Analysis of Defect Event Quantity Using *Priority-Cost Failure Mode, Effect, And Criticality Analysis* (PC-FMECA) Method (Case Study: Smoothmill Facility PT. Ebako Nusantara)

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ABSTRACT

FMEA (Failure Mode and Effects Analysis) is a method to identify potential failure modes of a process or product, which has been used since 1950 inside an aviation control system. To implement more efficient improvement of FMEA, criticality analysis was then added into every failure mode, termed Failure Mode, Effects, and Criticality Analysis (FMECA). However, those methods are yet to integrate cost variable, which are essential in the rapid growth of manufacturing industries. Priority-Cost FMECA (PC-FMECA) emerged to reach such objective.

PT. Ebako Nusantara is a high-end furniture manufacturing with several steps of production. Interview with QC Department and Defect Event Finding Data in October 2015 portrayed Smoothmill Facility as the area responsible for the largest defect event total in October 2015, which are 32,78%. This research is done to investigate the failures occurring during production so that defect event could be reduced, if not eliminated.

This research uses PC-FMECA method, which takes profitability of action into account. In this method, the New RPN is calculated with the adoption of AHP technique, where profitability values are then formulated. Criticality matrices are drawn using priority-profitability diagram to formulate priority of failure. Upon this method, the recommendations are then customized to not exceed the budget of the company.

Keywords: FMEA, PC-FMECA, defect event, New RPN, profitability

1. PREFACE

Efforts to minimize risks are essential to produce well-made and standardized products. Various risks occurring in manufacturing process could negatively affect cost, time, company management, even the sustainability of the company itself. As a company with busy production schedule and target to fulfill, PT. Ebako Nusantara needs to perform immediate corrective actions to eliminate defect, particularly in smoothmill facility. Smoothmill facility is an area at PT. Ebako Nusantara with the highest defect event as per October 2015. The corrective actions must also stay within the budget allocated by the company. A method capable to identify potential failure is used so that the priority of corrective actions in correspond to potential failure modes can be set. Since the aim of the research is to avoid the recurrence of the same failure mode and to rank corrective actions based on profitability, PC-FMECA (Priority-Cost Failure Modes, Effect, and Criticality Analysis) method is deemed fit.

PC-FMECA associates potential failure of a system or sub-system to its economic aspect[3]. Steps in performing this method are as follow:

1. Determining the scope of research, followed by potential failure mode identification.
2. Creating formula for *the New RPN* with the help of Analytic Hierarchy Process (AHP) method.
3. Calculating *the New RPN* in accordance with *severity, occurrence*, and *detection* score.
4. Calculating *impact, frequency*, and *control* variable to measure *Total Loss*.
5. Establishing corrective action to estimate *Total Loss Revision* and *Cost of Action*.
6. Computing *Profitability* and *Critical Index* for each potential failure mode to set the rank of corrective action.

2. RESEARCH METHOD

Primary and secondary data are used in this research. Included as primary data are interview result, Daily Inspection Report from QC Department, Defect event Finding from QC Department, and machinery details from Maintenance Department. Whereas field observation and other complementary data are considered secondary data.

The PC-FMECA method generates failure identification, corrective action priority ranking, and corrective action profitability, all of which could be integrated to act as a company guideline towards eliminating defect event at smoothmill facility PT. Ebako Nusantara.

2.1 AHP For The *New RPN*

Analytic Hierarchy Process (AHP) method is a basic approach in decision making process whose goal is to determine the optimum alternative of a certain criteria. The process of AHP consists of simple pairwise comparison which are then adopted to develop overall priority[5].

The use of AHP as a tool to produce *New RPN* formula is based on the following considerations:

- The precondition to integrate economic consideration with *severity, occurrence*, and *detection*[4]
- Each criterion may not acquire the same importance in every situation or company[1]
- AHP is a flexible multi-criteria decision making tool where both qualitative and quantitative aspects are taken into consideration[5]

When AHP is performed, normalized eigenvector of each criteria (*severity, occurrence*, and *detection*) are established, which shows the importance of each criteria as viewed by the company[1]. The *New RPN* will later be formulated and calculated accordingly.

2.2 *Severity, Occurrence, Detection*

Severity, occurrence, and *detection* variables in PC-FMECA method are identical to the ones in conventional FMEA or FMECA method. *Severity* variable shows the effect of a given failure mode. *Occurrence* variable displays the likelihood that the failure mode will be present in a certain period of time. *Detection* variable is a ranking number associated with the prospect of a failure mode being detected. The score of each variable is determined in the scale of 1 to 10 without regard to the other variables[2].

2.3 *Impact, Frequency, Control*

Impact, frequency, and *control* are three new variables introduced in PC-FMECA. *Impact* variable indicates the financial damage caused by the effects of a given failure mode. *Frequency* variable means how often a failure mode occurs in a certain time period. Lastly, *control* variable expresses the amount of money spent by the company to prevent a failure mode[3].

2.4 *Critical Index* (CI)

Critical Index (CI) expresses the distance between the urgency of action and the intervention economic convenience. CI can be calculated using the following formula, where *m* represents 45^0 strategy straight line slope, Pr_j represents normalized profitability of potential failure mode j, and RPN_j represents the RPN of potential failure mode j[3]. Potential failure mode with higher value of CI will result in higher priority, and vice versa.

$$CI_j = \sqrt{\frac{(m \times Pr_j + RPN_j)^2}{1 + m^2}} \quad (1)$$

3. THE CASE STUDY

PC-FMECA method is executed in a growing furniture manufacturer named PT. Ebako Nusantara. The interest of the research has been focused on potential failures occurring at smoothmill facility, where the largest number of defect event took place.

3.1 Potential Failure Mode

This variable refers to the state in which a production activity fails to fulfill the intended function[2]. In this particular case study, production activities are grouped into three major activities, each with its own purpose and means. *Potential failure modes* are identified with the help of historical data previously made by QC Department.

Table 1 Potential failure mode

No	Production Activity	Potential Failure Mode
1	Splitting and Cutting	Dimensional inconsistency
		Thickness disparity
		Chamfer does not exist
2	Profiling	Incorrect profiling
		Improper edging
		Damaged part with crack, dent, or twist
3	Joining	Disproportional pen and pen hole

3.2 The *New RPN*

Brainstorming session with QC and Maintenance Department concludes the company's standpoint towards the importance of *severity, occurrence*, and *detection* variable. *Severity* has been considered strongly more important than *occurrence*, scored 5. *Severity* has also been favored slightly more than *detection*, thus given a score of 3. *Detection* has been deemed slightly more important than *occurrence* and has also been given a score of 3. The calculation proceeding this statement produces the normalized eigenvector (also termed the priority vector[5]) of *severity, occurrence*, and *detection*, in consecutive order: 0,6397; 0,1030; dan 0,2573. The *New RPN* formula is:

$$New\ RPN = 0{,}6397\frac{S_j}{\sum_{i=1}^{n} S_i} + 0{,}1030\frac{O_j}{\sum_{i=1}^{n} O_i} + 0{,}2573\frac{D_j}{\sum_{i=1}^{n} D_i} \quad (2)$$

S_j symbolizes *severity* of j^{th} failure mode, S_i means *severity* of general failure mode, O_j and O_i represents *occurrence* of j^th failure mode and *occurrence* of general failure mode, D_j and D_i means *detection* of j^th failure mode and *detection* of general failure mode. The value of *new RPN* is enlisted in Table 2.

3.3 *Total Loss*

Total Loss, which reflects the economic loss of each failure mode, can be calculated by adding *impact* and *control* variable[3]. In PT. Ebako Nusantara, inspection is enforced to every product in specific areas. *Impact* variable measures the sum of men cost and machinery cost during rework, and *frequency* variable, which shows the quantity of defect event from each failure mode. *Control* variable gauges all necessary costs in performing inspection.

Table 2 The new RPN

Potential Failure Mode	S	O	D	New RPN
Dimensional inconsistency	5	7	6	**0,1614**
Thickness disparity	5	5	6	**0,1548**
Chamfer does not exist	4	2	3	**0,1031**
Incorrect profiling	7	7	5	**0,1902**
Improper edging	3	4	4	**0,0993**
Damaged part with crack, dent, or twist	6	3	5	**0,1586**
Disproportional pen and pen hole	5	3	4	**0,1326**

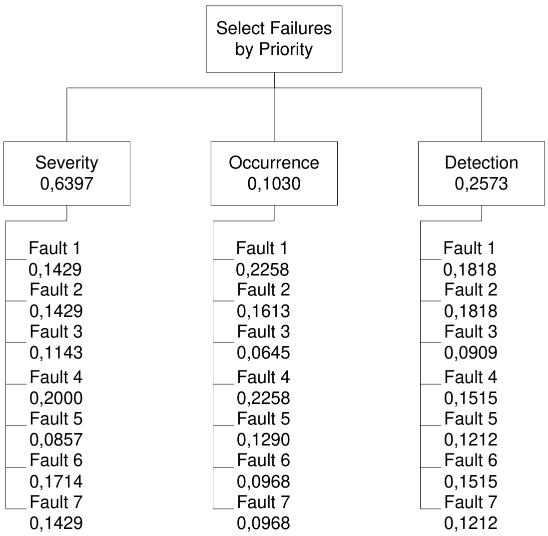

Figure 1 Hierarchical tree

3.4 *Total Loss Revision*

Total Loss Revision variable emerges as a result of implementing a definite intervention in regard to a given failure mode[3]. Table 4 tabulates the estimation of *Total Loss Revision* from corrective action that best counteract each failure mode.

Table 3 Total loss

Potential Failure Mode	Impact (Rp)	Control (Rp)	Total Loss (Rp)
Dimensional inconsistency	3.844.149	807.314	4.651.463
Thickness disparity	1.601.584	342.736	1.944.319
Chamfer does not exist	62.935	10.519	73.453
Incorrect profiling	9.937.389	490.700	10.428.089
Improper edging	1.933.179	117.810	2.050.989
Damaged part with crack, dent, or twist	400.822	55.749	456.571
Disproportional pen and pen hole	345.783	72.755	418.538
TOTAL	**18.125.840**	**1.897.583**	**20.023.422**

Table 4 Total loss revision

Potential Failure Mode	Corrective Action Recommendation	Total Loss Revision (Rp)
Dimensional inconsistency	Adding QC personnel to perform dimensional inspection	**2.325.731**
Thickness disparity	Blade maintenance by maintenance crew	**1.166.592**
Chamfer does not exist	Implementation of “Wood Cutting SOP”	**-**
Incorrect profiling	Adding QC personnel to perform profiling inspection	**5.214.044**
Improper edging	Visual check by every operator	**615.297**
Damaged part with crack, dent, or twist	Implementation of “Timber Storage in Lumberyard SOP”	**45.657**
Disproportional pen and pen hole	Machine cleaning and setting up by maintenance crew	**251.123**
TOTAL		**9.618.444**

3.5 *Profitability*

The value of *profitability* is indicated by the following formula[3] :

$$\text{Profitability} = \text{Advantage} - \text{Cost of Action} \qquad (3)$$

Advantage is the difference between *total loss* and *total loss revision*, while *cost of action* signifies various costs required to accommodate corrective action implementation. The *profitability* of each failure mode is presented in Table 5.

4. ANALYSIS

4.1 Corrective Action Recommendation

Corrective action refers to an intervention proposed to surmount a specific failure mode. A corrective action must be deemed suitable with characteristics of the company. Table 4 shows different values of *total loss revision*. This is based on the consideration that the company might still need adjustment before the corrective action could be thoroughly implemented and impractical use of tools (e.g. measuring tape to perform timber size inspection).

Total loss revision for potential failure mode *chamfer does not exist* is estimated to be 0 because if the company decides to impose "wood cutting SOP", the failure mode would be removed, hence erasing the *total loss revision* for the respective fault.

Table 5 Profitability

Potential Failure Mode	Advantage (Rp)	Cost of Action (Rp)	Profitability (Rp)
Dimensional inconsistency	2.325.731	1.683.000	**642.731**
Thickness disparity	777.728	70.125	**707.603**
Chamfer does not exist	73.453	17.531	**55.922**
Incorrect profiling	5.214.044	1.683.000	**3.531.044**
Improper edging	1.435.692	1.051.875	**383.817**
Damaged part with crack, dent, or twist	410.914	21.038	**389.877**
Disproportional pen and pen hole	167.415	87.656	**79.759**

4.2 Profitability and New RPN

By setting *New RPN* as x-axis and *profitability* as y-axis, a diagram can be drawn to illustrate the condition of every potential failure mode. Figure 2 illustrates such diagram, where *incorrect profiling* represented by Fault 4 appears as the most urgent potential failure mode with the highest profitability.

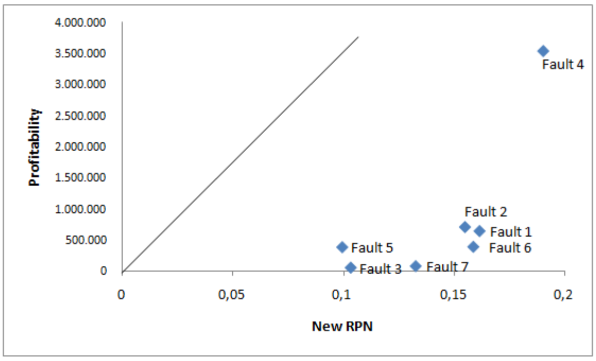

Figure 2 Profitability-new RPN diagram

5. CONCLUSION

The calculation of *critical index (CI)* variable using PC-FMECA method at smoothmill facility of PT. Ebako Nusantara for period of October 2015 shows that *incorrect profiling* has been regarded as the highest priority with Rp3.531.044,- *profitability* value and adding QC personnel as recommended corrective action. The following table contains the summary of prioritization as well as variables used in PC-FMECA.

Table 6 PC-FMECA summary

CI	Potential Failure Mode	Corrective Action	Total Loss (Rp)	Total Loss Revision (Rp)	Cost of Action (Rp)	Profitability (Rp)	RPN
0,6138	Incorrect profiling	Adding QC personnel	10.428.089	5.214.044	1.683.000	3.531.044	0,1902
0,1256	Thickness disparity	Blade maintenance	1.944.319	1.166.592	70.125	707.603	0,1548
0,1146	Dimensional inconsistency	Adding QC personnel	4.651.463	2.325.731	1.683.000	642.731	0,1614
0,0708	Damaged part with crack, dent, or twist	Timber Storage in Lumberyard SOP	456.571	45.657	21.038	389.877	0,1586
0,0685	Improper edging	Visual check by operators	2.050.989	615.297	1.051.875	383.817	0,0993
0,0167	Disproportional pen and pen hole	Machine cleaning and setting up	418.538	251.123	87.656	79.759	0,1325
0,0119	Chamfer does not exist	Wood Cutting SO	73.453	0	17.531	55.922	0,1031

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