RISK MANAGEMENT ON MACHINE DEFECTS AT PT. YOSKA PRIMA INTI WITH REALITY CHARTING BY APOLLO ROOT CAUSE ANALYSIS AND DEFECT FORECASTING BY ARIMA

THESIS

Submitted to International Program Faculty of Industrial Technology
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Name : Zerlynda Fitria Nur Mayanti
Student No. : 14 522 187

INTERNATIONAL PROGRAM
INDUSTRIAL ENGINEERING DEPARTMENT
FACULTY OF INDUSTRIAL TECHNOLOGY
UNIVERSITAS ISLAM INDONESIA
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AUTHENTICITY STATEMENT

For the sake of Allah, I confess that this work is my own work except for the excerpts and summaries that each of the sources have already been cited and mentioned. If in the future my confession is proved to be wrong and dishonest resulting the violence of legal regulation of the papers and intellectual property rights, then I would have the will to return my degree to be drawn back to Universitas Islam Indonesia.

Yogyakarta, June 2018

Zerlynda Fitria Nur Mayanti

THESIS APPROVAL OF SUPERVISOR

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By

Name : Zerlynda Fitria Nur Mayanti

Student Number : 14 522 187

Yogyakarta, June 2018

Supervisor

(Muhammad Ridwan Andi Purnomo, ST., M.Sc., PhD.)

THESIS APPROVAL OF EXAMINATION COMMITTEE

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By

Name : Zerlynda Fitria Nur Mayanti

Student Number : 14 522 187

Was defended before Examination Committee in Partial Fulfillment of the requirement for the bachelor degree of Industrial Engineering Department

Universitas Islam Indonesia

Examination Committee

Muhammad Ridwan Andi Purnomo, ST., M.Sc., PhD.
Examination Committee Chair

Annisa Uswatun Khasanah, ST., M.Sc
Member I

Agus Mansur, ST., M.Eng.Sc
Member II

Acknowledged by,

Head of Study Program

International Program Industrial Engineering

Universitas Islam Indonesia

UNIVERSITAS ISLAM INDONESIA ★ YOGYAKARTA ★ INTERNATIONAL PROGRAM

(Dr. Taufiq Immawan, ST., M.M.)

DEDICATION

This thesis is dedicated for my beloved mom, Dra. Jumilah, my father, Nur Siswanta, ST., my inspirational woman, Elly Roslilah S.T.P., Muhammad Fatih Abdur Rahman, my beloved high school friends, Azell, Anita, Na'ima, and Nadia, Industrial Engineering International Program Universitas Islam Indonesia, and all of my friends.

MOTTO

"And ease my task for me"

-QS. At-Taha(20) : 26

"So do not lose heart or be grieved, for you will surely prevail if you are believers"

-QS. Ali-Imran(3) : 139

"Always remember that striving and struggle precede success, even in the dictionary."

-Sarah Ban Breathnach

PREFACE

Assalamu’alaikum Wr. Wb.

All praises to Allah SWT. for His gracefulness and guidance so that the author is able to follow and finish entire series of thesis research in PT. Yoska Prima Inti. The research is being conducted on a topic entitled “Risk Management on Machine Defects at PT. Yoska Prima Inti with Reality Charting by Apollo Root Cause Analysis and Defect Forecasting by ARIMA”.

In the course of final thesis and report creation, author realizes that the entire activities in the research processes would not work well without help of many entities. Hereby, in this occasion author would like to express gratefulness and gratitude to whole entities involved who are very inspiring and helpful, such as:

1. Parents and author’s family who are always giving morale support and materials during the internship period.
2. Mr. Muhammad Ridwan Andi Purnomo, S.T., M.Sc., PhD as the research supervisor and the head of Industrial Engineering International Program Department, Universitas Islam Indonesia.
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The author realizes that there are still many shortcomings existed and full of weaknesses, here is why critics and suggestions are expected. The author hopes that this report would give advantages and inspiration for the readers.

Wassalamu'alaikum Wr. Wb.

Yogyakarta, May, 2018

Zerlynda Fitria Nur Mayanti

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ABSTRACT

Machine defect has been a critical problem which has huge economic impact. Therefore, machine defect forecasting is necessary to be considered due to its importance. However, several companies neglect the need of machine's defect forecasting. This research analyzed the machine defects historical data of PT. Yoska Prima Inti for root cause analysis using Apollo RCA and to do defect forecasting using ARIMA model. The tools that used for the data analysis are Reality Charting for Apollo RCA and XLSTAT for ARIMA modelling. The data were taken from historical data of 2016 – 2018. The defect forecasting is being conducted twice to see the effectiveness of risk control implementation. The modelling approach of ARIMA itself is following Box-Jenkins approach, which is started with model identification, parameter estimation, and model verification. The significance level used for the whole calculations is 0.05. There are also several tests being done, such as stationarity test, white noise test, normality test, and trend test. The results of this research are divided into two results. The first result is related with root cause analysis, which identified that there are twelve problems occurs during the production from 2016 until 2018. The analysis also results in the discovery of major causes and the possible solutions to mitigate the causes. The second result is a result related to the ARIMA defect forecasting. The forecasting is conducted twice, before and after defect mitigation. The result shows that the forecasted defect frequency to occur before defect mitigation is 2 until 3 defects for each month. However, the forecasted defect frequency to occur after risk mitigation is 1 until 2 defects each month. The effectiveness measured for the implementation of defect mitigation is 75% to obtain zero defect occurrence.

Keywords: Apollo, ARIMA, Mitigation, Forecasting

CHAPTER I

INTRODUCTION

In this chapter, the researcher will present a brief introduction which is being elaborated with the background, problem formulation, objectives, research scope, and benefit of the research.

1.1. Background

PT. Yoska prima Inti is one of manufacturing companies in good manufacturing of automotive components in metal stamping, painting, and dies and jig fixtures. In the production process of PT. Yoska prima Inti, there were several times of machine defects occurrences have ever happened. There were twelve problems that keep on reoccurring from 2016 until 2018. Those machine defects were the result of unexpected events which did not be managed properly.

The events of machine defects will also create direct and indirect impacts. Those direct or indirect and positive or negative impacts will be known as risk in industry. The risk will affect to human and environment. The negative risk is the risk that should be prevented and overcome. Through organizational point of view, this negative risk will bring business interruptions or even will also lead to business failure. Machine defects in PT. Yoska Prima Inti are known as risks that also lead on to the other risks which create disturbance to the production process and lead to disturbance in business process.

The effect of the machine defect occurrences in PT. Yoska Prima Inti are the loss in production and marketing. The loss in production happens because based on Samat et al (2012) stated that 15% to 40% of the total production cost is attributed in maintenance activities. Those 15% to 40% of cost can either be beneficial or loss. It can turn to be beneficial if the allocated fund is efficiently and optimally useful to prevent or eliminate the problems from recurring. However, it can turn into loss if the fund is not efficiently and optimally used so that the problems are keep on persisting. In addition to the loss in production, loss in marketing can be happened. The loss in marketing happens, as the company will have to address the problems to the customers which will result on the disappointment towards the company. It can lead to the reduction in customer trust and loyalty.

In order to truly prevent or eliminate the problems from recurring, the company needs to conduct an analytical research to analyze and prevent the future risks to happen. The analysis conducted should be able to find out the real causes of why the problems happened and keeps on recurring. The real causes should be mitigated to at least able to prevent the problems from recurring. In order to identify whether the problems are optimally and effectively mitigated or not, forecasting is needed to be done. Forecasting needs to be done to know the number of future defects that may occur.

The researcher chooses to do an analytical research by combining both of Reality Charting Method in Apollo Root Cause Analysis and Auto Regressive Integrated Moving Average Method in defect forecasting within risk management sector. Apollo Root Cause Analysis (ARCA) is being used to reveal the direct and indirect real root causes to be used as an input in risk management analysis and defect forecasting. In addition, ARIMA is being used to forecast the future machine defect occurrence before the risk control and after the risk control.

ARCA method is being chosen despite of any other root cause analysis methods and tools because in comparison that has been ever created, Duphily (2014), stated that Reality Charting method in ARCA is a method with complete analysis if compared to the other RCA methods and tools such as Events & Causal Factors, Change Analysis, Barrier Analysis, Tree Diagrams, Why-Why Chart, Pareto, Storytelling, Fault Tree, and FMEA. The method used has full ability to define the problem, define all known causes, provides a casual path to root causes, delineates evidence, explains how solutions prevent recurrence, and the easiness to follow report.

Duphily (2014) mentioned that taking a comparison example for the methods, the comparison of the commonly used method or tool such as FMEA, both of them are able to define problems, but the abilities of FMEA to define all known causes, delineates evidence, and easiness to follow report are none while FMEA’s abilities to provide a casual path to root causes and explain how solutions prevent recurrence are limited. In the other hand, Reality Charting by ARCA has full abilities to fulfill the comparison criteria.

Haiges (2017) stated that there are multiple models which can be used for forecasting items such as time series, regression, econometric, decomposition, co-integration, ARIMA, artificial systems such as the Artificial Neural Network (ANN), Grey prediction, Input-output, Fuzzy-logic, and the bottom-up models. The ARIMA model has gained extensive literature in defect forecasting, owing to its complex and reliable approach. It is also found suited for long term projection. Furthermore, in order to avoid a spurious or invalid forecast, ARIMA is a recommended approach since it is widely established.

To sum of everything, in order to be able to use the result of root cause analysis in risk management to create solution to prevent the similar or same risks to be happened in PT. Yoska Prima Inti, the needs of clear and full root cause analysis is needed. In addition to make sure that the risk control is suitable, defect forecasting is going to be conducted. Hereby, the researcher use Reality Charting by ARCA to conduct the root cause analysis and ARIMA to conduct the forecasting.

1.2. Problem Formulation

Based on the background above, the problems that should be formulated and generated are shown below:

1. What is the machine defect root cause analysis in production process of PT. Yoska Prima Inti based on analysis using Reality Charting by ARCA?

2. What are the solutions and recommendations to mitigate or eliminate the future risks?
3. How is the defect forecasting using ARIMA?
4. What is the effectiveness of the risk control analyzed by creating the defect forecast?

1.3. Research Objectives

Based on the problem formulation above, the research objectives are as follow:

1. Assessing machine defect data in production process based on analysis using Reality Charting by Apollo Root Cause Analysis.
2. Providing solutions and recommendations to mitigate and/or eliminate the future machine defects of PT. Yoska Prima Inti.
3. Analyzing the risk control using defect forecasting by ARIMA method.
4. Finding out the effectiveness of the risk control.

1.4. Research Scope

The research scope has a function to limit the research in order focus the study. Below is the research scope:

1. The research is in knowledge base of Risk Management, Root Cause Analysis, and Forecasting.
2. The research is being conducted at PT. Yoska Prima Inti.
3. The method that will be used is Reality Charting by Apollo Root Cause Analysis and ARIMA.

1.5. Research Benefits

The research is expected to increase the knowledge, particularly in Risk Management and Reality Charting by ARCA and forecasting by ARIMA. The other benefit of this research is to enhance the application or usage of Reality Charting by ARCA and forecasting by ARIMA in industrial practical problems.

CHAPTER II

LITERATURE REVIEW

In this chapter, the researcher will explain about inductive and deductive studies. The inductive study is a study derived from previous researches that have already scientifically published. The deductive study is a study that explains the basic theory used in this research generally. Both of the studies are required to identify the gaps between previous studies and current study to avoid any plagiarism.

2.1. Inductive Study

The inductive study below is derived from the previous researches accumulated from total 15 journals. It is mentioned the title of researches, authors, years, problems, method used, and solutions.

Kurniawan et al. (2013) mentioned that risks occur in onshore receiving fields which are caused by failures in equipment on purification and gas compression. The researchers applied probabilistic FMEA and 5 whys method RCA. The finding of the research is improvement program to reduce critical risk such as maintenance and long term pressure calibration.

Strang (2013) researched on a way to understand how a research guideline of risk management can be improved. The applied methods are general analytic approach and descriptive statistics. The research finding consists of usage comparison between post positivist, pragmatic or social constructivists.

Kloberkoch et al. (2017) researched the problem of operative risks during the production process that reduce the quality requirement. The applied method was risk modelling. The research finding was an operative production risk system.

Duphily (2014) researched the problem that can help to determine suitable method and software tools when detailed root cause analysis is needed. The research applied RCI method. It resulted comparison over 17 methods of RCA.

Kemblowski (2017) researched on a demonstration about how bayesian network can be used to assess and manage risks. The used method was Bayesian network with findings that consists of model of BBN and model of DDSM.

Setiawan et al. (2017) researched the identification on potential failure impact of risk in fabrication process with 23 failure modes. The method used was FMEA, which is commonly employed in this research field. The finding was a strategy to carry out regular inspection and maintenance.

Rolik (2016) researched on the analysis of possible risk, the measurement, and a way to reduce the negative impacts. The methods applied were SWOT and Mc Kinsey matrix. The findings consist of analyzed possible risk and risk input in project management.

Millan and Merlo (2014) researched on an identification the appropriate use of causal analysis techniques. The used method was NERC. The findings were the comparison between ACA and RCA.

Pittiglio et al. (2014) researched on the change of legislation from risk based on risk rates. The used method was advanced KB techniques. The finding consists of result of risk assessment on new rules implementation that focused on equipment.

Hu and Wang (2016) researched on the potential risk in assembly. The used method was job hazard analysis. The finding was technical and management measures as risk strategies.

Aurisichio et al. (2016) researched the understanding of the causes on adverse events associated with complex engineered systems. The used method was RCA approach based on the IBIS and FAD notations. The finding proposed IBIS-FAD approach to provides a rich description of the causes for an accident presented in a manner that facilitated information access and understanding.

Hrbackova (2016) researched the risk-based thinking incorporated with quality management system. The used methods were QAM and FMEA. The finding of the research was utilization methods of FMEA and QAM for identification, analysis, and risk assessment in production process.

Denas (2015) researched on the decrease deviations in time and cost estimation at complete. The method applied was EVM while the finding resulted the proposed model that can be efficiently applied through real case software projects.

York et al. (2014) researched the way to reduce loss of failure in global competitive market. The research method was cause mapping. The research finding indicated that cause mapping is efficient, effective, and easy to use.

Healy (2013) researched about the importance of RCA and its role in the continuous improvement of equipment over the life of the plant. The methods used by researcher were top down and bottom up. The finding explains that a RCA undertaking was only beneficial to the organization if it has been well focused.

After conducting review to all of above journals reviews, the comparison among 15 journals and the current research will be done and presented on the table 2.1 named as journal ticking table.

Table 2.1 Journal ticking table

Authors (Year)	Scalability	Clearly Define Problem	Multiple Root Causes	Corrective Action	Solution Rank	Software	Articulate the Need	All Stakeholder Encouragement	Result
Kurniawan et al. (2013)	√	√	√	√					Improvement program to reduce critical risk such as maintenance and long term pressure calibration
Strang (2013)					√		√		Usage comparison between post positivist, pragmatic or social constructivists.
Kloberkoch et al. (2017)	√	√				√			An operative production risk system
Duphily (2014)		√			√	√			Comparison over 17 methods of RCA
Kemblowski (2017)	√	√				√	√		Model of BBN and model of DDSM

Authors (Year)	Scalability	Clearly Define Problem	Multiple Root Causes	Corrective Action	Solution Rank	Software	Articulate the Need	All Stakeholder Encouragement	Result
Setiawan et al. (2017)	√	√	√	√					A strategy to carry out regular inspection and maintenance.
Rolik (2016)	√	√		√			√		Analyzed possible risk and risk input in project management
Millan and Merlo (2014)	√	√	√		√		√		Comparison of ACA and RCA.
Pittiglio et al. (2014)	√			√				√	Result of risk assessment on new rules implementation that focused on equipment.
Hu and Wang (2016)	√	√	√				√		Technical and management measures as risk strategies.
Aurisichio et al. (2016)	√	√	√				√		Proposed IBIS-FAD approach

Authors (Year)	Scalability	Clearly Define Problem	Multiple Root Causes	Corrective Action	Solution Rank	Software	Articulate the Need	All Stakeholder Encouragement	Result
									provides a rich description of the causes for an accident presented in a manner that facilitates information access and understanding.
Hrbackova (2016)	√				√		√		Utilization methods of FMEA and QAM for identification, analysis, and risk assessment in production process
Denas (2015)	√	√			√		√		The proposed model can be efficiently applied through real case software projects.

Authors (Year)	Scalability	Clearly Define Problem	Multiple Root Causes	Corrective Action	Solution Rank	Software	Articulate the Need	All Stakeholder Encouragement	Result
York et al. (2014)	√	√	√	v			√		Cause mapping is efficient, effective, and easy to use method.
Healy (2013)		√	√				√		A RCA undertaking is only beneficial to the organization if it has been well focused.
Mayanti (2018)	√	√	√	√	√	√	√	√	Current research

2.2. Deductive Study

2.2.1 Risk Management

Based on Defense (2015), risk can be defined as the combination of the probability of an event and its consequences. Risk management is a central part of any organization's strategic management. It is the process whereby organizations methodically address the risks attaching to the activities with the goal of achieving sustained benefit within each activity and across the portfolio of all activities.

The focus on risk management to identify and treat the risks. The risk can be caused from both internal and external factors. Figure 2.1 is the risk management process from Defense (2015):

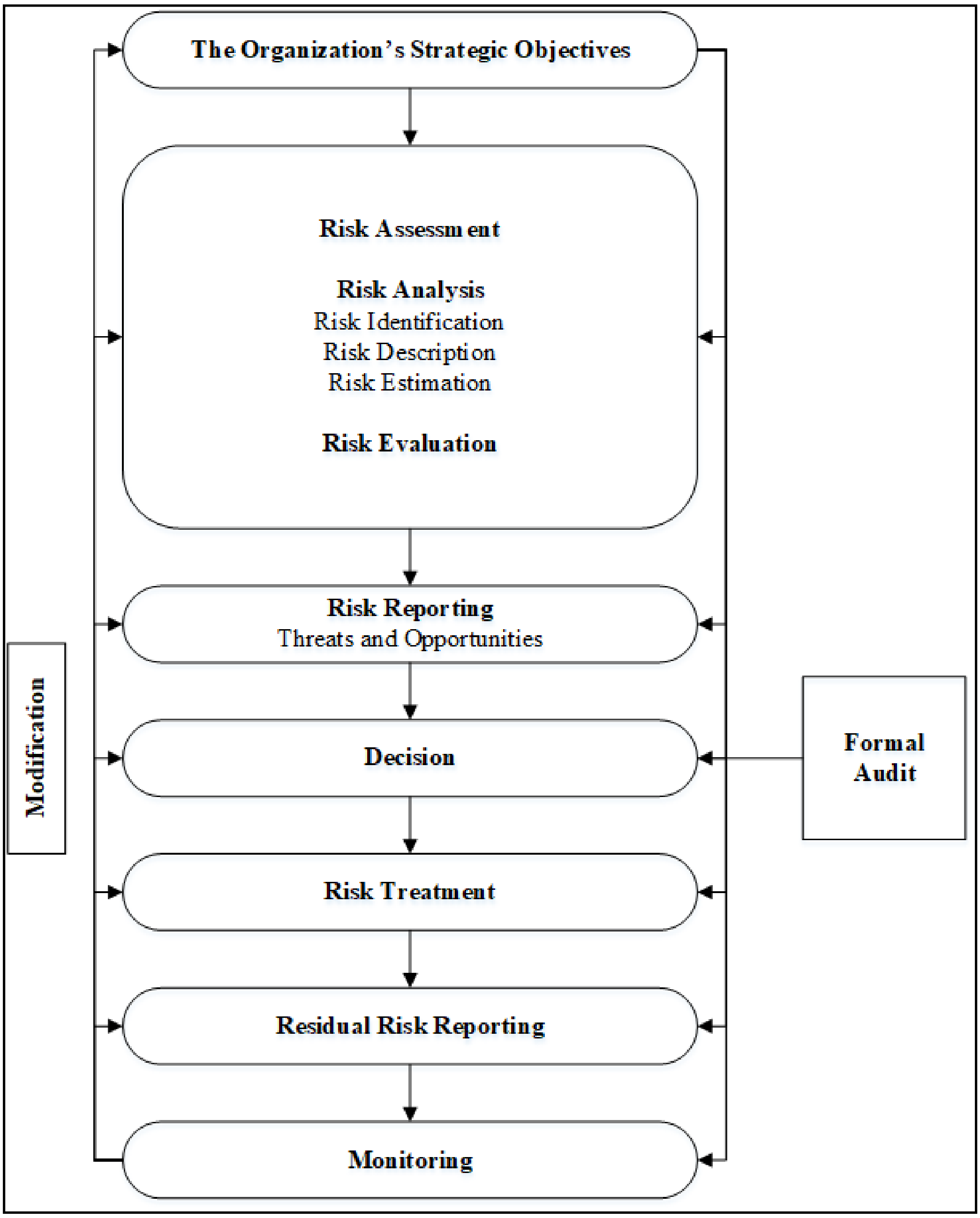

Figure 2.1 Risk management process

The process taken from risk management for this research are risk identification and risk treatment. The risk identification is implemented by using root cause analysis, while the risk treatment is implemented by calculating the risk mitigation which also known as defect mitigation. Defect mitigation itself is the calculation of defect reduction. The reduction value and defect residual are obtained from the following formulas by Goa (2017). The total reduction value itself is obtained by totalize the reduction value for each problem solutions.

$$Defect\ Reduction\ Value = \frac{EC-CC}{\sum(EC-CC)} \times 100\% \quad (2.1)$$

$$Defect\ Residual = Defect\ Frequency - (Defect\ Frequency\ \times \sum DRV) \quad (2.2)$$

Goa (2017) stated that risk assessment is the overall process of risk analysis and evaluation. The risk analysis includes risk identification, risk description, and risk estimation. Risk identification is to identify organization's uncertainty. The identification should be done in methodological way. The risk description is to display the identified risks in structured format. The risk estimation can be quantitative or semi quantitative/qualitative in terms of the probability of the occurrence. The risk evaluation is used to make decisions about the significance of risks to the organization.

Goa (2017) stated that risk reporting is divided into two, internal reporting and external reporting. The internal reporting includes board of directors, business units, and individuals. The external reporting includes government and stakeholders.

Goa (2017) stated that risk Treatment is process of selecting and implementing measures to modify the risk. Based on Goa (2017), risk financing refers to the mechanisms (e.g. insurance programs) for funding the financial consequences of risk. Risk financing is not generally considered to be the provision of funds to meet the cost of implementing risk treatment. Table 2.2 shows several techniques used in risk management:

Table 2.2 Techniques in risk management

Risk Identification	**Risk Analysis**		
	Upside Risk	**Both**	**Downside Risk**
1. Brainstorming 2. Questionnaires 3. Business studies which look at each business process and describe both the internal processes and external factors which can	1. Market survey 2. Prospecting 3. Test marketing 4. Research and Development 5. Business impact analysis	1. Dependency modelling 2. SWOT 3. Event tree analysis 4. Business continuity planning 5. BPEST	1. Threat analysis 2. Fault tree analysis 3. FMEA (Failure Mode & Effect Analysis) 4. RCA

Risk Identification	Risk Analysis		
	Upside Risk	Both	Downside Risk
influence those processes 4. Industry benchmarking 5. Scenario analysis 6. Risk assessment workshops 7. Incident investigation 8. Auditing and inspection 9. HAZOP (Hazard & Operability Studies) 10. RCA		6. Real Option Modelling 7. Decision taking under conditions of risk and uncertainty 8. Statistical inference 9. Measures of central tendency and dispersion 10. PESTLE	

2.2.2 Root Cause Analysis

Vorley (2008) stated that root cause analysis is a method used to address a problem or non-conformance, in order to get to the "root cause" of the problem. It is used so the causes can be corrected or eliminated, and to prevent the problem from recurring. The root cause analysis itself is application of a series of well known, common sense techniques which can produce a systematic, quantified and documented approach to the identification, understanding and resolution of underlying causes.

Organizations especially companies tend to respond to problems with short term solutions. Vorley (2008) mentioned that the organizations tend to rely on quick fixes which result in repetition of the same tasks due to the problem recurrence. Focusing on short term solutions is not a recipe for increased profitability and organizational growth.

Vorley (2008) explained about the basic steps of completing a root cause analysis. The basic steps consist of defining the problem, understanding the problem, immediate action, corrective action, and confirming solutions. There are also several root cause analysis techniques mentioned by Vorley (2008) which are 5 why's, pareto analysis, cause and effect diagram, brainstorming, Apollo, fault tree diagram, check sheet, etc.

2.2.3 Apollo Root Cause Analysis

Gano (1999) stated that traditional root cause analysis is a believe that finding and eliminating the single root cause will solve the problem. However, Gano (1999) realized that traditional root cause analysis methods were not working to be implemented in large and severe problems. The single root cause is a myth that was preventing problems from truly getting solved.

Gano (1999) proposed a method called Apollo root cause analysis. This method utilized a process called reality charting which encompasses all known causes as well as the relationships between each other to provide more complete picture. Meanwhile, Gano (1999) also stated that the other methods of problem solving are linear and subjective according to the point of view of the storyteller.

In reality charting, the process of the analysis explained by Gano (1999) is started by defining a problem, asking why the problem occurred, ensuring that the answer includes both action and condition, and asking why of each action and condition, while other forms of problem solving often focus only on the action causes and ignore the condition causes. Figure 2.2 shows the reality charting implemented in Apollo root cause analysis.

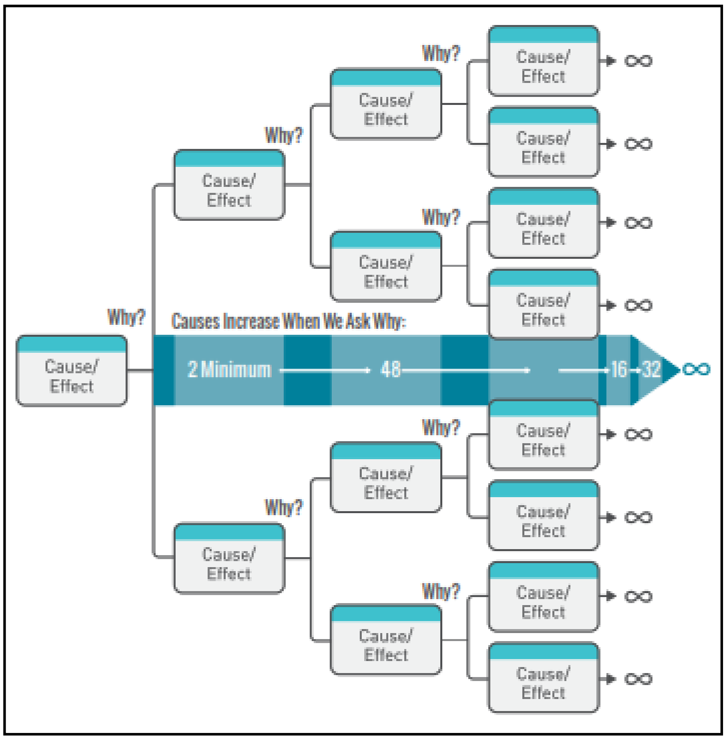

Figure 2.2 Reality chart by Gano (1999)

There are several benefits of Apollo root cause analysis and reality charting. The benefits were mentioned by Gano (1999) shown as follows:

1. Create a common reality, since all stakeholders can see the causal relationship in reality chart.
2. Eliminate recurring problem, Apollo root cause analysis trains the user to identify solutions within organization's control, prevent recurrence, and meet the organizations goals and objectives.
3. Get a definite result, Apollo root cause analysis is used to find clear causal connection between solutions and the defined problem, so the user can be confident that the problem is directly addressed and resolved effectively.
4. Address any size of problem.
5. Eliminate assumptions, the evidence required for each cause ensures the there is no story telling involved.
6. Avoid pointing fingers, since the goal is to find solutions that prevent recurrence, not find a guilty party.

2.2.4 Forecasting

Diebold (2017) stated that forecasting is an activity to calculate or predict some future events or conditions, usually as a result of rational study or analysis of pertinent data. Forecasting is widely used today in many fields, especially in industry, marketing, economy and finance. Such as in consumable product manufacturing, an accurate prediction of the future demand is very helpful in providing precise inventory, reducing transportation costs, then increasing profit.

Diebold (2017) mentioned that there are several considerations that are relevant for any forecasting tasks. Those considerations are forecast object, information set, model uncertainty and improvement, forecast horizon, structural change, forecast statement, forecast presentation, decision environment and loss function, model complexity and the parsimony principle, and the last is unobserved components.

One mathematical approach to forecast time series is known as the Box Jenkins method and was suggested by Box and Jenkins (1970). Technically, the Box Jenkins technique is an integration of the autoregressive and the moving average methods, so it is also named ARIMA (Autoregressive, Integrated, Moving Average) model. Since its first introduction, this ARIMA approach has become widely used in many fields such as specification, estimation, and diagnostic (Thomas 1983).

Box and Jenkins (1970) mentioned on the book that the ARIMA methodology is a statistical method for analyzing and building a forecasting model which best represents a time series by modeling the correlations in the data. In the empirical research, many advantages of the ARIMA model were found and support it as a proper way in especially short-term time series. Taking advantage of its strictly statistical approach, the ARIMA method only requires the prior data of a time series to generalize the forecast. Hence, the ARIMA method can increase the forecast accuracy while keeping the number of parameters to a minimum.

Thomas (1983) stated on the book that a significant difference between the ARIMA methodology and previous methods is that ARIMA excludes assumptions about the number of terms or the relative weights to be assigned to the terms. To specify the model, the analyst first selects the appropriate model, including the number of p, d, q terms, then calculates the coefficients and gives a refined suggestion of the model parameters by using a nonlinear least squares method.

Box and Jenkins (1970), stated that ARIMA has several data requirements in order to be able to better use the ARIMA method. The requirements consist of at least 40 historical data points, and this research has 43 historical data points. Also, it works best when the data exhibits a stable or consistent pattern, tested using homoscedasticity test. It will be superior to be implemented in exponential smoothing, where the data is reasonably long and the correlation between past observation is stable.

2.2.5 ARIMA Model

Kit (2015) stated that ARIMA modelling is an approach to time series forecasting that has flexibility to fit a model which is adapted from the data structure itself. ARIMA model is the most widely used to time series forecasting, and provides complementary approaches to the problem. ARIMA model aims to describe the autocorrelations in the data. Time series itself is a collection of observations of well-defined data items obtained through repeated measurements over time. As example of time series data is measurement of the unemployment level each month of the year. The data obtained in this research is also time series data, because it measures the machine defect frequency each month from 2016 until 2018. The ARIMA model has three main components, mentioned as follows:

1. Autoregressive (AR) refers to a model that shows changing variable that regresses on its own lagged.
2. Integrated (I) represents the differencing of raw observations to allow the time series to be stationary.
3. Moving Average (MA) incorporates dependency between observation and residual error from moving average model applied to lagged observation.

Kit (2015) mentioned that the AR component represents the autocorrelation between current and past observations while the MA component describes the autocorrelation of the error. The integrated component itself represent the level of differencing required to transform a non-stationarity series into stationarity series. The non-seasonal ARIMA model is denoted by (p, d, q) where p represents AR, d represents differencing, and q represents MA. Below are several tests conducted within ARIMA Model.

Kit (2015) mentioned that ARIMA is a form of regression analysis that gauges the strength of one dependent variable relative to other changing variables. The goal is to predict future condition by examining the differences between values in the series.

A. Stationarity

There are several tests that can be used to define the stationarity of the data. The stationarity test needs to be done to identify whether the data needs differencing or not. The common tests used are unit root tests, and trend tests. After the differencing is exposed, yet the data are not stationary, Box-Jenkins approach can be applied. However, if the data is stationary, Box-Jenkins approach can be directly applied. Box-Jenkin approach itself is an approach to find the best fit of a time series model to past values of a time series. Figure 2.3 shows the difference between stationary and non-stationary time series by Kit (2015).

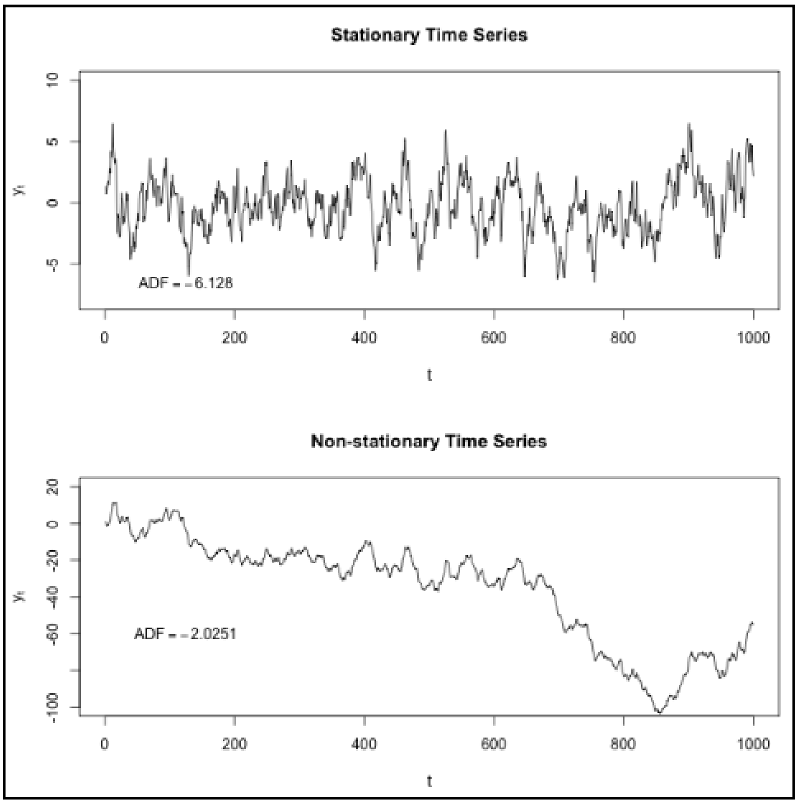

Figure 2.3 Stationary and non-stationary time series

Kit (2015), stated that in Box Jenkins approach, the approach starts with an assumption that the process generated the time series can be approximated using ARIMA if the model is non stationary. The process itself is stochastic modelling which has 3 steps which are identification of the data, estimation of the parameter, and diagnostic checking to evaluate the fitted model in the context of the available data and check for areas where the model may be improved. In diagnostic checking, the XLSTAT is used to compute the AICC for ARIMA models. The minimum AICC is chosen.

As for the model generation, the parameters consist of AICC, MSE, AR, MA, and constant. AICC stands for AICC stands for AIC with a correction for small sample sizes, while AIC stands for Akaike Information Criterion which is an estimator of the relative quality of statistical models for a given set of data. AICC has the advantage of tending to be more accurate than AIC. MSE stands for mean square error, which tells about how close a regression line is to a set of points. The smaller the MSE, the closer in finding the line of best fit. The one that gave the smallest MSE would be the line of best fit. AR stands for auto regression, which is representation of a type of random processes. AR in

ARIMA, indicates that the evolving variable of interest is regressed on its own lagged values. MA stands for moving average, which indicates the regression error, that actually a linear combination of error terms whose values occurred contemporaneously and at various times in the past.

a. ADF Test

The test for unit root's presence in a time series is Augmented Dickey-Fuller (ADF) test. The formula of ADF test can be seen below. The testing procedure of ADF test is applied to the following model.

$$\Delta Y_t = \alpha + \beta_1 t + \beta_2 t^2 + \gamma Y_{t-1} + \emptyset_1 \Delta Y_{t-1} + \cdots + \emptyset_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \text{ .... (2.3)}$$

Where:
Δ is the first different operator
α is a constant
β_1 is the coefficient on a time trend
β_2 is the coefficient on a squared time trend
$\gamma = 0$

The ADF test has hypothesis as follows:
H0 = The series is non-stationary (presence of unit root), $\gamma = 0$
Ha = The series is stationary, $\gamma < 0$

b. KPSS Test

KPSS test which also known as Kwiatkowski-Phillips-Schmidt-Shin test, is a test for stationarity as the null hypothesis opposed to the ADF test. Kit (2015) stated that KPSS test is oversized for processes that are highly autoregressive because it uses a semiparametric heteroscedasticity and autocorrelation consistent covariance estimator with positive finite sample bias. Below is the hypothesis of KPSS test.

The KPSS test, on the other hand, has the following hypotheses:
H0 = The series is stationary

Ha = The series is non-stationary (presence of unit root).

The formula for KPSS test is shown below.

$$X_t = r_t + \beta t + \varepsilon_1 \quad \text{(2.4)}$$

Where:

βt is deterministic trend

r_t is a random walk

ε_1 is a stationary error

c. Mann-Kendall Trend Test

Mann-Kendall trend test is used to test the presence of trend in a time series. The tested data do not have to be normally distributed since it is not a parametric test. The statistic obtained from the tests are S statistic and Kendall's tau. The S statistic divided into two categories which are positive and negative. The positive S means the upward trend while the negative S means a downward trend. The Kendall's tau itself measures the strength of dependence between two variables. The example of trend in a time series by Kit (2015) can be seen on Figure 2.4.

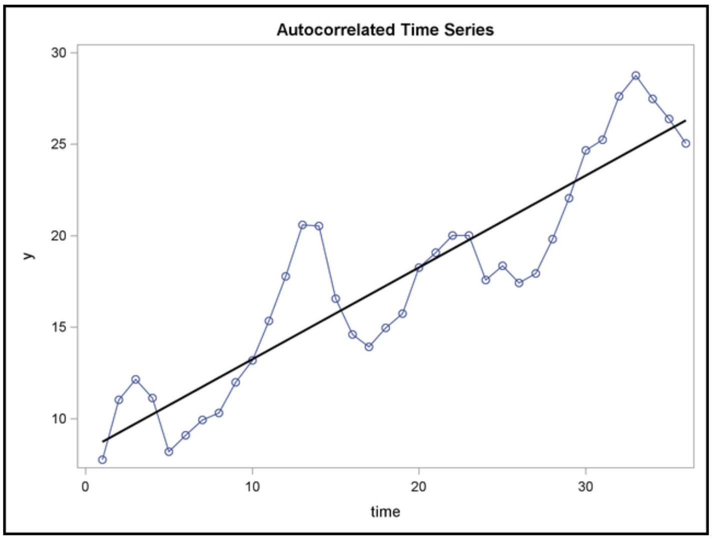

Figure 2.4 Example of trend in a time series

B. Independency

The basic assumption about the residual of ARIMA model is white noise. A white noise series have uncorrelated random shock with zero mean and constant variance. If the residuals are independent, it means that there is no more information could be extracted from the series. The way to determine the independence is to inspect the correlogram of the residuals. If the correlogram shows values that are close to zero, it means that the residuals are uncorrelated and independent. Figure 2.5 shows an example of correlogram or ACF that exhibits white noise by Kit (2015).

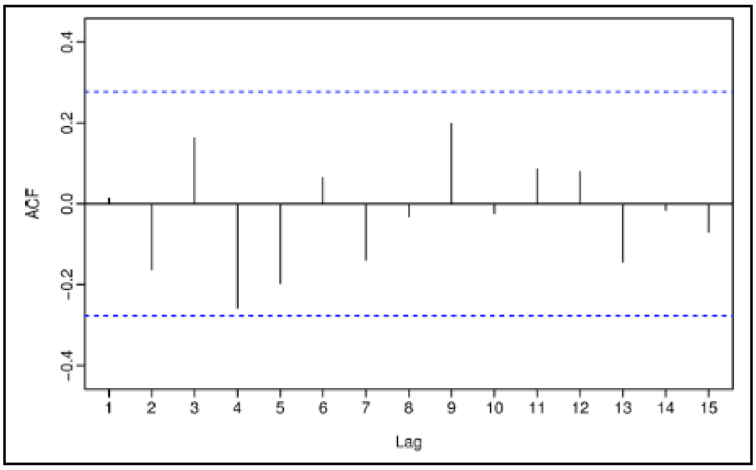

Figure 2.5 Example of correlogram or ACF that exhibits white noise

C. Homoscedasticity

Homoscedasticity is used to define the variance of the disturbance term in each observation is constant. If the residuals are homoscedastic, then the variances are stable. Kit (2015) stated that there are two main reasons why homoscedasticity is important. First is that it involves with the regression coefficients' variances, the variances should be as small as possible in order to produce maximum precision. Second is chances that the estimators of the standard errors of the regression coefficients could be wrong. The homoscedasticity can be detected using different tests, such as Spearman Rank Correlation test, the Goldfield-Quandt test, the Glejser test, and the Breusch-Pagan test.

In homoscedasticity test, especially Breusch Pagan test, the parameter used is LM observed value, LM critical value, and DF. The LM stand for Lagrange Multiplier. LM is a strategy for finding the local maxima and minima of a function subject to equality constraints.

D. Transformation

In many cases, analysis are done based on an assumption that the population is normally distributed stated by Kit (2015). However, the relevant assumptions are violated. Another researcher chooses to design a new model that retains the important aspect of the original model and satisfies the assumption rather than ignore the violation and continue with the analysis. This decision requires a transformation to the original data. One of the transformation methods is Box-Cox transformation. The Box-Cox transformation has a function to transform the original data to obtain new data with higher normality value. The transformation can be done using software. One of the software that provide this Box-Cox transformation is XLSTAT software.

In Box-Cox transformation, the used parameter is lambda. The value of the optimized lambda is obtained from the XLSTAT software. However, there is an operational action that may affect the value of the lambda. The example of the operational action is the risk mitigation itself. As example, in this case there is a proposed solution as operational action such as, conducting material studies. It can change the value of the lambda based on the implementation of the operational action. The difference way of implementing the operational action or the solutions will result in the difference of defect frequency value itself which also will result in the difference value of lambda.

E. Forecasting Comparison

The forecasting comparison is being conducted in order to measure the efficiency level of the defect prevention activities. Zawadzki (2012) stated that defect prevention effectiveness is a measure of how effective an organization’s processes, procedures, and controls are at preventing defects occurring in the first place. The value of DPE is commonly obtained based on the past project. However, due to the condition where PT.

Yoska Prima Inti does not have historical DPE value for past projects, the DPE values are chosen based on Zawadzki (2012) which are 75% and 85% for manufacturing company. The number of possible defects in terms of detailed requirement (DRQ) is also defined based on Zawadzki (2012), which is 1.84 as constant. Below is the formula of the maximum possible defects.

$$Maximum\ Possible\ Defects = Defect\ Frequency\ \times 1.84 \quad \text{.........................} (2.5)$$

CHAPTER III

RESEARCH METHOD

3.1. Problem Identification

The research was taken place in PT. Yoska Prima Inti, Gajah Tunggal Street, Pasir Jaya, Jatiuwung, Tanggerang. The company has been creating records about the machine card histories since 2016. The records contain the machine defect data that involve defect date, name of the problem, actions taken, and date end of the reparation. However, the research related to the machine defect has not been ever conducted yet. Based on the given machine defect data from the company, the actions taken were considered as short-term solutions. Hence, this research aims to know the real root causes of the problems and create the possible preventive solutions which will be able to reduce the machine defect recurring in the future upcoming period. Method used in finding the root causes is Apollo root cause analysis supported with reality charting software, while the possible solutions will be used to create mitigation analysis to be later used as input for the machine defect forecasting. The machine defect forecasting is being done using ARIMA method. The results of this research are the solutions to mitigate the defects, forecasted defect frequency for upcoming period before and after defect mitigation, and the effectiveness of the risk control implementation.

3.2. Problem Formulation

This research focuses on assessing the machine defect mitigation plan to prevent machine defect recurrence in PT. Yoska Prima Inti. The problem formulation is set as a basis to limit the research area and clearly define the issues that the researcher tries to address.

3.3. Literature Review

In literature review, the source for the references comes from previous studies and basic general theories. The previous studies can be found at the inductive study while the basic general theories can be found at deductive study. The basic general theories are mainly used to learn and find out about the method and formula used in the research. Meanwhile, the previous studies are used to know the difference of this research with the other previous researches and make sure that there is no plagiarism.

3.4. Data Collection

The data used for this research are derived from two major sources. Those are primary and secondary data. The primary data are divided into several sources which are interview, field observation, and database. The secondary data are obtained from literatures and books. In the data collection process, there is no software used due to the paper-based database system from the company. The data collected directly from PT. Yoska Prima Inti for 2 weeks long. The data collection started from April 16, 2018 until April 30, 2018.

The interview was conducted with the help of Mr. Arthur as the interviewee. Mr. Arthur is an expert in the production at PT. Yoska Prima Inti. The data gained from the interview were risk control expert rating and general view of the production process within the company. The other primary data sources are database and field observation. The data that gained from the company's database is machine defect historical data which consists of defect date, problem, actions taken, and treatment duration. The last data source of primary data is field observation. Field observation provided a general view of the production process within the company, general view of the usage of the machine, and general view of how the treatments were taken as responses of the defect occurrences.

The secondary data sources which derived from literatures and books were used to create research position to avoid plagiarism. The total literatures reviewed by the researchers were 15 journals and publications. The reviews stated about the research topic, methods used, and the finding of the researches.

3.5. Data Processing

The data processing is shown on the Figure 3.1. It is a figure of research flow. The research flow follows the method flow that is used by the researcher from the beginning until the end of the research.

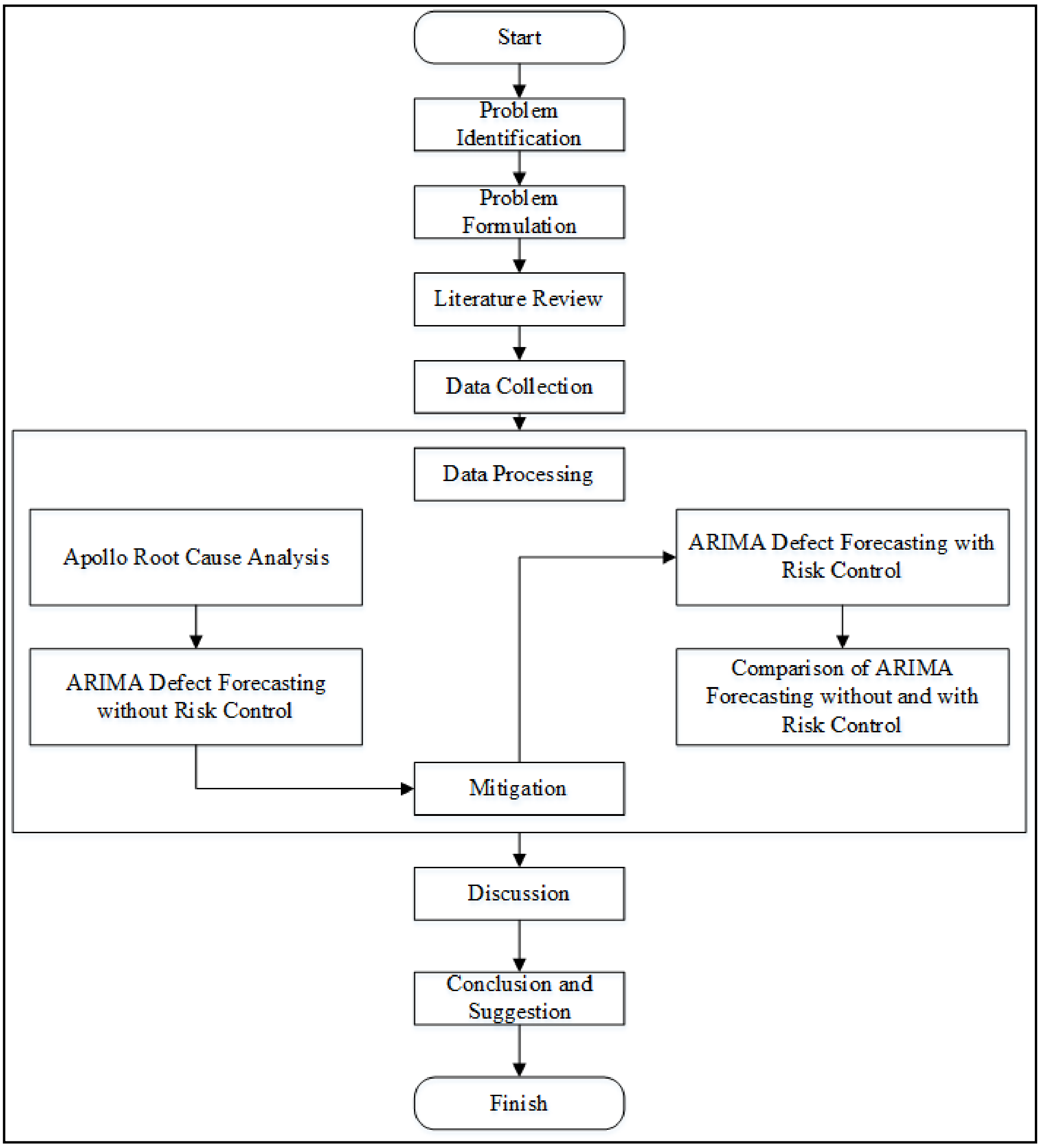

Figure 3.1 Research flow

The explanation for each step in the research flow will be explained below:

1. Problem Identification

The problem identification process is a process where the researcher defines the problem from the company so that the researcher will be able to set the overall purpose and objectives of the research and to help the researcher to determine the required data needed for the research. The identified problem for this research is that there were machine defects that keep on recurring even though the post defect actions were already taken. In addition to that, the company has not ever conducted any machine defect analysis and research yet.

2. Problem Formulation

Problem formulation was created in order to set a framework of the research. It is created to clear out matters related with the what research problem the researcher aims to address and to whom and where the research is relevant. The problem formulated of this research is that this research focuses on assessing the machine defect mitigation plan to prevent machine defect recurrence in PT. Yoska Prima Inti.

3. Literature Review

Literature review is an evaluative report of information found in previous researches related to the current research. The review should describe, summarize, evaluate, and clarify the literatures. The literature review was being divided into two parts which are inductive study and deductive study. The inductive study consists of the journal and publications reviews of the previous studies which consist of 15 journals and publications. In the inductive study the researcher also tried to do research positioning. The research positioning was being conducted by comparing the 15 previous studies with current research in order to avoid plagiarism and address the potential of the research in comparison with the previous researches. The deductive study consists of basic general theories related with the research topic to find out the suitable methods and formla to be used in the research.

4. Data Collection

Data collection is a process of gathering and measuring information on variables of interest, in established systematic process that enables one to answer stated research questions, conduct tests, and evaluate outcomes. The data collection here was being done at PT. Yoska Prima Inti for two weeks long, from April 16, 2018 until April 30, 2018. The process of data collection was divided into two processes which are primary data and secondary data. the primary data comes from interview with the expert from the company with risk control expert rating and general view of the production process as the outcomes, the next one is data obtained from company’s database, the outcome for this process is machine defect historical data, and the last one is field observation which has outcomes such as general view of the production process within the company, general view of the usage of the machine, and general view of how the treatments were taken as responses of the defect occurrences.

5. Data Processing: Apollo Root Cause Analysis

Data processing is a series of actions performed on data to verify, organize, transform, integrate, and extract information in appropriate output. In this section of data processing, Apollo root cause analysis is being done. The Apollo root cause analysis is being done to find the real root causes that cause the machine defects problems to occur and keep on recurring. The analysis also provide evidence for each causes. Besides evidence, the analysis also helps the researcher to generate suitable and acceptable solutions based on the causes and evidences. In this Apollo root cause analysis, there is a software that is being used which called as reality charting software. The outputs for this process are root causes and solutions for the problems. The output of the processes will later be used in risk mitigation process as an input.

6. Data Processing: ARIMA Defect Forecasting without Risk Control

In this ARIMA defect forecasting without risk control process, the defect is simply forecasted for the next twelve months using ARIMA. The input for this process is machine defect frequency from 2016 until 2018. The forecasting is being done without the influence of the previous step which is Apollo root cause analysis. The result of this step is forecasted defect frequency for the next twelve months. The output will be later used as input to do comparison with the forecasted defect frequency which has been influenced with risk control.

7. Risk Mitigation

Risk mitigation is a systematic reduction in the extend of exposure to a risk and / or likelihood of its occurrence. In this step, the solutions obtained from Apollo root cause analysis are being used as inputs and acted as risk controls. The mitigation is done by calculating the defect reduction value for each risk control and calculationg the defect residual. In calculation of defect reduction value, the risk control expert rating is being used also as an input to measure the current and expected conditions rating. The calculation of defect residual is being done after finishing the calculation of defect reduction value. The output of this step is monthly defect residuals which later be used as inputs for the ARIMA defect forecasting with risk control.

8. Data Processing: ARIMA Defect Forecasting with Risk Control

In this ARIMA defect forecasting with risk control process, the defect residual is simply forecasted for the next twelve months using ARIMA. The input for this process is machine defect residual from 2016 until 2018 which were obtained from the risk mitigation. The result of this step is forecasted defect frequency for the next twelve months with an influence from the risk control. The output will be later used as input to do comparison with the forecasted defect frequency which has not been influenced with risk control.

9. Comparison of ARIMA Forecasting without and with Risk Control

The comparison of ARIMA forecasting without and with risk control is conducted to measure the effectiveness of the solutions implementation. The calculations consist of the calculation of maximum possible defect and calculation of defect prevention effectiveness on 75% level of effectiveness and 85% level of effectiveness. The determination of the effectiveness levels was done by using literature review due to the condition where the company does not have any historical defect prevention effectiveness value for the past projects. The input for the calculation itself is the forecasted defect frequency before and after risk mitigation. The output for this step is monthly defect frequencies.

10. Discussion

Discussion has an objective to interpret and describe the significances of the research findings and explain any new understanding or insight about the problem taken the findings into considerations. The discussion is being divided into three sections which are root cause analysis in machine defect, risk mitigation, and machine defect forecasting. In the discussion of each section, the researcher explains any factors that might influence the implementation of the research result which are ignored due to research limitation and which are taken into considerations for future research.

11. Conclusion and Suggestion

In this section, the conclusion is created to answer all of the problem formulated in the beginning of the research. The conclusion is derived from the research results. In addition to the conclusion, the suggestion is generally arising out of the research limitations that have been identified. The research limitation itself is discussed on the discussion chapter. This means that the suggestions are derived from the discussion chapter. The suggestions address matter or factors that may be beneficial for the company and to be used for future research.

3.6. Discussion

After all data processing were finished. The discussion then was being conducted to discuss the result of the data processing which are the ARIMA defect forecasting and the effectiveness of the risk control. In the discussion, also mentioned several factors that may relate to the research.

3.7.Conclusion and Suggestion

In conclusion and suggestion, the problem formulations which are formulated since the beginning of the research, are being answered. There are also several suggestions made for the company and future related researches.

CHAPTER IV

DATA COLLECTION AND PROCESSING

4.1 Data Collection

This research was taken a place at PT. Yoska Prima Inti (YPI) that manufacture automotive components in metal stamping, welding, painting, and dies and jig fixtures. The company located at Gajah Tunggal Street, Pasir Jaya, Jatiuwung, Tanggerang – Banten. The data obtained from the company is historical data from 2016 until 2018. The work area for this research is in production of PT. Yoska Prima Inti. Root cause analysis will be conducted to define the risk causes and develop risk control. Later forecasting will be conducted to see the effectiveness of the risk control. The data for both analysis were obtained from the production historical data of the company, literature review, and interview with the expert. The data were collected from the company consists of machine defect data (machine type, date, problem, given action, and repair duration), while the literature review gives sequential formula to do the analysis with the given data. the interview is being conducted to obtain the rating for the related analysis. There is one expert for this research, which is head of production and marketing in PT. Yoska Prima Inti. The detailed data for this research will be further explained below.

4.1.1 Machine Defect Data

This research is specified to analyze the machine defect on stamping machine with 300T capacity. The machine has an average production which is known as gross stroke per hour (GSPH) for 250 strokes. The machine defect data from the production of 300T stamping machine is shown on the Table 4.1, 4.2, and 4.3.

Table 4.1 Defect Frequency

DATE	DEFECT FREQUENCY	DATE	DEFECT FREQUENCY
Jan-16	1	Mar-17	1
Feb-16	1	Apr-17	1
Mar-16	1	May-17	2
Apr-16	1	Jun-17	1
May-16	1	Jul-17	1
Jun-16	1	Aug-17	2
Jul-16	1	Sep-17	2
Aug-16	1	Oct-17	2
Sep-16	1	Nov-17	2
Oct-16	1	Dec-17	2
Nov-16	1	Jan-18	2
Dec-16	1	Feb-18	3
Jan-17	1	Mar-18	3
Feb-17	2	Apr-18	4

Table 4.2 Machine Defect Historical Data

Date	**Defect Frequency**	**Implemented Action**	**Problem**
Jan-16	1	Replace with new sill and replace with new screw	Sill, break, & screw holder leaked
Feb-16	1	Replace with new sill	Machine overload
Mar-16	1	Replace with new seal	Flywheel seal leaked
Apr-16	1	Repair pin	Dies height pin is broken
May-16	1	Replace with new sill and replace with new screw	Sill, break, & screw holder leaked
Jun-16	1	Outhouse service	Worn teeth of dies height
Jul-16	1	Replace with new axle bearing	Axle bearing of flywheel is broken
Aug-16	1	Replace with new seal and air tube	Seal, air tube leaked
Sep-16	1	Replace with new sill	Sill break leaked
Oct-16	1	Tighten the screw	Dies head screw slacked
Nov-16	1	Replace with new tube	Oil tube leaked
Dec-16	1	In-house repair	Cylindrical axle bended
Jan-17	1	Overload service and replace with new sill	Machine overload
Feb-17	2	Replace with new seal and air tube, Replace with new sill and replace with new screw	Seal, air tube leaked, Sill, break, & screw holder leaked
Mar-17	1	Outhouse service	Worn teeth of dies height
Apr-17	1	Replace with new axle bearing	Axle bearing of flywheel is broken
May-17	2	In-house repair, Tighten the screw	Cylindrical axle bended, Dies head screw slacked
Jun-17	1	Replace with new sill and replace with new screw	Sill, break, & screw holder leaked
Jul-17	1	Replace with new seal	Flywheel seal leaked
Aug-17	2	Replace with new tube, Overload service and replace with new sill	Oil tube leaked, Machine overload
Sep-17	2	Cleanse up and oil replenishment, Replace with new sill and replace with new screw	Machine overload, Sill, break, & screw holder leaked

Date	Defect Frequency	Implemented Action	Problem
Oct-17	2	Replace with new dies head, Overload service and replace with new sill	Broken dies head, Machine overload
Nov-17	2	Outhouse service, Overload and air valve setting	Worn teeth of dies height, Machine overload
Dec-17	2	Cleanse up and oil replenishment, Tighten the screw	Machine overload, Dies head screw slacked
Jan-18	2	Replace with new sill, Replace with new tube	Machine overload, Oil tube leaked
Feb-18	3	Replace with new seal, Replace with new dies head, Tighten the screw	Flywheel seal leaked, Broken dies head, Dies head screw slacked
Mar-18	3	Replace with new sill and replace with new screw, Replace with new tube, Overload service and replace with new sill	Sill, break, & screw holder leaked, Oil tube leaked, Machine overload
Apr-18	4	Overload and air valve setting, Overload service and replace with new sill, Outhouse service, Replace with new dies head	Machine overload, Machine overload, Worn teeth of dies height, Broken dies head

Table 4.3 Machine Defect Summary

No	Problem	Implemented Action	Repair Duration (Working Days)
1	Flywheel seal leaked	Replace with new seal	3
2	Dies height pin is broken	Repair pin	1
3	Worn teeth of dies height	Outhouse service	3
4	Axle bearing of flywheel is broken	Replace with new axle bearing	1
5	Seal, air tube leaked	Replace with new seal and air tube	1
6	Sill break leaked	Replace with new sill	27
7	Oil tube leaked	Replace with new tube	1
8	Broken dies head	Replace with new dies head	1
9	Machine overload	Cleanse up and oil replenishment	1
		Replace with new sill	1
		Overload and air valve setting	1
		Overload service and replace with new sill	1
10	Dies head screw slacked	Tighten the screw	1
11	Cylindrical axle bended	In-house repair	1
12	Sill, break, & screw holder leaked	Replace with new sill and replace with new screw	1

4.1.2 Expert

There was one expert who has been interviewed regarding to the data needed for the research. The factual data obtained from the expert is rating related to the risk control. The risk control is a result of the Apollo Root Cause Analysis conducted based on the defect data as mentioned in Table 4.1-4.3. The risk control rating data later will be used to analyze the effectiveness of risk control implementation which will be calculated using forecasting method of ARIMA. The data given by expert can be seen on the Table 4.4.

Table 4.4 Risk Control Expert Rating

No	Major Causes	Solutions	Current Condition (1-10)	% CC	Expected Condition (1-10)	% EC
1	Aging	Create routine maintenance schedule	4	15%	7	18%
2	No routine maintenance	Create routine maintenance schedule	4	15%	7	18%

No	Major Causes	Solutions	Current Condition (1-10)	% CC	Expected Condition (1-10)	% EC
3	Over Tonnage	Conduct material studies	5	19%	7	18%
4	Operator Error	Create good and safe working environment to maintain operator focus	6	22%	9	23%
5	Overuse	Lower tonnage capacity	8	30%	9	23%
		Total	27	100%	39	100%

4.2 Data Processing

4.2.1 Apollo Root Cause Analysis

The root cause analysis is carried out using reality charting software. The Apollo Root Cause Analysis is conducted to find out the real causes of the problem and the possible solutions in order to reduce the problem occurrence in the future. The input for the analysis is problem name, problem evidence, and causes. Figure 4.1 shows the Apollo RCA graph. The possible solutions generated based on the graph finalization of the root cause analysis is shown on the Table 4.5.

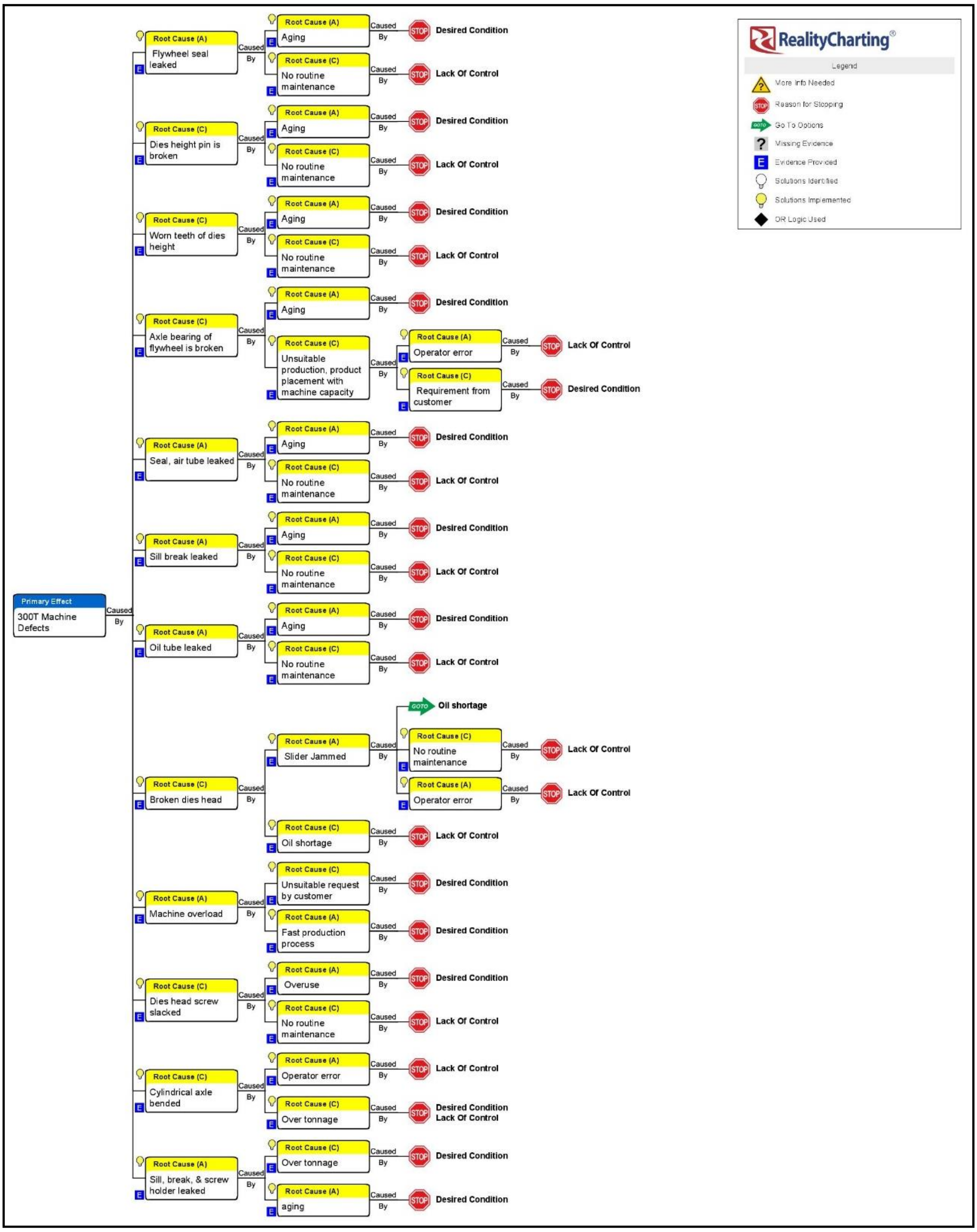

Figure 4.1 Apollo Root Cause Analysis Graph

Table 4.5 Risk Control

Date	Problem	Implemented Action	Major Causes	Risk Control
Jan-16	Sill, break, & screw holder leaked	Replace with new sill and replace with new screw	Over Tonnage	Conduct material studies
Feb-16	Machine overload	Replace with new sill	Overuse	Lower tonnage capacity
Mar-16	Flywheel seal leaked	Replace with new seal	Aging	Create routine maintenance schedule
Apr-16	Dies height pin is broken	Repair pin	Aging	Create routine maintenance schedule
May-16	Sill, break, & screw holder leaked	Replace with new sill and replace with new screw	Over Tonnage	Conduct material studies
Jun-16	Worn teeth of dies height	Outhouse service	Aging	Create routine maintenance schedule
Jul-16	Axle bearing of flywheel is broken	Replace with new axle bearing	Over Tonnage	Conduct material studies
Aug-16	Seal, air tube leaked	Replace with new seal and air tube	Aging	Create routine maintenance schedule
Sep-16	Sill break leaked	Replace with new sill	Aging	Create routine maintenance schedule
Oct-16	Dies head screw slacked	Tighten the screw	No routine maintenance	Create routine maintenance schedule
Nov-16	Oil tube leaked	Replace with new tube	No routine maintenance	Create routine maintenance schedule
Dec-16	Cylindrical axle bended	In-house repair	Operator Error	Create good and safe working environment to maintain operator focus
Jan-17	Machine overload	Overload service and replace with new sill	Over Tonnage	Conduct material studies

Date	Problem	Implemented Action	Major Causes	Risk Control
Feb-17	Seal, air tube leaked, Sill, break, & screw holder leaked	Replace with new seal and air tube, Replace with new sill and replace with new screw	Aging, Over Tonnage	Create routine maintenance schedule, Conduct material studies
Mar-17	Worn teeth of dies height	Outhouse service	Aging	Create routine maintenance schedule
Apr-17	Axle bearing of flywheel is broken	Replace with new axle bearing	Over Tonnage	Conduct material studies
May-17	Cylindrical axle bended, Dies head screw slacked	In-house repair, Tighten the screw	Operator Error, No routine maintenance	Create good and safe working environment to maintain operator focus, Create routine maintenance schedule
Jun-17	Sill, break, & screw holder leaked	Replace with new sill and replace with new screw	Over Tonnage	Conduct material studies
Jul-17	Flywheel seal leaked	Replace with new seal	Aging	Create routine maintenance schedule
Aug-17	Oil tube leaked, Machine overload	Replace with new tube, Overload service and replace with new sill	No routine maintenance, Over Tonnage	Create routine maintenance schedule, Conduct material studies
Sep-17	Machine overload, Sill, break, & screw holder leaked	Cleanse up and oil replenishment, Replace with new sill and replace with new screw	Overuse, Over Tonnage	Lower tonnage capacity, Conduct material studies
Oct-17	Broken dies head, Machine overload	Replace with new dies head, Overload service and replace with new sill	No routine maintenance, Over Tonnage	Create routine maintenance schedule, Conduct material studies
Nov-17	Worn teeth of dies height, Machine overload	Outhouse service, Overload and air valve setting	Aging, Over Tonnage	Create routine maintenance schedule, Conduct material studies

Date	Problem	Implemented Action	Major Causes	Risk Control
Dec-17	Machine overload, Dies head screw slacked	Cleanse up and oil replenishment, Tighten the screw	Overuse, No routine maintenance	Lower tonnage capacity, Create routine maintenance schedule
Jan-18	Machine overload, Oil tube leaked	Replace with new sill, Replace with new tube	Overuse, No routine maintenance	Lower tonnage capacity, Create routine maintenance schedule
Feb-18	Flywheel seal leaked, Broken dies head, Dies head screw slacked	Replace with new seal, Replace with new dies head, Tighten the screw	Aging, No routine maintenance, No routine maintenance	Create routine maintenance schedule, Create routine maintenance schedule, Create routine maintenance schedule
Mar-18	Sill, break, & screw holder leaked, Oil tube leaked, Machine overload	Replace with new sill and replace with new screw, Replace with new tube, Overload service and replace with new sill	Over Tonnage, No routine maintenance, Over Tonnage	Conduct material studies, Create routine maintenance schedule, Conduct material studies
Apr-18	Machine overload, Machine overload, Worn teeth of dies height, Broken dies head	Overload and air valve setting, Overload service and replace with new sill, Outhouse service, Replace with new dies head	Over Tonnage, Over Tonnage, Aging, No routine maintenance	Conduct material studies, Conduct material studies, Create routine maintenance schedule, Create routine maintenance schedule

4.2.2 ARIMA Forecasting without Risk Control

The ARIMA forecasting is being done to predict the defect frequency for the next 12 months. In this section, the forecasting was conducted without the influence of risk control.

A. Box Cox Transformation

This procedure is used to modify the distributional shape of a set of data to be more normally distributed. It is conducted as data preparation. The XLSTAT software tried to find the optimized lambda for the transformation. The optimized lambda is – 1.777. The result of box cox transformation is shown on the Table 4.6.

Table 4.6 Transformed Defect Frequency

DATE	DEFECT FREQUENCY	DATE	DEFECT FREQUENCY
Jan-16	0.000	Mar-17	0.000
Feb-16	0.000	Apr-17	0.000
Mar-16	0.000	May-17	0.399
Apr-16	0.000	Jun-17	0.000
May-16	0.000	Jul-17	0.000
Jun-16	0.000	Aug-17	0.399
Jul-16	0.000	Sep-17	0.399
Aug-16	0.000	Oct-17	0.399
Sep-16	0.000	Nov-17	0.399
Oct-16	0.000	Dec-17	0.399
Nov-16	0.000	Jan-18	0.399
Dec-16	0.000	Feb-18	0.483
Jan-17	0.000	Mar-18	0.483
Feb-17	0.399	Apr-18	0.515

B. Plotting the Series (ACF and PACF)

The main tools used for the identification of model were the visual displays of the series which includes the autocorrelation function and partial correlation function. Both of them are plotted using XLSTAT with descriptive statistics test. The ACF and PACF will be used to determine the behavior and stationarity of the series. If both of ACF and PACF values are insignificant and fall within the confidence band, it indicates that the observations are independent. In such a case the time series is a white noise process and no modelling could be performed. A stationary time series has a rapidly decaying ACF. If the ACF is slow decaying, it indicates that the series may be non-stationary and requires differencing. Table 4.7 and Figure 4.2 below show the result of descriptive test.

Table 4.7 Statistical Tests

Statistic	DF	Value	P-Value
Jarque-Bera	2	4.405	0.111
Box-Pierce	6	38.462	< 0.0001
Ljung-Box	6	45.916	< 0.0001
McLeod-Li	6	44.432	< 0.0001
Box-Pierce	12	40.864	< 0.0001
Ljung-Box	12	49.775	< 0.0001
McLeod-Li	12	47.764	< 0.0001

Jarque Bera test has an interpretation as the computed p-value of Jarque Bera is higher than the significance level alpha 0.05, one cannot reject the null hypothesis H0, which means the variable from which the sample was extracted follows a normal distribution. According to the Table 4.8 above, the white noise tests can be seen on Box-Pierce and Ljung-Box. As the computed p-value of Box-Pierce and Ljung-Box are lower than the significance level alpha 0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha which means there is no white noise.

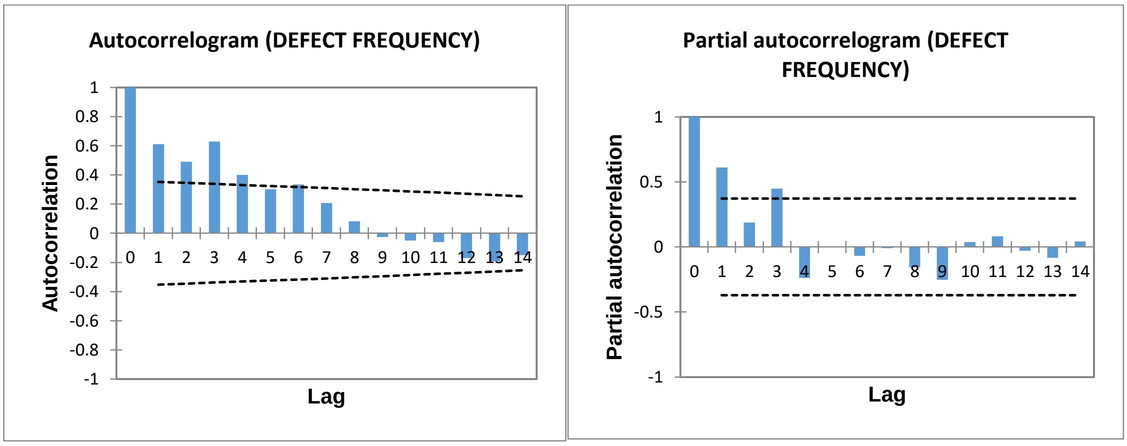

Figure 4.2 ACF and PACF of Defect Frequency Series

The ACF plot series exhibited slow decay, indicating the possibility of non-stationarity. The further stationarity test will be further explained.

C. Stationary Test

Stationarity test was carried out to confirm the initial presumption that the data were non-stationary. The test of stationarity used ADF test, KPSS test, and Mann-Kendall trend test. The result of the test is presented on the Table 4.8.

Table 4.8 Results of Stationarity Tests

Variable	**ADF Test**	**KPSS Test**	**Mann-Kendall Trend Test**	**Remarks**
	P-Value	**P-Value**	**P-Value**	
DF	0.502	< 0.0001	< 0.0001	Non-Stationary

The test confirmed that the data were non-stationary. The augmented Dickey-Fuller test and the KPSS test showed that it had unit roots. The Mann-Kendall trend test also detected a trend in the data. A data that has either a unit root or a trend was considered as non-stationary and therefore require differencing.

D. Differencing

The data were differenced once, twice, and triple to obtain the optimum *d*. The standard deviation of the original and differenced data is shown on the Table 4.9.

Table 4.9 Standard Deviations of Original Data and Differenced Data

Order, *d*	**Standard Deviation**
0	0.213
1	0.178
2	0.305
3	0.541

The result also shows that the first lag was lower than -0.5, which indicates over differencing. However, the second and third lags are higher than -0.5, and the series has positive autocorrelations out to a high number of lags, then it needs a higher order of differencing. Therefore, the differencing value to be used is $d = 0$. Therefore, the ARIMA models that seem reasonable to be tested were (1,0,0) and (1,0,1).

E. ARIMA Model and Diagnostic Checking

XLSTAT was used to compute the AICC for ARIMA models with p starting from zero to three and q starting from zero to three. The model which has the minimum AICC was chosen as the best model. Table 4.10 is tabulation table for the best model.

Table 4.10 Best ARIMA Model

	Defect Frequency
Best Model	(3,0,0)
AICC	-23.47510357
MSE	0.014951969
AR(1)	0.325
MA(1)	-
Constant	0.183

The result shows that the preliminary models are determined from the ACF and PACF of the differenced data are indeed the best model. The RACF and RPACF for the best ARIMA model are shown in the Figure 4.3.

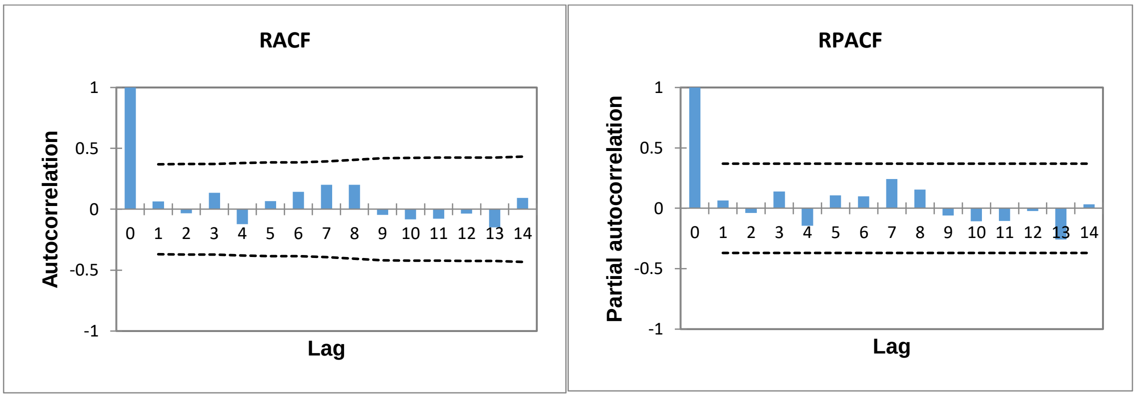

Figure 4.3 RACF and RPACF Model

The RACF and RPACF for the data fell within the confidence interval. They were in significant and this showed that the residuals were independent. The next requirement was residuals' homoscedasticity test. The result of the homoscedasticity test is shown on the Table 4.11.

Table 4.11 Homoscedasticity Test

Breusch-Pagan Test	
LM (Observed value)	0.015
LM (Critical value)	3.841
DF	1
P-Value (Two-tailed)	0.903
Alpha	0.05

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0. The risk to reject the null hypothesis H0 while it is true is 90.32%.

The residuals were homoscedastic which meant that they had a constant variance. Homoscedastic stage is important because it determined whether the model's ability to predict variable values was consistent.

The diagnostic checking was the distribution of the residuals. This diagnostic checking was being done to obtain a satisfactory confidence interval for the forecast. The result of normality test is shown on the Table 4.12 and the histogram is shown on the

Figure 4.4. the significance level used was 5% and the test result gave p-values higher than 0.05 indicate the normality.

Table 4.12 Results of Normality Test

Shapiro-Wilk Test P-Value	Anderson-Darling Test P-Value	Jarque-Bera Test P-Value
0.001	< 0.0001	0.013

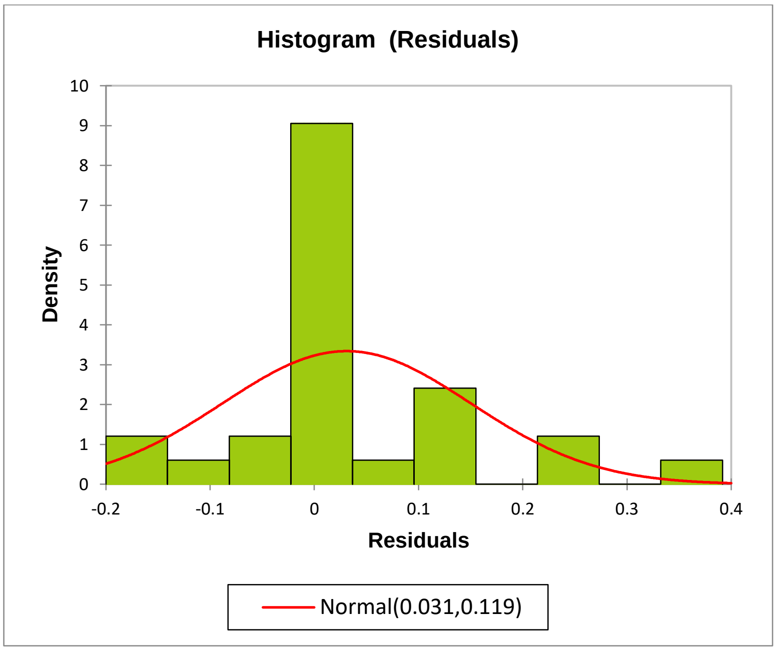

Figure 4.4 Histogram of Residuals

The series however failed the normality test but its histogram showed that it was very close to a normal distribution, which was good enough. Again, Box-Cox transformation can be applied to obtain normally distributed residuals, but it was not done in this study because it was not really necessary to normalize the residuals which were already close to normality. The series of ARIMA model passed the diagnostic checking stage with independent model, homoscedastic, and approximately normally distributed residuals.

F. Comparison of the Series Forecasting

The synthetic series generated by the ARIMA models were compared to the original series to check for model accuracy. Forecast series also generated for a lead time twelve months with 95% confidence intervals. Figure 4.5 shows the original, synthetic, and the forecast series while Table 4.13 shows the forecast values as well as the confidence interval.

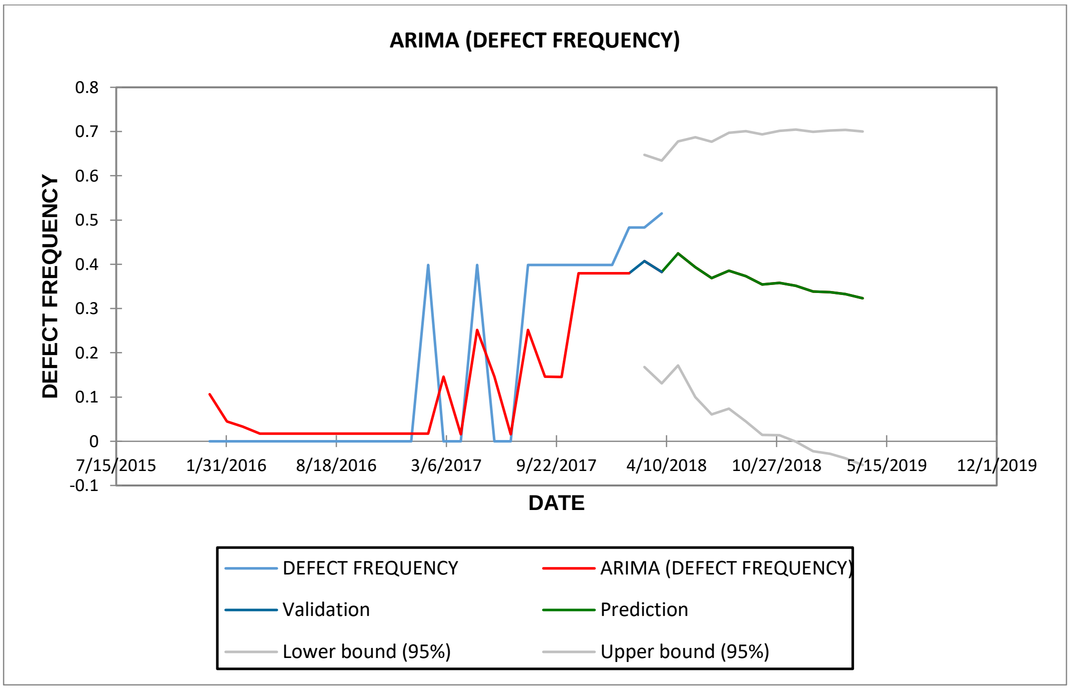

Figure 4.5 Original, Synthetic, and Forecast Series of Defect Frequency

Table 4.13 Forecast Values and Confidence Interval

Lead	**Forecast**	**Interval**		**Inverse Box Cox**	**Round Up of Inverse Box Cox**
		Lower Bound	**Upper Bound**		
1	0.424	0.171	0.678	2.20238	2
2	0.394	0.100	0.687	1.96662	2
3	0.369	0.060	0.677	1.82106	2
4	0.386	0.074	0.697	1.91595	2
5	0.373	0.045	0.701	1.84303	2
6	0.354	0.015	0.694	1.74784	2
7	0.358	0.014	0.702	1.76608	2
8	0.352	-0.001	0.704	1.73691	2
9	0.339	-0.022	0.700	1.67915	2
10	0.337	-0.029	0.702	1.67088	2
11	0.333	-0.038	0.703	1.65356	2
12	0.323	-0.053	0.700	1.61801	2

4.2.3 Mitigation

The risk mitigation or also known as defect mitigation is the calculation of defect reduction. Table 4.14 shows the reduction value to be implemented on the defect frequency. In addition, Table 4.15 shows the result of defect residual which has been already calculated using the reduction value. The total reduction value is obtained by totalize the reduction value for each problem solutions. The defect residual value later will be used as an input for the ARIMA forecasting with risk control.

Table 4.14 Defect Reduction Value

No.	Major Causes	Solutions	Current Condition	% CC	Expected Condition	% EC	Reduction Value	% RV
1	Aging	Create routine maintenance schedule	4	15%	7	18%	3	25%
2	No routine maintenance	Create routine maintenance schedule	4	15%	7	18%	3	25%
3	Over Tonnage	Conduct material studies	5	19%	7	18%	2	17%
4	Operator Error	Create good and safe working environment to maintain operator focus	6	22%	9	23%	3	25%
5	Overuse	Lower tonnage capacity	8	30%	9	23%	1	8%
	Total		27	100%	39	100%	12	100%

Table 4.15 Defect Residual

Date	Defect Frequency	Total Reduction Value	Decimal of TRV	Defect Residual	Date	Defect Frequency	Total Reduction Value	Decimal of TRV	Defect Residual
Jan-16	1	17%	0.17	0.83	Mar-17	1	25%	0.25	0.75
Feb-16	1	8%	0.08	0.92	Apr-17	1	17%	0.17	0.83
Mar-16	1	25%	0.25	0.75	May-17	2	50%	0.50	1.00
Apr-16	1	25%	0.25	0.75	Jun-17	1	17%	0.17	0.83
May-16	1	17%	0.17	0.83	Jul-17	1	25%	0.25	0.75
Jun-16	1	25%	0.25	0.75	Aug-17	2	42%	0.42	1.17
Jul-16	1	17%	0.17	0.83	Sep-17	2	25%	0.25	1.50
Aug-16	1	25%	0.25	0.75	Oct-17	2	42%	0.42	1.17
Sep-16	1	25%	0.25	0.75	Nov-17	2	42%	0.42	1.17

Date	Defect Frequency	Total Reduction Value	Decimal of TRV	Defect Residual	Date	Defect Frequency	Total Reduction Value	Decimal of TRV	Defect Residual
Oct-16	1	25%	0.25	0.75	Dec-17	2	33%	0.33	1.33
Nov-16	1	25%	0.25	0.75	Jan-18	2	33%	0.33	1.33
Dec-16	1	25%	0.25	0.75	Feb-18	3	75%	0.75	0.75
Jan-17	1	17%	0.17	0.83	Mar-18	3	58%	0.58	1.25
Feb-17	2	42%	0.42	1.17	Apr-18	4	83%	0.83	0.67

4.2.4 ARIMA Forecasting with Risk Control

The ARIMA forecasting is performed to predict the defect frequency for the next 12 months. In this section, the forecasting was conducted with the influence of risk control. The input for this calculation was the defect residual value from the Table 4.15.

A. Box Cox Transformation

This procedure is similar with the previous procedure about the box cox transformation, it is for data preparation. The XLSTAT software tried to find the optimized lambda for the transformation. The optimized lambda is – 2.665. The result of box cox transformation is shown on the Table 4.16.

Table 4.16 Transformed Defect Residual

Date	Defect Residual	Date	Defect Residual
Jan-16	-0.241	Mar-17	-0.432
Feb-16	-0.093	Apr-17	-0.241
Mar-16	-0.432	May-17	0.000
Apr-16	-0.432	Jun-17	-0.241
May-16	-0.241	Jul-17	-0.432
Jun-16	-0.432	Aug-17	0.128
Jul-16	-0.241	Sep-17	0.248
Aug-16	-0.432	Oct-17	0.128
Sep-16	-0.432	Nov-17	0.128
Oct-16	-0.432	Dec-17	0.200
Nov-16	-0.432	Jan-18	0.200
Dec-16	-0.432	Feb-18	-0.432
Jan-17	-0.241	Mar-18	0.168
Feb-17	0.128	Apr-18	-0.716

B. Plotting the Series (ACF and PACF)

This procedure is similar with the previous procedure about the plotting series of ACF and PACF. Both of them are plotted using XLSTAT with descriptive statistics test. The ACF and PACF will be used to determine the behavior and stationarity of the series. If both of ACF and PACF values are insignificant and fall within the confidence band, it indicates that the observations are independent. In such a case the time series is a white noise process and no modelling could be performed. A stationary time series has a rapidly decaying ACF. If the ACF is slow decaying, it indicates that the series may be non-stationary and requires differencing. Table 4.17 and Figure 4.6 below show the result of descriptive test.

Table 4.17 Statistical Test

Statistic	**DF**	**Value**	**P-Value**
Jarque-Bera	2	2.035	0.361
Box-Pierce	6	7.858	0.249
Ljung-Box	6	9.198	0.163
McLeod-Li	6	1.567	0.955
Box-Pierce	12	10.739	0.551
Ljung-Box	12	14.249	0.285
McLeod-Li	12	6.741	0.874

Test interpretation of Jarque Bera test as the computed p-value of Jarque Bera is higher than the significance level alpha 0.05, one cannot reject the null hypothesis H0, which means the variable from which the sample was extracted follows a normal distribution.

According to the Table 4.17 above, the white noise tests can be seen on Box-Pierce and Ljung-Box. As the computed p-value of Box-Pierce and Ljung-Box are higher than the significance level alpha 0.05, one cannot reject the null hypothesis H0, which means there is white noise. A white noise input series will result in periodogram values that follow an exponential distribution. Thus, by testing the distribution of periodogram values against the exponential distribution. The exponential distribution itself includes normal distribution, binominal distribution, gamma distribution, etc. The test whether the series is normally distributed will later be proved on the diagnostic checking analysis.

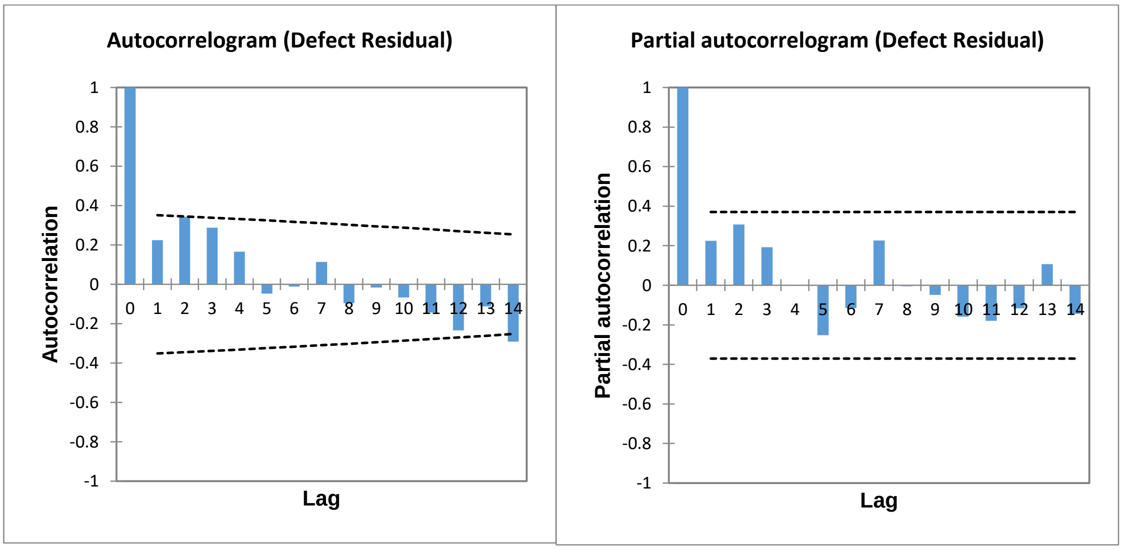

Figure 4.6 ACF and PACF of Defect Residual Series

The ACF plot series exhibited slow decay, indicating the possibility of non-stationarity. The further stationarity test will be further explained later.

C. Stationary Test

This procedure is similar with the previous procedure about the stationary test. Stationarity test were carried out to confirm the initial presumption that the data were non-stationary. The test of stationarity is using ADF test, KPSS test, and Mann-Kendall trend test. The result of the test is presented on the Table 4.18.

Table 4.18 Results of Stationarity Tests

Variable	**ADF Test**	**KPSS Test**	**Mann-Kendall Trend Test**	**Remarks**
	P-Value	**P-Value**	**P-Value**	
DR	0.825	0.020	0.040	Non-Stationary

The test confirmed that the data were non-stationary. The augmented Dickey-Fuller test and the KPSS test showed that it had unit roots. The Mann-Kendall trend test also detected a trend in the data. A data that has either a unit root or a trend was considered as non-stationary and therefore require differencing.

D. Differencing

This procedure is similar with the previous procedure about differencing. The data were differenced once, twice, and triple to obtain the optimum *d*. The standard deviation of the original and differenced data is shown on the Table 4.19.

Table 4.19 Standard Deviations of Original Data and Differenced Data

Order, *d*	**Standard Deviation**
0	0.273
1	0.300
2	0.460
3	0.849

The result also shows that the first lag, second lag, and third lag respectively were higher than -0.5, which indicates that the optimum differencing is the standard is at the lowest. Therefore, the differencing value to be used is $d = 0$. Therefore, the ARIMA models that seem reasonable to be tested were (1,0,0) and (0,0,1).

E. ARIMA Model and Diagnostic Checking

XLSTAT was used to compute the AICC for ARIMA models with *p* starting from zero to three and *q* starting from zero to three. The model who has the minimum AICC was chosen as the best model. Table 4.20 is tabulation table for the best model.

Table 4.20 Best ARIMA Model

	Defect Frequency
Best Model	(0,0,3)
AICC	-3.738090799
MSE	0.026607644
AR(1)	-
MA(1)	0.312
Constant	0.183

The result shows that the preliminary models determined from the ACF and PACF of the differenced data were indeed the best model. The RACF and RPACF for the best ARIMA model were shown on the Figure 4.7.

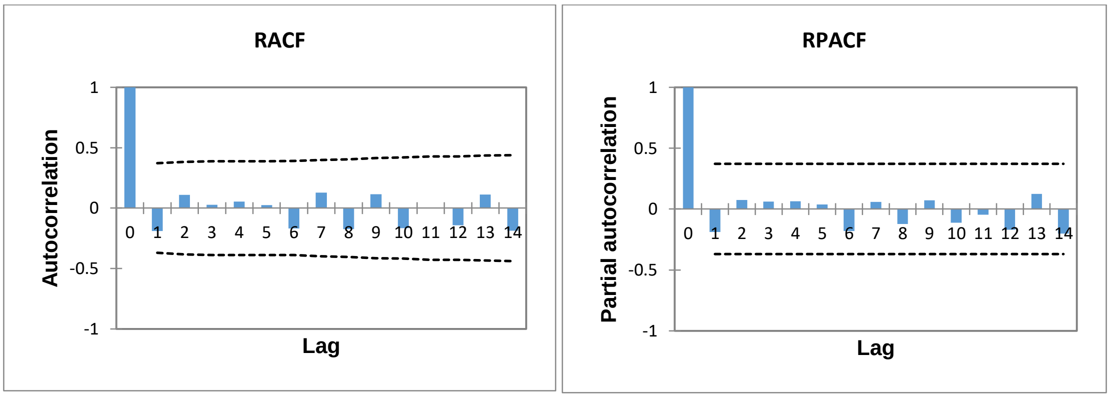

Figure 4.7 RACF and RPACF Model

The RACF and RPACF for the data fell within the confidence interval. They were insignificant and this showed that the residuals were independent. The next requirement was residuals' homoscedasticity test. The result of the homoscedasticity test is shown on the Table 4.21.

Table 4.21 Homoscedasticity Test

Breusch-Pagan Test	
LM (Observed value)	0.033
LM (Critical value)	3.841
DF	1
P-Value (Two-tailed)	0.855
Alpha	0.05

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0. The risk to reject the null hypothesis H0 while it is true is 85.50%.

The residuals were homoscedastic which meant that they had a constant variance. Homoscedastic stage is important because it determined whether the model's ability to predict variable values was consistent.

The diagnostic checking was the distribution of the residuals. This diagnostic checking was done to obtain a satisfactory confidence interval for the forecast. The result of normality test is shown on the Table 4.22 and the histogram is shown on the Figure 4.8. The significance level used was 5% and the test result gave p-values higher than 0.05 indicate the normality.

Table 4.22 Results of Normality Test

Shapiro-Wilk test P-Value	Anderson-Darling Test P-Value	Jarque-Bera Test P-Value
0.552	0.622	0.871

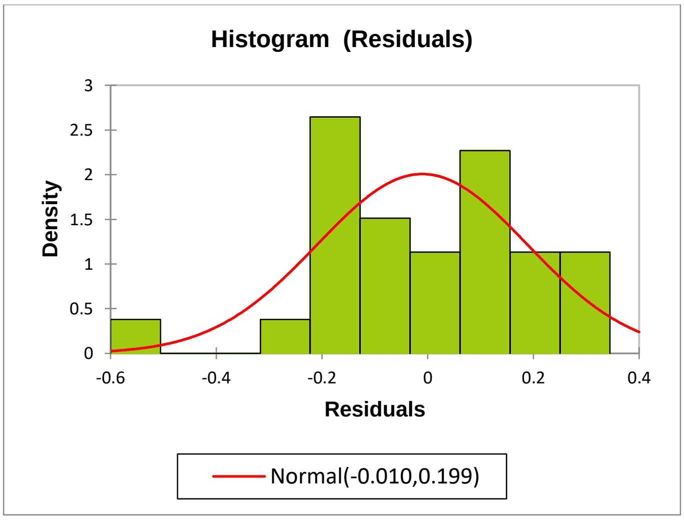

Figure 4.8 Histogram of Residuals of Defect Residual

The series succeed the normality tests and the histogram also showed that it is normally distributed. The series of ARIMA model passed the diagnostic checking stage with independent model, homoscedastic, and normally distributed residuals.

F. Comparison of Series Forecasting

The synthetic series generated by the ARIMA models were compared to the original series to check for model accuracy. Forecast series also generated for a lead time twelve months with 95% confidence intervals. Figure 4.9 shows the original, synthetic, and the forecast series while Table 4.23 shows the forecast values as well as the confidence interval.

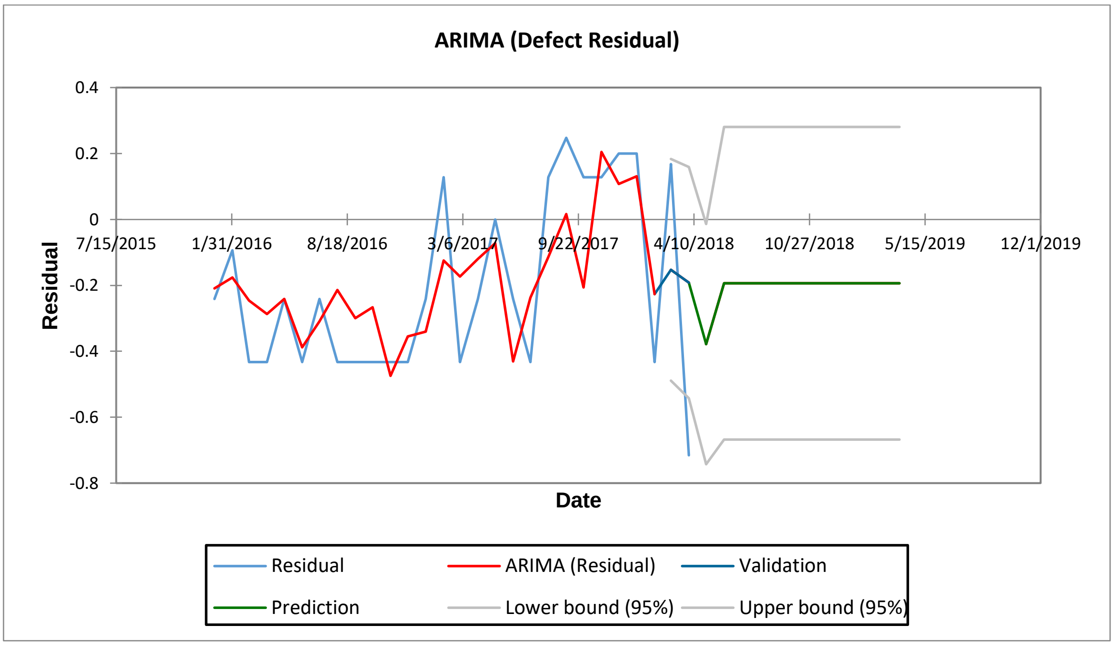

Figure 4.9 Original, Synthetic, and Forecast Series of Defect Residual

Table 4.23 Forecast Values and Confidence Interval

Lead	Forecast	Interval		Inverse Box Cox	Round Up of Inverse Box Cox
		Lower Bound	Upper Bound		
1	-0.3782	-0.7424	-0.0141	0.74079	1
2	-0.1936	-0.6673	0.28007	0.84355	1
3	-0.1936	-0.6673	0.28007	0.84355	1
4	-0.1936	-0.6673	0.28007	0.84355	1
5	-0.1936	-0.6673	0.28007	0.84355	1
6	-0.1936	-0.6673	0.28007	0.84355	1
7	-0.1936	-0.6673	0.28007	0.84355	1
8	-0.1936	-0.6673	0.28007	0.84355	1
9	-0.1936	-0.6673	0.28007	0.84355	1
10	-0.1936	-0.6673	0.28007	0.84355	1
11	-0.1936	-0.6673	0.28007	0.84355	1
12	-0.1936	-0.6673	0.28007	0.84355	1

4.2.5 Comparison of ARIMA Forecasting without and with Possible Solution

Defect removal efficiency also known as DRE measures how effective particular action at removing the defects. In addition, defect prevention effectiveness or DPE is a measure of how effective an organization's processes, procedures, and controls are at preventing defects occurring in the first place. In PT. Yoska Prima Inti does not have historical DPE for past project, so based on Zawadzki (2012), DPE for manufacturing company is between 75% and 85%. Table 4.24 below shows the calculation of ARIMA defect forecasting before and after mitigation. The forecasting starts from May 2018 until April 2019. Based on Zawadzki (2012), the number of possible defects in terms of detailed requirement (DRQ) spread across the processes is 1.84 as constant. DRQ values represented by the defect frequency values.

Table 4.24 ARIMA Defect Forecasting Before and After Mitigation

Date	Defect Before Mitigation				Defect After Mitigation			
	Defect Frequency	**Maximum Possible Defects**	**75 % DPE**	**85% DPE**	**Defect Frequency**	**Maximum Possible Defects**	**75 % DPE**	**85% DPE**
Jan-16	1.12	2.07	0.52	0.31	0.83	1.53	0.38	0.23
Feb-16	1.05	1.93	0.48	0.29	0.86	1.57	0.39	0.24
Mar-16	1.04	1.90	0.48	0.29	0.81	1.49	0.37	0.22
Apr-16	1.02	1.87	0.47	0.28	0.79	1.45	0.36	0.22
May-16	1.02	1.87	0.47	0.28	0.81	1.50	0.37	0.22
Jun-16	1.02	1.87	0.47	0.28	0.74	1.35	0.34	0.20
Jul-16	1.02	1.87	0.47	0.28	0.78	1.43	0.36	0.21
Aug-16	1.02	1.87	0.47	0.28	0.83	1.53	0.38	0.23
Sep-16	1.02	1.87	0.47	0.28	0.78	1.44	0.36	0.22
Oct-16	1.02	1.87	0.47	0.28	0.80	1.47	0.37	0.22
Nov-16	1.02	1.87	0.47	0.28	0.70	1.29	0.32	0.19
Dec-16	1.02	1.87	0.47	0.28	0.75	1.38	0.35	0.21
Jan-17	1.02	1.87	0.47	0.28	0.76	1.40	0.35	0.21
Feb-17	1.02	1.87	0.47	0.28	0.89	1.64	0.41	0.25
Mar-17	1.18	2.18	0.55	0.33	0.86	1.58	0.39	0.24
Apr-17	1.02	1.87	0.47	0.28	0.90	1.65	0.41	0.25
May-17	1.40	2.57	0.64	0.39	0.93	1.72	0.43	0.26
Jun-17	1.18	2.18	0.55	0.33	0.72	1.32	0.33	0.20
Jul-17	1.02	1.87	0.47	0.28	0.82	1.50	0.38	0.23
Aug-17	1.40	2.57	0.64	0.39	0.90	1.66	0.41	0.25
Sep-17	1.18	2.18	0.55	0.33	1.02	1.87	0.47	0.28
Oct-17	1.18	2.18	0.54	0.33	0.84	1.54	0.38	0.23

Date	Defect Before Mitigation				Defect After Mitigation			
	Defect Frequency	Maximum Possible Defects	75 % DPE	85% DPE	Defect Frequency	Maximum Possible Defects	75 % DPE	85% DPE
Nov-17	1.88	3.46	0.87	0.52	1.28	2.35	0.59	0.35
Dec-17	1.88	3.46	0.87	0.52	1.12	2.07	0.52	0.31
Jan-18	1.88	3.46	0.87	0.52	1.16	2.13	0.53	0.32
Feb-18	1.88	3.46	0.87	0.52	0.82	1.51	0.38	0.23
Mar-18	2.06	3.80	0.95	0.57	0.87	1.60	0.40	0.24
Apr-18	1.90	3.49	0.87	0.52	0.84	1.55	0.39	0.23
May-18	2.20	4.05	1.01	0.61	0.74	1.36	0.34	0.20
Jun-18	1.97	3.62	0.90	0.54	0.84	1.55	0.39	0.23
Jul-18	1.82	3.35	0.84	0.50	0.84	1.55	0.39	0.23
Aug-18	1.92	3.53	0.88	0.53	0.84	1.55	0.39	0.23
Sep-18	1.84	3.39	0.85	0.51	0.84	1.55	0.39	0.23
Oct-18	1.75	3.22	0.80	0.48	0.84	1.55	0.39	0.23
Nov-18	1.77	3.25	0.81	0.49	0.84	1.55	0.39	0.23
Dec-18	1.74	3.20	0.80	0.48	0.84	1.55	0.39	0.23
Jan-19	1.68	3.09	0.77	0.46	0.84	1.55	0.39	0.23
Feb-19	1.67	3.07	0.77	0.46	0.84	1.55	0.39	0.23
Mar-19	1.65	3.04	0.76	0.46	0.84	1.55	0.39	0.23
Apr-19	1.62	2.98	0.74	0.45	0.84	1.55	0.39	0.23

According to Table 4.24, the defect frequency after mitigation is two until three times lower than the defect frequency before mitigation. In addition to that, using defect prevention effectiveness with scale of 75% effectiveness and 85% effectiveness gives explanation that in 75% DPE of defect frequency before mitigation, the forecasting for defect frequency that occurs are one defect for each month. However, in 75% DPE of defect frequency after mitigation, the forecasting for defect frequency that occurs are zero defect for each month. Meanwhile, in 85% DPE of defect frequency before mitigation, the forecasting for defect frequency that occurs are zero until one defect for each month. However, in 85% DPE of defect frequency after mitigation, the forecasting for defect frequency that occurs are zero defect for each month. It can be stated that, in the implementation of risk control with at least 75% effectiveness of implementation will give a possibility to result in zero machine defect in the upcoming period.

CHAPTER V

DISCUSSION

5.1 Root Cause Analysis in Machine Defect

In this research, in order to identify the root causes of the 300 tonnage machine defects in PT. Yoska Prima Inti (PT. YPI), brainstorming, discussion, and field observation have been done together with the expert from PT. Yoska Prima Inti. In the beginning, the machine defects data have been collected from the machine historical data. There were no previous studies related to the machine defect. It merely records about damage report and machine repair. The root causes then are discussed based on the machine defect data with the expert. The method for root cause analysis is Apollo root cause analysis. The tool used in the Apollo root cause analysis is reality charting. The working procedure of the analysis is by defining the problem, determining the causal relationships, identifying effective solutions, and implementing and tracking the solutions.

The inputs for root cause analysis are problem name, problem evidence, and the causes. The causes itself are divided into two causes which are action and condition. As for the action the minimum next causes are 2 causes. There are twelve defects that had been occurred in the past from 2016 until 2018. Based on the root cause analysis, there are several major causes to be found which are aging, over tonnage, no routine maintenance, operator error, and overuse. The risk controls as mitigation plan were created based on the defined major causes. The risk controls consist of conduct material studies for over tonnage, lower tonnage capacity for overuse, create routine maintenance schedule for aging and no routine maintenance, and create good and safe working environment to maintain operator focus for operator error. The previous action taken to take care of the problems are considered as post defect actions and none of the actions are preventive actions. The risk controls mentioned before were created based on an objective to prevent the occurrence of future machine defects.

In addition to the causes found by the analysis, there is also another cause that affects the occurrence of the defect indirectly. The causes were originated from the other previous causes, such as in no routine maintenance cause, actually there is another cause which make this routine maintenance activity could not be executed yet at the company, even though the company already realize the importance to put routine maintenance in their production activity. It is due to the lack of human resources. The company has very limited machine operators and mechanics. The maintenance for the defects usually carried out by the mechanics. However, the total number of production machines is unequal with the number of the mechanics. In case, if the company apply the routine maintenance using the mechanics as the supervisors then the labor's tasks will be performed by the operators. This condition will reduce the operators' productivity in their main works. On the other hand, if the company hires more mechanics, it will be wasteful of resources because the mechanics working loads are not big enough for the available daily working hours. It will result to the losses in money and time. Due to the limitation of this research, the lack of human resource is ignored. The reason is because the analysis for this cause will be another detailed focus, because the scale for the analysis will affect to the whole production system. Besides, in the current analysis, the risk controls obtained can be implemented as add ins solutions which means, it can be implemented without changing the whole production system. The analysis for the relationship between machine defect with human resources can be used for future topic of research.

5.2 Risk Mitigation

The risk mitigation which is also known as defect mitigation is the calculation of defect reduction. The defect reduction value is obtained for each defect occurs. The total reduction value for each month will be multiplied with defect frequency and result in total monthly defect reduction value. In addition to that the defect residual for each month is obtained from the monthly defect frequency subtracted with total monthly defect reduction value. The highest monthly defect reduction value is 83% found on the April 2018 while the lowest monthly defect residual is 0.67 found on April 2018. Highest monthly defect reduction value does not always in the same period with lowest monthly defect residual, this condition occurs depend on the value of the defect frequency.

In addition to the risk mitigation, there is a recommended action to be executed, out from the risk controls found based on the root cause analysis. The recommended action should be taken by the company is to conduct seasonal preventive machine defect analysis. It can be done monthly, quarterly, or even yearly. The propose for this action is to create progress report related with the maintenance program within the production. The analysis will be progressive, and it will create progressive historical data which can be very useful to be used for further research related with machine defect. It also can be a supportive point to gain the client’s trust and loyalty. The reason is, the client will be assured that the production within the company will less likely face out an operational problem.

In this research, risk mitigation is necessary to be done. There is certain severity level that can occur if the risk is not being mitigated. The severity level can be seen from the defect frequency itself. The more frequent of the defect to occur, indicates that the company condition is more severe. The risk mitigation has a function to reduce the severity of the risk. The improvements made from the risk mitigation process can be seen through the comparison of defect frequency forecasting before and after mitigated. The reason for choosing the forecasted defect as the parameter for the comparison is caused by the fact that the data availability is only for past conditions. As for the comparison, it can be seen that the pre-mitigated defect frequency is 2 occurrences while the after mitigated defect frequency is 1 occurrence.

The improvement made from the solutions is seen from the reduction of the occurrences of the defect frequency. The improvement will affect business process and the production process of the company. The business process that is affected is marketing section. It is by gaining the customer loyalty and trust, while the production process that is being affected is by the productivity level of the company. It can optimize and increase the productivity, by cost and time effectiveness. Zawadzki (2012) stated that, the cost effective means that the 15%-40% of total production cost can be profit and not loss because the problems are solved and not reoccurring. The time effectiveness means that the production time will not be cut for maintenance caused by the machine defects.

The proposed solutions are able to reduce the defect because they have been consulted to the field's expert, Mr. Arthur. The process of choosing the solutions involved negotiation, consultation, and approval from the expert. It also can effectively reduce the defect which was proven from the comparison of the forecasting before and after the mitigation.

5.3 Machine Defect Forecasting

In this research, the defect forecasting is used to forecast the machine defect occurrences for twelve months ahead. The forecasting is conducted twice, before and after the risk mitigation. The reason is to see the effectiveness of the implementation on the risk control.

The machine defect forecasting before the risk control resulted in the occurrence of two defects each month. On the other hand, the machine defect forecasting after risk control resulted only one defect occurrences each month.

The calculation of risk control implementation effectiveness resulted in the maximum possible defect before mitigation is three until four monthly defects. The 75% DPE for defect before mitigation is one monthly defect. The 85% DPE for defect before mitigation is zero. Meanwhile, the maximum possible defect after mitigation is one until two monthly defects. The 75% DPE for defect after mitigation is zero monthly defect. The 85% DPE for defect after mitigation is zero monthly defect. This results shows that the implementation of risk control with at least 75% effectiveness will be able to eliminate the machine defect on the upcoming period. The defect reductions can be seen from 3 - 4 to 1 - 2 defects for maximum possible defect and one to zero defect for 75% DPE.

Due to the effectiveness for the implementation of this research, it is also recommended to be implemented to another company that faces the similar problems. The effectiveness of the solutions implementation can be seen on the defect reduction of maximum possible defect and 75% effectiveness implementation. This successful level of implementation can make whichever company to be aware of the benefit in conducting defect of failure researches. The research is not only able to be implemented for machine defect analysis, however, it can be widely implemented. The other possible implementations are in sales failure, supplier failures, distribution failures, and etc.

CHAPTER VI

CONCLUSION AND SUGESSTION

6.1 Conclusion

Based on the research results, several conclusions refer to the problem formulation can be concluded as follows:

1. There are 43 machine defects that occurred for 28 months from January 2016 until April 2018. Based on Apollo root cause analysis there are 12 problems which are flywheel seal leaked, dies height pin is broken, worn teeth of dies height, axle bearing of flywheel is broken, seal and air tube leaked, sill break leaked, oil tube leaked, broken dies head, machine overload, dies head screw slacked, cylindrical axle bended, and sill, break, and screw holder leaked. The root causes are found from the analysis consists of 5 root causes which are aging, no routine maintenance, over tonnage, operator error, and overuse.
2. Based on Apollo root cause analysis which has identified five major causes as the root causes of 12 problems occurred, there are four possible solutions to mitigate the future occurrence of machine defect. Those are creating routine maintenance schedule to mitigate aging and no routine maintenance, conducting material studies to mitigate over tonnage, creating good and safe working environment to maintain operator focus to mitigate operator error, and the last is lowering tonnage capacity to mitigate overuse.
3. The ARIMA defect forecasting is performed without and with the influence of risk controls. The forecasting itself is being done using 12 months lead time. The result shows that the forecasting without the influence of risk control has 2 defect occurrences for each forecasted month. In the other hand, the result of forecasting

with the influence of risk control has 1 defect occurrences for each forecasted month.

4. The effectiveness of risk control is calculated using defect prevention effectiveness. The scoring for DPE is obtained from literature review due to the condition where no previous study conducted related to machine defect so, PT. Yoska Prima Inti did not have the historical DPE value. The DPE used is 75% and 85% for manufacturing company, where the defect before mitigation analysis resulted in the value of maximum possible defect is 3 until 4 defects, 75% DPE is 1 defect, and 85% DPE is 0 defect. On the other hand, the defect after mitigation analysis resulted in the value of maximum possible defect is 1 until two defects, 75% DPE is 0 defect, and 85% DPE is 0 defect. The value of the defect itself is in monthly occurrence.

6.2 Suggestion

Some recommendations from the research is suggested as follows:

1. PT. Yoska Prima Inti should be aware and pay more attention to each machine defect occurred by doing several preventive actions, such as:
   a. Creating routine maintenance schedule for the production machine.
   b. Conducting material studies before contracting and before production.
   c. Creating good and safe working environment to maintain operator focus by reassessing the health and safety requirement and implementation at the company.
   d. Lower machine tonnage capacity by maximum is 20% for 300T stamping machine stated by AIDA (2008).
2. The preventive actions and machine defect analysis for PT. Yoska Prima Inti can be used to be implemented at another manufacturing company which has the same defect background. Hence, the other company can be aware of the benefit in conducting defect or failure researches for future development of the company.
3. For future research, conducting seasonal machine defect research might help the company to evaluate the defect that might be happened in the future deeper and through.

4. For future research, conducting research related with the machine defect and human resources can be very beneficial for manufacturing company. It can give optimized production capability and capacity in terms of the production maintenance sector.

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