences of the event. It also has some drawbacks, as it does not totally reflect the complete financial consequence of the event. It does not cover the lost opportunity (e.g. downtime) associated with the event. As we all know, the cost of downtime is much greater than the cost of maintenance on a dramatic downtime event.

Availability

This metric is useful to determine how available a given asset or set of assets has been historically. In a 24/7 operation the calculation is simply the entire year's potential operating time minus downtime divided by total potential operating time.

$$\frac{8760 \text{ (total hrs. in a year)} - 32 \text{ (4 failures of 8 hours each)}}{8760 \text{ (total hrs. in a year)}}$$

Availability = 99.63%

Equation 1.2: Sample Availability Calculation

This calculation can be modified in many ways to fit a specific business need. Although this metric is a good reflection of how available the assets were in a given time period, it provides absolutely no data on the Reliability or business impact of the assets.

Reliability

This metric can be a better reflection of how reliable a given asset(s) is based on its past performance. In the availability example above, we had an asset that failed 4 times in a year resulting in 32 hours of downtime. The availability calculation determined that the asset was available 99.63% of the time. This might give the impression of a highly reliable asset. But if we use the Reliability calculation shown below we would get a much different picture.

$$\text{Reliability} = e^{-\lambda t}$$

Natural logarithmic base: $e=2.718$

$$\text{Failure rate: } \lambda = \frac{1}{\text{MTBF}} = \frac{1}{91}$$

Mission time: $t = 365$ (days)

$$\begin{aligned}\text{Reliability} &= e^{-\lambda t} \\ &= 2.718^{-\lambda t} \\ &= 2.718^{-\frac{1}{91}(365)} \\ &= 2.718^{-4.0109} \\ &= 1.81\%\end{aligned}$$

Equation 1.3: Sample Reliability Calculation

The fact of the matter is, an asset that fails 4 times per year is extremely unreliable and the likelihood of that asset reaching a mission time of one year is highly unlikely even though its availability is very good.

These are only a few common KPI's. As you can imagine there are an array of metrics that can be used to help measure the effectiveness of a maintenance and reliability organization. We will discuss these in more detail in just a moment.

So we now understand that MTBF, MTBR, Availability and many others are common measures for the effectiveness of equipment reliability. But unless these metrics are measuring the performance of a given company objective they might not provide the benefit that is trying to be achieved. Therefore, we need to first look at each objective and then develop pertinent measurements to see if that objective is indeed being met.

For example, if our objective were to reduce production unit costs we would measure the cost per unit of product produced. This will help us to understand if we are getting better, worse or staying constant with respect to our production costs. However, this alone is not enough. We need to be more specific when we are defining our measurements. The term Key Performance Indicator (KPI) as it is often referred needs to delineate the difference between good and poor performance. For example, let's assume that our average cost per unit of product is \$10 this month. Is that cost high, medium or low? In order to have an indicator you must define the measurement thresholds. In our example, we said that the average cost per unit this month was \$10. Perhaps our target value for production unit cost is \$8. Therefore, our performance is not very good.

A KPI has several thresholds that should be defined prior to the monitoring of the measure's value. These are listed below:

1. **Target Value:** This value specifies the performance required to meet the objective
2. **Stretch Value:** This value represents performance above and beyond what is expected to meet our objectives
3. **Critical Value:** This value represents performance that is deemed unacceptable for meeting our objectives
4. **Best Value:** This is the best possible value for this objective
5. **Worst Value:** This is the worst possible value for this objective

When these thresholds are set properly for each measurement we can objectively assess our performance. Otherwise, we are simply collecting information with no real sense of whether the value is meeting our specified goals.

Let's get back to the strategy map discussion. The process is to review each objective that we deem as important to our strategy and list one or more KPI's that will be accurate measurements for that objective. Once we define the measurement and calculation, we needed to determine the target, stretch, critical, best and worst values for that measure. Upon completion of this process we now have a completed strategy map. Below is a table with some example KPI's that relate to our objectives and perspectives:

[Click Here to view](#)
 Table 1.1: Sample Completed Strategy Map

Balanced Scorecard

Let's explore the process of monitoring these KPI's on a routine basis. We will employ a balanced scorecard methodology to help us to do just that. A balanced scorecard takes the perspectives, objectives and measures introduced in the strategy map and put them into an easily understandable format. A sample of a balanced scorecard and KPI measurement are displayed below.

View Maintenance and Reliability Scorecard						
	Actual	Previous	Target	Trend	Frequency	Measurement Date
Corporate						
Increase Return on Investment (ROI)						
Return on Capital Employed (ROCE)	21.00	26.00	25.00	↓	Quarterly	6/1/2005
Improve Safety and Environmental Conditions						
Number of overall safety and environmental incidents	1.00	2.00	2.00	↓	Quarterly	6/1/2005
Reduction of Controllable Lost Profits						
Lost Profit Opportunity	150000.00	175000.00	200000.00	↓	Monthly	8/1/2005
Asset						
Minimize Unscheduled Equipment Downtime						
Number of Lost Profit Opportunity Events	5.00	1.00	3.00	↑	Monthly	8/1/2005
Improve System Availability						
Unit Availability	94.10	94.80	97.00	↓	Monthly	8/1/2005
Reduce Scheduled Maintenance Downtime						
Turnaround Downtime Days	13.00	5.00	10.00	↑	Quarterly	6/1/2005
Work Practices						
Reduce Repair Time						
MTTR	11.00	9.00	4.00	↑	Monthly	8/1/2005
Reduce Maintenance Material Inefficiencies						
Average Parts Wait Time	1.20	1.40	1.00	↓	Monthly	8/1/2005
Knowledge and Experience						
Improve Historical Equipment Data Collection						
% of populated required fields in work order history	71.00	76.00	80.00	↓	Monthly	8/1/2005

Figure 1.2: Sample Balanced Maintenance and Reliability Scorecard (1)



Figure 1.3: Sample Balanced Maintenance and Reliability Scorecard (2)

Having all of your critical performance information displayed in one place makes it easy for everyone involved in the enterprise to see their performance and to determine where to focus their attention.

This process will ensure that we are working on the critical issues that most affect the performance of the business. Once we begin to monitor the balanced scorecard on a routine basis we will begin to see the areas where we need to make improvements. For example, let's say we are monitoring unscheduled downtime as a measurement of the equipment downtime objective. We observe that our performance for that KPI is well below the target level. We then must investigate and collect information to see where which events are contributing to the poor performance for that objective.

The RCA Work Process

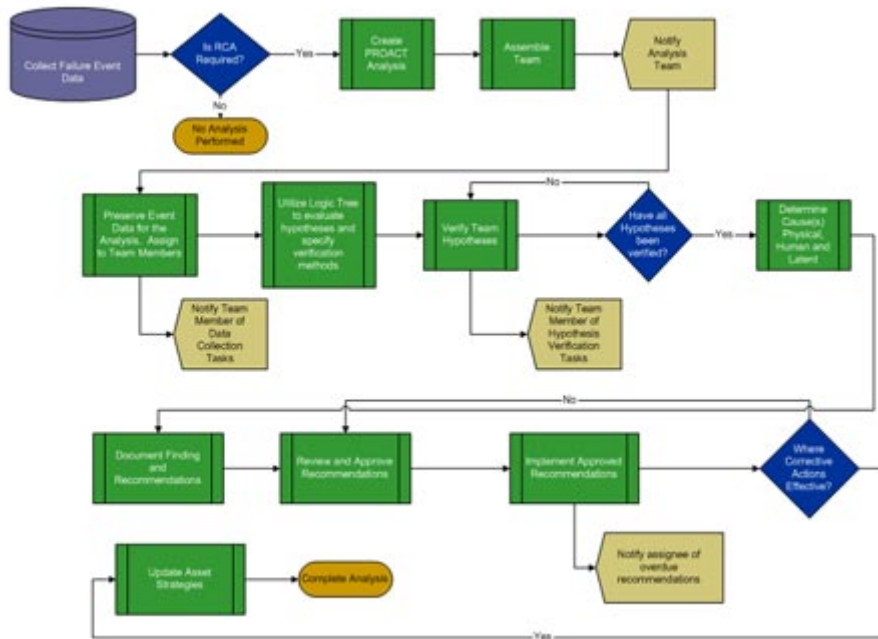


Figure 1.4: Sample RCA Work Process

A successful RCA initiative must have a strategic and tactical plan in place. We just discussed the concept of a strategy map to ensure that we are measuring the key metrics that will enable us to achieve our company objectives. Let's talk more about the tactical plan for implementing the RCA initiative.

First of all, we must have a means of collecting data related to the events that affect the performance of our stated objectives. This can be maintenance data, process data and other data related to the performance of our facility. We will talk much more about event data collection in Chapters 5 and 6.

Once we have a process for collecting data on these events then we must decide on criteria that will initiate the execution of an RCA analysis. For example, your strategy might dictate that any failures that occur on critical equipment must have an RCA performed. This is very common for events that relate to safety and environmental performance. We do not want to leave this process too ambiguous because people will not know when, and under what circumstances, to conduct an analysis.

It may be that you want to employ different levels of analysis for different performance criteria. Perhaps you have many events that occur on non-critical equipment but the frequency of the events is causing a large amount of maintenance expenditure. This might not justify a full-blown team to perform the analysis but still would justify some level of analysis to determine the reasons for the chronic maintenance events. These types of analyses might be much less formal than a full-blown RCA but still valuable.

Since every company is different and thus has different goals and objectives it would not be prudent for us to define a generic criterion. However, we can delineate some examples that might be considered. In any plant, there is a need to optimize maintenance expenditures. Therefore, we may want to consider a criterion that is based on the amount of maintenance expended for a given piece of equipment for a fixed time period (e.g. last 12 months). If a piece of equipment exceeds the threshold in that time period than an RCA will automatically be initiated.

Another common criterion can be based on production losses. This is especially true if your plant capacity is limited and you can market and sell everything that is produced in your facility. If there is a production loss that exceeds a specific financial value than an RCA should be initiated.

These are simple examples but it is important to make sure that there is an agreed upon criteria for when RCA analyses will be initiated and who will perform the analyses. At many facilities, there is a Reliability Engineer responsible for a given area of the facility and they are responsible to perform RCA's on equipment/events in their area. It is then their responsibility to determine what additional team members will be necessary to perform the analysis. We will discuss team formation in greater detail in Chapter 8.

The key to a successful analysis is to make sure that you have the data and subsequent information to determine what the underlying causes of the issue being studied. The team will review the problem and determine what data will be needed to determine the root causes. The PROACT methodology offers a simple but effective acronym called the 5P's to help in this effort. The 5P's represent the five categories of data required to analyze any problem. We will discuss the data collection effort and more specifically the 5P's in Chapter 6.

Have you ever sat in brainstorming meeting to solve a particular problem in the company? This is a very common approach to problem solving. We are not against the concept of brainstorming. In reality, we think it is a required activity in the RCA analytical process. The problem with most brainstorming sessions is that the group presents a variety of ideas but sometimes they lack the data to verify that the solution will work. For this reason, the PROACT methodology will utilize a Logic Tree approach to solve problems. This is a visual brainstorming tool. It is a hierarchical approach where the problem is defined in the beginning of the process and subsequently hypotheses and verifications are formulated and proved out. The end goal of the process is to

identify the true root causes of the problem. These causes can be physical, human or latent in nature. We will discuss this later in Chapter 9.

Identification of root causes, albeit important, will not solve the problem. The only way for the problem to be resolved is to implement corrective actions. This is typically done by creating a list of recommendations directed at eliminating or reducing the impact of the identified root causes. These must be thoroughly reviewed by all parties to ensure that they are the right solutions. Although causes are facts and cannot be disputed, recommendations should be thoroughly scrutinized and modified to ensure that they are the best course of action. We will discuss the process of communicating team findings and recommendations in Chapter 10.

As time passes we sometimes forget to follow up to make sure that our corrective actions were implemented and are providing the specified return we had intended. If the losses related to the problem are still affecting plant performance and negatively affecting our corporate strategy than we should reevaluate our corrective actions to determine why they are not providing the intended benefit. The strategy map discussed earlier will help but we would recommend having reevaluation criteria set for each recommendation. For example, we might measure the number of failures on that piece of equipment and if another failure occurs in the next 12 months we should reevaluate to see if the failure was related to the ineffectiveness of our corrective actions. We will discuss tracking results in Chapter 11.

Let's revisit our discussion on data collection methods. We have various methods to collect historical event information. We would like to break it into two categories, a manual or automated data collection process. In Chapter 5 we will discuss a process called Opportunity Analysis (OA) where we collect the data through the use of an interview process of various personnel within the affected area. In the subsequent chapter we will discuss a more automated approach to data collection that will utilize existing information systems that may already be employed at the company.

There are pros and cons to both approaches. It generally comes down to data collection processes and how effectively they have been employed. For many companies, they utilize a Computerized Maintenance Management System or CMMS to manage maintenance work and to document work history. For many, these systems are not utilized to their full potential and many times work history on assets is not fully documented. If this is the case, then a manual interview process can be utilized to perform the opportunity analysis.

Now that we have explored the concept of the RCA Work Process, we will now narrow the scope and look into field of RCA itself and what it means in the industry, both from a user and provider perspective.

Figures Aggregated

Figure 1.1: Sample Corporate Perspective Strategy Map

Figure 1.2: Sample Balanced Maintenance and Reliability Scorecard (1)

Figure 1.3: Sample Balanced Maintenance and Reliability Scorecard (2)

Figure 1.4: Sample RCA Work Process

Equation 1.1: Sample MTBF Calculation

Equation 1.2: Sample Availability Calculation

Equation 1.3: Sample Reliability Calculation

Table 1.1: Sample Completed Strategy Map

Robert J. Latino is Senior Vice-president of Strategic Development and a Senior Consultant for Reliability Center, Inc. Mr. Latino is a practitioner of root cause analysis in the field with his clientele as well as an educator. Mr. Latino is an author of RCI's Root Cause Analysis Methods© training and co-author of Problem

Solving Methods© training. Mr. Latino has been published in numerous trade magazines on the topic of root cause analysis as well as a frequent speaker on the topic at trade shows and conferences. His most recent publication is titled "Root Cause Analysis - Improving Performance for Bottom Line Results" He can be contacted at 804/458-0645 or blatino@reliability.com.

Mr. Latino has over 20 years of experience helping organizations implement reliability solutions. He has a Bachelor's of Science Degree in Computerized Information Systems. He began his career developing and maintaining maintenance software applications for the continuous process industries. After working with clients to help them become more proactive in their maintenance activities he began instructing industrial plants on reliability methods and technologies to help improve the reliability of their facilities. He has co-authored two Root Cause Analysis training workshops for engineers and hourly craftspeople. He has written numerous articles and books related to this topic. He currently serves as the President of the Practical Reliability Group, www.practicalreliabilitygroup.com, klatino@practicalreliabilitygroup.com.