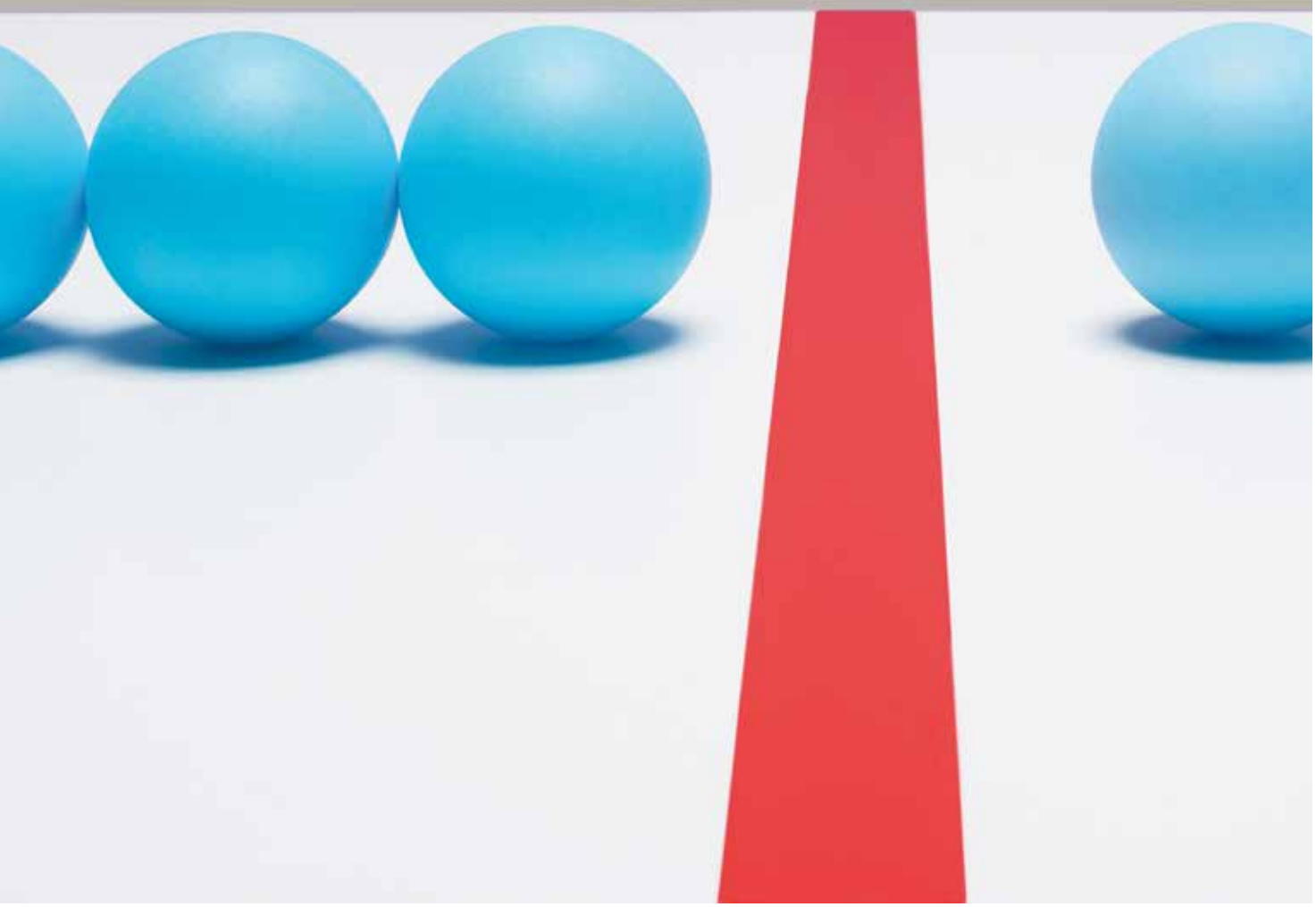
A closer look at difficult and confusing aspects of failure mode and effects analysis



Solve Your FMEA Frustrations

Topic
Failure mode and effects analysis

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The concept of failure mode and effects analysis (FMEA) is rather simple and widely known. In theory, everyone should be able to do it with some basic training. Yet, in practice, a huge variation in quality and competency exists. Confusion and various opinions about how to handle details exist. This article sheds some light on common confusion and disputes.

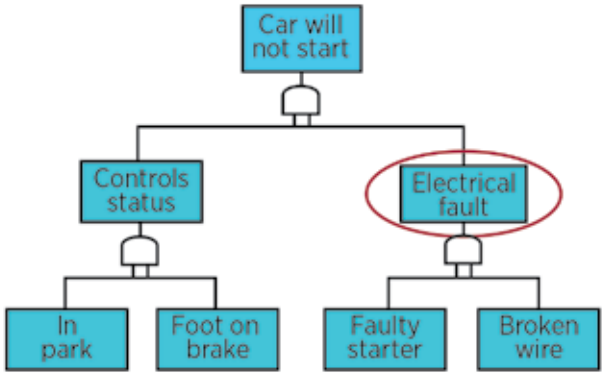
AIAG and VDA

Because ISO 9001:2015 raised the need for risk-based thinking and management, FMEA gained renewed attention and broader applications. As part of the management system upgrade, the Automotive Industry Action Group (AIAG) is partnering with the German Association of the Automotive Industry (VDA) to upgrade and harmonize their FMEA practices.[1] Dramatic changes are proposed.

Other industries are likely to quickly follow suit. At this transformational time, revisiting some typical struggles FMEA endures can add significant value. The six areas worth discussing are:

1. Types of failure modes (FM).
2. Cause or effect.
3. Risk assessment.
4. Types of control.
5. Process vs. design.
6. Interaction between structures.

Figure 1 FAULT TREE ANALYSIS EXAMPLE



Types of FM

FM refers to the ways failures can occur. It's the most critical part of FMEA and can be the most difficult. The success of FMEA largely hinges on whether the most critical FMs are appropriately identified. FMs also are the sources to potentially flood the system and bury the most critical FMs with trivial things.

In many cases, FMs are identified ad hoc. Some structures can help avoid missing important opportunities. ASQ offers FMEA training, which adopted a so-called "5+1" structure to help systematically identify FMs. The "5+1" structure refers to the numbered paragraphs one and four that follow. Personally, I think the "5+1" structure is insufficient and prefer a more expanded list, as follows:

1. Failing to meet the specification.
   - Complete failure.
   - Too little (partial, uneven or incomplete).
   - Too much (over).
   - Intermittent.
   - Failure over time.
2. Incorrect or inappropriate requirements.
   - Wrong, missing, hidden, unstated or assumed.
3. Unintended use, application or environment.
4. Doing harm to others.

The first three sub-bullets under numbered paragraph one are obvious and not worth mentioning. The sub-bullets "Intermittent" and "Failure over time,"

Table 1 **NEWLY PROPOSED ACTION PRIORITY LOGIC BY AIAG-VDA***

S	O	D	AP	DFMEA ACTION PRIORITY LOGIC
9-10	6-10	1-10	H	High priority due to safety and/or regulatory effects that have a **high** or **very high** occurrence rating.
9-10	4-5	7-10	H	High priority due to safety and/or regulatory effects that have a **moderate** occurrence rating and **high** detection rating.
9-10	4-5	5-6	H	High priority due to safety and/or regulatory effects that have a **moderate** occurrence rating and **moderate** detection rating.
9-10	4-5	1-4	M	Medium priority due to safety and/or regulatory effects that have a **moderate** occurrence rating and **low** detection rating.
9-10	1-3	7-10	H	High priority due to safety and/or regulatory effects that have a **low** occurrence rating and **very high** detection rating.
9-10	1-3	5-6	M	Medium priority due to safety and/or regulatory effects that have a **low** occurrence rating and **moderate** detection rating.
9-10	1-3	1-4	L	Low priority due to safety and/or regulatory effects that have a **low** occurrence rating and **low** detection rating.
5-8	8-10	2-10	H	High priority due to the loss or degradation of an essential or convenience vehicle function that has a **very high** occurrence rating.
5-8	6-7	7-10	H	High priority due to the loss or degradation of an essential or convenience vehicle function that has a **high** occurrence rating and **high** detection rating.
5-8	6-7	5-6	H	High priority due to the loss or degradation of an essential or convenience vehicle function that has a **high** occurrence rating and **moderate** detection rating.
5-8	6-7	1-4	M	Medium priority due to the loss or degradation of an essential or convenience vehicle function that has a **high** occurrence rating and **low** detection rating.
5-8	4-5	7-10	H	High priority due to the loss or degradation of an essential or convenience vehicle function that has a **moderate** occurrence rating and **high** detection rating.
5-8	4-5	5-6	H	High priority due to the loss or degradation of an essential or convenience vehicle function that has a **moderate** occurrence rating and **moderate** detection rating.
5-8	4-5	1-4	M	Medium priority due to the loss or degradation of an essential or convenience vehicle function that has a **moderate** occurrence rating and **low** detection rating.
5-8	1-3	7-10	M	Medium priority due to the loss or degradation of an essential or convenience vehicle function that has a **low** occurrence rating and **high** detection rating.
5-8	1-3	5-6	M	Medium priority due to the loss or degradation of an essential or convenience vehicle function that has a **low** occurrence rating and **moderate** detection rating.
5-8	1-3	1-4	L	Low priority due to the loss or degradation of an essential or convenience vehicle function that has a **low** occurrence rating and **low** detection rating.
2-4	8-10	1-10	H	High priority due to perceived quality (appearance, sound, haptics) with a **very high** occurrence rating.
2-4	6-7	7-10	H	High priority due to perceived quality (appearance, sound, haptics) with a **high** occurrence rating and **high** detection rating.
2-4	6-7	5-6	H	High priority due to perceived quality (appearance, sound, haptics) with a **high** occurrence rating and **moderate** detection rating.
2-4	6-7	1-4	M	Medium priority due to perceived quality (appearance, sound, haptics) with a **high** occurrence rating and **low** detection rating.

S	O	D	AP	DFMEA ACTION PRIORITY LOGIC
2-4	4-5	7-10	H	High priority due to perceived quality (appearance, sound, haptics) with a **moderate** occurrence rating and **high** detection rating.
2-4	4-5	5-6	M	Medium priority due to perceived quality (appearance, sound, haptics) with a **moderate** occurrence rating and **moderate** detection rating.
2-4	4-5	1-4	L	Low priority due to perceived quality (appearance, sound, haptics) with a **moderate** occurrence rating and **low** detection rating.
2-4	1-3	7-10	M	Medium priority due to perceived quality (appearance, sound, haptics) with a **low** occurrence rating and **high** detection rating.
2-4	1-3	5-6	L	Low priority due to perceived quality (appearance, sound, haptics) with a **low** occurrence rating and **moderate** detection rating.
2-4	1-3	1-4	L	Low priority due to perceived quality (appearance, sound, haptics) with a **low** occurrence rating and **low** detection rating.
1	1-10	1-10	L	Low priority due to no discernible effect.

*Automotive Industry Action Group (AIAG) and German Association of the Automotive Industry (VDA), *AIAG-VDA FMEA Handbook*, first edition, 2018.
AP = action priority
D = detection
DFMEA = design failure mode and effects analysis
O = occurrence
S = severity

as well as numbered paragraph four, "Doing harm to others," however, are worth more attention. Also worth concern are inappropriate requirements and unintended use, which is the opposite side of "5+1."

Cause or effect

A frequent debate is whether an identified problem belongs to FM, effect or cause. Indeed, the role may change depending on the situation. To better understand the dynamic, some knowledge of the chain of causation is needed.[2] In short, causes and effects form infinite chains of causation. In that chain of causation, an event is an effect if it is upstream and a cause if it is downstream.

The cause and effect role may shift depending on what link in the chain is being studied. In fact, an FM may have multiple causes and effects. The opposite is also true: A cause or effect may have multiple associated FMs. Because the FMEA format isn't designed to handle complicated cause and effect relationships, it's not a primary tool used for diagnosing, finding the root cause or problem solving.

Using Figure 1 (p. 9) as an example, is electrical fault a cause, FM or effect? The answer is it depends on what level you are looking at:

- At the car level, it's a cause.
- At the subassembly level, it's an FM.
- At the component level, it's an effect.

Risk assessment

Could the same FM have multiple effects with different levels of severity (S), occurrence (O) or detection (D)? Yes—it's possible to have any combination of the three. To simplify the analysis, a popular practice is to focus on the most severe effect. There is a small probability of missing an effect with lower severity but a higher risk priority number (RPN), but that's a risk taken when trading for efficiency.

Whether recommended actions can lower the severity of an FM is frequently debated. There are two schools of thought with opposite views, but ultimately what's affected is Criticality = S x O. To keep things simple and avoid confusion, a more common practice is to keep the severity unchanged and only change the occurrence.

The new AIAG-VDA harmonizing effort proposes dramatic changes in risk assessment practice that will affect the industry significantly. The

A frequent debate is whether an identified problem belongs to FM, effect or cause.

Figure 2 **PREVENTION VS. DETECTION CONTROLS**

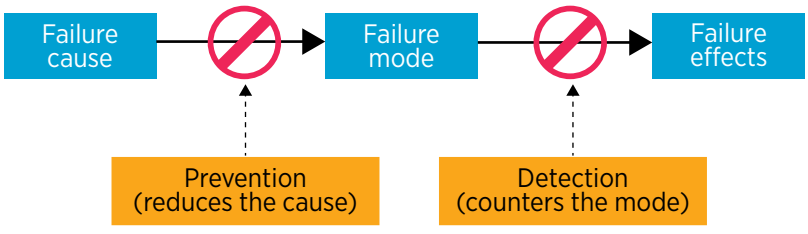


Table 2 **PREVENTION VS. DETECTION CONTROLS**

	DFMEA	PFMEA
Prevention controls	Typically occur prior to finalizing the design and reduce the risk of failures during product validation testing ✚ Engineering analysis and evaluation: anti-overstress feature ✚ Tolerance stack-up or statistical analysis ✚ Finite element analysis	Occur prior to manufacturing the product ✚ Equipment setup requirements ✚ *Poka-yoke*
Detection controls	Detect the failure mode, typically during product validation testing, prior to releasing design for customer orders ✚ Reliability testing and performance testing conducted as part of product validation testing	Occur after manufacturing the product but prior to shipping product to customers ✚ Product testing ✚ Inspection

DFMEA = design failure mode and effects analysis
PFMEA = process failure mode and effects analysis

The goal of FMEA is to prevent potential future problems.

organizations are eliminating RPN and replacing it with sophisticated action priority (AP), which employs a comprehensive table detailing priorities for various combinations of the three elements, as shown in Table 1 (pp. 10–11). It certainly has pros and cons, and—like any major change—already has incited heated debates.

Types of control

One of the most confusing struggles is how to appropriately identify whether existing controls are prevention or detection. As shown in Figure 2 (p. 11), prevention controls reduce the cause, and detection controls counter the mode.

There are different items for design FMEA (DFMEA) and process FMEA (PFMEA), as well as prevention and detection—there is no overlap, as shown in Table 2. For example, inspection in production can't be used as control for DFMEA. In general:

- **Prevention** focuses on preventing failures from occurring and thus affects occurrence.
- **Detection** focuses on preventing effects from occurring and thus affects detection.

Process vs. design

Another common struggle is determining whether a problem (FM) is a process issue or design issue. This is related to the scope of FMEA. Different views on this matter exist. For example, ASQ training adopted a critical assumption for PFMEA: All incoming components are defect

free. Therefore, defective incoming parts are out of scope. The thought behind this assumption is to contain FMEA workload. Yet in my view, if it will cause problems in your process, it should be in scope.

The goal of FMEA is to prevent potential future problems, so anything we do should build around that. Any problems that may jeopardize this goal are in scope. Under this notion, failures and solutions are not limited to the current design—they may lead to new designs, structures, components or processes.

Some FMs may belong to both process and design. Many process issues can be addressed through changing the design, which may be harder to do after product release but quite desirable pre-release. It's my opinion that if DFMEA doesn't lead to design change during the development stage, it's not as effective as it can be.

Interaction between (sub) structures (IBS)

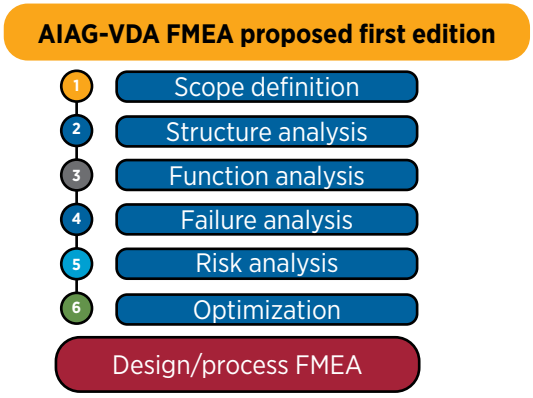
IBS-induced issues are hard to capture. The new AIAG-VDA harmonizing effort puts more emphasis on structural analysis, as shown in Figure 3, which should help. Still, the table format for FMEA isn't designed to handle a sophisticated relationship between substructures. System FMEA may capture interactions better, but not DFMEA. FMEA is not a primary tool for investigation.

Key takeaways

Although FMEA appears to be simple, constant struggles exist regarding its efficiency and effectiveness. The problem is worsened when the cost of FMEA actions isn't considered.

It'll be more effective and efficient to systematically integrate FMEA with related activities than to perform FMEA by itself.

Figure 3 **NEWLY PROPOSED FMEA STEPS BY AIAG-VDA**



AIAG = Automotive Industry Action Group
FMEA = failure mode and effects analysis
VDA = German Association of the Automotive Industry

A common struggle is determining whether a problem (FM) is a process issue or design issue.

Not all columns on an FMEA form are equally important. The most important one is FM, followed by actions, then RPN. Everything else on the form is secondary to help make better-informed decisions.

Focusing resources on the most important items—new, unique and difficult items, FM and action—can significantly improve the efficiency and effectiveness of FMEA. &

REFERENCES

1. Automotive Industry Action Group (AIAG) and the German Association of the Automotive Industry (VDA), *AIAG-VDA FMEA Handbook*, first edition, 2018.
2. Gary G. Jing, "Flip the Switch," *Quality Progress*, October 2008, pp. 50-55.

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