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The proposed improvements to minimize potential failures using lean six sigma and multi attribute failure mode analysis approaches

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Abstract. PT X is the largest steel industry in Indonesia. During the production process, still have large quantities of waste defect. The purpose of this research is to determine the waste that occurs in the production process, determine the characteristics of deformity or critical to quality (CTQ), determine the sigma value, determine the factors that caused the failure of the production process, and determine the proposed improvement to minimize the failure of the production process. The most dominant types of defects are serrated edge, wavy edge, poor cleanliness, pick up, edge crack, ripple edge, and bad weld. The sigma value of cold rolled coil product is 4,131 which is included into the industry average of USA (± 4σ). Factors that caused cold rolled coil production process failed based on criteria severity, occurrence, detection, and expected costs by Fuzzy Analytical Hierarchy Process (F-AHP) is material imported from outside with a total weight of 0.087. Proposed improvements done to minimize failure in cold rolled coil production processes are doing trial for products from HSM factory to test or know the slab specifications related to the chemical constituents of steelmaking and adjusting the format (such as thickness, length, width) and steel specifications to corresponding.

1. Introduction

PT X is Indonesia's largest steel industry development begins with the emergence of a notion of the necessity of the steel industry in developing countries like Indonesia. One product type PT X are cold rolled coils are manufactured by one of the unit of work is owned by PT X, i.e. Cold Rolling Mill (CRM). PT X always keep products produced both in terms of quality and specifications desired by consumers, although the production process there is still the problem of the incidence of defects in a product. A product can degrade the quality of the resulting product so PT X always do the control of the production process in order to produce a product in accordance with the specifications and quality is maintained. To get the quality of production that could compete with to be keep and control of the production process to be needed quality control methods a sustainable product.

In this study, the proposed improvements will be made to problems that occur in the production process, namely to manage the failure process of steel production Plant in cold sheet Rolling Mill Cold PT X by using Lean Six Sigma and Multi Attribute Failure Mode Analysis with a Fuzzy Analytical Hierarchy Process (Fuzzy AHP) approach. Tools used in lean will be integrated into the concept of six sigma DMAIC (define, measure, analyze, improve, and control). As for the tools used in this study includes a diagram of the SIPOC (supplier, input, process, output, customer), Value Stream Analysis Tools (VALSAT), Value Stream Mapping (VSM), project charter, the Critical To Quality (CTQ), the Map Control P, pareto diagrams, root cause analysis, Failure Mode And Effect Analysis (FMEA),

Fuzzy AHP, Multi Attribute Failure Mode Analysis, and 5W + 1 H to be used on stage to improve the proposed improvements.

The goal of Lean Six Sigma by using Multi Attribute Failure Mode Analysis, Fuzzy and AHP is to eliminate waste (non value added activity) of a process so that it can identify potential failure causes the production process that can lead to defects. Based on the concept of Lean Six Sigma efforts made continuously and target achievement performance of 6 sigma for companies expected to compete with other steel manufacturing company.

Based on the background of problem elaborated above, several problems were formulated as follow what are the waste that occurs in the production process of cold rolled coil in Cold Rolling Mill (CRM) PT X, what are the types of defects or characteristics Critical to Quality (CTQ) on a cold rolled coil production process in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM), how many sigma value on the production process of cold rolled coil in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM), and what factors cause cold rolled coil production process undergoes a process failure in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM), how the proposed improvements are being made to manage the failure on the production process of cold rolled coil failure in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM).

The objectives of this research are proposed below to know the waste that occurs in the production process of cold rolled coil in Cold Rolling Mill (CRM) PT X, to determine the types of defects or characteristics Critical to Quality (CTQ) on a cold rolled coil production process in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM), to determine sigma value on the production process of cold rolled coil in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM), to determine factors cause cold rolled coil production process undergoes a process failure in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM), and to determine the proposed improvements are being made to manage the failure on the production process of cold rolled coil failure in Cold Rolling Mill (CRM) PT X units production on a Continuos Tandem Cold Mill (CTCM).

The limitations of the research were proposed as follow research carried out on cold rolled coil products in the factory Cold Rolling Mill (CRM) PT X and focus on product defects that occur at the production unit Continuous Tandem Cold Mill (CTCM), the products examined were not paying attention to the grade and thickness, machine processing time was calculated at the time the production process is running so there is no time to set up, research using DMAIC concept which is only done to improve stage, the respondents used in this research is the appropriate expert, data analysis is evaluated by using the method of Multi Attribute Failure Mode Analysis (MAFMA) Fuzzy AHP FMEA approach and the recommendations proposed improvements by using the method of 5W + 1 H and only for cause of potential failure.

2. Theoretical Framework

2.1 Lean six sigma

The concept of Lean Six Sigma is a concept of business system, developed not long ago in the United States. The concept of the Lean management system concept rooted in Toyota developed and expanded, while the concept of Six Sigma management system concept rooted in Motorola. The power of both the concept of this synergy into a concept that integrates concept i.e. Lean Six Sigma [1].

2.2 Failure mode and effect analysis (FMEA)

FMEA (Failure Mode and Effect Analysis) is a structured procedure for identifying and preventing as many as possible modes of failure (failure mode). FMEA is used to identify the sources and root causes of a quality problem. A failure mode is what is included in the defect or failure in design, conditions outside the limits of the specifications has been defined, or changes in the product that causes disruption of the function of the product.

2.3 Analytical hierarchy process (AHP)

States that the AHP is a theory of the measurements used to the scale ratio either from the paired comparison of discrete or continuous [2] and [3]. The method of AHP helps solve complex issues with structure a hierarchy of criteria, interested parties, and results by attracting a variety of considerations in order to develop weights or priorities.

2.4 Fuzzy analytical hierarchy process (F-AHP)

F-AHP is a combination method of AHP by Fuzzy concept approach. F-AHP cover the weaknesses found in the AHP, that problem against the subjective nature of the criteria that have more. The uncertainty is represented with the sequence number of the scale. Determination of the degree of membership of Fuzzy AHP developed using membership function of triangular (Triangular Fuzzy Number) [4]. The membership function of the triangle is a combination between the two lines (linear). Triangular fuzzy numbers (Triangular Fuzzy Number) is a fuzzy set theory help in measurements related to the subjective assessment of wearing human languages or Linguistics. The core of the fuzzy AHP lies in a comparison of pairs is described with the scale ratio is related to the scale of the fuzzy.
Fuzzification scale of interest comparison between two criteria can be illustrated in graphical form as shown in figure 1 [5].

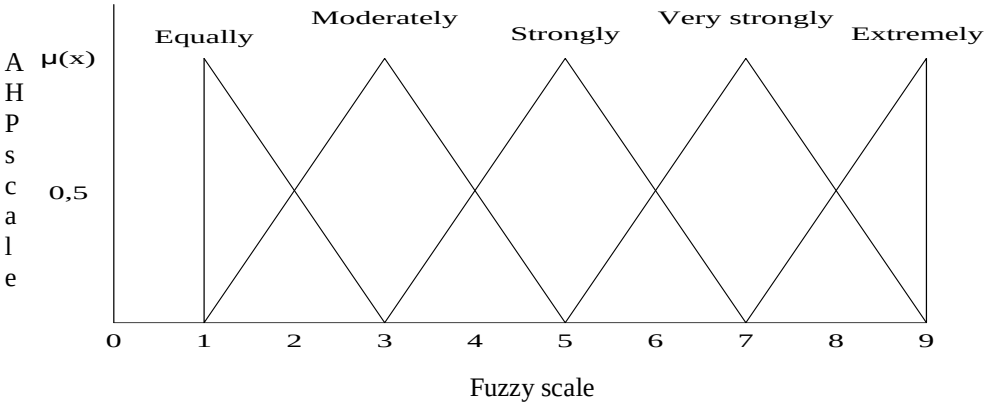

Figure 1. Membership function of fuzzy number.

2.5. Multi attribute failure mode analysis (MAFMA)

Multi Attribute Failure Mode Analysis (MAFMA) is a method of integrating the Failure Mode and Effect Analysis (FMEA) conventional by considering economic aspects [6]. According to Vaughan [7], the lack of consideration of economic aspects into one of the weaknesses of FMEA. FMEA is a technique of analysis by a team or an expert to identify the potential failure modes as well as the cause, in the manufacturing process. Alternative causes of failure are arranged in a hierarchical structure as shown in figure 2 [8].

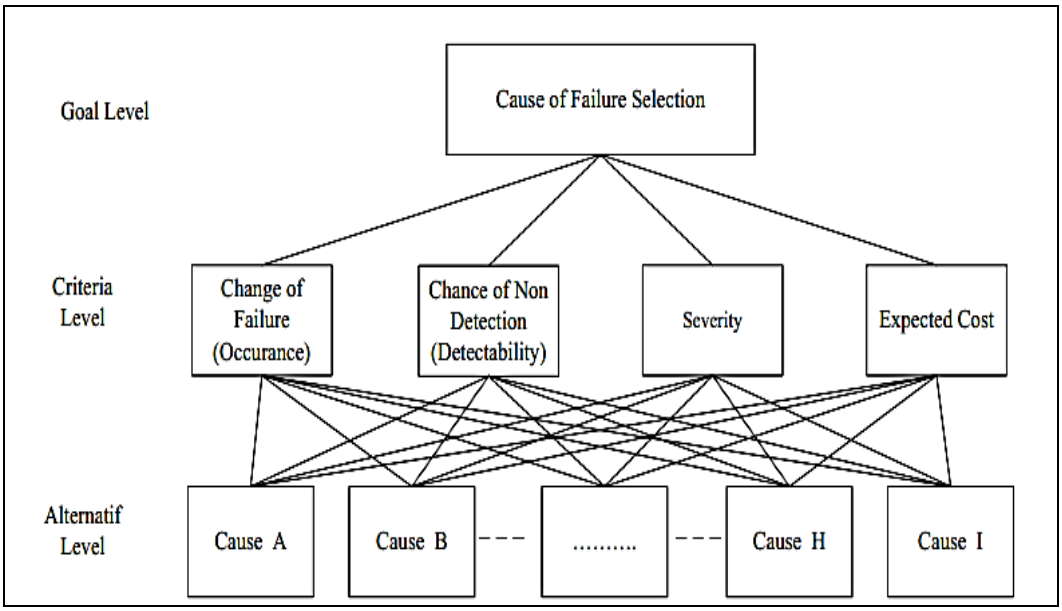

Figure 2. Cause of failure selection hierarchy structure.

3. Methodology

Research methodology is a guideline to conduct a research; such as determining instrumentation, sampling, data collection and data analysis. Basically, research method is a scientific way to gain data with a specific aim and purpose. In this research, the data collection was divided in two; those are primary data and secondary data. Below is the problem solving plot as an overall description of the research conducted at PT X:

1. The first stage the researcher begins to conduct research
2. Field observation
   At this stage the researches and direct observations to find out the problems that exist in the CRM factory PT.X
3. Study of literature
   At this stage the researcher studies various references and theories that are used as references in the problems in the company. Some related literature is about quality, Lean Six Sigma, Failure Mode and Effect Analysis (FMEA), Analytical Hierarchy Process (AHP) and Multi Attribute Failure Mode Analysis (MAFMA). Literature is obtained from reference books, journals and others.
4. Formulation of the problem
   At this stage problems were formulated relating to the research problem.
5. Research purposes
   At this stage set goals to be achieved in the research conducted
6. Scope of the problem
   At this stage set the boundaries of the problem made so that the discussion in this study is not too broad and more directed.
7. Data collection
   At this stage the data collection will be used to solve the problem, consisting of the primary data and secondary data. Primary data were obtained from observations and interviews while secondary data were obtained from company in the form of production data, defect data of cold sheet steel products and cycle time data.
8. Data Processing
   At this stage the data processing is carried out from the results of data collection using the Lean Six Sigma, Failure Mode and Effect Analysis (FMEA), Analytical Hierarchy Process (AHP) and Multi Attribute Failure Mode Analysis (MAFMA) methods.
9. Analysis and discussion

At this stage the researcher analyzes the data that has been processed and then conducts a discussion with references to support and strengthen the research results

10. Conclusion
    At this stage conclusion are obtained based on the results of data processing and analysis in accordance with the research objectives.
11. Finished
    After the final results are obtained, the research has been completed

4. Result and Discussion

4.1. Define

Problem on PT X can be defined by using several tools i.e. identifies the physical flow of the production process by using the SIPOC diagram, and then determine the dominant waste that occurs with the use of the approach (VALSAT value stream analysis tools). Next to facilitate the researchers then create map process production operations on disabilities most dominant, then identify the selection of Six Sigma projects by using the project charter, and identifies Critical to Quality (CTQ). Results of weighting for Value Stream Analysis Tools (VALSAT) are shown in table 1.

Table 1. Value **s**tream analysis tools (VALSAT).

No	Type of Waste	Weight	Mapping Tools							
			PAM	SCRM	PRV	OFM	DAM	DPA	PS	VATP
1	Overproduction	6	6	18		6	18	18		6
2	Waiting	6.333	57	57	6.333		19	19		19
3	Transportation	2.333	21						2.333	
4	Excess Process	6.333	57		19	6.333		6.333		
5	Inventory	2.667	8	24	8		24	8	2.667	24
6	Motion	4.667	42	4.667						
7	Defect	6.667	6.667			60				
Total Weight		35	197.667	103.667	33.333	72.333	61	51.333	5	49

4.2. Measure

Problem on PT X can be defined by using several tools IE identifies the physical flow of the production process by using the SIPOC diagram, and then determine the dominant waste that occurs with the use of the approach (VALSAT value stream analysis tools). Next to facilitate the researchers then create map process production operations on disabilities most dominant, then identify the selection of Six Sigma projects by using the project charter, and identifies Critical to Quality (CTQ).

1. DPMO Value calculation and the value of Sigma
   Calculation based on the value of sigma which has obtained registration 4.136 with an average 4555.244 of DPMO interpreted that out of a million opportunities there will be 4555.244 it is likely that the results of the production of coil will experience disability . From the results of the average value of DPMO, sigma and value then the sigma level of achievement can be found in the Cold Rolling Mill (CRM) PT X that is included in the industry average USA (± 4).
2. Performance Measurement Process
   Performance measurement process is done by making a map control to eliminate variation through the separation of the variations that are caused by specific causes. Map control (Control Chart) used in this study is the map control P.
3. The Identification Process of The Production Activity
   The identification process of the production activity is carried out in which the activity of the production process is what is included in the category of value added (VA), necessary non value added (NNVA), and non-value added (NVA were). As for the percentage to use time value added (VA) of 10.87%, necessary non value added (NNVA) of 89.13%, and non-value added (NVA were) of 0% or no on cold rolled coil production process.
4. Current State Value Stream Mapping Cold Rolled Coil Production
   Value stream mapping is a picture that is used to show the flow of the production process run by

the factory Cold Rolling Mill (CRM) PT X in producing cold rolled coil. The efficiency of the flow of the production process of steel cold sheets of 10.87%.

4.3. Analyze

At the stage of analysis and determination do analyze the root problem of a fault, the analyze was performed to analyze the factors cause the occurrence of defects in cold rolled coil products in Cold Rolling Mill (CRM) PT X.

Based on the results of the alternative weighting of criteria of severity, occurrence, detection, and expected cost obtained the conclusion that the material is supply imported from outside (cause 1) is a potential cause of the failure of cold sheets with steel production generate the highest weighting i.e. of 0.083 less, further controls to oversee the condition of the knife (cause 2) generates a weighting of 0.081, machine in-setting inappropriate (cause 3) produces the weights of 0.079, errors in the procedure replacement (cause 4) produces the weights of 0.074, temperature machine unstable (cause 5) generate the weights of 0.075, less control to oversee the condition of the knife (cause 6) produces the weights of 0.072, bad side trimming on finishing line (cause 7) generate the weights of 0.076, bad placement on knife trimming (cause 8) produces the weights of 0.072, tension reduction during winter (cause 9) generate the weights of 0.068, quality welding electrode is less good (cause 10) generate the weights of 0.069, unstable welding temperature (cause 11) generates a weighting of 0.068, open factory environment (cause 12) generates a weighting of 0.064, oil, dust, and particles which are still sticking to the coil (cause 13) produces the weighting of 0.065, and cleaning the surface of the coil of excrement less well (cause 14) produces the weights of 0.054.

Criteria in the hierarchical structure consist of 4 criteria, namely severity, occurrence, detection, and expected cost. This criterion is based on FMEA which has been developed into MAFMA with additional expected cost.

The determination of criteria weights in the MAFMA hierarchy structure is done by comparing the pairwise comparison test between the four criteria including severity, occurrence, detection and expected cost through a questionnaire with respondents from the FMEA team who are experienced working long enough in CRM plant.

4.4. Improve

Method of 5W + 1H explains in detail the solution to how to manage the improvements proposed, starting from an existing problem, the target improvement or the expected results, the reason the repair held, places of occurrence of problems or indicate the location of the holding repairs, schedule the time required to perform repairs, who will do the repair, and lastly how the method or manner done in the response.

Next to knowing the process flow efficiency, the next step that is making a proposal for a future state value stream mapping. In the lean process minimum efficiency values for the target to be achieved is 25% [9]. This means the duration value added has a share of more than 25% of the overall total than a lot of lead time. The projection table of the sigma value plan for proposed improvements in the initial conditions and target conditions can be shown in table 2.

Table 2. Sigma value projection plan for proposed improvements.

Condition	Total Production (Coil)	Total Defect (Coil)	CTQ	DPU	DPO	DPMO	Sigma
Initial	2463	666	58	0.270	0.004662123	4662.123	4.100
Target	2463	246	58	0.100	0.001724138	1724.138	4.425

In the initial condition seen that DPMO of 4662.123 with sigma values of 4.100, then in the target condition seen that DPMO of 1724.138 with sigma values of 4.425.

5. Conclusion

Based on this research, it can be concluded that waste that is prioritized based on the subjective assessment for repair of 3 respondents i.e. waste defects because the average assessment waste the most defects, type of defect or characteristic of the Critical to Quality (CTQ) on the production process of cold rolled coil in Cold Rolling Mill (CRM) Mill PT X production units on a Continuous Tandem Cold Mill (CTCM) as much as 58 CTQ, sigma value cold rolled coil products of 4.131 DPMO average of 4555.244, the main factors that cause the production process of cold rolled coil failure process in plant Cold Rolling Mill (CRM) PT X production units on a Continuous Tandem Cold Mill (CTCM) is supply material imported from outside, and the proposed improvements are being made to manage the failure on the production process of cold rolled coil failure process is doing a trial product from the manufacturer HSM to test or find out the specifications of the slab with regard to chemical content constituent of steel, make adjustments against the format (such as thickness, length, width) and steel specifications to suit.

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