



■ Spring 2008

Automotive

E X C E L L E N C E

**Using Energy
To Solve Technical
Problems**

**Gaining Competitive
Advantage**

**Asking What? Instead
of Why?**

Annual Cruise

Official Publication of the ASQ Automotive Division

SPRING 2008

2007-2008 DIVISION COUNCIL ROSTER

Chairperson (Voting Officer)

JACKIE PARKHURST
Tel: 313/220-0204
E-Mail: jackie.parkhurst@aam.com

Past Chair (Voting Officer)

CHERYL FRANKS DENMAN
Tel: 313/919-3294
E-Mail: denman@sbcglobal.net

Chair Elect (2008-2009) (Voting Officer)

JOHN CASEY
Tel: 248/202-8494
E-Mail: jic@dxc.com

Treasurer (Voting Officer)

FRANK BYKAYLO
Tel: 248/836-6045
E-Mail: fbkaylo@rdagroup.com

Secretary (Voting Officer)

DENISE TISO
Tel: 248/431-9852
E-Mail: denise.tiso@gm.com

07-08 AE Editor

AMY LICHONCZAK
Tel: 586/214-4131
E-Mail: alichonczak@comcast.net

Historian/MOC Liaison/AIAG Liaison/

QFD Liaison (Voting Officer)
LLOYD D. BRUMFIELD
Tel: 248/364-0196 Ext: 170
E-Mail: ldbrumfield@earthlink.net

Health Care Liaison

DAN REID
Tel: 248/857-1166
E-Mail: dan.1.reid@gm.com

Standards (Voting Officer)

DOUGLAS BERG
Tel: 248/348-2765
E-Mail: dougberg@earthlink.net

Examining Chair Publications Team

(Voting Officer)
JERRY BOWEN
Tel: 810/694-1586
E-Mail: ronaldjb@msn.com

Regional Councilor, WCQI/Annual

Boat Cruise
FRANCIS W. CURTISS
Tel: 763/425-3724
E-Mail: francur@comcast.net

Membership Chair/Professional

Development Detroit Section
CLEM GOEBEL (Voting Member)
Tel: 810/599-6188
E-Mail: cigoebel@cac.net

ASQ BOD President

RON ATKINSON
Tel: 248/821-4806
E-Mail: ronlakeo@aol.com

Awards Chair (Voting Member)

CHARLES L. TOMLINSON
Tel: 248/652-1844
E-Mail: cltsp@aol.com

Exhibits Chair

DENNIS C. SEEGER
Tel: 313/235-9601
E-Mail: seegerdc@ddeenergy.com

Quality Leader Award Chair

CAROLE MALONE
E-Mail: malonec@macomb.edu

Craig Award Chair

LARRY R. SMITH
Tel: 313/623-7724
E-Mail: lrsmith@peoplepc.com

Koth Award Chair

ALLY HAMOOD
Tel: 586/575-2838
E-Mail: ally.hamood@gm.com

Quality Professional of the Year Award/

Assistant Awards Chair/Recognition
Award Banquet
JAYNIE L VIZE
Tel: 248/371-2413
E-Mail: jlvize@wowway.com

Ann Arbor Liaison

ERIC ZINK
Tel: 734/741-5399
E-Mail: ericzink@eaton.com

Detroit Liaison/Coordinator Team India

ABHIJIT SENGUPTA
Tel: 313/595-5310
E-Mail: senguptaa@hotmail.com

Northeastern Illinois Section 1212

FRANCES BLOSSER
E-Mail: fab8850@aol.com

Scholarships

HIRA FOTEDAR
Tel: 440/933-3626
E-Mail: hirafotedar@yahoo.com

Assistant Scholarships/Saginaw

Liaison
KEN ZIMMER
Tel: 989/868-4811
E-Mail: zimmerken@aol.com

Vice Chair Programs

DAS NARAYAN
Tel: 586/492-4671
E-Mail: narayan.das@gm.com

Chair-Paper Symposium

ERIC HAYLER
Tel: 864/989-5577
E-Mail: eric.hayler@bmwmc.com

Coordinator Team India Project

BHARATH VIJAYENDRA
Tel: 248/836-6008
E-Mail: vijay@dagroup.com

Team Thailand Leader

MARIA STOLETOVA
E-Mail: m_stoletova@hotmail.com

ASQ Headquarters Administrator

SHIRL FURGER
Tel: 800/248-1946
E-Mail: sfurger@asq.org



Welcome to the Spring Edition of Automotive Excellence! Spring is right around the corner, and the perfect time to introduce a new look to the AE Newsletter. It took many months to refresh our look. Expect more enhancements to this new look in the 2008 issues.

The 6th Annual Quality Symposium on February 18, 2008 was held at the Macomb Community College's University Center. We had a great time listening to several speakers and participating in afternoon

workshops. This year's symposium also had a tribute to Dr. Deming which included a display and a reenactment of his Red Bead experiment. The Symposium was such a success that the Automotive Division is working to introduce a Fall Quality Symposium.

In this edition, the articles submitted were from from topics presented at the 6th Annual Quality Symposium. The Summer and Fall editions will include additional articles from the Symposium. Summer 2008 will be all about Failure Mode and Effects analysis (FMEA). Both Design and Machining FMEAs will be reviewed, along with Tips of improving the FMEA process at your company.

Don't forget to register for the ASQ World Quality Conference on Quality & Improvement, May 5-7, 2008 in Houston, Texas. Find out more at www.wcqi.asq.org.

Sincerely,
Amy Lichonczak
Vice-Chair Publications 2007-08
ALichonczak@comcast.net

Features

- 1 **Using Energy to Solve Technical Problems**
Bill Maxson, Shainin LLC
- 3 **ASQ Members & Friends Annual Dinner Cruise**
- 4 **Gaining Competitive Advantage**
Dave Ramsey, Aptimise
- 6 **Why Ask Why When You Should Be Asking What**
Christopher G. Vallee, System Improvements, Inc.

Upcoming Events

ASQ World Quality Conference

May 5-7, 2008

Quality Expo-Detroit

June 11-12, 2008

ASQ Automotive Division Awards Banquet

June 17, 2008

ASQ AUTOMOTIVE DIVISION

VISION: To be the worldwide automotive industry's leader on issues related to quality
MISSION: To facilitate continuous improvement and customer satisfaction by identifying, communicating and promoting: • Quality knowledge • Management's leadership role • Industry Cooperation • Professional development • Recognition • Opportunities to network
CUSTOMERS: PRIMARY • Automotive division members • Automotive suppliers - all tiers • ASQ sections • Division sustaining members • Potential Automotive Division members
SECONDARY • Automotive original equipment manufacturers (OEMs) • Other ASQ divisions • Strategic alliances - SAE, AIAG, SME, ESD, ASI, organized labor • Community colleges/universities • ASQ headquarters/Board of Directors/General Technical Council
TERTIARY • Quality award initiatives (federal/state/local) • Standards activities • Automotive dealerships • International global markets • Aftermarkets/ service parts • Third party registrars • Recruiters/ consultants

Automotive

EXCELLENCE

Published by Mirus Graphic Solutions and ASQ Automotive Division

Editor-in-Chief: Amy Lichonczak

Publication Committee: Jamie Topp

Publisher: Mirus Graphic Solutions

Direct all editorial submissions or advertising information to:
Amy Lichonczak @ alichonczak@comcast.net

When reordering request document number B0623

NOTE: Please forward all change of address requests to ASQ headquarters at www.asq.org

Automotive Excellence (ISSN) is published by Mirus Graphic Solutions, for ASQ Automotive Division. All editorial submissions should be directed to Amy Lichonczak, Editor-in-Chief, or Mirus Graphic Solutions, Publisher at 2531 Dequindre Rd., Madison Hts, Michigan 48071. Advertising inquiries should be directed to alichonczak@comcast.net Copyright © 2008, ASQ Automotive Division. No information may be copied without the express written permission of the Editor-in-Chief, ASQ, Automotive Division. Neither the ASQ, ASQ Automotive Division, nor the Publisher's office is responsible for the accuracy of information in editorial articles or advertising in this publication. Readers should independently evaluate the accuracy of any statements in the editorial or advertising of this publication which are important to them and rely on their own independent evaluation.

Using Energy to Solve Technical Problems

Bill Maxson

Shainin, LLC
February 2008

ABSTRACT

Engines that do not start, door handles that break, or brakes that squeal. On the surface, these problems seem very different, but one thing they do have in common is energy. Every one of these events requires energy to occur. Management wants these problems solved, so they assign engineers to eliminate them, but during their investigation, the engineer struggles to make progress eventually settling for unnecessary redesigns and containment.

A common reason for their lack of progress stems from their inability to develop a suitable measurement system to understand the problem. They measure things such as peak force, peak pressure, peak torque, etc. These types of metrics hide information making it more difficult to understand the physics of the problem.

Measuring energy instead provides more insight about the problem. Two events may appear identical when comparing peak values, but they can be very different when comparing energy for the same two events. This paper will discuss the differences between measuring peak values vs. energy to characterize an event and why energy is a better metric to solve malfunction and destructive event problems.

BACKGROUND

Many companies are applying Lean to their manufacturing operations to reduce waste. As they begin to eliminate work in process, increase inventory turns, and improve throughput, hidden technical problems begin to surface. These problems lied dormant and were masked by the excessive waste.

Lean has forced organizations to go back and readdress these forgotten unsolved technical problems. Unfortunately in their attempt to solve these problems for the second, third, or maybe fourth time, they will use some not so lean problem solving approaches. Their approach is wasteful because they implement unproven or multiple solutions and wait for accounting or their customer to tell them if they were right or not.

They use large DOEs to screen or identify potential causes instead of converging. They collect lots of data and look for correlations vs. identifying a strategy to eliminate suspects. They brainstorm to gather a long list of suspects driving lots of action consuming limited resources instead of using sound engineering to understand the physics of the problem. There is a Lean approach to problem solving, and it begins with recognizing the type of problem you are working on.

Any technical problem can be assigned to one of four categories: Defects, Features, Properties and Events. By identifying the type of problem, you can use standard work that brings in unique strategies and tools to solve the problem. Defects are problems such as contamination, dirt in paint, or porosity. Feature problem examples include roundness, length, and concentricity; think shape and geometry. Properties are datumless. They can be material, electrical, or chemical. Examples are hardness, dielectric strength, and viscosity. Finally, events are problems that deal with energy and time. When energy is removed, the malfunction goes away or, in some cases, damage is left behind.

Event problems tend to be more difficult to solve because they deal with the laws of physics occurring over time. They require more sophisticated measuring systems and they can be intermittent as well. Solving these difficult problems requires a suitable event strategy to find leveragable contrasts, but how and where you find these contrasts might surprise you. The upside, in many cases only one unit may be needed to find the cause for the problem. So for those rare warranty returns or for that single prototype failure there is a way to find the root cause, or Red X, to the problem, and it starts with a well-defined Green Y.

MEASURING THE GREEN Y®

William Thompson 1824-1907 (Lord Kelvin)
“When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind.”

Problems have been and will continue to be solved using subjective measurement systems. These are measurements that do not have a scale and are pass/fail in their response. They are usually fast and easy, but speed comes with a price. They can hide interactions and make it difficult to find differences. When dealing with malfunction or destructive events, problem solvers typically settle for a measurement system that records the peak value for their Green Y. For example, peak torque to stop a leak, peak force to crack a casting, or worse measuring

the length of the crack itself. Deciding how you measure the event can be the most important step in your problem solving approach. All events require energy; so think in energy terms to solve them.

DESTRUCTIVE EVENTS

A destructive event is a problem where damage is left behind after the energy is removed. Damage can be in the form of cracks, tears, scratches, burns, dents, etc. Comparing parts with damage to parts without damage is a common strategy. This strategy is ok at the beginning of the investigation because it can provide clues about the energy source, which is important if replicating the event becomes necessary. Understanding how the part was stressed is critical. This knowledge will prevent you from solving for a foolish failure mode.

More often than not, you will need to answer this question: Is this a strength or energy problem? In other words, was the part too weak to withstand the energy it was exposed to in manufacturing, customer use, or the environment, or was the part exposed to high levels of energy, levels that are beyond the expected levels of exposure? Comparing the length of the crack, area of the dent, or the depth of the burn will not answer the question. To answer this question, may require replicating the failure in the lab. Engineers do this with varying levels of success by measuring a peak value to characterize the strength of the part.

For example, a client was in a crisis for a cracked suspension component. The result of this part failing was disastrous if the vehicle was in motion. Engineering attempted to reproduce the failure and used number of cycles to failure as their Green Y. After two days of testing, the part finally failed but in a different location.

The Shainin consultant assigned to the problem realized the test engineering was using was unacceptable, and a much faster test that replicated the field failure and one that used energy to characterize the strength of the casting was needed. Figure 1 shows the test results for two suspension parts. What information can we get from the force-displacement curve?

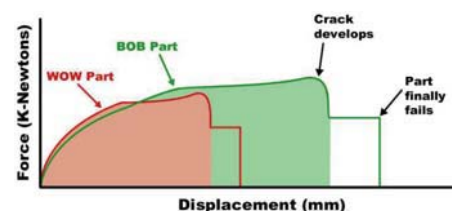
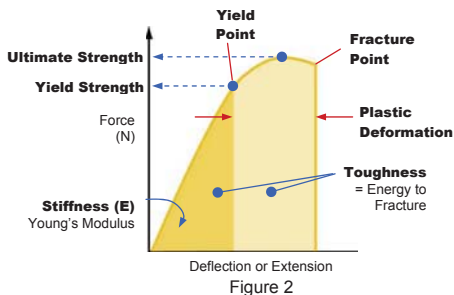


Figure 1

We can answer this by looking at a typical stress-strain curve, Figure 2. When measuring the load and change in length of a standard test sample, information such as stiffness, yield and fracture point, and toughness can be calculated. For problem solving, we can use the same approach and get similar information.



Looking at Figure 1, do the two parts have the same strength? If you only look at the peak force to fail both units, you probably concluded there is no difference in strength. In fact, most of you would have skipped graphing the results recording only the peak force instead, which is actually the stress to break not energy to break. Notice the shaded area under the curves is substantially different. What does this mean? It means the work or energy to fail the two parts was quite different. This changes your conclusion. The two parts have a considerable difference in strength.

The significant difference in energy to fail meant the casting failure was due to inadequate strength, not high levels of energy in the application. Measuring energy helped the team find the Red X for the weak parts in just two days.

MALFUNCTION EVENTS

Malfunction events are problems that do not perform at the expected level of performance and disappear as the input energy is removed. Some examples are noise, leaks, overheating, and vibration. Malfunction events can seem complicated and mysterious. They can be intermittent or repeatable.

Fortunately, the first and second laws of thermodynamics give you options. The first law is often referred to as the conservation of energy. Simply put, it states that the energy supplied to a closed system (E1) must equal the work being done (E2) plus losses (E3).

$$E1 = E2 + E3$$

Customers may complain about losses such as noise and vibration, and you can try to develop a measurement system to measure those losses, or you can measure the input energy or the work being done for the same event. You get to choose.

A client was struggling with sunroof binding at their final tester. For two years, this problem reduced first time quality and caused a significant amount of rework. The customer was struggling to solve this problem because after the sunroof would bind, it would not bind again on subsequent tests. Initially their Green Y was binding no bind, but with a one-and-done type problem this metric was leading them nowhere. A Shainin team was assigned to the problem and they chose a measurement system that could capture the event during the stall and allow the team to graph the test-event as it occurs. They did not want to represent the entire test-event with a single value such as time to close or peak force to close. Instead they plotted current draw by the motor vs. distance traveled.

To an experienced Shainin problem solver, this measurement system can reveal more information about the physics for the problem. With the ability to see the event as it occurs, the team can now determine if the problem lives in E1, E2, or E3.

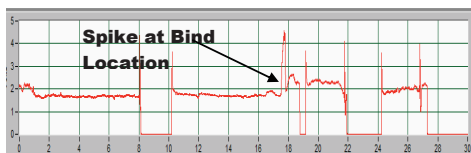


Figure 3

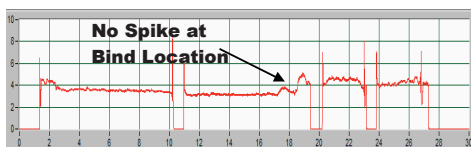


Figure 4

The clients initial Green Y of binding/no bind was inadequate to solve this problem. With intermittent problems, the problem solver must find an aggravator to force recurrence of the undesirable event or find another way to measure the event. Even though the sunroof does not bind anymore, see Figure 3, you can still see a current spike at the same bind location with the new measurement system. A BOB sunroof shows no current spike at the same position. See Figure 4. Conclusion, this is an E3 problem located at a specific location. This new insight about the problem allowed the Shainin team to find the Red X in a few days.

Not only did the sunroof case leverage the conservation of energy, it also leveraged the second law of thermodynamics. The second law of thermodynamics states that all isolated physical systems unavoidably become more disordered over time. It explains why machines cannot keep running forever. It also says there is an order or direction to events. There is a beginning, middle, and end for every event.

As a problem solver, mapping out the event as it occurs can yield clues to the malfunction potentially revealing contrast within the event.

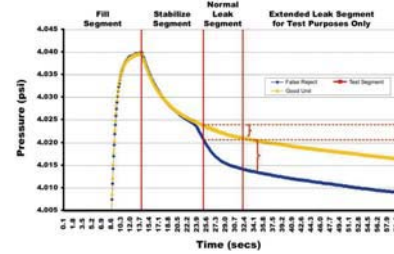


Figure 5

Figure 5 shows a typical measurement for leak decay. The device under test is pressurized to a predetermined psi, held for some period of time and a final psi reading is recorded. The delta between the two readings represents the entire leak event. By graphing out the event as it occurs you learn more about the leak. Did the unit fail to hold pressure at the beginning? Is there a WOW point where the leak begins in the middle of the test? What actions are happening to the unit or the tester at this point? By looking inside the event, you can find contrast that would have otherwise went unnoticed.

CONCLUSION

Understanding the physics of the problem should be the primary goal of any problem solver. With this level of understanding, the options to eliminate or control the problem become obvious. By leveraging the laws of physics, particularly the first and second laws of thermodynamics, you can gain insight into difficult event problems. Here are some key points to remember when dealing with event problems:

- Avoid peak values.
- Use energy to characterize a part's strength.
- Graph the event as it occurs.
- Develop a measurement system that can see within the event. If you can graph it, you can see within the event.
- Think in terms of E1, E2, and E3.

CONTACTS

Send your questions and comments to:
Bill Maxson at: wrmxson@shainin.com
For more info on Shainin, go to www.shainin.com

DEFINITIONS, ACRONYMS, ABBREVIATIONS

BOB: Best of the Best and Worst of the Worst are the extreme samples that can be readily taken from a distribution of the Green Y®.¹

Green Y®: is a response that has engineering leverage and reveals insight into the physics for the failure.¹

Red X®: is the product feature or process setting that drives the Green Y® from BOB to WOW.¹

WOW: Worst of the Worst and Best of the Best are the extreme samples that can be readily taken from a distribution of the Green Y®.¹

REFERENCES

1. Shainin LLC, Problem Solving for Engineering, v1.2c 2007
2. Alan Lightman Great Ideas in Physics: The Conservation of Energy, The Second Law of Thermodynamics, The Theory of Relativity, Quantum Mechanics (McGraw Hill)
3. J.E. Gordon Structures or Why Things Don't Fall Down (Da Capo)
4. <http://www.shainin.com>



ASQ Automotive Division Members & Friends Annual Dinner Cruise

Come join us as we board the "Spirit of Texas" for a pleasurable Paddlewheeler Cruise on Clear Lake & Galveston Bay immersed in an adventure of dining and dancing while we enjoy the sights and sounds while we cruise the Texas Shoreline. If you're looking for an enjoyable experience while participating in World Conference on Quality and Improvement in Houston area. This is it!

**Monday, May 5, 2008
5:30PM to 10:30PM**

Advanced Registration Required: \$50 till April 15, 2008, \$55 after April 28, 2008

Ticket price includes bus transportation from World Congress, cold appetizers, dinner, and entertainment. Cash bar

INSERT ALL INFORMATION REQUESTED INTO THE FORM BELOW FOR EACH PERSON THEN:

Mail with a Check in the Appropriate Amount, Payable to **"AUTOMOTIVE DIVISION ASQ"** to:

Francis W. Curtiss,
6209 Creekview Lane N.
Brooklyn Park, Minnesota 55443

Use your credit card by sending an e-mail containing all of the information requested below to francur@comcast.net

Name: _____ Phone: _____
Company: _____
Address: _____
City _____ State: _____ Zip: _____
Type of Credit Card _____ Credit Card # _____ Expiration Date ____
Name of Credit Card Holder _____

RESPONSE REQUIRED NO LATER THAN April 28, 2008
DIRECT QUESTIONS TO (763) 425-3724 - E-mail francur@comcast.net

Gaining Competitive Advantage

Lean Management, Six Sigma, or ISO 9000? A Company at the crossroads.

Dave Ramsey

Aptimise

The issue was clear. Calor's Bensonville distribution center was facing another year of strong performance; the opportunity for customer paid bonus payments for cost savings increase was high. However, the performance and cost improvement was coming at an increasing price.

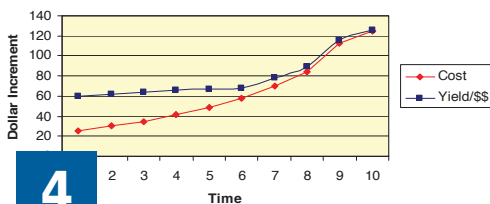
After 10 years of growth and in spite of a contract renewal from their main customer, Calor, a third party distribution operator was facing a crossroads. In spite of continuing strong performance and resulting bonus payments from its customer the cost of operation was overtaking revenue from performance. The number of errors was increasing, improvement activities were becoming more difficult and less rewarding, and overtime was being used as a crutch to make certain key shipments were finished on time. In short, the center had hit a proverbial "5 sigma wall."

At issue was the ability of the company to retain customer confidence and market advantage. Over the 10 years of its existence, Calor had grown from three facilities to 17 facilities. 5 of the facilities made up the Retail Division with the remaining facilities making up the Public Division.

The Bensonville facility was the flagship operation. Not only was it the highest producing, best performing operation, it was home to the Retail Division offices and housed a portion of the customer service function of the client. While this was a unique arrangement, it was consistent with the concept of a 3PL (third party logistics) company. The customer owned the building, the equipment, and the merchandise; Calor simply managed the operation and fulfilled the orders.

During the 10 years of operation, Calor had produced an exemplary record of performance. The record included a consistent improvement in cost per skid, cost per load, and under constantly increasing volume had exceeded safety and quality goals. This performance allowed Calor to routinely collect performance bonuses from the customer. In spite of this outstanding performance, the customer continued to demand improvement in service and reduction of cost. Complicating this situation even more was a condition that had senior management worried. Over the past 3 years, each improvement activity had resulted in a declining return on investment. In fact each improvement had cost more and returned a smaller cost improvement.

\$ Spent/Cost Improvement



4

Management was wondering if the next year was going to see any cost improvement at all.

Management had seen it coming, supervision and management training had been undertaken, state sponsored grants had been used to encourage additional schooling and cost reduction programs had been instituted. Additionally, so as to maintain competitive advantage, various members of the management team had quietly been investigating and discussing strategies such as Lean Management and Six Sigma. A decision was necessary.

Before a decision could be made however, Calor was approached to operate an international facility. ISO 9000 certification had become another strategy to investigate. Aware of the issues at hand and the impending need for action, Aptimise suggested leading a session to facilitate the decision making. Calor accepted the offer.

The session was designed to compare the three strategies on a side by side equal basis without giving preference to any of three. As the final part of the session Aptimise decided to bring the discussion to a decision point. In order to make certain that the outcome of the discussion resulted in a valid workable decision, Aptimise knew it had to provide enough information that a decision could be made and an initial plan formulated.

DEFINING THE PROJECT

As a consulting firm, Aptimise focuses upon working with clients to increase their competitive advantage. In order to fulfill this goal with Calor Bensonville, Aptimise approached the project in the same manner as usual, by identifying the end goal.

The goal? Increase Calor's competitive advantage by giving them the tools to continue to identify and implement performance improvement opportunities. To accomplish this goal, Aptimise knew that whatever the outcome of the discussion, Bensonville was going to implement one of the three strategies; ISO 9000 certification, Six Sigma, or Lean management. Which one was the right one? How could Aptimise make certain that they were involved in the implementation?

Based on their knowledge of Calor Bensonville Aptimise knew that none of the strategies by itself would be a good fit for the company. Each one of the strategies presented a significant obstacle. If Bensonville was to achieve additional competitive advantage, it needed a solution that was simple, quick to bear results, and easy to implement. At the same time, Calor management was hoping that whatever strategy that was chosen for Bensonville could be standardized and implemented at each of the other four Retail Division facilities.

Calor Bensonville was data rich. They consistently collected data of all kinds, but only the data that related to the key performance indicators upon which they were paid were used for decision making. While Six Sigma might appear to be a good solution, implementation issues such as the extensive training required, extensive time for implementation, the fact that Calor operations were transaction based and the overall initial cost of implementation were obstacles that were too significant to overcome.

In a similar analysis, Aptimise felt that both Lean and ISO certification offered some applicability. However, in each of these strategies there likewise was either significant obstacles or a critical element to success was missing.

In the case of ISO, it provided a foundation for standardization that could be used at other facilities. It would fit well at the international facility. However, it seemed expensive

plus the documentation the system elements required added undesired complexity. What appeared to be unwanted additional paperwork - paperwork that Calor was unaccustomed to and that management knew would be almost impossible to implement at the other facilities was a drawback. Unless a massive effort was undertaken to upgrade both the work force and operating practices ISO certification at other facilities would be impossible. Additionally, it seemed that the implementation cycle would take 18 months to complete. It was important that whatever strategy was chosen would produce results quickly.

Lean techniques on the other hand, were easily trained and produced relatively quick results. Additionally, the teamwork created by cross functional teams was appealing. However, the main focus of removing waste did not specifically focus on quality issues such as those that were causing excessive overtime and customer concern. Additionally, there was no apparent structure of standardization like what management desired.

CREATING A SOLUTION

In addition to being versed in Lean, Six Sigma, and ISO certification requirements, Aptimise uses elements of TRIZ in projects. TRIZ is the theory of inventive problem solving. Originally developed in Russia in 1948, it has been steadily growing in use in the United States over the past 7-10 years. It is being used to solve problems that otherwise seem to have no solution.

One of the key tenets of TRIZ is finding the contradictions in the problem and then applying engineering principles to solve the contradiction. Using TRIZ processes Aptimise was able to identify the contradiction in the problem of identifying the best solution for Calor.

The ISO 9000 system creates a solid, standardized foundation for quality and emphasis on continual improvement. However it introduces complexity in the form of extensive documentation and mandated control of documents. However, it offers no specific tools or methods for achieving the requirements. Lean techniques on the other hand, offer simplicity, ease of implementation and use. The inherent values and results of the two systems present the contradiction. "How can an organization achieve the simplicity of Lean management but at the same time achieve the requirements of ISO 9000?"

Aptimise used a similar contradiction, "How can Calor use the power of Six Sigma methodology while maintaining the flat, flexible management structure upon which they had built their success?" to evaluate Six Sigma as a choice. On one hand Calor had built and wished to retain the flat management structure that the owners had created and solidified. On the other hand, they appreciated the power of Six Sigma methodologies and the results that organizations had achieved in using them.

Aptimise connected the two contradictions by reducing them to one statement, "What is the best strategy for Calor if they want to maintain as much of the current system while increasing the competitive advantage?" As a way to solve the contradiction, Dave Ramsey and Ron Minke, the lead consultants on the project, wondered if there was a way to combine the power of all three strategies to create a system that added maximum competitive advantage and value to Calor.

To answer the question, Aptimise dissected each of the strategies to find the intended outcome, the prescribed methods, the principles and the purpose in each strategy. Through this analysis, it would be possible to identify the engineering principle that would allow solution. The table identifies the purpose and principles of each strategy.

	ISO Certification	Lean Management	Six Sigma
Purpose	<ul style="list-style-type: none"> Standardized quality management system Simple but comprehensive system Internationally recognized 	<ul style="list-style-type: none"> Elimination of waste Increase speed Increase throughput 	<ul style="list-style-type: none"> Reduce variation Control inputs Increase throughput Elimination of defects
Principles	<ul style="list-style-type: none"> Customer focus Leadership Continuous improvement Involvement of people Process approach System approach to management Fact based decision making Mutually rewarding supply chain 	<ul style="list-style-type: none"> Voice of the Customer Eliminate non-value added activities Quick wins Cross Functional Teams Emphasize value streams Stable systems Standardized processes 	<ul style="list-style-type: none"> Voice of the customer Six Sigma metric Statistical tools for measuring results Eliminate variation DMAC improvement process Focus on minimizing cost of quality Superior products & services

A quick review shows the areas where commonality exists. Additional review shows areas where differences exist. Aptimise created a chart to illustrate some of the findings. (The identification of specific tools used in each strategy was not undertaken at this time.)

While each of the strategies has a different purpose, the principles of each bear some commonality. In each of the systems, the customer requirements (Voice of Customer) is the factor that governs decision making. What is it that the customer believes is the most important for them?

Additionally, each of the strategies leads to continual improvement. In the case of ISO continual improvement is prescribed as part of the system. In Lean and Six Sigma continual improvement results from the consistent of methodology; for Lean it is definition of the value stream and ever finer definition of waste; for Six Sigma it is the application of the DMAIC process. Further commonality occurs in the fact each strategy seeks to create a climate where all employees understand the system, everyone is involved in the solution of problems and all are expected to identify opportunities for improvement.

Key differences occur in the fact that ISO is a management system that is non-prescriptive in methods and allows user defined techniques to achieve desired outcomes while Six Sigma and Lean prescribe tools and techniques and create experts for achieving user defined results.

Additional significant differences are seen when examining implementation requirements of each of the systems. In the case of Six Sigma, experts (Black Belts and Master Black Belts) must be trained, champions identified and a hierarchy of decision making created.

In the case of Lean, a cross functional team can be created and by the end of the following week a project can be implemented. Training of the teams takes place as projects implemented.

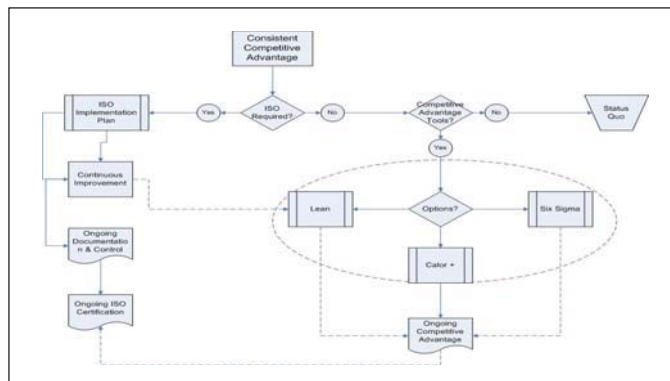
For ISO, planning must be undertaken using the certification requirements as a guide for system wide decision making and implementation undertaken in a consistent standardized manner.

THE SOLUTION

The Aptimise team, led by Ron and Dave applied the lean and six sigma tools to analyze the ISO requirements. What resulted was a system that they believed would allow Calor to achieve ISO registration, see almost immediate increase in return on improvement activities, plus provide a plan where Calor could readily obtain a new set of tools only when they were needed for additional projects. A key benefit of the system, Ron and Dave believed, would be the fact that lean and six sigma tools could be applied on as needed basis without adding additional rigidity, hierarchy and expense created by a traditional implementation of six sigma. Additionally, Aptimise believed that the system would allow Calor to achieve ISO 9000 certification within 6 months.

FACILITATING THE DISCUSSION

To have the results of the discussion come out with what was



truly best for Calor Aptimise knew that Calor management had to fully understand the basics of each strategy. While Calor staff had attended several different conferences and seminars, Aptimise doubted that each of the decision makers had been able to be fully informed on the details of each strategy.

Aptimise resolved to, in a condensed manner, lead the management team through the same analysis that had been completed in creating the solution that was planned to be proposed. To do so, they would have to systematically lead the management team through a series of "mini-decisions" that would culminate with the final decision of what Calor was going to do to regain the competitive advantage.

To facilitate and illustrate the necessary decision making, Aptimise created a decision-making flow chart (see diagram). As the discussion progressed sections of the flow chart were sequentially revealed to allow the managers to follow the flow of thought. In this manner the participants focused only on the decision at hand without looking ahead to the end solution.

Along the way, each of the strategies was identified; the purposes, principles, strengths, weaknesses initial costs and benefits; along with the implementation requirements were identified and discussed. To finalize the discussion, Aptimise described the Calor + concept and answered questions. It was then time to facilitate the decision making.

THE DECISION AND RESULTS

For Calor, the decision turned out easier than they had anticipated. Calor had listened to presentations from proponents of each of the other strategies. None of the other groups had so clearly identified pluses and minuses of each strategy. Even more uniquely, none had worked to develop a solution that combined the best of each strategy into a system that was uniquely tailored to the needs of Calor.

Calor + was chosen and implementation details were discussed. Under the guidance of the Aptimise team and over the next six months, Calor would implement Calor + at the Bensonville facility. Following the Bensonville implementation, a decision would be made about implementing the system at the four other facilities.

For Aptimise, the decision was significant. It provided a challenge to prove successful what they believed would be an ideal system for Calor. Without Aptimise knowing it, the decision was to provide additional opportunity for innovation.

As the implementation progressed, Aptimise identified the need for a Corrective Action/Preventive Action Plan. To fulfill the need, Aptimise worked with Calor management to define a plan and immediately implement it in a week long "kaizen blitz type" rapid improvement event that taught problem solving and applied the Lean and Six Sigma Tools of Value Stream Mapping, Pareto Charts, Sampling and introduced the basics of Project Management.

As the six month implementation period came to a close, Aptimise reviewed with Calor management the activities that had been undertaken. Anticipation and concern about the upcoming ISO audit were both running high. Aptimise did the best that they could to reassure them.

At the end of Day 1 the auditors had identified only one minor deficiency that was corrected before the project team went home. At the end of the second day, only two more minor deficiencies had been identified. Both of the additional deficiencies were corrected within two days of the closing conference.

Calor was certified as being ISO 9000: 2001 compliant 6 months and 2 days from the time the project was implemented.

PROJECT RESULTS

- ISO 9000: 2001 certification within 6 months
- Paperless documentation system created
- Paperless documentation management system created and actively used
- Corrective Action / Preventive Action System created and implemented
- First corrective project under way
- Six Sigma tools taught
 - Sampling
 - Value Stream Mapping
 - Pareto Charts
 - Cause and Effect Diagrams
 - Project Planning
- 650 employees ISO awareness level trained
- Online Problem Solving course developed and available to all employees

ABOUT APTIMISE

Aptimise is a consulting firm focused upon improving the competitive advantage of our clients. Using advanced tools such as TRIZ, Quality Function Deployment, Six Sigma, and Lean Management techniques, it seeks to increase the Innovation, Intellectual Property and Operational Effectiveness of the client organization. Aptimise staff is active in the American Society of Quality, Society of Plastics Engineers, the Fort Wayne Inventors Society, and a variety of regional and national organizations.

Dan Templeton, the firm's founder and CEO is President of the ASQ for the Fort Wayne region. Dave Ramsey, Senior Consultant and Director of Business Development, the project leader in this case is the President of the Board of Directors and a founding member of the Indiana Center for Organizational Excellence, which uses the Malcolm Baldrige National Award criteria. Aptimise has formed a collaboration with Ideation International, the developers of I-TRIZ. Ideation can be found at www.ideationtriz.com.

Aptimise can be found at www.aptimise.com or by directly contacting Dave Ramsey at (260) 407-0374

Why ask why when you should be asking what?

A human factors by-product of tunnel vision in problem solving

Christopher G. Vallee

M.A. Human Factors in Psychology, Wichita State University
Six Sigma Black Belt
Senior Associate, System Improvements Inc

ABSTRACT

Tunnel vision has been defined as a “phenomenon that can render an individual unaware of impending or existing danger” [1]. Guided by past experience, the problem solver’s attention is completely “tuned” into this narrow focus. What is the science behind this theory? How can you prevent this phenomenon from impacting your problem solving ability? Walk through an incident and see how you may have limited your root cause analysis. Being aware of your limitations and how they can be influenced by the incorrect selection of RCA tools must change your perspective and lead you to search for a robust tool.

AUDIENCES FOR THIS PAPER

Safety, quality, production, engineering, and medical staff who must solve incidents, defects, or sentinel events that are not due to common process variation [28, 29, 39] should read this paper. This is not to say that the causal factors related to this type of incident are not part of everyday processes, just that the convergence of these variables is infrequent. How many errors do you and other drivers on the road make before the right combination occurs to produce a collision? With increased regulation in many industries, root cause analysis (RCA) is widely being utilized in the oil, utility, nuclear regulatory, manufacturing, and medical industries. There is concern by some industry experts however that RCA output may not be replicable, verifiable, predictable, or creditable [39, 40] based on the infrequency of events combined to produce a single incident and the multiple RCA theories and tools available today. If you do not want to become susceptible to certain RCA tool limitations continue reading.

Caution, you will learn a little more about decision making processes in order to learn the strengths and weakness of key RCA techniques. While studies in decision making and discussion of RCA tools are not rare, the integration of subject matter experts (SME’s) heuristics and their limitations in RCA processes is new.

INTRODUCTION TO COGNITIVE TUNNELING

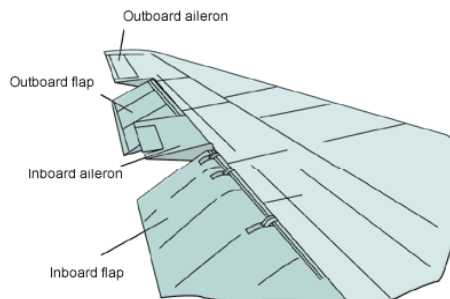
“I knew this project would fail...it is typical of our DMAIC led root cause analyses,” stated a structural engineer after a failed attempt to reduce flap buzz on a small jet-engine aircraft. While flap buzz occurs frequently for this particular aircraft, the condition is produced with little similarity in air maneuvers between aircraft. Unknown to the engineer following his statement, hindsight bias, a form of cognitive tunneling, is now superimposing a false reality on the project’s history. A “phenomenon that can render an individual unaware of impending or existing danger” [1], cognitive tunnel vision limits the problem solver’s abilities. Heuristics developed from past experience, guide the subject matter expert’s (SME) attention into a narrow focus [2, 3].

Heuristics (rules-of-thumb) are used to make decisions during each phase of the Define, Measure, Analyze, Improve, and Control process (DMAIC), one of many structured problem solving processes used in six sigma project facilitations. While most experts utilize their heuristics effectively daily, there is no guarantee of success [2,4]. Of interest to this author, is why certain RCA tools seem to be more effective in preventing cognitive tunneling in the Analyze stage than other tools. In an effort to improve DMAIC sensitivity to cognitive tunneling, the failed flap buzz project for company XYZ will be further examined asking three questions. What is the science behind decision making and heuristics in problem solving? Why do certain root cause tools compound heuristic biases made by SME’s? How can you reduce this phenomenon from impacting your root cause analysis efforts?

THE FLAP BUZZ PROBLEM

Flap buzz, sometimes called flap rumble, is a vibration felt through the pilot’s yoke or a vibration heard by the pilot during certain air maneuvers. This defect is produced when excessive air flows over or under an aircraft’s flap, causing the flap to flutter at a high frequency.

See Figure 1 for the location of an aircraft flap. A team of skilled experts was tasked to resolve recurrent customer complaints through a Define, Measure, Analyze, Improve, and Control (DMAIC) facilitation.



A six sigma black belt, aerospace structural engineer, flight operations managers, quality inspectors, pilots, and aircraft model specific mechanics gathered to define the flap buzz solution. As SME’s for their disciplines, the team was familiar with the corrective action

for this pilot write-up. There were gaps between the upper flap surface and the wing trailing edge that exceeded engineering requirements after assembly. The remedy has been to reform the trailing edge to reduce the gap and airflow. This method has proven to reduce or eliminate the flap buzz. Previous measurements had correlated excessive gap reduction (the reforming of the wing) with reduced flap buzz. While effective, this method was time consuming and dependent on key aircraft mechanics to perform.

CORRECTIVE ACTION FAILURE

The six sigma black belt facilitated the team through Define and Measure and into the Analyze section. Introducing brainstorming, cause and effect diagrams, 5 why’s, and prioritizing techniques, the team verified the root cause and determined that past attempts to remove the variation in assembly had not been successful. Looking for a permanent solution to reduce the excessive gap, the team decided to install a p-seal under the wing trailing edge above the flap. This seal would reduce the airflow normally corrected by forming the trailing edge.

With the new p-seal designed, approved, manufactured, and inspected, it was installed on three aircraft for testing purposes. End result, the flap buzz continued to the frustration of the SME’s. What went wrong in the decisions made while adhering to the structured DMAIC process using experts in the field? How could the root cause tools have failed their effectiveness in determining causal factors and root cause patterns?

THE ART OF DECISION MAKING

In each phase of the DMAIC problem solving process, a selection must be made between multiple system events, objects or solution alternatives. In the optimal setting, all information needed to make a complete assessment of causes within the context of the problem would be available. In a manufacturing part shortage for example, the DMAIC team would understand the integrated supply chain inputs to include manufacturing, engineering, planning, inspection and customer variations. All alternatives to a solution would be compared and be weighted to select the best solution with high probability of reducing the part shortage. This type of decision making is termed as a Normative or Rational process [2, 6, 7].

In this classical perspective of decision making, cognitive theorists, economists, and operations analysts attempt to map out decision making using theories such as subjected expected utility (SEU) [12]. SEU is a mathematical model of choice in which people make utility maximizing choices with certainty. Using this computation, DMAIC teams solutions while examining the same problem should be identical. An idealistic theory that would make DMAIC processes successful but use of SEU is improbable due to the imperfect nature of SME decision making.

In the real world, imperfect information is the norm [2, 8]. Descriptive theory research has identified many departures from the Normative theory of maximizing benefit [2, 12].

“People do not normally analyze daily events into exhaustive lists of possibilities... instead they commonly use a limited number of heuristics.” [20]

There are uncertainties that must be overcome while seeking problem cues and when selecting an action to resolve a problem. Rarely are all factors available to the decision maker and of those factors that are visible, many are selectively filtered out. For instance, a team proposes to reduce a product's cycle time to meet a new takt time, ignoring the fact that the original takt time could not be met. Simultaneously, a leading vendor is deciding to close its door unknown to the team. Termed as Descriptive decision making [2, 6, 7], “limitations in human attention, working memory, or strategy choices, known as heuristics, work well most of the time but occasionally lead to undesirable outcomes.” [2, 9, 10, 11]

Proposing the Satisficing Decision Theory, Simon [8], suggested that people think of options or alternatives one by one until they find one that meets or surpasses their minimum criterion, ignoring criterion that has not been met or solutions that would exceed requirements. To confound matters, SME's attempt to solve system problems from the perspective of their discipline expertise only. It is in the realm of satisficing, heuristics (rules-of-thumb), and biases (heuristics error) utilized during root cause analyses that the remainder of this paper will focus.

THE INFORMATION PROCESSING MODEL OF DECISION MAKING

The descriptive process is concerned with how the person frames certain problems, set goals, and develops new alternatives, hypotheses [12] while problem solving. How do we gain information from the environment and how are choices made from this information? Key to framing a problem is the person's ability to identify cues for pattern recognition and schemas from the environment and their long-term memory. To understand this process a model of information theory was developed [2,12,13]. Wickens and Holland [2] emphasize that cues can be ambiguous and misinterpreted in a “fuzzy haze” of uncertainty. Used frequently to blur our pattern recognition abilities is the sketch shown in Figure 2 [13]. Do you see a young lady or an old woman? Due to our cognitive limitations, you can't see both images at the same time. If the doctor diagnoses a heart problem, will another cause for the patient's symptoms be visualized? The doctor's rules for pattern recognition would prevent other diagnosis cues.



Figure 2 What do You See? [13]

For those not familiar with the Information Processing Model of Decision Making depicted in Figure 3, a brief walk through will follow [2, 13].

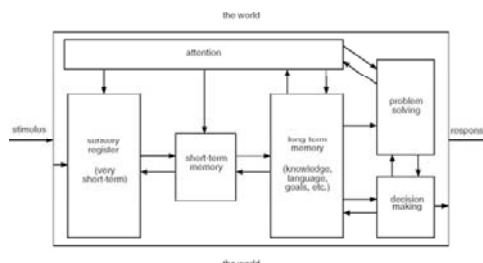


Figure 3 Information Processing Model of Decision Making [13]

Information Acquisition: To solve a problem, the decision maker must seek cues or sensory information from the existing stimulus, the environment and long-term memory. Not all external sounds, sights and texture stimulus can be discriminated by the observer because of environmental or internal noise [2]. For example, high blood pressure can cause excessive noise thus blocking out certain frequencies during hearing tests. For those stimuli able to be perceived, past experiences stored in the long-term memory, focus our attention selectively on salient cues in order to reduce or group the information present. Cues that are not considered salient are filtered out using applied heuristics developed by the decision maker. Heuristics, the Greek word meaning “to find”, will be discussed in the next section.

Picture this scenario; a patient comes in complaining of a sore throat. Based on past experience the doctor filters out symptoms not related to sore throat causes, thus focusing on viral or bacterial symptoms. After all, do you really need a full physical and CDC report of the surrounding area to treat a sore throat? Interns might search out this information initially, but once becoming a full-fledge doctor, who needs it? Okay the full-fledge doctor comment may be hindsight bias on the authors part, but the fact remains that we as experts in our field must quickly filter out stimulus to be effective in everyday decisions.

Information Processing: Once the cues have been selected from long term-memory or the environment and placed into the short-term memory, a diagnosis or situation assessment is made enabling the decision maker to reformat or affirm hypotheses about the current state and future of the world [2, 14, 15, 16, 17]. Common situational assessments can include whether or not one can cross the street safely to what patient symptoms precede certain illnesses prior to choosing a treatment. In the case of a safety incident analysis, what assessment did the parties involved make and what cues did they attend to?

Although we look for patterns of abstract representations in large amounts of stimulus, we can form abstract patterns with very little information in order to confirm our hypothesis. Look at Figure 4, what do you see?

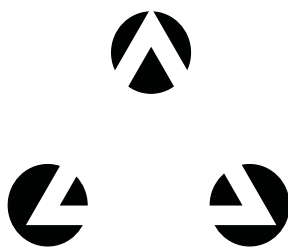


Figure 4 Three Dots

Without reducing information, a triangle matching limited cues exists. Assessment is an iterative process; each situation assessment and hypothesis can lead the decision maker to search for additional cues or filter out previously selected cues from the environment if there is doubt [2, 17].

Output (Choice): The third stage of decision making is choosing a response or action. Choices are guided by the risk associated with the select situational assessments made and retained by the decision maker [2]. Take the sore throat assessment earlier; if the cues indicated a virus (confirmation of previous pattern), the doctor would not prescribe antibiotics. Of course, there are tricky bacteria that mask themselves and the patient may not return for further treatment.

Meta-Cognition: Of interest to many researchers, [2, 12, 18, 19], is the role of metacognition in situational awareness. Metacognition is the awareness of one's knowledge, effort, and thought processes, which has an important influence on the quality of decision making. Residing in the area of uncertainty (prevalent in root cause analysis), does the person know that he or she does not possess all the relevant problem information necessary to make a valid choice [2]? Does that person monitor the application of successful and failed heuristics?

Is the person's mental model an accurate representation of the true system? An example of meta-cognition limitation will be reviewed in the failed flap buzz project later in this paper.

In summary the stages of decision making are: seek and filter out cues that can be perceived by applying user defined heuristics; assess situation and affirm hypotheses (repeat as needed) and assign risks to meeting or not meeting user goals; make choice based on situation assessments and act; monitor choices to enhance meta-cognition of the decision maker. We are getting closer to root cause analysis limitations and strengths but need to understand what heuristics are and how subject matter experts utilize these rules-of-thumb.

WHAT ARE HEURISTICS?

Heuristics, often referred to as a “rule-of-thumb”, are mental shortcuts based on the user’s experience. While not guaranteeing a correct solution, these rules simplify real-world decision situations that are complex, uncertain, or ambiguous [21]. Usually applied to problems for which existing processes failed to prevent or may have created, the DMAIC project scope is an excellent example of ambiguous and uncertain information. The author reviewed an ergonomic project where experienced aircraft assemblers’ solid rivet installation defects recently increased. Unknown to and created by a previous project team, a newly required ergonomic rivet gun (vibrated less) prevented the vibration feedback that normally indicated the rivet was set when installed.

The decision maker develops heuristics by using inductive learning when uncertain inferences are made from experience [22]. Forming mental models or representations that may or may not be correct, people continue to build on these inductive inferences until possibly refuted by further experience. For instance, look at the picture of the faucet handle in Figure 5, how would a person shut the water off with this type of faucet?



Figure 5 Faucet

For many, the operation would be to turn the faucet clockwise until the water stops running.

There was no in-depth testing of all faucets of this type before making this conclusion or heuristic. Despite the fact that those who travel frequently have found “backwards faucets” (turn clockwise to turn the water on), this heuristic still stays true for most people. One item to keep in mind is that inductive reasoning is not always a conscious effort and can become resistant to change. With no iterative process, this can be difficult to monitor in the metacognition stage for correctness [2, 22].

HEURISTICS USED IN UNCERTAIN CHOICE

Authors such as Heacox, Gwynne, and Kelly [21] have grouped certain heuristics with each stage of the Information Processing Model discussed earlier in this paper. Because of its relevancy to root cause analysis decision making, the author chose the same format and listed heuristics, biases, bias examples, and affect on the particular processing stage as well.

Information Acquisition:

Availability Heuristic– The ease and speed with which examples of an object or an event come to mind tend to lead people to estimate the probability that an event will occur or that an object exists. This ease quickly allows decision makers to

discriminate stimulus from noise in the environment. Think of the last time you ate something that made you sick, recall of that food item is a lot quicker than recalling the bland food you ate last (22). You will also estimate that there is a 90% chance you will get sick if you eat that food again.

Availability Bias – People have a tendency to recall the first or last event observed over time, especially if the event is very vivid [2, 22]. Simple inaccurate hypotheses are also easier to recall than more accurate complex hypotheses. When perceived frequency (or vividness) of an event diverges from the true probability of it occurring this is bias.

Availability Bias Example [23] – Participants in a study were given a list of an equal number of male and female names. The male names given were of well-known individuals. When asked whether lists of names contained more males or females the participants chose the male ignoring the actual count of female and males names. Whether this bias interfered with the perception of the stimulus or was just easy to recall after perception, the availability bias creates error in comprehension and future cue searching.

Framing Heuristic [2, 22, 20, 23] – The way in which someone describes a problem or the way a pattern of stimulus is introduced has a large effect on how people will solve, view, or react to it. It is a priming effect that stimulates the observer’s perspective or value to the stimulus being viewed. Non-Smoking campaigns have recently addressed the effects of smoking on one’s children eliciting different responses than previous warnings.

Framing Bias [2, 22, 20, 23] – People perceiving negative outcomes will take greater risks regardless of the actual probability of risk.

Framing Bias Example [20, 23] - Two groups of participants were given the option to make a choice that would save a certain amount of people; while stated differently, each equation was identical in value and variables. Note: the original study used an outbreak of Asian flu and treatment possibilities.

View A: You have 600 soldiers and need to decide what route to take. If you take the first route you will save 200 soldiers. If you take the second route the probability is 1/3 that all 600 will make it and 2/3 that none will survive. 3 out of 4 participants chose the first option to save 200 lives with route one.

View B: You have 600 soldiers and need to decide what route to take. If you take the first route 400 soldiers will die. If you take the second route, there’s at least a 1/3 probability that all 600 will make it out and 2/3 probability that none will make it out. 3 out of 4 people chose the second route this time.

Bias Affect on Information Acquisition: It affects saliency of information obtained from longterm memory and the environment. While it is important to limit the amount of information reviewed at one time, underestimating the value of certain cues can lead to a restricted range of decision opportunities [2]. Assigning saliency to items based on emotion can also lead to incorrect assessments.

Information Processing:

Anchoring and Adjustment Heuristic [2, 22, 20, 23] – When people make estimates, they often start at an

initial value or hypothesis that is salient or convenient then adjust from that starting point in the appropriate directions. For example, water boils when it is heated at a certain temperature. While variation in small degrees of the original temperature may be perceived, confirmation of the initial hypothesis does not stray very far.

Anchoring and Adjustment Bias (related to confirmation bias) – The strength of one belief will over ride contrary beliefs despite contrary evidence [2, 22, 20, 23].

Confirmation bias – People seek information to support their original beliefs and refuse to seek contradicting evidence. This bias also affects the saliency of cue seeking in the information acquisition stage of decision making [2, 22, 20, 23].

Anchoring and Confirmation Bias Example [2] – The nuclear reactor incident at Three Mile Island revealed anchoring and confirmation bias. Alerted of a reactor failure, operators focused on a closed valve indication and hypothesized that the water level in the reactor was too high. Following trained procedure and failing to search for other factors of the water actually being too low (despite other alarms going off), the operators overrode the emergency relief pump that would have provided additional water to the reactor. After all, the valve was “closed”; there could be no other reason except that the level was too high.

Representativeness Heuristic [2, 22, 20, 23] – People estimate the extent to which objects or events relate to one another and use this resemblance to group similar events and objects. A dog has four legs, wags its tail, and barks. A Labrador is a dog, so it probably barks.

Representativeness Bias [2, 22, 20, 23] – People overestimate the similarities of one event or object being similar to another (guilt by association). Often appears in sampling errors, when the pool of objects selected did not represent the true population.

Representative Bias Example [20, 23] – Researchers told participants that 100 people were randomly selected from a population with 70 farmers and 30 librarians selected. Given the characteristics of a shy and withdrawn person that was meek and tidy, participants were asked whether this person was probably a librarian or a farmer. Most participants indicated that the person was probably a librarian ignoring the fact that 70 percent of those selected were farmers.

Bias Affect on Information Processing - Inappropriate processing rules are applied to information and the consequent misinterpretation of the information [2, 22, 20, 23].

Output (Choice):

Control Heuristics [2, 22, 20, 23] – People have a belief that they can control future outcomes. This prevents second-guessing from causing over-analysis of the alternatives.

Illusion of Control Bias (Overconfidence Bias) – Additional alternatives are not entertained based on previous filtering [2].

Overconfidence Bias Example [24] – The average

driver believes that he or she is within the top 25 percent of safe drivers yet if accurately calibrated only 50 percent of people would only rate themselves as above average safe drivers.

Bias Affect on Output [2, 22, 20, 23] – Restricts the range of responses that can be made.

Meta-cognition:
After the Fact Analysis Heuristic [2, 22, 20, 23]
 – People can easily formulate plausible explanations after the fact, which aids in identifying causes or hypothesis with existing objects and events.

Hindsight Bias [2, 22, 20, 23] – People over estimate their ability to judge what happened, failing to see what was not known before the “I knew it all along” perspective was developed. This is an after the fact judgment that prevents problem solvers from seeing the true past evidence.

Hindsight Bias Example: I knew John was incompetent before I gave him the pump replacement task, of course he broke the flange during installation. Hindsight bias often encourages blame has opposed to encouraging further investigation of an incident.

Bias Affect on Meta-Cognition: Misconstrue and interfere with the learning required to make accurate predictions and future event relationships often superimposing incorrect representations of past incidents. Unfortunately, feedback from trial and error when refuting one’s own hypotheses in the meta-cognition stage of decision does not necessarily perfect an SME’s decision making quality [2]. In simple terms, trial and error while guessing does not build a better equipment troubleshooter or triage doctor; accurate system knowledge places a major factor here. While feedback in decision making is necessary, feedback comes with its limitations as well. Feedback can be ambiguous, delayed, and selectively processed.

Ambiguous feedback [2] – A poorly led decision process may be executed but by chance the outcome is successful leading to positive reinforcement. However, a properly executed decision making process is not guaranteed leading to a negative punishment.

Delayed Feedback [2] – Because of delayed long-term results, the decision maker fails to associate the results with the initial heuristics and process. Hindsight bias blocks the decision maker’s initial process preventing either positive or negative reinforcement.

Selectively Processed Feedback [2] – Anchoring and confirmation bias can filter what outcomes are reviewed.

THE EXPERTS USE OF DOMAIN HEURISTICS

The question to ask now is what do these cognitive theory revelations have to do with the six sigma black belt, structural engineer, flight operations managers, quality inspectors, pilots and aircraft model specific mechanics mentioned earlier? These experts were proven problem solvers in their individual domains. They knew their “stuff”. Johnston [18], Graber, Franklin, and Gordon [25] state that this subject matter expertise “paradoxically” is what makes the experts prediction (forecast) skills for root cause analysis unreliable. While experts detect patterns of events or objects that resemble true system defects quickly and more accurately than novices, this same skill becomes less dependable when abstract or complex symptoms mirror

existing events are reviewed [2, 18, 25]. Subjecting SME’s to examine infrequent combination of events leading to an incident or defect may actually limit the success of the RCA.

In a recent study examining diagnostic error in internal medicine [25], 74% of 90 cases resulting in patient injury or death resulted from faulty synthesis of the patients’ symptoms. In fact, it is the nature of the the heuristics applied, which led to premature closure of cases when the physician failed to consider additional alternatives. Bhasale [41] reported two types of errors made during the information process stage in diagnosis: inappropriately rejecting the correct hypothesis because of insufficient or incorrect evidence, and incorrect diagnosis and inappropriate examination. Easily recalled from the previous section, these errors relate to confirmation, availability, representativeness, and anchoring biases.

The mechanic, doctor, and engineer, enter their fields novices with general heuristics developed for everyday activities, not area of expertise specific [2, 18, 25]. Processing strategies need to be developed on newly formed operator mental models often with the help of mentors [2, 18]. Exposed to new tasks or events, the novice begins to learn domain specific guidelines and constraints. Building from select events and objects the novice begins to recognize patterns of behavior becoming a journeyman in their field. With time, the journeyman identifies patterns of behavior between tasks and events in more abstract similarities. Based on developed heuristics the journeyman begins to test hypotheses about future behavior based on past experiences. It is at this point that the expert becomes confident in his knowledge and does not need a mentor [18].

Using high-order principles of reasoning [18, 26], experts begin to look for patterns based on function whereas the novice would look for patterns based on color and size. Spending more time thinking about the problem in the beginning of a problem solving task than the novice, the expert uses previous cases as context for creating the mental models of the current problem [10, 11, 18]. Novices have trouble deciding what the problem is and hesitate after the collection of data. Note that more data is collected because of the inability to filter out non-salient cues.

Herein lies the problem of using an expert to solve problems in a complex or ambiguous environment, one that also includes other domains of specificity or unknown functionality. Experts searching for root causes for a specific problem will attempt to reduce the current objects and events into an existing pattern or rule developed from their past experience [18]. Subject to the heuristic biases listed earlier, the Information Processing Model for Decision Making can become contaminated with error through cognitive tunneling and misappropriate rule application.

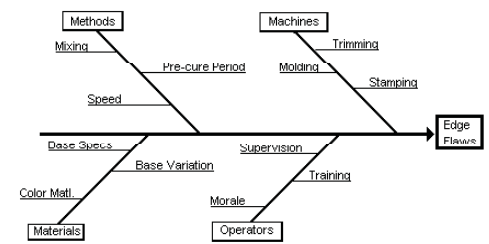
Compounding the lack of inter-domain specificity, experts are subject to heuristics biases within their field due to inefficiencies in meta-cognition. While a current diagnosis and treatment seem to cure an existing ailment, the physician is unaware that the treatment choice affects another variable unrecognized in his mental model of the system ([18, 23, 25].

Understanding that root cause analyses are usually performed in complex and ambiguous environments involving multiple domains, this knowledge of expert bias now becomes relative to failed data collection (Information Acquisition) and faulty synthesis (Information Processing). Because the nature of heuristics implies that the expert has already developed the why of what happened, the SME has a tendency to filter out “important” non-salient but relevant information and events (the what of an incident). Simply put, why ask why, when you should be asking what?

THE NATURE OF THREE ROOT CAUSE ANALYSIS TOOLS

Wow, we finally reached a section on RCA tools. Hopefully, you have not used your heuristics to filter out any non-salient but important information.

Doggett [28, 29] recently reviewed three popular root cause tools used in the DMAIC process: the cause-and-effect diagram (CED), the interrelationship diagram (ID), and the current reality tree (CRT). See Figures 6-8 for graphical representations of each method.



Cause and Effect Diagram for Edge Flaws

Figure 6 Cause and Effect Diagram [27]

His concern was that problem solvers would select a root cause analysis tool based on ease of use as opposed to its performance in solving problems. This could lead to availability and overconfidence bias in lieu of actual quality of output.

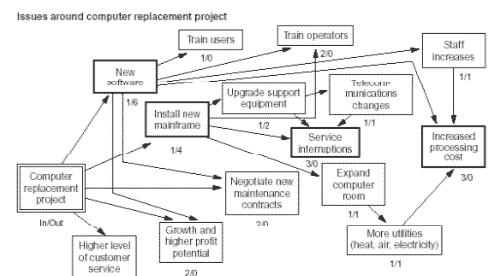


Figure 7 Interrelationship Diagram [30]

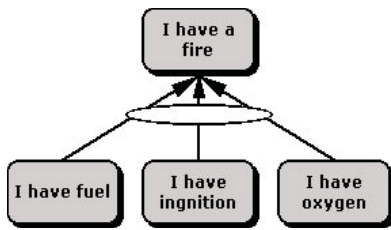


Figure 8 Current Reality Tree [31]

For each of the three mentioned root cause processes, Doggett [28, 29] examined three dependent variables: perceived ability of the tool to find root causes; perceived ability of the tool to find relationship between factors or categories of factors; and the overall perception of the tool's usability to produce outputs that were logical, productive, and readable.

In summary: the CRT was rated as more difficult and the CED was perceived better at identifying cause categories than either the ID or CRT. Even more interesting is the fact that participants using the CED seldom identified a single specific root cause whereas the CRT produced higher quality root causes and interfactor relationships.

Would the results have turned out differently if subject matter experts were tested in scenarios relevant to their domains as opposed to undergraduate students using general heuristics in a new scenario? What are the principle theories underlying these root cause searches? These findings [28,29] give ample reason for concern on the effectiveness and reproducibility of RCA tools results as cited by industry experts earlier [39, 40].

EXAMINING THE SAME THREE ROOT CAUSE TOOLS IN RELATION TO DECISION MAKING HEURISTICS

Using the steps listed in Doggett's [28, 29] study, the CED and CRT are matched with the possible biases in relation to the information processing stages. With these RCA tools, the SME's must fill in information and categories based on their current mental models of the system and incident being reviewed.

CED [28, 29, 32]

1. Decide on the problem to improve or control.
2. Write the problem on the right side and draw an arrow from the left to the right side.
3. Write the main factors that may be causing the problem by drawing major branches to the main arrow. Primary causal factors of the factors of the problem can be grouped into items with each forming a major branch.
4. For each major branch, detailed causal factors are written as twigs on each major branch of the diagram. On the twigs, still more detailed causal factors are written to make smaller twigs.
5. Ensure all items that may be causing the problem are included in the diagram.

Step 1: SME's label the problem in terms of a solution based on availability and framing biases instead of identifying what are the facts of the problem. For example, the problem is that there is no test procedure. Labeling a solution a problem causes the group to filter out any other possible causes in the system, cognitive tunneling.

Step 2: SME's frame the problem in a negative outcome to lead the analysis in a biased direction opposite of what the data may yield. Note that this is not always a conscious effort and may be due to unawareness of the concept.

Steps 3-5: May be skewed based on the SME's mental model accuracy and completeness for the system that has the problem. Category of causes although led somewhat by the common groupings such as manpower, machine, method, procedures, policies, etc., are limited by the ease of availability bias. Once listed on the CED, SME's will see patterns (representativeness bias) that may be similar to previous experience. Due to anchoring, any patterns that are in conflict with the previous pattern will be ignored [3]. Finally, overconfidence blocks the SME's from searching for additional data or alternative solutions.

In summary, the CED while perceived as easy to use and great at general brainstorming and conversation initiation falls short of identifying root causes. Keeping in mind that problems exist because previous patterns of knowledge have not been effective in prevention, this causes environment and long-term non-salient cues to be unrecognized, blocking new knowledge and relationship formation.

CRT [28, 29, 33, 34]

1. List between 5 and 10 problems or undesired effects (UDE's) related to the situation.
2. Test each UDE for clarity and search for a causal relationship between any two UDE's.
3. Determine which UDE is the cause and which is the effect.
4. Test the relationship using categories of legitimate reservation.
5. Continue the process of connecting UDE's using "if-then" logic until all UDE's are connected.
6. Sometimes the cause itself may not seem to be enough to create effect. Additional dependent cases can be shown using the "and" connector.
7. Logical relationships can be strengthened using words like some, few, many, frequently, and sometimes.

Step 1: SME's identify UDE's that are solutions as discussed previously. Any further investigation is then limited.

Steps 2-6: Isolating an initial set of UDE's, subjects the SME's to anchoring and conformation bias. The range of causal factors only extends from the initial measurement (or hypothesis) with non-salient cues

being filtered out (not necessarily a conscious effort). Causal factors that are not familiar to the SME's domain or level of system understanding will not be identified. Begging the question are we treating the symptom or the root cause regardless of the validation procedures?

Step 7: Semantic adjustments can lead to framing issues.

Note however that the CRT forces the SME's to test and review their initial understanding of the system. This in fact limits a certain amount of bias during the meta-cognition stage. SME's have the possibility to become aware of their domain specific misconceptions. The limit of CRT however is that it fails to recognize SME's narrow domain knowledge. With repetitive problems there may be external domain causes that need to be identified, domain causes that need to be introduced to the SME's.

THE PRINCIPLE THEORIES AND METHODOLOGIES OF RCA

Residing within all RCA tools to include the three studied by Doggett [28, 29] are implicit rules and assumptions, principles. Benner [40] recently reviewed five underlying principles of RCA: the single event perception and related "cause" theory; the chain-of-events perception and "domino" theory; the determinate variable(s) and "factorial" theory; the branched events chain perception and "logic tree" theory; and the multi-linear events sequences perception and "process" theory. Relating these assumptions to subject matter experts' heuristics, framing and anchoring are influenced by the particular principle or "mental model" used during an investigation. Being concise definitions, the following excerpts are Benner's words [40, p5].

Single event perception and cause theory:

Assumes and accident is a single event which has a "cause". Task is to find a cause, correct it and the accident will be prevented in the future, p19.

Chain-of-events perception and "domino" theory: Assumes "unsafe" conditions create vulnerable relationships in which "unsafe act" can trigger "chain-of-events" called accident. Task is to identify "unsafe conditions" and "unsafe acts" that caused the events sequence, p20.

Determinant variable perception and "factorial" theory: Assumes common factors are present in accidents and that they can be discerned with statistical analysis of the "right" data from accident investigations. Assumes hypothesis about determinant variables can only be identified by secondary examination of the facts, p20.

Branched events chain perception and "logic tree" theory: Assumes accidents are predictable, and structures predictive search for alternative event pathways leading to selected "undesired event", through

speculations by knowledgeable systems analysts. Follows rules of procedure for structuring speculations and assigning probabilities in a branched events chain, p20.

Multi-linear events sequences perception and “process” or “p-theory”: Assumes accident is transient segment of continuum of activities; views accidents as a transformation process by which homeostatic activity is interrupted with accompanying unintended harm state. Process is described with actions by interacting actors, each acting in a sequential order with each sequence related to each others interacting sequence in a specific temporal or spatial proceed/follow logic, p20. *(This authors words: Basically, each related cause and event happen at the same time with multiple cause-event pairings building off of each other until the event occurs. Each event has its own sequence of transformations and do not replicate to other incidents.)*

In collecting data to fulfill the above underlying principles, problem solvers have been observed using at least six different methodologies according to Benner [40, p7]. Such methodologies listed are: events reconstruction (reconstruction of the incident from evidence and interviews), statistical (comparing several incidents after the fact to find significant grouping of events and causes), modeling (“mental movie” or flow chart of the accident), simulation, and “hunt and peck (trial and error).

We now have a basic understanding of where CED, ID, and CRT’s can fail [28, 29], but what observations of failure did Benner identify in the higher-order RCA principles [40]?

RCA METHODOLOGIES AND COGNITIVE TUNNELING

A promising observation by Benner [40] is that most investigations truly attempted to gather “facts” and a “sequence of events” to determine causes. Discomforting however is the criteria used for a identifying a “fact”. Benner [40] reported that this criteria was either absent or stated in ambiguous terms. Facts were then sought out based on the investigators experience and personal background without validation, many times with arguments incited between the “experts” theories. Further analysis of the “facts” identified during the preliminary observations was guided by the same hypotheses.

Benner’s [40] final intriguing observation emphasizes that there was little evidence found in the 14 observed investigative process manuals relating major safety investigations with “safety” predictions.

Can you see that the experts’ own heuristics have biased the investigation from start to finish? Many investigations observed by Benner [40] were anchored in finding a “cause” or “fault finding” only, not how could they have predicted this incident from occurring. SME’s formed their own hypotheses

from the area of expertise perspective. Due to availability, representativeness, and hindsight bias, new “fact” identification and subsequent analysis was impeded. Even when events, causes, and effects were correlated to temporal relationships and sequential transformations, the data contained within the analysis is subject to be tainted by the SME’s rules-of-thumb; thus, it provides a skewed view of the incident, defect, or sentinel event. Cognitive tunneling is very resistant to brainstorming with much hesitance to change one’s current mental models of the real world.

REVIEW OF THE FLAP BUZZ EXPERT BIASES

So what actually happened to the flap buzz SME’s? What RCA tools did they apply [28, 29]? What underlying RCA principle and method was utilized [40]?

The first major barrier is how the problem was labeled. The SME’s “knew” why the flap buzz occurred, the trailing edge assembly was gapped more than engineering limits allowed.

Using the underlying principle of the single event perception and related “cause” theory [40], the cause was the excessive gap incurred during assembly. It is important to note that to many RCA investigators, this root cause would be considered an effect or event if other principles had been applied. The problem to be analyzed was “how to reduce the gap permanently”. Framing this solution cognitively narrowed the range of data to analyze. Previous pattern recognizing (learned heuristics) gave the SME’s an overconfidence bias that they could control flap buzz, supported by a “mental movie” methodology of what was happening in flight.

Facilitating the cause and effect diagram using 5-why’s (single event basis) and brainstorming techniques, the six sigma black belt, having limited experience in aero-dynamics, unconsciously led a biased analysis using the SME’s expert heuristics. The causal categories identified were just confirmations of the SME’s mental model of why flap buzz occurred...more of a fill in the blanks task and just going through the motions [35].

After the fact analysis of the data, determined that wing trailing edges were also being formed when the gap was within engineering limits in response to flap buzz write-ups. Of course, this data was overlooked due to anchoring and confirmation bias. The structural engineer and team knew without a doubt that this was an assembly and gap problem. Engineering needed to be followed correctly, representing overconfidence bias and representativeness bias.

Another six sigma black belt knowledgeable of aerodynamic principles joined the group following the failure and asked who was the aerodynamic air flow SME? No SME of that domain had been assigned. It turns out that as the mechanics formed the trailing edges to close the gap, they were

hardening the metal. This hardening reduced the sensitivity of vibration in the metal. Imagine the concept of woodwind instruments and the use of wood reeds to produce sound through vibration. As with physicians who cure certain ailments with imperfect understanding of why [25], these aircraft SME’s formed a wing thinking that closing the gap was the solution. With hindsight bias, the original six sigma black belt stated, “the group should have known to have an aerodynamic air flow SME.” True confessions here, the initial six sigma black belt, is the author of this paper.

HOW TO REDUCE THE EFFECT OF ROOT CAUSE TOOL EXPERT BIAS

Situational awareness that SME’s use heuristics to make decisions is the first step to reducing root cause analysis failure. So just by reading this paper you got a little better. Intelligence analysts showed partial improvement when researches administered training on the affects of anchoring and confirmation bias [2,36].

Understanding that certain root cause analysis tools compliment certain biases is the second step in improving RCA. In the following section, suggestions based on past research in improvement are presented. **Alternative Causes Approach**
Similar to CRT (uses the determinate variable(s) and the branched events chain perception and multi-linear events sequences perception [40]), studies have suggested using an alternative cause approach [3]. By encouraging SME’s to seek out alternative causes in their analyses, this process can lead the SME to determine the actual strength of their original mental model of the system. It changes the perspective that the previously decided solutions, such as those used by equipment troubleshooters, are not normative (absolute) but descriptive (based on uncertainties and not guaranteed). Increasing the users system domain knowledge, decision maker heuristics surpass the trial and error of simple pattern recognition stage developing more abstract patterns.

Debiasing Training
Targeting training to certain aspects of decision making flaws has been shown to reduce heuristic errors with differing success. Training weather forecasters to question why their forecast might not be correct researches reduced the bias of over confidence in the accuracy of their forecast [2, 37].

Provide feedback on the accuracy of decision making in four areas of probability: correct hit, correct rejection, false hit, and false reject [2, 38]. This will improve the cognitive tunneling that occurs when falsely rejecting a hypothesis or when applying an incorrect hypothesis. Reducing availability and anchoring biases by adding a criterion other than frequency, recency, or primacy of an event [14] will increase accurate probability of decisions.

The Leading Limitation in Most Root Cause Principles and Tools

The limitations of SME's as discussed earlier emphasized the person's limitations in forming system patterns outside their field of expertise. Unfortunately, most root cause analysis tools used in the DMAIC process (CED, ID, CRT, 5 Why's) and higher-order RCA principles require brainstorming, causal factor identification, and effect-cause-sequence relationships [28, 29, 40] based on the user's knowledge.

The process then becomes just a reformation of existing mental models from the SME's perspective and level of understanding only; in the case of the CRT [28, 29], a validation that the relationships exist also occurs. In retrospect, root cause analysis should be a learning process that raises existing knowledge to new levels of understanding, which in turn will increase prediction ability of infrequent incidents, defects, or sentinel events. It needs to reduce cognitive tunneling which leads to asking why an event happened prior to understanding the actual system. In each of the problem solving stages for these tools, availability, anchoring, framing, and confirmation biases can lead the user astray from the actual root cause. In an effort to widen the user's view of knowledge, root cause tools pulling the strengths of the previous tools should force external domain and process understanding.

SME KNOWLEDGE: LEVELS OF INTEGRATION

Known in science as levels of integration [42], fields of science can be organized into levels of complexity dependent on their level of integration. For instance, to understand human behavior scientists must be knowledgeable in the sciences of biology, chemistry, and physics. An individual science can be dissected into smaller parts and must be understood before you can understand how it is transformed by other sciences in a system; closer to manufacturing, it is like a hydraulic mechanic breaking down a hydraulic pump. It is essential for the mechanic to know how the pump works before he can understand how it can fail in a complete hydraulic system. In the imperfect gathering of data found during RCA analyses, this is where most SME's reside in their comprehension of an incident. Mental models are formed from their particular science, area of expertise, perspective only. Without aerodynamic system knowledge and material hardness affect, the flap buzz SME's were "destined" to fail.

If the scientist wants to know why a person behaves in a certain manner, he must understand how the interaction of biology, chemistry, and physics interact to transform behavior into a different entity [42]. A complex behavior cannot be reduced into individual parts like the foundation level sciences. When oxygen and hydrogen combine it becomes water; influences of bases and acids on water have separate affects that are not recognized until the combination and transformation is understood.

What does this have to do with problem solving and root cause analysis you ask? SME's form heuristics in order to reduce their domain (individual science) into manageable parts. While no guarantee exists that each rule will fit every condition, they can be quite effective in unambiguous domain specific situations. The SME is unable to visualize the impact of error sources outside their realm of knowledge no matter what RCA principle is applied.

To offset this limitation, root cause tools should develop queries that push the user to gather knowledge from areas outside their domain. Troubleshooting logic trees are an excellent example of pushing outside system queries. For instance, the experienced aircraft hydraulic mechanic may be successful in detecting mechanical pump failures but be completely unaware of the affect of a failed wiring matrix in the fuel system on the hydraulic pump. The troubleshooting logic tree has been developed with knowledge of the transformations within the complete aircraft system.

This is not to say, that all combinations and variables of incidents can be placed in a logic tree. It does however emphasize that frequent system errors and influences that transform complex or ambiguous events should be questioned during an analysis. This higher-order rules-of-thumb knowledge must be collaborated.

A COMPLETE ROOT CAUSE TOOL SUGGESTION

What would a complete system root cause analysis tool look like? How would it prevent the SME's experienced based heuristics from overriding the tool's intent?

This tool would query human error using models such as Rasmussen's error model [2]. It would query machine and tool design errors. It would understand human reward systems and organizational criterion affect on supervision. Even if a stimulus is perceived, how the SME perceives the risk of making a mistake will influence the probability of a correct hypothesis false rejection or false hypothesis being applied to a decision. It will understand the transformation that occurs in the human machine environment system relationship when changes disrupt or influence the sequence of events.

Preventing anchoring and confirmation biases by introducing troubleshooting logic trees would be developed which asks questions of SME's looking for breaks in the entire system, thus reducing overconfidence and hindsight bias. These questions would be framed in neutral standard perspectives, neither negative nor positive to reduce framing bias. Thus, standardizing cause-identifying criterion [40].

The logic tree would continue to be improved to match current system interactions. For example, aerodynamic queries will need to be input in flying defects at company XYZ.

With practice this root cause tool would reduce cognitive tunneling and induce learning. Being aware of your limitations and how they can be influenced by the incorrect selection of RCA tools must change your perspective and lead you to search for a robust tool meeting the qualifications above.

BIBLIOGRAPHY

1. Emergency Medical Ed. 2008. "Tunnel Vision." <http://www.emergencymedical.com/Definitions/Tunnel%20Vision.htm> (8 January 2008).
2. Wickens, C., and J. Hollands. 2000. *Engineering Psychology and Human Performance*. New Jersey: Prentice-Hall Inc.
3. Lehner, P., L. Adelman, R. DiStasio, M. Erie, J. Mittel, and S. Olson. "Confirmation bias in the Analysis of Remote Sensing Data." *Mitre No.06-1288*. http://www.mitre.org/work/tech_papers/tech_papers_07/06_1288/ (8 January 2008).
4. Kahneman, D. and A. Tversky. 1973. "On the Psychology of Prediction." *Psychological Review* 80: 254-273.
5. Flaps Ailerons (image). <http://virtuallskies.arc.nasa.gov/aeronautics/tutorial/images/FlapsAilerons.gif> (8 January 2008).
6. Edwards, W. 1987. "Decision Making." In G. Salvendy (ed.), *Handbook of Human Factors*. New York: Wiley: 1061-1104.
7. Lehto, M. 1997. "Decision Making." In G. Salvendy (ed.), *Handbook of Human Factors and Ergonomics*. New York: Wiley: 1201-1248.
8. Simon, H. 1955. "A Behavioral Model of Rational Choice." *Quarterly Journal of Economics* 69: 99-118.
9. Kahneman, D. P. Slovic, and A. Tversky. 1982. *Judgment Under Uncertainty: Heuristics and Biases*. New York: Cambridge University Press.
10. Hogarth, A. 1987. *Judgment and Choice* (2nd Ed). Chichester: Wiley.
11. Wallsten, T. (ed.). 1981. *Cognitive Processes in Decision and Choice Behavior*. New Jersey: Erlbaum.
12. Simon, H., and Associates. *Decision Making and Problem Solving*. <http://dieoff.org/page163.htm> (8 January 2008).
13. Information Processing Model and Lady (images) http://openlearn.open.ac.uk/file.php/2130/formats/T306_1_rss.xml (8 January 2008).
14. Prince, C., and E. Salas. 1997. "Situation Assessment for Routine Flight and Decision Making." *International Journal of Cognitive Ergonomics* 1(4): 315-324.
15. Endsley, M. 1995. "Toward a Theory of Situation Awareness in Dynamic Systems." *Human Factors* 37(4): 32-64.
16. Garland, D., and M. Endsley. 1995. *Proceedings of International Conference: Experimental Analysis and Measurement of Situation Awareness*. Daytona Beach: Embrey Riddle Press.
17. Rasmussen, J., and W. Rouse. 1981. *Human Detection and Diagnosis of System Failures*. New York: Plenum.
18. Johnston, R. 2003. "Integrating Methodologists into Teams of Substantive Experts." *Studies in Intelligence* 47: article 06.
19. Reder, L. 1998. *Implicit Memory and Meta Cognitive Processes*. New Jersey: Lawrence Erlbaum.
20. Kahneman, D. and A. Tversky. 1984. "Choices, Values, and Frames." *American Psychologists* 39: 341-350.
21. Heacock, N., J. Gwynne, T. Kelly, and S. Sander. *Cognitive Aspects of Decision-Making Process Summary*. <http://www.spawar.navy.mil/sti/publications/pubs/tr/1830/tr1830.pdf> (8 January 2008).
22. Anderson, J. 2000. *Learning and Memory*. United States: John Wiley and Sons, Inc.
23. Pavitt, C. "Theorizing about the Group Communication-Leadership Relationship: Input-Process-Output and Functional Models." In Frey, L. D., Gouran, and M. Poole (ed.s) *The Handbook of Group Communication Theory and Research*. <http://www.udel.edu/communication/COMM356/pavitt/chap12.htm> (8 January 2008).
24. Svenson, O. 1981. "Are We Less Risky and More Skillful than Our Fellow Drivers?" *Acta Psychologica* 47: 143-148.
25. Graber, M., N. Franklin, and R. Gordon. 2005. "Diagnostic Error in Internal Medicine." *Arch Intern Med* 165: 1493-1499.
26. Fel'tovich, C., and R. Glaser. R. 1981. "Categorization and representation of physics problems by experts and novices." *Cognitive Science* 5(2): 121-152.
27. Cause and Effect Diagram (image). <http://deming.eng.clemson.edu/pub/tutorials/qctools/ishik.gif> (8 January 2008).
28. Doggett, A. 2004. "A Statistical Comparison of Three Root Cause Analysis Tools." *Journal of Industrial Technology* 20(2): 1-9.
29. Doggett, A. 2005. "Root Cause Analysis: A Framework for Tool Selection." *QMJ* 12(4): 34-45.
30. Interrelationship Diagram (image). <http://www.asq.org> (8 January 2008).
31. Current Reality Tree (image). <http://www.focusedperformance.com/articles/resistcrtr.jpg> (8 January 2008).
32. Ishikawa, K. 1982. *Guide to Quality Control*, 2nd edition. Tokyo: Asian Productivity Organization.
33. Goldratt, E. 1994. *It's Not Luck*. Great Barrington: North River Press.
34. Cox, J., and M. Spencer. 1998. *The Constraints Management Handbook*. Boca Raton: St. Lucie Press.
35. Elstein, A., and A. Schwarz. 2002. "Evidence Base of Clinical Diagnosis: Clinical Problem Solving and Diagnostic Decision Making: Selective Review of the Cognitive Literature." *BMJ* 324: 729.
36. Tolcott, M., F. Marvin, and T. Bresocik. 1989. *The Confirmation Bias in Military Situation Assessment*. Reston, VA: Decision Science Consortium.
37. Cohen, M., J. Freeman, and B. Thompson. 1997. "Training the Naturalistic Decision Maker." In C. Zsombok and G. Klein (eds), *Naturalistic Decision Making: 257-268*.
38. Jenkins, H., and C. Ward. 1965. "Judgment of Contingency between Responses and Outcomes." *Psychological Monographs: General and Applied* 79.
39. Wald, H., and K. Shojania. 2008. "Chapter 5. Root Cause Analysis." *Health Services/Technology Assessment Text*. <<http://www.ncbi.nlm.nih.gov/books/b.fcgi?rid=hstat1.section.59569>> (11 January 2008).
40. Benner, L. 2007. *Accident Investigations-A Case for New Perceptions and Methodologies*. <http://www.members.cox.net/1bjr05/papers/SAE80.html> (> 11 January, 2008).
41. Bhasale, A. 1998. "The Wrong Diagnosis: Identifying Cause of Potentially Adverse Events in General Practice Using Incident Monitoring." *Family Practice* 15 (4): 318.
42. Walsh, K. *Person-Environment Psychology: New Directions and Perspectives*. http://books.google.com/books?id=yDe95vBHtq4C&pg=PA36&pg=PA36&q=levels-of+integration+psychology&source=web&ots=SMC-pMpdA_&sig=44Bf-6NWsbS1Uj7z7f8ibOssCKo#PPA36,M1 (11 January 2008).

Your Source for the Latest Ideas and Technology to Improve Quality

Quality[®] expo detroit



Exposition and Conference
June 11–12, 2008

Rock Financial Showplace • Novi (Detroit), MI



At Quality Expo Detroit, you'll meet face-to-face with top suppliers showcasing their newest advances in:

- Automatic Gaging Equipment
- Calibration Equipment and Services
- CMMs and DMMs
- Data Collection Equipment
- Electronics Test and Inspection Equipment
- Handheld Gages
- Linear Measurement Equipment
- Materials Test Equipment
- Noncontact Inspection/Measurement Equipment
- Nondestructive Test Equipment
- Quality Software
- Registration and Certification Services
- Surface Analysis Equipment
- Training and Consulting Services
- ...and more!

Sponsored by:

Quality
MAGAZINE

Register Today for FREE Expo Hall Admission at

QualityDetroit.com

Please use Promo Code: AB

ASQ Greater Detroit Section 2008 Schedule of Refresher Courses

All classes are held on Saturdays at Macomb Community College, South Campus, Building "T" (located between 12 Mile Road & Martin Road, west of Hayes Road). Refresher course starting dates are subject to change, student should verify.

Certification	Refresher Course #	Refresher Course Start Date	Examination Application (Last) Date	Examination Date	Fee
Certified Quality Engineer (CQE) 12 Sessions	CQE 808 CQE 209	08-09-2008 02-07-2009	10-03-2008 04-03-2009	12-06-2008 06-06-2009	\$450
Certified Quality Technician (CQT) 10 Sessions	CQT 1108 CQT 709	07-12-2008 11-08-2008	08-15-2008 01-09-2009	10-18-2008 03-07-2009	\$325
Certified Quality Inspector (CMI) 10 Sessions	CQI 1108 CQI 709	07-12-2008 11-08-2008	08-15-2008 01-09-2009	10-18-2008 03-07-2009	\$325
Certified Six Sigma Black Belt (CSSBB) 10 Sessions	CSSBB 608 CSSBB1108	06-21-2008 11-08-2008	08-15-2008 01-09-2009	10-18-2008 03-07-2009	\$1000
Certified Six Sigma Green Belt (CSSGB) 10 Sessions	CSSGB908 CSSGB309	09-20-2008 03-14-2009	10-03-2008 04-03-2009	12-06-2008 06-06-2009	\$500



REGISTRATION FORM

Greater Detroit Section 1000
27350 Southfield Rd., Suite 102
Lathrup Village, MI 48076
www.asqdetroit.org

Name	Last	First	Mid. Initial
Home Address	Home Phone		
Employer	Work Phone		
Employer Address			
ASQ Member	No <input type="checkbox"/>	Yes <input type="checkbox"/>	Member Number

Payment: Make check payable to **Greater Detroit Section, ASQ**

Mail to: Greater Detroit Section 1000
27350 Southfield Rd., Suite 102
Lathrup Village, MI 48076

For more information call **Rajinder Kapur** at 248-703-7148 or e-mail rajinderkapur@yahoo.com

Automotive

E X C E L L E N C E

Published by Mirus Graphic Solutions and ASQ Automotive Division

www.asq.org