

Failure Mode Effects Analysis



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Function

Item / Function	Potential Failure Mode	Potential Failure Effects	S E V	Potential Causes Mechanism(s) of Failure	O C C	Current Controls	D E T	R P N	Recommended Actions	Target Complete Date	Actions Taken	S E V	O C C	D E T	R P N
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- Functions should be written in verb-noun context if practical.
- An associated measurable metric is desirable.

As an example:

The problem is to design an automotive HVAC system which must defog windows and heat or cool cabin to 70 degrees in all operating conditions (-40 degrees to 100 degrees) within 3 to 5 minutes.



Functions

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- Therefore in this example, the functions are...
 - Defog windows
 - Heat cabin
 - Cool cabin



Failure Modes

Item / Function	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes Mechanism(s) of Failure	OCC	Current Controls	DET	RPN	Recommended Actions	Target Complete Date	Actions Taken	SEV	OCC	DET	RPN
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- **Identify Failure Modes.** A failure mode is defined as the manner in which a component, subsystem, system, process, etc. could potentially fail to meet the design intent.
 - How can the part/system fail to meet specifications?
 - What would a customer consider objectionable?
- **There are 5 classes of failure modes:**
 - complete failure,
 - partial failure,
 - intermittent failure,
 - over-function, and
 - unintended function



Failure Modes, examples

- **Examples:**
 - **Complete failure**
 - HVAC system does not heat vehicle or defog windows
 - **Partial failure**
 - HVAC system takes more than 5 minutes to heat vehicle
 - **Intermittent failure**
 - HVAC system does heat cabin to 70 degrees from below zero temperatures but not in all cases
 - **Over-function**
 - HVAC system cools cabin to 50 degrees
 - **Unintended functions**
 - HVAC system activates rear window defogger



Effect(s) of Failure

Item / Function	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes Mechanism(s) of Failure	OCC	Current Controls	DET	RPN	Recommended Actions	Target Complete Date	Actions Taken	SEV	OCC	DET	RPN
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- **Effects should be listed as customer would describe them (consider...)**
 - Reduced performance
 - Customer dissatisfaction
 - Potential risk of injury
 - Product liability
- **Effects should include (as appropriate) safety / regulatory body, end user, internal customers (manufacturing, assembly, service)**
- **For example:**
 - Cannot see out of front window
 - Air conditioner makes cabin too cold
 - Does not get warm enough
 - Takes too long to heat up



Severity

Item / Function	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes Mechanism(s) of Failure	OCC	Current Controls	DET	RPN	Recommended Actions	Target Complete Date	Actions Taken	SEV	OCC	DET	RPN
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Determine the *severity* of the failure effects (as a rating value)

Severity values may be available from governing bodies. In this example AIAG and SAE (see next slide)

If severity is based upon internally defined criteria or is based upon standard with specification modifications, rating tables should be included with the analysis.

Examples:

- Cannot see out of front window: severity 9
- Air conditioner makes cab too cold: severity 5
- Does not get warm enough: severity 5
- Takes too long to heat up: severity 4



Example of a Severity Table

Rating

Severity Description

1	The effect is not noticed by customer
2	Very slight effect noticed by customer, does not annoy or inconvenience customer
3	Slight effect that causes customer annoyance, but they do not seek service
4	Slight effect, customer may return product for service
5	Moderate effect, customer requires immediate service
6	Significant effect, causes customer dissatisfaction; may violate regulation or design code
7	Major effect, system may not be operable; elicits customer complaint; may cause injury
8	Extreme effect, system is inoperable and a safety problem. May cause severe injury.
9	Critical effect, complete system shutdown; safety risk
10	Hazardous; failure occurs without warning; life threatening



Cause(s) of Failure

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- **Causes must be identified for a failure mode**
- **Brainstorm causes (man, machine, material, method, environment...)**
- **Causes should be limited to design issues (what you can control)**
- **There is often more than one cause of failure for each failure mode**

For our example:

- **Poor vent location**
- **Routing of vent hoses (too close to heat source)**
- **Inadequate coolant capacity for application**



Occurrence (or Probability)

Item / Function	Potential Failure Mode	Potential Failure Effects	S E V	Potential Causes Mechanism(s) of Failure	O C C	Current Controls	D E T	R P N	Recommended Actions	Target Complete Date	Actions Taken	S E V	O C C	D E T	R P N
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- Occurrence ratings for design FMEA are based upon the likelihood that a cause may occur, based upon past failures, and/or performance of similar systems in similar applications
- Occurrence rating values may be standardized (AIAG, SAE in this example)
- If occurrence values are based upon internally defined criteria, a rating table should be included in FMEA (with explanation for use)
- Occurrence values of 1 should have objective data to provide justification for inclusion (since failure level so low...)

Examples

- Poor vent location: occurrence 3
- Routing of vent hoses (too close to heat source): occurrence 6
- Inadequate coolant capacity for application : occurrence 2



Sample of an Occurrence Table

<u>Rating</u>	<u>Approx. Probability of Failure</u>	<u>Description of Occurrence</u>
1	$\leq 1 \times 10^{-5}$	Extremely remote
2	1×10^{-5}	Remote, very unlikely
3	1×10^{-5}	Very slight chance of occurrence
4	4×10^{-4}	Slight chance of occurrence
5	2×10^{-3}	Occasional occurrence
6	1×10^{-2}	Moderate occurrence
7	4×10^{-2}	Frequent occurrence
8	0.20	High occurrence
9	0.33	Very high occurrence
10	≥ 0.50	Extremely high occurrence



Current Design Controls

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- Identify the existing controls that identify and reduce failures
- Controls may be *Preventive (designed in)* or *Detective (found by functional testing, etc.)*
 - Preventive controls are those that help reduce the likelihood that a failure mode or cause will occur (affect occurrence value)
 - Detective controls are those that find problems that have been designed into the product (assigned detection value)
 - If detective and preventive controls are not listed in separate columns, they must include an indication of the type of control



Current Design Controls

- **Examples:**

Engineering specifications provide preventive control (P)

Historical data provide preventive control (P)

Functional testing provides detective control (D)

Evaluation of existing or similar systems provides detective control (D)



Detection

Item / Function	Potential Failure Mode	Potential Failure Effects	S E V	Potential Causes Mechanism(s) of Failure	O C C	Current Controls	D E T	R P N	Recommended Actions	Target Complete Date	Actions Taken	S E V	O C C	D E T	R P N
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- Detection values should correspond any existing standards (AIAG, SAE)
- If detection values are based upon internally defined criteria, a rating table should be included in FMEA (with explanation for use)
- Detection is the value assigned to each of the detective controls. (Preventive controls are not used)
- Detection values of 1 mean the potential for failure is eliminated due to design solutions.

Examples:

Engineering specifications:

Historical data:

Functional testing:

General vehicle durability:

no detection value

no detection value

detection 3

detection 5



RPN (Risk Priority Number)

Item / Function	Potential Failure Mode	Potential Failure Effects	S E V	Potential Causes Mechanism(s) of Failure	O C C	Current Controls	D E T	R P N	Recommended Actions	Target Complete Date	Actions Taken	S E V	O C C	D E T	R P N
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- Risk Priority Number is the product of the severity, occurrence and detection ratings. (RPN = S*O*D)
Note: Lowest detection rating is used to determine RPN
- RPN threshold should not be used as the primary trigger for definition of recommended actions

From previous examples:

Cannot see out of front window (S = 9)

Incorrect vent location (O = 2)

Detection by functional testing (D = 3)

RPN = 54



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Recommended Actions

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- The RPN is used to identify items which require attention and assign a priority to them.
- All critical or significant failures should have recommended actions associated with them.
- Recommended actions should be focused on design, and directed toward mitigating the cause of failure, or eliminating the failure mode.



Recommended Actions

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- Recommended Actions (examples)
 - Try to eliminate the failure mode (some failures are more preventable than others)
 - Minimize the severity of the failure
 - Reduce the occurrence of the failure mode
 - Improve the detection



Responsibility & Target Completion Date

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- **All recommended actions should have a person assigned responsibility for completion of the action**
- **There should be a completion date accompanying each recommended action**



Action Results

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- **“Action taken” must detail what actions occurred, and the results of those actions**
- **Actions must be completed by the target completion date**
- **Update S, O, and D to reflect actions taken**
 - Unless the failure mode has been eliminated, severity should not change
 - Occurrence may or may not be lowered based upon the results of actions
 - Detection may or may not be lowered based upon the results of actions
 - If severity, occurrence or detection ratings are not improved, additional recommended actions must to be defined

