CHAPTER 4

ROOT CAUSE ANALYSIS LITERATURE

4.1 INTRODUCTION

As described in Chapter 1, root cause analysis can be traced to the broader field of TQM. Root cause analysis is an integral part of the large TQM toolbox of problem analysis, problem-solving and improvement tools (Andersen & Fagerhaug, 2006:12).

This chapter is the last of three that document a literature review that covers the central concepts used in this study. It provides a detailed overview of the key concepts and processes used in the root cause analysis.

This chapter is divided into the following sections:

- types of causes;
- understanding the concept of root cause analysis; and
- criteria for an effective root cause analysis system.

4.2 TYPES OF CAUSES

During the process of root cause analysis, causes are referred to in several different ways, including the following:

- *Presumptive causes*

  These causes may be apparent at the beginning of the investigation or emerge during the data collection process. These are hypotheses that would explain the effects of the problem, but that need validation (Ammerman, 1997:64).
- *Contributing causes*

  These causes alone would not have created the problem, but are important enough to be recognized as needing corrective action to improve the quality of the process or product (Ammerman, 1997:64). Contributing causes form links in the chain of cause-and-effect relationships that ultimately create the problem.

- *Compound causes*

  Different factors can combine to cause the problem (Andersen & Fagerhaug, 2006:4).

- *Root cause*

  This is the most basic cause or reason for a problem that can reasonably be identified and that management has control to fix. If this is corrected, it will prevent recurrence of the problem. In other words, root causes directly lead to the problem.

4.3 UNDERSTANDING THE CONCEPT OF ROOT CAUSE ANALYSIS

There does not seem to be a single, generally accepted definition of what root cause analysis is. In this study, two different, but complementary, explanations of root cause analysis are investigated. These explanations are based on the definitions developed by W.J. Rothwell (2005) and Andersen and Fagerhaug (2006) respectively.

4.3.1 Root cause analysis as an approach that traces causes and effects

W.J. Rothwell (2005:162) defines *root cause analysis* as a past-oriented approach that traces the causes and effects and pinpoints the causes of problems. This definition is similar to that of Latino and Latino (2006:117), who state that all root cause analysis approaches share the common characteristic of examining cause-and-effect relationships.

This approach to root cause analysis is based on the principle that cause and effect relationships govern everything that happens and as such is the path to effective root cause analysis. Based on their experience, Latino and Latino (2006:18) believe that any undesirable outcome will have, on average, a series of 10 to 14 cause-and-effect relationships that line up in a particular pattern in order for that event to occur. The event is the last effect and we notice that something is wrong because of the event.

Gano (1999:38-48) explains the characteristics of the cause and effect principle as follows:

- *Cause and effect are the same thing.*
  Cause and effect only differ in the way they are perceived. When one starts with an effect that has serious consequences, one wants to prevent that effect from occurring. When one asks why it occurred, one finds a cause; but if one asks "why" again, what was just a cause becomes an effect. Therefore, cause and effect are the same thing, only perceived from different perspectives.
- *Cause and effect are part of an infinite continuum of causes.*
  By repeatedly asking "why", one develops a cause chain or linear path of causes. One usually starts the process with an effect or consequence that one wants to solve and prevent from recurring. However, no matter where one starts, one is always in the middle of a continuous chain of causes and the starting point is merely a function of one's perception and goals.
- *Each effect has at least two causes in the form of actions and conditions.*
  Each effect has two or more causes – one in the passive state (conditions) and the other active (actions). Gano (1999:41) defines *action causes* as "momentary causes that bring conditions together to cause and effect", and *condition causes* as "causes that exist over time prior to an action". Several conditions usually come together with an action to cause an effect. Together, the action and condition causes form part of an ever-expanding infinite set of possible causes.
- *An effect exists only if its causes exist at the same point in time and space.*
  It is highly unlikely that a single technical failure or an isolated human error would be enough to cause a major incident (Reason & Hobbs, 2003:77). Every effect observed is caused by one or more

existing conditional causes that exist in the same time, are located in the same space, and are set in motion by an action. Latent conditions arise from strategic decisions made by designers, manufacturers, regulators and top management, and relate to things such as goal-setting, scheduling, budgeting, policy, standards and the provision of tools and equipment. These conditions could turn into error- and violation-producing conditions, which, in turn, interact with human psychology to cause unsafe acts, errors and violations (Reason & Hobbs, 2003:77-78). The instant the action occurs, the effect is created. If the time or space is changed, the effect will not be created. Gano (1999:46) describes this in the graphic illustration in Figure 4.1.

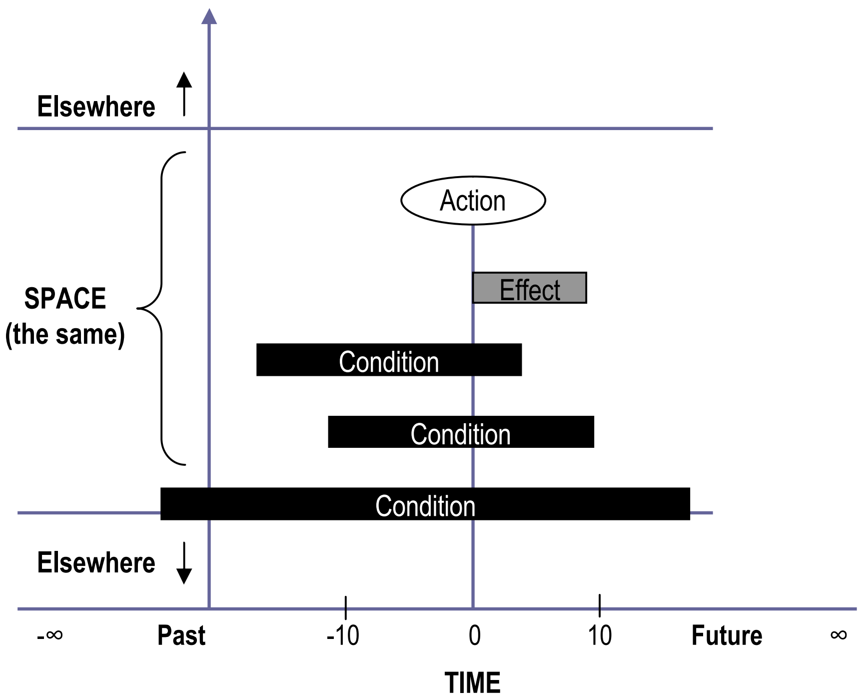

Figure 4.1 Cause and effect relationships in time and space

Source: Adapted from Gano (1999:46)

4.3.2 Root cause analysis as a structured investigation

Andersen and Fagerhaug (2006:12) define root cause analysis as “a structured investigation that aims to identify the true cause of a problem and the actions necessary to eliminate it”. This definition is supported by Paradies and Unger (2000:318). They claim that expert professional troubleshooters solve problems by doing the following (Paradies & Unger, 2000:318, *verbatim*) – they

- approach a problem systematically;
- carefully collect and preserve all the information available;
- obtain a history of equipment operation and performance;
- combine useful information into a sequence of events that helps decipher the causal relationship of multiple failures and discard superfluous facts;
- use knowledge of similar equipment and failure trouble-shooting guides to simplify the analysis process and save needless effort; and
- use a systematic root cause analysis tool to find the fixable cause of the failure, rather than just treat the symptoms.

Two structured approaches to root cause analysis are discussed for purposes of this study, namely a four-step root cause analysis process and change analysis.

4.3.2.1 A four-step root cause analysis process

According to EQE International Inc. (1999:6), a root cause analysis process follows four main steps (see next page).

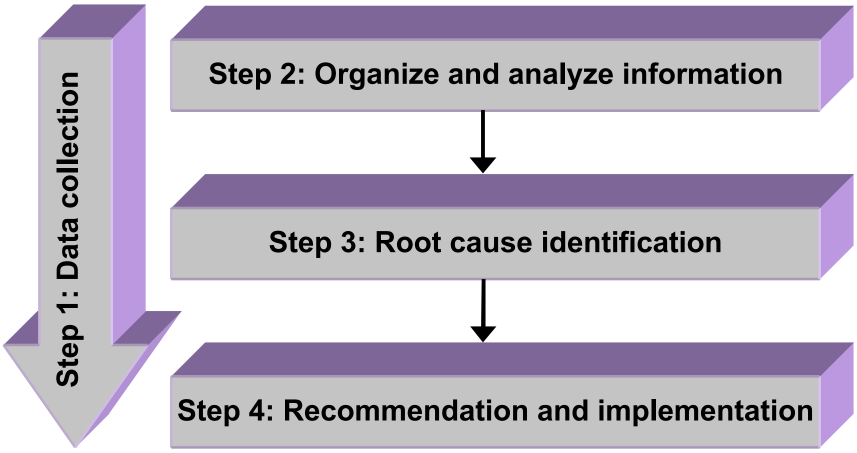

Figure 4.2 A four-step root cause analysis process

Source: Adapted from EQE International Inc. (1999:6)

Step 1: Data collection

The majority of time spent analysing an event is spent on gathering data and evidence. Evidence is data that supports a conclusion, or, as defined by Latino and Latino (2006:124), is "any data used to prove or disprove the validity of a hypothesis in the course of an investigation and/or analysis".

The factual evidence derived from data gathering serves as the basis for all valid conclusions and recommendations that are made as a result of the root cause analysis. We usually base a conclusion on one of the following (Gano, 1999:75-81):

- *Sensed evidence*

  This is the highest quality of evidence and consists of knowing by means of sight, sound, smell, touch and taste.
- *Inferred evidence*

  This is evidence that is known by repeatable causal relationships. It is less desirable than sensed evidence; and it relies on the assumption that the person concerned knows the causal relationship. There are two types of inferred evidence:

- *intuition* – inferred evidence based on both reason and emotions, but, because it occurs at a subconscious level, people usually cannot explain where it comes from; and
- *emotional evidence* – inferred evidence from a known repeatable causal relationship, but the five senses are not involved in the knowing process (although this type of evidence is very real and should therefore not be ignored as evidence of a cause, emotions should be regarded as suspect because they are not always reliable).

Data gathering is an ongoing process throughout the root cause analysis. Without effective data gathering, the event cannot be truly understood and the root cause(s) associated with the event cannot be identified. To ensure effective data gathering, a comprehensive workflow must be established and should address the following questions (Latino & Latino, 2006:72, *verbatim*):

- Who will collect the data?
- What data is important?
- When will the data be collected?
- Where will it be stored?
- Who will verify the data?
- Who will enter the data?

According to EQE International Inc. (1999:9-10) and Latino and Latino (2006:90-98), fives basic types of data are collected during a root cause analysis investigation:

- *Parts/physical*

  This data consists of something physical or tangible, such as parts, residues or chemical samples. The data is first identified and preserved, and then it is tested or analysed physically.
- *Position*

  This data consists of physical relationships among items and people at the scene and environmental factors, as well as time relationships that define the sequence of events and provide information for correlation analysis, or cause-effect relationships.

- *People*

  Interviews are conducted with witnesses. Efforts to talk to the physical observers of the event must be relentless and immediate to avoid the risk of losing some degree of short-term memory, as well as the risk that observers will discuss their opinion of what happened with others. This data is the most fragile and needs to be the first priority.

- *Paper*

  This data consists of data on paper and data stored electronically that can be printed out on paper, for example, documentation records, logs and data-recording results, procedures, memos, correspondence, programme manuals, and policy statements. Many management systems are documented on paper and, therefore, paper data can often lead to the discovery of the root cause(s).

- *Paradigms*

  Joel Barker (in Latino & Latino, 2006:97) defines a *paradigm* as "a set of rules and regulations that: (a) defines boundaries, and (b) tells you what to do to be successful within those boundaries". It describes how people view the world and react and respond to situations. This inherently affects how people approach problem-solving and ultimately determines the success of a root cause analysis effort.

Table 4.1 displays a summary of the items that are collected and reviewed, as well as the tools and methods that are used during data collection (Ammerman, 1997:14; Gano, 1999:131; Latino & Latino, 2006:73-101; Paradies & Unger, 2000:408).

Table 4.1 Data collection

Tools used for data collection	Methods used for data collection	Documents to be reviewed	Data items to be collected
• Digital and video cameras • Paper, pens, pencils and highlighters • Clipboard • Interview guidelines • Evidence preservation checklist • Wire tags and ID equipment • Grid paper for mapping • Photo log sheets • Observation sheets • Tape measure and steel ruler • Flashlight • Labels and tags • Calculator • Caution, boundary and masking tape • Feeler gauges • Marking pens and paint • Sealable plastic bags • Dictaphone or small tape recorder for notes • Magnifying glass • Magnet • Rags • Sample bottles/vials • Mirror • Sound level meter • Light meter • Thermometer (non-mercury containing) • Gloves • Hardhat, safety glasses, face shield and ear plugs • Steel toed shoes • Tweezers	• Conducting interviews • Observation at the workplace • Conducting surveys • Conduct focus group sessions • Taking photographs • Performing requested laboratory tests • Performing the work tasks under investigation	• Operating/working logs • Correspondence, including internal memos and emails • Sales contact information • Meeting minutes • Inspection/testing and safety records • Maintenance records/histories • Equipment history records and logs • Computer records • Recorder tracings • Policies • Procedures and/or instructions • Vendor manuals • Process and instrumentation drawings and specifications • Design information • Change documents • Trend charts and graphs • Plant parameter readings • Sample analysis and lab reports • Work schedules • Quality control reports • Equipment supplier and manufacturer records • Financial reports • Training records • Purchasing requisitions/ authorizations • Non-destructive testing results • Employee file information • Production histories • Medical histories/ patient records • Past root cause analysis reports • Labelling of equipment/products • Statistical process control/statistical quality control information	• Functional location • Asset ID • Event date • Equipment category • Equipment class • Equipment type • Unit or area • Failed component • Event mode • Model number • Material cost • Labour cost • Total cost • Lost opportunity cost • Other related costs • Out of service date/time • Maintenance start date/time • Maintenance end date/time • In service date/time

Max Ammerman (1997:15) offers the following guidelines for collecting data:

- Collect data pertinent to
  - conditions before, during, and after the event;
  - environmental factors such as weather conditions; and
  - time of day, day of the week, amount of overtime worked.
- When taking a series of photographs, carefully document and label each photograph, showing, for instance, the sequence of photographs, distances, orientations and times.
- Collect, label, and preserve physical evidence such as failed components, ruptured gaskets, burned leads, blown fuses, spilled fluids, or partially completed work orders or procedures.
- Establish a quarantine area for failed equipment or components, or tag and separate pieces of material.
- Consider things that occurred around the event area even if they might at first seem irrelevant, for example, hardware of software associated with the event, recent programme or equipment changes, and the physical environment.
- Ask the following questions to review and verify the data to ensure accuracy and objectivity:
  - Is eyewitness testimony consistent?
  - Does the information support the physical evidence?
  - Is more information needed?
  - Do I need to hold a second interview to check certain aspects of the situation?
  - Has information been used in such a way as to overcome personal bias?

Step 2: Organise and analyse information

The purpose of Step 2 is to organise and analyse the information gathered during the investigation and to identify gaps and deficiencies in the information. The goal of data analysis is to identify the key equipment failures and human errors that have led to or allowed the incident to occur.

Incidents usually develop from clearly defined sequences of events that involve performance errors, changes, oversights, and omissions. The investigator needs to identify and document not only the negative events, but also the relevant conditions and non-hazardous events related to the incident sequence. The following information is usually collected to describe an incident:

- events, actions or conditions that could have initiated a change during the sequence of events;
- actions – sensory, physical and mental – performed by people/things, or the state of the parameters that are related to the incident;
- sources of the data;
- times at which the event or condition started and ended; and
- the location where the event/condition began or occurred.

After all the data have been collected, the investigator is in a good position to identify factors that were major contributors to the incident. These are referred to as causal factors. Causal factors are those equipment failures and human errors that, if eliminated, would have prevented the incident or reduced its consequences.

Step 3: Root cause identification

Mark Paradies and David Busch (in Paradies & Unger, 2000:52) define a *root cause* as "the most basic cause (or causes) that can reasonably be identified that management has control to fix and, when fixed, will prevent (or significantly reduce the likelihood of) the problem's recurrence."

The following key ideas are significant in the above definition (Paradies & Unger, 2000:52-53):

- When the root cause is found, something is found that management can fix that will prevent the problem's recurrence.
- According to the definition, a root cause is something that falls within management's grasp to fix.
- An investigator has expended a "reasonable" effort if the fixable cause of an incident has been found.
- A problem may have more than one root cause. Paradies and Unger's (2000:53) research has proven that simple incidents have on average two to three root causes, while more complex incidents in more complex systems have 10 or more root causes.

The identification of root causes helps the investigator to examine and establish, in a systematic way, why the incident occurred so that the problems surrounding the occurrence can be fixed.

Step 4: Recommendation and implementation of solutions

The facts discovered during the investigation should lead to causal factors and root causes, which, in turn, should lead to recommendations of solutions. Gano (1999:90) defines a *solution* as "an action taken upon a cause to affect a desired condition". The purpose of Step 4 is thus to generate achievable recommendations of solutions (or corrective actions) that will avoid the recurrence of the root cause(s).

Preventing recurrence implies that the event does not happen again for the same (known) set of causes. Even though it might not always be possible, organisations should strive for 100%

non-repeat. This may require a combination of solutions – one solution may prevent recurrence 90% of the time, while a second solution may prevent it the other 10%. This means that the solutions that are developed should not only address the specific circumstances of the event that has occurred, but should also seek to make improvements in management systems and/or inherent safety. With this is mind, it means that, in general, three types of solutions should be generated for each root cause (EQE International Inc., 1999:33), first, solutions that will correct the specific problem; second, solutions that will correct similar existing problems; and, third, solutions that will correct the system that created the problems.

According to Gano (1999:100), the following list represents the most common favourite solution categories that should be avoided as sole or final solutions, because using these favourite solutions as a first or only resort indicates that the organisation is in a rut, and chances are that the problem will repeat itself:

- punishment;
- reprimand;
- replacement of the broken part;
- investigation;
- revision of the procedure;
- writing of a new procedure;
- changes to the management programme (re-engineering);
- redesign;
- putting up a warning sign; and
- ignoring the problem ("stuff happens").

Before solutions or corrective actions are recommended, they should be reviewed to ensure that they will be efficient and effective and that they will not cause more unexpected problems. Paradies and Unger (2000:77-82) suggest two techniques to assist with this, namely the Safeguard Analysis and the SMARTER procedure.

a. *Safeguard Analysis*

The Safeguard Analysis – which is similar to safeguarding, as discussed in Chapter 3 – is used to judge the adequacy of the suggested solution or corrective actions. This is done by reviewing the sequence of events to determine whether the proposed corrective actions will provide enough defence in-depth to reasonably assure that the incident will not recur. The information gained from the Safeguard Analysis can also be used in an environment where resources (time, money and people) are limited, to determine which of the suggested corrective actions is/are most important.

b. *SMARTER*

Each corrective action should be reviewed for each of the following elements – is it (Paradies & Unger, 2000:81, *verbatim*)

Specific?	• Who will do what by when? • Are corrective actions specified in numbers?
Measurable?	• Can the corrective action be measured (quantitatively) to see when it is done and to see if it worked? • Will it prevent future incidents?
Accountable?	• Is the person responsible for implementing the corrective action clearly defined? • Is the due date clearly specified?
Reasonable?	• Is every suggested corrective action practical? • Is there a simpler or less expensive way to do the same thing? • Can you convince management that there

	is a reasonable return on investment for this corrective action?
	• Have you discussed the corrective action with those who will own it – those who will have to implement it and live with it – and do they believe it is reasonable?
Timely?	• Is the due date for the corrective action soon enough, given the consequences of another failure? • If the frequency of failure is high and the consequences of failure are significant, does the report offer interim action to reduce the risk while the final corrective actions are being implemented?
Effective?	• Will the corrective action prevent or significantly reduce the odds of this problem happening again?
Reviewed?	• Will this corrective action cause any problems? • Has someone independent from the investigation team reviewed the corrective action for unintended negative impacts on the process or the people?

In addition to checking the suggested solution for its efficiency and effectiveness, it is also important to ensure that it is viable.

The following criteria will ensure that the solution or recommended corrective actions are viable (EQE International Inc., 1999:33; Gano, 1999:93):

- The solutions must prevent recurrence of the condition/event.

- The solutions must be within both the control and capability of the organisation to implement.
- The solutions must be directly related to the root causes.
- The solutions must meet the following goals and objectives:
  - The solution must not cause undesirable problems.
  - The solution must avoid similar occurrences, for instance, at different locations.
  - The solution must offer reasonable value for its cost.
- Implementation of the solutions must not introduce unacceptable risks.

The following questions will help ensure that the above criteria for developing and implementing solutions are met (EQE International Inc., 1999:34):

- Is there at least one solution associated with each root cause?
- Does the solution specifically address the root cause?
- Will the solution cause detrimental effects?
- What are the consequences of implementing the solution?
- What are the consequences of not implementing the solution?
- What is the cost of implementing the solution?
- Will training be required as part of implementing the solution?
- In what time frame can the solution reasonably be implemented?
- What resources are required for successful development of the solution?
- What resources are required for successful implementation and continued effectiveness of the solution?
- What impact will the development and implementation of the solution have on other work groups?
- Is implementation of the solution measurable?

Once the solutions or corrective actions have been approved, a system needs to be set up to track the implementation and measure its effectiveness. Paradies and Unger (2000:96) suggest the following process:

- *Document any immediate, short-term fixes*
  What actions have been taken to repair damage, fix broken equipment, care for or rehabilitate injured people, and get the process back in operation?
- *Document, track and validate long-term fixes*
  Did the corrective action meet its intent and was it effective? If the fix worked, share the proven results with other facilities in the organisation.

To make the implementation process successful requires management involvement. Management can be involved by, first, spending some of its time focusing on the company's improvement efforts; and, second, ensuring resources are being applied to the performance improvement efforts (Paradies & Unger, 2000:98).

4.3.2.2 Change Analysis

In addition to the four-step process outlined above, Change Analysis is another structured root cause analysis process. Change Analysis was popularized in the early 1960's when Charles Kepner and Ben Tregoe developed a technique that identifies and compares differences between two similar, but not identical, processes or outcomes, to uncover changes that could cause problems (Paradies & Unger, 2000:350).

Figure 4.3 (see next page) illustrates the Change Analysis process.

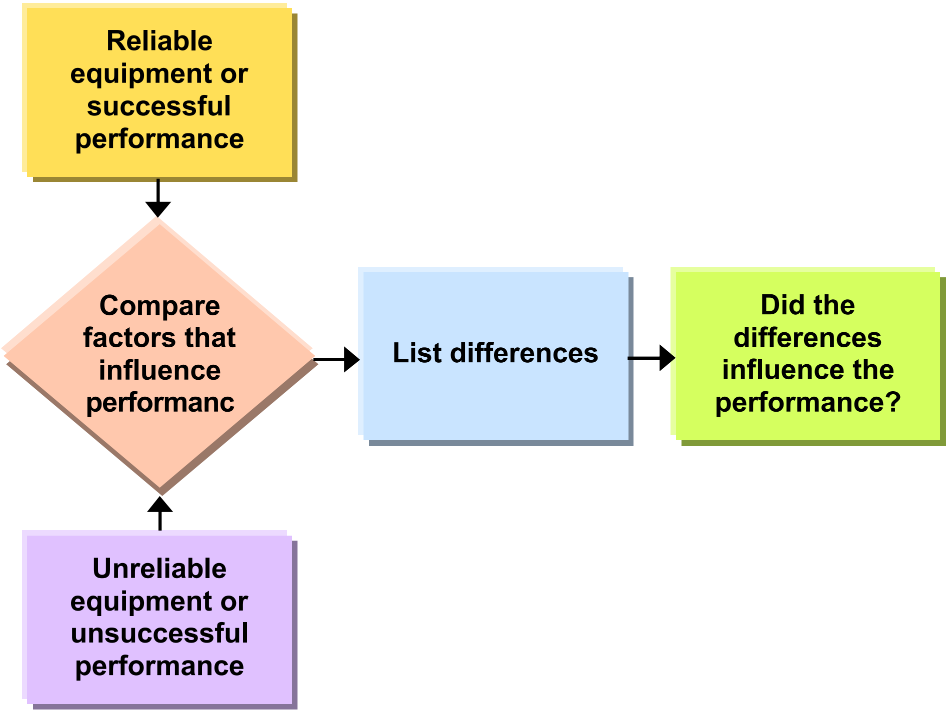

Figure 4.3 The Change Analysis process

Source: Adapted from Paradies and Unger (2000:351)

The quality of the Change Analysis depends on the quality of the list of factors that have been developed. If key factors have been overlooked, then important information that contributed to the problem might be missed. The following seven questions can be used to help identify the factors that influence performance (Paradies & Unger, 2000:354, 380):

- Who performed the work?
- What tools, equipment, displays, controls, distributed control system, procedures, technical manuals, administrative controls, drawings, status boards, chemicals, communication equipment, warning signs, labels, or other aids were used to perform the work?
- When was the work performed?
- Where was the work performed?
- Why?
- To what extent?

- Under what conditions was the work performed?

According the Paradies and Unger (2000:354), the following categories can be evaluated to make a more complete list for human performance issues:

- procedures;
- training;
- quality control;
- communications;
- management systems;
- human engineering; and
- work direction.

Changes do not always cause problems; and not all changes cause problems. Change Analysis does, however, help investigators to recognize problems caused by subtle changes or differences which frequently do cause problems.

4.4 CRITERIA FOR AN EFFECTIVE ROOT CAUSE ANALYSIS SYSTEM

Effective root cause analysis means that the same problem never occurs again due to the same causes. Ineffective root cause analysis occurs due to the following five factors (Gano, 1999:31-33; Latino & Latino, 2006:110-111):

- *Incomplete problem definition*
  This is caused by the false belief that the problem is obvious and the subsequent rush to find a solution. The belief that the problem is obvious is caused by the belief in a single reality discussed above and the notion that people all think the same. If the problem is not properly defined, causes are ignored, and the focus is on sharing favourite solutions to show everyone else how smart one is. As a result, little or no synergy occurs; the problem is never fully understood and therefore occurs again. When the problem does recur, another favourite solution is implemented and the cycle continues.

- *Unknown causal relationships*

  Causal relationships often remain unknown because people do not seem to think causally. They tend to think and talk in terms of human error, lack of training and other categorical causes aligned with their favourite solution.
- *A focus on solutions*

  By focusing on solutions without following the root cause analysis discipline and clearly defining the problem and its causes, organisations often find themselves solving the wrong problem. People focus on solutions because the human mind searches for what it already knows and when people find what they know, they validate the rightness of the search and cease to look any further. They seek the familiar and call it “right” or “real”. This tendency is called “the favourite solution mindset” and it prevents effective root cause analysis most of the time.
- *Acceptance of opinions as facts*

  This phenomenon often occurs when methodologies are used that promote solutions before proving that hypotheses are factual, or when there is a lot of pressure to reach consensus quickly and implement solutions so that things can get back to “normal”. This leads to a trial-and-error approach and to spending money – which does not solve the problem.
- *Destructive team behaviour*

  A dominating team member can make other team members feel intimidated. When that happens, they will not participate, and it puts pressure on them to accept the dominating team member’s opinion as fact. Team members that are reluctant to participate, that go off on a tangent or that argue a lot are detrimental to the team’s achieving success during a root cause analysis.

In addition to the above reasons for ineffective root cause analyses, research conducted by Robert Nelms (in Latino & Latino, 2006:25) indicated the following reasons why root cause analysis initiatives fail:

- root cause analysis is almost contrary to human nature (according to 28% of the respondents);
- incentives and/or the priority to do root cause analysis are absent (19%);

- root cause analysis takes time (people say they do not have time) (14%);
- root cause analysis processes are ill-defined or misdefined (12%);
- "western culture" seems to have a short-term focus and people are rewarded for short-term results (9%);
- people say they have not had to do root cause analysis in the past, so they ask why they should do so now (8%);
- most people do not understand how important it is to learn from things that go wrong (5%); and
- root cause analyses are not the respondents' responsibility (5%).

The above list shows that every objection to root cause analysis can be overcome if a proper strategy and support structure are developed and implemented. Paradies and Unger's (2000:53-55) extensive research since 1983 pinpointed the following criteria for a good root cause system – it is

- easy to use in the field by non-experts;
- effective in consistently identifying root causes (two people with the same information and using the same technique should arrive at the same answer; and effective root cause analysis helps the problem solver to analyse the event systematically, so that he/she can understand exactly what happened, can spot what has caused it, can go beyond his/her own knowledge to find the problem's root causes, and can develop effective corrective actions that – when they are implemented – will prevent the problems' recurrence or significantly reduce their likelihood);
- well documented (clear documentation of the system and techniques is essential for effective learning and consistent application);
- accompanied by effective user training followed by application of the techniques in the field, to learn and develop root cause analysis skills;
- credible with the workforce (it must stop the negative cycle of blame fixing and help the problem solver to develop effective corrective actions);
- helpful in presenting the results to management, so that management understands what needs to be fixed and the results convince management to take action; and

- designed to allow collection, comparison, and measurement of root cause trends.

4.5 CONCLUSION

The aim of this chapter was to enable a better understanding of some of the concepts and processes used in root cause analysis. The following is evident from the literature discussion in this chapter:

- One approach to root cause analysis is to focus on cause and effect relationships. Cause and effect relationships help organisations to identify patterns and to understand better the sequence of events and what has happened.
- Another approach to root cause analysis is to follow a systematic, structured process that focuses on data collection, information analysis, the identification of root causes and the implementation of solutions.
- The root cause analysis system that is used must be credible and well-documented. An effective root cause analysis process would identify root causes effectively and consistently and would control the causes in a way that would prevent them from recurring.

This was the last of three chapters that covered the literature that is central to this study. The next chapter discusses the type and nature of the study's research approach.