Risk-based Decision-making Guidelines

Volume 3
Procedures for Assessing Risks

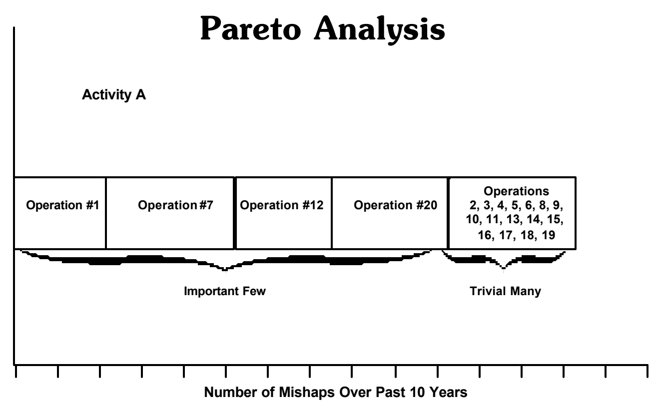
Applying Risk Assessment Tools

Chapter 3 — Pareto Analysis

Chapter Contents

This chapter provides a basic overview of the Pareto analysis technique and includes fundamental step-by-step instructions for using this methodology to assess system or activity accidents. Following are the major topics in this chapter:

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



Summary of Pareto Analysis

Pareto analysis is a prioritization technique that identifies the most significant items among many. This technique employs the *80-20* rule, which states that about 80 percent of the problems or effects are produced by about 20 percent of the causes.

Brief summary of characteristics

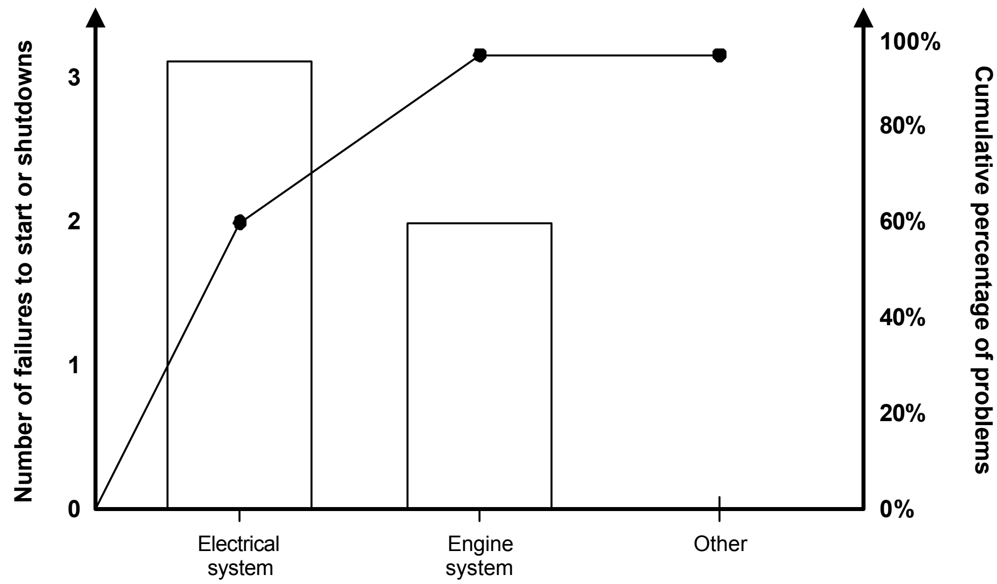
- Used as a risk assessment technique at any level, from activity level to system level
- Yields broad, quantitative results that are graphically depicted on simple bar charts
- Depending on the information analyzed, generally requires some form of data tracking (e.g., monitoring the number of accidents caused by piloting)
- Applicable to any activity or operating system

Most common uses

- Most often used to rank activity or system accidents
- Can be used to rank the causes that contribute to accidents
- Also used to evaluate the risk improvement that results from activity or system modifications with “before” and “after” data

The following graph is an example of the final results from a Pareto analysis.

Pareto Graph of Propulsion System Problems



Period: Since 1995

Limitations of Pareto Analysis

- **Focuses only on the past**
- **Variability in levels of risk assessment resolution**
- **Dependent on availability and applicability of data**

Limitations of Pareto Analysis

Although Pareto analysis is highly effective in identifying the most significant contributors to activity or system problems, this technique has three limitations:

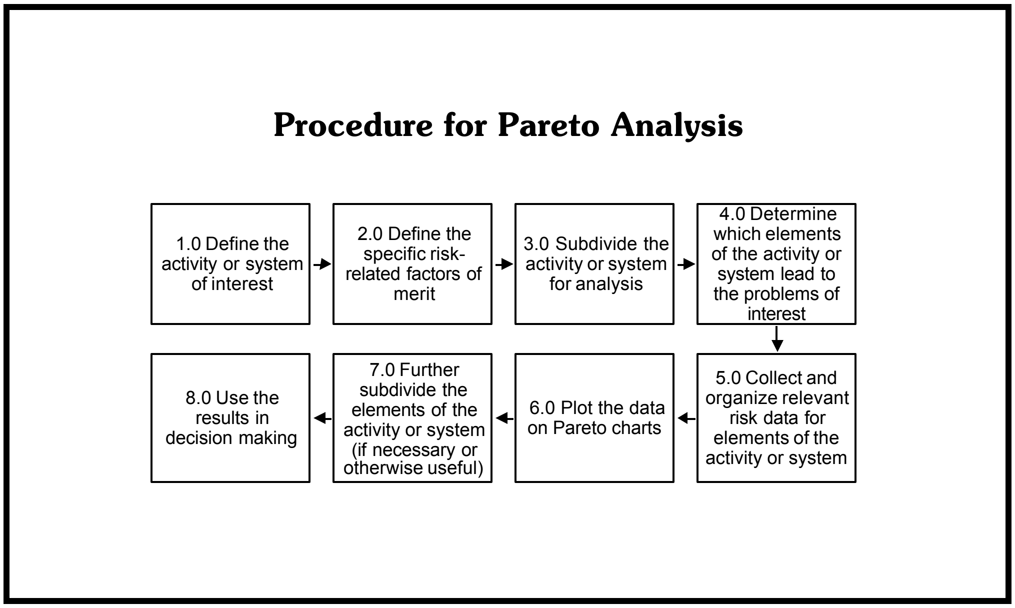
Focuses only on the past. Pareto analysis develops risk-related characteristics for an activity or system based solely on the numbers and types of problems encountered in the past. While Pareto analysis offers a valuable look at key contributors to past problems, the exclusive reliance on historical data can be misleading in the following ways:

(1) The data underrepresent events that, luckily, have not happened yet or have occurred rarely but that, statistically, are just as likely as events that have occurred more frequently. This can skew decisions and resource allocations, especially when a relatively small total number of problems has occurred for individual components or types of components.

(2) Recent changes in operating practices, maintenance plans, equipment configurations, etc., may invalidate historical trends, or at least reduce their accuracy. This situation can also skew decisions and resource allocations, both when relatively recent changes have not been in place long enough to affect the data or when data are analyzed over extremely long time intervals during which numerous changes have been made.

Variability in levels of risk assessment resolution. Deciding how to group elements of an activity or system for a Pareto analysis is an inherently subjective exercise. It produces significant variability in (1) the time required to perform the analysis and (2) the level of resolution in the results. Grouping elements at too high a level may mask significant variations among elements in each group. On the other hand, grouping elements at too low a level may falsely indicate relative importances of individual components.

Dependent on availability and applicability of data. The quality of Pareto analyses is completely dependent on the availability of relevant and reliable data for the activity or system being analyzed. A diligent focus on collecting meaningful data is critical to a successful Pareto analysis.



Procedure for Pareto Analysis

The procedure for performing a Pareto analysis consists of the following eight 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 of the activity or system for which risk-related information is needed.

2.0 Define the specific risk-related factors of merit. Specify the metrics that best characterize the problems of interest. These factors can be the number of accidents, failures, near misses, etc. Virtually any metric can serve as the basis for a Pareto analysis.

3.0 Subdivide the activity or system for analysis. Section the activity or system into its major elements, such as operations or subsystems. The analysis will begin at this level.

4.0 Determine which elements of the activity or system lead to the problems of interest. Not every element of an activity or system necessarily contributes to every type of problem that the activity or system can experience. If specific accidents are of interest, omit some elements of an activity or system from the analysis.

5.0 Collect and organize relevant risk data for elements of the activity or system. Use data to estimate the contributions of activity or system elements that were not screened from consideration in the previous step.

6.0 Plot the data on Pareto charts. Present the data graphically on bar-line charts, showing the contributions of each activity or system element to the problems of interest.

7.0 Further subdivide the elements of the activity or system (if necessary or otherwise useful). If data are not available at the current level of analysis, further subdivide selected elements of the activity or system to successively finer levels of resolution until applicable data are found. Even when data are available at higher levels of the hierarchy, further subdivision helps identify and emphasize the key contributors to risk-related characteristics. Generally, the goal is to minimize the level of resolution necessary for an analysis.

8.0 Use the results in decision making. Use the estimated risk-related factors of merit to help make key decisions.

1.0 Define the activity or system of interest

- **Intended functions**
- **Boundaries**

1.0 Define the activity or system of interest

Intended functions. All risk assessments are concerned with how an activity or system can fail to perform an intended function. A clear definition of the intended functions for an activity or system is, therefore, an important first step in any analysis. This step does not have to be formally documented for most Pareto analyses.

Example

The vessel must be able to take passengers to a destination safely.

Boundaries. Few activities or systems exist in isolation. Most interact with other activities or systems. By clearly defining the boundaries of an activity or system, the analyst can avoid (1) overlooking key elements of an activity or system at interfaces and (2) penalizing an activity or system by associating other issues with the subject of the study. This is especially true of boundaries that support activities or systems such as electric power and compressed air.

Example of boundaries for a Pareto analysis

Vessel Systems

Within boundaries

- Bridge control systems
- Electrical systems
- Fuel, water, and oil storage systems
- Propulsion systems
- Steering systems
- Structural systems

Outside of boundaries

- Heating, ventilation, and air conditioning (HVAC) systems

2.0 Define the specific risk-related factors of merit

- Safety and health incidents
- Environmental incidents
- Number of near misses
- Number of failures
- Others

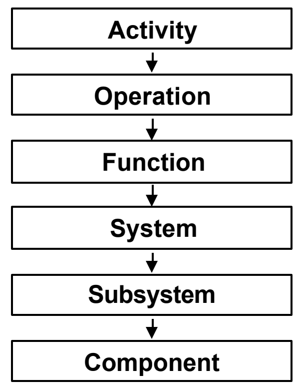
2.0 Define the specific risk-related factors of merit

Specify the metrics that best characterize the problems of interest. Virtually any metric can serve as the basis for a Pareto analysis. Sometimes, the metrics are even more restrictively defined by being linked to a specific type of activity or system problem, such as the number of failures of elements of a vessel's propulsion system. The key is to define the factors of merit that will best help decision makers make more informed decisions. A Pareto analysis can address more than one factor of merit simultaneously, but separate plots must be created for each. In other words, the systems most important for preventing safety events may not be the same systems as those most important for preventing environmental problems.

Example

Goals	(1) Reduce the threat to passenger safety by reducing the number of times the vessel loses propulsion while in transit (2) Reduce the threat to passenger safety by reducing the number of times that the vessel is unable to maneuver while in transit
Factors of Merit	(1) Number of failures experienced by the elements of the vessel's propulsion system while in transit during the last five years (2) Number of failures by the elements of the vessel's maneuvering system while in transit during the last five years

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 different levels of resolution, as illustrated above. Generally speaking, Pareto analyses should try to characterize risk-related performance for an activity or system at the broadest level possible, based on the availability of applicable data. The procedure for subdividing an activity or system for Pareto analysis is typically iterative, beginning with a broad subdivision into major operations or subsystems. An example breakdown is shown below.

This strategy of beginning at the operation or subsystem level helps promote effective and efficient risk assessments by (1) ensuring that all key issues are considered, (2) encouraging analysts to avoid unnecessary detail, and (3) using a structure that helps avoid overlooking lower-level issues (if further subdivision of the activity or system is necessary).

Example of system subdivision

Vessel systems within the boundaries of the analysis

- Bridge control systems
  - diesel engine control system
  - steering control system
- Electrical systems
  - power system
  - safety interlock system

- Fuel, water, and oil storage systems
  - Fuel tanks and piping
  - oil tanks and piping
  - water and ballast tanks and piping
- Propulsion systems
  - diesel engine
  - diesel engine cooling system
  - diesel engine ignition system
  - diesel engine lubrication system
  - fuel system
  - screw
  - transmission and drive system
- Steering systems
  - hydraulic system
  - steering lubrication system
- Structural systems
  - cable trays
  - engine mounts
  - pipe hangers
  - pump mounts

4.0 Determine which elements of the activity or system lead to problems of interest

Activity XYZ

Operations	Problems of Interest 1	Problems of Interest 2	• • •
1	✓ (Operation failure mode A)	✓ (Operation failure mode B)	• • •
2	—	—	
3	✓ (Operation failure mode C)	—	
⋮	⋮	⋮	

4.0 Determine which elements of the activity or system lead to the problems of interest

Only elements of the activity or system that have produced the problem of interest should be included in the Pareto analysis. Omit others from the analysis.

Example of items leading to the problems of interest

Vessel Systems*	Types of Problems Experienced: Failure of elements of the vessel's propulsion system during transit	Types of Problems Experienced: Failure of elements of the vessel's maneuvering system during transit
Bridge control system		
Electrical systems	✓	✓
Fuel, water, and oil storage systems		
Propulsion system	✓	✓
Steering systems		✓
Structural systems		

* Shaded items will be omitted from the analysis

5.0 Collect and organize relevant risk data for elements of the activity or system

- **Incident records**
- **Near-miss records**
- **Maintenance records**
- **Operations reports**
- **Survey records**

5.0 Collect and organize relevant risk data for elements of the activity or system

Relevant risk-related data for elements of activities or systems are available from a number of sources. These include the following:

- Accident records
- Near-miss records
- Maintenance records
- Operations reports
- Survey records

This step generally involves two activities:

- Gathering the raw data about events of interest
- Tabulating the data in a convenient format for generating the Pareto charts, as shown in the following example

Example

Raw Data for Vessel

Failures of Elements of the Vessel's Propulsion System During Transit (since 1995)

Date	Number of Events	System	Subsystem	Component	Notes
06/28/96	1	Electrical	Safety interlock	Engine overspeed switch	Defective switch
02/17/98	1	Electrical	Power	Generator	Fuel oil leak
09/04/99	1	Electrical	Power	Generator	Mechanical failure of fuel control linkage
01/07/98	1	Propulsion	Diesel engine	Ignition module failure	Defective component
04/24/99	1	Propulsion	Diesel engine	Cooling water pump drive belt	Improperly installed during routine maintenance

Summary Data for Vessel

System/Subsystem	Number of Failures of Elements of Vessel's Propulsion System During Transit
Electrical system	3 (60%)
• Power	2 (40%)*
• Safety interlock	1 (20%)*
Propulsion system	2 (40%)
• Diesel engine ignition	1 (20%)*
• Diesel engine cooling	1 (20%)*
Total	**5**

*Percentage of total number of failures

6.0 Plot the data on Pareto charts

- **Choose one factor of merit**
- **Construct the framework of a chart**
- **Arrange the contributing elements along the horizontal axis**
- **Plot the data**
- **Repeat the process for other important factors of merit**

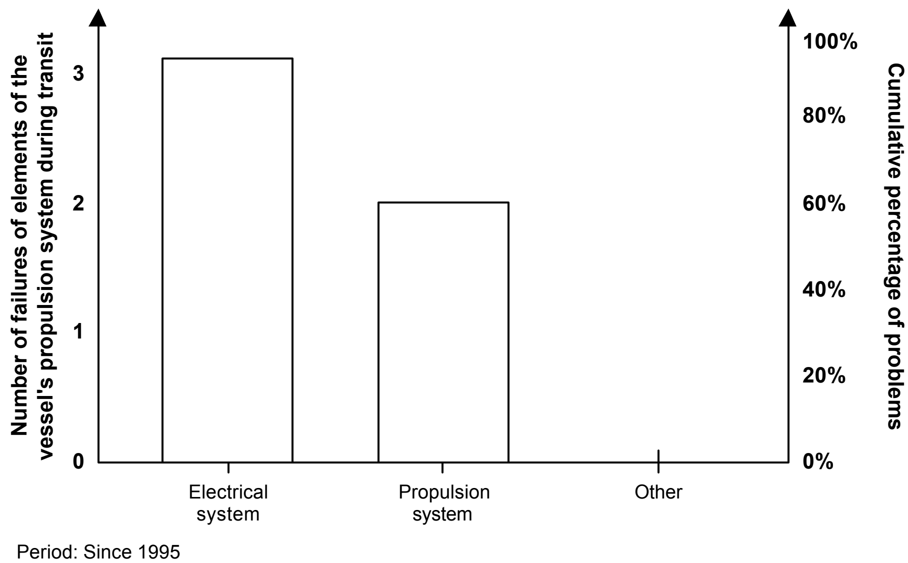
6.0 Plot the data on Pareto charts

Choose one factor of merit. Select one of the factors of merit listed previously.

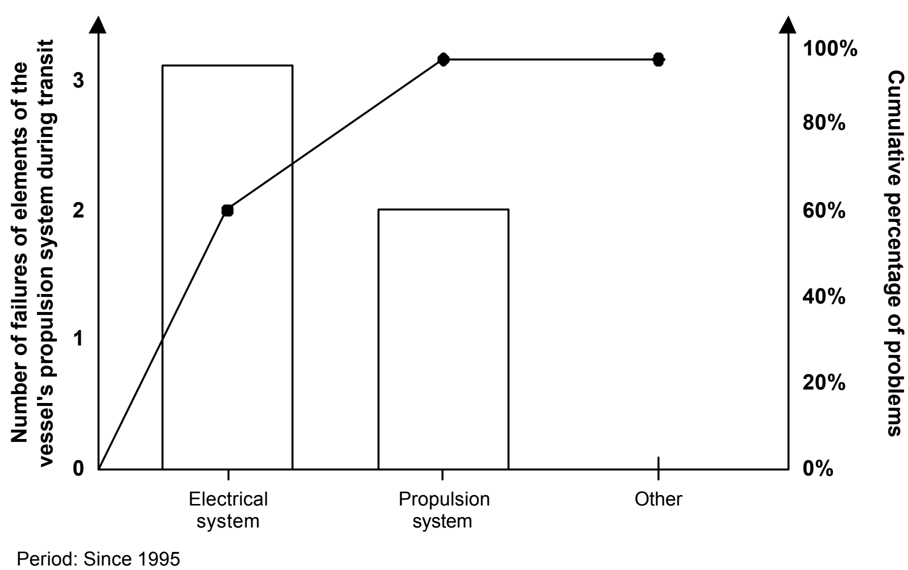
Construct the framework of a chart. Define the grid for plotting contributions of the various elements of the activity or system. A dual vertical axis plot is generally used, with the left axis defining the range for actual values of the factor of merit (e.g., the range of actual accidents for various elements of the activity or system) and the right axis defining the cumulative contribution of the elements.

Arrange the contributing elements along the horizontal axis. Begin on the left side of the horizontal axis by listing the element that contributes most to the selected factor of merit. Then, moving toward the right of the horizontal axis, list each of the other contributing elements successively in decreasing order of their contribution. You may choose to combine several less important elements into an "other" category to simplify your chart. Be sure you do not combine so many elements together that "other" becomes a dominant contributor.

Plot the data. For each element, draw a vertical bar that relates to the left axis of the chart and indicates the actual value of the factor of merit attributed to that element.



Then, draw a point based on the right axis of the chart indicating the cumulative percentage that the element with all of the other elements to its left contributes to the total value of the factor of merit for the activity or system. In this example, there were three failures out of five total failures attributed to the electrical system for this factor of merit. Therefore, the first element contributed three out of five, or 60%, of the cumulative percentage of problems. The second element contributing to this factor of merit, propulsion system, added an additional two failures. Adding these additional two failures to the three from the element to its left (electrical system) produces five out of the five total failures, or 100% of the cumulative.

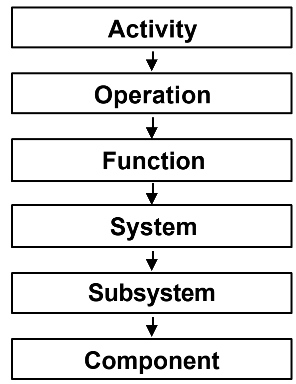


Repeat the process for other important factors of merit. Repeat the previous steps for any other factors of merit that are pertinent and for which data have been collected. In this example, another chart could be generated to show the distribution of the number of failures of elements of the vessel's maneuvering system during transit.

The “important few” failures can easily be seen on this graph. For systems with a history of affecting the vessel’s propulsion ability during transit, electrical system and engine system problems deserve the highest priority and should perhaps be subdivided.

Certainly, other types of chart formats (e.g., pie charts) can be equally effective for presenting Pareto analysis results. Use the formats with which management feels most comfortable.

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



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

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

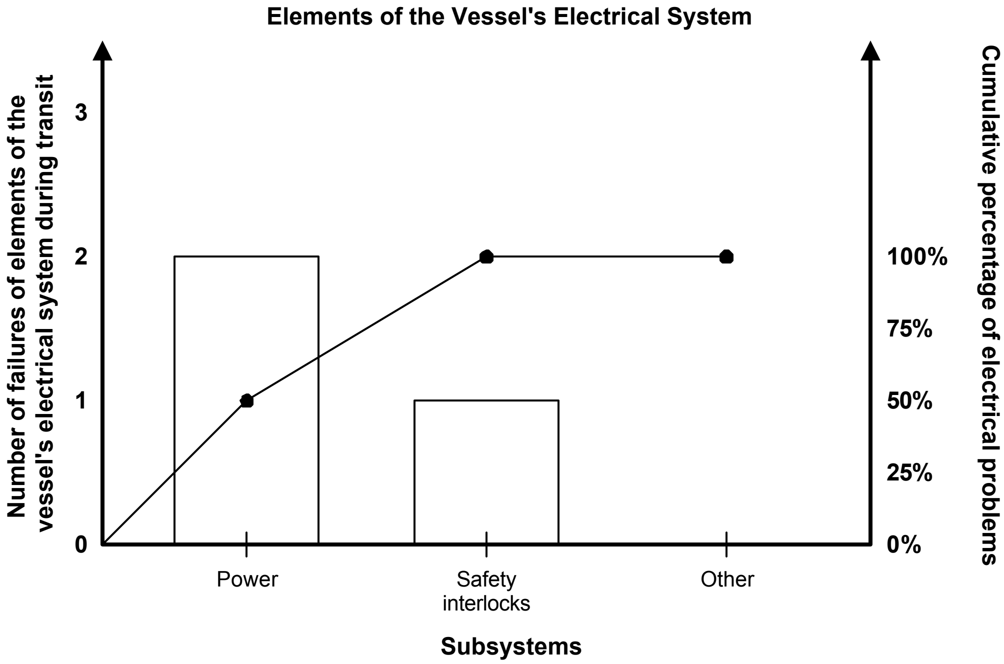
- Applicable data at an activity or system level are not available
- Decision makers need information at a more detailed level

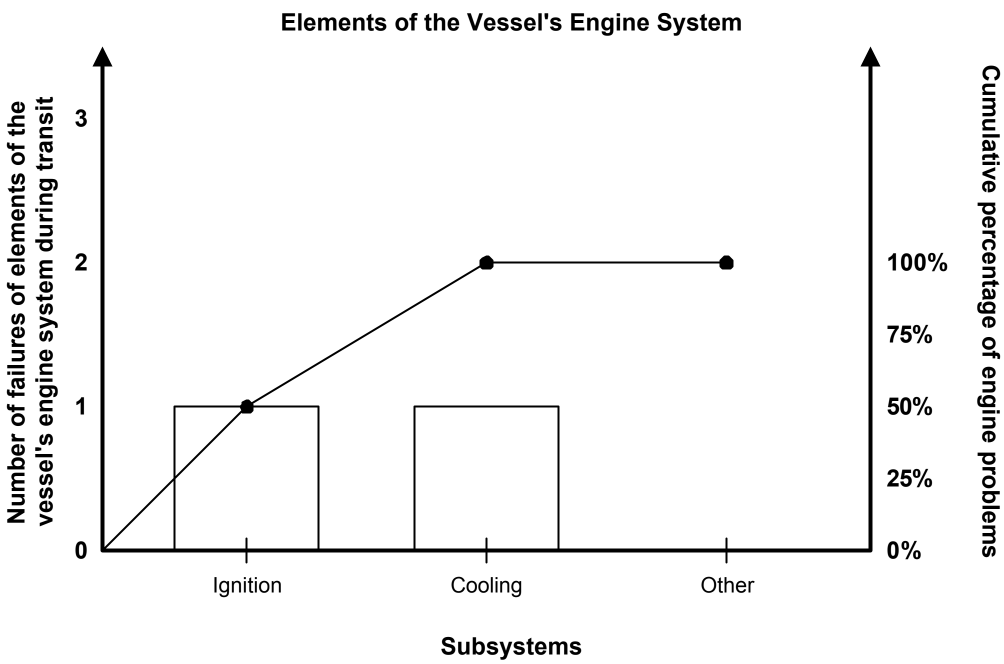
Often, only a few activities or systems must be expanded.

If the above criteria apply to one or more activities, those activities may be further divided into operations. In a similar manner, operations may be divided into functions, functions into systems, etc.

At each level, the process of collecting, organizing, and plotting data is repeated. For operation, function, subsystem, and component charts, the cumulative percentages can be based on (1) the percentage of the overall factor of merit for the entire activity or system (as shown in the graphs on the next page) or (2) the percentage of the factor of merit attributed to the next higher level of the hierarchy (that is, the percentage a function contributes to an operation or a component contributes to a subsystem)

Example


Elements of the Vessel's Electrical System
Number of failures of elements of the vessel's electrical system during transit
0
1
2
3
Cumulative percentage of electrical problems
0%
25%
50%
75%
100%
Power
Safety interlocks
Other
Subsystems


Elements of the Vessel's Engine System
Number of failures of elements of the vessel's engine system during transit
0
1
2
3
Cumulative percentage of engine problems
0%
25%
50%
75%
100%
Ignition
Cooling
Other
Subsystems

8.0 Use the results in decision making

- **Assess the applicability of the results to your current situation**
- **Judge acceptability**
- **Identify improvement opportunities**
- **Make recommendations for improvements**
- **Justify allocation of resources for improvements**
- **Monitor changing contributions over time**

8.0 Use the results in decision making

Assess the applicability of the results to your current situation. Study the data to determine whether any recent changes might invalidate the trends reflected in the risk assessment results.

Judge acceptability. Decide whether the overall value of the factor of merit for the activity or system meets an established goal or requirement.

Identify improvement opportunities. Identify elements of the activity or system that are the largest contributors to future risk-related problems. These are the "important few" elements with the largest percentage contributions to the pertinent risk-related factors of merit.

Make recommendations for improvements. Develop specific suggestions for improving future 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 for improvement will affect future risk-related performance. Compare the economic benefits of these improvements to the total life cycle costs of implementing each recommendation.

Monitor changing contributions over time. Periodically (e.g., monthly or quarterly), reevaluate activity or system performance to identify changes in the overall factors of merit as well as the key contributors to each factor of merit. This ongoing monitoring can provide the following benefits:

- Document that goals and requirements have been met and are being maintained or improved upon
- Provide quick recognition of negative trends in system performance so that root cause analyses may be launched to solve emerging problems
- Document the benefits that specific improvement recommendations are producing
- Identify instances where specific improvement recommendations are not producing the desired effects and need to be reevaluated