Vol 19.16 15 November 2017 Regn no KARENG/2004/13762

Qualityinfo

Volume 19, Issue 16 *Fortnightly, Free soft copy* **15th November 2017**

Empirical Root Cause Analysis

The need for empiricism

There are many reasons for performing a root cause analysis (RCA). These reasons include determining the cause of a failure in a product or a process as well for determining the root cause of the current level of performance when a product or process has been selected for improvement. There are many tools available to help with performing an RCA. These tools include some of the seven quality tools such as the Ishikawa diagram, run chart, and scatter plot. Another possible tool set is the seven management and planning tools, which include tree diagrams and matrix diagrams.

Other tools may be useful depending on the nature of the problem being investigated. Calipers can be useful for taking measurements, microscopes can be used to view the structure of welds, and chemical titration can be performed to determine the composition of a solution. Even a hammer might prove useful in gaining new information when performing an RCA.

Empiricism in RCA

A hypothetical RCA was once discussed with a with a quality consultant. The hypothetical failure being discussed pertained to a plastic component that was breaking during assembly (see figure 1). The consultant attempted to explain how to perform an RCA. He said that first you do a failure mode and effects analysis (FMEA) and then a quality function deployment (QFD)." The consultant was asked about the need to actually look at the part due to the need for empiricism in RCA, to which he replied, "A QFD *is* empirical; you need to go into production and look at the work instructions."

Figure 1: Hypothetical failed component

The example in question pertained to a failure rate of approximately 1 out of every 1,000 units, and the root cause was insufficient material thickness due to the design. In this scenario, the weak area would occasionally break during the assembly operation. Such a failure may not be identified in an FMEA or QFD. However, it would be obvious that the failure was occurring at an area with limited material if one only looked at the failed part. For an actual failure in production, there may not be time to assemble a proper FMEA team and to schedule FMEA meetings, whereas simply looking at the failed part may quickly provide sufficient information to identify the root cause of the failure. Performing an FMEA and looking at work instructions are not necessarily wrong, but they are no substitute for actually looking at the defective component. The consultant is not alone in neglecting this; much of the available literature on RCA describes how a team should sit together and use quality tools to analyze a failure. Unfortunately, many authors fail to mention the need to "talk to the part,". Teams and tools are often needed during an RCA, but the defective part should be a part of the team.

Looking at the failed part provides data. Hypotheses can then be generated while sitting around a table, but they must be evaluated with empirical data and not simply by brainstorming while sitting at a table. Empirical data are needed; this requires observing, testing, or measuring. William Thompson (Lord Kelvin) has been attributed with saying, "When you can measure what you are speaking about, and express it in numbers, you know something about it; when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind...."

An RCA needs to be empirical, and concepts to achieve this already exist. The scientific method can be combined with Box's iterative inductive-deductive process and Deming's plan-do-check-act (PDCA) cycle. These three concepts can be combined into one simple and easy-to-use approach to RCA.

How to achieve empiricism when performing a RCA by combining the scientific method and graphical explorations of data?

The statistician John Tukey believed data should be viewed graphically and came up with ideas as a basis for further testing. He called this exploratory data analysis (EDA) in contrast with confirmatory data analysis (CDA), where the objective is to evaluate a hypothesis. The scientific method can be supported by the use of Tukey's EDA to generate data that can be empirically investigated. Tukey's EDA explores data graphically to gain new insights.

The available data are used to form a tentative hypothesis or multiple hypotheses. The principle of Occam's razor is used to choose between competing hypotheses, and the simpler of the two is selected. Remember that a good hypothesis should be simple, general, and avoid making too many assumptions. Also, it should be refutable, that is, testable. A hypothesis that can't be refuted can't be evaluated. In fact, Karl Popper warns against accepting any hypothesis as truly proven because it can always be disproved later when new evidence emerges. However, a hypothesis is more likely to be correct if it has survived rigorous testing that attempted to disprove it. The hypothesis should also make a prediction that can be evaluated.

Experimentation is sometimes necessary during an RCA. Attempting to re-create a failure under simulated conditions can often be informative. The experiment may not lead directly to the root cause, but it could eliminate potential root causes that are not the actual cause of the problem under investigation. It is essential to control your variables when performing an experiment; don't change all variables at once.

George Box's iterative inductive-deductive process uses cycles of deduction and induction for discovery. Deduction forms a conclusion based on a general premise, and induction uses empirical data to form a general conclusion. This means deduction is used to form a hypothesis based on what is known; the hypothesis is then evaluated empirically, and then induction is used to form a general conclusion based on empirical data. The process is repeated until the root cause is discovered.

W. Edwards Deming's plan, do, check, act (PDCA), also known as plan, do, study, act (PDSA), is an iterative process that is often used for quality improvement. It can also be applied to RCA as a framework for the scientific method. The four steps of PDCA for RCA are:

- Plan: Describe the problem and gather data to form a tentative hypothesis.

- Do: Test the hypothesis.

- Check: Check the results and form conclusions.

- Act: Repeat or verify the root cause and begin improvements.

Tukey's EDA and the scientific method can be combined with Box's iterative inductive-deductive process as a part of PDCA.

The first step is to collect data. Quoting Sherlock Holmes, "It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts." The data should then be explored graphically. A hypothesis should be formed using deduction, and then the hypothesis needs to be evaluated empirically. Induction is then used to form a new hypothesis based on information gained during the experiment if the root cause is not identified.

The combination of PDCA, the scientific method, EDA, and the iterative inductive-deductive process is shown as the RCA helix in figure 2. Data are collected and explored graphically in the plan phase. A tentative hypothesis is then formed and evaluated empirically during the do phase. The method of evaluation varies depending on the problem being investigated. A quick look at a failed component may be sufficient to identify an obvious cause of failure; other situations may require long-term testing of many sample parts.

The results of the evaluation are then interpreted. The plan phase is repeated using any new information from the evaluation if the root cause is not identified. The root cause needs to be verified if it has been found. Improvement actions are planned and then implemented if the root cause has been confirmed. Improvements may also be necessary for other products or processes that may potentially have the same problem.

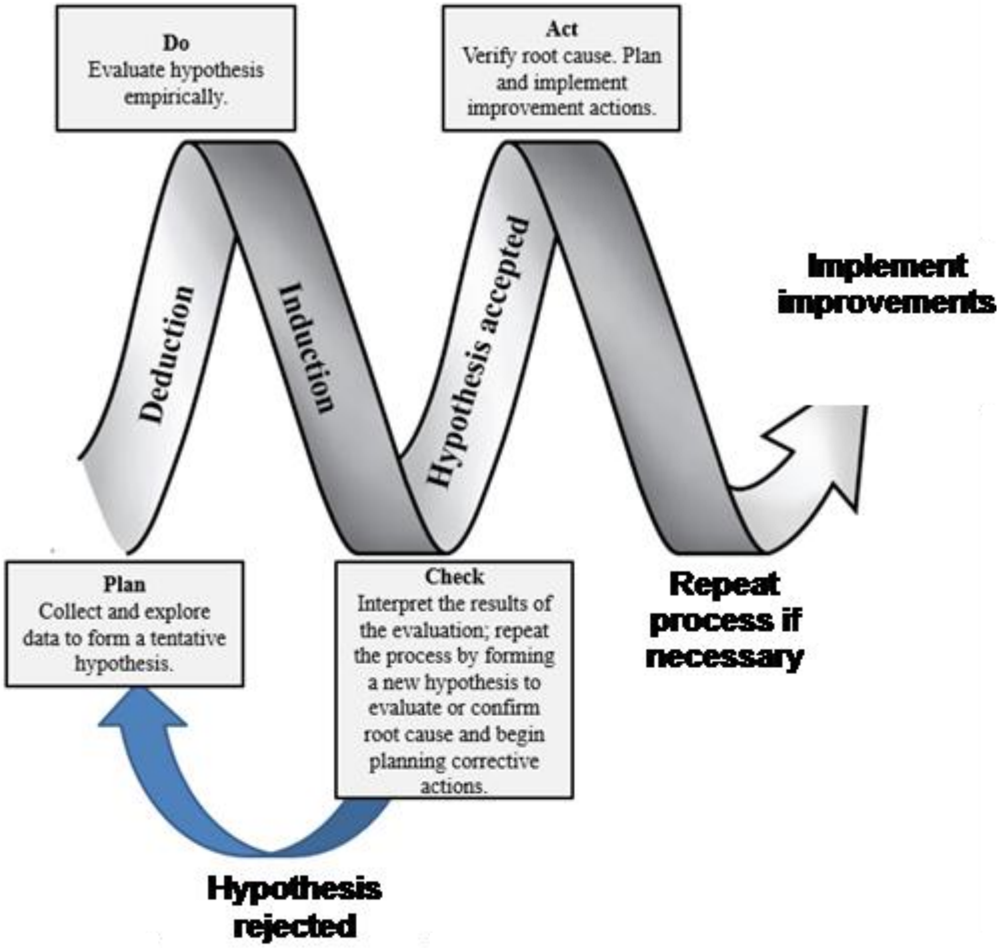

Figure 2: RCA helix.

Case studies in RCA

The investigation into the failure of vibration sensors was facilitated by the use of a hammer. The sensor consisted of a metal casing with a spring-mounted magnetic mass moving within a coil to generate a signal. Multiple units were returned from the customer due to lack of a signal, and the top hypothesis was “dent in the casing from mounting screw is restricting movement of the magnetic mass.” This hypothesis was quickly rejected by intentionally denting a functioning unit by hitting it with a hammer. The hammer dent was far deeper than that of the mounting screws, yet the unit continued to generate a signal. This quick and crude test made it possible to discard an incorrect hypothesis before more time and effort were expended in a line of inquiry that would turn out to be a dead end.

In another situation, a plastic bushing mounted in a metal bracket was failing. The failure was resulting in free play in the system, but it was not possible to directly observe the bushing being mounted in a bracket. The mounting process was simulated by fixing a bracket in a vise and then pushing a bushing in. The simulated insertion operation showed the bushing was losing material as it was inserted into the bracket. Minimal material loss did not cause free play; however, repeated trials showed free play resulted when there was heavy material loss on both sides of the bushing. This knowledge led to a containment action until a more robust bushing was introduced.

Conclusion

There are many potential approaches to RCA. It is essential that some methodology is used, and that methodology must include empirical methods. Simply brainstorming potential causes and then implementing a solution without empirical evidence risks a reoccurrence of the problem because the RCA team’s favorite root cause may not be the actual root cause. The RCA helix and its combination of PDCA, the scientific method, EDA, and the iterative inductive-deductive process provides an empirical methodology for RCA.

Readers may please note that D. L. Shah Trust brings out two e-journals on a fortnightly basis. These are mailed to those persons or institutions who are desirous of receiving them: These two e-journals are:

1. Safety Info
2. Quality Info

If you or your friends or colleagues wish to receive these journals, you may send us an e-mail requesting for the same. There is no charge for these journals. Our e-mail address is:

dlshahtrust@yahoo.co.in **or** haritaneja@hotmail.com **or** dlshahtrust@gmail.com

You can also access these journals on our website: www.dlshahtrust.org

Sponsored by: **D. L. Shah Trust** **For Applied Science, Technology, Arts & Philosophy** Mumbai. email: dlshahtrust@yahoo.co.in Ph: 022-22838890	Edited by Hari Taneja, Mumbai and Published by R. Ramamurthy, Bangalore 560084. email: dlshahtrust@yahoo.co.in