

TRENDING THE CAUSES OF MARINE INCIDENTS

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SUMMARY

There are many objectives in performing incident investigations, including: to identify the causal factors so that those factors can be remedied by management to avoid recurrence, for purposes of training system development, and to identify trends of causal factors across, for example:

- Types of operations
- Navigating regions
- Types of trade
- Trade routes
- Time

The longstanding approach to incident investigation (data gathering, analysis, fault/causal factor identification, recommending improvements, reporting) has proved adequate to identify causal factors and to develop recommendations to avoid recurrences. This approach, however, makes difficult the analysis and identification of trends in the causes of incidents. The chief impediments are that:

- Taxonomies of causes are not uniformly specified and applied.
- Products of investigations typically exist as written reports, requiring the reading of reports and subsequent codification within a causal taxonomy.
- Methodological differences in investigation (particularly depth-of-analysis) lead to differences in the specificity of causal factors identified.

To obviate these, ABS has developed MaRCAT (Marine Root Cause Analysis Technique), providing a technique for investigating incidents of any magnitude (near miss to major calamity) using a consistent approach imposing a detailed taxonomy of maritime specific intermediate and final root causes.

1. INTRODUCTION

Incident investigation is a process that is designed to help organizations learn from past performance and develop strategies to improve safety. The marine industry experiences incidents that range from major accidents to near misses. Other reasons these incidents should be investigated include: many flag administration regulations require it, international agreements mandate it (such as the International Maritime Organization's SOLAS Chapter IX, Management for the Safe Operation of Ships, more widely known as the "International Safety Management Code") [1], and industry initiatives, such as the Oil Companies International Marine Forum's Tanker Management Self Assessment (TMSA) scheme [2], encourage it.

Investigation, however, is not enough. The need to *consistently* analyze and document accidents and near misses is made clear if one reviews marine accident databases. ABS performed a multi-year project to identify publicly available databases of marine accidents, review the database structures, and analyze the contents. The objective of the project was to better understand the

role of the human in accident causation and consequence mitigation. While this was accomplished in the end, the task of comparing causes and consequences across databases highlighted the fact that there is no internationally recognized investigation method and as a result the cited accident causes themselves differed without consistency both within databases and across databases. Such inconsistencies make comparisons between databases difficult. It was only by reading individual reports and performing meta analyses and developing a common taxonomy of causes across the following databases that comparison of results and determination of causes was possible:

- US Coast Guard
- UK Marine Accident Investigation Board (MAIB)
- Transportation Safety Board (TSB) Canada
- Australian Transportation Safety Board (ATSB)
- Marine Accident Reporting Scheme (MARS)

Common patterns that were found included:

- Human error continues to be the dominant factor in maritime accidents, contributing to 80 to 85 percent of accidents.

- Based on USCG data, for all accidents over the reporting period of 1999 to 2001, approximately 80 to 85% of the accidents analyzed involved human error. Of these, about 50% of maritime accidents were *initiated* by human error, and another 30% of were *associated* with human error.
- In MARS reports (voluntary mariner self reporting of accident and near misses), mariners note human error in the majority of reports, and chiefly attribute accidents and near misses to: lack of competence, knowledge and ability; human fatigue; workload; manning; complacency, and; risk tolerance.
- USCG data on offshore pollution events in California suggests that 46% are caused or associated with human error.
- For accidents associated with pollution events in the State of California, accident causes are chiefly attributed to failures of situation awareness (94%).
- Among all human error types classified in numerous databases and libraries of accident reports, failures of situation awareness and situation assessment overwhelmingly predominate, being a causal factor in about 45% (offshore) to about 70% (ships) of the recorded accidents associated with human error (see Figure 1, below).

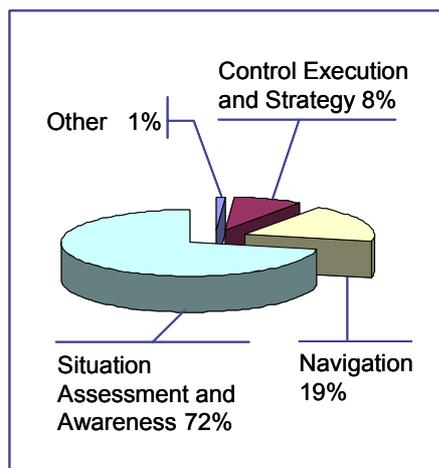


Figure 1. Human Errors – Tankers and Freighters (USCG Data)

Related findings indicate that means to analyze and classify incidents should be provided in databases that:

- Allow trending of accidents over time and conditions (time of day, weather).
- Impose means to make identification of root causes consistent, using consistent analysis methodologies, and a marine specific taxonomy of root causes.
- Enhances accessibility of the data collected thereby allowing analysis of that data.

These finding heavily influenced the development of The ABS Marine Root Cause Analysis Technique (MaRCAT). MaRCAT provides an effective and

efficient approach for investigating, analyzing and documenting marine incidents of any magnitude. ABS developed the MaRCAT methodology by customizing and combining the best techniques available and by proving and improving the overall approach through MaRCAT’s application during numerous investigations. The ABS MaRCAT approach to incident investigation caters to the unique needs of the marine industry, including human element; machinery and engineering; structural and security concerns. The objectives of the ABS MaRCAT approach are as follows:

- Assist clients with investigating a variety of types (e.g., groundings, collisions, etc.) and sizes of incidents (minor to major, and near misses) related to their vessels and facilities (ashore and at sea).
- Allow analysis of losses as they are related to safety, the environment, human element concerns, security, reliability, quality or business losses.
- Provide ABS clients with a technique that will guide incident investigators in the conduct of root cause analyses and in provide a structured approach for identifying, documenting and trending the causes of accidents and near misses.
- Assist and facilitate decision-making about contributing factors, causes, and consequences using constrained language and a database structure to facilitate trending of results.
- Support Class-related activities such as supporting compliance with the International Safety Management Code and the International Ship and Port Facility Security Code [3].
- Provide a technique that is sufficiently flexible to allow customization to a client’s own management system, Health, Safety and Environment programs or related initiatives.

This paper describes the application of MaRCAT to incident investigation and the trending of those events. Beginning with event categorization (severity) and initiation of an investigation, MaRCAT proceeds through gathering and analyzing data, identifying root causes, drawing conclusions, and developing recommendations to prevent recurrence. The means by which each of these steps is documented within MaRCAT facilitates trending for identifying patterns amongst incidents later. The basic process followed during a MaRCAT investigation is presented as Figure 2.

The MaRCAT approach and in particular, the root cause taxonomy (documented in the ABS Root Cause Analysis Map) is based on an ABS review of the approach and causal factors of thousands of shipping accidents. While it is widely accepted that human error is associated with up to 90% of maritime accidents [4,5], the database analyses showed a poor breakdown of human element causes. MaRCAT is capable of closely identifying human element, as well as other causes, contributing to

accidents. The imposition of the root cause taxonomy allows straightforward analysis of causal factor trends. The mechanism allowing those analyses is a software tool that guides the accident investigation activities and that warehouses findings within the context of the root cause taxonomy. Documents describing the MaRCAT methodology and a graphical representation of the Root Cause Analysis Map are available, free of charge, from: <http://www.eagle.org/absdownloads/index.cfm>

The MaRCAT approach is described below.

2. CATEGORIZING INCIDENTS AND INITIATING INVESTIGATIONS

The MaRCAT approach recommends that once an incident is reported, the event should be categorized according to its impact, regulatory exposure, complexity, etc. Categorization is important for many reasons, including the need to match the depth of the investigator(s) and the availability of investigation resources. To do this, it is best if an organization already has trained investigators on staff but regardless the resources must be made available for the investigation. Having an incident investigation policy / program in place will provide the tools and define the administrative support necessary to help control the pre- and post-incident activities as well as help ensure the consistency of investigations.

3. GATHERING DATA

The ABS Guidance Notes for the Investigation of Marine Incidents emphasizes that success in identifying the root causes of an accident or near miss depends extensively on accurate and comprehensive information collection. Often critical pieces of data (like timing of events) will come from people. Interviewing skills are essential for gathering key data from people. Critical evidence can also be found by examining equipment components, computer files, chemicals/residues, and written logs/documents, but good investigation techniques must be used to get the most from these sources of data. Gathering data is not a single, discrete step in an investigation. In fact, the more efficient investigations overlap data gathering with data analysis, allowing the data-gathering effort to be driven by the analysis of significant possibilities. Unfortunately, analysts typically find more evidence than is needed for *some* facts, but rarely find all the evidence necessary to unequivocally state the chain of events and conditions leading to the incident. Sound data analysis techniques (discussed in the next section) address this concern.

4. ANALYZING FOR ROOT CAUSES

When the appropriate data have been collected (by interviewing witnesses, reviewing paper and computer records, examining/analyzing physical evidence, examining logs, reviewing maintenance records etc.) and documented, the next step in an investigation is an

analysis of that data. Analysis during an investigation is typically a three-step process.

4.1 STEP 1

The first step in any analysis, even simple investigations, is to convert the data into statements of either fact or supposition, and then to chart these facts and suppositions using a technique such as a causal factor chart. When done correctly, this exercise will help to identify which facts and suppositions are irrelevant to the suspected causal sequence(s) and will also help to identify where more data are needed to fill gaps in a sequence. Documenting the nature of the data also assists with thinking logically through the problem. Placing the findings in a chart or table provides a useful illustration to describe the sequence of events to others, if necessary. Figure 3 is an example of a causal factor chart segment for a maritime casualty.

4.2 STEP 2

The next step is to find the data, or develop educated guesses, to bridge information gaps. For very simple incidents, this step may not be necessary. For more complex incidents (and for many incidents that look straightforward) it will usually need to be determined *how* an event could have occurred. Once possible scenarios are developed, the investigation team must compare these scenarios to the available data to determine the scenario that best fits, or at least to eliminate scenarios that don't appear to fit. There are various approaches for bridging gaps in data, including failure modes, effects, effects analysis (FEMA), influence diagrams, change analysis (CA), and fault tree analysis (FTA). Each has merit, and since the techniques have broad application, each can be used as primary analytical tools in an investigation (though for most investigations, these techniques are best used as supplemental tools

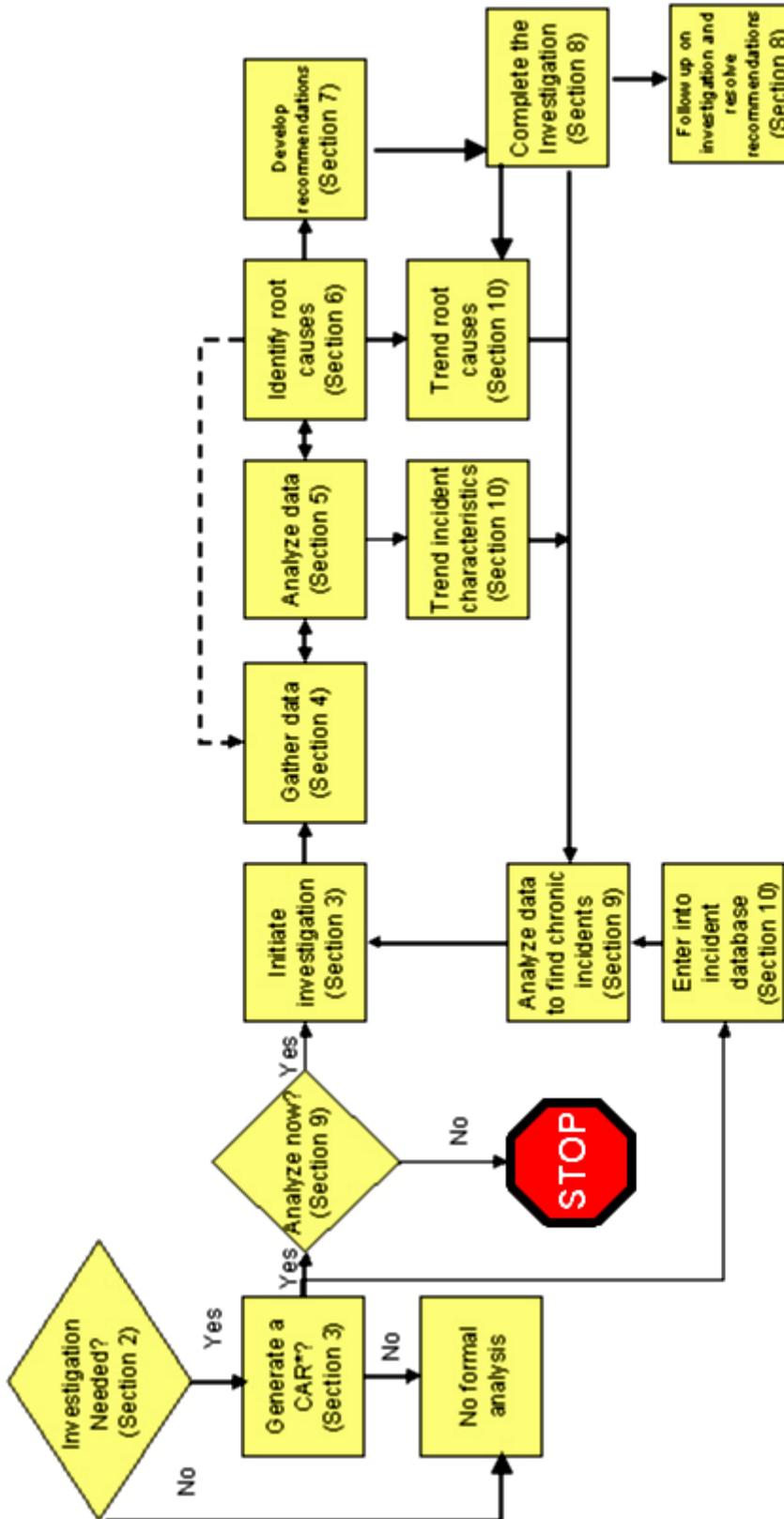


Figure 2. ABS Incident Investigation Model

4.3 STEP 3

After completing Steps 1 and 2, what happened and how it more likely happened will be better understood. The final step is to determine why the contributing conditions existed and why certain negative actions occurred. This will identify *causal factors* and subsequently, *root causes*. A variety of methods can be used for the identification of *causal factors*. The ABS Guidance Notes for the Investigation of Marine Incidents describes three techniques (5 Whys, Fault Trees and Causal Factor Charts). One of the more typical causal factor identification techniques is the 5 Whys.

The 5 Whys is a brainstorming-type technique that question “why” events occurred or conditions existed. Judgment and experience are required to use the 5 Whys technique effectively, and it can be time consuming, but it works. A major failing of the 5 Whys technique is lack of consistency.

Therefore, the causal factors found in investigations cannot be easily trended to identify recurring problems because the categories and subcategories of causal factors have not been defined. Also, the level of scrutiny is up to the individual, because the goal is to ask “why?” enough times to reach a management system deficiency. Sometimes this takes two “whys,” sometimes five or more “whys.” Figure 3 presents an example of an application of the 5 Whys technique for the first event (CF1) in Figure 2.

The ABS *Root Cause Analysis Map* is an alternative, or in actuality a supplement, to the 5 Whys technique. It provides a uniform structure to the reasoning process for identifying intermediate and root causes and it ensures consistency across all investigations. Figure 4 presents the ABS *Root Cause Analysis Map* and a key for the types of information that are in it. The darkened blocks in the ABS *Root Cause Analysis Map* depict the path from the causal factors (i.e., CF1 and CF2) to root causes. Using the ABS *Root Cause Analysis Map*, along with the ABS *Guidance Notes on the Investigation of Marine Accidents* [5] is recommended to supplement the 5 Whys technique, or other causal factor identification methods, because of the improvement in consistency and thoroughness realized in using the map.

Using the Marine Root Cause Analysis Map, the user determines the root causes of *each* causal factor. This should result in identifying multiple root causes of the incident. One must be careful, however, to avoid the pitfall of using the root cause identification map too soon: It is vital that one determines what happened and how it happened before determining why it happened. Otherwise, it may appear that the right root causes have

been identified when in reality only one of many causes may have been found. Worse, the user may have come to an unfounded conclusion and missed the actual incident causes altogether. This results in a waste of resources committed to “fix” aspects of a design or operation not related to the actual causes(s).

5. DEVELOPING CONCLUSIONS AND RECOMMENDATIONS

Finally, having determined the what, how, and why of an incident, the investigation team can proceed to the important task of developing recommendations to prevent a recurrence. The recommendations must be based on conclusions founded on the facts. To be more effective, recommendations must be feasible and must address all levels of the analysis. MaRCAT uses the following four levels of recommendations:

1. Address the causal factor
2. Address the causes of this particular event at the root cause level
3. Address other similar, existing situations at the root cause level
4. Address the management system that created the causal factors (the root causes)

By addressing each of these levels, the organization gets the greatest return for the investment made in the investigation. Table 1 lists example recommendations for the causal factors depicted in Figure 2. Each recommendation addresses the causal factor, intermediate and root causes that were identified by using the *Root Cause Analysis Map* (Figure 4). The responsibility for follow-through on recommendations can reside with the investigators or can be assigned by and tracked by management

6. GENERATING A REPORT

In most cases, an organization will want to generate a concise report that summarizes the results of the activities described up to this point. The report should include key data (such as when the incident occurred, when the investigation began, what happened, how it happened, and why it happened). The report should also be as brief as possible (to ensure it gets read by all affected individuals). Sometimes, it is also necessary to retain (and in some cases attach to the report) background information, such as the charts and tables developed during the three-step data analysis approach described above. Most companies require that raw data such as written testimony and transcripts of interviews be retained in an evidence file for the incident.

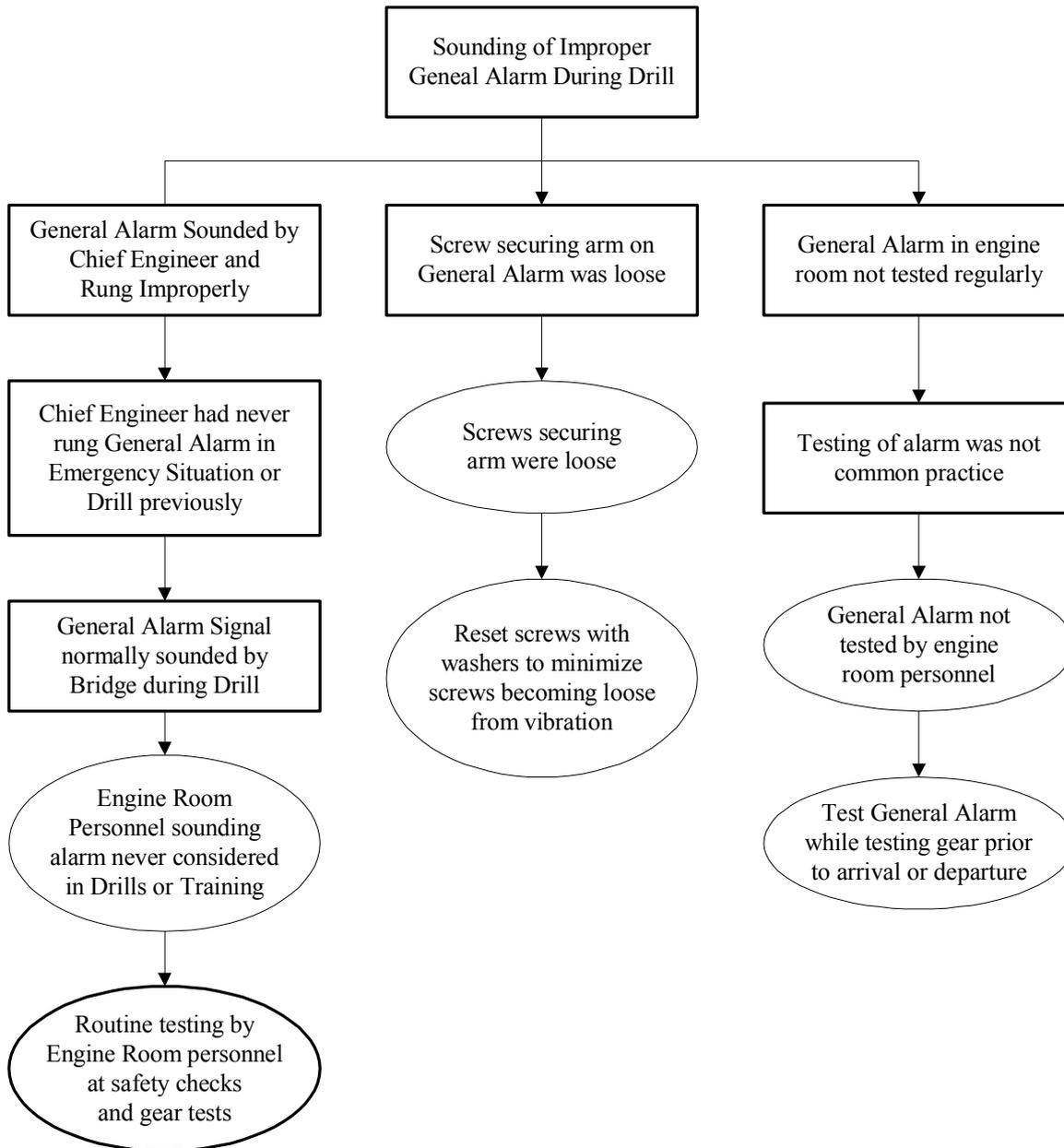


Figure 3. Example Application of the 5 Whys Technique

7. TRENDING

Trending of incident data is important to detect persistent root causes and relationships in various incidents. Trending is usually not the responsibility of the person or team conducting the investigation, but MaRCAT can facilitate trending of the results by an organization since it uses standardized approach and predefined taxonomies of intermediate and root causes.

It is suggested that at a minimum, organizations should seek to trend the following:

- Location and time
- Type of operation/system
- Type of incident
- Consequence/severity
- Root cause categories and individual root causes

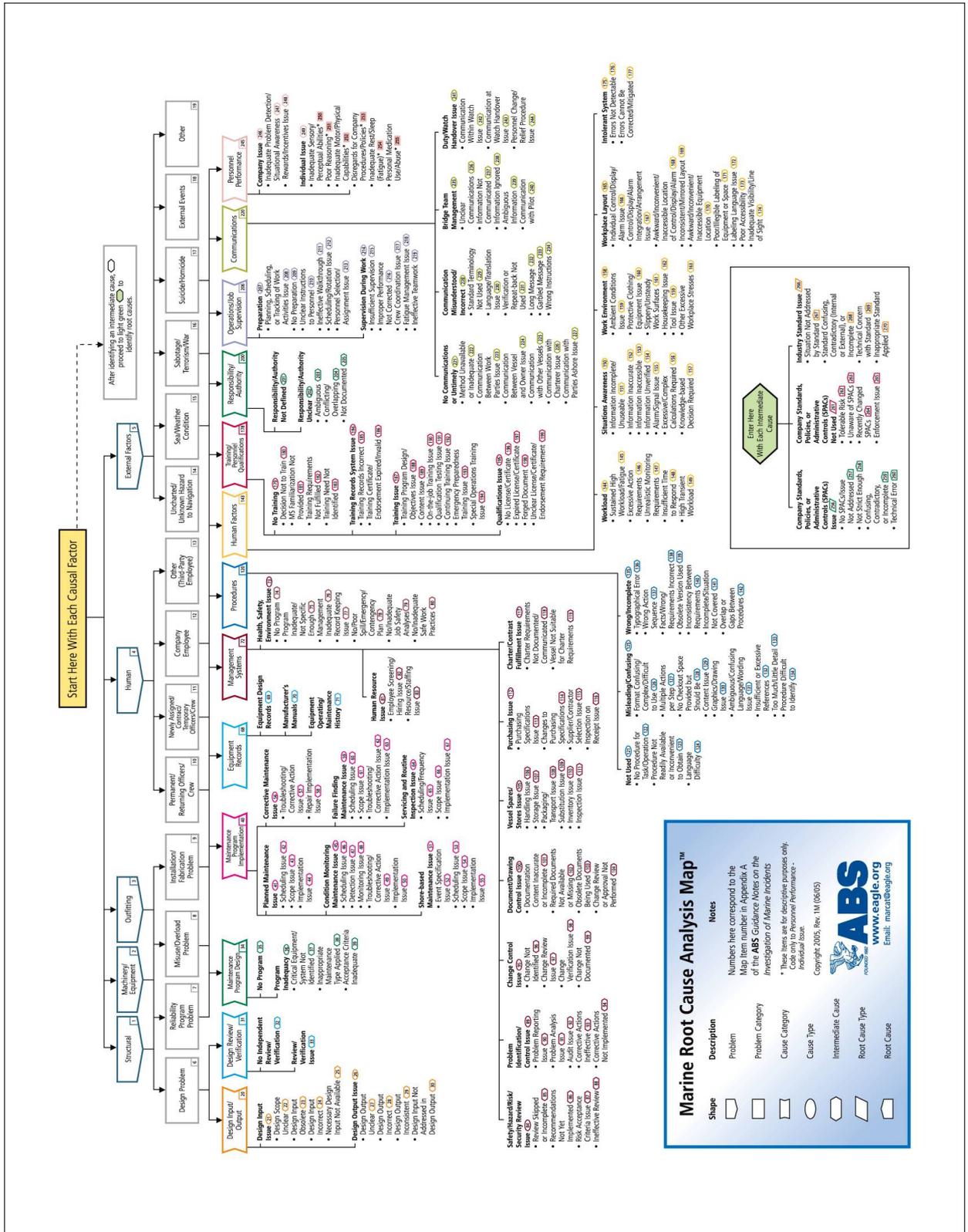


Figure 4. Marine Root Cause Analysis Map

Example Causal Factors	Paths through Root Cause Map	Example Recommendations
<p>CF 1: #1 lube oil pump fails to maintain adequate system pressure</p> <p>Background:</p> <ul style="list-style-type: none"> • Transient air leaks at flanges in close proximity to #1 lube oil pump might occur because of excessive pump vibration. • Low sump lube oil level alarm is set below specifications, which could permit the drawing of air into the supply line to #1 lube oil pump. • Quarterly testing does not check set points for automatic control devices. • Lube oil purifier strainers may not be cleaned often enough for the condition of oil used aboard ship. • Lube oil has been contaminated by water and particulate matter and is long overdue for replacement. • Continuous recirculation of lube oil through purifier system not guaranteed because of lack of spare parts to support auxiliary equipment. 	<ol style="list-style-type: none"> 1. Equipment Difficulty Equipment Reliability Program Problem Equipment Reliability Program Implementation LTA* <ol style="list-style-type: none"> a. Failure Finding Maintenance LTA Scope LTA b. Preventive Maintenance LTA Frequency LTA 2. Equipment Difficulty Equipment Reliability Program Problem Administrative Management Systems Procurement Control Purchasing Specifications LTA 3. Equipment Difficulty Equipment Reliability Program Problem Equipment Reliability Program Design LTA Allocation of Resources LTA 	<ol style="list-style-type: none"> 1. Determine the cause of the lube oil pump vibration. 2. Implement failure-finding testing procedures for detection and actuation systems. 3. Review the frequency of strainer cleaning. Monitor the effects on equipment performance to determine the effects on a reduced frequency. 4. Review lube oil purchase specifications with input from masters, procurement specialists, and others within logistics support to ensure schedules and quantities are met. 5. Ensure spare parts are stocked in accordance with the priorities determined in the equipment reliability program analysis. 6. Determine if these recommendations should be applied to other lube oil pumps and other vessels.
<p>CF 2: Automatic lube oil pump changeover feature not enabled although required to be switched on</p> <p>Background:</p> <ul style="list-style-type: none"> • Procedures require that #2 lube oil pump is in automatic standby when the ship is operating in restricted waters. • Engineers thought they knew the requirement for the pump to be in automatic standby and thought they had enabled the feature when they performed their pre-departure activities. 	<ol style="list-style-type: none"> 1. Personnel Difficulty Company Employee Procedures Misleading/Confusing Inadequate Checklist 2. Personnel Difficulty Company Employee Immediate Supervision Preparation Job Plan LTA 	<ol style="list-style-type: none"> 1. Develop a checklist for all safety-critical tasks to provide a quick reference for experienced users. 2. Adopt a standard job plan for pre-departure engineering activities. 3. Apply these lessons learned to other vessels.
<p>*LTA means "Less than adequate"</p>		

Table 1. Example Recommendations for Example Causal Factors

The key to trending is to define terms, nomenclature, and constrain the language used for describing incidents such that it will be easy to find patterns in incidents. The Root Cause Analysis Map within MaRCAT provides specific intermediate and root cause descriptions to facilitate trending efforts.

To further promote consistency in documenting, analyzing and reporting incidents, ABS developed a software tool to allow MaRCAT users to record details about the circumstances around an incident as well as the analysis, findings, conclusions, and recommendations. This is accomplished by providing a database structure that:

- Accounts for the structure and data issues within existing accident databases
- Constrains root cause language
- Provides analysis aids to identify causal factors
- Defines taxonomies and structures for identifying incident causes
- Allows the attachment of documents (photographs, drawings, etc.) to an incident record
- Provides aids to facilitate decision making
- Provides data import and export functions enabling causal trending among incidents.

Steps were also taken to ensure that data fields in the software corresponded to the data that most Flag Administrations require for accident reports. All these efforts were considered important for supporting an organization's need to be able to look for patterns amongst accidents and near misses. The discovery of such patterns will aid further loss control efforts.

8. CONCLUSIONS

The tools/techniques used, and the depth to which they are applied, will and should change to match the complexity of the incident. A general approach such as MaRCAT is flexible enough to take this into account. Using this approach consistently for all investigations will provide significant benefits by helping to identify root causes and avoid recurrence, using an effective and efficient methodology.

9. ACKNOWLEDGEMENTS

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