Comparison of Simulated AP and RPN for PFMEAs

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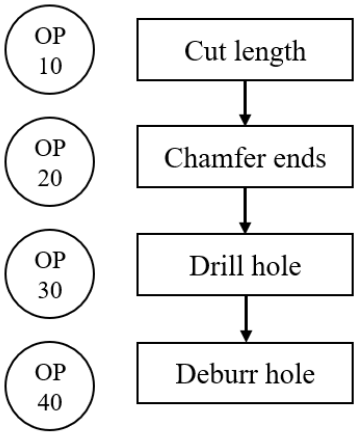
Introduction

- PFMEAs (Process Failure Modes and Effects Analysis) have traditionally prioritized risks for improvement using RPN (Risk Priority Number)
  - RPN = Severity x occurrence x detection
  - Improvements implemented for the highest RPN values
- The AIAG/VDA FMEA Handbook replaced RPN with AP (Action Priority) for prioritizing improvement actions
  - AP is derived using a table with the most emphasis on severity, followed by occurrence and the least emphasis on detection
  - Three levels of AP
    - Actions mandatory for high AP, should be implemented for medium AP, and optional for low AP

PFMEA: Structure Analysis

- The process structure is analyzed using a process flow diagram
  - The 4Ms (Material, operator (man), environment (Milieu), and machine) are used to identify the 4M type of the process work element



Function Analysis		
1. Function of Process Function of System, Subsystem, Part or Process	**Function of the Process Step and Product Characteristic**	**Function of the Process Work Element and Process Characteristic**
Plant Drilling of rod **Customer** Assembly to system **End user** Connecting assemblies	Bore hole	Operator

PFMEA

PFMEA: Function Analysis

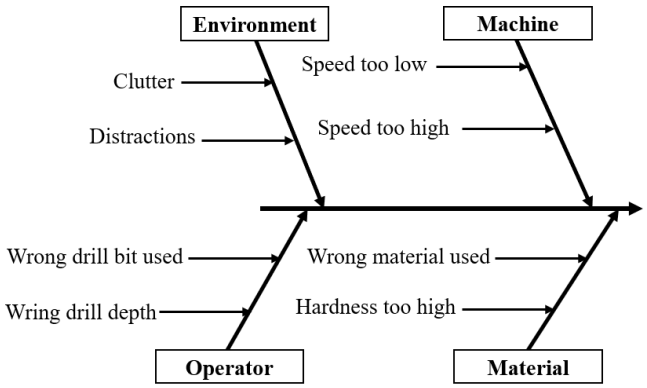
- The functions of the process steps are identified

Function Analysis		
1. Function of Process Function of System, Subsystem, Part or Process	**Function of the Process Step and Product Characteristic**	**Function of the Process Work Element and Process Characteristic**
Plant Drilling of rod **Customer** Assembly to system **End user** Connecting assemblies	Bore hole	Employee

PFMEA

PFMEA: Failure Analysis

- Failure causes, failure mode, and failure effects are assigned to the structure and the severity of the failure effect is rated
  - An Ishikawa diagram is used to identify failure causes



Failure Analysis			
Failure Effects at Next Higher Level and/or End User	**Severity**	**Failure Mode at Focus Element**	**Failure Cause at Work Element**
Plant Bored hole diameter too big **Customer** Loose connection **End user** Rattle noise	4	Bore hole too big	Wrong drill bit selected (too big)

PFMEA

PFMEA: Risk Analysis

- Prevention actions for the failure cause and detection actions for the failure cause or failure mode are assigned and rated
  - The AP is then derived from a table

Risk Analysis						
Prevention Actions	**Occurrence**	**Detection Actions**	**Detection**	**AP**	**Special Characteristi**	**Filter code**
Work Instruction 67654	3	100% visual inspection	8	M		

PFMEA

PFMEA: Optimization

- Optimization actions identified, implemented, and evaluated to reduce the AP
  - Actions are permitted when they have no impact on AP

Optimization												
Planned Prevention Actions	**Planned Detection Actions**	**Responsible**	**Deadline**	**Status**	**Actions Taken**	**Date of Completion**	**Severity**	**Occurrence**	**Detection**	**Special Characteristi**	**AP**	**Comments**
None	Automated inspection with Go/No-Go gage	J. Smith	18 May	Open	Detection: Automated inspection with Go/No-Go gage	18 May	4	3	3		L	

PFMEA

Study Methodology

- Statistical software used to generate10,000 values from 1 to 10 for simulated severity, occurrence, and detection and then the order was randomized and RPN was calculated

↓	C1	C2	C3	C4	C5	C6	C7
	Severity_Random	Severity	Occurrence_Random	Occurrence	Detection_Random	Detection	RPN
1	63,798	8	57,994	3	59,968	4	96
2	66,108	6	65,342	5	60,910	9	270
3	68,680	4	66,427	1	61,028	8	32
4	68,996	1	67,585	4	63,386	2	8
5	69,346	1	67,792	3	63,471	3	9
6	69,495	10	67,877	7	63,934	5	350
7	69,744	8	68,443	4	64,099	3	96
8	69,745	10	68,635	2	64,751	3	60
9	69,823	2	69,084	10	66,294	3	60
10	69,825	5	69,606	10	67,302	6	300
11	69,908	2	69,949	2	67,452	5	20
12	69,986	7	70,010	7	67,728	7	343
13	69,993	7	70,262	3	67,805	7	147
14	70,274	8	70,912	3	68,223	8	192
15	70,349	7	70,937	8	68,413	6	336
16	70,739	9	71,100	5	68,467	1	45
17	71,556	7	71,215	10	68,931	7	490
18	71,569	5	71,298	8	69,287	2	80
19	71,722	3	71,341	4	69,343	7	84
20	71,771	7	71,361	1	69,377	7	49

PFMEA

Study Methodology

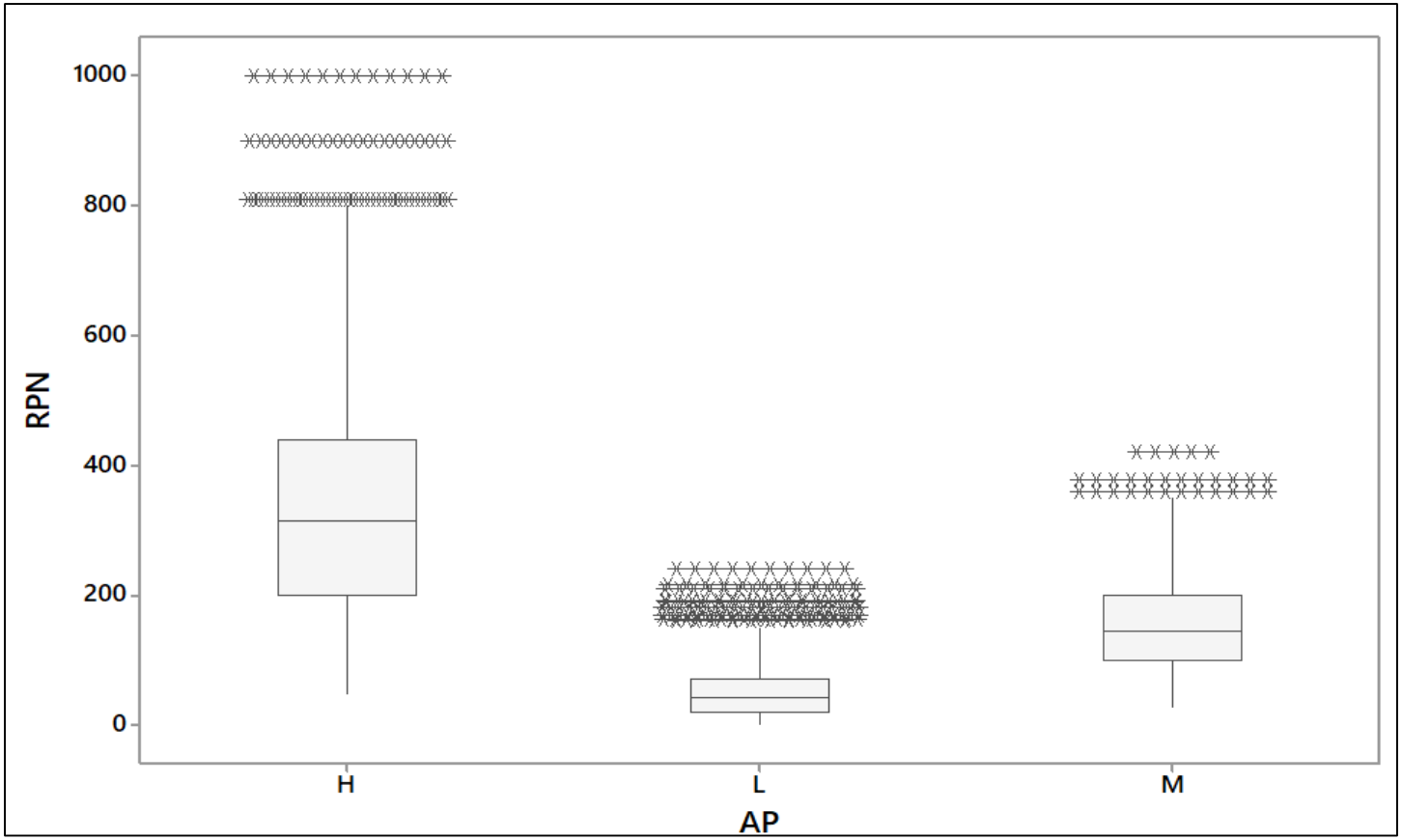
- AP calculated using a formatted spreadsheet and then data was copied back to the software

↓	C1	C2	C3	C4	C5-T
	Severity	Occurrence	Detection	RPN	AP
1	8	3	4	96	L
2	6	5	9	270	M
3	4	1	8	32	L
4	1	4	2	8	L
5	1	3	3	9	L
6	10	7	5	350	H
7	8	4	3	96	M
8	10	2	3	60	L
9	2	10	3	60	L
10	5	10	6	300	H
11	2	2	5	20	L
12	7	7	7	343	H
13	7	3	7	147	M
14	8	3	8	192	M
15	7	8	6	336	H
16	9	5	1	45	M
17	7	10	7	490	H
18	5	8	2	80	M
19	3	4	7	84	L
20	7	1	7	49	L

PFMEA

Study Methodology

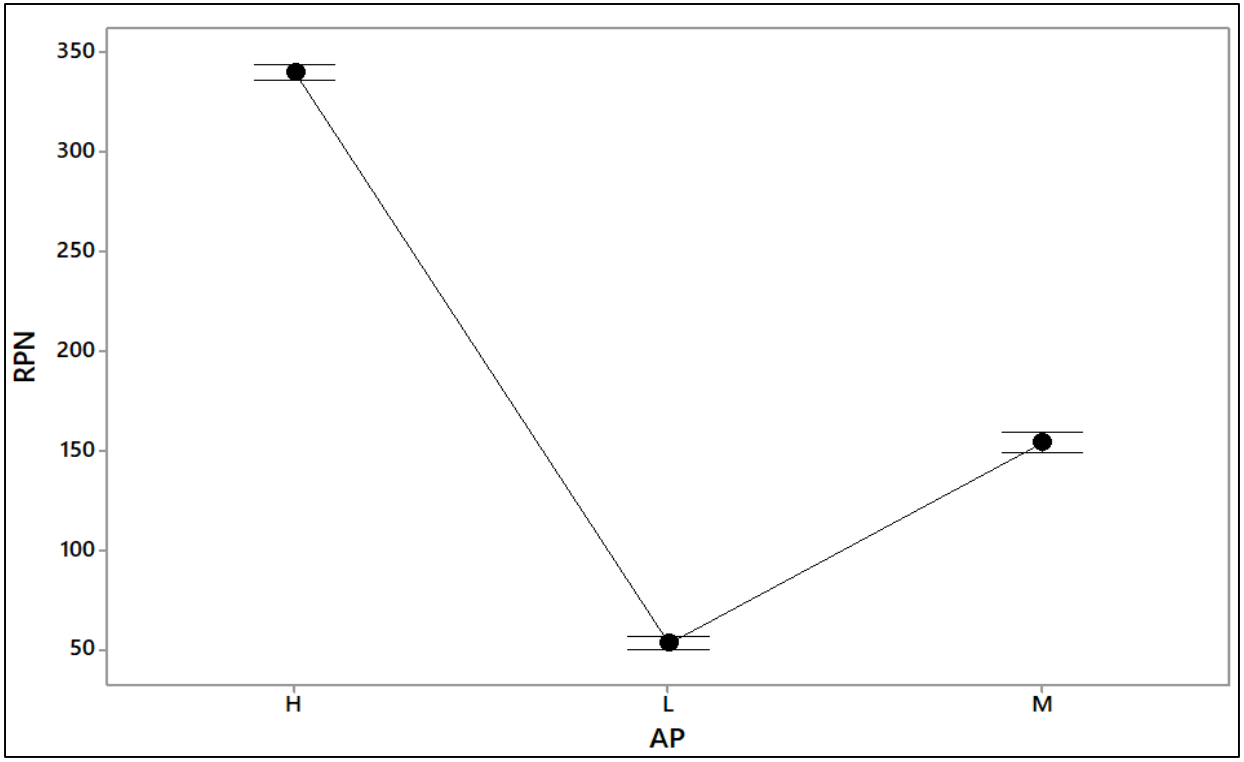
- RPN values were sorted into new columns by AP



PFMEA

Study Methodology

- An ANOVA was performed to determine if means of RPNs different between APs
  - There was a statistically significant difference with an alpha of 0.05



PFMEA

Study Methodology

- The number of RPNs equal to or greater than 100 was determined for high, medium, and low AP

	High AP	Medium AP	Low AP
RPN ≥ 100	2,950 (92.2%)	1,545 (75.2%)	646 (13.6%)
RPN < 100	249 (7.8%)	510 (24.8%)	4,100 (86.4%)

PFMEA

Study Methodology

- A statistical test of two proportions was performed to determine if there was a statistically significant difference in the number of actions required based on RPN equal to or greater than 100 verses high AP
  - There was a statistically significant difference between with RPN requiring more actions than high AP

	Only High AP	High and medium AP	RPN ≥ 100
Actions Needed	3,199	5,254	5,141

Test and CI for Two Proportions

Method

p_1: proportion where Sample 1 = Event

p_2: proportion where Sample 2 = Event

Difference: $p_1 - p_2$

Descriptive Statistics

Sample	N	Event	Sample p
Sample 1	10000	3199	0.319900
Sample 2	10000	5141	0.514100

Estimation for Difference

Difference	95% CI for Difference
-0.1942	(-0.207599; -0.180801)

CI based on normal approximation

Test

Null hypothesis	H_0: $p_1 - p_2 = 0$	
Alternative hypothesis	H_1: $p_1 - p_2 \neq 0$	
Method	Z-Value	P-Value
Normal approximation	-28.41	0.000
Fisher's exact		0.000

Study Methodology

- A second hypothesis test of two proportions compared the number of actions required for RPN equal to or greater than 100 verses high and medium AP combined
  - There was no statistically significant difference in the number of actions required when high and medium APs were combined

	Only High AP	High and medium AP	RPN ≥ 100
Actions Needed	3,199	5,254	5,141

Test and CI for Two Proportions

Method

p_1: proportion where Sample 1 = Event

p_2: proportion where Sample 2 = Event

Difference: $p_1 - p_2$

Descriptive Statistics

Sample	N	Event	Sample p
Sample 1	10000	5254	0.525400
Sample 2	10000	5141	0.514100

Estimation for Difference

Difference	95% CI for Difference
0,0113	(-0.002547; 0.025147)

CI based on normal approximation

Test

Null hypothesis	H_0: $p_1 - p_2 = 0$	
Alternative hypothesis	H_1: $p_1 - p_2 \neq 0$	
Method	Z-Value	P-Value
Normal approximation	1.60	0.110
Fisher's exact		0.113

Discussion and Conclusions

- Less improvement actions are required when using only high AP verses RPNs of 100 or greater
- There is no difference between the number of actions when high and medium APs both require actions
  - However, these actions the most critical due to the emphasis on high severity and occurrence ratings
- Results in an organization will vary from this study
  - Organizations with more safety risks will require more improvement actions than organizations with less safety related risks

PFMEA

Thank you

PFMEA

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