Strengthen your Six-Sigma™ program with root cause analysis

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Introduction

Over the last several years, companies who have been enjoying the successes and improvements generated through Six-Sigma™ have begun incorporating Apollo RCA™ into their Six-Sigma™ programs. Their experiences demonstrate that most programs can be improved by augmenting and optimizing a very important step in the process – one that historically has been weak and required unnecessary additional experimentation and data crunching later in the process.

RCA augments the *Analyze* and *Improve* phase of Six-Sigma™ when used in conjunction with -- or as an alternative to -- the “Five Whys,” “Fishbone” and “FMEA.” It combines the visual aspect of a Fishbone diagram with the structured detail of an FMEA. If your organization has already implemented or is using Six-Sigma, understanding the causal relationships uncovered in an RCA is the key in defining the relationships between dependent and independent variables or causes or, 

\[ Y = f(x) \]

When you integrate the following RCA techniques in your Six-Sigma™ project, you may discover a tremendous opportunity to further enhance the effectiveness of your program.

**Cause-and-effect relationships:** These help you determine the function "\( Y = f(x) \)" that is needed for your analysis.

a. When you begin a Six-Sigma™ project, the "\( Y = f(x) \)" function is rarely or never defined for you, and is -- in fact -- your biggest challenge. If you know this function -- also referred to as the problem statement -- you can start working on, measuring, analyzing, optimizing, eliminating, changing or controlling the variables associated with your "\( Y \)" also known as “outcome” or “primary effect.”

b. Design of Experiment (DoE): When you know the "\( Y = f(x) \)" function you can perform DoE. DoE is probably the most powerful technique within the Six-Sigma initiative, but also the least used due to the fact that the "\( Y = f(x) \)" function is often not defined and is time consuming. Analyzing cause-and-effect relationships can help you define your function and reduce your experimentation time.

c. Another benefit of analyzing the cause-and-effect relationship is that -- when completed -- you have also documented your current process. This may not be the designed process or the desired process. But now you
have documented the current process that led you to this event, and will help you establish the baseline of your project. Now you can change or modify your process to reach the desired improvement goal.

d. The more causes or "x" variables you identify in this causal relationship the better you understand your process or how this event occurred. Ultimately you are in search of that vital "x" or root cause(s) that you will need to eliminate, change or control. So the more causes you identify, the more accurate your \( Y = f(x) \) function is and the greater your chance of discovering the vital "x." This leads you to discovering more potential solutions which you can brainstorm later in your project.

**Evidence or Data:** In addition to performing “gauge reliability and repeatability” (gauge R&R), also rely on “sensed” and “inferred” evidence or data.

a. “Sensed” is simply data using your five senses -- taste, smell, touch, sound, and sight. Your facility should contain all kinds of sensory evidence, such as databases, reports, gauges, pictures, and employee statements.

b. “Inferred” evidence is strictly based on your experience. If you walk by a pump and you see the gauge on it in the red zone, what is that telling you? Clearly something is not right, and you will need to take some type of corrective action. If the gauge is not working properly, when you report the gauge reading to the maintenance team, you will get a chance to fix it if it is malfunctioning. The point is that you saw the gauge in the red zone, you collected a data point based on your experience, and you took a corrective action!

**Risk:** It is all about risk when it comes to problem solving. Remember that even with a Risk Priority Number (RPN) equaling one – used in FMEA, if you choose not to take a corrective action, you are sending a signal to everyone that you are willing to take the risk that the cause or identified risk will occur again. Before you move on, simply ask, “Should we eliminate, change or control this risk?” Whatever the answer is, make sure you document it in your project files before you move on as this becomes part of your new process!

a. Risk is defined in many different ways. The most commonly used are:

i. "Risk = P \times C \times C" : the probability of this cause occurring multiplied by the consequence of this cause if it is to occur, multiplied by whether the cause is controllable by the current system.

ii. In Failure Mode and Effect Analysis (FMEA), "Risk = S \times O \times D" : how severe (or how significant) is the impact, multiplied by occurrence (or how likely is the cause to occur), multiplied by detection (or how likely the current system to detect the cause if it is to occur).

iii. "Risk = F \times L \times I" : the frequency multiplied by the likelihood of this occurring, multiplied by its impact

b. Typically a scale of 1 to 10 is used (or a percentage scale), 1 being low risk and 10 being high or severe. You will need to see what works for your organization.

**“Five Whys” – the Benefits and Limitations:**

a. The “Five Why” exercise is a great start to building the cause-and-effect relationship. And the more Five Whys you perform on the same primary effect, the clearer the picture gets.

b. The Five Why process has three fundamental limitations:

i. It is a linear analysis method being applied to a non-linear event.

ii. It does not go far enough in time to help identify all a problem’s causes.

iii. It does not support causes with evidence.

**“Fishbone” -- the Benefits and Limitations:**

a. The benefit of doing a fishbone is that you have almost all the variables affecting your process without the constraints of chronology or correlation. This is a great start in identifying your cause-and-effect relationship.

b. The fishbone is also a great source of evidence or data. Sources of causes and evidence are: people, procedure, hardware and nature.

c. The Fishbone method has three fundamental limitations:

iv. It identifies causes under pre-defined categories only.

v. It does not relate causes to each other and to each category.
vi. It does not support causes with evidence.

**Brainstorm:** Regardless of where in the process you insert brainstorming, you should follow these steps:

a. Silent brainstorming: You should perform this first. Ask your participants to write down on sticky notes the causes affecting your primary effect, and ask them to document at least five causes – seven is even better. When you do this, you ensure that everyone has participated and that their input is documented and heard. This should address a known problem of Six-Sigma – the tendency to be limited in participation and stakeholders.

b. Open brainstorming: Collect the causes from the silent brainstorming session, share them with the entire team, and then start the open brainstorming session. The team will identify significantly more causes than they ever did before.

**Summary**

By incorporating RCA techniques into the “**analyze**” and “**improve**” phase of your Six-Sigma program, you should expect the following enhancements:

- Clearer, faster, and more accurate definition of the function 
  \[
  Y = f(x)
  \]
- More involvement of key stakeholders and process owners.
- Reduction in time and resources spent on:
  - DoE -- reducing the number of experiments performed and in data validation.
  - The “**analyze**” and “**improve**” phase -- if the solution does not yield the desired improvement in the “\(Y\)".
  - 100% certainty that you have discovered the vital “\(x\)” variables affecting your process.
- Greater solution choices on the vital “\(x\)” variables leading to more cost-effective solutions.

**About the Author**

*Fadi E. Rahal* currently serves as the President of Effective Problem Solving LLC. Rahal has worked in the Energy industry for more than 18 years and additionally has extensive experience leading investigations within all types of businesses around the globe. Rahal has also institutionalized and implemented Six-Sigma program in concert with Continuous Improvement - Root Cause Analysis programs in various organizations, including GE and Black & Veatch.

As an investigator, Fadi has led countless RCA incident investigations with Fortune 500 companies resulting in millions of dollars in cost savings. His many investigation areas include: machine and plant shutdown, machine reliability, EHS incidents, fire and explosion in a mine, employee productivity, product delivery, on-time and on-budget project execution, product sourcing and purchasing, scrap and rework, and customer dissatisfaction.

As a trainer, Fadi has led more than 200 RCA facilitator training sessions and trained thousands of students across North America for such companies as GE, Honeywell, Oncor Electric, REC Silicon, The Delta Group, Moog, Siemens, Carmeuse, Quaker, Tropicana, Kennametal, Ameren, Sonoco, Smith-Aerospace, American Society of Safety Engineers and in the Middle East for such companies as ARAMCO, SABIC, SASREF, SIPCHEM, EQUATE, KPC, KNPC, QAFCO, Oman LNG, and Pakistan Exploration.

Rahal holds a Master of Engineering degree from Rensselaer Polytechnic Institute, Troy, NY. He is a graduate of the Edison Engineering Program and obtained both Black Belt and Master BB certifications, as well as RCA Leader Qualification from General Electric. In 2009, he received the Master Apollo RCA™ Instructor Certification – the only one ever awarded.

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**References**

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Key Terms and Definitions

**Actions**
Causes on the Apollo Cause and Effect chart that are the result of an action by a human, system, equipment or nature.

**BB**
Black Belts are knowledgeable and skilled in the use of the Six Sigma methodology and tools. Six-Sigma™ team leaders are responsible for implementing process improvement projects (DMAIC or DFSS) within the business - to increase customer satisfaction levels and business productivity.

**CC**
Common Cause is a source of failure that is always present as part of the random “Variation” inherent in the process itself. See also Special Cause.

**Conditions**
Causes on the Apollo Cause and Effect chart that are the result of pre-existing environmental states.

**DFSS**
Design for Six-Sigma™ or new product/service introduction. DFSS is the same as DMADV. DMADV consists of five interconnected phases: Define, Measure, Analyze, Design, and Verify. DMADV is a data-driven quality strategy for designing products and processes, and it is an integral part of a Six-Sigma™ Quality Initiative.

**DPMO**
Defects per Million Opportunities (DPMO) is the average number of defects per unit observed during an average production run divided by the number of opportunities to make a defect on the product under study during that run normalized to one million.

**DMAIC**
DMAIC refers to a data-driven quality strategy for improving processes, and is an integral part of the company's Six-Sigma™ Quality Initiative. DMAIC is an acronym for five interconnected phases: Define, Measure, Analyze, Improve, and Control.

**Fishbone**
A tool used to solve quality problems by brainstorming causes and logically organizing them by branches. It is also called the Cause & Effect diagram and Ishikawa diagram.

**FMEA**
Failure Mode and Effect Analysis  A procedure and tool that helps to identify every possible failure mode of a process or product, to determine its effect on other sub-items and on the required function of the product or process. The FMEA is also used to rank and prioritize the possible causes of failures of a product or services and then determine the frequency and impact of the failure as well as develop and implement preventative actions, with responsible persons assigned to carry out these actions.
Gage R&R  Gage Repeatability and Reproducibility, is a statistical tool that measures the amount of variation in the measurement system arising from the measurement device and the people taking the measurement.

MBB  Master Black Belt is Six-Sigma™ Quality expert that are responsible for the strategic implementations within an organization. A Master Black Belt main responsibility include training and mentoring of Black Belts; helping to prioritize, select and charter high-impact projects; maintaining the integrity of the Six Sigma measurements, improvements and tollgates; and developing, maintaining and revising Six Sigma training materials.

SC  Special Cause is an intermittent, unpredictable or unstable cause that lies outside the process or product acceptable limits. A source of “quality” failure.

Vital “X”  Vital “X” or vital few derived from the Pareto chart, the term indicates that many defects come from relatively few causes (the 80/20 rule).

5 Why’s  The “5 Why’s” typically refer to the practice of asking, five times, why the failure has occurred in order to get to the root cause/causes of the problem. There can be more than one cause to a problem as well. In an organizational context, generally root cause analysis is carried out by a team of persons related to the problem. No special technique is required.

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