CHAPTER 2
THEORY AND LITERATURE SURVEYS

2.1 Failure Mode and Effects Analysis (FMEA)

FMEA is acronym for "Failure Mode and Effects Analysis" that began in the United States Military. Military Procedure MIL-P-1629, titled Procedures for Performing a Failure Mode, Effects and Criticality Analysis, is dated November 9, 1949. In 1988, the International Organization for Standardization issued the ISO-9000 series of business management standards. These requirements pushed organizations to develop formalized Quality Management Systems that are focused on the needs, wants, and expectations of customers. QS-9000 is the automotive analogy to ISO9000. A Task Force representing Chrysler Corporation, Ford Motor Company, and General Motors Corporation developed QS-9000 in an effort to standardize supplier quality system. According to QS-9000 standards, compliant automotive suppliers shall utilize Advanced Product Quality Planning (APQP), including design and process FMEA, and develop a Control Plan. The Automotive Industry Action Group (AIAG) and the American Society for Quality Control (ASQC) copyrighted industry-wide FMEA standards in February of 1993 and this is the technical equivalent of the Society of Automotive Engineered procedure SAE J-1739. The standards are presented in an FMEA Manual approved and supported by all three automotive makers. This manual provides general guidelines for preparing an FMEA. (www.fmeca.com/ffmethod/history.htm, 2001:1) However, at present time FMEA can apply to many organizations such as refinery industry, hospitals, cement industry, electronic industry and etc.

2.2 Understanding failure mode

The failure mode is the event that comes between cause and effect. But, any cause that itself has a cause and any effect that itself has an effect might

be failure mode. Moreover, a single event may be cause, effect or failure mode depending on the different contexts.

The example in Figure 4 is the series of events about the malfunction of the penlight.

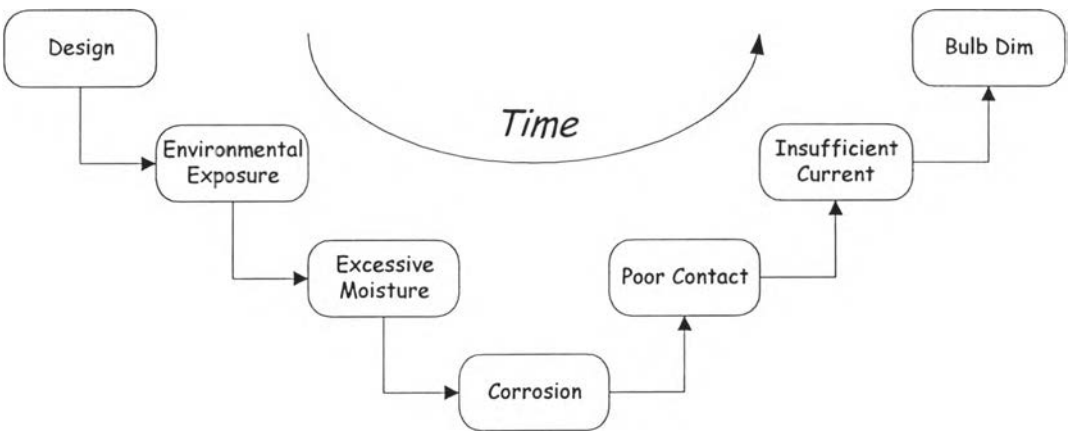

Figure 2.1: Series of events of a malfunctioned penlight

(www.fmeca.com/ffmethod/understa.htm)

In the analysis of the exterior casing of a penlight, "Allows excess moisture" would be a failure mode if the penlight case were intended to protect the internal components from excess moisture. But if the design of the case is intended to protect the moisture, the failure to prevent the moisture during normal operation is a failure mode.

In the real event, a single cause may have multiple effects, a combination of causes may have only one effect, or multiple effects. Cause may have itself upstream cause and effect may have its downstream effect. (www.fmeca.com/ffmethod/understa.htm, 2001:1-2).

2.3 Identifying FMEA elements

FMEA elements are the building block of related information that are used in the analysis that are function, failure mode, effect, cause, and current control.

- *Functions and failure modes*

The function is an intended purpose of the process to be analyzed. For example, "provide light at 3.0 ± 0.5 candela" is the function of the penlight. For the failure mode, the way to fail or malfunction is identify that fall into 1 of 5 possible failure categories.

1. Complete failure
2. Partial failure
3. Intermittent failure
4. Failure over time
5. Over-performance of function

In order to define the function effectively, the five categories of the failure must be considered.
(www.fmeca.com/ffmethod/elem/function.htm, 2001:1-2).

- *Effects*

After the potential failure mode has been identified, the effect of the failure mode will be identified by using team-brainstorming activity. According to Haviland Consulting Group, it is assumed that the effects always occur when failure mode occurs.

In order to identify effects of the failure mode, this procedure should be followed. (www.fmeca.com/ffmethod/elem/effects.htm, 2001:1-2).

a) Refer the identified failure mode and list all of its potential consequences
b) Separate the consequences that occur whenever the potential failure mode occurs and identify these as effects.
c) Write additional failure modes for the remaining consequences.
d) Separate the consequences that occur whenever the additional failure modes occur and identify them as the effects of the additional failure modes.

- *Severity*

The severity of the effects will be quantified by using scale 1 to 10, 10 is the most severe. In order to evaluate the severity of the effects, the team should agree on the criteria of ranking system. The effects that come from the same failure mode will be evaluated as a group. Appendix B and C show the example of severity table of Process Failure Mode and Effects Analysis (PFMEA) and Design Failure Mode and Effects Analysis (DFMEA).
(www.fmeca.com/ffmethod/elem/severity.htm, 2001:1-2).

Notes of interest:

- The scale can not identify the different between the failure that has very high severity such as death, injury or government regulation violation.
- A defect noticed by most customers is less than halfway up the scale.
- The lowest scale is 1 for "no effect".

- *Causes*

After effects and severity level are addressed, the next step is to identify the cause of the effect by the working team. To identify the cause, the failure mode that is most severity will be started.
(www.fmeca.com/ffmethod/elem/causes.htm, 2001:1-2).

- *Occurrence*

In the AIAG FMEA model, when the cause occurs, it is assumed that the failure mode *could* occur, but not necessary. With this definition, there is no way to quantify the likelihood that the failure mode and effects will result. Then, Ford Motor Company has added a cause-failure mode condition to the AIAG model to state that if the cause occurs, the failure mode always results. So, occurrence is the likelihood that the cause will occur and result the failure mode during the life of the product. Unlike effects, the every causes of the failure mode will be evaluated individually. Appendix D and E show the example of occurrence table of Process Failure Mode and Effects

Analysis (PFMEA) and Design Failure Mode and Effects Analysis (DFMEA). (www.fmeca.com/ffmethod/elem/occurren.htm, 2001:1-2).

Notes of interest:

- The probability show the likelihood that the cause occurs and result in the failure mode, not just only a chance that it may occur.
- The scale is not linear
- The scale 10 (> 1 of 2) can not separate the cause that occurs over the half of time and that occurs every time.
- The scale 1 (≤ 1 in 1,500,000) can not separate the cause the remotely occurs and that never occurs.

- *Current control*

The design and process control purpose can be separated into 3 types:

Type (1): To prevent the cause of the failure mode from occurring or reduce the rate of occurrence.

Type (2): To detect the cause of the failure mode in order to establish the corrective action.

Type (3): To detect the failure mode before the product is delivered to the customer. The customer may be the next operation or end customer.

The different between control to prevent the failure (type 1) and to detect the failure (type 2 and 3) is important. Type1 reduce the occurrence that affect to the occurrence rating but type 2 and 3 detect the causes and failure modes that affect the detection rating. (www.fmeca.com/ffmethod/elem/current.htm, 2001:1).

- *Detection*

Detection values are associated with the current controls. Detection is a measurement of the ability of type 2 and type 3 control to detect the cause and the effect of the failure mode. The detection evaluation of the current controls can be grouped if the increasing of the individual can increase the overall detection ability. Appendix F and G

show the example of detection table of Process Failure Mode and Effects Analysis (PFMEA) and Design Failure Mode and Effects Analysis (DFMEA). (www.fmeca.com/ffmethod/elem/detectio.htm, 2001:1).

Notes of interest:

- High value indicates lack of detection.
- The criteria are not quantitative.
- The rating is generally linear relationship.
- The value 1 is full detection ability.

2.4 The FMEA form

The FMEA form has been standardized by AIAG. All of the FMEA elements will be fill in the identified table in the form. Appendix A is the sample of the FMEA form.

2.5 Reducing risk

In order to reduce risk, the action purposed to lower severity, occurrence and detection rating will be implemented. The severity and occurrence rating can be lower by revise design or process and the detection rating can be reduced by control ability to detect the cause and the effect.

2.6 RPN

The Risk Priority Number (RPN) is the multiple result of severity, occurrence and detection rating as shown in the following equation

$$RPN = S.O.D$$

The RPN number is used to identify the serious risks and establish the appropriate actions needed to reduce the risk.

2.7 Literature Surveys

In Failure Mode and Effects Analysis development, Chrysler Corporation, Ford Motor Company and General Motors Corporation (1995) presented the development of both design and process FMEA in automotive industry by using FMEA data collection form that is applied to automotive industry as examples. In the examples, the principle and method to fill the information in each column in the form is explained clearly that help the user to understand the principle and can analyze the information correctly.

Another important thing in FMEA implementation is to define the scope to be analyzed. http://www.fmeca.com/ffmethod presented the meaning of Failure Mode clearly by using the analysis of the penlight as an example. From the example, it illustrated that the Causes, Effects and Failure Modes can change depending on the function being analyzed and the function depending on the object of the analysis.

In the implementation of FMEA, this technique has been implemented in many fields of industry as following examples.

Kolarik (1995) presented the using of base format FMEA and also the variation of FMEA format that are functional level analysis and part level analysis. In this book, FMEA technique has been used in radar performance analysis, no.2 wooden lead pencil production, house and residential fireplace.

- FMEA was conducted during the early stages of radar system development to identify system failures and their subsequence effects on system operation. After the analysis, FMEA identified two major areas of high criticality that are the radar transmitter and accidental irradiation of ground personnel.

- The result of basic FMEA development for a simple no. 2 wooden lead pencil is a tabulation of the effects of various equipment failures within a system.

- For a development of FMEA for a house, the functional level analysis is used and interrelationship of the subsystems can be observed.

For a residential fireplace, the part level analysis is used to analyze the failure modes of each major component.

Halpern (1979) presented the using of FMEA technique to solve the failures in integrated circuit from lead bonding problem. The analysis used to solve this problem may include optical inspection, radiographic inspection, microscopic examination or chemical inspection and the found problems will be defined in standard code.

From the principle of FMEA that is to identify the failure mode that cause the problem in function or quality, it can be used in energy conservation activity by changing the purpose to fine out the causes of the loss of energy. Because the implementation of FMEA in energy conservation purpose is never done before, the standard indicator must be used to measure the result of the implementation. Another standard indicator used for measurement of energy utilization for oil refinery is Energy Intensity Index (EII). The EII is calculated from the energy used in the process in form of standard fuel oil and the process's utilization. With EII, we can compare the optimization of energy used between process units or monitor the improvement of the energy utilization of the process. (Solomon Associates ;1995)