Root Cause Analysis: A Framework for Tool Selection

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Root Cause Analysis: A Framework for Tool Selection

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This article provides a framework for analyzing the performance of three popular root cause analysis tools: the cause-and-effect diagram, the interrelationship diagram, and the current reality tree. The literature confirmed that these tools have the capacity to find root causes with varying degrees of accuracy and quality. The literature, however, lacks a means for selecting the appropriate root cause analysis tool based upon objective performance criteria. Some of the important performance characteristics of root cause analysis tools include the ability to find root causes, causal interdependencies, factor relationships, and cause categories. Root cause analysis tools must also promote focus, stimulate discussion, be readable when complete, and have mechanisms for evaluating the integrity of group findings. This analysis found that each tool has advantages and disadvantages, with varying levels of causal yield and selected causal factor integrity. This framework provides decision makers with the knowledge of root cause analysis performance characteristics so they can better understand the underlying assumptions of a recommended solution.

Key words: collaboration, decision making, problem solving, quality methods

INTRODUCTION

Beneath every problem is a cause for that problem. In order to solve a problem one must identify the cause of the problem and take steps to eliminate the cause. If the root cause of a problem is not identified, then one is merely addressing the symptoms and the problem will continue to exist. For this reason, identifying and eliminating root causes of problems is of utmost importance (Andersen and Fagerhaug 2000; Dew 1991; Sproull 2001).

Tools that help groups and individuals identify potential root causes of problems are known as root cause analysis tools. The cause-and-effect diagram (CED), the interrelationship diagram (ID), and the current reality tree (CRT) are three root cause analysis tools frequently identified in the literature as viable mechanisms for solving problems and making decisions. The literature provides detailed descriptions, recommendations, and instructions for their construction and use. Furthermore, the literature is quite detailed in providing colorful and illustrative examples for each of the tools so they can be quickly learned and applied. In summary, the literature confirms that these three tools are capable of finding potential root causes.

Conversely, although there is much information about the individual attributes of these root cause analysis tools, there is little information regarding the performance of these tools relative to each other. Thus, problem solvers and decision makers are likely to select a tool based on convenience rather than on its actual performance characteristics. Thus, the purpose of this article is to explore and synthesize the current literature for a head-to-head performance analysis of the CED, ID, and CRT. The intent is to provide problem solvers with a mechanism that can be used to select the appropriate root cause analysis tool for the specific problem.

The first section of this article presents an overview and a background of the CED, ID, and CRT. For each tool, there is a brief history, a presentation of various construction techniques, and a summary of the tool's advantages and disadvantages. The second section reviews published articles that compare these tools. The third section analyzes the literature and provides a conceptual framework with a head-to-head comparison for problem-solving practitioners and decision makers. The final section concludes with implications and recommendations for management.

AN OVERVIEW OF ROOT CAUSE ANALYSIS TOOLS

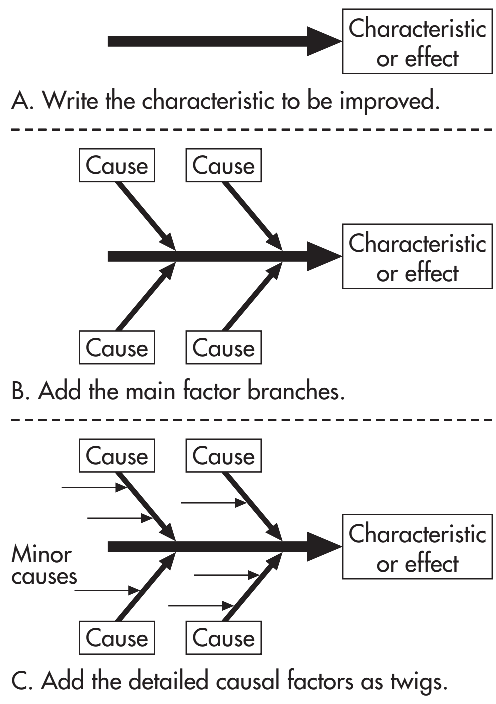
Cause-and-Effect Diagram (CED)

The CED was designed to sort the potential causes of a problem while organizing the causal relationships. Professor Kaoru Ishikawa developed this tool in 1943 to explain to a group of engineers at Kawasaki Steel Works how various manufacturing factors could be sorted and interrelated. The original intent of the CED was to solve quality-related problems in products caused by statistical variation, but Ishikawa quickly realized it could be used for solving other types of problems as well. The tool later came into widespread use for quality control throughout Japanese industry (Ishikawa 1982). As its use spread to other countries, it became known as the Ishikawa diagram, or more informally, the "fishbone" because of its appearance once complete (Arcaro 1997; Moran, Talbot, and Benson 1990; Sproull 2001).

Brassard and Ritter (1994, 23) assert that the CED "enables a team to focus on the content of the problem, not on the history of the problem or differing personal interests of team members." Andersen and Fagerhaug (2000, 14) write that the CED is "an easily applied tool used to analyze possible causes to a problem," while Wilson, Dell, and Anderson (1993, 195) call it a "highly visual technique which aids the process of defining the elements of a problem or event and determining how it probably occurred."

CEDs are drawn primarily to illustrate the possible causes of a particular problem by sorting and relating

Figure 1 Steps in building a cause-and-effect diagram.



them using a classification schema. The construction and study of the diagram is intended to stimulate knowledge acquisition and promote discussion, but it can also educate others about a process or problem. The CED encourages data collection by highlighting areas of expertise or by showing where knowledge is lacking. Fredendall et al. (2002, 51) calls the CED process "an exercise in structured brainstorming." The logic of the CED is that one cannot act until the relationship between the cause and effect of a problem is known. Consequently, the CED attempts to show related causes so action can be taken.

Ishikawa (1982) outlines the following steps for constructing a CED.

- Step 1: Decide on the problem to improve or control.
- Step 2: Write the problem on the right side and draw an arrow from the left to the right side, as shown in Figure 1(A).
- Step 3: Write the main factors that may be causing the problem by drawing major branch arrows to the main arrow. Primary causal factors of the problem

can be grouped into items with each forming a major branch, as shown in Figure 1(B).

- Step 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, as shown in Figure 1(C).
- Step 5: Ensure all the items that may be causing the problem are included in the diagram.

Major cause category branches can be initially identified using the four Ms: material, methods, machines, and manpower, or more correctly, the four Ps: parts (raw materials), procedures, plant (equipment), and people. Categories can also be tailored depending on the problem (Moran, Talbot, and Benson 1990; Scholtes 1988; Sproull 2001). Sometimes measurement or environment is the fifth category. Arcaro (1997) suggests using no more than eight major categories.

There are various types of CEDs. The *dispersion CED* develops groups of probable causes as the main branches. Participants are asked to identify why dispersions (or variations) in the problem occur. The reasons for the dispersions are then drawn as twigs on the branches (Ishikawa 1982; Sproull 2001). The advantage of this method is that breaking down causes into more detail helps organize and relate the factors. The disadvantage is that the final form is highly dependent on the person or group constructing it, and small causes of variation may be overlooked (Andersen and Fagerhaug 2000).

The *process classification CED* lists all the process steps on the main arrow. Factors that may affect that particular process step are added as branches or drawn as individual CEDs. This type of diagram is like an assembly line with each process step drawn on the main arrow with detailed branches added. The advantage of this method is that it is easy to understand because it follows the sequence of the process. The disadvantage is that similar causes may appear repeatedly, while causes due to interdependent factors are difficult to illustrate (Andersen and Fagerhaug 2000; Ishikawa 1982).

The *cause enumeration CED* simply lists all proposed possible causes of the problem and organizes them according to their relationship to the problem and each other. The advantage of this method is that all proposed causes are listed and solutions are encouraged without confining thinking, with the resulting diagram being quite complete. The disadvantage is that it may be difficult to establish a direct relationship between any given cause and the final effect (Andersen and Fagerhaug 2000; Ishikawa 1982).

A thoroughly completed CED looks rather complicated with many branches, twigs, and smaller twigs. Conversely, too simple a diagram generally indicates that knowledge of the process or problem is shallow and requires further investigation (Ishikawa 1982). Also, the CED may highlight knowledge gaps through the lack of probable causes on a particular category branch.

A drawback to using the CED is that there is no specific mechanism for identifying a particular root cause once complete. One technique is to look on the diagram for causes that appear repeatedly within or across major categories. Selecting a single root cause, however, may prove difficult unless the characteristics of the problem are well known or documented. As a last resort, groups can select a root cause through unstructured group consensus or a structured technique such as multivoting or nominal group technique (Brassard and Ritter 1994).

Overall, the advantage of the CED is that it is easy to use, it promotes structure while allowing some creativity, and it works best when the problem is well defined and data driven (Scholtes 1988). The disadvantage of the CED is that it is heavily dependent on detailed knowledge of the problem and it only identifies possible causes (Sproull 2001). Bhote (1988) criticizes the CED as ineffective, saying it is a hit-and-miss process that may take months or years to find root causes because it tends to emphasize opinions and overlook causal interactions.

Interrelationship Diagram (ID)

The ID, originally known as the relations diagram, was developed by the Society of Quality Control Technique Development in association with the Union of Japanese Scientists and Engineers (JUSE) in 1976.

The relations diagram was part of a toolset known as the seven new quality control (7 new QC) tools. It was designed to clarify the intertwined causal relationships of a complex problem in order to identify an appropriate solution. The relations diagram evolved into a problem-solving and decision-making method from management indicator relational analysis, a method for economic planning and engineering. Original relations diagrams analyzed cause-and-effect relationships using complex calculations for each factor (Mizuno 1988).

In 1984, GOAL/QPC, an educational consulting company, formed the Statistical Resource Committee to research, review, and redesign its training materials for statistical process control (SPC). The result of the committee's work is a practitioner's handbook, *The Memory Jogger,* which describes the various SPC tools for practitioners and front-line managers. These tools are known as the seven quality control (7QC) tools and include the CED. During the development of the handbook, the authors at GOAL/QPC became aware of the seven new QC tools as proposed and published by Mizuno. After translating a working version of Mizuno's book, which was not published in English until 1988, the Statistical Resource Committee refined Mizuno's tools into another toolset called the seven management and planning (7MP) tools. The committee developed the term 7MP to indicate that this was not a "new" toolset to replace the "old" QC set of tools, but rather supplement them and more accurately describe their intended application (Brassard 1996). As an outcome, GOAL/QPC published the *Memory Jogger Plus+* in 1989, which features the 7MP tools and a variation of Mizuno's relations diagram called the interrelationship digraph. A digraph is a combination of the words *diagram* and *graph* (Moran, Talbot, and Benson 1990). Thus, the terms interrelationship digraph, interrelationship diagram, and relations diagram are generally used interchangeably.

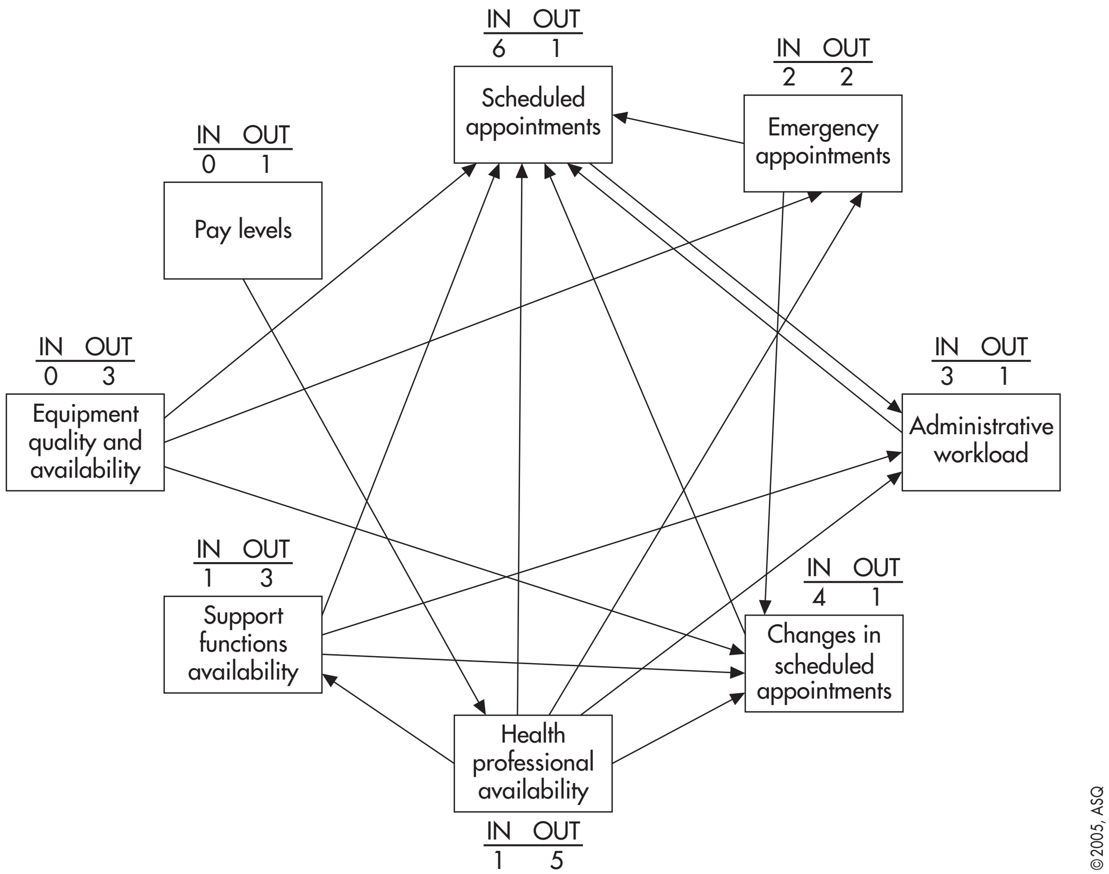
The interrelationship diagram "…takes complex, multivariable problems and explores and displays all of the interrelated factors involved. It graphically shows the logical (and often causal) relationships between factors" (Brassard 1996, 5). Andersen and Fagerhaug (2000, 14, 19) state that the ID is "a tool used to identify logical relationships between different ideas or issues in a complex or confusing situation" and "borders on being a tool for cause-and-effect analysis." Brassard and Ritter (1994) state that the ID allows groups to identify, analyze, and classify the cause-and-effect relationships that exist among all critical issues so that key factors can be part of an effective solution. The intent of the ID is to encourage practitioners to think in multiple directions rather than linearly so that critical issues can emerge naturally rather than follow personal agendas. The ID assists in systematically surfacing basic assumptions and reasons for those assumptions. In summary, the ID helps identify root causes.

The ID uses arrows to show cause-and-effect relationships among a number of potential problem factors. Short sentences or phrases expressing the factor are enclosed in rectangles or ovals. Whether phrases or sentences are used is a group decision, but authors recommend the use of at least a noun and a verb (Brassard 1996; Brassard and Ritter 1994). Arrows drawn between the factors represent a relationship. As a rule, the arrow points from the cause to the effect or from the means to the objective. The arrow, however, may be reversed if it suits the purpose of the analysis (Mizuno 1988).

The format of the ID is generally unrestricted with several variants. The *centrally converging* ID places the major problem in the center with closely related factors arranged around it to indicate a close relationship. The *directionally intense* ID places the problem to one side of the diagram and arranges the factors according to their cause-and-effect relationships on the other side. The *applications format* ID can be unrestricted, centrally converging, or directionally intense, but adds additional structure based on factors such as organizational configuration, processes, or systems.

The ID may use either quantitative or qualitative formats. In the qualitative format, the factors are simply connected to each other and the root cause is identified based on intuitive understanding. In the quantitative format, numeric identifiers are used to determine the strength of relations between factors and the root cause is identified based on the numeric value (Andersen and Fagerhaug 2000).

Figure 2 Example of an interrelationship diagram.



Mizuno (1988) recommends the following when creating a relations diagram:

- Step 1: Collect information from a variety of sources.
- Step 2: Use concise phrases or sentences as opposed to isolated words.
- Step 3: Draw diagrams only after group consensus is reached.
- Step 4: Rewrite diagrams several times to identify and separate critical items.
- Step 5: Do not be distracted by intermediate factors that do not directly influence the root causes.

Mizuno recommends asking *why* questions to surface true cause-and-effect relationships and to slow the process so participants can critically evaluate, revise, examine, or discard factors.

Andersen and Fagerhaug (2000) write that the first step for using an ID is to determine and label the factors, then place them on an easel or whiteboard in a circular shape and assess the relationship of each factor on other factors using arrows. After all relationships have been assessed, count the number of arrows pointing into or out of each factor. A factor with more "out" arrows than "in" arrows is a cause, while a factor with more "in" arrows than "out" arrows is an effect. The causal factors form the starting point for analysis. Figure 2 shows an example of an unrestricted quantitative interrelationship diagram.

A variant of the ID is the ID matrix, which places all the factors on the first column and row of a matrix. This format creates a more orderly display and prevents the tool from becoming too chaotic when there are many factors. The strength and direction of the relationships can be represented through arrows, numbers, or other symbols placed in the cells of the matrix. Brassard (1996) and Brassard and Ritter (1994) argue that users become careless with large, complicated diagrams, so the ID matrix is a good technique to force participants to pay attention to each factor in a more systematic fashion.

A particular concern of the ID is that it does not have a mechanism for evaluating the integrity of the selected root cause. In using the quantitative or qualitative method, practitioners must be able to assess the validity of their choices and the strength of the factor relationships. Some users may simply count the number of arrows and select a root cause without thoroughly analyzing or testing their assumptions about the problem.

Overall, the ID's strength is that it is a structured approach that provides for the analysis of complex relationships using a nonlinear approach. The disadvantage is that it may rely too heavily on the subjective judgments about factor relationships and can become quite complex or hard to read (Andersen and Fagerhaug 2000).

Current Reality Tree (CRT)

Goldratt (1990, 3) promotes the idea that the factors of problems are interdependent and result from a few core (root) causes. Goldratt asserts, "We grossly underestimate the power of our intuition." Intuitively, most people know how to solve problems, but are unable to because they have no method of focusing their intuition. Without a means to focus, people will do the opposite of what they really believe and will "…play a lot of games with numbers and words." Goldratt expands on the idea of problem solving through focused intuition in the book *It's Not Luck* (Goldratt 1994), which introduces the CRT. The CRT is one of five thinking process (TP) tools, a toolset that Goldratt developed for implementing the theory of constraints (TOC).

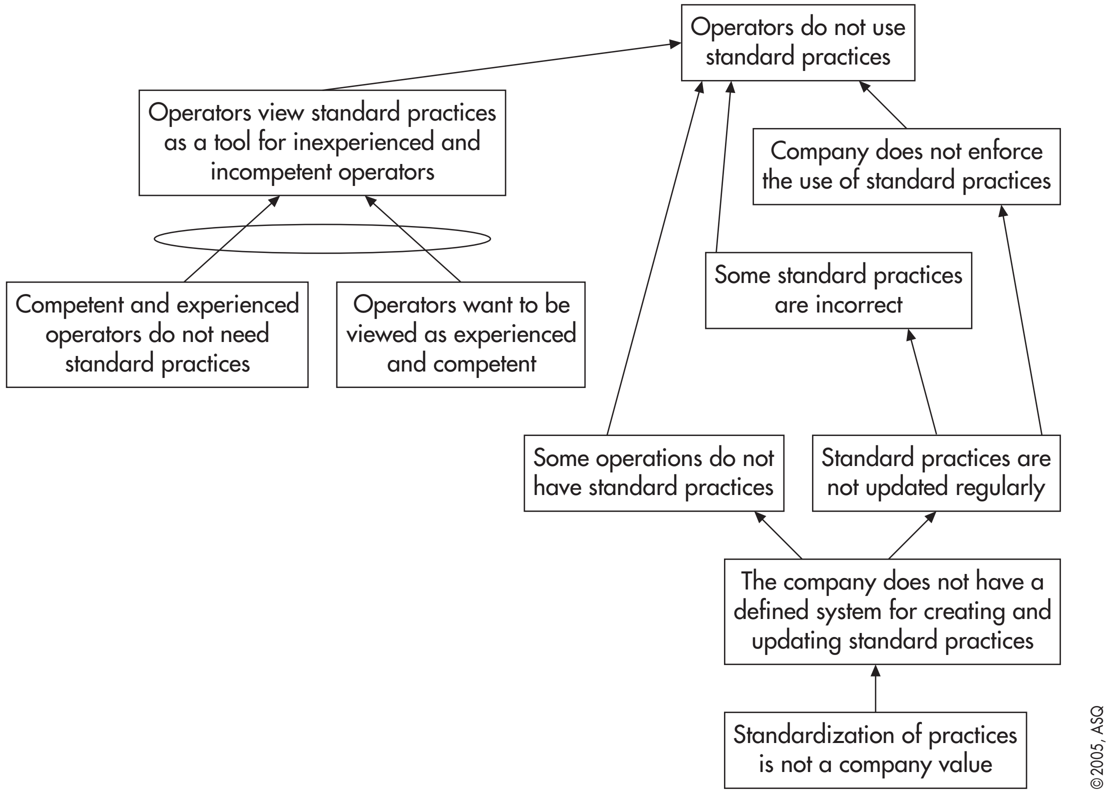
The CRT addresses problems by relating multiple factors rather than isolated events. Its purpose is to help practitioners find the links between symptomatic factors, called undesirable effects (UDEs), of the core problem. The CRT was designed to show the current state of reality as it exists in a system. It reflects the most probable chain of cause-and-effect factors that contribute to a specific set of circumstances and creates a basis for understanding complex systems (Dettmer 1997). Schragenheim (1998, 19-20) writes, "The current reality tree depicts the current state of an organization with the objective of identifying a root cause…." Scheinkopf (1999, 144) states that the CRT "is used to pinpoint a core driver—a common cause for many effects." The CRT assumes that all systems are subject to interdependencies among the factor components. Therefore, related causes must be identified and isolated before they can be addressed.

Like the other tools, the CRT uses entities and arrows to describe a system. Entities are statements within some kind of geometric figure, usually a rectangle with smooth or sharp corners. An entity is expressed as a complete statement that conveys an idea. An entity can be a cause, an effect, or both (Dettmer 1997). Arrows in the CRT signify a sufficiency relationship between the entities. Sufficiency implies that the cause is, in fact, enough to create the effect. Entities that do not meet the sufficiency criteria are not connected. The relationship between two entities is read as an "if-then" statement such as, "If [cause statement entity], then [effect statement entity]" (Dettmer 1997; Scheinkopf 1999).

In addition, the CRT uses a unique symbol, the oval or ellipse, to show relationships between interdependent causes. The literature distinguishes between interrelationship and interdependency using sufficient cause logic such that effects due to interdependency are attributed to multiple and related causal factors. Because the CRT is based on sufficiency, there may be cases where one cause is not sufficient by itself to create the proposed effect. Thus, the ellipse shows that multiple causes are required for the produced effect. These causes are contributive in nature such that they must all be present for the effect to take place. If one of the interdependent causes is removed, the effect will disappear. Relationships that contain an ellipse are read as, "If [first contributing cause entity] and [second contributing cause entity], then [effect entity]." Figure 3 shows an example of a CRT.

The CRT also allows for looping conventions that either positively or negatively amplify the effect. In this situation, an arrow is drawn from the last entity back to one of the earlier causes. If the original core cause

Figure 3 Example of a current reality tree.



creates a negative reinforcing loop, but can be changed to a positive, the entire system will be reinforced with a desirable effect (Dettmer 1997). Although constructed from the top, starting with effects, then working down to causes, the CRT is read from bottom to top using "if-then" statements. The arrows lead from the cause upward (Gattiker and Boyd 1999).

The procedure for constructing a CRT was first described by Goldratt (1994) via narrative format in the book *It's Not Luck*. Cox and Spencer (1998) later outline the paraphrased procedure:

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

This process continues as entities are added downward and chained together. At some point no other causes can be established or connected to the tree. The construction is complete when all UDEs are connected to very few root causes, which do not have preceding causal entities (Cox et al. 1998; Dettmer 1997). The final step in the construction of the CRT is to review all the connections and test the logic of the diagram. Branches that do not connect to UDEs can be pruned or separated for later analysis.

The assumptions and logic of the CRT are evaluated using rules called CLRs. These rules ensure rigor in the CRT process and are the criteria for verifying, validating, and agreeing upon the connections between factors. They are also used to facilitate discussion, communicate disagreement, reduce animosity, and foster collaboration (Scheinkopf 1999). The CLRs consist of six tests or proofs: clarity, entity existence, causality existence, cause insufficiency, additional cause, and predicted effect (Dettmer 1997).

Clarity, causality existence, and entity existence are the first level of reservation and are used to clarify meaning and question relationships or the existence of entities. The second level of reservation includes cause insufficiency, additional cause, and predicted effect. They are secondary because they are used when questions remain after addressing first-level reservations. Second-level reservations look for missing or additional causes and additional or invalid effects (Dettmer 1997; Scheinkopf 1999).

Variations are the use of the CRT to identify business constraints as part of TOC or to persuade others to take a particular course of action (Cox et al. 1998; Goldratt 1990; Lepore and Cohen 1999; Smith 2000). When used as a persuasion tool, it is known as the communication CRT. When used to identify business constraints, it becomes one of the five TP tools used in the TOC process (Scheinkopf 1999).

A particular concern of the CRT is its complexity of construction and rigorous logic system. Practitioners may find the application of the CRT too difficult or time consuming. Conversely, the strength of the CRT is the rigor of the CLR mechanism that encourages attention to detail, ongoing evaluation, and integrity of output.

PREVIOUS COMPARISONS OF THE TOOLS

Fredendall et al. (2002), in a comparison of the CED with the CRT, declare that they use much of the same causal logic and can be used in tandem. For example, a group may use the CED to brainstorm possible causes and then use the CED output to develop a list of UDEs for the CRT. There are, however, some critical differences between the two approaches.

First, the physical layout of the tools is different. The CED is horizontal and reads from left to right, while the CRT is vertical and reads from bottom to top. Second, the CED does not easily show systematic causes of an effect, while the CRT shows "if-then" logic more precisely. Third, practitioners may find the strict application of the CRT logic intimidating and resent having to phrase their suggestions or objections as CLRs. Consequently, most people view the CED as easier because it requires less training and is quicker to construct. Fourth, the CED does not quickly identify the root cause of the problem, while the CRT is structured so that it visually points to it, which then leads more precisely to finding a potential permanent solution (Fredendall et al. 2002).

Pasquarella, Mitchell, and Suerken (1997) present a detailed comparison of the tools in a three-part proceedings article, with each author writing a section. Suerken does not compare the tools, but recommends using the TP tools, including the CRT, in educational settings. Pasquarella's section compares the TP tools to 10 quality control tools (adding three more tools to the 7QC tools), including the CED. Pasquarella also compares the TP tools to the 7MP tools, including the ID.

In comparing both sets of tools to the TP tools, Pasquarella comes to three conclusions. First, organizational managers will choose simple methods when confronted with too many tools or if they perceive a tool as too complex. Thus, most managers will choose the CED because it fits their perception of a simple analysis tool. Second, simple methods are heavily influenced by the emotions of the people using them. Conversely, complicated methods require a degree of expertise and facilitation. Therefore, managers will again choose the CED despite its subjective nature because they are reluctant to assign groups complex methods. Third, most tools do not address systemwide problems unless they can be integrated and rigorously applied. In other words, most tools cannot be used in isolation to solve larger systemic problems. Consequently, organization managers tend to use simple tools that do not solve systematic problems.

Pasquarella claims the TP tools superior for the following reasons:

1. They are logical, simple, and there are less of them to consider.
2. The TP tools capitalize on intuition and emotion without skewing the process because the CLRs force rigor into the process.
3. Each TP tool is clearly identified for a specific function so it can be used as a stand-alone application as well as collectively for systematic problems. As a result, Pasquarella declares that the TP tools (and the CRT) produce the best results because they are more robust, powerful, and intuitive than the other tools.

Mitchell's section reports the results of a qualitative study that measured the effectiveness of the CED, the ID matrix, and the CRT. Mitchell asked students from an advanced quality management course to find the root cause of an airline transport accident. The students applied each of the three root cause analysis tools and then drew comparisons.

Mitchell's students found that the CRT pinpointed a root cause of the airline accident while the CED did not. Mitchell does not indicate whether the students found a root cause using the ID matrix, but he states that the matrix was a good tool for keeping the group organized and focused. Mitchell's students also reported that the CRT was the only tool that displayed interdependencies between causes. While the ID matrix showed interrelationships, it did not show whether the effect resulted from multiple related causes. The CRT was the only tool to show both interrelationships and intermediate factors. Both the CED and the CRT were effective in grouping cause categories. Mitchell reports that the CRT created more discussion than the CED, but did not compare the ID matrix. All three tools were deemed effective for focusing problem-solving activity.

In terms of the process, Mitchell's students found the CED easiest and least time consuming, followed by the CRT and ID matrix. In this study, the ID matrix required extra process time to clarify and correct incomplete relationships after initial construction. Mitchell's students rated the CRT highest for readability because the root cause was easy to locate at the bottom of the diagram. The ID matrix was rated second for readability, as it was easier to read at a glance, and the CED was most the difficult to read.

Mitchell's students concluded that the CRT was the best of the three tools because it was able to pinpoint root causes while identifying causal interdependencies. The common weakness of the CED and ID was their inability to identify causal interdependencies. Mitchell offers the opinion that a clear understanding of causal interdependency is critical to successful problem-solving efforts. Without this understanding, overlooked negative effects will creep back into a system and create recurrent problems that will eventually need attention.

Using a repeated measures design with several sections of students from team building and leadership courses, Doggett (2004) found statistically significant differences between the tools with regard to perceptions of usability (F (1.881, 74) = 9.156, $p < .001$) that was driven primarily by ease or difficulty of use. Large effect sizes (1.15 and 1.18) between the CRT and the other tools indicated that the CRT was perceived as more difficult. In terms of identifying cause categories, the CED was perceived better than either the ID or CRT (F (2, 74) = 7.839, $p = .001$). None of the students, however, perceived any differences between the tools with regard to finding root causes, identifying factor relationships, or developing group discussion and contribution. In terms of the process, the CRT was the most time consuming, with the ID and CED taking the same amount of time on average.

Of greater interest in Doggett's study was an apparent incongruence between the statistical perceptions of participants and the quality of the tool outputs. While participants perceived few differences between the tools, the characteristics of the tool outputs varied greatly. The technical accuracy of both the CED and the ID were high, whereas the technical accuracy of the CRT was mixed. Students using the CED were seldom able to identify a specific root cause, however, the students using the ID found root causes more often. Because the students using the CED could not identify specific root causes, the integrity and reasonableness of their selections also suffered. While the ID groups found a root cause most of the time, the integrity and reasonableness of their root causes was mixed. In contrast, CRT groups identified a root cause most of the time with high integrity more than half the time. In addition, the CRT groups were able to do this using fewer factors and relationships than the other tools.

Doggett postulates that the incongruence between perceptions and actual performance is due to the nature of group dynamics that tends to avoid creating tension. Because the students were involved in the complexity of building the CRT, they did not take the time to assess or reflect on the meaning of their outputs. Their reflection was impaired by the emotionally laden group process. Thus, students perceived the tension generated by the CRT as an added degree of difficulty. Although the majority of the CRT groups were uncomfortable during the process, the quality of their outputs was better.

SUMMARY OF THE LITERATURE

The literature indicates that the CED is an easy-to-use tool for developing and classifying root cause categories. It assumes the existence of enough knowledge to be able to isolate and identify probable root causes, but the identified causes may not be specific or reasonable. The CED has the potential to highlight information that is lacking or inadequate through the lack of identified causes in certain categories; however, it does not identify relationships between factors, has no formal mechanism for selecting and evaluating root causes, and may be influenced by group bias.

The literature indicates that the ID is an easy-to-use tool to help clarify intertwined relationships between multiple factors, although the factors may not be causal. The ID is used to identify, analyze, and classify possible relationships among critical issues using a nonlinear structured method. Authors view the ID as a borderline tool for cause-and-effect analysis because of its mixed performance in identifying root causes. The ID does not have a mechanism for evaluating the integrity of the output, and may rely too heavily on subjective judgments of factor relationships.

The literature indicates that the CRT is a complex tool for pinpointing root causes and identifying causal interdependencies. The CRT builds chains of cause and effect, starting with effects, to guide the verbalization of intuition in a logical fashion leading to the identification of a core problem. Khaimovich (1999, 53) writes, "Experts (tool practitioners) rarely look for root causes moving from symptoms backwards along possible causal links." In this respect, the CRT is unique. Of the three root cause tools, the CRT is the only method that has a mechanism for testing logic. Groups may find the logic and construction rules of the CRT intimidating, difficult, and time consuming. While it is not clear that all of the tools stimulate dialogue and discussion, the CRT provides opportunities for groups to dialogue using the CLRs.

A synthesis of the literature reviewed in this article is shown in Table 1. If the reviewed literature does not specifically address a performance criterion for the specific tool, it is not indicated.

Table 1 Head-to-head comparison of root cause analysis tools.

Performance criteria	CED	ID	CRT
Ability to find a specific root cause	No	Yes	Yes
Ability to find reasonable root cause	No	Mixed	Yes
Ability to show systematic causes of effect	No	No	Yes
Shows causal interdependency	No	No	Yes
Identifies factor relationships	No	Yes	Yes
Shows intermediate factors	No	No	Yes
Identifies cause categories	Yes	No	?
Stimulates dialogue and discussion	?	?	Yes
Focuses activities	Yes	Yes	Yes
Has mechanism for testing logic	No	No	Yes
Construction process time	Low	Low	High
Construction accuracy required	High	Medium	Low
Extent of subjective influence on output	High	High	Low
Amount of problem knowledge required	High	?	?
Ease of use	High	High	Low
Overall readability	Low	Low	High
Number of factors to analyze relative to the problem	Many	?	Few

CONCLUSION

Most of the literature describes the three tools independently. Only three studies compare the CED, ID, and CRT to each other. Two of the studies are qualitative and one study is mixed. Problem solvers and decision makers continue to have little data regarding the actual effectiveness of root cause analysis tools. Thus, it appears that there is an opportunity to gain a better understanding the ability of these tools to find actual root causes—the most important characteristic of a root cause analysis tool. There are also the relational and causal factors that exist around or close to the problem. If managers use tools that find causal relationships and categories close to where the problem resides, they can focus improvement efforts more precisely and accurately in areas of greatest potential.

Alternatively, root cause analysis tools must also have the characteristics to promote collaboration, stimulate discussion, be readable or understandable, and have mechanisms for evaluating integrity. The influence of group dynamics on process outcomes is a common theme in research but beyond the scope of this article. Self-motivated groups can probably overcome many root cause analysis tool limitations. Conversely, a dysfunctional group is probably not capable of producing good results using even the best root cause analysis tool. Teams that use dialogue and discussion effectively within a supportive context might overcome the restrictions of a mediocre tool, but even the best analytical tool cannot turn a mediocre team into a great problem-solving group. The limitation of this type of research is the inability to isolate aptitude-treatment interactions. If managers use tools that effectively focus effort on finding root causes rather than conflicting personalities, they unleash the capability of the organization to learn and address systemwide issues.

The implications for management are that effective problem solving requires the identification of specific and reasonable root causes. Several methods exist for identifying root causes, but their effectiveness is dependant on the rigorous application of the group and the integrity of the selected root cause. If the selected root cause is trustworthy, it produces a clear managerial decision for an action. Each analysis tool has distinguishing characteristics that can potentially affect group output. Therefore, reliable decision making requires that managers have a working knowledge of root cause analysis tools, their processes, and their likely outcomes.

The complexities of modern business require approaches that are more sophisticated. A popular view is that if enough minds are put to the task, an answer to the problem will be found. Bhote (1988) criticizes unstructured processes because they put too much emphasis on opinions, take too long, and don't produce lasting results. Leaders need to establish standards and policies for problem-solving training, and group facilitation and practice using structured root cause analysis tools. The alternative is to continue to assume that existing efforts will somehow produce different results. Assuming that groups can work together on a problem without a tool, standard, and method for critical evaluation is a policy doomed to fail.

REFERENCES

Andersen, B., and T. Fagerhaug. 2000. *Root cause analysis: Simplified tools and techniques.* Milwaukee: ASQ Quality Press.

Arcaro, J. S. 1997. *TQM facilitator's guide.* Boca Raton, Fla.: St. Lucie Press.

Bhote, K. R. 1988. *World class quality: Design of experiments made easier, more cost effective than SPC.* New York: AMA.

Brassard, M., and D. Ritter. 1994. *The memory jogger II: A pocket guide of tools for continuous improvement and effective planning.* Salem, N.H.: GOAL/QPC.

Brassard, M. 1996. *The memory jogger plus+: Featuring the seven management and planning tools.* Salem, N.H.: GOAL/QPC.

Cox, J. F. III, R. H. Draman, L. H. Boyd, and M. S. Spencer. 1998. A cause and effect approach to analyzing performance measures: Part 2—internal plant operations. *Production and Inventory Management Journal,* 39, no. 4:25-33.

Cox, J. F. III, and M. S. Spencer. 1998. *The constraints management handbook.* Boca Raton, Fla.: St. Lucie Press.

Dettmer, H. W. 1997. *Goldratt's theory of constraints.* Milwaukee: ASQ Quality Press.

Dew, J. R. 1991. In search of the root cause. *Quality Progress* 24, no. 3:97-107.

Doggett, A. M. 2004. A statistical comparison of three root cause analysis tools. *Journal of Industrial Technology* 20, no. 2.

Fredendall, L. D., J. W. Patterson, C. Lenhartz, and B. C. Mitchell. 2002. What should be changed? *Quality Progress* 35, no. 1:50-59.

Gattiker, T. F., and L. H. Boyd. 1999. A cause-and-effect approach to analyzing continuous improvement at an electronics manufacturing facility. *Production and Inventory Management Journal* 40 no. 2:26-31.

Goldratt, E. M. 1990. *What is this thing called theory of constraints and how should it be implemented?* New York: North River Press.

Goldratt, E. M. 1994. *It's not luck.* Great Barrington, Mass.: North River Press.

Ishikawa, K. 1982. *Guide to quality control, second edition.* Tokyo: Asian Productivity Organization.

Khaimovich, L. 1999. Toward a truly dynamic theory of problem-solving group effectiveness: Cognitive and emotional processes during the root cause analysis performed by a business process re-engineering team. Ph.D. diss., University of Pittsburgh. Abstract in *Dissertation Abstracts International* 60:04B: 1915.

Lepore, D., and O. Cohen. 1999. *Deming and Goldratt: The theory of constraints and the system of profound knowledge.* Great Barrington, Mass.: North River Press.

Mizuno, S., ed. 1988. *Management for quality improvement: The seven new QC tools.* Cambridge: Productivity Press.

Moran, J. W., R. P. Talbot, and R. M. Benson. 1990. *A guide to graphical problem-solving processes.* Milwaukee: ASQ Quality Press.

Pasquarella, M., B. Mitchell, and K. Suerken. 1997. A comparison on thinking processes and total quality management tools. *1997 APICS constraints management proceedings: Make common sense a common practice.* Falls Church, Va.: APICS.

Scheinkopf, L. J. 1999. *Thinking for a change: Putting the TOC thinking processes to use.* Boca Raton, Fla.: St. Lucie Press.

Scholtes, P. 1988. *The team handbook: How to use teams to improve quality.* Madison, Wis.: Joiner.

Schragenheim, E. 1998. *Management dilemmas: The theory of constraints approach to problem identification and solutions.* Boca Raton, Fla.: St. Lucie Press.

Smith, D. 2000. *The measurement nightmare: How the theory of constraints can resolve conflicting strategies, policies, and measures.* Boca Raton, Fla.: St. Lucie Press.

Sproull, B. 2001. *Process problem solving: A guide for maintenance and operations teams.* Portland: Productivity Press.

Wilson, P. F., L. D. Dell, and G. F. Anderson. 1993. *Root cause analysis: A tool for total quality management.* Milwaukee: ASQ Quality Press.

BIOGRAPHY

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