MichiganTech

Department of

Electrical and Computer Engineering

Adapting

Failure Modes and Effects Analysis (FMEA)

to Outcomes Assessment

Roger M. Kieckhafer
Associate Chair for Computer Engineering
rmkieckh@mtu.edu

Lecture Overview

MichiganTech

- **Observations & Motivation**
- **What is FMEA, Really?**
  - ✦ *Definitions*
  - ✦ *Types of FMEA and Coverage*
- **Adaptation of FMEA to Outcomes Assessment**
  - ✦ *General Procedures and Sequence of Events*
  - ✦ *Quantifying FMEA parameters*
    - ∗ Severity (S)
    - ∗ Credibility (C)
    - ∗ Recurrence (R)
    - ∗ Risk Priority Number (RPN)
  - ✦ *Implementation and Administration*
  - ✦ *Examples*

What is FMEA?

- **An industrial-strength Risk Assessment tool**
- **A set of systemized group activities intended to:**
  1. *Identify potential "failure modes" of a product or process*
  2. *Evaluate the "effects" of each failure mode on the system*
  3. *Define and prioritize action items to*
     - reduced the chance of failure mode to occurrence, or
     - break the links between failure modes and effects
  4. *Track the progress of all action items*
  5. *Document the entire process*
     - demonstrate "all due care"
     - record the reasoning of the designers

Industry Standards

- **FMEA is a very widespread practice**
- **Different Industries have different standards**
  - *All are very similar in philosophy and procedures*
  - *They vary mostly in product-specific details*
- **Examples:**
  - *SAE Standard: J-1739*
    - Automotive Systems
  - *SAE Standard: ARP-5580*
    - Aerospace Recommended Practice
  - *Military Standard: MIL-STD-1629A*
    - Failure Mode, Effects and Criticality Analysis (FMECA)

Types of FMEA and Coverage

- **Two standard categories of FMEA**
  - *Design FMEA:*
    - addresses potential failure modes arising during design
  - *Process FMEA*
    - addresses potential failure modes arising during fabrication
- **We have adapted the method to outcomes assessment**
  - *Program FMEA*
    - addresses potential "failure modes" arising in
      - *the degree program (curriculum)*
      - *the outcomes assessment process*

Definitions

- **Failure Mode =**
  - *Design FMEA: The physical cause of a malfunction*
  - *Program FMEA: A problem or weakness in*
    - the academic degree program itself
    - the assessment processes
- **Effect =**
  - *Design FMEA: Incorrect behavior caused by a failure*
  - *Program FMEA: Degradation in the ability to either:*
    - achieve one or more outcomes, or
    - assess one or more outcomes

(1) Identifying Failure Modes

- **Design FMEA**
  - *Meetings – lots of meetings*
  - *Brainstorming to ID "all" potential failure modes*
    - expertise and experience of participants
    - histories, test data, analyses, simulations, ...
  - *Uses a standard FMEA Form to record everything*
- **Program FMEA**
  - *Assessment Instruments*
    - 10 annual instruments
    - a few ad hoc or aperiodic instruments
  - *Most are common to both EE and CpE*
  - *A few are specialized for one major or the other*

(2) Evaluating the Effects

- **Design FMEA**
  - *More Meetings & Brainstorming*
    - to predict & project possible effects of each failure mode
    - write them all down on the FMEA Form
- **Program FMEA**
  - *Analysis and evaluation of assessment instrument results*
    - Examine the problem items revealed by each instrument
    - Map each problem item to the outcome(s) affected
  - *Each analysis becomes an Appendix of the Annual Report*
    - Related instruments are lumped together in one appendix
    - Each appendix is written by one evaluator
    - AY 2003-2004 report had nine Appendices

(3) Define & Prioritize Actions

- **Design FMEA**
  - *Still More Meetings & Brainstorming*
  - *(a) Prioritize the Problems using three parameters*
    - S = Severity of the effect, given that the failure occurs
    - O = Occurrence probability of the failure mode
    - D = Detection likelihood of the failure or effect not being detected before it is released for production
  - *(b) Rank each parameter (S, O, D) on a [1 ...10] scale*
    - 10 = worst
    - Each ranking level has a detailed verbal description
      - *makes it difficult to completely mis-represent a threat*
      - *at worst, ratings get "fudged" between adjacent levels*
      - *minimizes the impact of "judgement" on numerical value*

(3) Define & Prioritize Actions

- **Design FMEA Cont'd**
  - *(c) Derive a Risk Priority Number (RPN) for each effect*
    - RPN = (S x O x D) each of which $\in$ [1...10]
    - RPN $\in$ [1...1000]
    - Higher RPNs represent higher risks
  - *(d) Define action item(s) for each problem identified*
    - Goal of an action item is to reduce the RPN of a problem
      - *Reduce S, Reduce O, or Reduce D*
    - An action item inherits the RPN of its respective problem(s)
    - Actions are thus prioritized on a [1…1000] scale
  - *(e) Assign responsibility for each action item*

(3) Define & Prioritize Actions

MichiganTech

- **Program FMEA**
  - ✦ *Same Idea, Different Details*
  - ✦ *(a) Prioritize the Problems using three parameters*
    - ∗ S = Severity of the problem, relative to outcomes
    - ∗ C = Credibility of the instruments that identified the problem
    - ∗ R = Recurrence likelihood for the problem if no corrective action is taken
  - ✦ *(b) Rank each parameter (S, C, R) on a [1 ...10] scale*
    - ∗ again, 10 = worst
    - ∗ Each ranking level has a detailed verbal description
    - ∗ Uses three rubrics to define the levels

Severity

MichiganTech

Severity (S)	Criteria for Severity of Effect
10	***Failed Outcome:*** complete or nearly complete failure to achieve one or more outcomes and/or to assess one or more outcomes
9	***Indeterminate Outcome:*** marginal, ambiguous, or indeterminate level of success in achieving one or more outcomes and/or in assessing one or more outcomes
8	***Low Quality Outcome:*** less than desirable level of quality in achieving one or more outcomes and/or in assessing one or more outcomes
7	One or more department programs or processes fail to achieve ***at least*** level 4 in one or more categories of the ABET *Matrix for Implementation Assessment*
6	The assessment process is deficient in one or more of the *Target Attributes* specified in Subsec. 5.2
5	A required course failed to contribute to the outcome(s) assigned to it in Table 1 and/or 2 due to deficiencies in, or failure to adhere to, the course specification
4	Cohesiveness or completeness of curriculum is compromised or threatened
3	A required course is now or is likely to become irrelevant or obsolete.
2	One or more assessment instruments is ineffective or superfluous for assessing the outcomes assigned to that instrument by Table 4.
1	Negligible effect on outcomes, assessment process, and degree programs

Recurrence

MichiganTech

Recurr (R)	Criteria for Likelihood of Problem to Reccur (without corrective action)
10	Nearly 100% chance to appear continuously or annually and ***expected*** to increase in severity
9	Nearly 100% chance to appear continuously or annually but ***not expected*** to increase in severity
8	At least 50% chance to appear continuously or annually and ***expected*** to increase in severity
7	At least 50% chance to appear continuously or annually but ***not expected*** to increase in severity
6	Continuous or annual recurrence is a risk, but chances are less than 50% or very difficult to estimate
5	Intermittent phenomenon with recurrence period estimated as two years
4	Intermittent phenomenon with recurrence period estimated as more than two years
3	Transient phenomenon whose impact will self-correct within three or four years
2	Transient phenomenon whose impact will self-correct within two years
1	One-time anomaly, almost certain *not* to reoccur

Credibility

MichiganTech

Credib. (C)	Criteria for Credibility of Indicators
10	Beyond a Reasonable Doubt: Multiple instruments yielded unanimous strong evidence with no contradictions
9	Strongly Inconsistent: Multiple Instruments yielded both strong evidence and strong contradictions
8	Highly Credible: Multiple Instruments yielded strong evidence with only weak contradictions
7	Credible: A single instrument yielded strong evidence with no contradictions
6	Ad Hoc Assessment Process Observation: Observed and documented by AC or UPC while executing assessment process
5	Externally Imposed: Recommended by an entity external to the department (other than ABET)
4	Ad Hoc Instructor Observation: Observed and documented by instructor(s) in performance of their duties
3	Weakly Credible: One or more instruments yielded weak evidence with no contradictions
2	Weakly Inconsistent: Instruments yielded both weak evidence and weak contradictions
1	Not credible: No credible evidence, or the contradictions are stronger than the evidence

(3) Define & Prioritize Actions

- **Program FMEA Cont'd**
  - *(c) Derive a Risk Priority Number (RPN) for each effect*
    - RPN = (S x C x R) $\Rightarrow$ RPN $\in$ [1...1000]
    - Higher RPNs represent higher risks
  - *(d) Define action item(s) for each problem identified*
    - Goal of an action item is to reduce the RPN of a problem
    - An action item inherits the RPN of its respective problem(s)
    - Actions are thus prioritized on a [1…1000] scale
  - *(e) Assign responsibility for each action item*

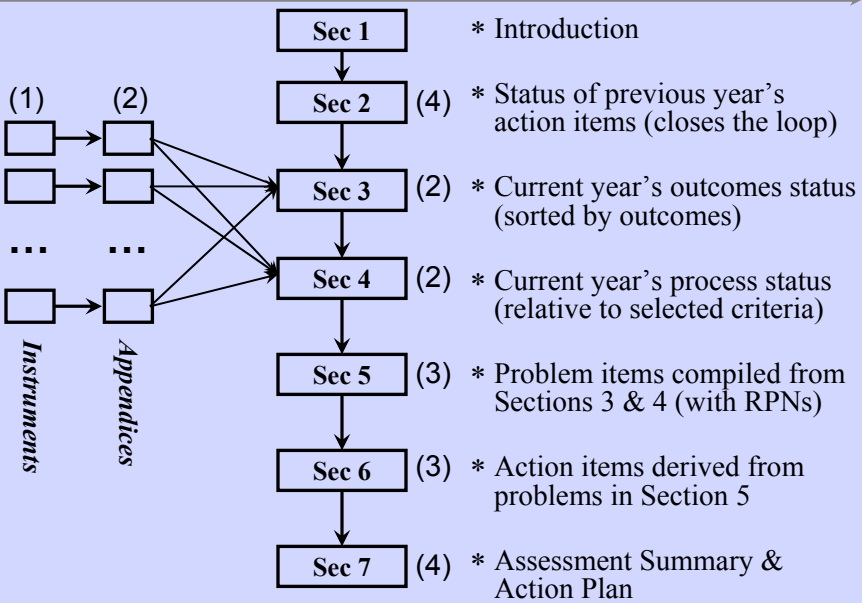
(4) Track Status of Actions

- **Management (Assessment Coordinator)**
  - *Monitors action items*
  - *Keeps track of status of each*
  - *Harrasses, harangues, cajoles, threatens, stalks…*
    - whatever it takes
  - *Threatens to "tell" in the next annual report*

(5) Document the Process

- **Design FMEA**
  - ✦ *Uses the Standard FMEA form*
- **Program FMEA**
  - ✦ *Uses the Annual Outcomes Assessment Report*
  - ✦ *Form, format, style and content are strictly prescribed*
    - ∗ Each section serves a specific purpose
  - ✦ *Presented to dept faculty each fall*
  - ✦ *Faculty must vote-on and approve the report*
    - ∗ including all action items mandated therein

Annual Report Structure



Previous Action Status

- **Note that one uncompleted action item had a high RPN**
- **It was an item that needed extra-departmental assistance**

Table 2.1: Summary of Action Item Status

Total Number of Action Items	21
Number of Mandatory Action Items	21
Number of Mandatory Items Completed	19
Pcnt of Mandatory Items Completed	**90%**
Highest RPN for Incomplete Items	**729**

Current Action Assignments

Table 6.1: Summary of Action Items, RPNs, and Deadlines (Sorted by action item RPN)

Action Item (from Sec 6.1)	Problem items addressed (from Sec 5)	Action Item RPN (max Prob RPN)	Execution Responsibility	Monitoring Responsibility	Deadline (Sem / Week)
10	10	576	UPC	DOW	spr / 14
5	5	448	RMK	RMK	fall / 09
6	6	448	RMK	RMK	fall / 14
11	11	378	RMK	RMK	fall / 09
7	7	360	UPC	LJB	fall / 09
12	12	324	UPC & lead inst	DOW	spr / 14
3	3	315	RMK	RMK	fall / 14
4	4	315	UPC	RMK	spr / 14
1	1	288	UPC & lead inst	RMK	fall / 09
2	2	240	UPC & GEA	LJB	spr / 14
8	8	63	RMK	RMK	optional
9	9	63	RMK	RMK	optional

Latest RPN History

MichiganTech

Figure 7.3 Outcome and Process RPN History

(a) Computer Eng'g

CpE Outcome	Problem Item(s)	Max RPN AY 01-02	Max RPN AY 02-03	Max RPN AY 03-04
a	1,2	500	378	288
b	3	630	378	315
c	2	500	378	240
d	3	900	441	315
e	2	378	378	240
f	4	0	0	315
g	3,4	900	0	315
h	5	567	648	448
i		0	0	0
j	6	900	810	448
k	2,7	500	360	360
l		378	0	0
m		315	0	0
n	1	0	0	288
o		0	0	0
p	8,10	315	378	576
q	7,9	0	360	360
r		0	0	0
s		500	0	0
	Max	**900**	**810**	**576**
	Mean	**404**	**260**	**252**
	StDev	**340**	**286**	**198**

(b) Electrical Eng'g

EE Outcome	Problem Item(s)	Max RPN AY 01-02	Max RPN AY 02-03	Max RPN AY 03-04
a	1,2	500	378	288
b	3	630	378	315
c	2	500	378	240
d	3	900	441	315
e	2	378	378	240
f	4	0	486	315
g	3,4	900	378	315
h	5	567	648	448
i		0	378	0
j	6	900	810	448
k	2,7	500	360	360
l	10,12	0	729	576
m	1,8,10	500	378	576
n	10,12	500	378	576
	Max	**900**	**810**	**576**
	Mean	**513**	**495**	**379**
	StDev	**331**	**174**	**167**

(c) Assessment Procs

	7,11	900	810	378

A Few Interesting Trends (CpE)

MichiganTech

- **(d) Multidisciplinary teaming (typical)**
  - *900 – undefined and unassessed*
  - *441 – defined "multidisciplinary" and started assessment*
  - *315 – improved assessment methods*
- **(g) Technical Communication (writing)**
  - *900 – not properly assessed (Sr Design teams only)*
  - *000 – individual writing assessment added to EE-3970*
  - *315 – new instructor: writing assignments were too easy*
- **(p) knowledge of (various aspects of applied math)**
  - *315 – Mostly weaknesses in complex numbers*
  - *378 – General dissatisfaction with applied math abilities*
  - *576 – Continued dissatisfaction with applied math*

Summary

- **FMEA in general:**
  - *Is a formalized group-based risk assessment method*
    - Similar to other design review standards in many industries
    - Has become an industry-standard approach
  - *Goal is to accomplish the following:*
    1. Identify failure modes
    2. Evaluate the effects on the system
    3. Define and Prioritize actions to correct the problems
       - *prioritization method is the signature feature of FMEA*
    4. Track corrective actions and their effects
    5. Document the entire decision process

Summary

- **Adaptation to Outcomes Assessment**
  - *failure mode = a problem or weakness in the program or assessment processes*
  - *effect = the impact of a problem on delivery or assessment of outcomes*
- **Follows the same basic procedures**
  - *the difference is in the details*

Summary

- **Implementation of Program FMEA steps:**
  1. *Identify failure modes*
     - execute of assessment instruments
  2. *Evaluate the effects on the system*
     - evaluate results of the assessment instruments
     - map problems to their relevant outcomes
  3. *Define and Prioritize actions to correct the problems*
     - proritize the problem items (RPN = S x C x R)
     - define action items & inherit RPNs
  4. *Track corrective actions and their effects*
     - Assign responsibility and monitor
  5. *Document the entire decision process*
     - Annual Outcomes Assessment Report

Further Information

- **References list in the Supplemental Materials**
- **The ECE department website www.ece.mtu.edu**
  - *In the left-hand menu, click on Program Assessment*
  - *takes you to our assessment table of contents page*
  - *Has links to various assessment documents*
    - Standard Operating Procedures (SOPs) with archive
    - Reports (annual reports in particular) with archive
    - Publications (where these slides will be posted)