REDUCING DEFECT HANDLING FOUND IN HOT ROLLED COILS USING DMAIC PHASES IN FINISHED PRODUCT DISTRIBUTION WAREHOUSE

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A Thesis presented to the
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THESIS ADVISOR
RECOMMENDATION LETTER

This thesis is entitled "**Reducing Defect Handling Found in Hot Rolled Coils Using DMAIC Phases in Finished Product Distribution Warehouse**" prepared and submitted by **Marsha Tinambunan** in partial fulfillment of the requirements for the degree of Bachelor Degree in faculty of Engineering has been reviewed and found to have satisfied the requirements for a thesis fit to be examined. I therefore recommend this thesis for Oral Defense.

Cikarang, Indonesia, February 28, 2017

Burhan Primanintyo B.Sc, M.Eng

DECLARATION OF ORIGINALITY

I declare that this thesis, entitled "**Reducing Defect Handling Found in Hot Rolled Coils Using DMAIC Phases in Finished Product Distribution Warehouse**" is, to the best of my knowledge and belief, an original piece of work that has not been submitted, either in whole or in part, to another university to obtain a degree.

Cikarang, Indonesia, March 7, 2017

Marsha Tinambunan

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ABSTRACT

Steel industry directly supports industrialisation, determines the welfare of the people, but also determines the name of Indonesia in a global scale. PT. X as a leading steel manufacturing company in Indonesia is responsible to ensure that the products have high quality, because PT. X acts as a role model for other local steel companies, and also ships the products worldwide—therefore determines the good name of Indonesia. Product quality of PT. X is related to the reputation of the company—how PT. X is in the point of views of the customers—the handling of the products, and the costs incurred for the rework and defect claims—product return—from the customers. The products manufactured by PT. X should have Product Transfer Note document issued for every finished product so that each finished product can be monitored until the finished product is shipped. Hot Rolled Coil is one of the types of product manufactured by PT. X. This product is the most highly requested product of PT. X with expected capacity of 3,1500,000 tons in year 2017. Finished Product Distribution (Hot Rolled Coil) department is one of the departments under Finished Product Distribution division, which is responsible for the state of Hot Rolled Coils before and after the shipment. This department faced an issue of high number of defective products in the warehouse of finished products, where the products should be in a Ready To Ship (RTS) state. Therefore, a study is conducted using the phases of DMAIC (Define, Measure, Analyse, Improve, and Control) to analyse the problem and reduce 50% of the defect percentage. By doing so, the high rework cost reduction can be IDR766,909,000.

Keywords: *Hot Rolled Coil, Send Back Defect, Finished Product Distribution, DMAIC, Defect Reduction, Six Sigma*

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LIST OF TERMINOLOGIES

Defects	: the variations that occur in a certain set of products.
Defect Handling (DH)	: defects caused by careless handling of the products, such as scratches.
Hot Rolled Coil (HRC)	: one of the finished products manufactured by PT. X. Can be used as a Hot Rolled Coil only, but can also be processed further into other types of finished products.
Send Back Defect	: the defective products in Finished Product Distribution warehouse returned for rework or downgrading due to the quality mismatch between the actual condition of the product and the requirement(s).
Product Transfer Note (PTN)	: a document should be issued for the transfer of products between departments.
Finished Product Distribution (FPD)	: the distribution responsible for the acceptance of the finished products from Work In Process (WIP) warehouse, finished product storage, and finished products shipment.

CHAPTER I
INTRODUCTION

1.1 Problem Background

Steel industry has an essential part in the economic growth of a certain country (Adam & Negara, 2012). A cross-country study was conducted related to the relationship between Gross Domestic Product per capita and steel production, and the result showed that the higher the Gross Domestic Product per capita of a certain country, the higher consumption and production of steel per capita are (Tambunan, 2006). This correlation exists because steel is a fundamental element of industrialisation. Developing countries like Indonesia has several main objectives in order to become a developed country some of which are to achieve a higher standard in economic and social progress and raise the living standard of the people—all of which can be achieved through industrialisation (Narasalah, 2003). Indonesia, as a developing country, has high demand for steel, mainly for construction, infrastructure, and various industries such as automotive, shipbuilding, railway, machinery, and electronic appliances (Adam & Negara, 2012). On a related note, local steel industry should also make way into the international market and become one of the leading nations in the field of steel industry.

PT. X is a leading steel manufacturing company in Indonesia. Every year, PT. X manufactures more than 2,000,000 tons of steels that are shipped to both local and international customers. On the run of PT. X, PT. X always do the best attempts to satisfy the customers and uphold the reputation of Indonesia through achieving local and international standardisations and certifications. To ascertain the quality of products before shipment, PT. X has a mechanism of pre-shipment hold in the Finished Product Distribution warehouse of PT. X, in which the products are held for inspections before shipment.

Finished Product Distribution is a division in PT. X responsible to ensure that the finished products are delivered to the customers in excellent quality. Finished Product Distribution division is directly related to many departments in the company, such as Finance, Logistic, Sales, Production, Production Planning and Control ,and also to the elements outside of the company, which are Transporter and Customer. Finished Product Distribution division has several departments, one of which is Finished Product Distribution of Hot Rolled Coil specifically responsible for the type of product with the highest production capacity. Before shipment, this department conducts final inspection, in which the Hot Rolled Coil from Work In Process Warehouse is inspected thoroughly prior to shipment. To arrive at this stage, Hot Rolled Coil should undergo Product Transfer from Work In Process Warehouse to Finished Product Distribution Warehouse.

A further study is then done in Finished Product Distribution Warehouse, where the Product Transfer is conducted. In the observation conducted in July to September 2015, high numbers of defective Hot Rolled Coils are found in the Finished Product Distribution Warehouse, which causes nearly 6% the Hot Rolled Coils being sent back to Work In Process to undergo rework. Reworking the Hot Rolled Coils reduces the value of the Hot Rolled Coils, because the rework process causes scrap loss of up to 320 kg per coil. Therefore, Finished Product Distribution-Hot Rolled Coil department should immediately fix this problem since the loss incurred to PT. X is not only in regards of money, but also time and reputation. In order to solve this issue, one of the techniques of Six Sigma, DMAIC is used.

1.2 Problem Statement

The background of the problem leads to the statement below:

- What is the most dominant type of send back defect found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X?

- What are the root causes of the most dominant type of send back defects found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X?
- How to reduce the most dominant type of send back defect found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X?

1.3 Objectives

The problem statement leads to the objectives of this project, which are:

- To find the most dominant type of send back defect found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X.
- To find the root causes of the most dominant type of send back defects found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X.
- To reduce the most dominant type of send back defect found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X.

1.4 Scope

Due to the limited time and resources in composing this internship report, there are some aspects in regards of scope available during the period of project conduction, which are:

- The observation is conducted in Finished Product Distributin division warehouse of the Slab Plant of PT. X.
- The observation is conducted from July 2015 to September 2016, with the data from July to September 2015 as the data before improvement, and from July to September 2016 as the data after improvement.

- The data used for process capability are only from the number of shipments and defects in the aforementioned periods for aforementioned products.
- The observation is only conducted on the finished Hot Rolled Coil.

1.5 Assumptions

Due to the limited time and resources in composing this internship report, there are some aspects in regards of scope available during the period of project conduction, which are:

- In this thesis, Indonesian Rupiah to United States Dollar exchange rate is IDR13,000.
- The average mass of each unit of Hot Rolled Coil is 15,000 kilograms (15 tons).
- Every defective Hot Rolled Coil is repaired (no downgrading/ use of coils for commercial use).
- Scrap loss is assumed to be 320 kg for each coil.
- "In the field" politics, such as bribery, nepotism, or others that can affect the process negatively are ignored.

1.6 Research Outline

Chapter I **Introduction**

This chapter consists of the background of study, study identification, objective of the study, scope, assumption of the study and also the outcome from the conducted study.

Chapter II **Literature Study**

This chapter elaborates the terminologies, methods, theories, and tools used in the report based on the previous studies and transcripts of the related field/ topic.

Chapter III **Research Methodology**

This chapter elaborates the process of conducting the study, from deciding the problem and defining the background to solving the problem.

Chapter IV **Data Collection and Analysis**

This chapter provides the data collected throughout the process of composing this thesis and the analysis conducted to answer the preceding questions in the previous chapters.

Chapter V **Conclusion and Recommendation**

This chapter summarises the study and provides recommendations and also further studies.

CHAPTER II
LITERATURE STUDY

2.1 Six Sigma

Six Sigma is a methodology used to decrease the amount of variations in all critical process. According to Pyzdek & Keller, Six Sigma is the best methodology to improve quality and therefore reduce waste through helping companies to produce products and services in a higher quality, lower price, and swifter speed. According to the journal by Chakraborty and Chuan, there are several advantages of Six Sigma methodology, which are the disciplined approach (Hahn *et* al., 1999), thus results in clear framework (Goh, 2002). Six Sigma does not only help companies to reduce defects, whether in forms of products, services, or processes, as commonly known in the industry (Desai, T. N. & Shrivastava, R. L., 2008), but also has an important role in improving the acknowledgement of the understanding, needs, business systems, productivity, and financial performance of the customers (Kwak, Y. H. & Anbari, F. T., 2006). Productivity results in product quality; therefore from the productivity, the level of error can measure the product quality in the millions. In order to achieve the strict quality levels, the whole system, starting from the designing phase should be constructed in a way as such so that the system can produce correctly at the first time.

The name Six Sigma is originated from the sigma in Greek, used as the symbol of standard deviation in statistics. Sigma can also indicate the variability in a certain process or set of data. In a normal distribution, although there is no such thing as perfection—where the probability of a data to be equal to the mean is 100%—the variations can still be estimated, which are usually a little above or below the mean. The sigma level indicates how much data is deviated from the mean or the accuracy of the data. The 1.5 shift in Six Sigma acts as a "tolerance" limit in a certain process.

According to *isixsigma.com*, Motorola pioneered Six Sigma in the 1980's. An engineer of Motorola named Bill Smith started the use of this methodology with the support of his superintendent, Bob Galvin. The name of this methodology "Sigma" is used to determine how good is the variation within a process in terms of customer satisfaction. The objective of Six Sigma is to reduce the variations within a process so that the outcomes of the process can satisfy or even exceed the expectation of customers. This objective is achieved by reducing the defects manufactured by a company to 3.4 defects per million opportunities.

2.2 Define, Measure, Analyse, Improve, and Control (DMAIC)

The Six Sigma problem-solving algorithm includes five phases called the DMAIC cycle (Define, Measure, Analyze, Improve, and Control) (Bergman and Klefsjo, 2003; Magnusson et al., 2003); DMAIC is typically used to guide implementation of Six Sigma and to achieve company objectives. Based on the journal by Ertürk et. al, the DMAIC cycle has a lot of similarities with Deming's ''Plan-Do-Check-Act'' cycle (Bertels, 2003). However, not only that Six Sigma is more perfected due to the later development, Six Sigma also provides a well-defined target for quality that the process defect rate should not exceed 3.4 defects per million opportunities.

The first phase of DMAIC is Define. The objective of this step is to clearly set the business problem, goal, potential resources, project scope, and high-level project timeline. The purpose of this step is to clearly articulate the business problem, goal, potential resources, project scope and high-level project timeline.

The second phase of DMAIC is Measure. The objective of this step is to establish current baselines objectively as the basis for improvement. In this step, data collection is conducted in order to establish process performance baselines. The performance metric baseline(s) from the Measure phase will then be compared to the performance metric at the conclusion of the project to determine objectively whether significant improvement has been made. The team will then decide what purpose of this step is to objectively establish current baselines as the basis for improvement.

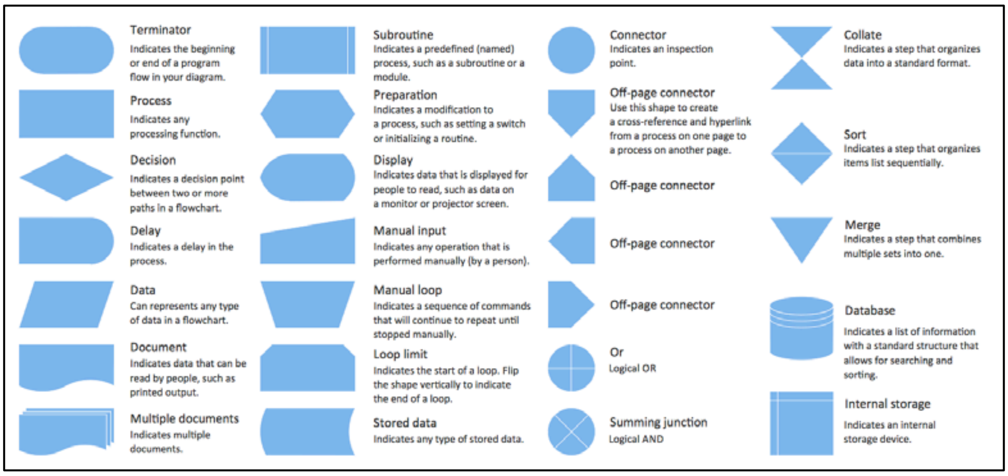
The next step is the Analyse phase. The objective of the Analyse phase is to identify, to validate, and to select the root cause of the problem to eliminate. In this phase, the causes of the problems and the outcomes of the causes can be seen and will then assist the author to find the root of the problem.

The next step is the Improve phase. The objective of this phase is to be able to find, identify, test, and implement a solution and put an end to the problem; in part or in whole. The solving of the problem wholly depends on the situation. The main idea of the Improve phase is to find creative solutions for eliminating the key root causes so that the process problems can be fixed and or prevented.

The final step is the Control phase. The objective of this step is to sustain the improvement attained during the DMAI phases. In the Control phase, the observer is also expected to monitor the improvements in order to make sure that the success is continued and sustained. A control plan should also be created as a guide to be in the right track. The current documents, business process, and training records should also be changed and updated as required.

2.3 Flow Diagram

In the Define phase, a process mapping should be done to further study the process. This tool is used to provide a graphical display of the process in the study (in this case, Product Transfer process). In flow diagram, a step-by-step approach is used in the diagram with different symbols for each step in the process (Nasution, 2003). This tool also provides functional relationships between elements in the process.



Source: conceptdraw.com
Figure 2.1 Symbols in Flow Diagram

Symbols in flow diagram are shown in Figure 2.1. There are 27 symbols commonly used in flow diagrams. However, in this study, only 5 symbols are used, which are to indicate start and end, operation, decision, storage, and documentation. Flow diagram is also used in Chapter III to give a visual representation of the research methodology.

2.4 Project Charter

According to Enani, a project charter provides an explanation about a certain project. A project charter also provides an explanation about the objectives, approach used, voice of customer, and the names of people involved in the project. In this study, after the problem has been acknowledged, a project charter is made to settle the way to solve the problem by gathering all information related to the problem solving. In short, the project charter defines the agreement of the stakeholders and provides a written permission to continue doing the project (McKeever, 2006).

Sample Project Charter and Scope Statement from Schwalbe's Information Technology Project Management, Third Edition, 2004.

Table 3-4: Project Charter

Project Title: Project Management Intranet Site Project
Project Start Date: May 2, 2005 **Projected Finish Date:** November 4, 2005

Budget Information: The firm has allocated $140,000 for this project. The majority of costs for this project will be internal labor. An initial estimate provides a total of 80 hours per week.

Project Manager: Erica Bell, (310)889-5896, erica_bell@jwdconsulting.com

Project Objectives: Develop a new capability accessible on JWD Consulting's intranet site to help internal consultants and external customers manage projects more effectively. The intranet site will include several templates and tools that users can download, examples of completed templates and related project management documents used on real projects, important articles related to recent project management topics, article retrieval service, links to other sites with useful information, and an "Ask the Expert" feature, where users can post questions they have about their projects and receive advice from experts in the field. Some parts of the intranet site will be accessible free to the public, other parts will only be accessible to current customers and/or internal consultants, and other parts of the intranet site will be accessible for a fee.

Approach:

- Develop a survey to determine critical features of the new intranet site and solicit inputs from consultants and customers
- Review internal and external templates and examples of project management documents
- Research software to provide features such as security, managing user inputs, and the article retrieval and "Ask the Expert" capability
- Develop the intranet using and iterative approach, soliciting a great deal of user feedback
- Determine a way to measure the value of the intranet site in terms of reduced costs and new revenues and this information during the project and one year after project completion

Roles and Responsibilities:

Name	Role	Position	Contact Information
Joe Fleming	Sponsor	JWD Consulting, CEO	joe_fleming@jwdconsulting.com
Erica Bell	Project Manager	JWD Consulting, manager	erica_bell@jwdconsulting.com
Michael Chen	Team Member	JWD Consulting, senior consultant	michael_chen@jwdconsulting.com
Jessie Faue	Team Member	JWD Consulting consultant	jessie_faue@jwdconsulting.com
Kevin Dodge	Team Member	JWD Consulting, IT department	kevin_dodge@jwdconsulting.com
Cindy Dawson	Team Member	JWD Consulting, IT department	cindy_dawson@jwdconsulting.com
Kim Phuong	Advisor	Client representative	kim_phuong@client1.com
Page Miller	Advisor	Client representative	page_miller@client2.com

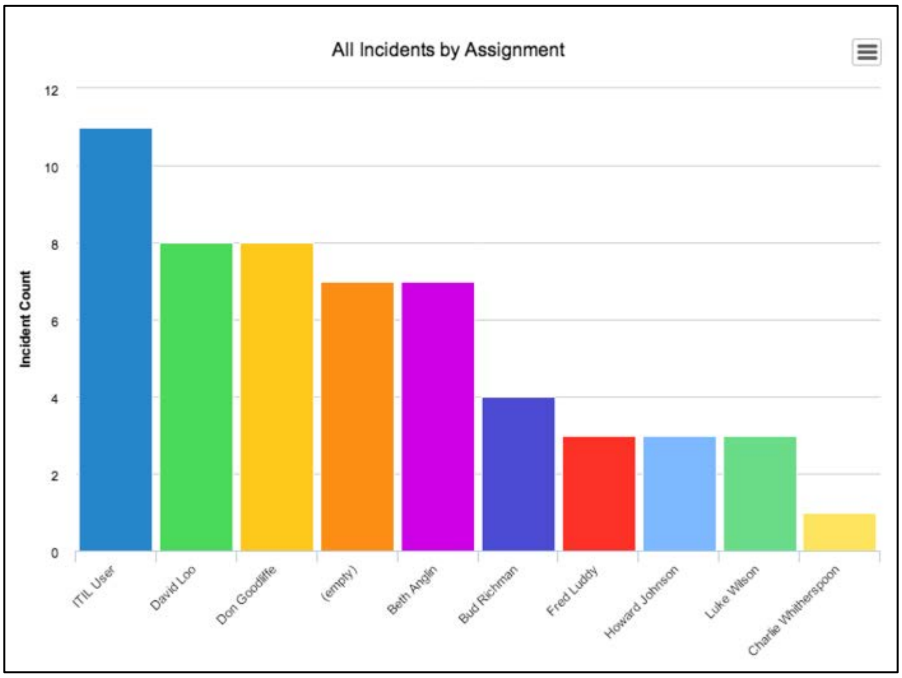
Comments: (Handwritten or typed comments from above stakeholders, if applicable)
"I will support this project as time allows, but I believe my client projects take priority. I will have one of my assistants support the project as needed." --Michael Chen
"We need to be extremely careful testing this new system, especially the security in giving access to parts of the intranet site to the public and clients." --Kevin Dodge and Cindy Dawson

Source: wordpress.com
Figure 2.2 Project Charter

Figure 2.2 shows a project charter. A project charter, as stated above, typically contains the project title, project background, objectives and assumptions of the project, names of people involved, and the approach used in the project. The project charter then helps the members of the project to carry the project out better. Quoting from Schwalbe (2008) in a journal by Jamil Enani (2015), when a project charter is settled and approved, no one can change the project charter. Therefore, not only that project charter is detailed but also requires commitment from parties in the company.

2.5 Bar Chart

Often mistaken as histogram, bar chart is a tool that presents the data in columns with the Y-axis being the values or amount of data and the X-axis being the categories of the data. Bar chart provides ease in acknowledging the rough percentage of each element through the height of the columns. A decrease in the bar chart indicates reduction, and vice versa. In this Define phase, bar chart is used to compare the number of send back defects throughout the months of July to September 2015.

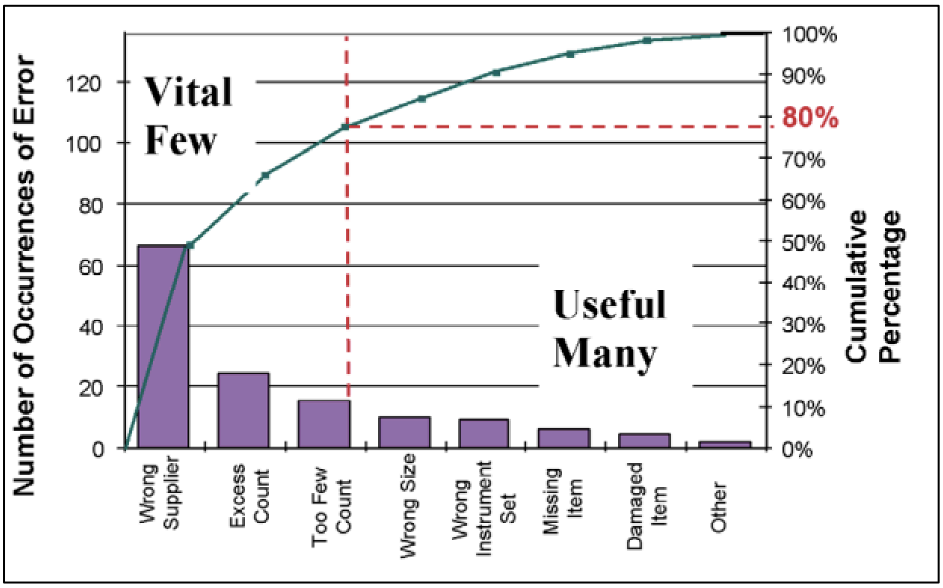


Source: conceptdraw.com
Figure 2.3 Bar Chart

Figure 2.3 shows an example of bar chart. As explained above, bar chart provides a visual representation of a certain set of data, with the Y-axis being the amount or values of data and the X-axis being the categories of the data. From Figure 2.4 the tendency of the data—increase or decrease—can be seen easily since the columns show the rankings of the data. In this study, bar chart is used in Chapter IV in the Define phase and the Result Analysis.

2.6 Pareto Chart

A Pareto chart is a tool used to identify vital problems of a certain process (Mitra, 2008). This tool is a type of bar chart in which the various factors that contribute to an overall effect are arranged in order according to the magnitude of their effect. This ordering helps identify the “vital few” (the factors that warrant the most attention) from the “useful many” (factors that, while useful to know about, have a relatively smaller effect). Using a Pareto chart helps a team concentrate its efforts on the factors that have the greatest impact. This tool also helps a team communicate the rationale for focusing on certain areas.



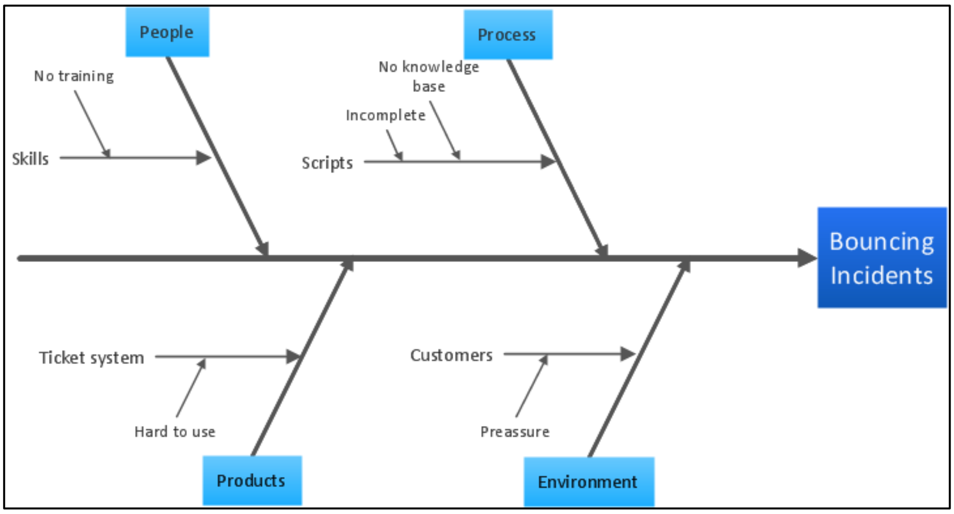
Source: isixsigma.com

Figure 2.4 Pareto Chart

Figure 2.4 shows an example of a Pareto chart. Can be seen that the Y-axis of the Pareto chart on the left side shows the amount or values of data presented in the Pareto chart and the right side shows the cumulative percentage of the data. The X-axis shows the categories of the data. From this representation, the vital few (the "20") and the useful/ trivial many (the "80) can be seen. Therefore, the scope of the research can be narrowed due to the settled priority of the problems.

2.7 Cause and Effect (Ishikawa) Diagram

Cause-Effect diagram is a tool of analysis that provides a systematic way of looking at effects and the causes that create or contribute to the aforementioned effects (Mitra, 2008). The Cause-Effect diagram is also known as the Fishbone diagram for the shape that looks like a fishbone. The Cause-Effect diagram is also known as the Ishikawa diagram, which was named after Kaoru Ishikawa, a Japanese quality control statistician, the man who pioneered the use of this chart in the 1960's. The Cause-Effect diagram is used as a tool to identify the root causes of quality problems.



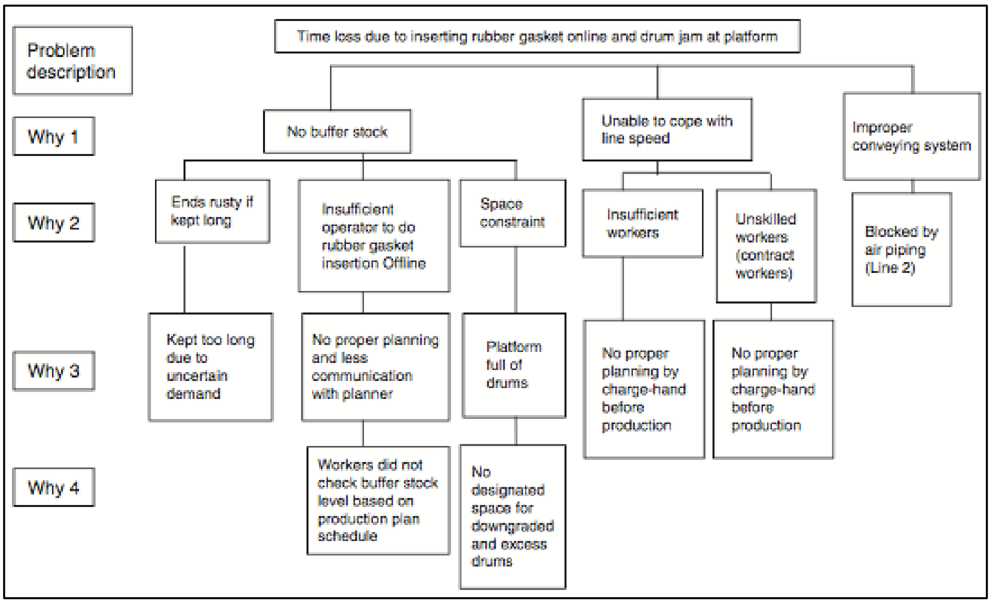
Source: conceptdraw.com

Figure 2.5 Cause-Effect Diagram

Figure 2.5 shows the Cause-Effect diagram. The Cause-Effect diagram basically represents a model of suggestive presentation for the correlations between an effect (event) and its multiple possible and happening causes. The structure of the diagram enables the analysts to think in a very systematic way. Some of the benefits in constructing a Cause-Effect diagram are that the Cause-Effect diagram helps to determine the root causes of a certain problem or quality characteristic with a structured approach, encourage group participation and utilise the knowledge of the group members, and identify the areas where data should be collected for further study.

2.8 Whys Analysis

Whys analysis is one of the tools used to analyse root causes of a problem (Kumar, et al, 2013). The name "Whys Analysis" clearly defines the concept of this tool. Basically, Whys Analysis enquires "why" to every cause possible until the cause is no more questionable. This tool can be used to analyse the root cause of a certain problem by giving critical analysis until the point when the question becomes unquestionable.



Source: emeraldinsight.com
Figure 2.6 Concept of Whys Analysis

Figure 2.6 shows the concept of Whys Analysis. Can be seen that every possible cause is faced with "why" enquiry, which then leads to the next "why", up until the point that there is no more "why" possible to be enquired. The Whys Analysis is often related to the Cause-Effect Diagram. The reason is because Whys Analysis provides an answer for every cause, which is pretty much the same concept, compared to Cause-Effect Diagram, but more detailed. Therefore, in this study, this tool is preferred. There are some benefits of the Whys Analysis, such as that this tool helps to identify the root cause of a problem, enables the determination of relationship between root causes of a certain problem, and not to mention, simple but correct.

2.9 Nominal Group Technique

First introduced in the 1960's, Nominal Group Technique was originally made to facilitate an effective group discussion by encouraging ideas and effective communication (Potter, 2004). This tool is widely used in various fields, such as education, health, social service, and industry, even government organisations. Nominal Group Technique is ideal for an environment where there are shy members of the project who prefer a more silent approach or when there is a need of diminishing competition—which often happens in a group discussion for attainments of hidden agendas. However, should be noted that Nominal Group Technique is ideal when there is only one problem addressed because Nominal Group Technique has a rigid and straightforward approach that takes into account one problem at a time only.

	Quality	Engineering	R&D	Marketing	Manufacturing	Total
Idea 1	1	4	5	4	1	**15**
Idea 2	2	1	2	1	6	**12**
Idea 3	3	3	4	3	3	**16**
Idea 4	4	6	6	5	4	**25**
Idea 5	5	2	1	6	5	**19**
Idea 6	6	5	3	2	2	**18**

Source: cqeacademy.com

Figure 2.7 Nominal Group Technique

Figure 2.7 shows a Nominal Group Technique. Can be seen that there are six ideas with five groups from which the members are originated, and the total indicates the score of importance of each idea. In Nominal Group Technique, each idea is measured and given weight (usually the weights vary from 1 – 4, which shows the importance; the more the weight, the more important the idea is). Each member of the group then writes down the ideas for the improvement of each issue without any interaction, then provide weight for each idea. The facilitator then sums the weights and therefore results in scores. The scored ideas are then used to determine priorities of the ideas that are to be implemented.

In conclusion, Chapter II includes the method and tools used in this thesis. The methodology used to analyse the problem of send back defects in PT. X is Six Sigma Define Measure Analyse Improve Control (DMAIC) and the tools are flow diagram, project charter, bar chart, Pareto chart, Cause-Effect Diagram, Whys Analysis, and Nominal Group Technique. Six Sigma DMAIC is chosen as the method because the methodology is very customer-oriented, timeless, has clear and systematic steps, and focuses on defect reduction. All of the aforementioned tools are used accordingly in each phase of DMAIC. The next chapter—Chapter III will discuss about the research methodology of the thesis, or how the thesis is done. The next chapter includes two parts, which are the framework of the research and the detailed framework that explains in detail about the research framework.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Framework

Research methodology consists of the steps/ procedures done in order to conduct this project. In general, the procedures used are as follow.

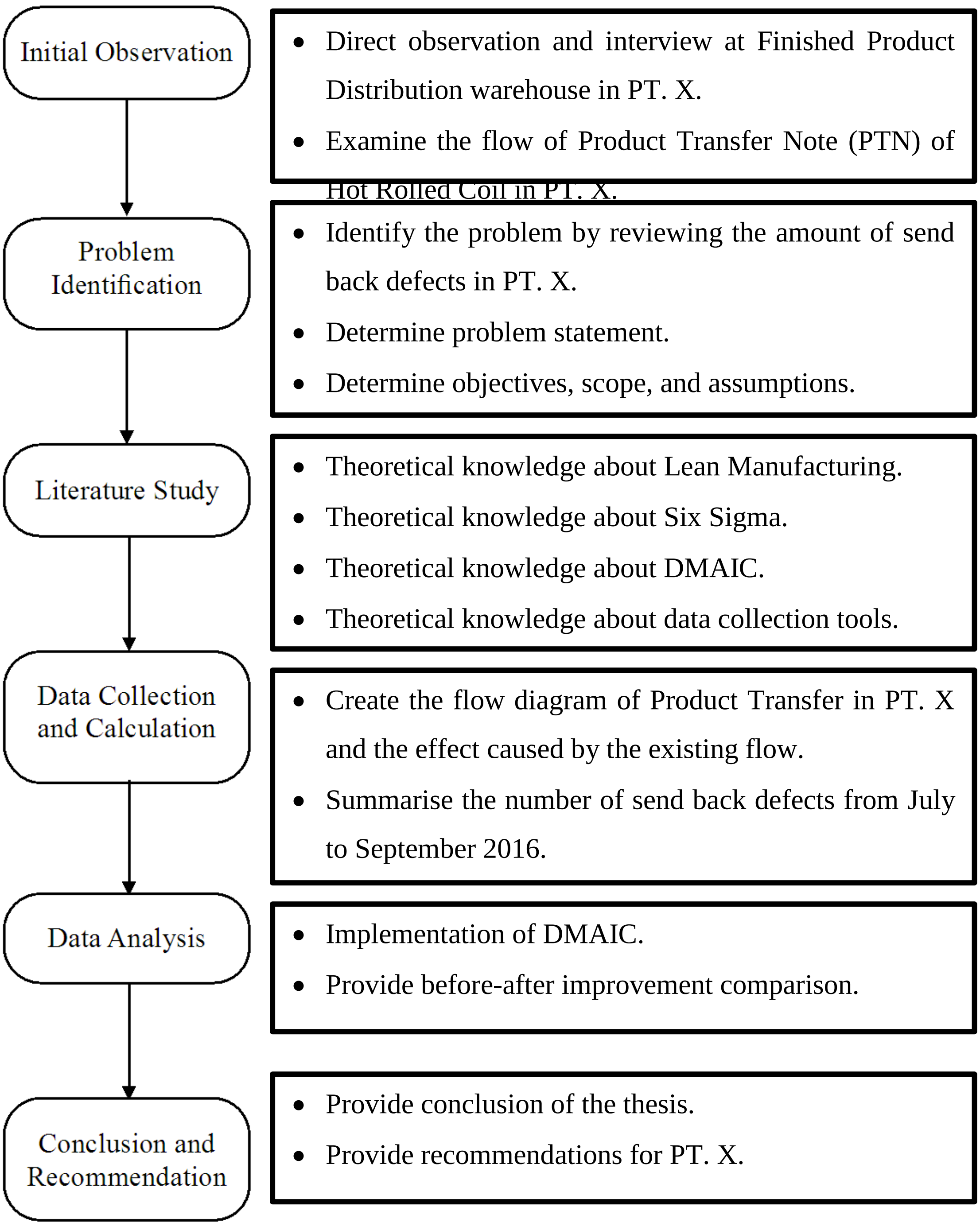


Figure 3.1. General Research Framework

3.1.1 Initial Observation

The first step in doing this research is conduct direct observation to the Finished Product Distribution area, specifically the warehouse, where the Hot Rolled Coil are ready to be shipped. In the aforementioned area, the high amount of defective Hot Rolled Coil is found. In order to know the cause of the high number of defective Hot Rolled Coil in the shipment area, interviews with the employees are conducted. In this step, the high amount of defective Hot Rolled Coil and the causes are acknowledged.

3.1.2 Problem Identification

Problem identification is a step that identifies the problem(s) that are about to be analysed in this research. The first step is to elaborate the background of the problem—high number of defective Hot Rolled Coil in Finished Product Distribution area specifically Defect Handling. The next is to compose the problem statement(s), which focus(es) in finding the root cause of and reduce the high number of Defect Handling found in Hot Rolled Coil in Finished Product Distribution warehouse. The next is to compose the research objective(s), which should be a set of aims of research that provide an answer to the problem statement(s)—find the root cause and reduce the high number of Defect Handling found in Hot Rolled Coils in Finished Product Distribution warehouse. The assumptions and scope of the research are also defined in this part.

3.1.3 Literature Study

After the problem has been identified, the next step is to make literature study. The purpose of literature study is to provide theoretical knowledge and explain about the terminologies, tools, and method used in this research. In this chapter, theoretical knowledge and further explanations about the tools and method, which are lean manufacturing, Six Sigma, Define, Measure, Analyse, Improve, and Control (DMAIC), Business Process, Flow Diagram, tools in the Define phase (Project Charter, Pareto Chart, and Flow Diagram), tools in Measure phase (Defect Percentage), tools in Analyse phase (Fishbone Diagram, 5 Whys, Nominal Group Technique).

The terminologies that are explained in literature study are Finished Product Distribution, Product Transfer Note, and Product Return Note.

3.1.4 Data Collection

In this step, the data necessary for the research is collected. The data are originally from PT. X. The data are presented in units of Hot Rolled Coil and in days of months. In data collection, the data of flow process of Product Transfer Note is presented with flow diagram and the data of defectives in July – September 2015 is summarised with bar chart.

3.1.5 Data Analysis

After the data collection is completed, the next step is to make data calculation and analysis. There are several steps in this step, which are:

1. Define

   The first step of DMAIC is to define the problem (Define phase). In this step, first of all, a project charter is made in order to elaborate the problem background, set a clear objective and theme of project, acknowledge who are responsible, and the scope of the project. The next step is to state and explain about the types of defects of Hot Rolled Coil that often occur in Finished Product Distribution warehouse. The next is to present the number of send back defects of Hot Rolled Coil in Finished Product Distribution Area. The last is to make the Pareto chart to se the priority and narrow the focus of the problem.

2. Measure

   The second phase of DMAIC is to measure the baseline of the research (Measure phase). In this phase, the steps are to measure the target to achieve by calculating the defect percentage of each type of defect to ensure which type of defect to reduce and how much more to reduce to reach the target.

3. Analyse

   The third phase of DMAIC is to analyse the causes of the high number of Defect Handling found in Hot Rolled Coil in Finished Product Distribution area of PT. X. Firstly, a Fishbone diagram is made to acknowledge the causes of high number of Defect Handling found in Hot Rolled Coil in Finished Product Distribution area. The next is to make Whys analysis to analyse the Cause and Effect Diagram.

4. Improve

   The fourth phase of DMAIC is to conduct improvement as a solution to the problem of high amount of Defect Handling found in Hot Rolled Coil in Finished Product Distribution area of PT. X. The first step is to provide suggestion for improvement by making proposal based on the Cause and Effect Diagram. The next is to make the Nominal Group Technique. Afterwards, the improvement plan is formulated.

5. Control

   The fifth and last phase of DMAIC is to control the aforementioned steps that have been implemented in order to keep the process in control, with monitoring using barcode, Manufacturing Execution System, and weekly meeting.

6. Before-After Analysis

   This part contains comparisons between the defect percentage and potential losses before and after the improvement are implemented.

3.1.6 Conclusion and Recommendation

This is the last step of the research that contains conclusion of the research and recommendation for future research. The conclusion consists of the responses towards the objectives and thus summary of each phase of DMAIC.

3.2 Detailed Framework

After determining the research flowchart, the next action is to create research framework to visualize the research in clearer step from the beginning until obtaining the result after conducting the research. The research framework is as following.

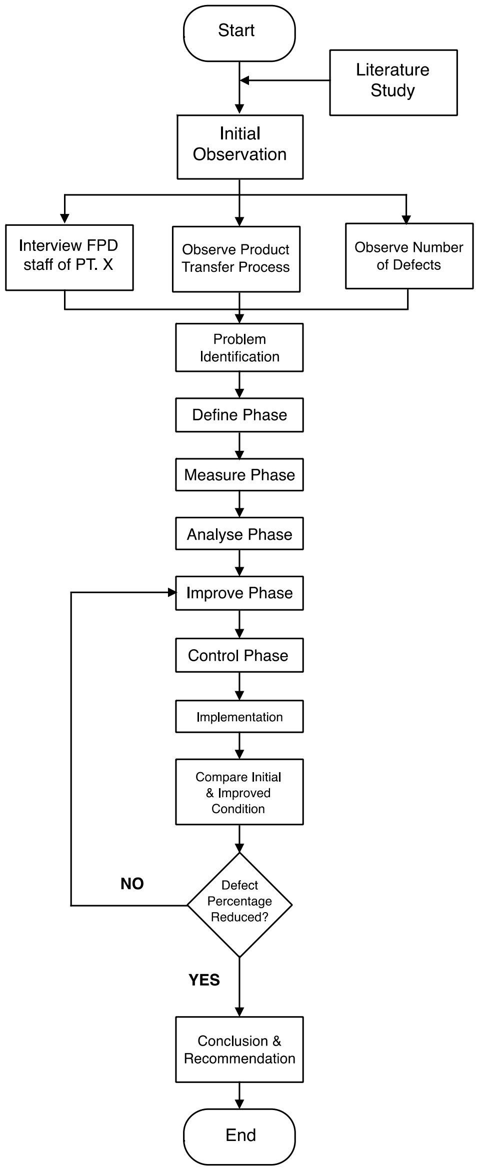


Figure 3.2 Detailed Framework

Figure 3.2 shows the detailed framework of the thesis. In brief, the thesis is initiated by initial observation, then problem identification, implementation of DMAIC phases, and if the improvement is successful, the research shall proceed to the composing of conclusion and recommendations. Otherwise, the research should return to the Improve phase. The DMAIC phases is done accordingly with the tools mentioned in the previous elaborations. In each phase, every tool should be used correctly in order to proceed to the next phase. The formulation of conclusion and recommendations marks the end of the thesis.

In conclusion, Chapter III explains about how the thesis is done. Through the research framework and the detailed framework, the methodology of the research is explained. The next chapter is Chapter IV, and this chapter will explain about the data collection and analysis. Data collection includes the result of the data collection from the company and data analysis includes the DMAIC phases and the results of the improvement.

CHAPTER IV
DATA COLLECTION AND ANALYSIS

4.1 Data Collection

Data collection is a part where the data that are collected from Finished Product Distribution division of PT. X for analysis purposes are shown and explained. Finished Product Distribution (Hot Rolled Coil) department of PT. X is responsible for ensuring that the Hot Rolled Coils are delivered in prime condition and excellent quality to the customers. In this chapter, the data are collected from direct observation, series of interviews, and secondary data.

4.1.1 Product Description

Hot Rolled Coil is one of the products manufactured by PT. X, aside from Hot Rolled Plate, Cold Rolled Sheet, Cold Rolled Coil and Wire Rod. Hot Rolled Coil is processed in the Slab Steel Plant of PT. X, specifically in the Hot Rolling Mill. The dimensions of Hot Rolled Coils manufactured by PT. X vary depend on the customer requirements. Hot Rolled Coil can be used for making gas, oil, or water pipes and for the bodies of vehicles, such as trucks, buses, ships, and even for war vehicles.

Source: Courtesy of PT. X

Figure 4.1 Hot Rolled Coil

Figure 4.1 shows an example of Hot Rolled Coil. As seen in Figure 4.1, the Hot Rolled Coil is tied and marked prior to labeling and packaging. The markings indicate whether or not the Hot Rolled Coil needs further processing (slitting, recoiling, or shearing) and whether or not the Hot Rolled Coil is defective. A good Hot Rolled Coil should have smooth edges (no edge folds, edge cracks, and other damages on the edges), smooth surface (no scratch), no rusting, tightly tied, and exact dimension like the customer specified.

4.1.2 Production Process of Hot Rolled Coil in PT. X

Hot Rolled Coil is manufactured in the Slab Steel Plant of PT. X, specifically in the Hot Strip Mill. As the name clearly stated, the Slab Steel Plant of PT. X uses steel slabs as the main material of the finished products manufactured in the Slab Plant. The slabs used in this plant are made from the raw materials from PT. X or suppliers outside the company, which are pellets made from iron ore, H_2O, and natural gases that are processed in the direct reduction plant of PT. X. The pellets are then mixed with pig irons and steel scraps, processed in the continuous casting machine, and therefore results in slabs. The images of the materials can be seen in Appendix.

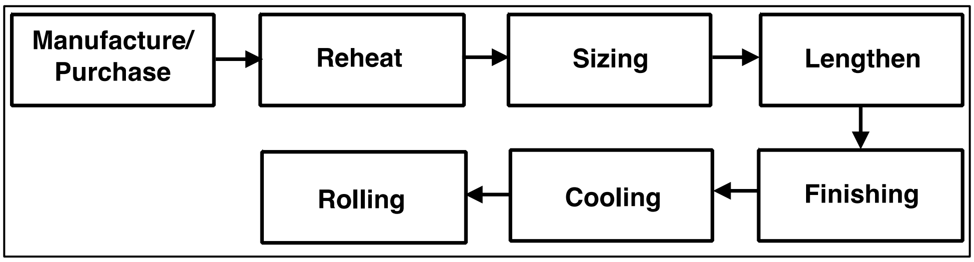
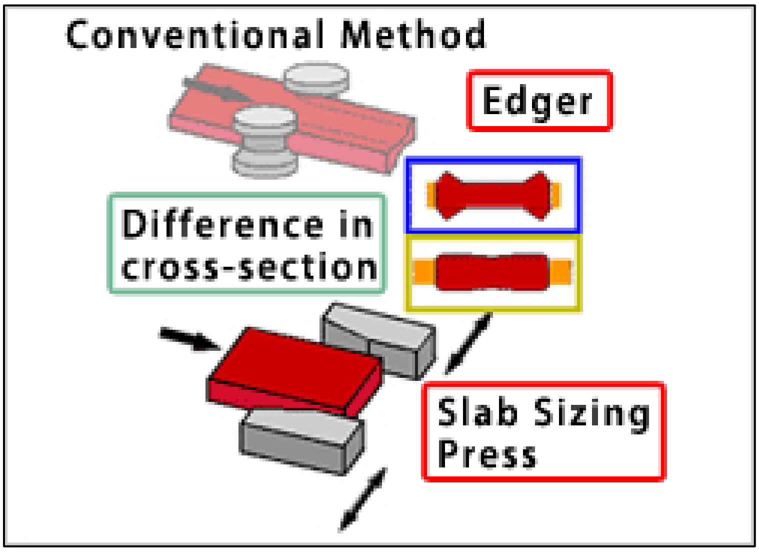


Figure 4.2 Simplified Production Process of Hot Rolled Coil

Figure 4.2 shows the simplified production process of Hot Rolled Coil. The first is to manufacture or purchase the raw material, which is steel slab. The next step is to reheat the slab to a temperature of around 1200 deg. Celsius with the reheating furnace machine.

After the slab has been reheated, the next step is to press the slab width into the designated width using the sizing press. The output of the sizing process is a leaner steel slab.



Source: primetals.co.jp
Figure 4.3 Illustration of Sizing Press

Figure 4.3 shows a simplified drawing of slab sizing press machine. After the slab is out from the sizing press, the next step is to lengthen and reduce the thickness of the slab using the roughing mill. The purpose of reducing the thickness is to obtain the final length of the slab, which is as per the specifications requested by customers.

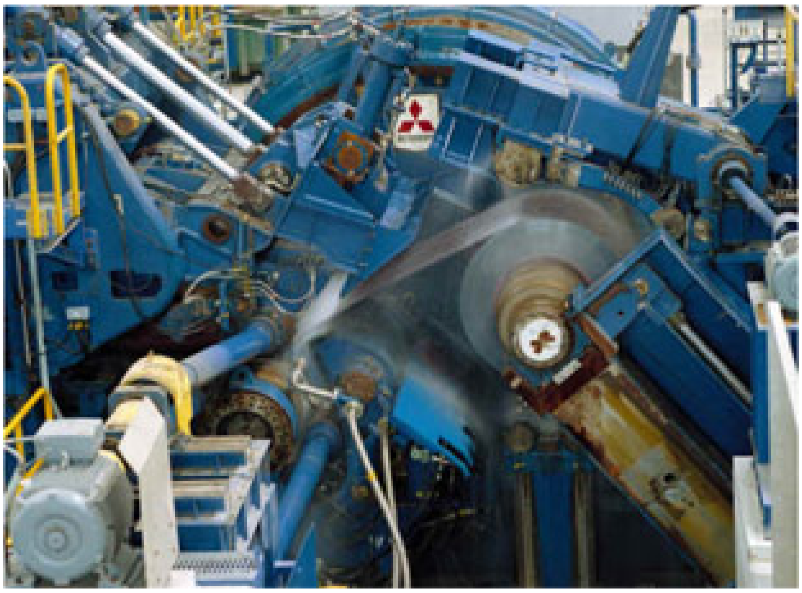
This step is done in the roughing mill, which requires the slab to go back and forth for about 5 to 7 times until the desired thickness and length are obtained. In this step also, the slab undergoes secondary descaling, which is a step of cleaning the scales formed during the process, for a square head and end of the slab are necessary for the next processes.

Source: hfinster.de
Figure 4.4 Roughing Mill

Figure 4.4 shows the roughing mill. Roughing mill is also known as the finishing mill, however, the difference is that roughing mill typically consists of one or two roughing stands while finishing mill has five to seven roughing stands. In the roughing mill, there are three parts of the machine, which are the part that reduces the thickness of the slab—explained above—, water descaler to clean the dirt and scales present in the slab due to oxidation, and crop shear, which is to cut either the tail or head part of the coil—if necessary. The next step, finishing, is a step that is done in the finishing mill. The finishing mill allows the slab to go back and forth until the final length and thickness are achieved. The output of the finishing mill is the slab with typically 20 mm thickness, namely steel sheets. After the processing in the finishing mill, the slab needs a certain period of time in the laminar-cooling machine. In this machine, the slab is driven through twelve banks of low-pressure, high volume water sprays that cool the red hot strip into a slab with specified temperature—typically 600 to 900 deg. Celsius.

Source: siemens.com
Figure 4.5 Laminar Cooling Machine

Figure 4.5 shows the laminar-cooling machine. Laminar cooling machine allows the slab to be further processed. This step is essential for the slab is very fragile in high temperature, which then makes the slab incapable of being rolled, or proceed to the last step of the production process of Hot Rolled Coil, which is rolling. This step is done in the down coiler, or a machine that rolls the steel sheets into a roll, like tissue rolls.

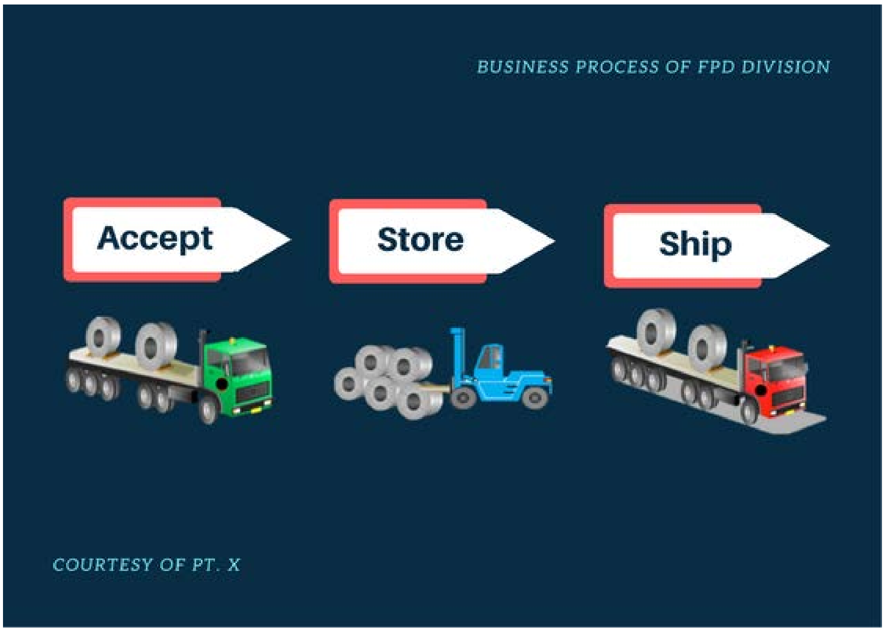


Source: primetals.co.jp
Figure 4.6 Down Coiler Machine

Figure 4.6 shows a picture of down coiler machine. As explained above, the down coiler machine stretches the steel sheets in one side and the other side rolls the steel sheet into Hot Rolled Coil. Periodically, the rolling sheet is stretched to ensure that there is no gap between one roll and another. Finally, the output of this process is Hot Rolled Coil, which then taken to the Work In Process warehouse for inspection. If the Hot Rolled Coil passes the inspection, then the Hot Rolled Coil may proceed to the Finished Product Distribution Warehouse. Otherwise, the Hot Rolled Coil must undergo rework, or if rework is not possible, the Hot Rolled Coil is downgraded.

4.1.3 Business Process of Finished Product Distribution Division of PT. X

As explained above, after all of the manufacturing processes are done—the processing of the raw materials, namely iron ore, natural gases, and water, then to the corresponding plants and processed into the various types of products—the finished products are taken to and inspected in the WIP warehouse. When the Hot Rolled Coil passes the series of inspections and is non-defective, the finished products can proceed to the final stage of the production process and be shipped to the customers.



Source: Courtesy of PT. X

Figure 4.7 Business Process of Finished Product Distribution Division of PT. X

Figure 4.7 shows the business process of Finished Product Distribution department (Hot Rolled Coil) in PT. X. There are three steps in the business process. The first step is to accept, which means that the Hot Rolled Coil from Work In Process warehouse is accepted into the Finished Product Distribution Warehouse. The input of this step is Hot Rolled Coils manufactured in the Hot Strip Mill of PT. X, using the raw materials (slab steels) either from PT. X or from suppliers. In order for the coil to proceed from Work In Process warehouse to Finished Product Distribution warehouse, the coil needs to undergo the Product Transfer process, in which the coil is inspected for eligibility to be transferred to Finished Product Distribution warehouse, for the coils that are in the Finished Product Distribution warehouse have to be non-defective, or Ready To Ship.

The next step is to store. This step means that after the coil is accepted from Work In Process warehouse or the Product Transfer process is done, the next step is for the coils to be prepared for shipment. This preparation step includes the release of the picking list, which is a list of coils that are Ready To Ship—or to "call" the coils from Finished Product Distribution warehouse. If the coils in the picking list are ready, then the next step is to assign batches of coils to ship, which is a step of determining whether or not the coils in the picking list are eligible and to decide which mode of transportation to use to deliver the coils, based on the location of the customer, mass of the coils, or by request of the customer. After the batch of coils is assigned and the transportation is ready, then the coils undergo final inspection before proceeding to the next step.

The last step is to distribute or ship the coils. The batches of coils that have already passed the final inspection are distributed to the customers. The customers of PT. X are both local and international. Can be concluded that that the series of processes are directly responsible for the reputation of PT. X.

4.2 Define Phase

The first phase of DMAIC is Define phase. In this phase, the problem, objectives, and the needs of the study are clearly defined and explained. There are several parts in this phase. The first is to show and present explanation about the send back defect of Hot Rolled Coil from July to September 2015, along with the types of defects and a Pareto chart in order to decide which type of defect should be prioritised. The next is to show and present explanation about Defect Handling percentage. After that, the flow of Product Transfer Note is shown and explained. The next is to make a project charter in order to acknowledge the background of the project, set the objectives, timeline, and persons in charge. The last step is to summarise the Define phase.

4.2.1 Send Back Defect of Hot Rolled Coil from July to September 2015

Send back defect is a type of defect that occurs in the Finished Product Distribution area. If a finished product happens to be attributed to send back defect, then the finished product will either be repaired or downgraded. Reparation means to rework the coil, which includes cutting the defective part, polishing, or recoiling. If rework is not possible, then the coil is downgraded, which means sold for commercial purposes in cheaper price.

In this study, the send back defect study is limited only on Hot Rolled Coils in PT. X, which is one of the best-featured products of PT. X manufactured in the Hot Strip Mill. As explained in the business process of PT. X (see Figure 4.7), when a finished product enters the Finished Product Distribution warehouse, then the product should be in a Ready To Ship state. The reason is so that the coil can be in prime condition and therefore is able to be sold in the prime value. Reworking steel products affects the worth of the product since the rework process causes the coil to experience scrap loss, which is an inevitable loss for steel products. Not to mention the extra production cost, both money and time, and also the risk of the coil for not delivered on time. From July to September 2015, the number of send back defects of Hot Rolled Coil in PT. X continually increases.

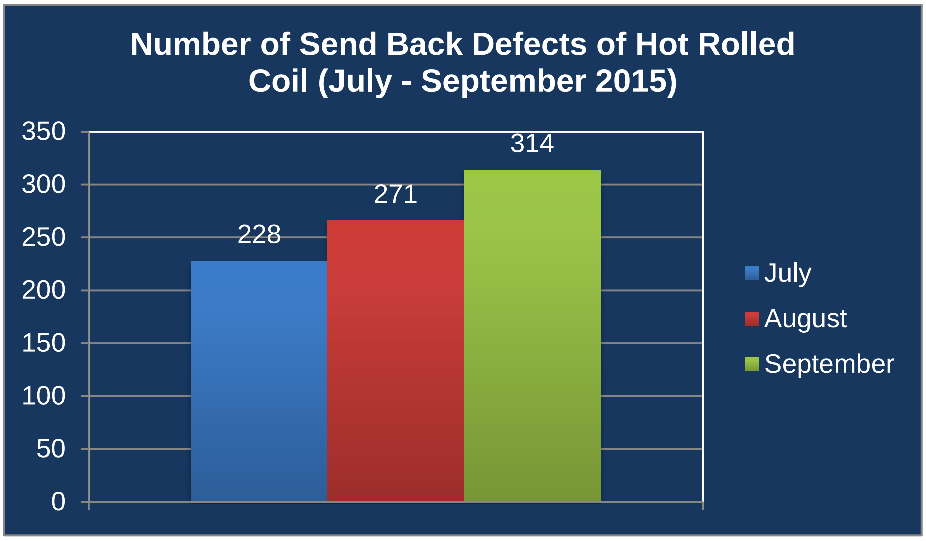


Figure 4.8 Number of Send Back Defects of Hot Rolled Coil (July – September 2015)

Figure 4.8 shows the number of send back defects of Hot Rolled Coil in Finished Product Distribution Division of PT. X. Can be seen that in July 2015, the number of send back defects is 228 coils. This number increases in the next month to 271 coils. Finally, on September, the number of send back defects increases to 314 coils. The increasing number of send back defects shows that there is something faulty in the process and therefore requires further investigation.

4.2.2 Types of Defects in Hot Rolled Coils from July - September 2015

As explained above, a further investigation is required to find out which part of the process is faulty. The first step to do so is to acknowledge the types of defects that may occur in a Hot Rolled Coil. Consequently, the opportunities of a Hot Rolled Coil can be identified. The opportunities can then be used to calculate the Sigma Quality Level to find out how good is the quality of the product transfer process of Hot Rolled Coils in the Finished Product Distribution Division of PT. X.

a. Defect Handling (DH)

Defect Handling, as the name clearly stated, is a type of send back defect caused by occurrences during handling, whether by crane or manual. The examples of Defect Handling are scratches on the surface, folds, and cracks on the body of the coil. The severity of this type of defect depends of the area that the defect covers, the length of defect, and the depth of the defect.

Source: flickr.com/leeber

Figure 4.9 Scratched Surface of Hot Rolled Coil

Figure 4.9 shows an example of Defect Handling. As explained above, one example of Defect Handling is scratches on the surface of Hot Rolled Coil. The scratches are likely caused repeated handling that causes the coil to have friction with narrow edges. Scratches are like in Figure 4.9, such condition is very undesirable for customers.

b. Edge Fold (EF)

Edge Fold is an occurrence of folded—whether inwards or outwards—edge of the coil. This type of defect is mainly caused by inappropriate handlings. The severity of this defect depends on the depth of folds, area of folded edges, and number of folded edges.

Source: Courtesy of PT. X
Figure 4.10 Edge Fold Defect

Figure 4.10 shows an example of Edge Fold defect. In this type of defect, instead of the surface, only the edge is folded. In Figure 4.10, the edge is folded inwards and there are two edge folds seen in the coil.

c. Edge Crack (EC)

Edge Crack is a type of defect that, as the name obviously suggests, when visible cracks are seen on the edges of the coil. The possible causes of this type of defect are improper handling of coil, the coil dropped from an intolerable height, or the coil is hit by a certain hard and dull material.

Source: Courtesy of PT. X
Figure 4.11 Edge Crack Defect

Figure 4.11 shows the picture of Edge Crack defect. Can be clearly seen that scratches are present in the coil but only in the edge. The severity of the defect depends on the area of cracks, the number of cracks, and the depth of cracks in the edges. In Figure 4.11, can be seen that there are numbers of cracks with different sizes in the coil.

d. Protruding (PT)

Protruding, as the name clearly stated is a type of defect that is caused by loss ties of the coils. As explained in the previous part of the chapter, every coil is processed in the down coiler, which is when the sheet of thin coil is rolled into Hot Rolled Coil. After a coil is rolled, the coil is then tied with strings-like steels to keep the rolled shape of the coil. A good coil is tightly tied and has flat edges to ensure the shape of the coil when being unrolled. If the coil is not tightly tied, then when unrolled, the coil will not be shaped like a flat sheet, but a bent sheet instead. The easiest way to notice when the coil is not tightly tied is to see the edges of the coil. If the edges of the coil are not flat, then the coil is definitely not tightly tied.

Source: Courtesy of PT. X

Figure 4.12 Protruding Defect

Figure 4.12 shows a picture of a protruding defect. Can be seen that the edges of the coil stick outwards, instead of flat. This type of defect likely occurs because either the coil is not tightly tied or the tension given in the down coiler machine is not enough. The severity of this defect depends on the area that the defect affects and the number of protruding edges.

e. Wavy (WV)

Wavy is a type of defect that occurs due to machine error during the production process. A good coil has flat and straight edges. This type of defect happens when the coil has the opposite characteristic—wavy edges. This type of defect is very easy to notice for the edges of coils are visible.

Source: Courtesy of PT. X
Figure 4.13 Wavy Defect

Figure 4.13 shows an example of wavy defect. Can be seen that the edges are not straight, but wavy. The severity of this defect depends on the depth of the wavy edges and the area that the defect covers. If this type of defect occurs, the possible way is to repair by straightening the edges of the coil.

f. Telescope (TL)

Telescope is a type of defect that occurs due to the machine error during the production process. When the coil is rolled in the down coiler machine, the tension should be enough to ensure that the coil is rolled tightly from one sheet on another in order to prevent the gaps from being visible. This type of defect is similar to Protruding (see Figure 4.12), however, this type of defect is when the gaps between the sheets of coil are more visible rather than the edges sticking out.

Below is an example of Telescope defect.

Source: Courtesy of PT. X
Figure 4.14 Telescope Defect

Figure 4.14 shows telescope defect. Another possible cause of Telescope type of defect is that the coil is cut into an uneven diameter, which causes the coil, that should be in a form of roll with equal diameter shaped like a telescope instead. Similar to Protruding defect (see Figure 4.12), this type of defect is unfavourable beacause when the string of the coil is loosened, the coil is not shaped evenly as a straight sheet, but with bent surface instead.

g. Mild Rusting (MR)

Mild Rusting is a type of defect that occurs due to an improper storage. This type of defect occurs when the coil is not stored in a proper storage, such as outdoor field and exposed to oxygen and rain. Finished Product Distribution (Hot Rolled Coil) division of PT. X has two types of warehouses in the Slab Steel Plant based on the location of the warehouse, which are indoor and outdoor warehouse. Ideally, the coils should be placed indoor, but due to the limitations of the company, such as inadequate space and ease of handling purposes, there are some coils that are stored in the outdoor and some in the indoor warehouse.

Source: Courtesy of PT. X

Figure 4.15 Mild Rusting Defect

Figure 4.15 shows Mild Rusting. This type of defect occurs when the coil is only exposed to water and oxygen for a short period and returned to the indoor storage immediately. When the rusting is on a small diameter and does not cover a large area of the coil, then the rusting is categorised as mild. As seen in Figure 4.15, the rusting only covers several area of the coil instead of a whole surface or a large area of the coil. When the rusting is only minor and small, will be possible for the operator to clean the rusting with fabric and chemicals, but when this type of defect occurs, then the rusting is no longer able to be treated manually, therefore requires machinery.

h. Heavy Rusting (HR)

Heavy Rusting is a type of defect that occurs due to an improper storage, but in a heavier extent. Similar to Mild Rusting (see Figure 4.16), this type of defect occurs when the coil is not stored in a proper storage, such as outdoor field and exposed to oxygen and rain in a longer period. However, different from Mild Rusting, this type of defect is different because the rusting area is larger compared to Mild Rusting and very visible.

Source: Courtesy of PT. X

Figure 4.16 Heavy Rusting Defect

Figure 4.16 shows an example of Heavy Rusting. Can be seen that the rusting occurs in a whole surface of the coil until the coil turns into brown, which indicates heavy rusting. However, heavy rusting occurs when the Hot Rolled Coil is exposed to water and oxygen for a longer period and not returned to the indoor storage immediately. The inemmediate return of the coil to indoor storage could be either for ease of handling or the inavailability of space for storage.

i. Ripped (RP)

Ripped is a type of defect that occurs due to either machine error or improper handling. This type of defect is very visible, because when a coil is torn apart into two or more parts that means that the coil is ripped. A good coil should be whole and not torn into pieces. This type of defect is similar to Edge Crack (see Figure 4.11), however the difference is that this type of defect is when the sheet of coil—

that is already rolled—is torn into two or more parts, unlike cracks where the part of the coil is fractured.

Source: sixstringobsession.blogspot.com
Figure 4.17 Illustration of Ripped Defect

As seen in Figure 4.17, the illustration of Ripped defect can be seen. There are two likely causes of Ripped defect, which are machine error and improper handling. If the defect is caused by machine error, the error in the cutting machine is the most likely the cause. In improper handling, defect can be caused by a harsh exposure of coil to another sharp and hard material.

j. Loss (LO)

Loss indicates that the coil is not tied tightly enough. Unlike Telescope and Protruding (see Figure 4.12 and Figure 4.14) that are either caused by inadequate tension given at the down coiler machine this defect is definitely caused by loose ties of the coils. This type of defect is also unfavourable because when the coil is untied, the surface of the coil will not be straight but will be bent to a certain extent.

Below is an example of Loss defect.

Source: klse.i3investor.com
Figure 4.18 Loss Defect

Figure 4.18 shows an example of Loss defect. Can be seen that the coil is not tied tightly therefore causes the coil rolled untidily. The gaps between the sheets of coil are visible due to the loose ties. The only way to repair this type of defect is to unroll the coil and then redo the tying of the coil by applying the right tension to the strength and then tie the coil tightly.

In conclusion, there are ten types of defects found in Hot Rolled Coils in Finished Product Distribution warehouse, which are Defect Handling (DH), Edge Fold (EF), Edge Crack (EC), Protruding (PT), Wavy (WV), Telescope (TO), Mild Rusting (MR), Heavy Rusting (HR), Ripped (RP), and Loss (LO). The causes of defects vary from machine error to improper handling.

4.2.3 Product Transfer Note (PTN) Release Flow in PT. X

Product transfer is a process of moving an item from one place to another, in this case, moving a finished product from Work In Process Warehouse to Finished Product Distribution warehouse. As explained in the previous part of the chapter, the coil moved into the Finished Product Distribution warehouse should be in a Ready To Ship state, which means not defective. In PT. X, such action should be done using the Product Transfer Note documents so that the movement of each coil can be monitored. The following flow diagram is the product transfer flow from Work In Process warehouse to Finished Product Distribution warehouse.

Figure 4.19 shows the Product Transfer flow of Hot Rolled Coil from Work In Process warehouse to Finished Product Distribution warehouse.

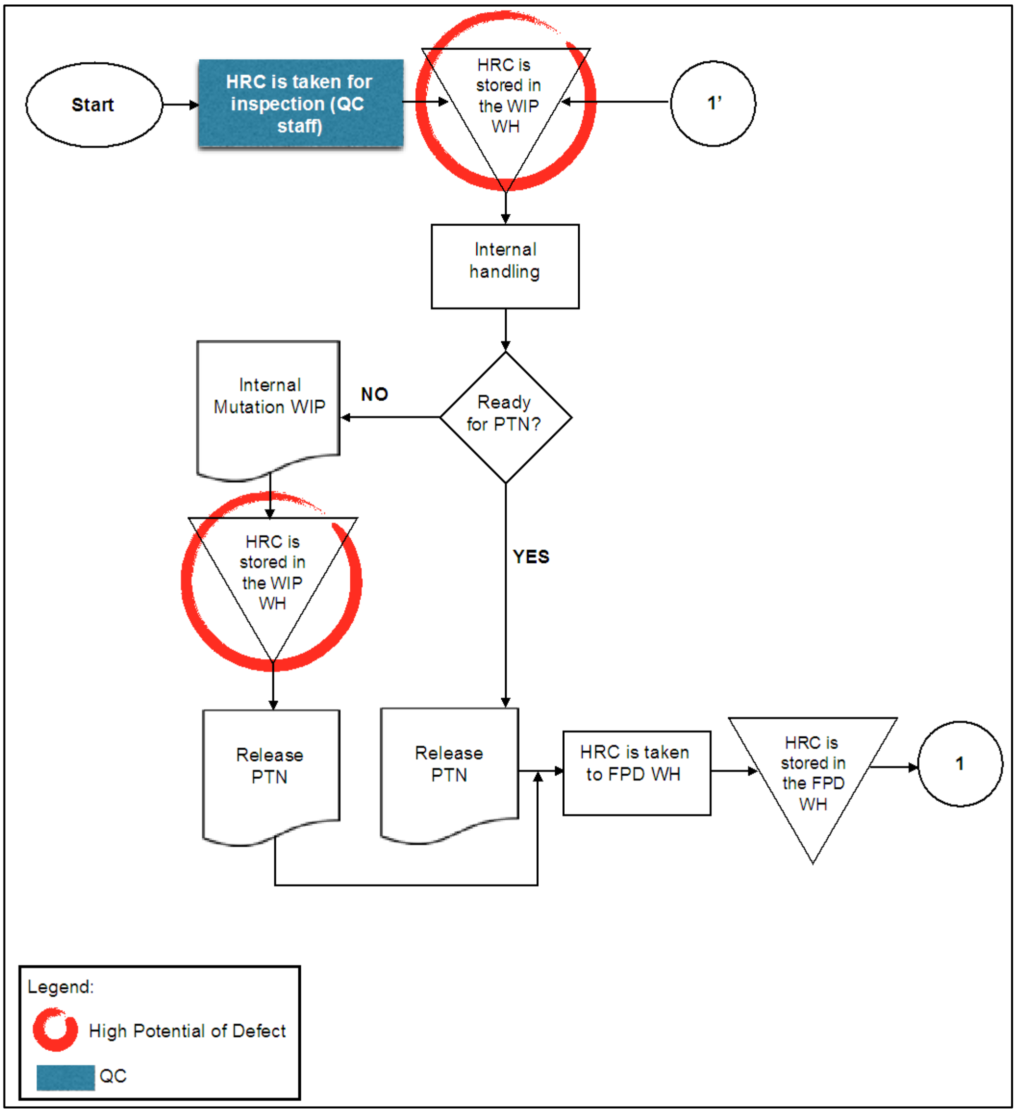


Figure 4.19 Product Transfer Flow of Hot Rolled Coil from Work In Process Warehouse to Finished Product Distribution Division Warehouse in PT. X

Figure 4.19 shows the product transfer flow of Hot Rolled Coil from Work In Process to Finished Product Distribution warehouse. The first step is that a Quality Control inspector takes the coil to the Work In Process warehouse for inspection. Note that the Work In Process warehouse is divided into two sections, which are the rework Work In Process and the final Work In Process, firstly in the process, the coil is delivered to the latter, where the only concern is only in regards of labeling and other final attributes of the coil. Assuming that the coil is at Ready To Ship condition, the inspection is only done based on the visual appearance of the coil, such as the availability of labels, whether or not viewable defects present on the coil, but not the deeper characteristics of the coil such as the tensile strength and temperature. Afterwards, if the coil is defect-free, then the Product Transfer Note of the coil can be released—the coil can be moved to the Finished Product Distribution warehouse. Otherwise, the coil is returned to the rework Work In Process warehouse—thus the internal mutation—and when the coil has been repaired as per the instructions to match the required specifications, Product Transfer Note document can be released and thus be taken to Finished Product Distribution warehouse.

In Figure 4.19, there are two steps in the process that are marked with red circles. These signs indicate that the steps have high defect potential. The reason of high defect potential in the first process (after the coil is taken for inspection) is that the fact that after the repair of the coil, no Quality Control staff is present for inspection. This lack of inspection results the possibility of defective coils proceeding to the next process (internal handling). The next part marked with red circle is the one after internal mutation in Work In Process warehouse. There is a lot of handling in the process and there is a change in the coil after the repair, and yet there is no Quality Control inspector present to ensure that the coil matches the requirements and is not defective.

Figure 4.19 also shows a process that goes to the storing of Hot Rolled Coil in the Work In Process Warehouse (marked by (1’). This process will be explained in the next flow diagram, which is a continued flow diagram from Figure 4.19.

Figure 4.20 below shows the continued Product Transfer flow of Hot Rolled Coil from Finished Product Distribution warehouse to shipment.

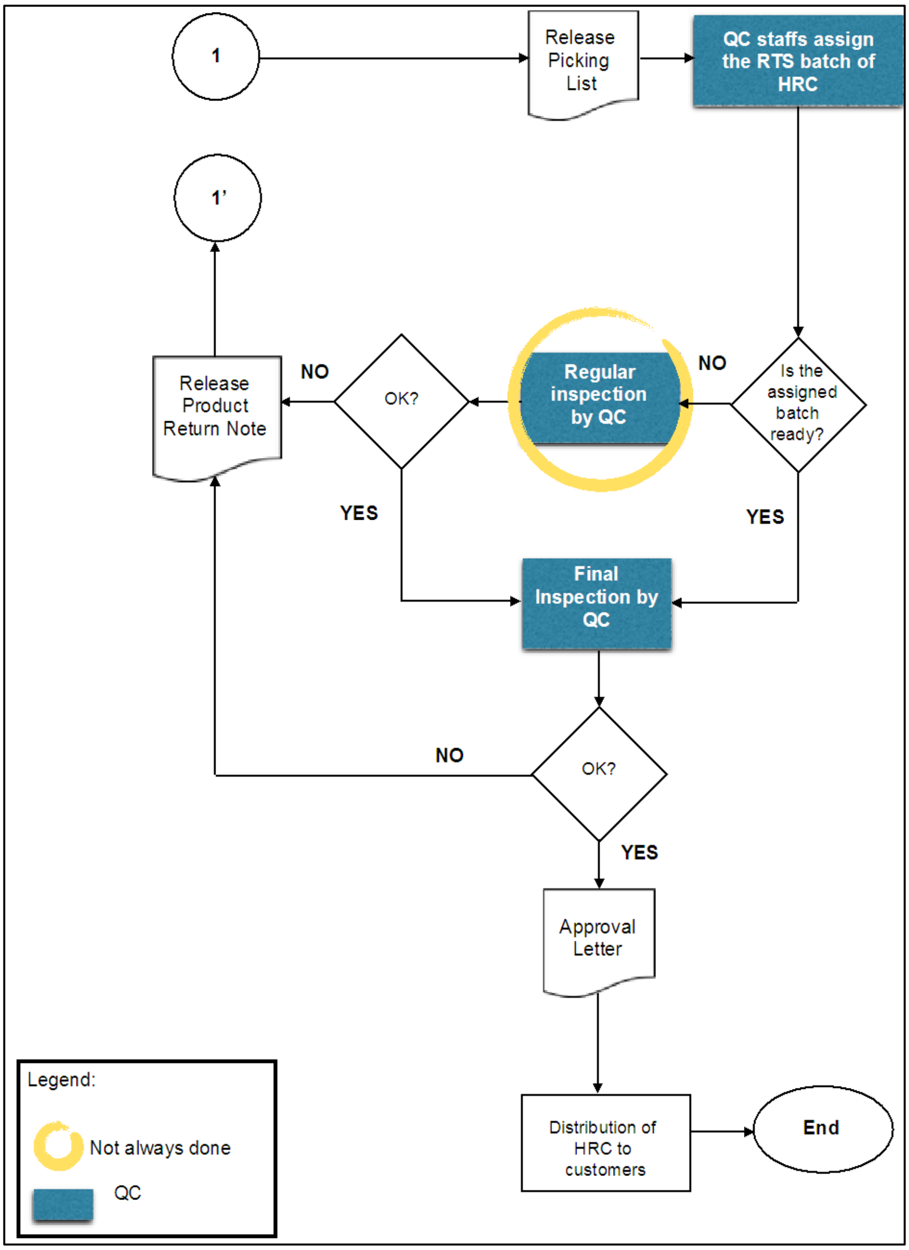


Figure 4.20 Product Transfer Flow of Hot Rolled Coil from Finished Product Distribution Warehouse to Shipment in PT. X (continued)

Figure 4.20 shows the product transfer flow of Hot Rolled Coil from Finished Product Distribution warehouse to shipment. After the coil has been delivered to Finished Product Distribution warehouse, the next step is to release the picking list of coils that are to be delivered. As explained in the previous part of the chapter (see Business Process of Finished Product Distribution of PT. X), picking list is a list that consists of the Ready To Ship (RTS) coil(s) that should be delivered to the customers. The next step is for Quality Control inspectors to assign the batch of Ready to Ship coils along with the preparation of vehicles to carry the coil(s)—whether with ship, trucks, or train. If the assigned batch of coils is ready, then the coil(s) shall proceed to the final inspection step by Quality Control inspector. Otherwise, a Product Return Note should be released to return the coil to Work In Process warehouse for repairing. Product Transfer Note is a document that works in an opposite way of Product Transfer Note, which is to return the item to the previous stage instead of moving it forward. If the assigned batch is not Ready To Ship but then after the regular inspection the not Ready To Ship claim is false, then the coil shall proceed to the final inspection step by Quality Control inspector. After the final inspection, the next step is the release of approval letter, which is a letter that states that the coil is already shipped, like an invoice. The distribution of the coil marks the end of the process.

Can be seen that there is a step in the process marked with yellow circle. As the legend states, the yellow circle means that the step is not always done. The reason why the regular inspection is not always done is because of a lack of monitoring in the process, which makes the personnel who is supposed to do inspection does not actually inspect the coil in the field, but only does a documentation instead. If a defective coil that passes the process from Figure 4.19 also passes through the final inspection, the coil should have a Product Return Note released and return to step (1'), which not only makes the coil has a lot of handlings, but also a considerable waste of time (up to two days without including the repair).

Therefore, can be concluded that a further investigation should be done in order to reduce the number of not Ready To Ship/ defective coils from getting into Finished Product Distribution warehouse.

4.2.4 Pareto Chart

From the previous part (see 4.2.1), can be concluded that a high number of not Ready To Ship coils managed to enter Finished Product Distribution warehouse, thus a further study should be done to reduce the number of not Ready To Ship coils or the number of send back defects to get into Finished Product Distribution warehouse. Before the investigation is conducted and a further action is planned and formulated, the exact number of send back defects from and ratio of send back defects and shipment during the period (July to September 2015) should be acknowledged.

Table 4.1 Number of Shipment, Send Back Defects, and Ratio of Hot Rolled Coils in PT. X from July – September 2015

Shipment (coils)	Send Back Defects (coils)	Ratio (%)
15,450	813	5.23

Table 4.1 shows the number of shipment, send back defects, and ratio of send back defects/ shipment of Hot Rolled Coil in PT. X from July to September 2015. The ratio is 5.23%, which is high for three months period. For the shipment of 15,450 coils, there are 813 defective coils. Therefore, can be concluded that the problem is the high amount of send back defects found in Finished Product Distribution warehouse of PT. X. Therefore, the main purpose of the study is then decided, which is to reduce the number of not Ready To Ship coils that enters the Finished Product Distribution warehouse. The next problem that arises is to decide what is the most dominant type of defect, which should be the main focus of the study in order to reduce the number of send back defects in Finished Product Distribution warehouse.

A Pareto chart of the send back defects is made in order to narrow the focus of the study. As explained in Chapter 2, a Pareto chart embodies the 80:20 rule. This Pareto principle means that 80% of a result is accountable to 20% of the input. Therefore, with this principle, the study can be narrowed to the significant 20% of the defects, instead of the trivial 80%.

Below is the Pareto chart of send back defects found in the Finished Product Distribution warehouse of PT. X.

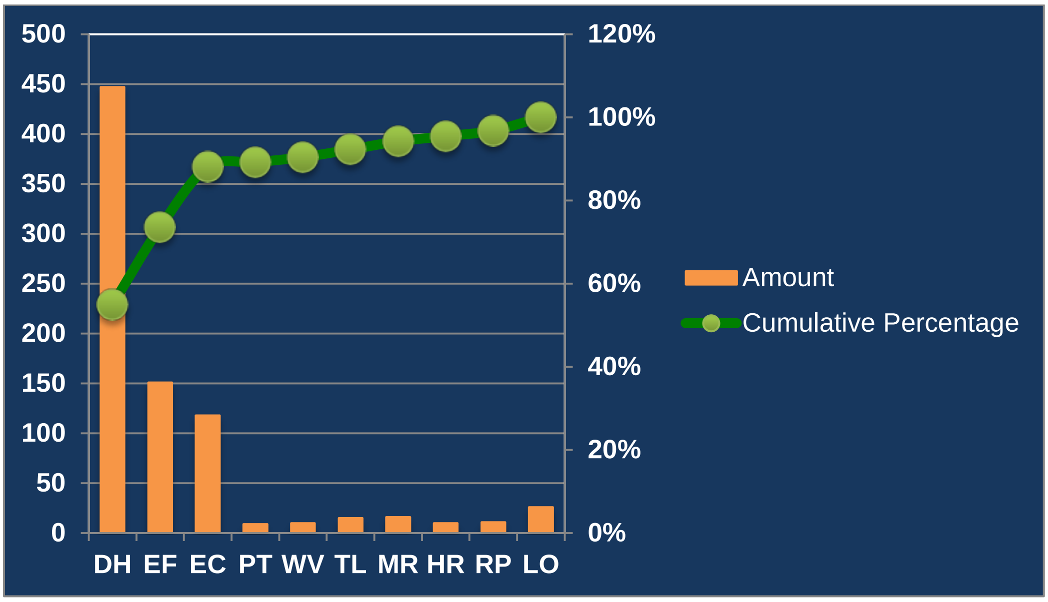


Figure 4.21 Pareto Chart of Types of Send Back Defects

Figure 4.21 shows a Pareto chart of types of send back defects of Hot Rolled Coil in Finished Product Distribution warehouse of PT. X. There are ten types of defects, which are the ones stated in the previous part (see part 4.2.2). From Figure 4.21 can be seen that the highest type of defect is Defect Handling (DH). The next highest type of defect is Edge Fold (EF), and then followed by Edge Crack (EC).

Below is the stratification of send back defects found in the Finished Product Distribution warehouse of PT. X from July to September 2015.

Table 4.2 Stratification of Send Back Defects

Send Back Defects of PT. X				
Category	**Amount**	**Cumulative Amount**	**Percentage**	**Cumulative Percentage**
DH	447	447	54.98	54.98%
EF	151	598	18.57	73.55%
EC	118	716	14.51	88.07%
PT	9	725	1.11	89.18%
WV	10	735	1.23	90.41%
TL	15	750	1.85	92.25%
MR	16	766	1.97	94.22%
HR	10	776	1.23	95.45%
RP	11	787	1.35	96.8%
LO	26	813	3.20	100%
Total	**813**		**100.00**	

Table 4.2 shows the stratification of send back defects found in Hot Rolled Coil in Finished Product Distribution warehouse of PT. X. Just like the result of the Pareto chart (see Figure 4.21), can be seen that the most dominant type of defect found in the Finished Product Distribution warehouse of PT. X is Defect Handling. Below is the number of shipment, Defect Handling found in Finished Product Distribution warehouse, and ratio of Hot Rolled Coils in PT. X from July to September 2015.

Table 4.3 Number of Shipment, Defect Handling, and Ratio of Hot Rolled Coils in PT. X from July – September 2015

Shipment (coils)	Defect Handling (coils)	Ratio (%)
15,450	447	2.89

Table 4.3 shows the number of shipment, Defect Handling, and ratio of Defect Handling per shipment of Hot Rolled Coil in PT. X from July to September 2015. The ratio is 2.89%, which is more than half of the total send back defects of Hot Rolled Coils in PT. X. From the total send back defects (see Table 4.1) of 813 coils, there are 447 coils attributed to Defect Handling. Therefore, can be concluded that the focus of the problem is the high amount of Defect Handling (DH) found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X.

Therefore, can be concluded that the focus of the study can be narrowed to the most dominant type of defect in Finished Product Distribution warehouse of PT. X, which is Defect Handling. This main focus of this study can then be decided to be reducing the number of Hot Rolled Coils attributable to Defect Handling in Finished Product Distribution warehouse of PT. X. All attempts of achieving the objective should be done. The next step after the focus of the study is decided is then to form a project charter to decide the important elements of the project and to set clear objectives of the study.

4.2.5 Project Charter

Project charter is a project management tool used typically in the Define phase of DMAIC. The reason is because project charter provides a comprehensive explanation for the team members about the project. In this part, a project charter aims to explain three main things, which are:

1. Problem Background

As stated in Chapter 1, the background of this study using Six Sigma methodology is the high number of send back defects found in Hot Rolled Coils manufactured by PT. X. In this project, the object of the study is Hot Rolled Coil manufactured in the Slab Plant of PT. X. In order to fulfil the demand from the market, PT. X should keep the quality of products at bay. The high number of send back defects found in PT. X from July to September 2015 does not only affect the visual quality of the products but also the trust given by the customers. If there is no serious action, PT. X will have a high amount of loss—money, time, and trust—and being less preferred than the competitors.

2. Objectives

The use of Six Sigma to analyse this problem has several objectives, which are:

- To find the root causes of the most dominant type of send back defects found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X.

- To reduce the percentage of the most dominant type of send back defect found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X.

3. Limitations/ Scope of the Project

This study is done in the Finished Product Distribution area, where Hot Rolled Coils—along with other types of finished products—are stored and inspected prior to being shipped to the customers. The data collection starts from July– September 2015. The study is only limited to one type of product of PT. X, which is Hot Rolled Coil.

4. Profile

This study involves employees from Quality Control, Work In Process, and Finished Product Distribution division who are responsible and directly related to this issue. A manager, a supervisor, and four staffs act as members in this project. The team members are responsible for observing actual conditions and holding weekly meeting to discuss the project.

Table 4.4 Project Charter of High Defect Handling Found in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X

Project Title	Reducing the Number of Defect Handling HRC from Entering Finished Product Distribution warehouse
Background	Starting from July 2016 to September 2016, the number of send back defects in Finished Product Distribution warehouse keeps increasing (228 to 226 to 314 coils). After a series of observation and analysis, the highest defect type found in the high percentage of send back defects is Defect Handling (DH). The high percentage of Defect Handling (54.28% of the send back defects) is caused by the inefficient flow process in Product Transfer Note that takes too long (up to 2 days excluding the rework) and occurrence of repeated Product Return Note.

Table 4.4 Project Charter of High Defect Handling Found in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X (continued)

Objectives	• Find the root cause of high Defect Handling found in Hot Rolled Coils in Finished Product Distribution warehouse. • Reduce the number of Defect Handling found in Hot Rolled Coils in Finished Product Distribution warehouse.
Scope	• The project will only take into account data from July – September 2016.
Voice of Customer	• Hot Rolled Coils quality.
Profile	Facilitator: Manager Finished Product Distribution Head: Finished Product Distribution Supervisor -Project Leader Secretary: Finished Product Distribution Staff Project team members: Staffs from Finished Product Distribution, Quality Control, and Work In Process
Expected Financial Benefit	A considerable cost saving due to reduction of Defect Handling found in Hot Rolled Coils in Finished Product Distribution warehouse.
Expected Customer Benefit	Receiving the Hot Rolled Coils with expected quality and on time delivery.

Table 4.4 shows the project charter of reducing high number of Defect Handling in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X. Can be seen that the project is titled "Reducing the High Number of Defect Handling Hot Rolled Coil in Finished Product Distribution Warehouse". The background of the project is the arising numbers of send back defects, especially Defect Handling. The objectives of the project are to find the root cause of high Defect Handling in Hot Rolled Coil in Finished Product Distribution area and to reduce the number of Defect Handling in Hot Rolled Coil in Finished Product Distribution area. The scope of the project is that the data used are only from July to September 2015.

The purpose of Voice of Customer is to address the concern of customers, and in this case, the concern is the quality of Hot Rolled Coil. Therefore, the Voice Of

Customer is the quality of Hot Rolled Coil. The profile shows the people involved in this project, namely the Manager, Supervisor of Finished Product Distribution, Finished Product Distribution staff, 1 Finished Product Distribution staff, 2 Quality Control staffs, and 1 Work In Process staff. The expected financial benefit is a considerable cost saving due to Defect Handling reduction in Finished Product Distribution area, and lastly, the expected customer benefit is to have the customers receive Hot Rolled Coil with the quality expected and on time delivery.

This marks the end of the Define phase. The tools used in the Define phase are flow diagram, bar chart, Pareto chart, and project charter. The first step in the Define phase is to determine the proceed to determining the production process of Hot Rolled Coils, business process of Finished Product Distribution (Hot Rolled Coil) in PT. X, then proceed to the types of defect, the stratification of defects with the Pareto chart to find the most dominant type of defect, and the last is to make a project charter to solve the problem. The next phase is the Measure phase and in this phase, the target and baseline of the research is determined.

4.3 Measure Phase

In the DMAIC methodology, after the Define phase is done, the next step is to do the Measure phase. In this phase, a number of calculations are done in order to define the baseline of the study or the target of the project and the existing process capability and the desired process capability. The purpose of defining the baseline of the study and determining the current process capability is to acknowledge what PT. X is capable of (how strong PT. X currently is), and then the target is to acknowledge how much work PT. X should do to solve the problem (how strong PT. X needs to be). The calculations done in this part are send back defect percentage per category. There are two parts in this phase, which are the calculation of Sigma Quality Level (SQL) before improvement or from July to September 2015 and the second part is the determination of the target based on the Specific, Measurable, Achievable, Realistic, and Time-bound (SMART) principle.

4.7.1 Calculation of Sigma Quality Level Before Improvement

Sigma Quality Level is calculated to gain a general picture of process capability. There are a few steps to calculate the Sigma Quality Level of the process. The first step is to calculate Defect Per Unit (DPU), and then proceed with Defect Per Opportunities (DPO). Defect Per Unit is calculated by dividing the number of defects and the number of shipments, while Defect Per Opportunities is calculated by dividing Defect Per Unit with the number of opportunities. The next step is to calculate the Defect Per Million Opportunities (DPMO) by multiplying the Defect Per Opportunities with 1,000,000 (one million). After the Defect Per Million Opportunities has been obtained, the next step is to find the value of the opportunity yield. The yield is then used to calculate the Sigma Quality Level.

a. Calculation of Defect Per Unit

The first step in calculating the Sigma Quality Level is to calculate the Defect Per Unit (DPU). Defect Per Unit shows the number of defects or failure in every unit of production. This calculation is done to obtain a general picture of the amount of defect per unit. In this research, the defect calculation is done per unit of coil.

$$DPU = \frac{Number\ of\ defects}{Number\ of\ shipments} \tag{2-1}$$

$$DPU\ for\ July - September\ 2015 = \frac{813}{15{,}450} = 0.05262136 \tag{2-2}$$

Equation (2-1) and (2-2) show the formula and result of the calculation of Defect Per Unit (DPU) of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2015. Can be seen that the Defect Per Unit is 0.05262136, which is obtained from dividing the number of defects during July – September 2015 with the number of shipments from July to December 2015. The result means that for each shipment of each unit of Hot Rolled Coil, 0.05262136 unit of defect is found. The next step of this process is to calculate the Defect Per Opportunity (DPO).

b. Calculation of Defect Per Opportunity

The next step in calculating the Sigma Quality Level is to calculate the Defect Per Opportunity (DPO). Defect Per Opportunity shows the number of defects or failure in every opportunity. This calculation is done to obtain a general picture of the amount of defect per opportunity. In this research, the defect calculation is done by dividing the DPU with the number of opportunities—which is 10, according to the amount of defects that can possibly occur in a hot rolled coil.

$$DPO = \frac{DPU}{Number\ of\ opportunities} \tag{2-3}$$

$$DPO\ = \frac{0.05262136}{10} = 0.005262136 \tag{2-4}$$

Equation (2-3) and (2-4) show the formula and result of the calculation of Defect Per Opportunities (DPO) of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2015. Can be seen that the Defect Per Unit is 0.05262136 obtained from Equation (2-1) and calculation in Equation (2-2). The obtained value is then divided with the number of defect opportunity during July – September 2015. The next step of this process is to calculate the Defect Per Million Opportunity (DPMO).

c. Calculation of Defect Per Million Opportunity

The next step in calculating the Sigma Quality Level is to calculate the Defect Per Million Opportunity (DPMO). Defect Per Million Opportunity shows the number of defects or failure in every million opportunities. This calculation is done to obtain a general picture of the amount of defect per million opportunities. In this research, the defect calculation is done per unit of coil.

$$DPMO = DPO\ x\ 1{,}000{,}000 \tag{2-5}$$

$$DPMO = 0.005262136\ x\ 1{,}000{,}000 = \ 5262.135922 \tag{2-6}$$

Equation (2-5) and (2-6) show the formula and result of the calculation of Defect Per Million Opportunities (DPMO) of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2015. Can be seen that the Defect Per Opportunities is 0.005262136, which is obtained from dividing the number of Defects Per Unit during July – September 2015 with the number of opportunities. This result is then multiplied with 1,000,000 to find Defect Per Million Opportunities, thus the result of 5262.135922 is obtained. The result means that for each million opportunities there are 5262.135922 defects. The next step of this process is to calculate the Yield value.

d. Calculation of Yield

The second last step in calculating the Sigma Quality Level is to calculate the Yield value. There are several types of Yield, but in this research, the calculated Yield value is the Throughput Yield, which is the most sensitive among all types of Yields. This calculation is done to acknowledge the probability of a coil passing through the Product Transfer process with no defect or the Product Transfer process capability.

$$Yield = 1 - \frac{Number\ of\ defects}{Number\ of\ shipments} \tag{2-7}$$

$$Yield = 1 - \frac{813}{15{,}450} = 0.947378641 = 94.7\% \tag{2-8}$$

Equation (2-7) and (2-8) show the formula and result of the calculation of Yield value of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2015. Can be seen that the Yield value is 94.7%, which is obtained from the formula in Equation (2-7). The result means that for each unit of Hot Rolled Coil, the probability of the coil to undergo the Product Transfer process with no defect is 94.7%. The next step of this process is to calculate the Sigma Quality Level (SQL).

e. Calculation of Sigma Quality Level

The last step in calculating the Sigma Quality Level is to calculate the Sigma Quality Level. Sigma Quality Level shows the Product Transfer process capability. The higher the level of Sigma, the better the process is. In this research, the defect calculation is done per unit of coil.

$$SQL = NORM.S.INV(Yield) + 1.5 \quad (2\text{-}9)$$

$$SQL = 3.12 \quad (2\text{-}10)$$

Equation (2-9) and (2-10) show the formula and result of the calculation of Sigma Quality Level of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2015. Can be seen that the Sigma Quality Level is 3.12, which is obtained from Equation (2-9) done using Microsoft Excel. The result means the process capability of the Product Transfer process stands at the level of 3.12 or an average company.

4.3.1 Target Before and After Improvement

The Define phase has narrowed the scope of the study by calculating the most dominant type of defect. From the Define phase can be concluded that the most dominant type of defect is Defect Handling, which is 2.89% of the total shipments in July – September 2015. The Measure phase then defines the target of the study. In determining the target for a certain project, the team should consider that a good target should be SMART (Specific, Measurable, Attainable, Realistic, and Timely).

- Specific target means that the target should not be too general and sets a narrow scope to analyse as a priority. In this study, the study is generally about increasing the quality of steel manufacturing company in Indonesia. Steel manufacturing company in Indonesia is then more specified to PT. X as the leading steel manufacturing company in Indonesia. Afterwards, the scope is more specified to the most crucial division, which directly relates to the customer and measures the capability of all other divisions in the company—Finished Product Distribution division. In order to do so, the target should be more specified to the type of product Finished Product Distribution division handles—which is then decided to be Hot Rolled Coil as the highest demanded product of PT. X. The scope is then more specified to the most crucial process in Finished Product Distribution (Hot Rolled Coil) warehouse, which is Product Transfer Note flow. In this process, there is a high percentage of send back defects. Now, the type of defects are specified and calculated to find the most dominant type of defect (see Define phase), which is Defect Handling with a percentage of 2.89% of the total shipments. Therefore, the target is to reduce the percentage of Defect Handling found in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X.
- Measureable target means to be able to quantify or set a certain success indicator. In this project, the objective is to reduce the percentage of the most dominant type of defect in order to reduce the total percentage of send back defects. Based on the meeting conducted by the members of the project (see Project Charter), the target of reducing the percentage of Defect Handling found in Hot Rolled Coils in Finished Product Distribution warehouse is then settled to be 50%.

Table 4.5 Target After Improvement

Details	Before Improvement	After Improvement
Defect Handling (%)	2.89%	1.45%

Table 4.5 shows the target of the project. Given the limitation of time and resources in conducting improvement actions, the target is then settled to be

50% of the current percentage of Defect Handling. The percentage of Defect Handling per shipment of Hot Rolled Coil during the period of July – September 2015 is 2.89%. This percentage is expected to reduce to 1.45%. The amount of reduction of Defect Handling is expected to reduce the total send back defects to 50%.

- Achievable

  With the time given to conduct the improvement project (September 2015 to June 2016) that includes the Define, Measure, Analyse, Improve, and Control phases, the target of reducing the percentage of Defect Handling to 1.45% is agreed to be achievable. Based on the result of the meeting conducted with the project members and the corresponding elements and resources outside the project, reducing the Defect Handling percentage is also expected to reduce the percentage of total send back defects.
- Realistic

  With the given resources to conduct the project, this target is agreed to be realistic. Due to the given period of the project, some proposed solutions such as hiring new staffs is not possible. New hires will consume more time, both for selection and training, therefore, reducing the Defect Handling percentage from 2.89% to 1.45% is agreed to be reasonable.
- Time-Bound

  A good target should be time-bound, which means that a good target should have a “deadline”. Otherwise, the target will remain as a utopic idea. Therefore, a deadline is agreed for this project, which is June 31 2016 and the following three months (July – September 2016) will be the period of observation. During July to September 2016, the results of the improvement will be observed and the results of the DMAIC phases will also be analysed.

To conclude the Measure phase, the target of the project is determined. A 50% reduction of the percentage of the most dominant type of defect (Defect Handling) is expected, or to reduce the percentage of Defect Handling found in Hot Rolled Coils in the Finished Product Distribution warehouse of PT. X from 2.89% to 1.45%. The result of the DMAIC phases is also expected to increase the Sigma Quality Level or the process capability.

4.4 Analyse Phase

In this phase, as stated in the previous parts of the chapter, is the following phase from Define and Measure. From the previous parts of the chapter, has been stated that the type of defect that has the highest percentage is Defect Handling. The main purpose of this phase is to find the causes of high number of Defect Handling in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X. By doing so, the root cause of the problem can be acknowledged. By finding the root cause, the problem can therefore be solved.

The first step of this phase is do individual analysis with the help of literature and experience from classes taken in university. The results are then listed for further discussion with the employee of PT. X. With the given problem of high percentage of defects in the Finished Product Distribution warehouse, several possible causes in correlation to Manpower, Machine, Method, and Mother Nature (Environment) can be determined.

After the possible causes are listed, the next step is to do direct observation in the Slab Steel Plant, specifically in the Work In Process and Finished Product Distribution warehouses where the product transfer process occurs. After the observation is done, there are two things that can be concluded in correlation to the analysis of the causes of high number of Defect Handling in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X. The first is that the most common types of defects found in the Finished Product Distribution warehouse are defects that are most likely caused by accidents in handling process, one of which is Defect Handling. The second is that there are a couple of times during the observation of product transfer in the warehouse in which the coils are being handled inappropriately and given very minimal to none inspection upon entering the Finished Product Distribution warehouse, which caused the coil having to undergo many handlings. The third is the unavailability of Quality Control inspectors in the critical points of the product transfer from Work In Process to Finished Product Distribution warehouse, which then causes defective coils to enter Finished Product Distribution warehouse.

The next step is to discuss the findings and the individual analysis result to the employee of PT. X. The purpose of the discussion is to have another point of view in order to be open to every other possibility, and gain an internal insight about the problem. After the discussion, apparently there is another cause of the problem, which is the type of lamp used in the Finished Product Distribution warehouse, which will be put under “Tools” category. The discussion is expected to be able to verify the causes. The final result of this step is a Cause and Effect Analysis Diagram that consists of the causes of high number of Defect Handling in Hot Rolled Coils in Finished Product Department Warehouse of PT. X.

After the Cause and Effect Diagram has been made, the next step is to make the Whys Analysis to analyse the diagram. Each of the Why will be addressed to every cause possible in the Cause and Effect Diagram. The Whys analysis will help in giving a deeper analysis in finding the root cause of the problem.

4.4.1 Cause and Effect Diagram

The Cause and Effect diagram shows the possible causes of high number of Defect Handling in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X. The head of the fish in this diagram shows the problem that is about to be solved in this study, which is the high number of Defect Handling found in Finished Product Distribution warehouse of PT. X. The bones are the possible causes of the problem. In this diagram, the possible causes are listed until the root cause of each factor (Man, Method, Mother Nature, and Tools) is found.

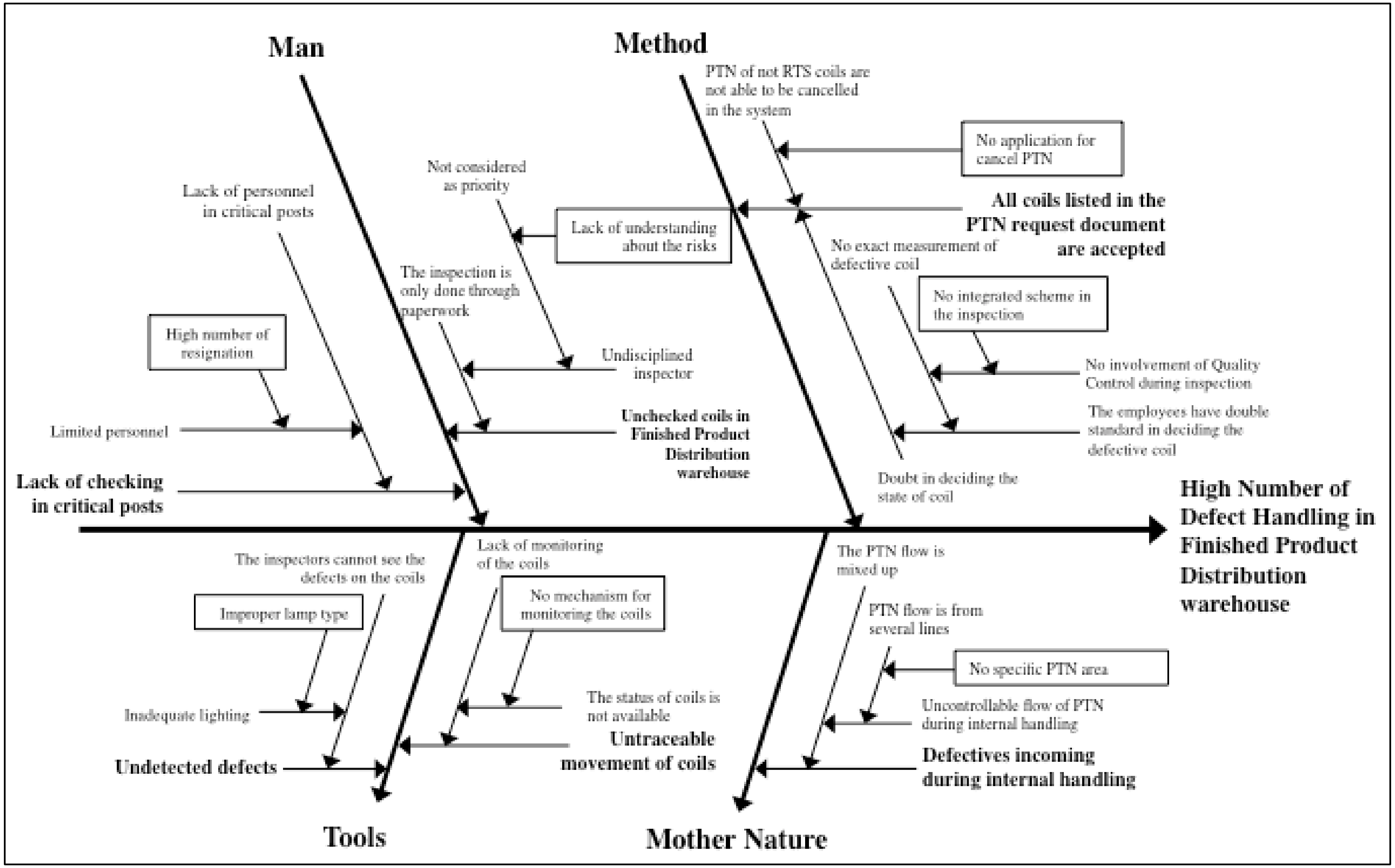


Figure 4.22 Cause and Effect Diagram

Figure 4.22 shows the cause and effect diagram of high number of Defect Handling in Hot Rolled Coils in Finished Product Department Warehouse of PT. X. There are five factors that cause the high number of Defect Handling in Hot Rolled Coils in Finished Product Department Warehouse of PT. X, which are Manpower, Method, Mother Nature, and Tools. The categories are obtained from the result of observation, interview, and brainstorming. Each factor has at least one cause that contributes to the high number of Defect Handling in Hot Rolled Coils in Finished Product Distribution warehouse of PT. X. The causes are then analysed using the Whys Analysis tool.

4.4.2 Whys Analysis

In this part, Whys Analysis of each factor is made. There are five Whys Analysis parts, for each represents one factor. The first Whys table is the Whys analysis that represents the Method factor. The Whys analysis is as follows.

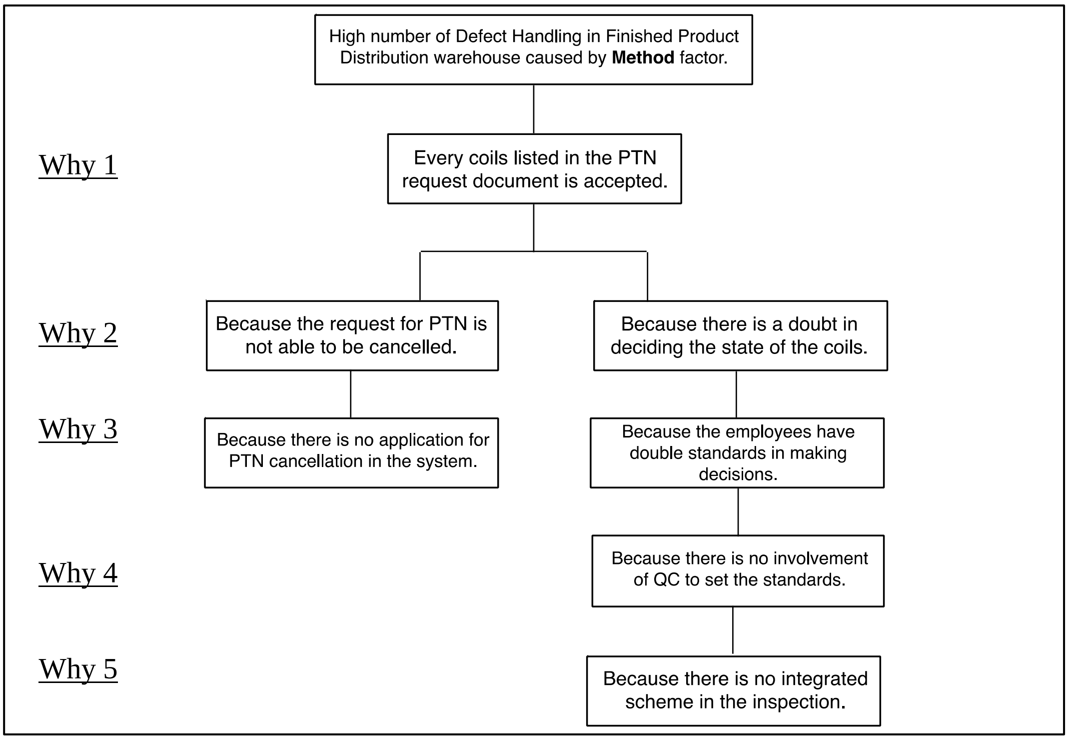


Figure 4.23 Whys Analysis of Method Factor

Figure 4.23 shows the Whys Analysis of Method factor in the cause and effect diagram. Each analysis for each cause is enlisted in the table. Can be seen that the root causes from the Method factor is there is no application for Product Transfer

Note cancellation in the system and there is no integrated scheme of Product Transfer Note inspection. Therefore, the proposed solution should be in regards of adding a Product Transfer Note cancellation in the system and a fix in the Product Transfer Note flow to prevent defective coils from entering the Finished Product Distribution warehouse.

The second Whys analysis is the Whys analysis that represents the Manpower factor. The Whys table is as follows.

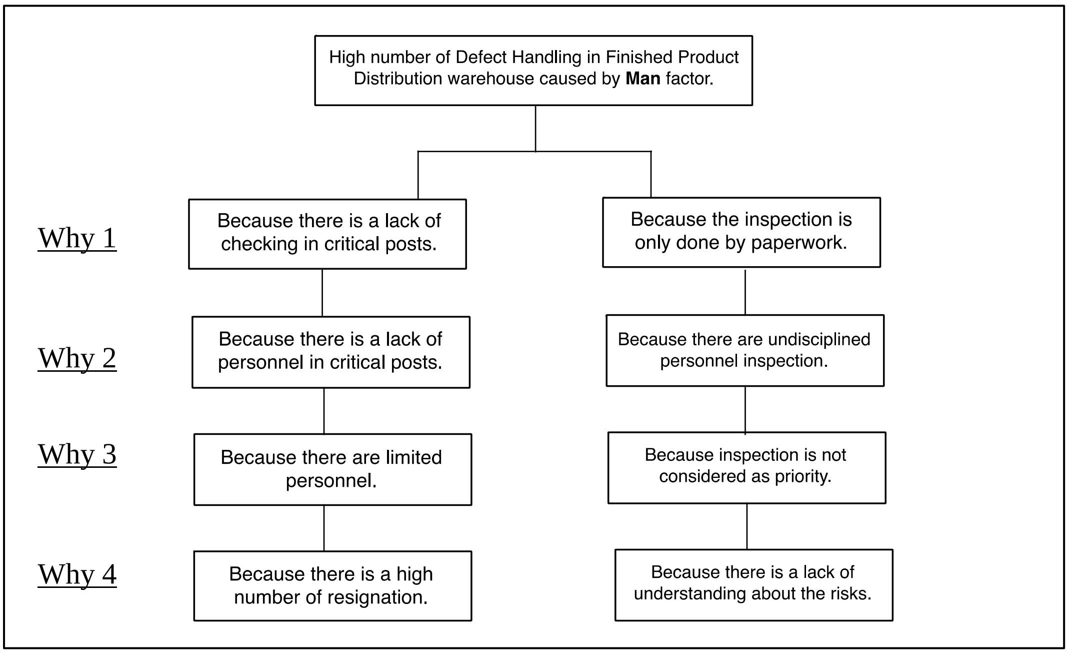


Figure 4.24 Whys Analysis of Man Factor

Figure 4.24 shows the Whys Analysis of Manpower factor in the cause and effect diagram. Each analysis for each cause is enlisted in the table. Can be concluded that the root causes of high number of Hot Rolled Coil with Defect Handling in Finished Product Distribution warehouse of PT. X from Man factor are high number of resignation of Quality Control personnel in PT. X and a lack of understanding about the risks.

The third Whys analysis is the Whys analysis that represents the Mother Nature (Environment) factor. The Whys analysis is as follows.

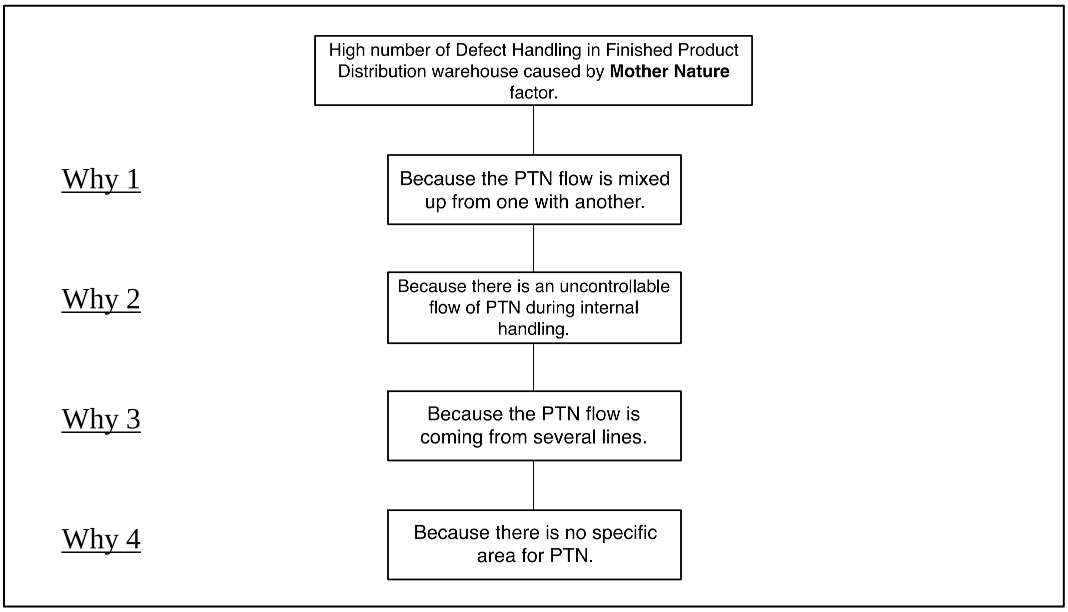


Figure 4.25 Whys Analysis of Mother Nature Factor

Figure 4.25 shows the Whys Analysis of Mother Nature factor in the cause and effect diagram. Each analysis for each cause is enlisted in the table. Can be concluded that the root cause of high number of Hot Rolled Coil with Defect Handling in Finished Product Distribution warehouse of PT. X from Mother Nature factor is that because there is no specific Product Transfer Note area. Therefore, the proposed solution should be in regards of providing a specific area for Product Transfer Note in the warehouse.

The fourth Whys analysis is the Whys analysis that represents the Tools factor. The Whys analysis is as follows.

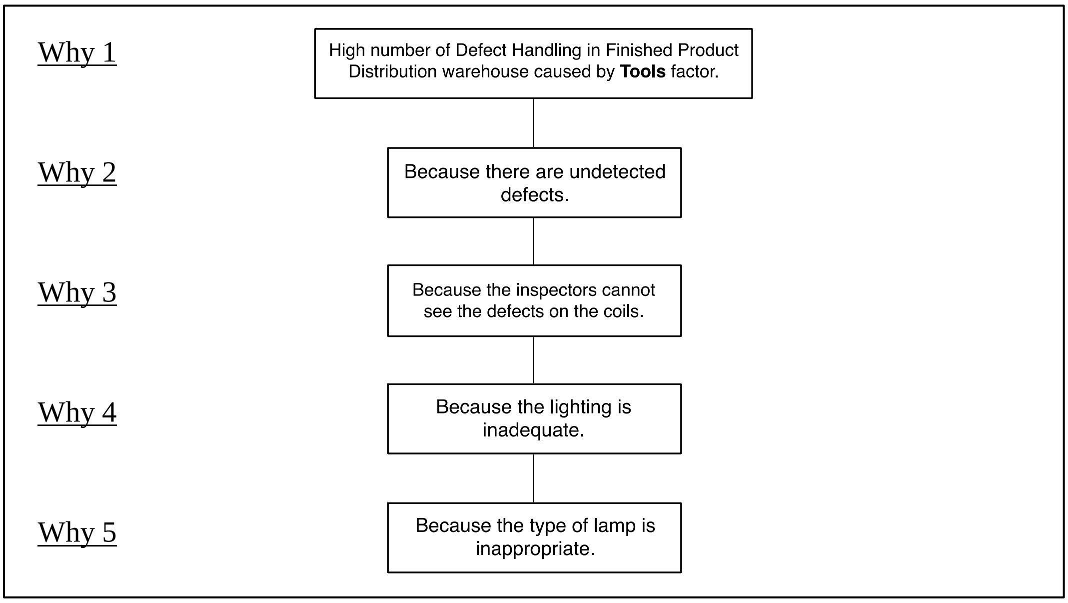


Figure 4.26 Whys Analysis of Tools Factor

Figure 4.26 shows the Whys Analysis of Tools factor in the cause and effect diagram. Each analysis for each cause is enlisted in Figure 4.26. Can be concluded that the root cause of high number of Hot Rolled Coil with Defect Handling in Finished Product Distribution warehouse of PT. X from Tools factor is that the type of lamp is inappropriate. Therefore, the proposed solution should be in regards of providing an appropriate lighting for inspection.

4.5 Improve Phase

In the Improve phase, the purpose is to propose the improvements and implement the propose improvements in order to achieve the objectives of the project. The Improve phase consists of three parts, which are the proposal of the improvement, implementation of the improvement, and results after improvement. The proposal of the improvement consists of the suggestions for the improvement based on the Cause and Effect diagram (Figure 4.22) and the result from the Nominal Group Technique conducted by the project team members listed in the project charter (Table 4.4). The implementation of the improvement is an elaboration of the implemented improvement. The results show the outcome of the implementation of the improvement.

4.5.1 Proposal of the Improvement

This is the first part of the Improve phase. This part consists of the proposed improvement based on the root cause diagram and the result of Nominal Group Technique. The first step is to define what corrective actions should be done in order to improve the condition. There are four types of causes in the proposed improvement.

Table 4.6 Proposed Improvement

Cause Type	Causes	Suggestions
Man	Lack of understanding about the risks	Train the employees about the risks of error in inspection or make rewards/ sanctions if the employess manage to comply/ fail to
	High resignation	Hire new personnel or reassign personnels to fill the posts necessary
Method	No integrated scheme of Hot Rolled Coil inspection	Make an integrated scheme of inspection where every unit responsible for this issue is involved
	No application for Product Transfer Note cancellation	Make an application for PTN cancellation in MES
Mother Nature	No specific handover area	Make a specific handover area in the WIP Warehouse
Tools	Inaproppriate lamp type	Change the lamp type (from yellow lamp to white mercury lamp)

Table 4.6 shows the proposed improvement. Can be seen in Table 4.6 that there are five types of causes with each having at least one cause. Each cause is provided with at least one solution. After deciding what are the improvements that are possible, the next step is to give weights to the improvement plans with the Nominal Group Technique.

The Nominal Group Technique is based on the result of the result of the actual Nominal Group Technique conducted by the project team members. The result of the Nominal Group Technique is weight for each solution for each cause. The weights will indicate how much of a priority are the causes. Consequently, the corrective actions can be taken as per the degree of importance shown by the weights.

Table 4.7 Result of Nominal Group Technique

No	**Root Cause**	**Score Given by Member of PKM**						**Average**
		A	**B**	**C**	**D**	**E**	**F**	
1	No integrated scheme of HRC inspection	4	4	4	4	4	4	**4.0**
2	No application for PTN cancellation	4	4	4	3	4	4	**3.8**
3	Limited personnel	4	3	3	3	3	3	**3.2**
4	The personnels lack of understanding about risks	2	1	1	1	2	1	1.3
5	Improper type of lamp	3	3	4	4	3	4	**3.5**
6	Defective HRC from production	3	1	2	2	1	1	1.7
7	No specific area for HRC handover	3	4	4	3	4	4	**3.7**

Table 4.7 shows the result of the Nominal Group Technique. There are six people who participated in the Nominal Group Technique, which are the members of the project whose names are represented by alphabet. Can be seen that there are seven root causes based on the Cause and Effect diagram. Each cause is given weight ranging from 1 to 4 based on the degree of importance by each member of the project. Consequently, two out of the seven causes are not considered due to the small amount of average weight and therefore little of importance. The most important solution based on the average weight is the lack of integrated scheme of Hot Rolled Coil inspection.

4.5.2 Implementation of Improvement

In this part, the implementation of the improvement is shown. Based on the proposed improvements, there are five actions that can be done in order to improve the situation—reduce the high number of Defect Handling in Hot Rolled Coils in Finished Product Distribution Warehouse. The implementation of the improvement includes two parts, which the formulation of the improvement plan and the implementation of the improvement. The implementation is done based on the plans formulated prior to the implementation of the improvement.

Below is the formulation of the improvement plan.

Table 4.8 Formulation of Improvement Plan

No	Root Cause	Why	What	Where, When, & Who	How
1	No integrated scheme of HRC inspection	So that inspection can be done with the units related	Create an integrated inspection procedure	PT. X	Compose new PTN procedure
				Corresponding Staffs	Conduct socialisation to related personnels
2	No application for PTN cancellation	So that PTN of the HRC that are not RTS can be cancelled	Make an application of PTN cancellation in MES	PT. X	Implementation of PTN cancellation application in MES
				Corresponding Staffs	
3	Limited personnel	So that every HRC handover can be inspected together	Personnel placement setting	PT. X	Analysis of existing personnel
				Corresponding Staffs	Replacement of related personnels
4	Improper lamp type	So that the HRC inspected can be seen clearly	Replace the existing lamps	PT. X	Find the replacement of the existing type of lamp
				Corresponding Staffs	Conduct trial of the replacement lamp
5	No specific area for HRC handover	So that handover of the HRC can be done in a specific place	Determine the proper location	PT. X	Do relayout if necessary Choose the best location
				Corresponding Staffs	Complete the inspection facilities, such as container, desk, and computer

Table 4.8 shows the formulation of the improvement plan. There are five root causes that include 5 Whys and 1 How in order to formulate a good improvement plan.

4.5.2.1 New Product Transfer Note (PTN) Release Process in PT. X

In this part, the new product transfer flow is shown. As explained in the previous part, the product transfer flow used during July – September period should be improved because of the unavailability of QC staffs in defect-prone steps.

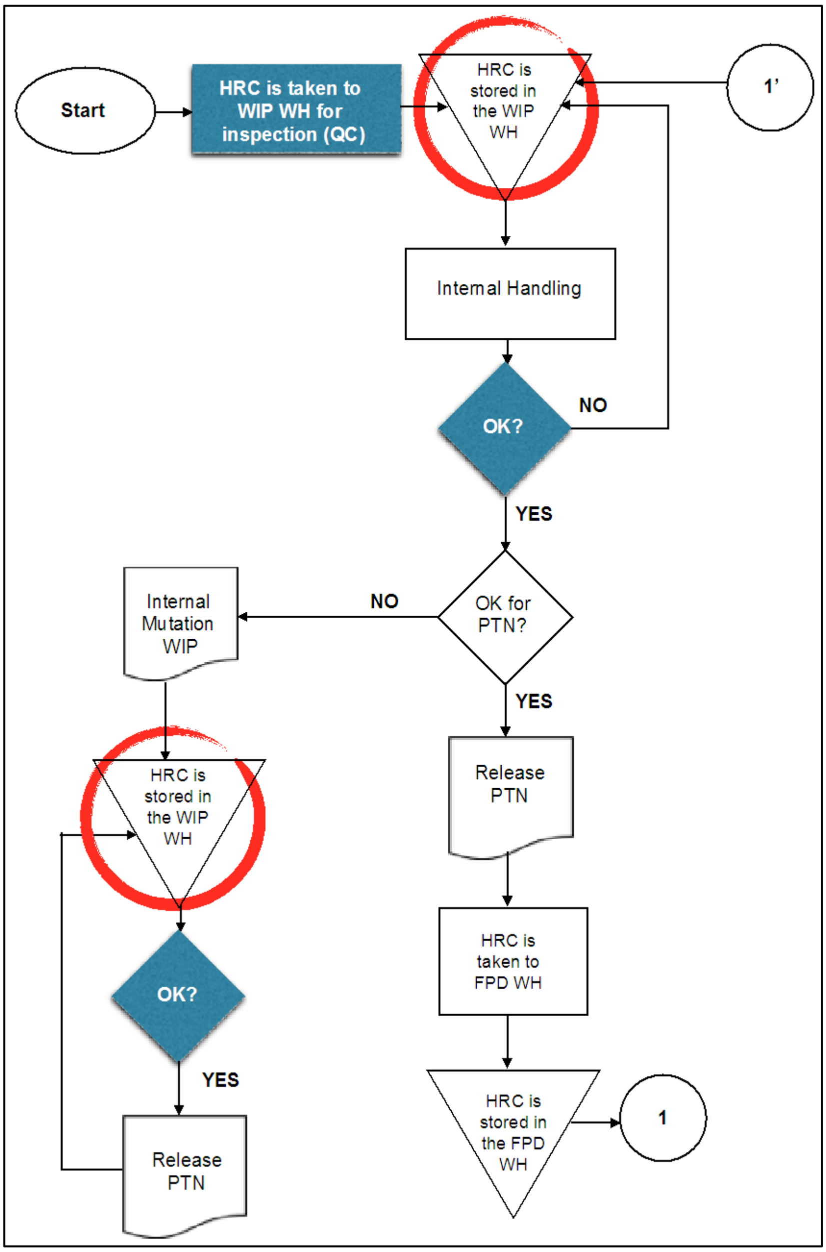


Figure 4.27 Flow Diagram of New Product Transfer Note Release in PT. X

Figure 4.27 shows the new product transfer flow. The new product transfer flow starts with the Hot Rolled Coil being taken to the Work In Process warehouse and then after that, the coil is inspected for visual appearances (the availability of labels, scratches, and others). The process is pretty much the same with the previous flow, the difference is that in the high defect potential stages, Quality Control staffs are assigned so that not Ready To Ship coils cannot enter the next phase and will be directed to Work In Process warehouse for rework immediately, without risking the coil to go further.

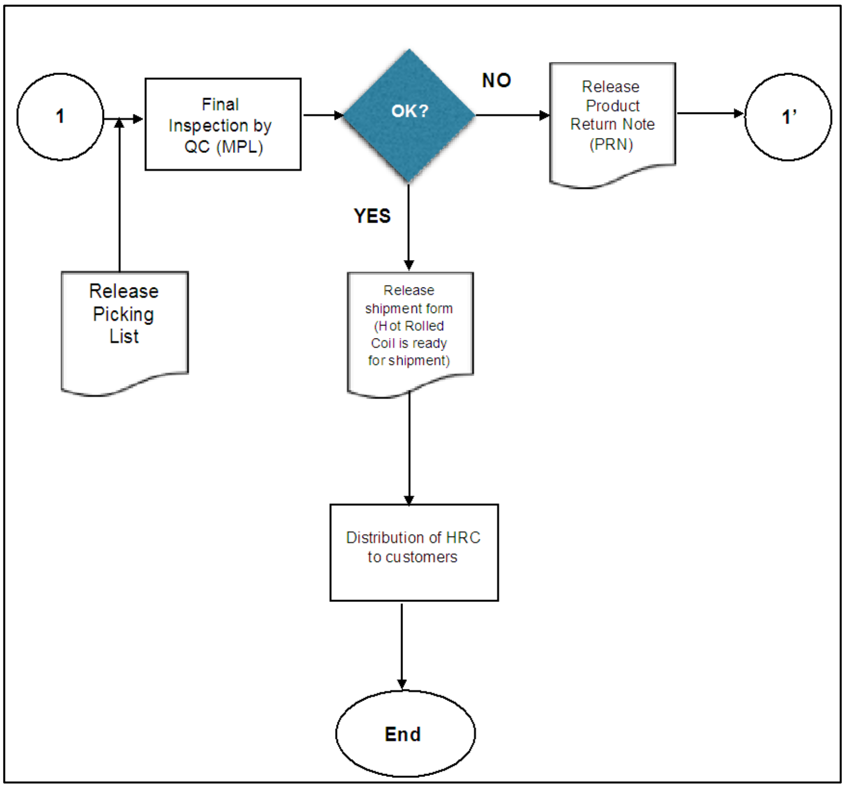


Figure 4.27 New Flow Diagram of New Product Transfer Note Release in PT. X (continued)

Figure 4.27 (continued) shows the continued new product transfer flow. The flow is from Finished Product Distribution to shipment. The flow is pretty much the same, the difference is that no more—or much less—not Ready To Ship coils can enter the Finished Product Distribution warehouse, unlike in the previous flow because in this new flow, Quality Control staffs are assigned in the right stages.

4.5.2.2 Application of Product Transfer Note Cancellation in Management Execution System

PT. X uses Management Execution System to monitor the in and out flow of the Hot Rolled Coils transferred out from the Work In Process warehouse to the

Finished Product Distribution warehouse. Previously, there is no Product Transfer Note cancellation in the system; therefore all of the Product Transfer Note given into Finished Product Distribution is accepted first in order to make new ones. Not only that the previous system results in waste and inefficiency, error in acknowledging which ones are RTS and which ones are not can risk not Ready TO Ship coils to enter Finished Product Distribution warehouse, even being shipped. Therefore, an application for Product Transfer Note cancellation is enabled in the system so that when there is a coil which Product Transfer Note wants to be cancelled due to the not Ready To Ship qualities of the coil, the system facilitates. The not Ready To Ship coil can directly be taken to Work In Process warehouse for rework without having to do the whole product transfer process first.

4.5.2.3 Personnel Reassignment

As one of the concerns in the previous part, personnel reassignment is essential because where the personnel are located determine the success rate of the process. Due to the limited amount of personnel, will be impossible to employ much more than what PT. X has, therefore, the feasible option is to reassign the posts. Except for Quality Control staffs that needs to be reassigned in the posts inside the flow. The personnel reassignment can be seen in Figure 4.19 and Figure 4.20, from which the posts that used to have no Quality Control inspectors have inspectors available to check the coils before proceeding to the next stages of the process.

4.5.2.4 Replacement of Existing Lamps

During the observation of this study, the lamp used in the warehouse is not adequate for inspection, especially in the nighttime. The light from the lamp cannot accommodate the inspection process, therefore oftentimes; the defects cannot be seen clearly. The unseen defects then proceeds to the next steps where the defective coils are not supposed to be, therefore loss occurs.

Source: kaskus.com

Figure 4.28 Illustration of Previously Used Lamp

Figure 4.28 shows the illustration of the previously used lamp (during July – September 2015). Can be seen that the lamp is dim and yellow hued, which makes the inspectors, especially the ones assigned during nighttime cannot see the defects clearly. This inability then makes the defects being unseen and therefore proceeds to the next step, because the Product Transfer Note is approved and there is no Quality Control inspector to check the coils.

Source: Courtesy of PT. X

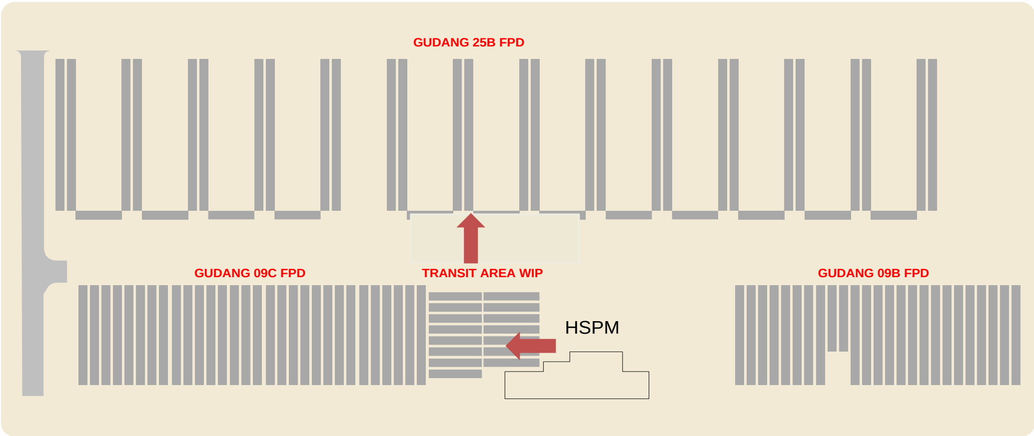
Figure 4.29 New Lamp

Figure 4.29 show the lamp used after the improvement. The lamp is a type of mercury spotlight, which provides a very bright light that enables the Quality Control inspectors to see the defects during nighttime. By implementing the use of this lamp, no more defect is expected to pass through the inspections during Product Transfer Note flow.

4.5.2.5 Preparation of Proper Product Transfer Location

During the observation of this study, there is no space allocation for inspection. Currently, in PT. X, the warehouse of Work In Process and Finished Product Distribution is combined altogether in a building. The differences between both are just the coordinates of the locations of the storage. Therefore, there is no allocation for Product Transfer Note flow specifically. Currently, the transit area for Work In Process is located next to the place where Hot Rolled Coils are stored.

Below is the layout of the Work In Process (WIP) and Finished Product Distribution warehouse of PT. X.

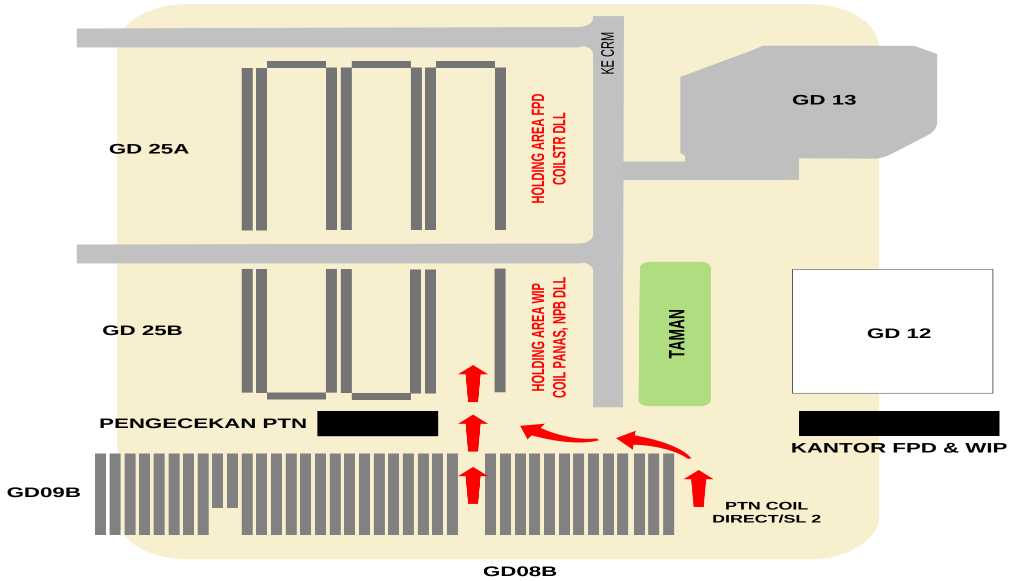


Source: Courtesy of PT. X

Figure 4.30 Layout of Finished Product Distribution Warehouse Before Improvement

Figure 4.30 shows the layout of Work In Process and Finished Product Distribution warehouse before improvement. Can be seen that there is no specific area for Product Transfer Note flow in the warehouse. HSPM stands for Hot Skin Pass Mill, which is one of the mills for rework. The flow of the coils are from the Hot Skin Pass Mill to the transit area of Work In Process, then straight to the warehouse of Finished Product Distribution, without any inspection.

The improvement proposes to allocate a specific space for inspection in the product transfer process. Therefore a space in the warehouse is allocated for the inspection process. Below is the layout after improvement.



Source: Courtesy of PT. X

Figure 4.31 Layout of Finished Product Distribution Warehouse After Improvement

Figure 4.31 shows the layout of Finished Product Distribution warehouse after improvement. There is a space between the storage, which is now a place of Product Transfer Flow Checking Station, where the flow of the coils from Work In Process is changed. After the improvement, the coils should pass through the inspection station first before entering the Finished Product Distribution warehouse.

4.6 Control Phase

There are four methods used in the Control phase to control the improvement for keeping up and running. The four methods used are the use of barcode in Hot Rolled Coils, monitoring in Management Execution System and Systems Applications Products, pre-Product Transfer Note document, and weekly progress meeting.

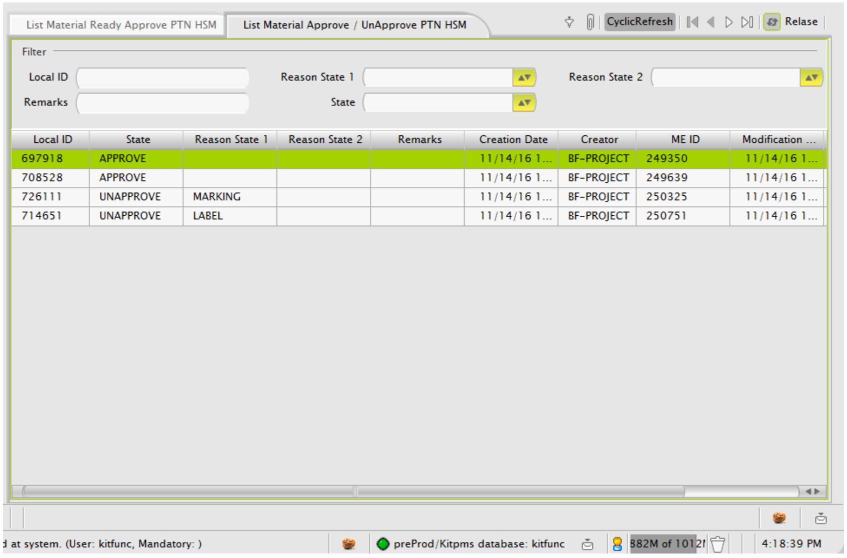
Source: flickr.com

Figure 4.32 Barcode Use on Finished Products

Figure 4.32 shows an example of barcode usage during inspection. During the period when high number of send back defects are present, many of the staffs that are supposed to inspect the product do not actually inspect the product, instead, only fill in the documents to indicate that the product have been checked when the products are actually have not checked. The purpose of barcode usage is to prevent such occurrence from happening, because using barcode; the coil cannot proceed to the next process if the barcode is not scanned.

The other means of control are monitoring in Management Execution System. In the improvement, PT. X uses Manufacturing Execution System by Systems Applications Products (Enterprise Resources Planning) that integrates the business and manufacturing processes in PT. X, thus enables monitoring the movements of coils, specifically during the Product Transfer Note flow. The input of this process is the scanned barcode from the coils and then the process is to input the barcode into the system, and the last is the approval/ cancellation of Product Transfer Note.

Below is the example of Product Transfer Note cancellation application in the Management Execution System.

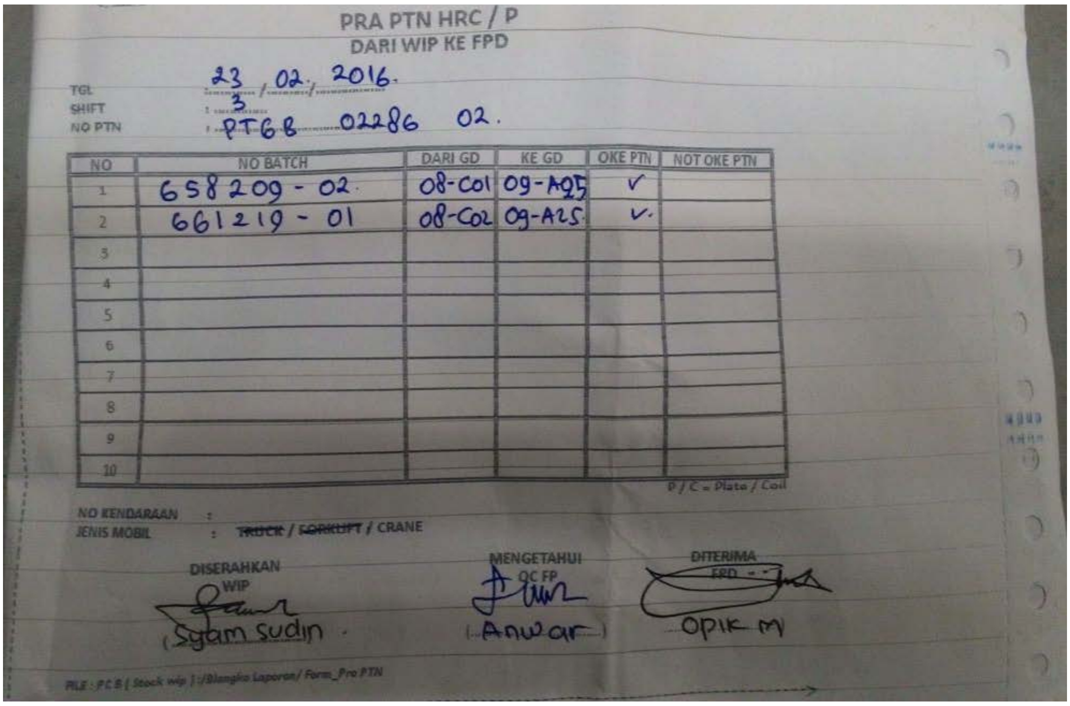


Source: Courtesy of PT. X

Figure 4.33 Example of Product Transfer Note (PTN) Cancellation in Management Execution System (MES) of PT. X

Figure 4.33 shows an example of Product Transfer Note cancellation in Management Execution System of PT. X. Can be seen that there is an option of “Approve” or “Unapprove” depends on the state of the coil. Can also be seen that in the system, the reason for “Unapprove” is also listed so that the rework staff can acknowledge what type of rework should be done to the coil. By implementing this, the inspection should actually be done on the spot, other than just doing the paperwork.

The other means of control is pre-PTN document, which is a document that should be filled, signed, and acknowledged by the field manager and Quality Control staff to ensure that the coil has really passed the inspection.



PRA PTN HRC / P
DARI WIP KE FPD

TGL : 23 / 02 / 2016.
SHIFT : 3
NO PTN : PT68 02286 02.

NO	NO BATCH	DARI GD	KE GD	OKE PTN	NOT OKE PTN
1	658209 - 02.	08-C01	09-A25	✓	
2	661219 - 01	08-C02	09-A25	✓.	
3					
4					
5					
6					
7					
8					
9					
10					

P / C = Plate / Coil

NO KENDARAAN :
JENIS MOBIL : ~~TRUCK~~ / ~~FORKLIFT~~ / CRANE

DISERAHKAN WIP (Syam sudin.)
MENGETAHUI QC FP (Anwar)
DITERIMA FPD (Opik M)

FILE : PC B (Stock wip) :/Blangko Laporan/ Form_Pra PTN

Source: Courtesy of PT. X

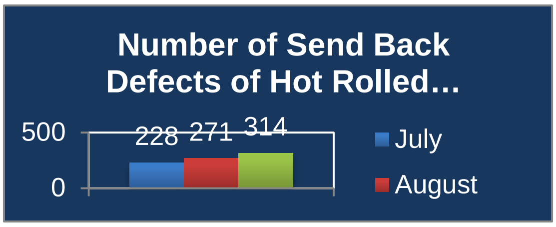
Figure 4.34 Example of Pre-Product Transfer Note (PTN) Document

Figure 4.34 shows an example of Pre-Product Transfer Note document used in PT. X. Can be seen that there are six categories in the document, which are number, batch number, origin (building), destination (building), OK PTN, and NOT OK PTN (from left to right). The use of this document is prior to the printing of Product Transfer Note. This document will ensure that every batch of Hot Rolled Coils going in and out of the corresponding warehouses are in good condition. The last mean of control is weekly progress meeting to ensure that the improvement is up and running.

With the three aforementioned means of controls implemented in the field, the last mean of control or weekly progress meeting is conducted to ensure the improvement remains on the track. The meeting is conducted weekly with the related staffs and manager to discuss the progress of the improvement.

4.7 Before and After Improvement Analysis

Aside from the change in the flow, layout, and other improvements, there are also other benefits that the improvement will bring. The expected benefits of the improvement for the company will be in regards of cost saving.



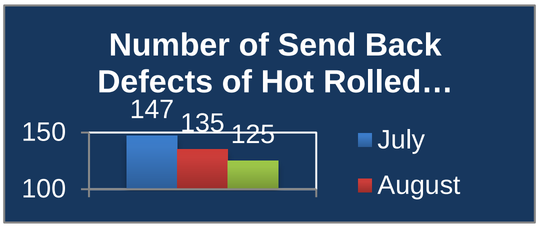


Figure 4.35 Number of Send Back Defects from July – September 2015 (Left) and July – September 2016 (Right)

Figure 4.35 shows the comparison results before and after the study. Can be seen that the number of total number of send back defects is significantly reduced. Can be seen that before the improvement takes place, the defects from September 2015 are 314 coils, compared to the defects on September 2016, the defects are only 125 coils. Aside from the change in the flow, layout, and other improvements, there are also other benefits that the improvement will bring. The expected benefits of the improvement for the company will be in regards of cost saving.

4.7.1 Ratio of Defect Handling per Shipment Analysis of Hot Rolled Coils in PT. X

As explained in the previous part, the targets of this study are in regards of the ratio of send back defect per shipment, and ratio of Defect Handling per shipment. Since the send back per shipment ratio analysis have been explained, therefore, the next analysis result is in regards of the ratio of Defect Handling per shipment. Below is the bar chart of Defect Handling per shipment ratio comparison from before and after improvement.

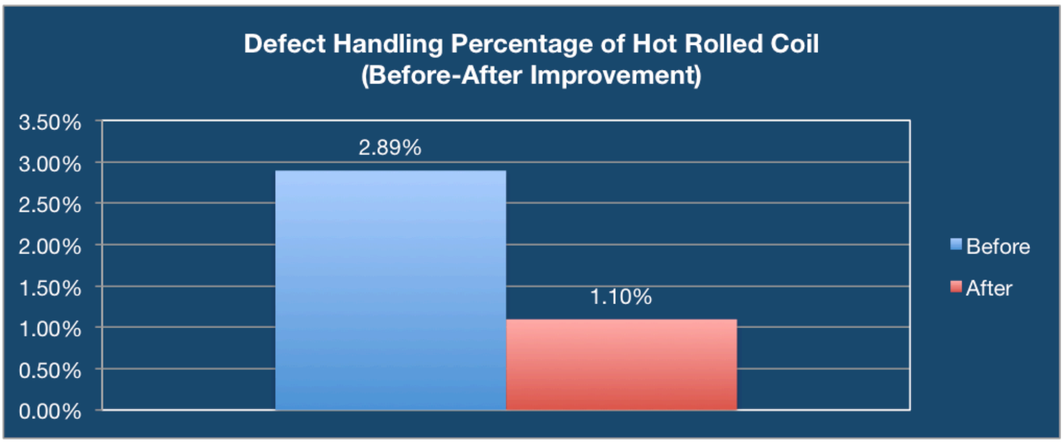


Figure 4.36 Defect Handling per Shipment Ratio Comparison from Before and After Improvement

Figure 4.36 shows the before and after improvement ratio comparison of Defect Handling per shipment of Hot Rolled Coil in PT. X. As stated in the previous part of the chapter, the most dominant type of defect found in the Finished Product Distribution warehouse of PT. X. From Figure 4.35, can be seen that the ratio significantly decreases from 2.89% to 0.33%. As stated in the previous part of the chapter, the target is to reduce the ratio to 50%, which is from 2.89% to 1.45%. However, the result shows that the reduction is more than 50%, which is a very good thing since the improvement results in more than the expectation.

Table 4.9 Number of Shipment, Defect Handling, and Ratio of Hot Rolled Coils in PT. X from July – September 2016

Shipment (coils)	Defect Handling (coils)	Ratio (%)
15,699	172	1.10

Table 4.9 shows the number of shipment, Defect Handlings, and ratio of Defect Handling/ shipment of Hot Rolled Coil in PT. X from July to September 2016. As stated, the ratio is 1.10%, which is significantly reduced compared to the state before improvement. For the shipment of 15,699 coils, there are 172 Defect Handlings.

Therefore, can be concluded that the number of Hot Rolled Coils attributed to Defect Handling found in Finished Product Distribution warehouse of PT. X is reduced more than 50%.

4.7.2 Ratio of Send Back Defect per Shipment Analysis of Hot Rolled Coils in PT. X

After the improvement is implemented, there are some comparisons made to show the results of the improvement. The results also show that the improvement has been successfully implemented. The next result is in regards of the ratio of send back defect per shipment. Below is the bar chart of send back defect per shipment ratio comparison from before and after improvement.

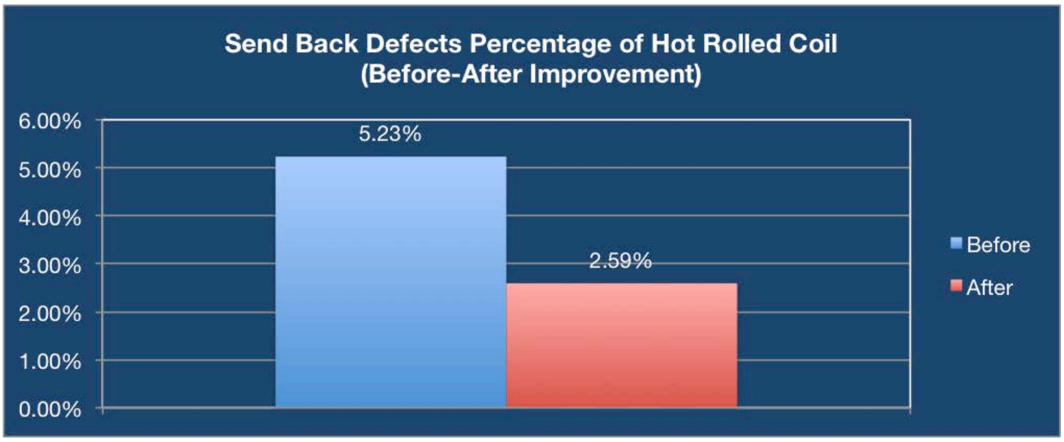


Figure 4.37 Send Back Defect per Shipment Ratio Comparison from Before and After Improvement

Figure 4.37 shows the before and after improvement comparison of ratio of send back defect per shipment of Hot Rolled Coil in PT. X. Can be seen that the ratio significantly decreases from 5.23% to 2.59%. As stated in the previous part of the chapter, the target is to reduce the ratio to 50%, which is from 5.23% to 2.61%. However, the result shows that the reduction is more than 50%, which is a very good thing since the improvement results in more than the expectation.

Below is the number of shipment, send back defects, and ratio of Hot Rolled Coils in PT. X from July to September 2016.

Table 4.10 Number of Shipment, Send Back Defects, and Ratio of Hot Rolled Coils in PT. X from July – September 2016

Shipment (coils)	Send Back Defects (coils)	Ratio (%)
15,699	407	2.59

Table 4.10 shows the number of shipment, send back defects, and ratio of send back defects/ shipment of Hot Rolled Coil in PT. X from July to September 2016. As stated, the ratio is 2.59%, which is significantly reduced compared to the state before improvement. For the shipment of 15,699 coils, there are 407 defective coils. Therefore, can be concluded that the number of send back defects found in Finished Product Distribution warehouse of PT. X is reduced more than 50%.

Table 4.11 Comparison of Before vs. Target vs. Actual Defect Handling Percentage

Details	Before Improvement	After Improvement (Target)	After Improvement (Actual)
Defect Handling Percentage	2.89%	1.45%	1.10%

Table 4.11 shows the comparison of Defect Handling percentage from before improvement, with the target and the actual percentage after improvement. Can be seen that initially, the target of the improvement is 50% reduction. After the implementation, the actual achievement is more than 50%, which is a very good thing. However, would be better if the improvement continues along with the study because the number of send back defects shown in Figure 4.36 also shows a gradual decrease. This means that the reduction might still continue throughout time.

4.7.2 Calculation of Sigma Quality Level After Improvement

Sigma Quality Level is calculated to gain a general picture of process capability. There are a few steps to calculate the Sigma Quality Level of the process. The first step is to calculate Defect Per Unit (DPU), and then proceed with Defect Per Opportunities (DPO). Defect Per Unit is calculated by dividing the number of defects and the number of shipments, while Defect Per Opportunities is calculated by dividing Defect Per Unit with the number of opportunities. The next step is to calculate the Defect Per Million Opportunities (DPMO) by multiplying the Defect Per Opportunities with 1,000,000 (one million). After the Defect Per Million Opportunities has been obtained, the next step is to find the value of the opportunity yield. The yield is then used to calculate the Sigma Quality Level.

a. Calculation of Defect Per Unit

The first step in calculating the Sigma Quality Level is to calculate the Defect Per Unit (DPU). Defect Per Unit shows the number of defects or failure in every unit of production. This calculation is done to obtain a general picture of the amount of defect per unit. In this research, the defect calculation is done per unit of coil.

$$DPU = \frac{Number\ of\ defects}{Number\ of\ shipments} \tag{2-11}$$

$$DPU\ for\ July - September\ 2016 = \frac{407}{15{,}699} = 0.02591694 \tag{2-12}$$

Equation (2-11) and (2-12) show the formula and result of the calculation of Defect Per Unit (DPU) of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2016. Can be seen that the Defect Per Unit is 0.02591694, which is obtained from dividing the number of defects during July – September 2016 with the number of shipments from July to December 2016. The result means that for each shipment of each unit of Hot Rolled Coil, 0.02591694 unit of defect is found. The next step of this process is to calculate the Defect Per Opportunity (DPO).

b. Calculation of Defect Per Opportunity

The next step in calculating the Sigma Quality Level is to calculate the Defect Per Opportunity (DPO). Defect Per Opportunity shows the number of defects or failure in every opportunity. This calculation is done to obtain a general picture of the amount of defect per opportunity. In this research, the defect calculation is done by dividing the DPU with the number of opportunities—which is 10, according to the amount of defects that can possibly occur in a hot rolled coil.

$$DPO = \frac{DPU}{Number\ of\ opportunities} \tag{2-13}$$

$$DPO\ = \frac{0.02591694}{10} = 0.002591694 \tag{2-14}$$

Equation (2-13) and (2-14) show the formula and result of the calculation of Defect Per Opportunities (DPO) of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2016. Can be seen that the Defect Per Unit is 0.02591694 obtained from Equation (2-11) and calculation in Equation (2-12). The obtained value is then divided with the number of defect opportunity during July – September 2016. The next step of this process is to calculate the Defect Per Million Opportunity (DPMO).

c. Calculation of Defect Per Million Opportunity

The next step in calculating the Sigma Quality Level is to calculate the Defect Per Million Opportunity (DPMO). Defect Per Million Opportunity shows the number of defects or failure in every million opportunities. This calculation is done to obtain a general picture of the amount of defect per million opportunities. In this research, the defect calculation is done per unit of coil.

$$DPMO = DPO\ x\ 1{,}000{,}000 \tag{2-15}$$

$$DPMO = 0.002591694\ x\ 1{,}000{,}000 =\ 2591.694 \tag{2-16}$$

Equation (2-15) and (2-16) show the formula and result of the calculation of Defect Per Million Opportunities (DPMO) of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2016. Can be seen that the Defect

Per Opportunities is 0.002591694, which is obtained from dividing the number of Defects Per Unit during July – September 2016 with the number of opportunities. This result is then multiplied with 1,000,000 to find Defect Per Million Opportunities, thus the result of 2591.694 is obtained. The result means that for each million opportunities there are 2591.694 defects. This amount is certainly an improvement from the amount of Defect Per Million Opportunities before improvement because of the reduction. The next step of this process is to calculate the Yield value.

d. Calculation of Yield

The second last step in calculating the Sigma Quality Level is to calculate the Yield value. There are several types of Yield, but in this research, the calculated Yield value is the Throughput Yield, which is the most sensitive among all types of Yields. This calculation is done to acknowledge the probability of a coil passing through the Product Transfer process with no defect or the Product Transfer process capability.

$$Yield = 1 - \frac{Number\ of\ defects}{Number\ of\ shipments} \quad (2\text{-}17)$$

$$Yield = 1 - \frac{407}{15{,}699} = 0.97408306 = 97.4\% \quad (2\text{-}18)$$

Equation (2-17) and (2-18) show the formula and result of the calculation of Yield value of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2016. Can be seen that the Yield value is 97.4%, which is obtained from the formula in Equation (2-17) and an increase of Yield is seen in the calculations. Previously, the Yield is 94.7%, but after the improvement, the Yield is 97.4%. The result means that after the DMAIC phases has been conducted, for each unit of Hot Rolled Coil, the probability of the coil to undergo the Product Transfer process with no defect is 97.4%. The next step of this process is to calculate the Sigma Quality Level (SQL).

e. Calculation of Sigma Quality Level

The last step in calculating the Sigma Quality Level is to calculate the Sigma Quality Level. Sigma Quality Level shows the Product Transfer process capability. The higher the level of Sigma, the better the process is. In this research, the defect calculation is done per unit of coil.

$$SQL = NORM.S.INV(Yield) + 1.5 \tag{2-19}$$

$$SQL = 3.45 \tag{2-20}$$

Equation (2-19) and (2-20) show the formula and result of the calculation of Sigma Quality Level of Hot Rolled Coils in Finished Product Distribution warehouse from July to September 2016. Can be seen that the Sigma Quality Level is increased from 3.12 to 3.45, which is obtained from Equation (2-19) done using Microsoft Excel. The result means the process capability of the Product Transfer process stands at the level of 3.45 or still an average company. However, the value is increased, which shows an improvement as a result of the DMAIC phases.

4.7.3 Rework Cost Analysis

The process of rework consists of returning the coil to the Work In Process (warehouse where the coils should wait for the machine queues and the process of Product Return Note, and then when the wait is done, the coil can be processed in the rework stations. In reworking the coils, there are several types of costs that are incurred, which are production cost and scrap cost.

Table 4.12 List of Costs Incurred for Rework

Source: PT. X

Rework		
Operation	**Mass (kg)**	**Price**
Production	1	IDR65
Scrap	1	IDR2,900
Total		**IDR2,965**

Table 4.12 shows the list of costs incurred for rework. Can be seen that the cost for rework is measured per kilogram, (kg). Production cost is the cost attributed to the company in order to do a production process. In PT. X, rework is also included as a production process since the machines should have extra usage and the employees should have overtime. Scrap is the defective part that needs to be cut in order for the coil to undergo rework. Therefore, scrap cost is the cost of scrap per kilogram. The average scrap per coil is 320 kg and the average mass of each coil is 15,000 kg or 15 tons.

Table 4.13 Rework Cost of Hot Rolled Coil

Operation	**Mass (kg)**	**Cost (IDR)**
Production	15,000	IDR975,000
Scrap	320	IDR928,000
Total		**IDR1,903,000**

Table 4.13 shows the calculation of cost of rework for each Hot Rolled Coil. As seen in the Table 4.13, the total rework cost for each Hot Rolled Coil is IDR1,903,000. This cost is obtained from the sum of extra production cost with the scrap loss cost. The production cost is IDR65,000 per ton, and therefore for 15,000 kg of coil (1 coil), the production cost is IDR975,000. The scrap loss cost for each kg of coil is IDR2,900. For each coil, the average scrap is 320 kg, therefore, the scrap loss cost for each coil is IDR928,000. The total rework cost is therefore IDR1,903,000. This applies only for one coil.

Before improvement, the total number of send back defects is 813 coils (see Table 4.1). The cost of the total rework cost incurred to the company before improvement is then calculated based on the data of cost obtained from PT. X and shown in Table 4.12. The result is as follows.

Table 4.14 Rework Cost of Hot Rolled Coil in July – September 2015

Operation	**Mass (kg)**	**Cost (IDR)**
Production	12195000	IDR792,675,000
Scrap	260160	IDR754,464,000
Total		**IDR1,547,139,000**

Table 4.14 shows the calculation of cost of rework attributed for the total number of send back defects in Hot Rolled Coil during the period of July – September 2015. As seen in the Table 4.14, the total rework cost for each Hot Rolled Coil is IDR1,547,139,000. This cost is then multiplied with the total mass of 813 coils, using the average mass of each coil, which is 15,000 kg. The production cost is IDR65,000 per ton, which is IDR65 per kg. Therefore for 12,195,000 kg of coil (813 coils) the extra production cost is IDR792,675,000. The scrap loss cost for each kg of coil is IDR2,900. For each coil, the average scrap is 320 kg, therefore, the scrap loss cost for 813 coils is IDR754,464,000. The total rework cost during the period of July – September 2016 is therefore IDR1,547,139,000.

After improvement, the total number of send back defects is 410 coils (see Appendix). The cost of the total rework cost incurred to the company before improvement is then calculated based on the data of cost obtained from PT. X and shown in Table 4.12. The result is as follows.

Table 4.15 Rework Cost of Hot Rolled Coil in July – September 2016

Operation	**Mass (kg)**	**Cost (IDR)**
Production	6,150,000	IDR399,750,000
Scrap	131,200	IDR380,480,000
Total		**IDR780,230,000**

Table 4.15 shows the calculation of cost of rework attributed for the total number of send back defects in Hot Rolled Coil during the period of July – September 2016. As seen in the Table 4.15, the total rework cost for Hot Rolled Coils after the improvement is implemented is IDR780,230,000. This cost is obtained from the sum of extra production cost with the scrap loss cost. This cost is then multiplied with the total mass of 410 coils, using the average mass of each coil, which is 15,000 kg. The production cost is IDR65,000 per ton, which is IDR65 per kg. Therefore for 410 coils or 6,150,000 kg of coil, the extra production cost is IDR399,750,000. The scrap loss cost for each kg of coil is IDR2,900. For each coil, the average scrap is 320 kg, therefore, the scrap loss cost for 410 coils is IDR380,480,000. The total rework cost during the period of July – September 2016 is therefore IDR780,230,000.

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

From the DMAIC phases, can be concluded that the most dominant type of defect in Finished Product Distribution (Hot Rolled Coil) warehouse of PT. X is Defect Handling, precisely 55.47% of all send back defects. Through series of considerations (based on the SMART principle), the target is to reduce the defect handling percentage to 50% from the initial amount.

Through the DMAIC phases, specifically in the Analyse phase, the root causes of Defect Handling are found, which are:

Table 5.1 Summary of Root Causes of Defect Handling Found in Hot Rolled Coils in Finished Product Distribution warehouse

Factor	Root Causes
Man	Because there is a high number of resignation.
	Because there is a lack of understanding about the risks.
Method	Because there is no application for PTN cancellation in the system.
	Because there is no integration in inspection scheme.
Mother Nature	Because there is no specific area for PTN.
Tools	Because the type of lamp is inappropriate.

Table 5.1 shows the summary of the root causes of defect handling found in hot rolled coils in Finished Product Distribution warehouse. There are four factors with six root causes in total, and each are treated accordingly in the Improve phase. The results of the Improve phase are then controlled with pre-PTN document, barcode, cancellation application in MES, and weekly progress meeting.

As a result of the DMAIC phases, the target is achieved—a 61% reduction of the number of Hot Rolled Coils attributed to Defect Handling found in Finished Product Distribution warehouse of PT. X is obtained. This improvement is estimated to save PT. X from incurring to IDR766,909,000 for rework cost of Hot Rolled Coils.

5.2. Recommendation

In order to increase the effect of the improvement, the implementation should be done for a longer period of time for more types of products. Also, a thorough and constant control should be done in order to keep the improvement up and running well and prevent “on the field” politics, such as bribery, seniority, and gratification, from going. For a more accurate result of process capability, a control chart, preferably “C Chart” should be made to acknowledge the origins of the most dominant type of defect and therefore act upon the cause accordingly. Also, for a higher increase of process capability, the DMAIC phases should be done in a longer period and with more consistency. A more detailed calculation by taking into account the labour cost, system modification, and other costs should be considered in order to get a more accurate calculation of the cost.

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APPENDICES

Appendix – 1 Send Back Defects of July 2015

Date	Type of Send Back Defect (July 2016)										TOTAL
	DH	EF	EC	PT	WV	TL	MR	HR	RP	LO	
7/1/15											0
7/2/15											0
7/3/15											0
7/4/15											0
7/5/15											0
7/6/15											0
7/7/15											0
7/8/15											0
7/9/15	4	1	1								6
7/10/15	2		1							1	3
7/11/15	2										2
7/12/15	9	1	3								14
7/13/15	1						1				2
7/14/15	1										1
7/15/15	3		1			1					5
7/16/15	1										1
7/17/15	9	1	2					1			13
7/18/15	25	5	6		1	2			2	1	42
7/19/15	4	1	1								6
7/20/15	2										2
7/21/15	18	1	1		1	1					22
7/22/15	1	1						1			3
7/23/15	3		1	1					1		6
7/24/15	5	2		1			1				9
7/25/15	2	1	1								4
7/26/15	16	3	2							2	23
7/27/15	26	4	6		1	1			1	2	41
7/28/15	2		4								6
7/29/15	3	2	2								7
7/30/15	1	1						1			3
7/31/15	4	1	2								7
Total	**144**	**25**	**34**	**2**	**3**	**5**	**2**	**3**	**4**	**6**	**228**

Appendix – 2 Send Back Defects of August 2015

Date	Type of Send Back Defect (August 2016)										TOTAL
	DH	EF	EC	PT	WV	TL	MR	HR	RP	LO	
8/1/15	4	3	2		1	1				5	16
8/2/15	6	2	2	1		2			1		14
8/3/15	2	1	1								4
8/4/15	3	1									4
8/5/15	8	3	1				1				13
8/6/15	4	2									6
8/7/15	1							1			2
8/8/15		1	1								2
8/9/15	4	3									7
8/10/15											0
8/11/15	5	1	2		1					1	10
8/12/15	1	1	1								3
8/13/15	6		3							1	11
8/14/15	1	1									2
8/15/15	4	2									6
8/16/15		1	1			1					3
8/17/15	6	3	1		1				1		12
8/18/15	2	1					1			1	5
8/19/15	4	2	1								7
8/20/15	3										3
8/21/15	10	3	1	2				1			17
8/22/15	5	1	1			1					8
8/23/15	7	4	4							2	17
8/24/15	5	2									6
8/25/15	1	1	2								4
8/26/15	6	1	1		1						9
8/27/15											0
8/28/15	10	5	3								18
8/29/15	8	3	4								15
8/30/15	19	4	4			1					28
8/31/15	7	4	3	1			2		2		19
Total	**138**	**55**	**39**	**4**	**4**	**6**	**4**	**2**	**4**	**10**	**266**

Appendix – 3 Send Back Defects of September 2015

Date	Type of Send Back Defect (September 2016)										TOTAL
	DH	EF	EC	PT	WV	TL	MR	HR	RP	LO	
9/1/15	3	1	2					1			7
9/2/15	1										1
9/3/15											0
9/4/15	3	1	1					1		2	8
9/5/15	5	1	1								7
9/6/15	11	5	2		1				1		15
9/7/15	15	3	2			1			1	5	27
9/8/15	7	1	1								9
9/9/15	16	7	8	1			1				33
9/10/15	7	1	2								10
9/11/15	1	1	2								4
9/12/15	2	2	1								5
9/13/15	13	1	3			1			1		19
9/14/15											0
9/15/15	10	4	2		1						17
9/16/15	1	2	1								4
9/17/15	10	9	3								22
9/18/15											0
9/19/15		1	1								2
9/20/15	18	10	3	1			9			2	43
9/21/15	5	2	1					2			10
9/22/15	2	1	1			2					6
9/23/15	19	8	3		1						31
9/24/15	2	1	1							1	5
9/25/15	1	2	1	1							5
9/26/15	1	1									2
9/27/1	5	1	1					1			8
9/28/15	3	3									6
9/29/15	1		1								2
9/30/15	3	2	1								6
Total	**165**	**71**	**45**	**3**	**3**	**4**	**10**	**5**	**3**	**10**	**314**

Appendix – 4 Send Back Defects of July 2016

Date	Type of Send Back Defect (July 2016)										TOTAL
	DH	EF	EC	PT	WV	TL	MR	HR	RP	LO	
7/1/16	3	1	2							2	8
7/2/16	2	1		1			2				6
7/3/16										2	2
7/4/16	2	1	1								4
7/5/16	2					1		2			5
7/6/16		1		1	1				2		7
7/7/16	2		2		1			1			6
7/8/16	4	1	2								7
7/9/16	3	2							1		6
7/10/16		1		1				2		3	7
7/11/16		1									1
7/12/16			1	1							2
7/13/16	4	3					1				8
7/14/16	3	2	1								6
7/15/16	2		2	1							5
7/16/16	3										3
7/17/16											0
7/18/16											0
7/19/16											0
7/20/16	3	1	2				1		1		8
7/21/16	1	1				1					3
7/22/16						1					1
7/23/16	3		1								4
7/24/16	3	3					1				7
7/25/16	4		2								6
7/26/16	1	2			2						5
7/27/16	3	1	2			1					7
7/28/16	4	1	2								7
7/29/16	1	2	2								5
7/30/16	3		1								4
7/31/16	4	1	2								7
Total	**62**	**26**	**25**	**5**	**4**	**4**	**5**	**5**	**4**	**7**	**147**

Appendix – 5 Send Back Defects of August 2016

Date	Type of Send Back Defect (August 2016)										TOTAL
	DH	EF	EC	PT	WV	TL	MR	HR	RP	LO	
8/1/16	1			1							2
8/2/16			1		1			1		2	5
8/3/16							1				1
8/4/16	2	1		1							4
8/5/16		1	1			1			1		4
8/6/16			1				2				3
8/7/16		2	3	1				1			7
8/8/16	1	2			2		2				7
8/9/16		1	2			1			1	2	7
8/10/16	3	1	2								6
8/11/16	1										1
8/12/16	2	1	1								4
8/13/16	4	2	1								7
8/14/16	1	1	1								3
8/15/16	2	1				1		3			7
8/16/16	3										3
8/17/16	1										1
8/18/16		1									1
8/19/16	3	1	2								6
8/20/16	3										3
8/21/16	4	2	1								7
8/22/16	4	2	1								7
8/23/16		2				1		2			5
8/24/16	1								2		3
8/25/16	4										4
8/26/16	3	2	1								6
8/27/16	4	2	1								7
8/28/16	3		1								4
8/29/16	2		2								4
8/30/16	3	1	2								6
Total	**55**	**26**	**24**	**3**	**3**	**4**	**5**	**7**	**4**	**4**	**135**

Appendix – 6 Send Back Defects of September 2016

Date	Type of Send Back Defect (December 2016)										TOTAL
	DH	EF	EC	PT	WV	TL	MR	HR	RP	LO	
9/1/16	4			1		1		1		2	9
9/2/16	3		3								6
9/3/16	2	3			2						7
9/4/16							1			2	3
9/5/16	3	1									4
9/6/16			3								3
9/7/16											0
9/8/16											0
9/9/16	4	2	1								7
9/10/16	1	1	1								3
9/11/16	2	1									3
9/12/16	3	1									4
9/13/16	2	1	2								5
9/14/16		2					2	1			5
9/15/16	2		2								4
9/16/16	3	1	3								7
9/17/16	1	1									2
9/18/16											0
9/19/16	3	2									5
9/20/16	1		1								2
9/21/16	3	2	1			1					7
9/22/16				1		2					3
9/23/16		1	2					1			4
9/24/16	1								2		3
9/25/16	3	3	1								7
9/26/16	2	1	1								4
9/27/16	4	1	1								6
9/28/16	2										2
9/29/16	1	1									2
9/30/16	2	2	1								5
10/1/16	3										3
Total	**55**	**27**	**23**	**2**	**2**	**4**	**3**	**3**	**2**	**4**	**125**

Appendix – 7 Example of Cargos Attributed to Send Back Defe

Cargo X: 26 – 28 July 2015 (Malaysia),
30 coils required PRN issuance, must be repaired