RISK-BASED DECISION-MAKING GUIDELINES

Volume 3
Procedures for Assessing Risks

Applying Risk Assessment Tools

Chapter 4 — Checklist Analysis

Chapter Contents

This chapter provides a basic overview of the checklist analysis technique and includes fundamental step-by-step instructions for using this methodology to evaluate a system against preestablished criteria. The following are the major topics in this chapter:

See an example of a Checklist Analysis in Volume 4 in the Checklist Analysis directory under Tool-specific Resources.

Checklist Analysis

Evaluation Points	Yes	No	Not Evaluated	Comments
Subject Area 1				
Evaluation Point 1-1	✓			
Evaluation Point 1-2	✓			
Evaluation Point 1-3		✓		Recommendation A
• • •				
Subject Area 2				
Evaluation Point 2-1			✓	
Evaluation Point 2-2	✓			
Evaluation Point 2-3	✓			
• • •				
Subject Area 3				
• • •				

Summary of Checklist Analysis

Checklist analysis is a systematic evaluation against preestablished criteria in the form of one or more checklists.

Brief summary of characteristics

- A systematic approach built on the historical knowledge included in checklist questions
- Used for high-level or detailed analysis, including root cause analysis
- Applicable to any activity or system, including equipment issues and human factors issues
- Generally performed by an individual trained to understand the checklist questions. Sometimes performed by a small group, not necessarily risk analysis experts
- Based mostly on interviews, documentation reviews, and field inspections
- Generates qualitative lists of conformance and nonconformance determinations, with recommendations for correcting nonconformances
- The quality of evaluation is determined primarily by the experience of people creating the checklists and the training of the checklist users

Most common uses

- Used most often to guide boarding teams through inspection of critical vessel systems
- Also used as a supplement to or integral part of another method, especially what-if analysis, to address specific requirements
- A special, graphical type of checklist called a Root Cause Map™ is particularly effective for root cause analysis. (A Root Cause Map is included at the end of this chapter)

Example

Responses to Checklist Questions for the Vessel's Compressed Air System

Questions	Responses	Recommendations
Piping Have thermal relief valves been installed in piping runs (e.g., cargo loading and unloading lines) where thermal expansion of trapped fluids would separate flanges or damage gaskets?	**Piping** Not applicable	**Piping** —
• • •	• • •	• • •
Compressors Are air compressor intakes protected against contaminants (rain, birds, flammable gases, etc.)? • • •	**Compressors** Yes, except for intake of flammable gases. There is a nearby cargo tank vent • • •	**Compressors** Consider rerouting the cargo tank vent to a different location • • •

Limitations of Checklist Analysis

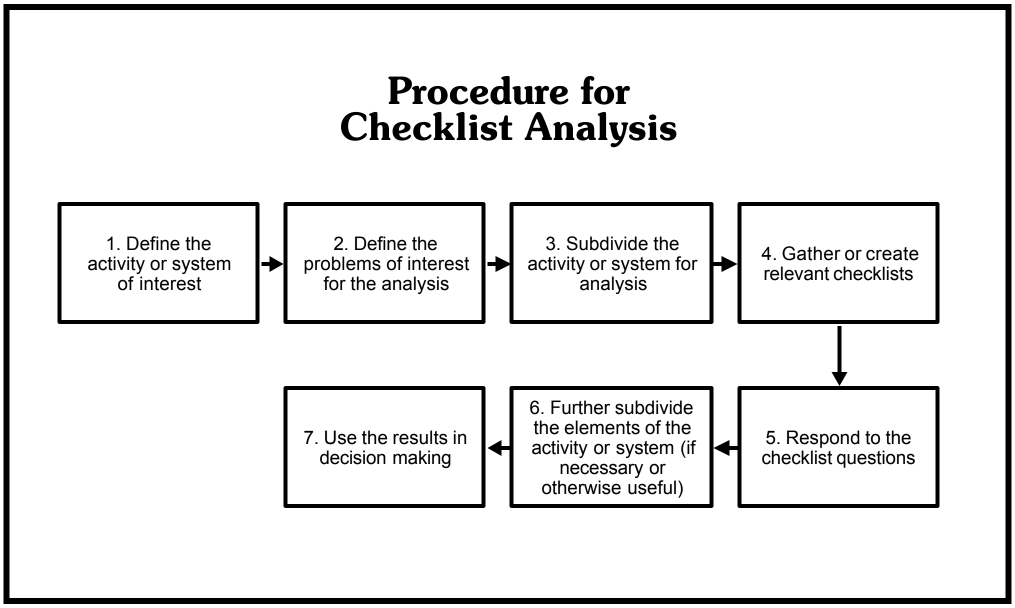
- **Likely to miss some potential problems**
- **Traditionally provides only qualitative information**

Limitations of Checklist Analysis

Although checklist analysis is highly effective in identifying various system hazards, this technique has two key limitations:

Likely to miss some potential problems. The structure of checklist analysis relies exclusively on the knowledge built into the checklists to identify potential problems. If the checklist does not address a key issue, the analysis is likely to overlook potentially important weaknesses.

Traditionally only provides qualitative information. Most checklist reviews produce only qualitative results, with no quantitative estimates of risk-related characteristics. This simplistic approach offers great value for minimal investment, but it can answer more complicated risk-related questions only if some degree of quantification is added, possibly with a relative ranking/risk indexing approach.



Procedure for Checklist Analysis

The procedure for performing a checklist analysis consists of the following seven steps. Each step will be further explained on the following pages.

1.0 Define the activity or system of interest. Specify and clearly define the boundaries for which risk-related information is needed.

2.0 Define the problems of interest for the analysis. Specify the problems of interest that the analysis will address. These may include safety problems, environmental issues, economic impacts, etc.

3.0 Subdivide the activity or system for analysis. Section the subject into its major elements. These may include locations on the waterway, tasks, or subsystems. The analysis will begin at this level.

4.0 Gather or create relevant checklists for the problems of interest. Identify and collect lists of important questions or issues related to the type of potential problems within the scope of the analysis. If useful checklists are not available, consider developing your own checklists with the assistance of subject matter experts.

5.0 Respond to the checklist questions. Use a team of subject matter experts to respond to each of the checklist questions. Develop recommendations for improvement wherever the risk of potential problems seems uncomfortable or unnecessary.

6.0 Further subdivide the elements of the activity or system (if necessary or otherwise useful). Further subdivision of selected elements of the activity or system may be necessary if more detailed analysis of one or more elements is desired. Section those elements into successively finer levels of resolution until further subdivision will (1) provide no more valuable information or (2) exceed the organization's control or influence to make improvements. Generally, the goal is to minimize the level of resolution necessary for an analysis.

7.0 Use the results in decision making. Evaluate the recommendations from the analysis and implement those that will bring more benefits than costs over the life cycle of the activity or system.

1.0 Define the activity or system of interest

- Intended functions
- Boundaries

1.0 Define the activity or system of interest

Intended functions. Because all risk assessments look at ways in which intended functions can fail, a clear definition of these intended functions is an important first step in any risk assessment. This step does not have to be formally documented in most checklist analyses.

Boundaries. Few activities or systems operate in isolation. Most interact with others. Boundaries may include areas where a vessel will transit or boundaries with support systems such as electric power and compressed air. By clearly defining the boundaries of the study, the analyst helps to avoid the following:

- Overlooking key elements of an activity or system at interfaces
- Penalizing an activity or system by associating other equipment with the subject of the study

Examples

Deep Draft Oil Tankers		
Intended Functions	Boundaries of Analysis	
	Within Scope	Outside of Scope
• Harbor transit • Docking • Unloading • Loading	• Operations within the controlled harbor's waterways • Onboard loading and unloading systems	• Operations outside of the harbor • Shoreside loading, unloading, and storage systems • Cargo other than liquids

Definition for an onboard compressed air system study

Compressed Air System		
Intended Functions	Boundaries of Analysis	
	Within Scope	Outside of Scope
• Provide compressed air at 100 psig • Remove moisture and contaminants from the air • Contain the compressed air	• Breaker supplying power to the compressor • Air hoses and piping at pneumatic equipment	• Power supply bus for the compressor • Air hose connections on pneumatic equipment

2.0 Define the problems of interest for the risk assessment

- **Safety problems**
- **Environmental issues**
- **Economic impacts**

2.0 Define the problems of interest for the analysis

Safety problems. The risk assessment team may be asked to look for ways in which improper performance of a marine activity or failures in a hardware system may result in personnel injury. These injuries may be caused by many mechanisms, including the following:

- Vessel collisions or groundings
- Person overboard
- Exposure to high temperatures (e.g., steam leaks)
- Fires or explosions

Environmental issues. The risk assessment team may be asked to look for ways in which the conduct of a particular activity or the failure of a system can adversely affect the environment. These environmental issues may be caused by many mechanisms, including the following:

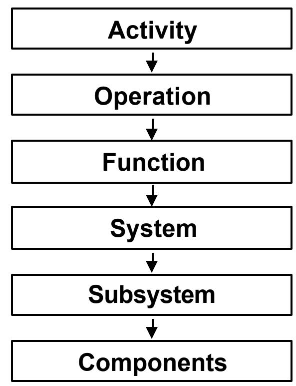
- Discharge of material, intentionally or unintentionally, into the water
- Equipment failures, such as seal failures, that result in a material spill
- Overutilization of a marine area, resulting in a disruption of the ecosystem

Economic impacts. The analysis team may be asked to look for ways in which the improper conduct of a particular activity or the failure of a system can have undesirable economic impacts. These economic risks may be categorized in many ways, including the following:

- Business risks such as vessels detained at port, contractual penalties, or lost revenue
- Environmental restoration costs
- Replacement costs for damaged equipment

A particular analysis may focus only on events above a certain threshold of concern in one or more of these categories.

3.0 Subdivide the activity or system for analysis



3.0 Subdivide the activity or system for analysis

An activity or system may be divided at many levels of resolution. Generally speaking, analysts should try to describe risk-related characteristics for an activity or system at the broadest level possible. The procedure for subdividing an activity or system for risk assessment is typically repetitive, beginning with a broad subdivision into major sections or tasks.

This strategy of beginning at the highest level helps promote effective and efficient risk assessment by (1) ensuring that all key attributes are considered in the risk assessment, (2) encouraging analysts to avoid unnecessary detail, and (3) using a structure that helps to avoid overlooking individual components or steps if further subdivision is necessary.

Example

Systems associated with the vessel's compressed air system

- Compressor system
- Dryer system
- Distribution system

4.0 Gather or create relevant checklists

- **Internal checklists**
- **External checklists**
- **Customized checklists**

4.0 Gather or create relevant checklists

Following are the three major types of checklists that you will likely be able to use in your risk assessment:

Internal checklists. Many formal and informal checklists commonly exist internally. In some cases, Coast Guard or regulatory standards mandate the use of specific checklists at key points. Examples include boarding checklists, design checklists, fabrication or installation checklists, pre-startup checklists, etc. These checklists may be updated regularly to help build organizational knowledge and to prevent problems from recurring. Frequently, there are less formal checklists used within selected geographic, functional, or organizational groups. The following are some examples:

- Checklists of key equipment that must be inspected on foreign flagged vessels while they are in port
- Checklists of key equipment specification and configuration requirements for selected applications. These are often based on vendor-specific design standards
- Checklists of best practices for making systems more maintainable
- Checklists of best practices for making systems easier to operate. These would include human factors and ergonomic issues

Many of these checklists may be general purpose and applicable to a variety of situations; others will be for more specific applications.

Checklists should generally be created and maintained by a team of experts. This is especially true of checklists that will be broadly applied. This team approach builds the checklists from many years of experience and forces consensus on important issues rather than relying on one person's ideas about what is best or necessary.

External checklists. When internal checklists do not exist or additional ideas about potential issues must be considered, external checklists may be used. External checklists may come from a variety of sources, including the following:

- Requirements in codes, standards, and regulations
- Industry best practices and guidelines
- Application guidelines from vendors
- Checklists gathered from other companies or organizations with similar applications

Of course, the key issue with external checklists is to be certain that they are applicable to your specific situation. If not, they may overlook important issues or may drive you to implement unnecessary changes.

Customized checklists. For many risk-based decisions for which a checklist analysis is appropriate, no suitable previously developed checklist will be available. In these cases, a customized checklist must be developed.

Questions for customized checklists should be derived from suitable existing checklists as much as possible. Where other checklists are not helpful, the analyst or the analysis team should discuss important issues and compose specific checklist questions to structure the risk assessment. Frequently, these questions ask whether particular safeguards are in place to protect against key weaknesses. The questions should then be sorted according to subject area and incorporated with other checklist questions obtained from other sources. If the checklist may be used for many applications in the future, you may want to use a more structured risk assessment tool, such as what-if analysis, to help build a reasonably complete checklist of important issues.

Volume 4 of these *Guidelines* has examples of various types of checklists that may help you in your risk assessment. Be sure to see whether existing checklists will be useful before spending too much time to develop your own from scratch.

Example

Equipment-specific Questions	Topic-area Questions
Piping Have thermal relief valves been installed in piping runs where thermal expansion of trapped fluids would separate flanges or damage gaskets? • • •	**Human factors** Are displays and gauges visible near the places where the process must be adjusted or controlled? • • •
Vessels Is a vacuum relief system needed to protect the vessel during cooldown or liquid withdrawal? • • •	**Maintainability** Have efforts been made to minimize the need for special tools, methods, or parts for maintaining this equipment? • • •
Compressors Are air compressor intakes protected against contaminants (rain, birds, flammable gases, etc.)? • • •	**Installation issues** Have steps been taken to isolate sensitive equipment from the vibration of rotating equipment? • • •

5.0 Respond to the checklist questions

- **Is the checklist question applicable?**
- **Are there system weaknesses related to this question?**

5.0 Respond to the checklist questions

Each checklist question must be answered by people who are knowledgeable about the subject of the risk assessment, including the design, operation, and maintenance of associated systems.

Answering checklist questions generally involves two decisions:

(1) Is the question applicable to this situation?

(2) If so, are there weaknesses related to this question? This is typically indicated by "no" answers to checklist questions.

When weaknesses are identified, the respondents generate recommendations for improvements to address those weaknesses.

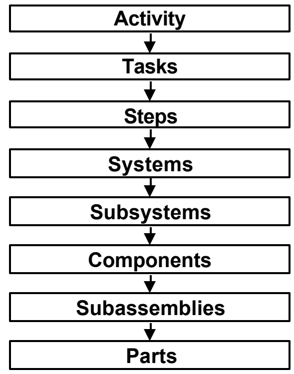
There are three basic levels of documentation possible for a checklist analysis, as shown in the following table.

Level of Documentation	Description
Complete	Full responses for every question and a complete list of recommendations generated from the analysis
Steamlined	Responses to questions that result in suggestions for improvement, along with the complete list of recommendations generated from the analysis
Minimal	Complete list of recommendations generated from the analysis

Example of complete checklist documentation

Responses to Checklist Questions for the Vessel's Compressed Air System		
Questions	**Responses**	**Recommendations**
Piping Have thermal relief valves been installed in piping runs (e.g., cargo loading and unloading lines) where thermal expansion of trapped fluids would separate flanges or damage gaskets? • • •	**Piping** Not applicable • • •	**Piping** — • • •
Compressors Are air compressor intakes protected against contaminants (rain, birds, flammable gases, etc.)? • • •	**Compressors** Yes, except for intake of flammable gases. There is a nearby cargo tank vent • • •	**Compressors** Consider rerouting the cargo tank vent to a different location • • •

6.0 Further subdivide the elements of the activity or system



6.0 Further subdivide the elements of the activity or system (if necessary or otherwise useful)

Further subdivision of activities or systems occurs only under the following conditions:

- Applicable data at the higher levels are not available
- Decision makers need information at a more detailed level

Often, only a few activities or systems must be subdivided.

If the above criteria apply to one or more subsystems, they may be further divided into components. In a similar manner, broad activities or tasks may be divided into individual steps. At each level, the process of performing the checklist analysis is repeated.

Example

Subsystems associated with the vessel's compressor system

- Electrical supply to the compressor
- Lubrication system
- Seal system
- Drive system, including the motor
- Mechanical compression system
- Control system
- Relief system
- Filter system

Checklist analyses of any or all of these subsystems might occur if they were important from a risk perspective.

7.0 Use the results in decision making

- **Judge acceptability**
- **Identify improvement opportunities**
- **Make recommendations for improvements**
- **Justify allocation of resources for improvements**

7.0 Use the results in decision making

Judge acceptability. Decide whether the activity or system meets established requirements.

Identify improvement opportunities. Identify the elements of the activity or system most likely to contribute to future risk-related problems, based on identified deficiencies.

Evaluate recommendations for improvements. Evaluate the specific suggestions for improving the activity or system performance, including any of the following:

- Equipment modifications
- Procedural changes
- Administrative policy changes such as planned maintenance tasks, operator training, etc.

Justify allocation of resources for improvements. Estimate how implementation of expensive or controversial recommendations will affect future performance. Compare the risk-related benefits of these improvements to the total life-cycle costs of implementing each recommendation.

Special Applications of Checklist Analysis

- **Error-likely Situation Checklist**
- **Root Cause Map™**

Special Applications of Checklist Analysis

There are several special applications of checklist analysis. One is error-likely situation checklist analysis, which is designed to assess the potential risk to a system from human errors. There are also various other forms of human factors and ergonomics checklists, and a few of these are included in Volume 4 of these *Guidelines*. Another special application of checklist analysis, Root Cause Map, is a structured approach to determine the root causes of human errors and equipment failures.

Error-likely Situation
Checklist Analysis

Error-likely Situation	Key Areas of Applicability	Weaknesses in Current Practices	Related Deviations	Actions

Error-likely Situation Checklist Analysis

The error-likely situation checklist analysis technique applies a checklist of human factors issues to key areas of an activity. The checklist can be generic or customized, and it is designed to uncover weaknesses that may cause deviations from normal operations. Personnel applying the technique should understand the following terminology:

Error-likely situation — a human factors issue that can increase the likelihood of human errors. These issues guide discussion of weaknesses of a particular operation.

Key areas of applicability — areas of an activity in which a particular human factors issue may be relevant

Weaknesses in current practices — negative features of an activity related to a particular human factors issue

Related deviations — potential accidents for which the identified weaknesses heighten the risk

Actions — suggestions for design changes, procedural changes, or further study

Limitations

- Requires knowledge of current practices
- Is difficult to apply to a new operation or activity, because the operating environment is often not well understood

Most common uses

This checklist analysis technique is typically applied to general activities, such as the following:

- Lifting with cranes
- Launching lifeboats
- Unloading a barge

It is most effective when applied to activities that are highly dependent on human actions and communications.

Procedure

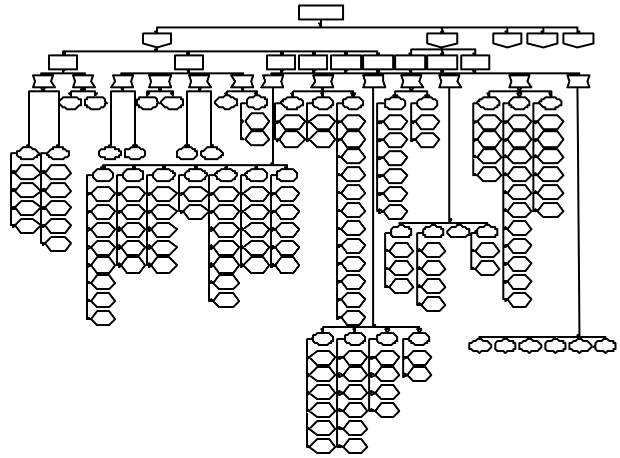
1. Choose a general activity to analyze.
2. Select a human factors issue from the error-likely situations checklist. (See the example of an error-likely situation checklist in Volume 4 of these *Guidelines*. Volume 4 also contains other types of human factors and ergonomics checklists.)
3. Identify areas of the operation where the human factors issue may be applicable.
4. For each area identified, note weaknesses related to the human factors issue.
5. Brainstorm potential accidents that could occur because of current weaknesses.
6. Judge the current risk associated with each potential accident and generate suggestions for improvement if needed.

Example

The following table includes a partial example of a completed error-likely situation checklist.

Error-likely Situation	Key Areas of Applicability	Weaknesses in Current Practices	Related Deviations	Actions
Deficient Procedures	Procedures for launching and recovering the lifeboat	The procedures for launching and recovering the lifeboat could have a more user-friendly format A few minor inconsistencies exist in procedures for launching and recovering the lifeboat (e.g., the recovery procedures do not have a step requiring the deck crew to insert the locking pins for the davits)	Various types of incidents possible	Make procedures user friendly and incorporate changes to make procedures consistent
Inadequate, Inoperative, or Misleading Instrumentation	Bridge instrumentation Special deck instrumentation	No important weaknesses identified for bridge instrumentation Deck crews and boat crews do not use any special instrumentation while performing small boat launch and recovery operations	Excessive sway during lowering and raising	______
• • •	• • •	• • •	• • •	• • •

Root Cause Map™



Root Cause Map™ Technique

The Root Cause Map technique was originally derived from the management oversight and risk tree (MORT) for the Department of Energy's Savannah River Laboratory. The map structures the reasoning process for identifying root causes by identifying detailed root causes, such as management system weaknesses and deficiencies, for each major root cause category. Use of the map ensures consistency across all root cause investigations and supports trending of *root causes* and *categories*.

A copy of the Root Cause Map is included at the end of this chapter.

Observations about the structure of the map

- Items associated with hardware and engineered systems appear toward the left side of the map, while items associated with personnel appear toward the right side of the map
- Moving from left to right on the map parallels the progression of system development. That is, it begins with equipment design and progresses through operations management and personal performance.
- Some segments of the map are not resolved to *root causes*. This maintains consistency in the level of detail with other segments of the map. Further expansion is certainly acceptable.
- A different arrangement of the map would not change its fundamental use as a graphical checklist to help provide a comprehensive search for root causes
- Various organizations may need to modify the map structure and terminology slightly to mesh with their organizational culture and management systems

Limitations of the Root Cause Map Technique

- **Requires another tool to identify causal factors of an accident**
- **Structure and terminology may not mesh with organizational culture and management systems**
- **Considers only the root causes listed in the map**

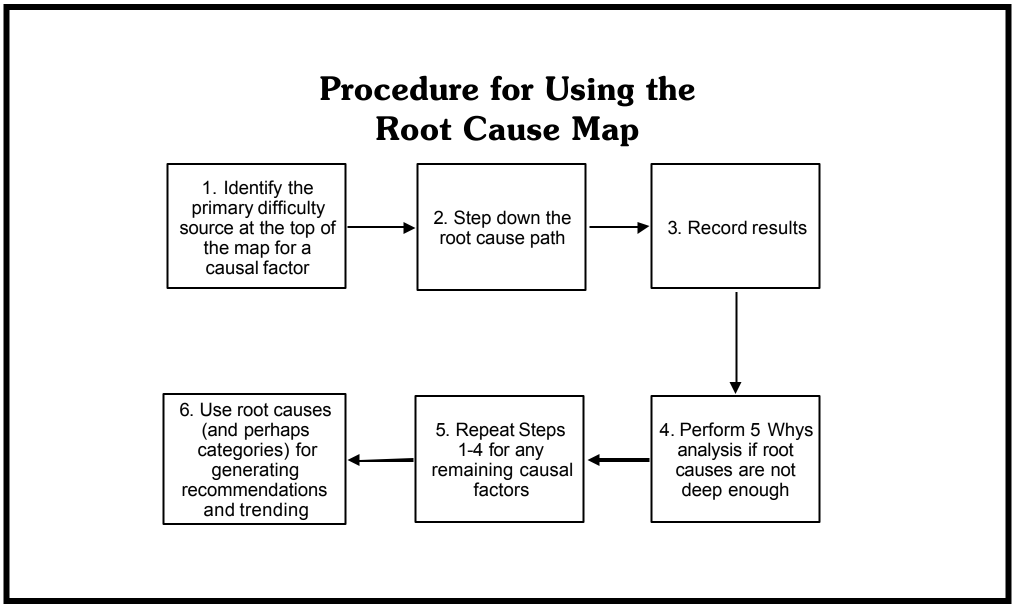
Limitations of the Root Cause Map Technique

The Root Cause Map technique provides a structured process for efficiently identifying root causes, but it has three primary weaknesses:

Requires another tool to identify causal factors of an accident. Causal factors are the specific equipment failures, human errors, and external conditions that led to an accident. The Root Cause Map assumes that you have already found these causal factors and are now ready to look for the underlying root causes of each causal factor. Occasionally, the Root Cause Map can be used without identifying causal factors, but another cause-event tool such as event and causal factor charting will usually be needed to identify the causal factors.

Structure and terminology may not mesh with organizational culture and management systems. For some organizations, the structure and terminology of the map may need to be customized to fit the organization. Customization can improve the efficiency and effectiveness of the map.

Considers only the root causes listed in the map. The Root Cause Map is a checklist. As in all checklists, important issues not included in the checklist are not considered. For some situations, a branch of the map or a root cause may be missing. This is infrequent, but possible.



Procedure for Using the Root Cause Map Technique

The procedure for conducting a root cause investigation consists of the following steps:

1. **Identify the primary difficulty source at the top of the map for a causal factor.** Using the causal factors identified from a cause-event tool, identify the level A (primary difficulty source) cause that most closely matches the causal factor. If you have not yet identified causal factors, review the level A (primary difficulty source) or level B (problem category) causes of the map and identify the most likely causal factors associated with the accident under review.

2. **Step down the root cause path.** Once the level A cause is identified, step down each level of the map, working to a root cause. Often, more than one path will apply for a causal factor.

3. **Record results.** Record the causes identified at each level so that cause chains are created. Each chain should have a cause from each category identified.

   – primary difficulty source

   – problem category

   – major root cause category

   – near root cause

   – root cause

4. **Perform 5 Whys analysis if root causes are not deep enough.** Once a root cause is reached, decide if it is necessary to investigate further. If so, use a tool such as the 5 Whys technique to further break down the root cause identified from the map. The 5 Whys technique is a simple form of fault tree analysis described in Volume 3, Chapter 11. You probably will not need to do this often.
5. **Repeat Steps 1 through 4 for any remaining causal factors.** For each causal factor identified, work through the map to determine the root causes.
6. **Use root causes (and perhaps categories) for generating recommendations and trending.** For each root cause, consider recommendations for eliminating the root cause. It may be possible to develop recommendations that will affect entire categories of root causes. Over time, the root causes can be used to identify trends for the type of root causes that are occurring.

The table on the following page shows the results from using the Root Cause Map to determine the root causes of one causal factor contributing to a broader incident.

Example Root Cause Summary Table

Causal Factor A	Paths Through Root Cause Map™	Recommendations
Two engineers entered a gas-filled compartment without ascertaining if a sufficient oxygen level was available to sustain life **Background** Twenty thousand barrels of No. 6 oil were being offloaded from a tank barge. Suction problems were encountered in the product suction line when the product depth reached 1 foot. The engineers entered the tank and assessed the problem. After being in the tank for 4 minutes, they returned to the deck for equipment. After about 10 minutes, they reentered the tank. Upon reaching the pipe, one engineer fell unconscious. While the other engineer was calling for help, he fell unconscious face down in the oil. A safety team with self-contained breathing apparatuses (SCBAs) was dispatched and retrieved the two men nearly 30 minutes later. The engineer who had been face down in the oil was dead on arrival. The survivor stated he was not aware of any dangers involved with tanks containing No. 6 oil. There were no requirements to perform an oxygen level check before entering the tank	Possible root cause #1 ▪ Personnel difficulty ▪ Operations problem ▪ Administrative or management system ▪ Standards, policies, or administrative controls (SPAC) ▪ No policy requiring an atmosphere test before entering tank barge (no SPAC) Possible root cause #2 ▪ Personnel difficulty ▪ Operations problem ▪ Training ▪ Lack of training ▪ Training requirements were not identified for entering a tank barge	Require an oxygen level test be performed before entering a tank barge Install a safety placard on the tank barge hatch that warns of low oxygen atmosphere Require loading and unloading stations to provide at least two well-maintained SCBAs and a device to test the oxygen level in a tank Require personnel entering a tank barge to be tied off with a rope