Volume-3, Issue-1, January-2019: 161-171 P-ISSN: 2659-1561
International Journal of Recent Innovations in Academic Research E-ISSN: 2635-3040

**Research Article**

# Productivity Enhancement Using Process Failure Mode and Effect Analysis (PFMEA) At Z Company Philippines Corporation

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**Received:** Jan 4, 2019 **Accepted:** Jan 11, 2019 **Published:** Jan 15, 2019

**Abstract:** Z Company Philippines Corporation is one of the vehicle manufacturer's which pass the Philippines government standards precisely on mass production. By that, the researcher aspires to make a study on how their production is moving mostly nowadays. Every process they intend to not make defects.

Failure is said to be a state of inability to perform a normal function. There are many instances that this situation may occur at any given time. When systems fail, business risk might occur. In this study, the researcher abides not just on the company's reliability but also with the probabilities of the failures that might occur. Failure mode and effects analysis (FMEA) is a popular tool for reliability and failure-mode analysis. As for this study, the researcher applied this failure-mode in analyzing the risk factors. There are three stages in Process FMEA to ensure the success of the analysis. The first stage is to determine the potential failure modes. The second stage is to find the data for occurrence, detection, and severity rankings. Rankings of data will be based on suggested DFMEA criteria. The third stage is the modification of the current process design and the development of the control process based on the PFMEA report.

The proper use of check sheets for body shop reduced from 400 to 200 and from 288 to 128. Also, through this, savings is gained when downtime is reduced. On the other hand, the RPN (Risk Priority Number) of parts rack of trim line is reduced from 400 to 20.

**Keywords:** FMEA, Process Flow Chart, Tree Diagram, Why-Why Analysis, Total Preventive Maintenance, Trim Line, Body Shop line, Risk Priority Number.

## Introduction

Failure Modes and Effects Analysis (FMEA) is commonly used in a variety of industries for Productivity Enhancement, where simple quantification of risk is insufficient, and where identification of root causes of risks and means of mitigation are paramount. FMEA is one of the useful and effective tools for developing designs, processes and services. The goal of FMEA is to align the risks as closely as possible with its source. This enables the determination of the root cause of the risk, and allows the selection of ways to detect the occurrence of a particular failure and/or to find options to prevent or mitigate the effects of a particular failure. Good FMEA methodology allows for the identification and documentation of potential failures of the system and their resulting effects. It also allows for the assessment of the potential failure to determine actions that would reduce severity, reduce occurrence, and increase detection (Villacourt, 2008).

The study will focus on establishing an FMEA analysis to provide information which will be a guide to identify potential failures. Once it is done, controls will be determined to be use in

case of the occurrence of failures. Through the observation of the manual process, particularly on specific area of the study which is production line, all data acquired will be used and subjected to analysis. At the beginning of the study researcher will be abide on making a thorough observation regarding the subject matters. Through FMEA, potential failures will be cured once it arises as early as possible. Establishment of FMEA at the production line will be a great help as a foundation of this study and also to the occurrence of failure on the company's process.

Problems acquired regarding the study will be the foundation of this research. Response will obtain directly on the analysis from the data acquired on the company and from the researcher observation. Somehow, encounters between man and machine failures will also be under studied. Status of the process and the company's operation will also be analyzed for further information with respect to this study.

The aim of the study was to identify the failure modes on a specific line at Z Company Corporation through generating PFMEA worksheet. In order to achieve this, the proponent gathered data and pieces of information from the company which are pertinent to the growth of the study. The research study is focused on identifying the potential failures which arise on an identified section, which are the Production Engineering section.

The entire study will use the concept of a reliability tool, the Failure Mode and Effect Analysis, to construct a study regarding the consistency of the process. The production lines which are the Body Shop, Trim Line and the Chassis and Final Line are the extent of the study. Only the data regarding the contributor of the failure will be subjected to analysis and investigation. Moreover this study is intended to find ways and provide recommendations for improvement which can be proposed in order to resolve the results of the assessment toward the enhancement of the production line.

**Objectives of the Study**

This study dealt with the analysis of the factors causing process failure. The study aimed to identify the highest contributing output in terms of process failure.

1. To determine the current status of Z Company in production operation in terms of:
1.1. Flow Process
1.2. Machine Breakdown
1.3. Human Error
1.4. State of Maintenance
2. To identify the problems encountered during the production processes?
3. To apply the process failure mode and effect analysis in the production of N-series trucks?
4. To assess the significant impact of improvement through FMEA to the Z Company with regards to:
4.1. Flow Process
4.2. Machine Breakdown
4.3. Human Error
4.4. State of Maintenance

**Related Literature**

According to Macaraig (2015), their study entitled "Productivity Enhancement through Man: Machine Ratio Analysis of SOT404 Diebond Wirebond at NXP Semiconductors Cabuyao Philippines Inc." was focused on the allotment of manpower at SOT404-Frontline area.

Their goal is to make the productivity better through man: machine ratio analysis by increasing the output, lessen delays and so as to minimize defective units.

In order to achieve this, they evaluated the working instructions and work load verification. One of the tools they utilized in this study is the Failure Mode and Effect Analysis. Another is the time and motion study for the process development. Finding out the standard time to accomplish a process is necessary because the management can make it as a basis for their efficiency and productivity.

The study conducted by Dimaano (2014), entitled "Productivity Enhancement through Minimizing Machine Downtime at Wirebond Process of NXP Semiconductors Cabuyao Inc.", they used the concept of FMEA as the reference of identifying the root cause of existing problem and generating feasible improvements.

The study is all about seeking out improvement on the productivity since this has been always the goal in any semiconductor industries. As the result, FMEA had been an effective solution to find the main causes of unscheduled machine errors in the production. With this the proponent have implemented the corrective measures in the production.

Based from the study of Baradas (2013) which entitled "Failure Mode and Effect Analysis: A Strategic Tool for Error Prevention with Focus on Quality Improvement at Littelfuse Philippines Inc." the study identified the process which contributes the most error encountered using Pareto Diagram.

The proponent suggested ways to improve quality and increase productivity of the company through the reduction and elimination of defects. As a result, it increased the productivity from 98.62% to 99.24%. On the other hand, the number of errors or defects lessened from 51,653 to 29,774 units. With the use of the said study, the company can build quality products and increase company's profitability as well.

A study accomplished by Heidi Kate N. Bonifacio (2008), entitled "A System Study on the Warehouse Operations of IDS Logistics (Philippines) Inc." used the idea of FMEA to determine the root cause of incurring variance from wrong pick which is further categorized into three parts: wrong serve, wrong barcode and short/over issuance. Evaluating each category, five causes were identified namely: different locations assigned for specific customers, inadequate pick list design, product placement for pallet utilization, inadequate lighting and unfamiliarity and confusion caused different bundling quantities of the products. The new system is proposed to address the identified causes is composed of assignment of pickers to pick only on one location (1601 or 1608), regulating /controlling the method of releasing pick lists, redesigning the pick lists, changing of layout and changing of lights.

In the study of Deng *et al.*, (2007), entitled "The Failure Mode and Effect Analysis at Laser Marking Process Company", applied the reliability of the design of the equipment in semiconductor. This research firstly implements FMEA technique in laser marking process improvement on semiconductor testing factory and finds out which subsystem has priority failure risk. When failure modes were identified, corrective actions can be taken to eliminate the potential failure for occurrences. FMEA provides an organized, critical analysis of potential failure modes in the system. Based on the analysis result, FMEA implementation solution for laser marking process improvement can increase yield rate and reduce production cost.

Prajapati, conducted a study in 2012 entitled, "Application of FMEA in Automobile Industries: A Case Study". This study gave emphasis on two products, the air inlet manifold and the fuel injection pump. Researcher studied and analyzed the plant's manufacturing practice through the utilization of Failure Mode and Effect Analysis considering the severity value, occurrence number, detection and risk priority number. Causes and effects of several potential failures were discussed together with the preventions to be imposed. The recommended suggestions for each particular product significantly minimized the loss of the plant concerning money and time. It greatly improved the automobile industry, making the manufacturing process more efficient and productive.

In the study of Namdari, in 2010 entitled, "Using FMEA method to optimize fuel consumption in Tillage by Moldboard Plow" it aimed to minimize the consumption of fuel in mouldboard plowing in tillage through the utilization of FMEA, tillage belongs to the greatest energy consumer when it comes to agricultural industry.

Implementation of FMEA uncovered the factors which seriously affect the tillage fuel consumption; plowing speed with 640 RPN, soil moisture content with 480 RPN and plowing depth having 420 RPN. Effectiveness of FMEA is proven after countermeasures were executed, fuel consumption dropped by 16.40%.

**Materials and Methods**

This research study is a descriptive type of research. The main objective of this study is to identify and analyze the potential complex system failure. The proponent had thoroughly analyzed the data and pieces of information which were collected from the company through the use of reliability tool and other industrial engineering means that helped the proponent to conclude the results of the study. Possible solutions to the problem generated from the study will be subjected to reflect on the company's production process.

Figure 1 shows the conceptual paradigm of the study to assess if the study is reliable, the researcher considered the input, process and output which served as its basis. Failure occurrence is uncertain affecting the process.

Thus, production line processes of Body Shop, Trim Line, Chassis and Final Line and other problem stated by the company will be the primary input of the study. Also, additional inputs are the sales of N Series, production output, breakdown of machines and the maintenance of the production line.

On the other hand, the process includes different theories and tools. Theories to be used were based on the production study and the potential failures during the production line. To utilize the study, tools such as Process Flow Chart, Tree Diagram, Why-Why Analysis and Process Failure Mode and Effect Analysis will be used.

Using Process Flow Chart, breakdown process will be identified to distinguish the potential failures that may be encountered on the specific line. Why-Why Analysis is used to identify the root cause of failure occurrence.

Tree Diagram and Process Failure Mode and Effect Analysis also contribute greatly to identification of failure and countermeasures to be executed when failures arise. As an output of the study the objective would be attained. These are to control failures which to provide the production process an effective countermeasure during its occurrence.

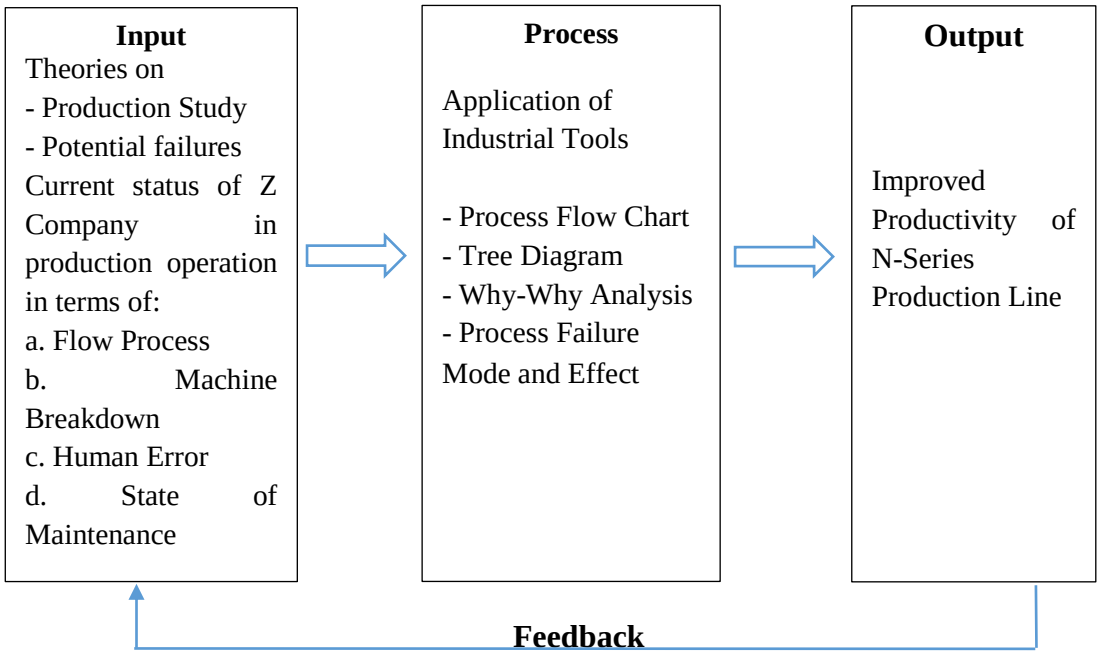


**Figure 1. Conceptual Paradigm**

The proponent had thoroughly analyzed the data and pieces of information which were collected from the company through the use of reliability tool and other industrial engineering means that helped the proponent to conclude the results of the study. Possible solutions to the problem generated from the study were raised to improve company's production process.

**Data Gathering Procedures**

Data gathered were based from thorough observation and analysis of the process in order to identify the failures accumulated during the production. Brainstorming is performed to fabricate ideas and solutions through intensive and freewheeling group discussion. However, during our study, one of the process line tends to undergo kaizen. With that, this study is bounded from body shop line to the trim line process only. To identify the failures, the proponent use the concept of Tree Diagram.

Constructing the Process Failure Mode and Effect Analysis (PFMEA) is used as the tool to provide controls regarding the failures. Analyzation of the acquired information is execute for evaluation. After constructing the PFMEA, current controls is invented to lessen the failure or improve the specified area of study. These data had been the primary input of the study and were subjected to investigation and analysis. After collecting enough data, it was analyze using a reliability tool to identify the cause of failure within the production. Once the problem has been identified, establishment of countermeasures are recommended from the researcher.

**Results and Discussion**

**1. Current status of Z Company**

**1.1 Process Flow**

Z Company is a manufacturer of vehicular means. They aim on satisfying the customer's by means of a quality. By that, the proponent scrutinize the production process of N-series. As shown in Figure 2, is the flow process of production in truck line. Devanned crates will be moved on unboxing area. Parts sorting and picking will be done by material control staff. After this, parts will be delivered to in-line processes. On body shop line, thick sheets of

metal are merge using a special type of spot gun. After this, it will be transferred to paint shop. Different are of unboxing is provided for trim line. Small parts and internal accessories are installed on this line. However, chassis frame are assembled at chassis station. Installments of external parts are done after chassis. On that same line after the trim is the final process which is the cab dropped. After finalization of process, a unit is ready for QC inspection and other tests used to implicate reliability for the customer's satisfaction and delightfulness.

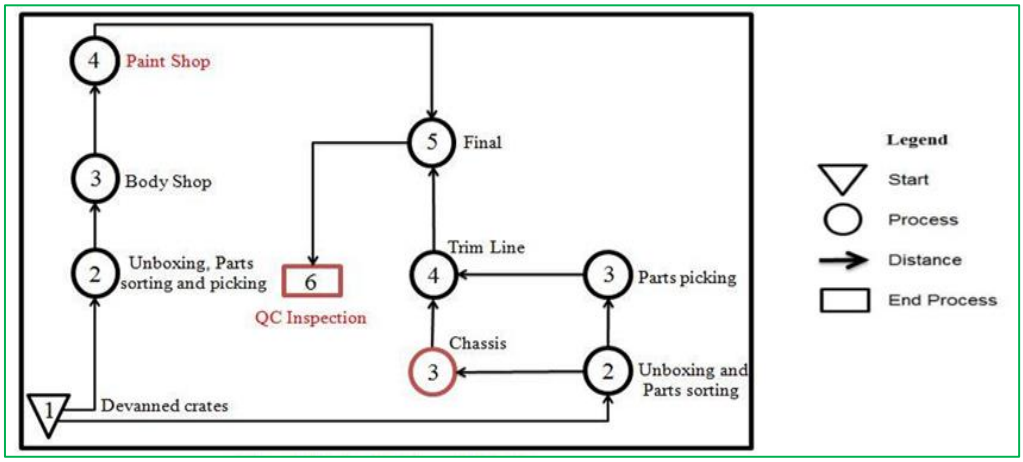


**Figure 2. Process Flow of N-Series**

### 1.2 Machine Breakdown

From the Figure 3, body shop process starts with the sorting and picking process of the parts. This parts are the formed bulky sheets of metals use to merge; to form the frame of the cab. Parts are distributed to its station named as the floor assembly station, main body assembly station and the end process which is the metal finish. Clearly, stated station names are comprehensible on what process are each station commits. Moreover, the proponent state that the machine breakdown is considered to arise at the body shop since, the said process use machines to execute the task.

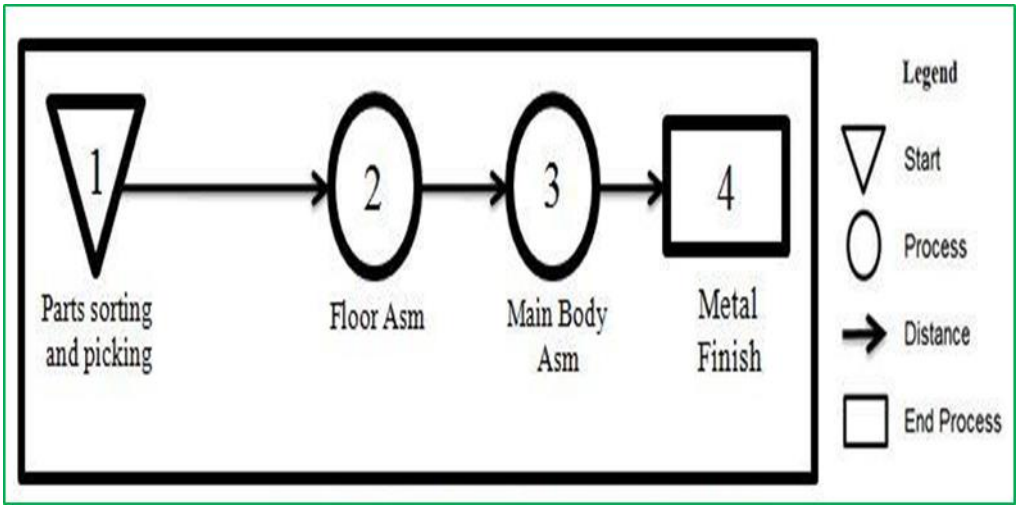


**Figure 3. Process Body Shop**

As stated, body shop line is using lots of machine which is the spot guns. Shown in Figure 4, is the floor layout of the spot guns. The study focus on the spot guns which is located on the floor assembly and the main body assembly.

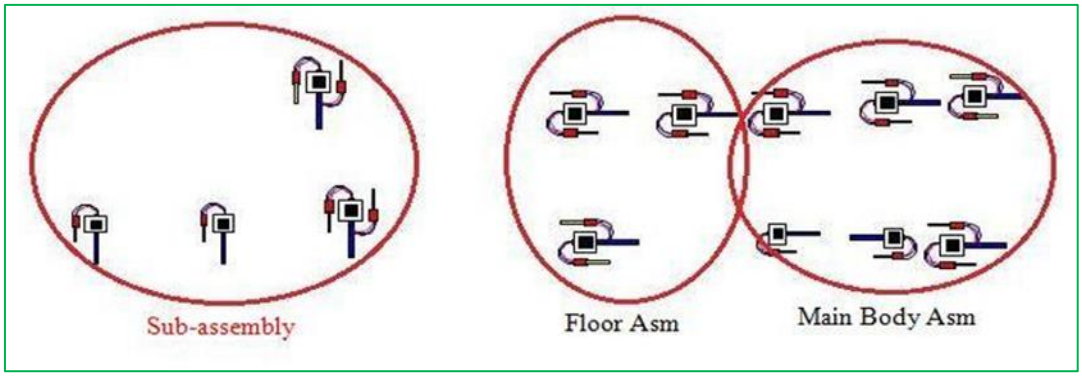


**Figure 4. Spot Gun Layout of Body Shop**

### 1.3 Human Error

Human error assessment of IPC is noticed if the operator is newly acquitted to the task. Moreover, trainings will be given before they commit to the actual task. However, on the Trim line, it is observed that the current status of racks in the identified department contains different parts instead of the standard parts that it should enclose according to the company's standard.

### 1.4 State of Maintenance

Maintenance in IPC is categorized in three: the Preventive Maintenance, Predictive Maintenance and the Corrective Maintenance. In Preventive Maintenance, downtime is prevented during specific time given. Schedule of maintenance is monthly, semi-annually and annual checking of machines. This is done by the maintenance personnel assigned. Predictive Maintenance is for advanced schedule of possible failures. It consists Vibration test for the motors and thermography for electrical. During actual failures, Corrective Maintenance is acquired to evaluate and control the occurrence of failure. This is scheduled with no particular time.

## 2. The Problem

Figure 5 shows the why-why analysis of body shop line. IPC didn't meet its target machine availability. From the analysis shown, undated check sheets exist and they don't have a cross functional chart to properly distribute the work. This will be the core of study for the researcher; this will be the basis for improvement in particular with the body shop line.

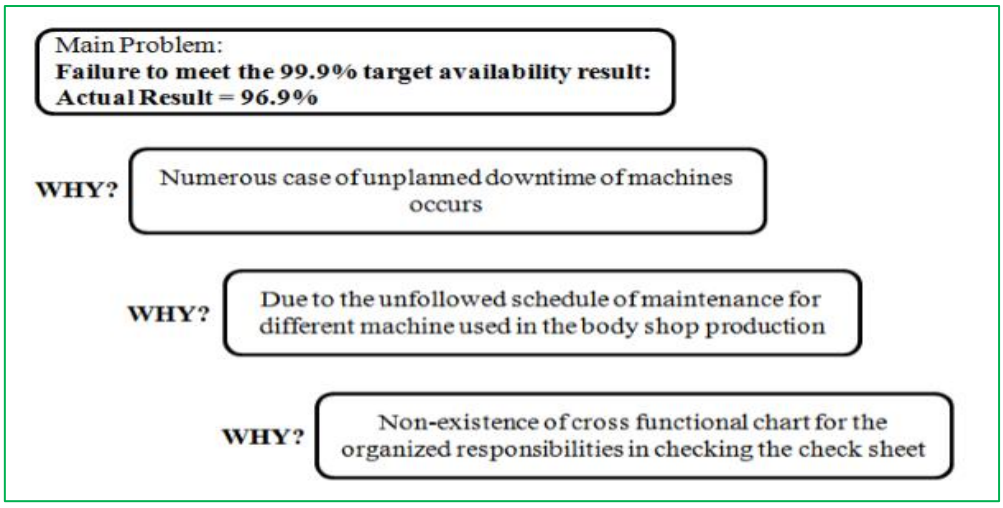


**Figure 5. Why Why Analysis**

## 3. The Process Failure Mode and Effect Analysis

In this point, the researcher identified the potential and existing failures in the production. The proponent used the concept of PFMEA (Process Failure Mode and Effect Analysis) Analysis as the general tool on providing countermeasures for the said failures. The succeeding table 1 shows the acquired data of the researcher. Through the observation acquired from the specific line, data gathered would be subjected for further analysis. Process Failure Mode and Effect Analysis are acquired to broaden the study. Foremost, failures are generated from different department. Using PFMEA, risk factors are analyzed. To ensure the success of the analysis, the proponent determine the potential failure modes. This is to identify the failures need to be controlled. In addition to that, failure occurrence is obtained to identify the specific failure which the process might occur. Finally, modify the current process design and the development of the control process based on the PFMEA report. These modes are rated based on the specified rating ahead. Followed to that, the Risk Priority Number (RPN) will be calculated. With that, it is assumed that the highest generating RPN will be prioritized for further improvement. To sum it up, the following were the major failure needed for feasible solution:

1. Manual spot welding process of main body assembly and main body re-spots
2. Automated jigs for main body assembly
3. Sorting of parts for the in-line process of Trim

**Table 1. Process Failure Mode and Effect Analysis**

**Process Failure Mode and Effect Analysis**

| Line | MAIN BODY ASSEMBLY | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Process | AUTOMATION OF PANEL CLAMPING | | | | | | | | |
| | | | | Potential Causes | | Countermeasure | | | |
| PROCESS IDENTIFICATION | FAILURE MODE | FAILURE SEVERITY | FAILURE EFFECT | DETAILS OF FAILURE | Occurrence | DETECTION ACTION | DETECTION FREQUENCY | RPN | COUNTERMEASURE |
| Automated setting of jig clamps to loose panel<br><br>Function: Clamps are made to hold all loose parts during the welding process | Clamp does not engage | 10 | Cannot weld loose parts | Clamp switch not working | 10 | Daily check up of switch before operation and after breaks | 4 | 400 | Replace switch |
| | | 10 | | No Air Supply | 5 | Install Air Pressure Gauge | 1 | 50 | Check Air Supply Line |
| | Slow clamping time | 10 | Delay in operation | Defective Pneumatic Cylinder | 2 | Daily check up of switch before operation and after breaks | 1 | 20 | Replace pneumatic cylinder |
| | | 8 | | Air leak in pipe line | 5 | Visual Inspection thru Air Pressure Gauge | 1 | 40 | Repair Pipe Line |
| | | 8 | | Low Air pressure | 4 | Visual Inspection thru Air Pressure Gauge | 1 | 32 | Maintain air pressure |
| Manual spot welding process<br><br>Funtion: Spot welding | Spot gun does not fire | 6 | Delay in operation | Damaged trigger switch | 6 | Replace trigger switch | 4 | 144 | Replace switch |
| | | 6 | | Damaged control cable | 5 | Repair of control cable | 3 | 90 | Repair control cable |
| | | 6 | | Disconnected wire | 9 | Replace wire | 4 | 216 | Repair disconnected wire |

In the Table 2 shows is the machine breakdown with the highest RPN. The countermeasure is provided on the occurrence of failure. Machine breakdown in the particular process is essential for maintenance; this is to prevent downtime of the process. The researcher provided a check list to maintain the reliability of the machines. Daily check-up is required particularly on and before the production.

**Table 2**
**FMEA of Body Shop**

| PROCESS | FAILURE MODE | FAILURE SEVERITY | FAILURE EFFECT | Potential Causes | | Countermeasure | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | DETAILS OF FAILURE | Occurrence | DETECTION ACTION | DETECTION FREQUENCY | RPN | COUNTERMEASURE |
| Automated setting of jig clamps to loose panel | Clamp does not engage | 10 | Cannot weld loose parts | Clamp switch not working | 10 | Daily check up of switch before operation and after breaks | 4 | 400 | Replace switch |
| Manual spot welding process | Spot gun does supply an unstable weld | 8 | Improper merge of metal sheets | Refusal of current | 9 | Check the connecting wire | 4 | 288 | Check for cable wires |
| | | 8 | Nuisance | Grounded thyristor | 9 | Check the internal connections | 4 | 288 | Repair thyristor |

As shown in Table 3, the MC of Trim line process has also the highest RPN. The failure shown is the existence of different parts rack data, from the company's SOP to the actual location of parts. It is also shown that to organize the failure, the researcher recommends to redistribute the location of parts which is according to the sorter. Evaluation on the best possible solutions is made. Through visual observation and brainstorming, the researcher provide control on the said failure.

**Table 3**
**FMEA of Trim**

| PROCESS | FAILURE MODE | FAILURE SEVERITY | FAILURE EFFECT | Potential Causes | | Countermeasure | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | DETAILS OF FAILURE | Occurrence | DETECTION ACTION | DETECTION FREQUENCY | RPN | COUNTERMEASURE |
| Sorting of parts for the in line process | Different parts location | 10 | Non-standard parts rack data | Unstandard parts distribution (Not following the standard operating procedure for parts sorting) | 10 | Daily check up of standard parts distribution sheet | 4 | 400 | Redistribution of parts which depends on the sorter |

## 4. Impact of Improvement

### 4.1 Process Flow

Z Company commits to provide a customer's satisfaction. By which they assured their products quality: tried, tested and trusted vehicles. Impact of improvements results were scrutinized through further analysis. In the Body Shop process, the researcher provide an improved maintenance check sheet in the particular machine for its reliability. This is to prevent downtime once failure occurs. Together with this, cross functional chart and policy

were also imposed. However, in Trim line, countermeasures are executed for the reliability of company's data particularly in the identified process which is the sorting. Standard operating procedure of the process is reassessed.

### 4.2 Machine Breakdown

Failures arise on the body shop line are evaluated. Through FMEA analysis, it is rated and by means of RPN, it states which will be the first priority. The researcher provide a daily and monthly check lists which will help on monitoring and scrutinize the machines where failure arises. Also, provided are the machine record, verify and ensure the reliability of machines. This will help to maximize the use of the mechanisms in the in line processes. Risk assessed was analyzed to evaluate its ratings. Average monthly downtime of 310 minutes was detected in body shop line. These are the unexpected machine breakdown which arises during the actual production. Shown in table 11 is the monthly profit loss of the production, were the average downtime accumulated per month is converted into its equivalent cab units.

### 4.3 Human Error

In–line process of trim line is scrutinized. After observations and trials, production parts allocation is considered as the basis data and the requirement needed for the company and the production's improvement. However, adjustments regarding the productions parts distribution process will be the best possible solution that the proponent proposed. The proponent provide a data based on the standard data for production. Also, through this, human error will be eliminated. The researcher provide a detailed record of the parts location on the parts rack. These data is to assured that there will be no confusions regarding the data.

### 4.4 State of Maintenance

After providing the control on the failure occurrence, the proponent provide a check lists particularly in body shop to maintain the functions of the machines. On the other hand, in trim line, detailed parts rack is provided for the maintenance of the company's data. This will be the basis for maintaining the parts location once a new trainee comes up. Continuous maintenance on the process is necessary.

## Conclusions

The implementation of the proposed improvements was significant in the company especially in the production area of Z Company. After conducting the study, the researcher has drawn the following conclusions:

1. The proponent acquired a conclusion with regards to the variables stated on the statement of the problem:

1.1. Process flow of IPC needs further studies in order to maintain and obtain the expectations in the process.

1.2. From the findings acquired with the Body Shop line, the researcher concluded that the machines running in line with the process should be analyse in order to generate an effective control as soon as the failure occurs.

1.3. In the trim line, it is concluded that, accurate data is a must have to maintain the standard operating procedure of the company.

1.4. Maintenance status of the IPC is improved. Additional inputs
regarding with the check sheets is recommended.

2. In line with the reliability of the company, the researcher concluded that the company should have their standard tool to identify the failures that arises within the processes. Industrial engineering tools are used for the analysis of process to identify failures. Further analysis is gain to counter the failure occurrence.

3. Through PFMEA, the detailed failures on the Body Shop were acquired to locate the main failures of the process and provide a current control for the productivity of the production lines. However, in trim line, the researcher concluded to rearrange the production's data and the company's data regarding the parts stacking at the parts rack. FMEA analysis also uses to provide a countermeasure to eliminate the failure occurrence by means of starting with the highest priority.
4. The researcher concluded regarding the monitoring of the machines and jigs of Body Shop through a check sheet. Also, it is seen that the machine availability affects the production and causes unplanned downtime. On the other hand, Trim Line is still under Kaizen for the further improvement of the parts rack. Although rearrangement of parts on the parts rack is taken as an initial action. The researcher concluded that the proper use of check sheets for body shop reduced from 400 to 200 and from 288 to 128. Also, through this, savings is gained when downtime is reduced. On the other hand, the RPN of parts rack of trim line is reduced from 400 to 20.

**Conflicts of interest:** There is no conflict of interest of any kind.

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**Citation:** Engr. Joel R. Cornejo. 2019. Productivity Enhancement Using Process Failure Mode and Effect Analysis (PFMEA) At Z Company Philippines Corporation. International Journal of Recent Innovations in Academic Research, 3(1): 161-171.