Fault Tree Analysis: Complete Guide with Examples and Diagrams

Fahad Usmani, PMP | October 2, 2025

Every system faces risks, and you must prepare for failures before they happen. Fault tree analysis (FTA) gives you a structured way to find root causes of problems and prevent them from spreading. By creating a visual diagram of failures and their contributing factors, you can understand how and why a system might fail.

Originally developed in the 1960s by Bell Labs for the U.S. Air Force, FTA is now utilized worldwide in various industries, including aerospace, nuclear power, automotive, and healthcare. It helps identify risks that may lead to catastrophic failures, improves safety, and supports compliance with strict regulations.

In today's blog post, I will explain what fault tree analysis is, its importance, its components, the step-by-step process, and real-world examples.

Let us get started.

What is Fault Tree Analysis?

Fault Tree Analysis (FTA) is a deductive risk analysis method that starts with a top-level failure and works downward to find all possible causes. It utilizes a visual diagram called a fault tree, which illustrates how various events combine to cause a system-level failure.

The process begins by defining the top event, or the failure you want to prevent. Then, you identify all lower-level events that could lead to that top event. These events are connected through logical gates, such as AND, OR, or NOT, which explain how causes interact with one another. By studying the diagram, you can understand how failures link together, calculate the probability of risks, and identify weak points in the system.

FTA helps teams improve safety, reliability, and decision-making. It is widely used in engineering, manufacturing, aviation, and other industries where preventing failures is critical. This structured approach makes complex risks easier to analyze and manage.

FTA Vs Other Risk Management Tools

- **FTA Vs FMEA:** Fault Tree Analysis begins with a top-level failure and works backward to identify possible causes. Failure Mode and Effects Analysis (FMEA) works by studying the potential failure modes of each component and their corresponding impacts. FTA focuses on system-level risks, while FMEA focuses on component-level risks.
- **FTA Vs Event Tree Analysis (ETA):** FTA is a top-down approach that investigates the causes leading to a single failure event. Event Tree Analysis (ETA) is a forward-looking method that begins with an initiating event and explores possible outcomes. FTA identifies why failures occur, while ETA predicts the consequences that follow an event.
- **FTA Vs HAZOP:** FTA uses a logical diagram to identify how failures combine to cause system breakdowns. Hazard and Operability Study (HAZOP) is a structured brainstorming method in which a team systematically reviews processes to identify deviations and potential hazards. FTA is diagram-based, while HAZOP is discussion and guideword-based.
- **FTA vs HAZID:** FTA analyzes potential failure causes and their interactions through a fault tree diagram. Hazard Identification (HAZID) is an early-stage qualitative study to spot hazards in a project or operation. FTA is structured and quantitative, while HAZID is broader, brainstorming-based, and qualitative.

FTA is useful when combined with other tools, as it offers both qualitative insights (cause-and-effect mapping) and quantitative results (probability of system failure).

Why Fault Tree Analysis is Important

You will always face risks from complex systems. A single failure can trigger a chain reaction, leading to accidents, financial losses, or safety issues.

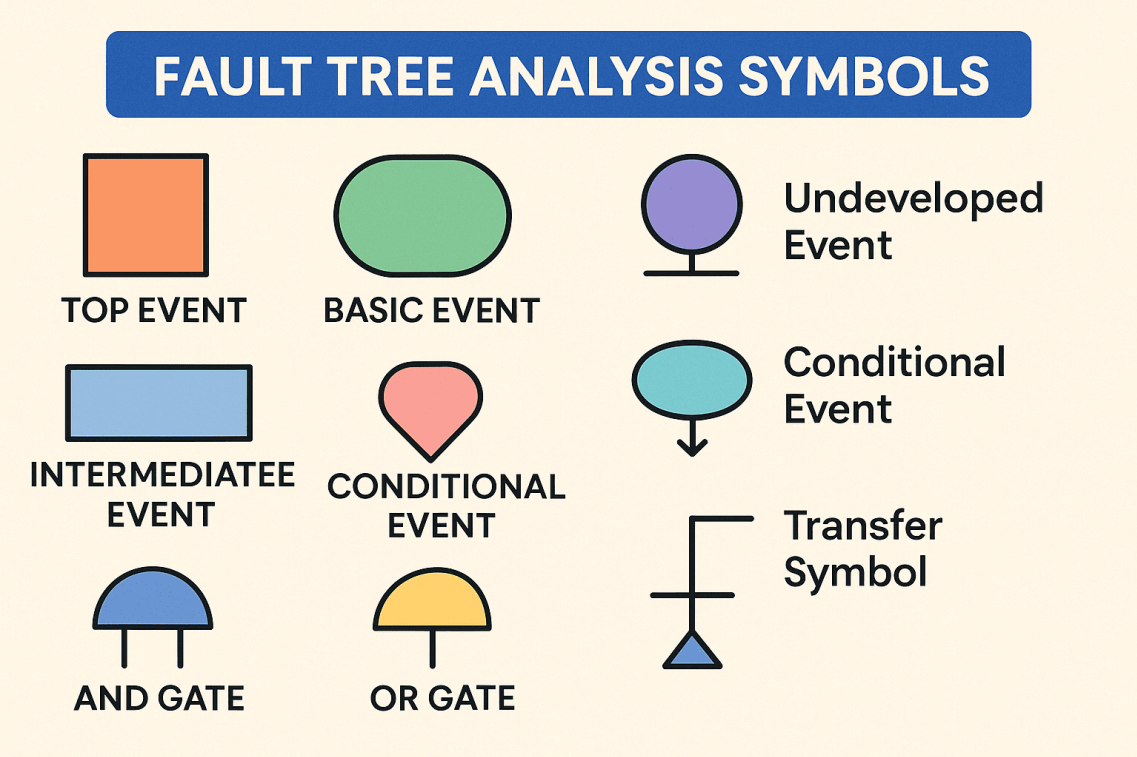
Fault tree analysis helps you reduce these risks in the following ways:

- **Identify Root Causes:** Teams see the complete set of failure factors instead of guessing. This clarity supports accurate troubleshooting and more effective planning.
- **Support Compliance:** Industries such as aviation, nuclear power, and medical devices require a structured risk analysis. FTA helps companies meet strict regulatory and safety standards.
- **Save Time and Costs:** Detecting failures early prevents costly downtime, product recalls, or legal issues, ensuring smoother operations and long-term financial savings.
- **Improve Decision Making:** FTA delivers data-based insights that guide leaders to make smarter investments in safety, reliability, and preventive measures.
- **Enhance System Reliability:** By mapping failure paths, FTA highlights weak points, encouraging preventive maintenance and design improvements that strengthen overall system reliability.

Fault tree analysis enables organizations to identify potential problems before they occur, address weaknesses in advance, and develop safer, more reliable systems.

Key Components of a Fault Tree

An FTA diagram uses standardized symbols and logical connections. Understanding these components is crucial for comprehending and analyzing the fault tree.



These components are as follows:

- **Top Event:** The main failure or problem.
- **Intermediate Event:** Failures that occur from combinations of lower events.
- **Basic Event:** Root-level causes that cannot be broken down further.
- **Undeveloped Event:** Events that are not thoroughly analyzed due to a lack of data.

Logical Gates:

- **AND Gate:** All input events must occur for the output failure.
- **OR Gate:** Any single input event can cause the output failure.
- **Inhibit Gate:** An event occurs only if another condition exists.
- **Voting Gate (k-out-of-n):** Output occurs if a specific number of input events occur.

Symbols:

Circles, rectangles, diamonds, and triangles are used to represent these events and gates. This standardization ensures clarity across industries.

How Fault Tree Analysis Works: Step-by-Step Process

Fault Tree Analysis works as a structured process that visually connects failures, assesses risks, and guides preventive measures for safer systems.

How Fault Tree Analysis Works (Step-by-Step Process)

Define the Top Event

Start by clearly describing the main failure you want to prevent. This is called the top event.

Identify Contributing Events

Next, list all the smaller faults or issues that could lead to top event.

Build the Tree

Use logical gates to connect the events in a structured diagram.

Quantify Probabilities

If you have data, assign probabilities to each event in the fault tree.

Analyze and Recommend Solutions

Study the diagram to identify the most critical paths. Then suggest ways to minimize the risk of failure.

You can follow the following steps to conduct fault tree analysis:

Define the Top Event

Start by clearly describing the main failure you want to prevent. This is called the top event. For example, a “plant-wide power outage” can serve as the starting point. Defining the top event gives the analysis a clear focus and helps the team understand exactly what risk needs to be managed or prevented.

Identify Contributing Events

Next, list all the smaller faults or issues that could lead to the top event. These may include equipment breakdowns, software errors, or human mistakes. By breaking the problem into smaller causes, you create a clear picture of how failures may interact. This step ensures no possible factor gets ignored during the risk analysis process.

Build the Tree

Use logical gates, such as AND, OR, or INHIBIT, to connect the events in a structured diagram. This visual tree illustrates how various causes combine to produce the top event. Building the tree helps you see the relationships between failures, making complex risks easier to understand, communicate, and evaluate for improved system safety.

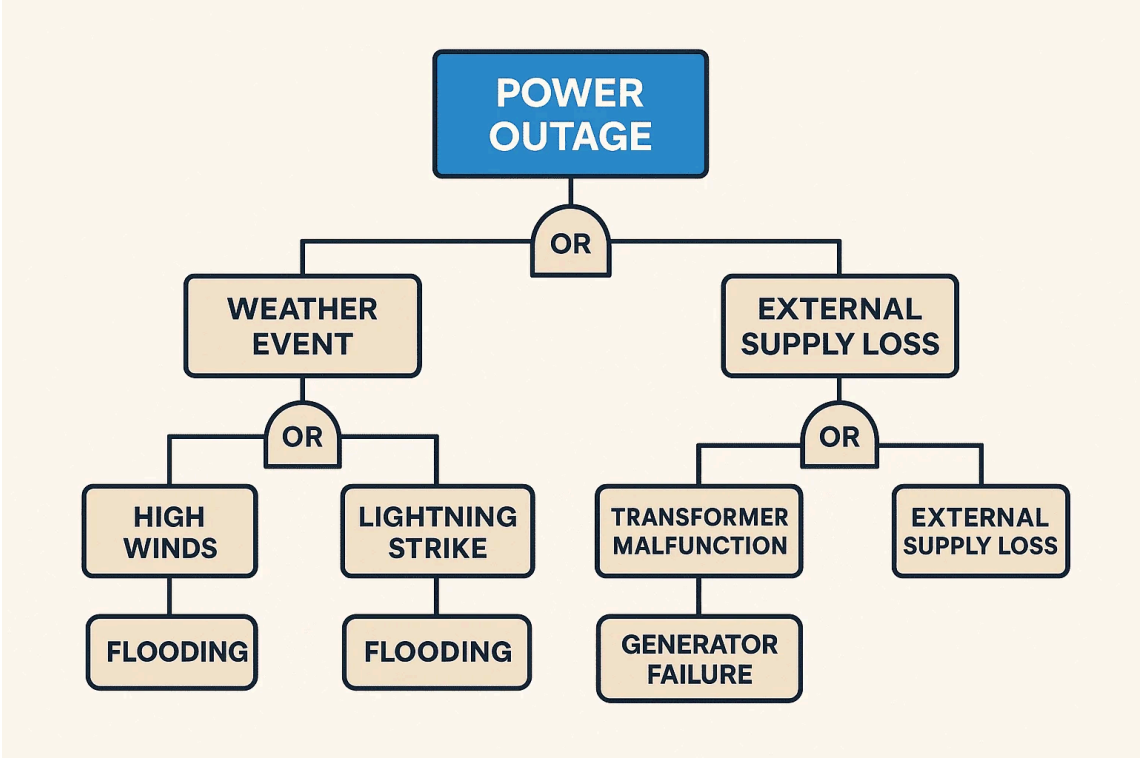
Quantify Probabilities

If you have data, assign probabilities to each event in the fault tree. This allows you to calculate the chance of the top event happening. Quantifying probabilities adds a numerical layer to the analysis, making it easier to prioritize risks and focus on the most critical areas that need immediate attention.

Analyze and Recommend Solutions

Study the diagram to identify the most critical paths leading to the top event. These paths show weak points that increase the risk of system failure. Based on this analysis, recommend preventive actions, redundancy measures, or design changes. This step ensures teams can take practical actions to reduce risks and improve reliability.

Fault Tree Analysis Example: Power Outage



Consider a factory where the top event is “Plant-wide power outage.”

- **Basic Events:** Generator failure, main supply cut, wiring damage.
- **Intermediate Event:** Both backup generators fail (AND gate).
- **OR Gate:** Any one of generator failure, transformer malfunction, or external supply loss causes an outage.

This case shows how small failures combine to create a larger problem. By analyzing it, the company may install better redundancy, perform regular maintenance, and monitor supply reliability.

Benefits of Fault Tree Analysis

- **Clear Visualization:** Fault Tree Analysis turns complex risks into a simple diagram, making failure causes easy to understand and communicate.
- **Qualitative & Quantitative:** It supports both descriptive insights and data-driven analysis, allowing teams to study risks from multiple useful perspectives.
- **Better Safety & Compliance:** FTA aligns with strict industry standards, helping organizations meet regulatory requirements while improving overall system safety.
- **Improved Efficiency:** It directs time and resources toward the most critical risks, reducing waste and improving decision-making across the system.
- **Supports Preventive Action:** By identifying weak points early, FTA encourages preventive measures that improve reliability and reduce the chance of costly failures.

Limitations of Fault Tree Analysis

- **Time-intensive:** Creating a comprehensive diagram for large or complex systems requires a significant amount of time, effort, and specialized expertise.

- **Data Requirements:** Reliable probability calculations demand accurate historical or experimental data, which may not always be available or accessible.
- **Oversimplification:** Real-world systems often include feedback loops and dynamic interactions that Fault Tree Analysis cannot fully represent or capture.
- **High Cost:** Conducting detailed FTA studies can be expensive, especially when involving specialized software, expert teams, or extensive data collection.
- **Static Approach:** FTA provides a snapshot in time, making it less effective for continuously changing systems or evolving operational conditions.

FAQ Section

Q1: What is the purpose of fault tree analysis?

Fault tree analysis identifies root causes of system failures, helping organizations prevent problems, improve safety, and ensure compliance with industry standards.

Q2: How is fault tree analysis different from FMEA?

Fault tree analysis is a deductive approach that starts with a failure, whereas FMEA is an inductive method that analyzes each component for potential issues.

Q3: Can fault tree analysis calculate failure probability?

Yes. By assigning probabilities to events, FTA can estimate the overall likelihood of a top event, supporting quantitative risk management.

Q4: Which industries use fault tree analysis?

Industries such as aerospace, automotive, nuclear, healthcare, and IT use FTA to analyze risks, prevent accidents, and maintain compliance.

Q5: What are the limitations of fault tree analysis?

Fault tree analysis requires detailed data, can be time-intensive, and sometimes oversimplifies complex systems; therefore, it should be used in conjunction with other tools to provide a comprehensive understanding.

Summary

Fault tree analysis is one of the most powerful tools for identifying risks and preventing failures. From aerospace to IT, it helps organizations find weaknesses, ensure compliance, and improve safety. By visualizing how failures connect, FTA supports better decisions and long-term system reliability. While it requires effort and data, the benefits far outweigh the limitations.

Organizations that adopt fault tree analysis not only meet compliance standards but also gain a strategic advantage by avoiding costly failures and ensuring operational success.

Further Reading:

- What is a Failure Mode and Effects Analysis (FMEA)?
- Fishbone (Cause and Effect or Ishikawa) Diagram
- What is a Bow Tie Analysis in Risk Management
- What is a Monte Carlo Simulation?
- Risk Assessment Matrix: Definition, Example, and Template

Reference:

- What is Fault Tree Analysis?

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I am Mohammad Fahad Usmani, B.E. PMP, PMI-RMP. I have been blogging on project management topics since 2011. To date, thousands of professionals have passed the PMP exam using my resources.

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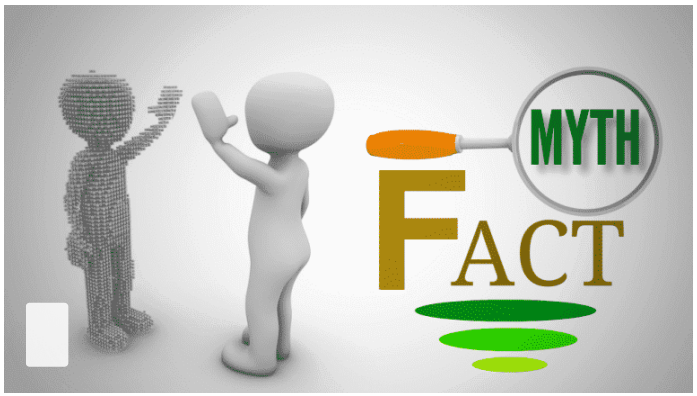

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