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.

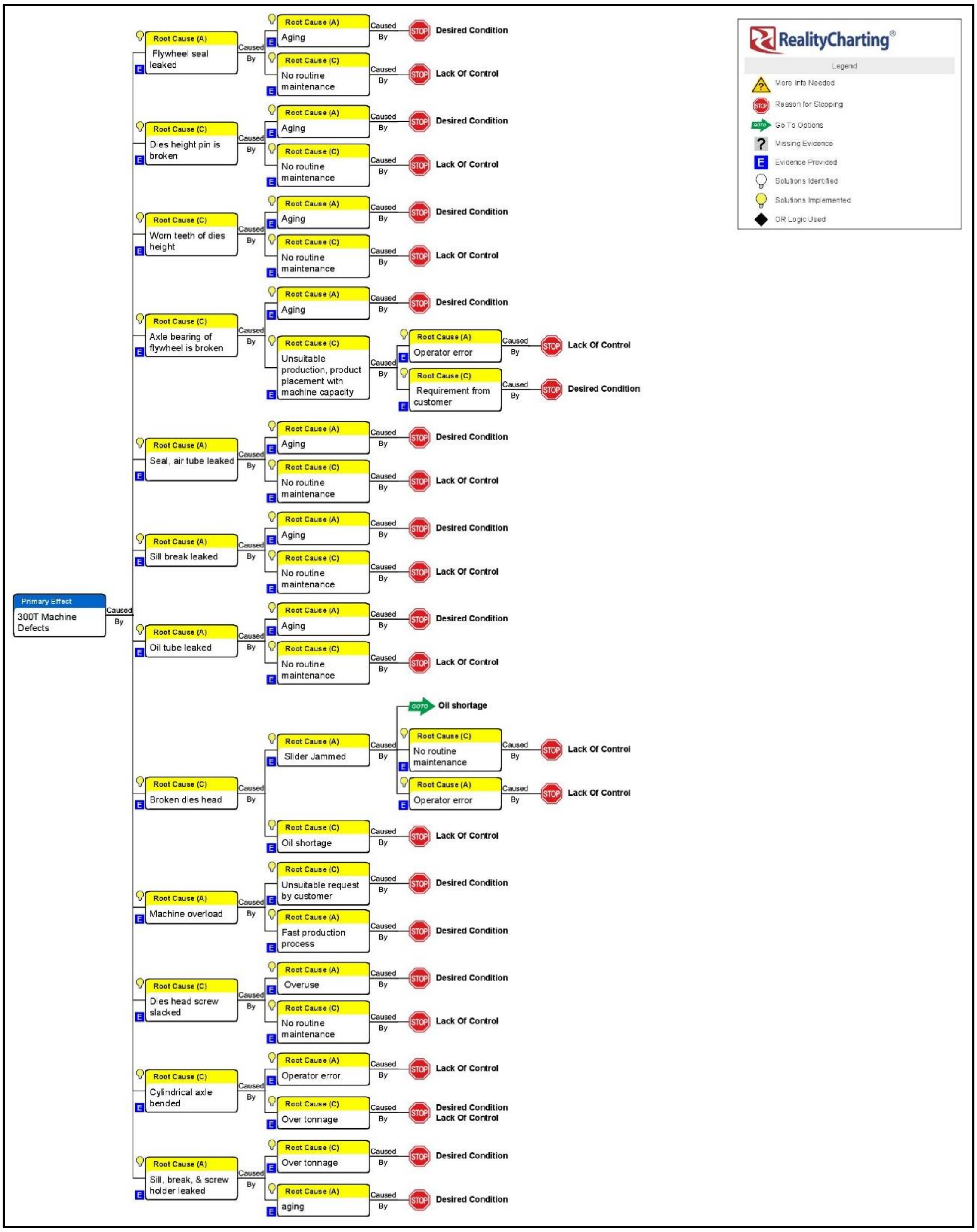

Figure 4.1 Apollo Root Cause Analysis Graph

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.

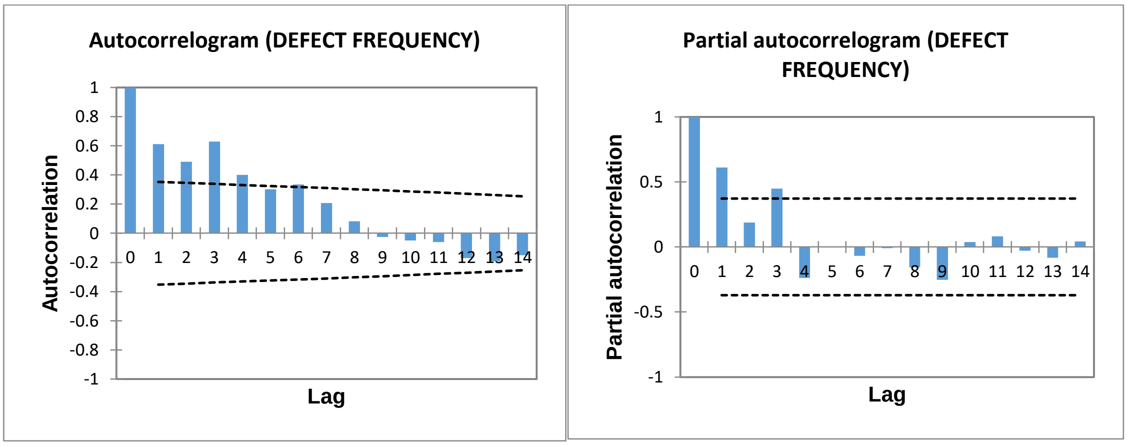

Figure 4.2 ACF and PACF of Defect Frequency Series

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.

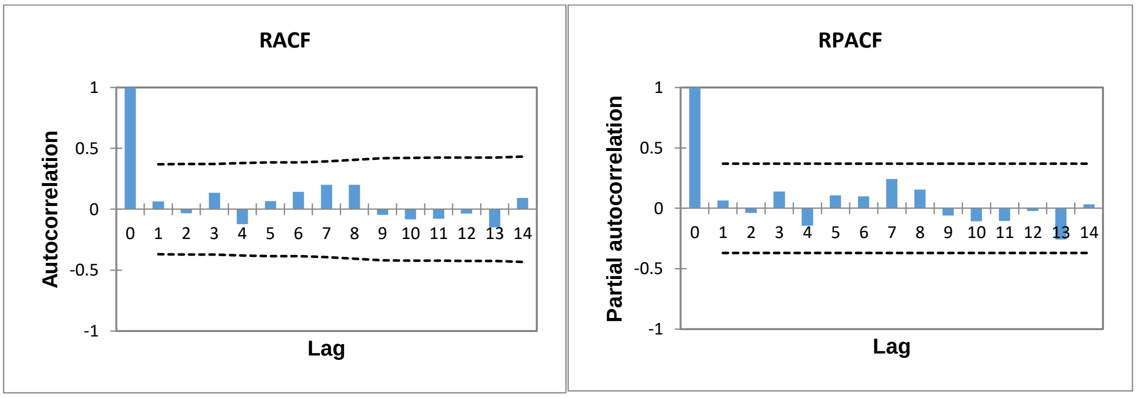

Figure 4.3 RACF and RPACF Model

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

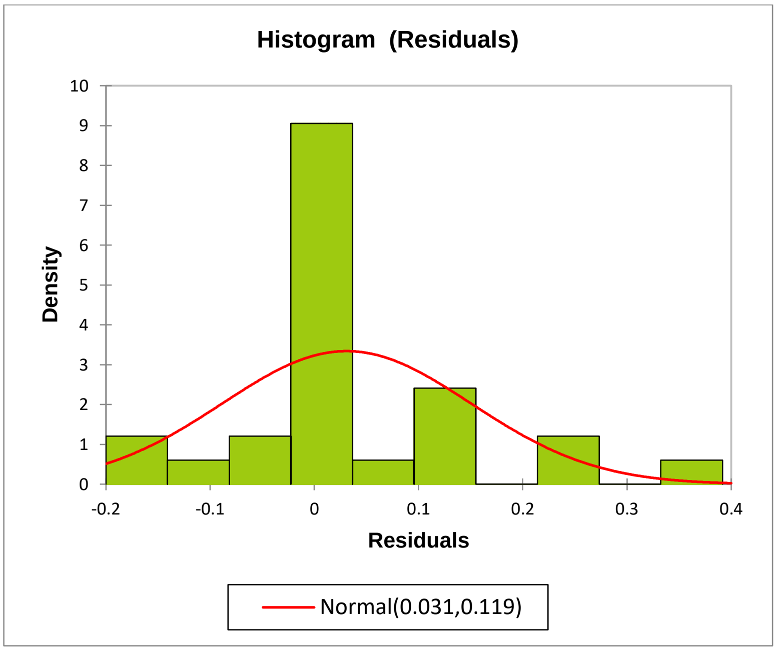

Figure 4.4 Histogram of Residuals

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.

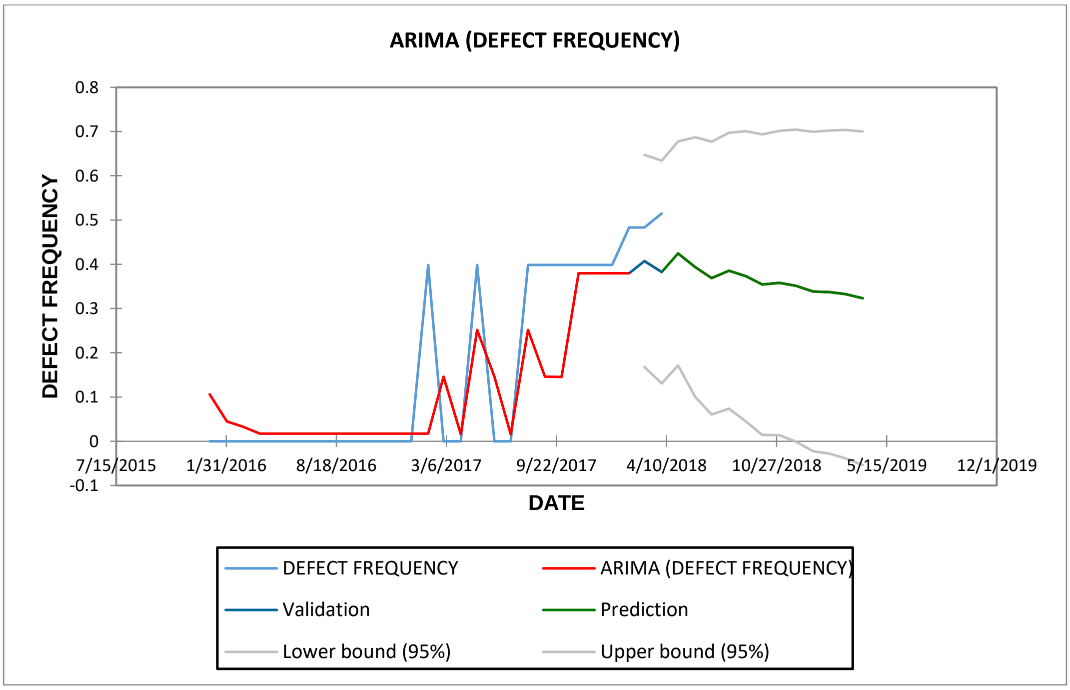

Figure 4.5 Original, Synthetic, and Forecast Series of Defect Frequency

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.

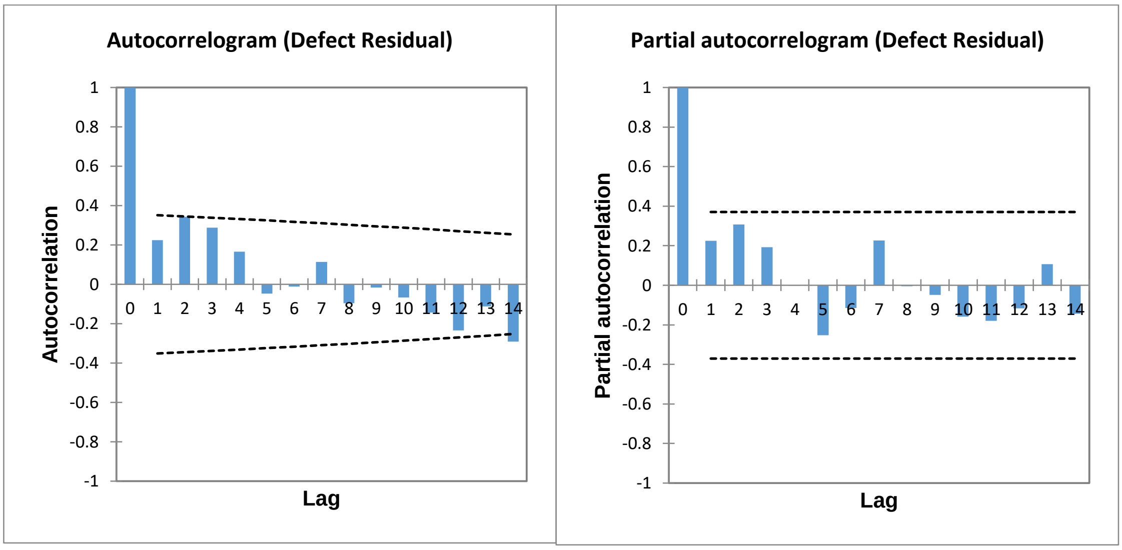

Figure 4.6 ACF and PACF of Defect Residual Series

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.

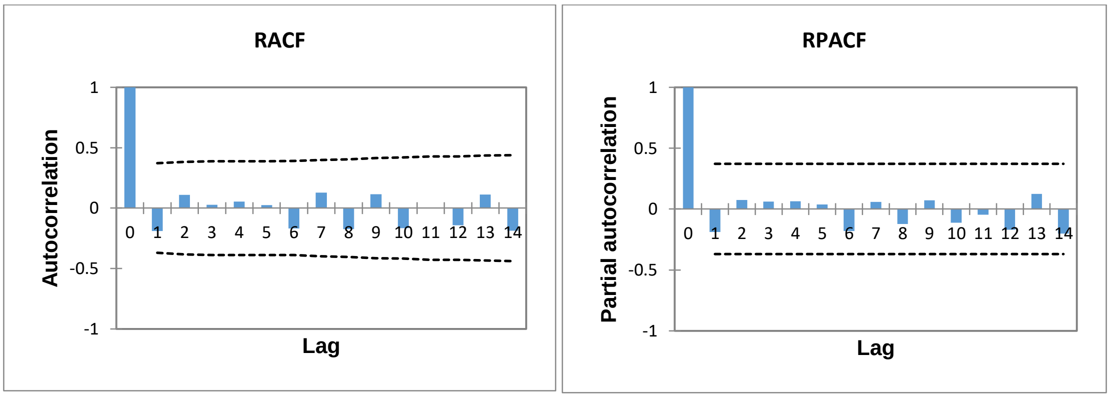

Figure 4.7 RACF and RPACF Model

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

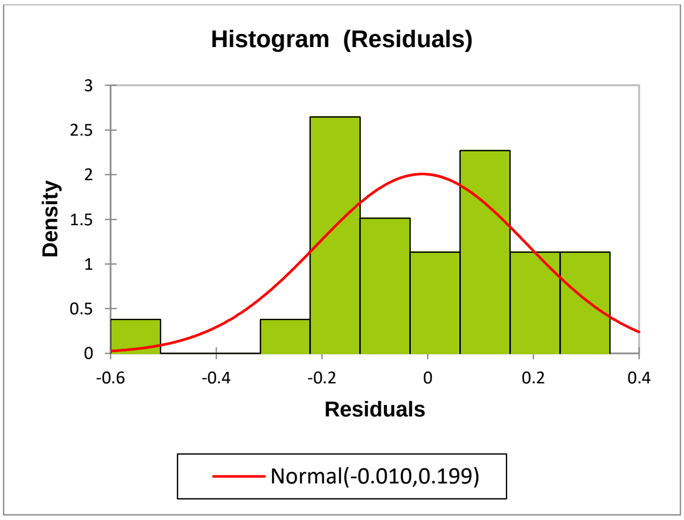

Figure 4.8 Histogram of Residuals of Defect Residual

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.

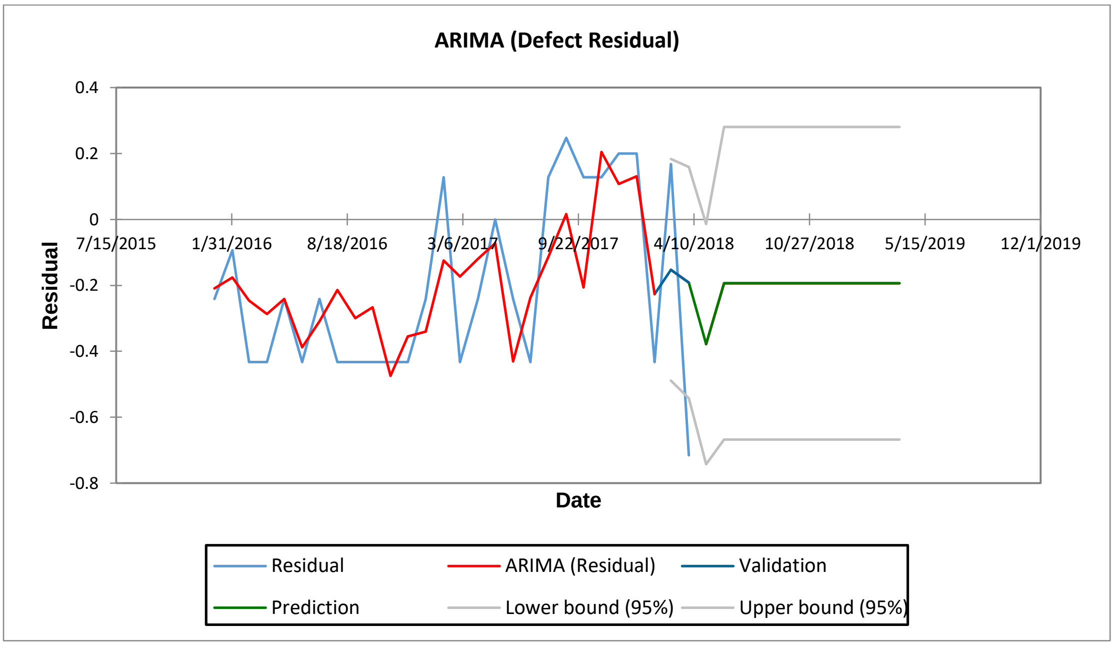

Figure 4.9 Original, Synthetic, and Forecast Series of Defect Residual

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.