SK34
Forecasting Model Selection in Six Sigma Concepts

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Abstract: The implementation of Six Sigma concept in a company may help the company not only to strengthen its performance but also their ability to increase its profit. The systematic method is needed for increasing the quality product. DMAIC is the abbreviation for Define, Measure, Analyze, Improve and Control. It is a formal method in the concept of Six Sigma can assist in the business. This method is to provide better solutions in driving out waste of the organization at every level and improving product quality to the level of only 3.4 defects per million opportunities towards meeting the customer's needs by delivering products without any defects. This method is used to evaluate the effectiveness of using the concept of Six Sigma in a company for optimizing quality in the manufactured process. Forecasting model is a method of quality control used to control the quality of the process so that it can manage the forecast sales, reduce the defects products, and optimize the quality in manufactured the process.

Keywords : Six Sigma, DMAIC, quality process, forecasting model

1. Introduction

1.1 Background of Study

Six Sigma is a quality management strategy presented by Bill Smith at Motorola in 1986. It is an approach that resulted in changes to the organization by combining elements of total quality management, re-engineering course work, and employees involvement. It appears to improve the quality of the Motorola Company and it has been used by others industries or companies as a comprehensive framework for business management. Six Sigma seeks to improve product qualities by identifying and eliminating errors and variability in the field of production and business. Six Sigma is a quality management program in which it helps the new industries or companies in promoting their quality improvement processes in terms of improving the customer satisfaction and financial benefits of maximize profit, aside from minimizing costs for business production. This concept of Six Sigma is used in Balda Solution Malaysia Sdn. Ltd. in their operation management. Balda Solutions Malaysia Sdn. Ltd. offers a unique One-stop Solution that help customers looking into lowering products cost without even sacrificing the products. The company produces in the manufacturing of electronic products with special focus given on the radio frequency (RF) and acoustical.

1.2 Problem Statement

Quality and satisfaction are difficult to be improved without the appropriate method. Balda Solutions Malaysia Sdn. Ltd., a company producing electronic product, is trapped into situation in which few problems arise in such manners for instance:

i) Raw materials: some ingredients of the materials are not appropriate for the use of producing
ii) Equipment: the equipments are not adequate
iii) Employees: Not experience or not well trained
iv) Machine: technology used are outdated compared to others

v) Molding: neither freezing nor heating system are handled well
vi) Methods: low level of efficiency in terms of its raw materials management system or products

In dealing with these few listed problems, there is a method that is capable to sort out the quality matters which is the forecasting model. The forecasting model consists of few models of quality control but the problem lies in choosing the applicable forecasting model to analyze the data.

1.3 Research Objectives

Identify the most suitable type of forecasting model to be used in the quality control process. Make a comparison between the methods adhere in the type of forecasting model. Choose the average percentage of errors and the lowest value of the defect so that the type of forecasting model can be selected and analyzed. Data in p-chart analysis is used for this case study.

1.4 Importance of Study

This study is equally important in the terms of the improvement on the products quality for it would lead the improvement in other circumstances such as enhancing the financial profitability, reducing operating costs, increasing productivity, reducing cycle time, increasing sales, reducing check and the cost of poor quality.

2. Methodology

2.1 Collection of Data

Collection of data such as graphs, charts or figures in which able to show the results of the implementation of Six Sigma in the quality of the process are required for the sake of review and analyze.

2.2 Data Analysis

Forecasting model was used in this study to analyze the data. In addition, use Microsoft Excel for the formulation of bar charts, graphs, and diagrams in the form of brightly-colored in order to have the information in more precise and clearer form. Statistics used to summarize a large number of data and more in interpreting the results thus determine the different experimental as referred to.

2.3 Methodology Data Analysis

Type of forecasting model for the analyze of data are chosen among the models of Moving Average model, Simple Exponential Smoothing model, and the Box Jenkins model. Make a comparison between the methods in the term of Akaike Information Criterion (AIC), Bayerian Information Criterion (BIC), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE) and Mean Absolute Deviation (MAD). Choose the average percentage of errors and the lowest value of the defect so that the most suitable type of forecasting model can be selected and analyzed. Data in p-chart analysis is used for this case study.

3. Data Analysis

3.1 Introduction

In this study, qualitative methods are used where it is produced or collected from the interview to achieve the objectives of this study. The researcher used the information data of p-chart to analyze the forecasting model and see whether the objective can be achieved or not.

3.2 Data Analysis

The Figure 1 and Table 1 below is the data provided from the company Balda Solutions Malaysia Sdn. Ltd. used for analyze.

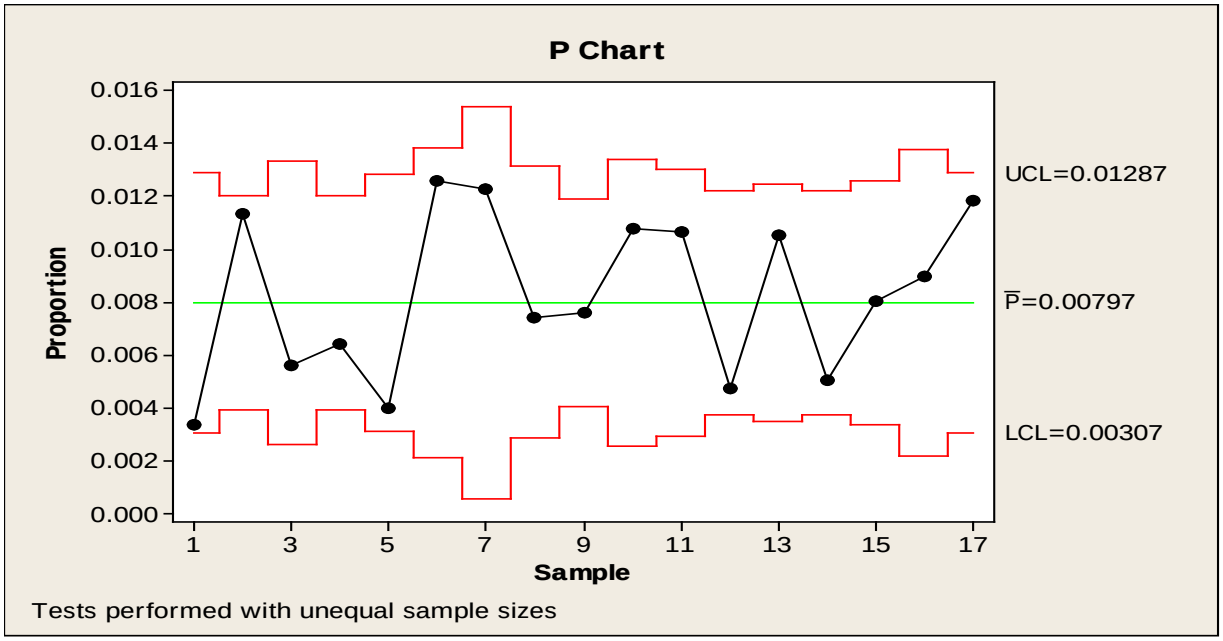

Figure 1: The Quantity Inspection and Reject Products Examined in Each Week.

Table 1: The Quantity Inspection and Reject Products Examined in Each Week

Week	Quantity inspection	Number of Reject	Week	Quantity inspection	Number of Reject
WK1	2962	10	WK10	2417	26
WK2	4325	49	WK11	2813	30
WK3	2500	14	WK12	4000	19
WK4	4371	28	WK13	3519	37
WK5	3000	12	WK14	3970	20
WK6	2071	26	WK15	3375	27
WK7	1304	16	WK16	2125	19
WK8	2710	20	WK17	2966	35
WK9	4625	35			

From the figures and data provided by the company Balda Solutions Malaysia Sdn. Ltd., researcher use Microsoft Excel to calculate the percentage of defects attained in each week.

Table 2: Percentage of Defects in Each Week Received

Week	Quality Inspection	Reject	% Reject	Week	Quality Inspection	Reject	% Reject
1	2962	10	0.3376	10	2417	26	1.0757
2	4325	49	1.1329	11	2813	30	1.0665
3	2500	14	0.56	12	4000	19	0.475
4	4371	28	0.6406	13	3519	37	1.0514

5	3000	12	0.4	14	3970	20	0.5038
6	2071	26	1.255	15	3375	27	0.8
7	1304	16	1.277	16	2125	19	0.8941
8	2710	20	0.738	17	2966	35	1.18
9	4625	35	0.7568				

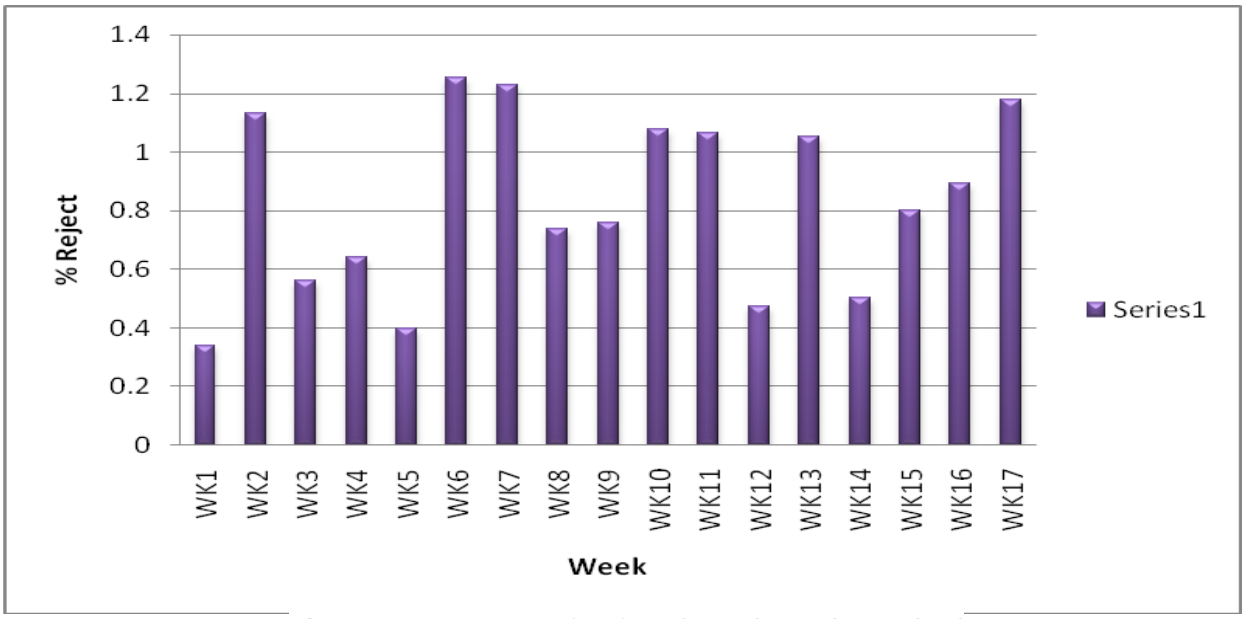

Figure 2: Percentage of Defects in Each Week Received

By using a forecasting model (Forecast X software), the percentage of defects is taken into account in the models mentioned such as Moving Average model, Simple Exponential Smoothing model, and the Box Jenkins model. In this study, the percentage of defects are compared through the Akaike Information Criterion (AIC), Bayerian Information Criterion (BIC), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE) and Mean Absolute Deviation (MAD) is carried out in this chapter.

Moving Average Model:

The equation of Moving Average (MA):

$$\hat{Y}_{t+1} = \frac{Y_t + Y_{t-1} + \ldots + Y_{t-k+1}}{k}$$

where $\hat{Y}_{t+1}$ = forecast value for next period
Y_t = actual value at period t
k = number of terms in the moving average

Table 3: Forecast The Percentage of Errors on Next Period By Using Moving Average Model

Model (Moving Average)	AIC	BIC	MAPE	MAE	MSE	RMSE	MAD
Moving Average k=1	23.02	23.85	52.73%	0.37	0.2	0.45	0.26
Moving Average k=2	16.27	17.11	45.40%	0.33	0.14	0.37	0.26
Moving Average k=3	15.15	15.98	44.62%	0.31	0.13	0.36	0.26
Moving Average k=4	11.4	12.23	39.47%	0.27	0.1	0.32	0.26
Moving Average k=5	12.33	13.16	39.77%	0.27	0.11	0.33	0.26
Moving Average k=6	12.61	13.44	40.06%	0.28	0.11	0.33	0.26
Moving Average k=7	11.6	12.43	39.04%	0.27	0.1	0.32	0.26
Moving Average k=8	11.92	12.77	39.96%	0.28	0.11	0.32	0.26
Moving Average k=9	11.52	12.35	39.48%	0.28	0.1	0.32	0.26

Refer to Table 3 above, the most recent moving average value provides a forecast for the next period with a number of methods that study the percentage of errors that will cause the loss of a company. In this table, it was found that the lowest percentages of errors are moving average 7 with the percentage of 39.04% MAPE shown. In addition, the values of MSE and RMSE for the moving average 7 are respectively 0.1 and 0.32 of the errors of the lowest compared with the other. Therefore, the researcher decided to select the moving average 7 for this model.

$$Y_t = \Phi_0 + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \ldots + \Phi_p Y_{t-p} + \varepsilon_t$$

where

Y_t = response (dependent) variable at time t

$Y_{t-1}, Y_{t-2}, \ldots, Y_{t-p}$ = response variable at time lags $t-1$, $t-2$, …, $t-p$, respectively

$\Phi_0, \Phi_1, \Phi_2 \ldots \Phi_p$ = coefficient to be estimated

ε_t = error term at time t

Table 4: Forecast The Percentage of Errors on Next Period By Using Simple Exponential Smoothing Model

Model (Simple Exponential Smoothing)	AIC	BIC	MAPE	MAE	MSE	RMSE	MAD
Simple Exponential Smoothing (alpha= 0.1)	10.62	11.45	41.91%	0.27	0.1	0.31	0.26
Simple Exponential Smoothing (alpha= 0.2)	11.63	12.46	39.40%	0.28	0.1	0.32	0.26
Simple Exponential Smoothing (alpha= 0.3)	12.79	13.62	39.80%	0.28	0.11	0.33	0.26
Simple Exponential Smoothing (alpha= 0.4)	13.98	14.82	40.85%	0.24	0.12	0.34	0.26
Simple Exponential Smoothing (alpha= 0.5)	15.22	16.06	42.00%	0.31	0.13	0.36	0.26
Simple Exponential Smoothing (alpha= 0.6)	16.51	17.35	43.00%	0.32	0.14	0.37	0.26
Simple Exponential Smoothing (alpha= 0.7)	17.84	18.68	43.70%	0.32	0.15	0.39	0.26
Simple Exponential Smoothing (alpha= 0.8)	19.22	20.05	44.03%	0.33	0.16	0.4	0.26
Simple Exponential Smoothing (alpha= 0.9)	20.65	21.48	44.50%	0.33	0.18	0.42	0.26

Refer Table 4 above, the simple exponential smoothing model is a procedure for continually revising a forecast in the light of more recent experience and has predicted a future trend by using the method of reviewing the percentage of errors that will bring the loss of a company. In this table, it was found that the lowest percentage of errors is simple exponential smoothing with alpha = 0.2. In the simple model average smoothing (alpha = 0.2), the percentage of errors for MAPE = 39.40% are the lowest compared to other alpha values. In addition, the MSE and RMSE is also part and parcel of the method in analyzing the errors with the results of 0.1 and 0.32 respectively.

Box Jenkins Model

Refer Table 5, the ARIMA Box Jenkins model consists of AR (autoregressive), I (integrated), MA (moving average) and is a model to analyze and predict the future trend of a relationship. Refer to Table 5, researcher can see that the lowest MAPE for p is 9, namely 9.93%. In addition, the lowest MAPE for d is 0, namely 38.33%. For the lowest MAPE in q is 9, namely 21.30%. Upon receiving the data p, d, q, researcher make the selection of p, d, q of choosing the lowest MAPE value of ARIMA (9,1,1) whose value is 9.93%. In addition, the values of the other methods in the ARIMA (9,1,1) also showed the lowest as compared to another.

Table 5: Forecast The Percentage of Errors on Next Period By Using Box Jenkins Model

Model (Box Jenkins)	AIC	BIC	MAPE	MAE	MSE	RMSE	MAD
when p=0 until 9							
ARIMA (0,1,1)	14.87	15.7	32.16%	0.27	0.12	0.35	0.26
ARIMA (1,1,1)	24.03	25.69	44.98%	0.34	0.19	0.44	0.26
ARIMA (2,1,1)	10.65	13.15	31.89%	0.23	0.08	0.28	0.26
ARIMA (3,1,1)	11.37	14.7	25.90%	0.21	0.07	0.27	0.26
ARIMA (4,1,1)	13.76	17.92	25.39%	0.2	0.07	0.27	0.26
ARIMA (5,1,1)	15.58	20.58	24.86%	0.2	0.07	0.27	0.26
ARIMA (6,1,1)	6.67	12.5	20.66%	0.16	0.04	0.2	0.26
ARIMA (7,1,1)	8.59	15.26	20.77%	0.15	0.04	0.19	0.26
ARIMA (8,1,1)	-10.78	-3.28	10.23%	0.08	0.01	0.1	0.26
ARIMA (9,1,1)	-9.36	-1.03	9.93%	0.08	0.01	0.1	0.26
when d=0 until 2							
ARIMA (1,0,1)	11.82	14.32	38.33%	0.29	0.08	0.29	0.26
ARIMA (1,1,1)	24.03	25.69	44.98%	0.34	0.19	0.44	0.26
ARIMA (1,2,1)	22.51	24.18	47.08%	0.34	0.17	0.42	0.26
when q=0 until 9							
ARIMA (1,1,0)	15.67	16.5	38.15%	0.31	0.13	0.36	0.26
ARIMA (1,1,1)	24.03	25.69	44.98%	0.34	0.19	0.44	0.26
ARIMA (1,1,2)	10.71	13.21	28.45%	0.23	0.08	0.28	0.26
ARIMA (1,1,3)	14.98	18.31	31.62%	0.22	0.09	0.3	0.26
ARIMA (1,1,4)	14.43	18.59	28.05%	0.22	0.08	0.28	0.26
ARIMA (1,1,5)	13.56	18.56	28.45%	0.21	0.06	0.25	0.26
ARIMA (1,1,6)	16.99	22.82	30.29%	0.22	0.07	0.26	0.26
ARIMA (1,1,7)	18.46	25.13	29.74%	0.21	0.07	0.26	0.26
ARIMA (1,1,8)	19.94	27.43	23.13%	0.18	0.07	0.26	0.26
ARIMA (1,1,9)	19.74	28.07	21.30%	0.18	0.06	0.24	0.26

So, by having three types of forecasting models under review, the researcher could plot the chart below:

Table 6: Comparison of Types of Forecasting Models Assessing The Percentage of Errors

Model	AIC	BIC	MAPE	MAE	MSE	RMSE	MAD
Moving Average k=7	11.6	12.43	39.04%	0.27	0.1	0.32	0.26
Simple Exponential Smoothing (alpha=0.2)	11.63	12.46	39.40%	0.28	0.1	0.32	0.26
ARIMA (9,1,1)	-9.36	-1.03	9.93%	0.08	0.01	0.1	0.26

Refer to Table 6, it was found that the value of MAD for the three types of models are the same, namely 0.26. In addition, the percentage of errors in the method of MAPE for Box Jenkins model is the lowest of 9.93% compared with the model of Simple Moving Average and Exponential Smoothing are respectively 39.04% and 39.40%. The value of MAE, MSE, and RMSE in the Box Jenkins model is the lowest, and each of them are 0.08, 0.01 and 0.1 respectively. In this study, researcher need to achieve the objective of selecting the most appropriate forecasting model through comparison between the MAPE, MAE, MSE, and RMSE by selecting the lowest percentage of errors. Compared the percentage of errors among the several existing methods in the type of forecasting model, it was found that the Box Jenkins model is the best model to forecast for the company Balda Solutions Malaysia Sdn. Ltd. In this case study. Box Jenkins model is a method to predict the trend well. In conclusion, the Balda Solutions Malaysia Sdn. Ltd. should select the ARIMA model (Box Jenkins) in the prediction model (Forecast X

software) as their prediction model and research for their companies to help them to deal with quality problem and get preparation in managing productively.

Comparative Three Diagrams of Forecasting Model

In addition, graphs for the three types of forecasting model can be compared based on predicted lines.

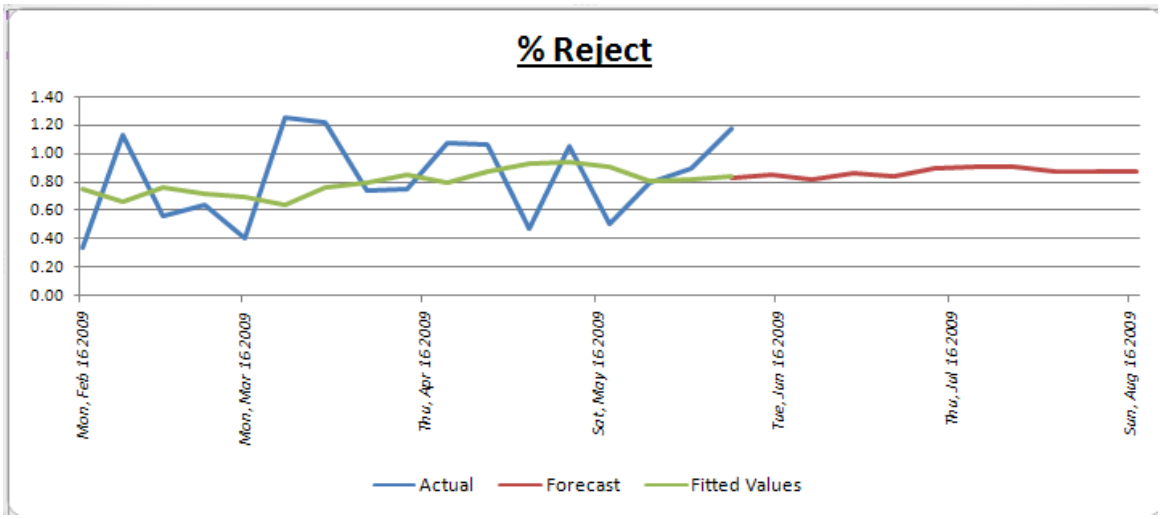

Figure 3: Forecast The Percentage of Errors By Using Moving Average 7 Model

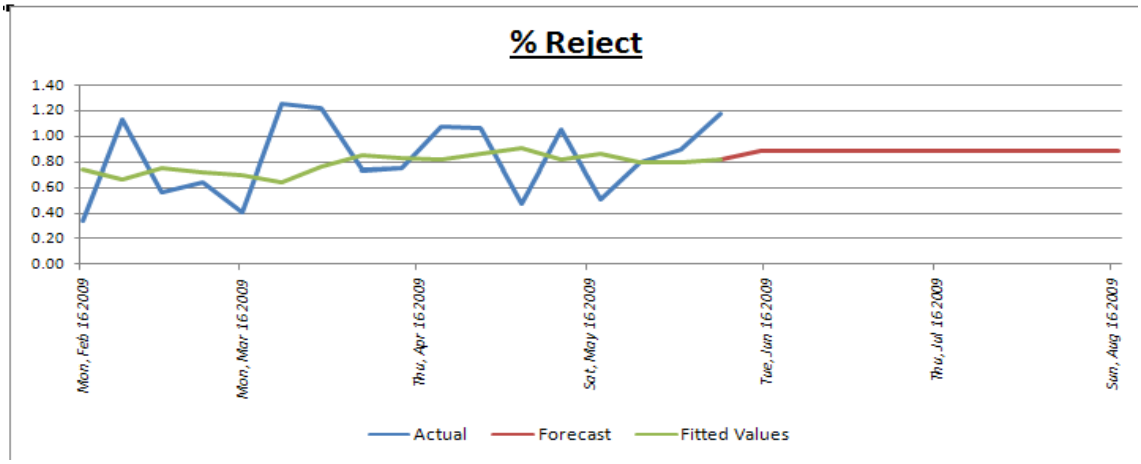

Figure 4: Forecast The Percentage of Errors By Using Simple Exponential Smoothing (alpha= 0.2) Model

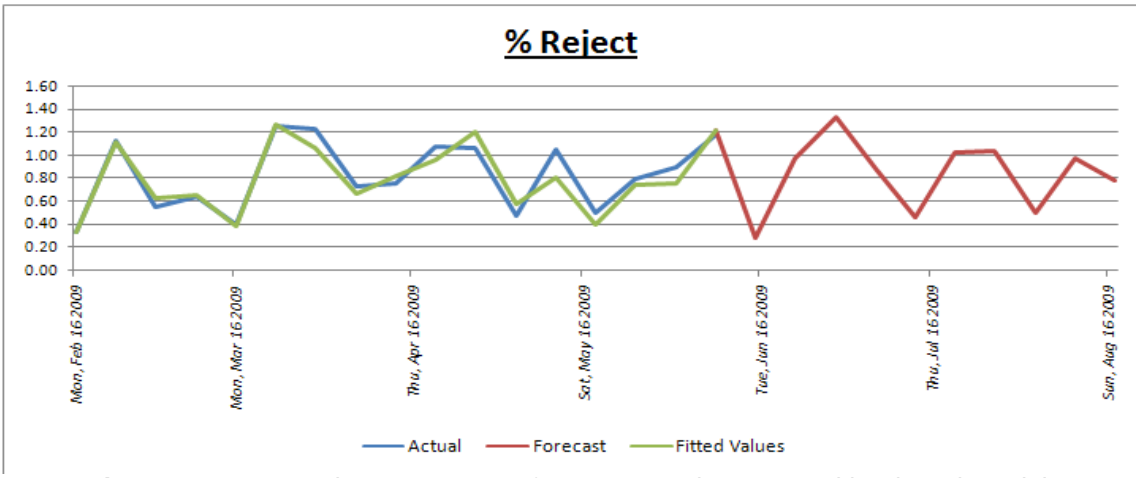

Figure 5: Forecast The Percentage of Errors By Using Box Jenkins (9,1,1) Model

From the three figures shown above, it found that the forecast Figure 5 Box Jenkins is the most appropriate and accurate forecasts to predict as shown in the line within Figure 5. The predicted line is almost the same as before. Box Jenkins model can be selected and used as a quality control method that can predict and control the process for Balda Solutions Malaysia Sdn. Ltd.

4. Conclusion

Refer Figure 6, the study of the next 10 weeks are basically started from weeks 18 to 27. The percentage of errors predicted from week 18 are 0.28%, week 19 was 0.98%, week 20 was 1.34%, week 21 was 0.89%, week 22 was 0.47%, week 23 was 1.03%, week 24 was 1.04%, week 25 was 0.51%, week 26 was 0.98%, week 27 was 0.78%. Referring to figure 4.6, it indicated that the forecast has an average errors prediction of 9.93% and standard deviation of 0.31. In addition, a summary of comments from the figure 4.6 has shown that what is predicted by the percentage of accuracy is 88.24%. In conclusion, researcher can study and predict that in 20 weeks, the percentage of errors is the highest which are 1.34%. This can give a prediction that in the coming weeks the company Balda Solutions Malaysia Sdn. Ltd. should make preparations as control of the work carried out in more detail and significant for instance, review of 2 times before use raw materials to produce. Strictly in control of the work to be carried out for the sake of minimize the expected percentage of errors.

Forecast -- Box Jenkins Selected			
		Forecast	
Date	Weekly	Monthly	Quarterly
Mon, Jun 15 2009	0.28		
Mon, Jun 22 2009	0.98		
Mon, Jun 29 2009	1.34	2.60	2.60
Mon, Jul 6 2009	0.89		
Mon, Jul 13 2009	0.47		
Mon, Jul 20 2009	1.03		
Mon, Jul 27 2009	1.04	3.43	
Mon, Aug 3 2009	0.51		
Mon, Aug 10 2009	0.98		
Mon, Aug 17 2009	0.78		
Total	8.30		
Avg	0.83	3.02	2.60
Max	1.34	3.43	2.60
Min	0.28	2.60	2.60

Summary Comments	
The forecast has an average error of	9.93%
The data has a standard deviation of	0.31
The forecast exceeds the accuracy of a simple average by	88.24%

Figure 6: Percentage of Forecast Errors in 10 Weeks Coming (Box Jenkins Model)

The researcher founds that the Box Jenkins forecasting model is most suitable model able to predict the most accurate prediction compared to the previously with reference given the through available graphs and data in which can be made as an early control

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