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UNIVERSITY
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Operational & Strategic Risk Management

PMG630

Lecture 5

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FMEA FORMAT

A tabular form or worksheet is used to collect information and document failure analysis in FMEA. Figure 3.6 shows an of an FMEA worksheet. Similar to HAZOP studies, the FMEA worksheet is often done in reference to a larger system analysis.

Correspondingly, each FMEA worksheet typically refers to one of the parts or components depicted in a system diagram such as PFD or P&ID used in the application of HAZOP. An item analysis for simple systems may also be used, as illustrated in Figure 3.5. An item analysis is a listing of a system's basic components.

FMEA FORMAT

The FMEA worksheet generally follows the key questions of the risk management process. Very notably, the precursory question What should go right? Is posed first. It is similar to the notion of design intention HAZOP.

However, in FMEA, the design intent is explicitly documented and captured in the worksheet itself, unlike in HAZOP where it is primarily implied. The following are the descriptions of columns that correspond to the FMEA worksheet shown in Figure 3.6.

Risk Priority Number

Risk priority number (RPN) is a function of the three parameters such as: the severity of the effect of failure, the probability of occurrence, and the ease of detection for each failure mode. RPN is calculated by multiplying these three numbers as per the formula below,

$$RPN = S \times P \times D$$

where S is the severity of the effect of failure, P is the probability of failure, and D is the ease of detection.

FMEA FORMAT

- What should go right?

{ Column 1: Functional objectives of the subsystem or component

- What can go wrong?

{ Column 2: Failure modes that prevent the achievement of objectives

- What are the causes and consequences?

The failure modes are described as risk events in terms of

FMEA FORMAT

- { Column 3: Consequences of failure (labeled effects in the FMEA worksheet)
- { Column 4: Severity (S) of the consequences
- { Column 5: Potential causes of failure

FMEA FORMAT

- What are the likelihood or chances of occurrence?
{ Column 6: Likelihood (L) of each causes or failure (labeled occurrences in the FMEA worksheet)
- What can be done to detect, control, and manage them?
{ Column 7: Existing detection, prevention, and control measures
{ Column 8: Rating for existing detection (D), prevention, and control measures

FMEA FORMAT

- { Column 9: The risk score determined by the likelihood, severity, and effectiveness of existing detection, prevention, and control measures to address failure, evaluated as $L \times S \times D$
- { Column 10: Recommendations for additional prevention and control measures to address the failures, their causes, and consequences

FMEA FORMAT

FMEA Item No.: 1.8				Item description: Hand brake subsystem Date:						
(1) Function or process	(2) Potential failure modes	(3) Potential effect(s) of failure	(4) Severity (S)	(5) Potential cause(s) of failure	(6) Occurrence rating (L)	(7) Current design controls (prevent)	(7) Current design controls (detect)	(8) Detection rating (D)	(9) RPN $L \times S \times D$	(10) Recom- mended action(s)
<i>What should go right, what is supposed to happen</i>	<i>What are the ways that pre- vent the process or function to achieve its objective</i>	<i>What is the conse- quence of the failure</i>	<i>How sig- nificant is the impact</i>	<i>How can the failure occur</i>	<i>What is the likelihood of occur- rence</i>	<i>What are in place so that failure is prevented</i>	<i>What are in place so that failure is controlled</i>	<i>How effec- tive are the measures</i>		<i>What can be done</i>
Provide the correct level of friction between brake pad assembly and wheel rim	Insufficient fric- tion between brake pads and wheels during normal operat- ing conditions or extreme conditions	Bicycle wheel does not slow down when the brake lever is pulled potentially resulting in injury	5	Cable binds due to inadequate lubrication or poor routing	2	Make sure hand brake is consistent with design guide	Make sure testing satisfies established bicycle system durability tests	1	10	Review manual
				Foreign mate- rial reduces friction between brake pads and wheel rim	1					
				Cable breaks	3					

Figure 3.6. FMEA worksheet for bicycle brake component.¹⁴

GENERALIZED STEPS FOR FMEA

1. Define the system and the scope of the study.
2. Identify the key functional objectives.
3. For each objective, identify the ways failure can occur (the failure modes).

GENERALIZED STEPS FOR FMEA

4. For each failure mode, identify the consequences (effects) if failure occurs.
5. Rate the consequences in terms of severity.
6. Identify the root causes for each failure mode.

GENERALIZED STEPS FOR FMEA

7. Rate each root cause in terms of chance of occurrence.
8. Identify current preventive and control measures for each root cause.
9. For each root cause and failure, rate how well or early they can be detected and addressed.

GENERALIZED STEPS FOR FMEA

10. Calculate the risk priority number (RPN) based on the consequences, occurrence, and detection.
11. Identify the failures that are considered critical.
12. Determine additional preventive or control measures as needed.

GENERALIZED STEPS FOR FMEA

Step 1 identifies the system and the scope of the study. FMEA can be a comprehensive look at the total system as a whole, or it may focus on certain subsystems, elements, or components. As an example, consider the bicycles a system of interest. An item analysis of the bicycle system is shown in Figure 3.5.

GENERALIZED STEPS FOR FMEA

The FMEA worksheet in Figure 3.6 focuses on a particular subsystem, the hand brake subsystem, and refers to Item 1.8 (shaded in gray) in the item analysis of the bicycle in Figure 3.5.

GENERALIZED STEPS FOR FMEA

ITEM ANALYSIS—BICYCLE EXAMPLE

1.0 Bicycle System

← *System item*

- 1.1 Frame subsystem
- 1.2 Front wheel subsystem
- 1.3 Rear wheel subsystem
- 1.4 Sprocket–pedal subsystem
- 1.5 Chain–derailleur subsystem
- 1.6 Seat subsystem
- 1.7 Handle bar subsystem

1.8 Hand brake subsystem

← *Subsystem item*

- 1.8.1 Brake lever
- 1.8.2 Brake cable
- 1.8.3 Brake pads
- 1.8.4 Brake caliper

← *Component item*

- 1.9 Suspension subsystem

Figure 3.5 Item analysis of bicycle ¹³

GENERALIZED STEPS FOR FMEA

Step 2 identifies the key functional objectives of the system, subsystem, or component of interest. It describes what the component is supposed to do to achieve the functional objective—description of what needs to go right. Thus for the bicycle, one of its critical functions is the ability to stop safely within a required distance under all operating conditions.

GENERALIZED STEPS FOR FMEA

This function is achieved through the hand brake by providing the correct level of friction between the brake pad assembly and the wheel rim when the brake lever is pulled. This information is entered in Column 1 of the FMEA worksheet. It describes what the hand brake subsystem is supposed to do to achieve the function of stopping or braking (What should go right?).

GENERALIZED STEPS FOR FMEA

Step 3 identifies the failure modes. As Column 1 defines what the component is supposed to do, Column 2 describes what can happen (What can fail?) that will prevent the component from doing what it is supposed to do. In other words, the failure modes are the different ways the component can fail to accomplish its functional objective.

GENERALIZED STEPS FOR FMEA

For the bicycle, one potential failure mode is having insufficient friction between the brake pad and wheel rim during normal or extreme conditions such as heavy rains. This information is entered in Column 2 of the FMEA worksheet. Note that it is important to describe in detail the conditions in which the failure mode can occur.

GENERALIZED STEPS FOR FMEA

Step 4 identifies the consequences (effects) on the system as a whole, its elements, and the environment for each failure mode.

It helps to ask What happens when this failure occurs?

GENERALIZED STEPS FOR FMEA

What does the user experience because of this failure? For the bicycle, insufficient friction means the bicycle wheel does not slow down when the brake lever is pulled, potentially resulting in collision, loss of control, and eventual injury.

This information is entered in Column 3 of the FMEA worksheet.

GENERALIZED STEPS FOR FMEA

Step 5 provides a severity rating for each effect. Rating scales such as those used in Lecture 2 can be used. For the bicycle, the worse potential result of the identified failure mode is safety failure; the severity is evaluated as catastrophic (see Table 2.2).

A level 5 is entered in Column 4.

GENERALIZED STEPS FOR FMEA

Step 6 identifies all potential root causes for each failure mode. What specifically causes this failure mode to occur? Here it is important to establish the causal chain of events to identify root causes. For the bicycle example, there are three potential causes for having insufficient friction between the brake pads and wheel rim

GENERALIZED STEPS FOR FMEA

1) failure of cable binds due to inadequate lubrication or poor routing, (2) foreign material on brake pad or wheel rim that reduces friction, (3) cable itself breaks, and (4) brake lever misalignment. This information is entered in Column 5 in the FMEA worksheet.

GENERALIZED STEPS FOR FMEA

Step 7 rates the root causes according to their likelihood of occurrence. This rating evaluates the chance of failure because of a particular root cause. It follows that if a particular root cause is more likely to occur, then failure from this root cause is also more likely.

GENERALIZED STEPS FOR FMEA

For the bicycle, the cable breaking is the most likely cause of insufficient friction among the causes. Using Table 2.3, its likelihood of occurrence is moderately possible and given a rating of 3. This information is entered in Column 6 in the FMEA worksheet.

GENERALIZED STEPS FOR FMEA

Steps 8 and 9 describe and rate the effectiveness of preventive and control measures that currently exist. Each measure is evaluated according to how well or early the failure mode or its cause can be detected and addressed before the effects occur. Detection is rated on a scale from 1 to 5, where 1 means the control is absolutely certain to detect the cause or failure and 5 means the inability for detection.

GENERALIZED STEPS FOR FMEA

For the bicycle example, detection of the cable binding due to inadequate lubrication or poor routing is given a rating of 2. This is due to the quality and testing process in the manufacturing of bicycles. Table 3.2 can be used to determine a detection rating. The information for steps 8 and 9 are entered in Column 7 and Column 8 of the FMEA worksheet, respectively.

GENERALIZED STEPS FOR FMEA

Table 3.2. Example of detection scale¹⁵

Likelihood of detection	Criteria: likelihood of detection by design control	Rank
High to absolute uncertainty	No current design control or cannot be detected	5
Remote	Detection controls have a weak detection capability	4
Low	Product verification with pass or fail testing	3
Medium	Product verification with test to failure testing	2
High	Product verification with degradation testing	1

GENERALIZED STEPS FOR FMEA

One can also evaluate reactive measures. Specifically, how the system is able to detect failure after the cause has already happened; and how the system is able to address the failure before the impact of the effects occurs. For example, if the bicycle had an indicator or an alarm that the hand brake subsystem has failed. This measure can inform the user to use alternative means for stopping or breaking.

GENERALIZED STEPS FOR FMEA

In step 10, upon identifying the likelihood (L), consequences (S) of failure modes, and the current system's ability to address (D) the causes of failure, failure modes are then evaluated for criticality using a risk score similar to PHA. For FMEA, the risk score is known as the RPN and can be derived by multiplying $L \times S \times D$, corresponding to Columns 4, 6, and 8 respectively. The RPN score entered in Column 9 can provide guidance for ranking potential failures in the order they should be addressed.

GENERALIZED STEPS FOR FMEA

Step 11 describes recommendations and proposed additional preventive control measures if necessary. Particular attention is given to proposals that will decrease the likelihood of occurrence, lower the severity of the consequences, or increase the capability or effectiveness to detect early and mitigate the causes of failure. Part of the recommendation should include the organizational functions responsible for these actions and target completion dates. This information is entered in Column 10 of the FMEA worksheet.

References

Resources:

Operational Risk Management

C. Ariel Pinto

Luna Mylene Magpili

Raed M. Jaradat