

Lecture 4: Quality of Design Techniques

Failure Mode and Effects Analysis (FMEA)

Overview

- **Definition:** FMEA is a systematic approach to identify, evaluate, and prioritize potential failure modes of a product or process and its impact on system performance or customer satisfaction.
- **Objective:** To enhance the quality and reliability of products/processes by anticipating potential problems and implementing corrective actions before they occur.

Notes

Historical Background:

- Developed by the U.S. military in the 1940s.
- Later adopted by NASA, the automotive industry, and eventually across a wide range of sectors.

Types of FMEA:

- **Design FMEA (DFMEA):** Focuses on potential failures in a product design. Helps to identify design weaknesses and suggests improvements.
- **Process FMEA (PFMEA):** Concentrates on failures that can occur during the manufacturing process. It looks at how product quality can be compromised during manufacturing or assembly.

Key Components:

- **Severity (S):** A ranking of the seriousness of the effect of a failure mode.
- **Occurrence (O):** A ranking of how frequently the failure mode is expected to occur.
- **Detection (D):** A ranking of the ability of the current design controls to detect a failure mode.
- **Risk Priority Number (RPN):** An index used to prioritize failure modes, calculated as $RPN = S \times O \times D$.

FMEA Process Steps:

1. Define the scope of the FMEA (product, subsystem, or process).
2. Assemble a cross-functional team.
3. Describe the item's function(s).
4. Identify potential failure modes.
5. List potential effects of each failure mode.
6. Assign severity, occurrence, and detection rankings.
7. Calculate RPN for each failure mode.
8. Prioritize issues based on RPN.

9. Develop action plans to address the most critical issues.
10. Reassess RPN after corrective actions are taken.

Real-world Example:

- In the automotive industry, FMEA is used rigorously to ensure car components don't fail. For instance, when designing brake systems, DFMEA could be used to anticipate what might go wrong, such as brake line leakage or brake pad wear. The corresponding effects, severity, occurrence, and detection rankings would be analyzed to ensure safety and reliability.

Benefits:

- Reduces product development time and cost.
- Increases reliability and safety of products/processes.
- Enhances customer satisfaction by reducing field failures.
- Drives continuous improvement.

Limitations:

- As effective as the FMEA process is, it requires time and resources.
- It is dependent on the experience and knowledge of the team.
- FMEA is proactive but cannot guarantee the discovery of all potential failures.

References:

- Stamatis, D. H. (1995). **FMEA: From Theory to Execution**. ASQC Quality Press.
- Automotive Industry Action Group (AIAG). **Potential Failure Mode and Effects Analysis (FMEA)** (4th ed.).

Quality Function Deployment (QFD)

Overview

- **Definition:** QFD is a structured method used to transform qualitative user demands into quantitative parameters, which guide product or service development.
- **Objective:** To prioritize and translate customer requirements into design specifications, process plans, and production techniques.

Notes

Historical Background:

- Originated in Japan in the late 1960s, particularly in the Yoji Akao's works.
- Became popular in the West during the 1980s, especially in industries aiming to align product development closely with customer needs.

QFD Matrix – The House of Quality:

- **Customer Requirements (WHATS):** Lists what customers have indicated they want or need from the product.
- **Design Requirements (HOWS):** Technical attributes or features that a product must have to meet the customer requirements.
- **Relationship Matrix:** Shows the interrelation between the WHATS and HOWS.
- **Planning Matrix:** Includes data such as target values and competitive assessments.

Key Components:

- **Customer Voice:** Collected data from customers about their needs and preferences.
- **Technical Descriptors:** Specifications and characteristics that designers and engineers can handle.
- **Prioritization:** Determining the relative importance of different customer demands and translating them to design focus.

QFD Process Steps:

1. Identify customer requirements.
2. Determine the relative importance of each requirement.
3. Define the design attributes that influence these requirements.
4. Relate customer needs to design attributes using the QFD matrix.
5. Compare with competing products to identify areas of improvement.
6. Set specific, measurable targets for design attributes.
7. Use the completed House of Quality to guide design, testing, and production.

Real-world Example:

- When designing a new smartphone, manufacturers might use QFD to translate features that customers prioritize (like battery life, screen clarity, or camera quality) into technical parameters and specific design attributes.

Benefits:

- Aligns product development more closely with customer needs.
- Reduces the iteration loop, saving time and resources in product development.
- Facilitates better communication among interdisciplinary teams.
- Improves market reception by delivering products more attuned to user requirements.

Limitations:

- Complexity: The House of Quality matrix can become cumbersome for products with numerous features.
- It relies on accurate capture and interpretation of customer requirements.
- Potential for misalignment if customer needs evolve rapidly after initial data collection.

References:

- Akao, Y. (1990). ***Quality Function Deployment: Integrating Customer Requirements into Product Design***. Productivity Press.
- Hauser, J. R., & Clausing, D. (1988). *The House of Quality*. *Harvard Business Review*, May–June 1988.

Value Analysis & Engineering

Overview

- **Definition:** Value Analysis (VA) and Value Engineering (VE) are systematic methodologies aimed at ensuring optimal value for a product or service by examining all functions related to that product or service. The primary goal is to preserve or enhance the value while minimizing cost.
- **Objective:** To identify and remove unnecessary costs while ensuring that desired function, quality, and performance are retained or improved.

Notes

Historical Background:

- Originated during World War II at General Electric (GE). Lawrence D. Miles, who worked at GE, developed this technique as a response to the scarcity of raw materials.
- The method's principles revolved around the idea of function-based assessment: if two solutions deliver the same function, but one does so at a lower cost, it's the preferred solution.

Key Principles:

- **Function Analysis:** Understanding the primary and secondary functions of a product or process.
- **Cost Reduction:** The primary driver for VA/VE. It aims to lower the cost of a product or process without compromising its core functionality.
- **Performance Consistency:** While cost reduction is the goal, it shouldn't come at the expense of the product's primary functions.

The Process Steps:

1. **Information Phase:** Gathering data about the product or process, understanding its functions and associated costs.
2. **Function Analysis Phase:** Identifying and classifying the functions of the product in terms of importance.
3. **Creative Phase:** Brainstorming alternative ways to perform each function.
4. **Evaluation Phase:** Analyzing and ranking the potential value of each alternative.
5. **Development Phase:** Turning the best alternatives into feasible solutions.
6. **Presentation Phase:** Sharing the solutions with stakeholders for feedback and implementation.

Real-world Example:

- Automakers frequently use Value Analysis when designing new vehicle models. For instance, they might explore alternative materials that offer the same durability and safety standards as older materials but at a lower cost. This could include shifting from metal to certain high-strength polymers in specific car parts.

Benefits:

- Achieves cost savings while maintaining or enhancing performance and quality.
- Fosters innovation as teams search for alternative materials or processes.
- Enhances interdisciplinary collaboration as various departments work together to find optimal solutions.
- Reduces waste and inefficiencies by focusing on essential functions.

Limitations:

- Resistance from teams or departments attached to the existing way of doing things.
- Potential for overlooking crucial functions in the drive to reduce costs.
- Can become a periodic exercise rather than an ingrained culture, which reduces its long-term impact.

Value Engineering vs. Value Analysis:

- While the two terms are often used interchangeably, there is a subtle difference. Value Engineering is typically applied during product development (before a product exists), while Value Analysis is applied to existing products or processes.

References:

- Miles, L. D. (1972). *Techniques of Value Analysis and Engineering*. McGraw-Hill Education.
- Snodgrass, A., & Kasi, M. (1986). *Function Analysis: The stepping stones to good value*. *Value World*, 9(3), 4-5.