The True Meaning of Root Cause and Root Cause Analysis (RCA)

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TE Connectivity
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ICQI 22 (with updates)

Why This Topic

- Gary Jing, Root Cause Analysis and Troubleshooting Techniques, Encyclopedia Of Information Systems And Technology, To be published.
Topics to be Covered

• The true meaning of root cause
• The point of RCA
• The connection between troubleshooting and RCA
• Techniques generic for RCA
• Techniques good for troubleshooting
• Summary

* The workshop is based on the publication series the speaker authored

Speaker’s Connection to This Topic

ASQ Fellow,  MBA, PhD in IE,  CQM / CQE
Isixsigma DFSS Award. Finalist of IQPC MBB of The Year.
Editorial Review Board of Six Sigma Forum Magazine
Founding MBB @ Seagate TCO
Sr. Mgr., Global LeanSigma / Founding MBB @ Entegris
LDFSS Deployment Leader / MBB @ TE Connectivity (ADC)

Two patents in disc drive modeling from his Sigma work
Series publications on Lean Sigma
Personally trained dozens of BB’s
Development of ASQ BB Certification Program (participant)
Delphi panel expert for SME/AME/Shingo Lean Certification Program
The Definition of “Root Cause”

From Wikipedia:

- A root cause is an **initiating** cause of a **causal chain** which leads to an outcome or effect of interest. Commonly, root cause is used to describe the depth in the causal chain where an **intervention** could reasonably be implemented to change performance and prevent an undesirable outcome.

- The term root cause has been used in professional journals as early as 1905, but the **lack of a widely accepted definition** after all this time indicates that there are significantly different interpretations of exactly what constitutes a root cause.

The True Meaning of “Root Cause”

- **A Paradigm Shift**

  - “Have you found ‘the root cause’ yet?”
    - The term “root cause” is somewhat misleading
    - Tons of publications explaining tools / methods to do RCA
    - Hardly any literature explains or explores the true meaning of root cause (RC)

  - What’s in your mind about root cause?
    - Is it like treasure hunting – Gold buried somewhere waiting to be discovered?

  - **The truth:** There is no “true” absolute RC per se.
    - A so-called “root cause” is something subjectively chosen to serve that role – a moving target
The Concept of Infinite Chain of Causation

- Cause-effect relationship relies on the law of nature and physics to establish.
- The same item is both a cause and an effect at the same time.
- Causes and effects form an infinite chain of causation.

<table>
<thead>
<tr>
<th>EFFECTS</th>
<th>CAUSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury</td>
<td>caused by Fall</td>
</tr>
<tr>
<td>Fall</td>
<td>caused by Wet Surface</td>
</tr>
<tr>
<td>Wet Surface</td>
<td>caused by Leaky Valve</td>
</tr>
<tr>
<td>Leaky Valve</td>
<td>caused by Seal Failure</td>
</tr>
<tr>
<td>Seal failure</td>
<td>caused by Poor Maintenance</td>
</tr>
</tbody>
</table>

5 Why’s (no ending) Reference: Apollo Root Cause Analysis, Dean L. Gano

The Concept of Infinite Chain of Causation

- Not widely recognized in the engineering world.
- Widely seen in philosophical level discussion. e.g., Hegel’s philosophy.
- “An important feature of causality is the continuity of the cause-effect connection. The chain of causal connections has neither beginning nor end. It is never broken... And no one can say where this chain began or where it ends. It is as infinite as the universe itself. There can be neither any first (that is to say, causeless) cause nor any final (i.e., inconsequential) effect. If we were to admit the existence of a first cause we should break the law of the conservation of matter and motion. And any attempt to find an ‘absolutely first’ or ‘absolutely final’ cause is a futile occupation, which psychologically assumes a belief in miracles.” - A. Spirkin, Dialectical Materialism
- Applied by Dean L. Gano in Apollo Root Cause Analysis - A New Way Of Thinking, He warned that “because this book challenges conventional wisdom, it may not validate your existing belief system”. -
Root Cause Analysis (RCA)

A PROBLEM WHICH HAS OCCURRED

CAUSE
Events/conditions that led to the problem

??

EFFECT
Symptoms that provide evidence of the problem

CORRECTIVE
Eliminates the CAUSE of a problem

ADAPTIVE
Limits the EFFECT of a problem of deviation

SOLUTIONS

It’s generally encouraged to continuously shift attentions to cause side when possible.


The Point of RCA

- Traditional RCA Theme
  - Continuously migrate the focus to upstream causes
  - Keep asking “why” like a 2-year old
  - Why? Impact ↑

- Challenge!!!:
  - The research cost ↑ too.
  - With infinite layers of Cause and Effect, how do we know where to stop and claim “Root Cause”?

- Case study 1: Jefferson Memorial
  (Detailed discussion refers to Jing, Flip The Switch, Quality Progress, Oct ‘08.)
So, Where to Stop? – The Psychology

• The trick is not to find the “true” root cause.
• The trick is to find the leverage point that benefits the problem most then treat it as the root cause.
• That wisdom is what differentiates an adult from a 2-year old; an expert from a novice.

• The key is ROI (return on investment).
  – low cost with high return (reward).
• That’s what people are doing subconsciously without realizing it.
• Staying within the scope of the pursuit helps ROI.

ROI Leverage Point Thinking

• A lot can be said about ROI assessment. In a way, RCA is about ROI calculation, intentionally or unintentionally.
• Realizing it or not, that’s what going through people’s mind, maybe subconsciously, when choosing RC.
• The trick: solution cost ↓ = research cost ↓ + implementation cost ↓
• ROI assessment could be short-term or long-term, internal (self), external (customer) oriented. The results could be very different. – Tends to be overlooked.
• Short-term fixes are mostly driven by cost constraint.
• ROI may change over time, so does root cause.
• To make the fix long lasting or sustainable, all parties’ (stakeholders) interests need to be balanced.
Three Tips to Find the Leverage Point

• Pareto Principle – 80 / 20 rule

■ Desirability Matrix for Leverage Point

• Span of Control / Sphere of Influence

**Pareto Principle**
80 / 20 rule: 80% of the problems are caused by only about 20% of the contributing factors.

**ROI Matrix for Leverage Point**

The desirability of an item increases as you move from the lower right to the upper left, and as the circle gets larger:
Span of Control / Sphere of Influence

Ideally, the root causes should be situated within the span of control; at worst, they should be within the sphere of influence.

**Span of Control** - areas where we have a high degree of control over parts or functions, virtually complete authority to change anything

**Sphere of Influence** - areas where we can influence things to varying degrees but don't have direct control.

**Outside Environment** - where we have neither control nor influence

Scope of the Pursuit vs.
Self-imposed Constraint

- Staying within the scope of the pursuit improves ROI and leverage.
- Going beyond the intended scope causes distractions, dilutes the effort and diminishes the return.
- BUT be careful, sword has 2 edges.
  - Self-imposed scope also serves as constraint.
  - It may prevent longer-term solutions.
Case Study 2: 1854 London Cholera Epidemic

The “Snow Map”

The cause of the 127 deaths in 3 days: cholera outbreak.

Detailed discussion refer to Jing, Flip The Switch, Quality Progress, Oct’ 08.

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Case Study 2: 1854 London Cholera Epidemic

- Snow knew nothing about cholera.
- A decade later, Italian scientist Filippo Pacini was credited as discovering cholera.
- The poor living conditions of Soho neighborhood was the more fundamental cause of the series breakout.
- Snow wasn’t anywhere close to identify the true “root cause”. But he was able to get the “handle” of the problem, literally.
- For More Info: http://www.ph.ucla.edu/epi/snow.html

John Snow Memorial and Pub on the Broadwick Street, London
RCA Summary

• Potential causes (cause-effect relationships) rely on the law of nature and physics to discover.

• Root cause is selected based on ROI within the scope of the pursuit.

Connection B/W Troubleshooting & RCA

• Troubleshooting is the 1st of the 2 stages of RCA.

• Difference is in scope of the pursuit.
  o 1st stage focuses on what happened (where and how), short-term oriented for quick turnaround.
  o 2nd focuses on why happens, long-term oriented.
  o No obvious transitions in many cases.

• Consumers usually care about 1st stage / troubleshooting, while providers care about 2nd / RCA.

• Focusing on RCA 2nd stage when the need is troubleshooting may cause distractions, dilutes the effort and diminishes the return.
Topics to be Covered

• The true meaning of root cause
• The point of RCA
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Five Popular Generic RCA Techniques

1. Is/Is Not Comparative Analysis – Zoom in through segregation
2. 5 - Whys – Go deep
3. Fishbone Diagram (Cause-effect Diagram) - Traditional approach to brainstorming and diagramming Cause-Effect relationships. Good tool when there is one primary effect being analyzed. Go broad.
4. Root Cause Tree - A problem analysis diagram that combines Fishbone and 5-why together and allows to study relationships between causes. Go complex.
5. Cause & Effect (X-Y) Matrix - Used to study the relationship of a group of causes (inputs, X) and a group of effects (outputs, Y) and quantify the relationships / impacts.
Cause-Effect Analysis

I keep six honest serving men,

They taught me all I knew,

Their names are

What, Why, How, Where, When and Who

Rudyard Kipling

Is / Is Not Comparative Analysis

- Zoom in through segregation. Divide and conquer

<table>
<thead>
<tr>
<th>Problem</th>
<th>Is</th>
<th>Is Not</th>
<th>Differences and Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>What</td>
<td>What is the specific object has the defect? What is the specific defect?</td>
<td>What similar objects could have the defect but do not? What other defects could be observed but are not?</td>
<td></td>
</tr>
<tr>
<td>Where</td>
<td>Geographically? Physically on the part?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>When</td>
<td>When was the defect first observed? When since then? When in the product life cycle?</td>
<td>Where, when and what size could the defect have been but it was not?</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>How many objects with the defect? How many defects per object? Size of defect? Trend?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fish Bone Diagram

- Focusing on single effect with simple cause-effect relationships
- Search broad but not deep

“Fishbone” Cause-Effect Diagram

Advantages
- Helps organize and relate factors
- Provides a structure for brainstorming
- Involves everyone

Drawbacks
- Might become very complex
- Requires patience
- Does not rank the causes in an if-then manner

C/N/X
- C = Control Factor
- N = Noise Factor
- X = Factor for DOE (chosen later)

Opportunity:
H: High
M: Medium
L: Low

Controllability:
C: Within control
I: Have influence
N: No influence
For Product: “5M’s + E”

Product: The 5M’s

- Man
- Machine
- Methods
- Materials
- Measurement

Five Key Sources of Variation + Environment / Mother Nature

For Transactional or Process: 4P’s + M&E

- People
- Policies
- Procedures
- Place
- Measurement

Five Key Sources of Variation + Environment / Mother Nature

For Transactional or Process: 4P’s + M&E
Root Cause Tree (RCT)

- For more complicated cause - effect relationships (causes may be dependent on each other)
- Combination of Fishbone and 5-Why

Example of RCT

AGB project: Potting Leaks

Flowmeter Cover Potting Leaks
Cause/Effect

- Potting Leaks or Flowmeter Covers
- Groove/Insertion: Fit between cover and grommet
- Chemical used to clean: Does it effect RTV cure
- Size of Cable: Insulation material
- Groove size: Hole
- RTV: Placement, Quantity (amount)
- Cure process: Is it the right sealant?
- Is it the right location?
- Movement: Time, Location, Preferred positioning
**Mind Map Example**

- Radio Signal
- Eject smoke
- Beep
- Wave Flag
- Emit a Signal
- Magnetic Ball
- Passive Emitter
- Bright Color
- Dog Detects Scent
- Golf Course Systems
- Light Beams
- Radar
- Video follows Ball
- Detect Golf ball
- Change Ball
- String Attached To ball
- Jumping Ball

- **Mind Map self documents brainstorming session**
- **Very useful for post session analysis and expansion**

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**Example RCT**

- SRA = Sulfur related anion

  - **Opportunity:** High, Medium, Low
  - **Controllability:** Within control, Have influence, No influence

  - **Customer suffered a corrosion problem, meantime they tested a surge of sulfate with our product. They suspect it's the primary contributor and demand for the root cause and control.**

  - **A. Understand the meaning and "reliability" of customer data**
  - The readings are the calculated Sulfate concentration of product / resin? (surface only?) or the sulfate concentration of test coupon / water?

  - **Correlation doesn’t mean causation. Is Sulfate really the primary contributor?** (Otherwise it may not help the problem) – Need to work with customer and their data.

  - **What’s the repeatability and reproducibility of customer data.**

  - **What’s the correlation between our data and their data.**

  - **B. Internal measurement of Sulfur related anion**

  - **C. SRA originated from original material**

  - **D. SRA introduced during manufacturing process**

  - **E. SRA introduced after manufacturing**

  - **E1. Product absorb SRA overtime.**

  - **E2. Bag contamination M.N.**

  - **E3. Product contains SRA from B3.**

  - **F. Sample size.**
Focus on Undesirable Effects

Which statements are positive, negative or neutral?

1. “The window is closed”
2. “The people in the office are sweating from the heat”
3. “My in-basket is overflowing with paperwork”
4. “Everyone in the office enjoys going out to lunch”

- UDE’s are negative on their own merit
- No further explanation why is needed
- Effects are negative at face value

Two “Rules of Thumb”

1. What bearing does the effect have on the system goal?
2. Does the effect pass the “So What” test?

How to Generate the Tree

Top down approach

1. Fish Bone 1st, if not enough, turn the bone structure 90 degree counter clock wise to form the initial tree; study the (and, or) relationship among the existing causes and then expand from there.
2. 5-why “horizontally” to exhaust all possible 1st layer causes; study the relationship among the 1st layer items; repeat the same process on the previous layer items and keep expanding to next layers.
3. Mind mapping to generate ideas; study relationship and consolidate items and rearrange in tree structure.

Bottom up approach

4. Affinity Diagram to generate and organize ideas.
Cause and Effect Matrix

- To evaluate and quantify the impact of a group of causes (inputs, X) on a group of effects (outputs, Y)

C-E Matrix: Example

<table>
<thead>
<tr>
<th>Rating of Importance to Customer</th>
<th>10</th>
<th>6</th>
<th>9</th>
<th>8</th>
<th>5</th>
<th>6</th>
<th>TOTAL %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>PROCESS INPUTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Customer Input</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>252</td>
<td>11.36%</td>
<td></td>
</tr>
<tr>
<td>2 Equipment Specs</td>
<td>8</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>264</td>
<td>11.90%</td>
<td></td>
</tr>
<tr>
<td>3 Bill of Materials</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>230</td>
<td>10.37%</td>
<td></td>
</tr>
<tr>
<td>4 # of Revisions</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>8</td>
<td>270</td>
<td>12.17%</td>
<td></td>
</tr>
<tr>
<td>5 Label Documentation</td>
<td>8</td>
<td>2</td>
<td>8</td>
<td>9</td>
<td>236</td>
<td>10.64%</td>
<td></td>
</tr>
<tr>
<td>6 DC Drawings</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>102</td>
<td>4.60%</td>
<td></td>
</tr>
<tr>
<td>7 Pre-CCP Meeting</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>114</td>
<td>5.14%</td>
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<tr>
<td>8 Ownership</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>276</td>
<td>12.44%</td>
<td></td>
</tr>
<tr>
<td>9 Approval Cycles</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>237</td>
<td>10.69%</td>
<td></td>
</tr>
<tr>
<td>10 AMK Delays</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>237</td>
<td>10.69%</td>
<td></td>
</tr>
</tbody>
</table>

Sometime used to rank fishbone inputs.
Cause-Effect Matrix Analysis Example

Input Variables - Materials

<table>
<thead>
<tr>
<th>Material ID</th>
<th>Added quantity</th>
<th>Subtracted quantity</th>
<th>Added $</th>
<th>Subtracted $</th>
<th>Overall</th>
<th>Added/Consumption</th>
<th>Subtracted/Consumption</th>
<th>Rank without Consumption Info</th>
<th>Rank by Subtracted $</th>
<th>Overall Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>830R25</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.840</td>
<td>-0.840</td>
<td>11</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>225</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.820</td>
<td>-0.820</td>
<td>17</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>100-00037-01</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.810</td>
<td>-0.810</td>
<td>17</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>200</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.800</td>
<td>-0.800</td>
<td>24</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>100-00037-01</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.790</td>
<td>-0.790</td>
<td>30</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>102-047</td>
<td>0.018</td>
<td>0.002</td>
<td>0.016</td>
<td>0.000</td>
<td>0.063</td>
<td>-0.569</td>
<td>-0.569</td>
<td>32</td>
<td>403</td>
<td>11</td>
</tr>
<tr>
<td>800-700</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.550</td>
<td>-0.550</td>
<td>40</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>800-700</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.540</td>
<td>-0.540</td>
<td>40</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>700-706-01</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.530</td>
<td>-0.530</td>
<td>50</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>800-700</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>-0.520</td>
<td>-0.520</td>
<td>60</td>
<td>60</td>
<td>12</td>
</tr>
</tbody>
</table>

Output Variables that Reflect the Impact of Adjustment

| AGB project: Inventory Accuracy |

1. Is/Is Not Comparative Analysis
2. Relationship Diagram
3. Fault Tree Analysis (FTA)
4. Event Tree Analysis (ETA)

Sometime the ranking can be objective, data driven.

Techniques Good for Troubleshooting

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Relationship Diagram

Fault Tree Analysis

Usually stop at the component level.
### Common Symbols Used to Create Fault Trees

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AND Gate</strong></td>
<td>If all input events occur, the output event will occur.</td>
</tr>
<tr>
<td><strong>Priority AND Gate</strong></td>
<td>Output event occurs if all events occur in the right order from left to right.</td>
</tr>
<tr>
<td><strong>OR Gate</strong></td>
<td>If any input event occurs, the output event will occur.</td>
</tr>
<tr>
<td><strong>Exclusive OR Gate</strong></td>
<td>Output event occurs if one, but not both of the two input events occurs.</td>
</tr>
<tr>
<td><strong>Event</strong></td>
<td>Any higher level event that is a result of lower level events.</td>
</tr>
<tr>
<td><strong>Inhibit Gate</strong></td>
<td>Input produces output when conditional event occurs.</td>
</tr>
<tr>
<td><strong>Basic Event</strong></td>
<td>The lowest level event. The limiting resolution in our analysis.</td>
</tr>
<tr>
<td><strong>Conditional Event</strong></td>
<td>Used with inhibit gate.</td>
</tr>
</tbody>
</table>

### Fault Tree Analysis with Probability

![Fault Tree Diagram](image-url)
Event Tree

• Similar to FTA but different.
• Examine a chronological series of subsequent events or consequences
• Display event sequence in opposite direction to FTA.

Event Tree Examples with Probably
Summary

• Truth of root cause – None, subjectively chosen
• The point of RCA - ROI
• Popular RCA Tools, focusing on why.
  – Is / Is not analysis
  – 5 Why’s
  – Fishbone Diagrams (Cause-effect Diagram)
  – Root Cause Tree
  – C&E Matrix
• Tools good for Troubleshooting, focusing on what.
  – Is/Is Not Comparative Analysis
  – Relationship Diagram
  – Fault Tree Analysis
  – Event Tree Analysis