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Industrial Engineering Solution in the Industry: Artificial Neural Network Forecasting Approach

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Abstract

Zero defect as a goal for the manufacturing sector especially when the factory engage in global market which the market is required a highest grade quality product. A defect will occur when it is fail to meet the intended design. Hence, defect prediction methods play an important role to forecast the number of product defect. For this study, Artificial Neural Network (ANN) used to forecast the product defect in furniture manufacturing in in order to develop a well suit ANN model for the product defect prediction and obtain an accurate prediction defect number for decision making. Colour defect as one of the product defect category. Therefore, data of colour defect was collected within eight (8) working hours for fourteen (14) days and the analysis process carried out by MATLAB R2015a application using the neural network toolbox. The neural network framework for the colour defect prediction was developed with the minimum error. The company is able to conduct prediction process with the framework and make a better decision based on the result in order to reach their goal.

Keywords
Artificial Neural Network. Forecasting, Defect

1.0 Introduction
The latest technology today has bringing uncountable convenience to the human activity. For example, navigation system helps the people go to unfamiliar places through a simple and faster way. The growth of the technology was successfully to make people easier to find out the problem and then conduct the proper solution. For the most familiar technology is namely as program and computerizes technology. This kind of technology could be laughing in many type of the software and useful in few of sector. For this project, furniture manufacturing sector will be focused because this sector involved a lot of software or machine to produce their desired product. But then, a product with a good design does not mean that essentially parallel to a good product. A defect product will be occur when it is fail to reach the intended design and improperly manufactured (Azeem & Usmani, 2011). It will able to increase a large portion of the manufacturing cost and time consuming due to the quality of the product. Defect prediction plays an important role to represent the quality and reliability of the software. It can be predicted well based on defect classification and through the available prediction model due to the effective management of defect (Fenton et al., 2008). The expert system known as a soft computing which is combining the essential techniques with some engineering disciplines; there consists of computer science technique, Artificial Intelligence techniques and the last is Machine Learning techniques (Verma & Singh, 2015). The Artificial Neural Network prediction model as an expert system which is familiar applied by many countries. A reliability and capable defect prediction models able to explore a defect process in quickly and effective way and then provide the information to improve the product quality (Tunnell, 2015). An expert system leads to greater generality and friendly relationship with reality as well.

1.1 Research Background
Forecasting is a process or activity should be carry out by organization where using their initial real data base and apply the appropriate forecasting method to evaluate it. The management department able to generate a series of strategies based on the capacity of organization from the forecast result in order to reach the high yield level where describe by the William (2011). Hence, the accuracy of forecast result is important for those users. The research take place in AX Furniture, a furniture manufacturing factory located in Muar, Johor. There was started their business

and then continuously development it from year 2000. It has over last 8 years involved in vast wood material activities and yet it was a world class home furniture producer. Their effective product planning and the manufacturing process are bringing them to be one of the exporter furniture companies in year 2005.

1.2 Problem Statement
Manufacturing sector will be involved a project team in order to produce a zero or few defect product with high quality. According to the Parashar & Parashar, (2015), zero defect as a goal for the manufacturing sector especially when the factory engage in global market which the market is required a highest grade quality product. A process of defect prediction is able to dedicate the significantly in a part of successful project before excess to the market (Azeem & Usmani, 2011). A few of researchers had been done their research on defect prediction. For example, Dhiauddin et al. (2012), carried out a defect research by using the regression analysis model, Han et al. (2014), conducted a residual defect prediction by applied multiple technologies and Umar (2013) was using the multiple linear regression to predict the defect. However, those techniques only can obtain the defect number and it did not provide enough required information to the management for decision making (Hong et al., 2008). They would be involved in traditional capture recapture method to predict the defect number, but it do not available in post inspection stage due to no estimate number of defect and just depend on expert inspectors (Bucholz & Laplante, 2009). As a result, those applications do not show the classification and functions approximation of the input or variables.

2.0 Literature Review
2.1 Overview of Forecasting
Forecasting development is began in the seventeenth century accompany with the time series methods where the scientists intended to analyzed the number of sunspots and price indices (Bátori & Hartványi, 2011). According to Kerkkänen (2010), the function of forecasting is used to predict or estimate a future condition to provide information based on the result for decision making in management department. The management department able to generate a series of strategies based on the capacity of organization from the forecast result in order to reach the high yield level where describe by the William (2011). They have to apply a synthesized forecast model to gain the high accuracy result due to the possible condition has been consider as well (GhasemiGol et al., 2015). In other words, the characteristic of a measurement is used to construct a forecast model (Babkin et al., 2015).

2.2 Artificial Neural Network (ANN)
Artificial Neural Network (ANN) always comply with a non-linear continuous function (Vijaya, 2014). A simple explanation was written by Babkin et al. (2015) which is a set of neurons will connected in term of interconnections and composed in two or three layers in order to identify the input layer and also output layer. It is a multilayer network structure. Interconnection is meaning to a connection between a pair of neurons with an approximate weight to point out the strength between the connections (Vashisht, Lal, & Sureshchandar, 2015). Figure 1 show an Artificial Neural Network framework.

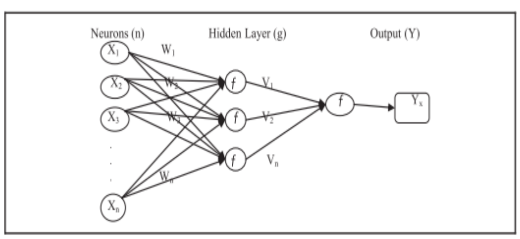

Figure 1: ANN Framework (Gupta & Kashyap, 2015)

With a multilayer perceptron, feed-forward back propagation was commonly used to forecast in diversity field of research such as science and engineering (Chau & Cheng, 2002) due to the important role of learning algorithm (Ebrahimzadeh & Khazaee, 2010). Therefore, back propagation algorithm is more famous used by researcher compare with others algorithm type. According to Balejk et al. (2012), neural network can best fit to experiment data and it is widely apply by a different field of researcher to conduct a forecast process. For example in field of inflation (Gupta & Kashyap, 2015), thermal conductivity (Afrand et al., 2016; Longo et al., 2012; Ariana et al., 2015), software defect prediction (Vashisht et al., 2015; Singh & Salaria, 2013; Gayathri & Sudha, 2014), air temperature prediction (Mustafaraj et al., 2010; Mba et al., 2016) and crude palm oil price prediction (Karia et al., 2013). There have a same conclusion and agree that ANN method provide a positive result for their research which are obtaining a high accuracy prediction result, can training with less formal statistical, suitable to apply in complicated nonlinear continuous function and predict in large number of variables (Ziaei-Rad et al., 2016; Khandanlou et al., 2016; Karia et al., 2013) . Those of the result shown that ANN is a flexible tool which involved a variety of network model with an appropriate learning algorithm (Babkin et al., 2015; Lin & Sheu, 2016) so as to reflect in giving a correct or nearly correct answers for the sample patterns and even for new similar patterns also when ANN is trained properly (Vashisht et al., 2015).

2.4 Overview of Defect Prediction Model

Defect can defined as a low quality or even no quality of one product, it is deviation from expectation or specification which it fail to reach the standard in operation (Han et al., 2014). A lot of defect prediction model were developed by researchers in order to find out the causes and the end generate a few of solution to solve that such as software prediction model (Verma & Singh, 2015) and regression analysis model (Dhiauddin et al., 2012). An appropriate defect prediction model based on defect classification can help to obtain an accuracy predict result in order to manage the defect in effective way (Fenton & Neil, 1999). A statistical techniques and machine learning as a methodologies and algorithms (Nagappan et al., 2006; Lessmann et al., 2008) for those defect prediction model where required the historical data to predict the future defect (Han et al., 2014) or compare with the actual rate of defect with predict result in order to select evaluate a most suitable defect prediction model (Umar, 2013; Han et al., 2014). According to Menzies et al., (2007), artificial intelligence (AI) based defect prediction model such as Artificial Neural Network (ANN), Decision Tree, Support Vector Machine (SVM), Fuzzy Logic (FL) is capable to detect a higher degree of defection, 70% on average compare to the other method for software defect prediction such as inspection (Umar, 2013). According to Verma and Singh (2015), the neural network model is the best model to predict defect compare to other prediction model.

3.0 Methodology

A kind of single case study method will be applied to this study. A set of colour defect data collected from the AX Furniture within fourteen days and recorded in a way of hour by hour which is total eight (8) working hours. After the data was collected, the method of Artificial Neural Network would be applied and used software namely of MATLAB R2015a to carry out a prediction process.

3.1 Artificial Neural Network (ANN)

According to Babkin et al. (2015), it is a set of neurons will connected in term of interconnections and composed in two or three layers in order to identify the input layer and also output layer. It is a multilayer network structure or defined as multilayer perceptron network. Figure 3.1 is shown a neural network model which is multilayer neural network with one hidden layer and one neuron output and Figure 2 show the process of developing an Artificial Neural Network model.

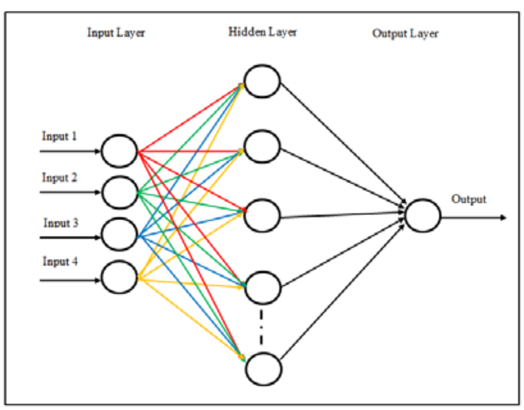

Figure 2: Artificial Neural Network Architecture

Artificial Neural Network applied in feed-forward back-propagation algorithm learning with multilayer perceptron structure network to carry out the forecasting process in order to minimize the error by the time the network learns the training data (Ziaei-Rad *et al.*, 2016; Gupta & Kashyap, 2015). Firstly, the input is propagated forwardly and the desired output will compare with the actual output; secondly, the weight will be changes after the creation of backward action in order to minimize the error as expected between the desired output and actual output (Tan *et al*., 2015).

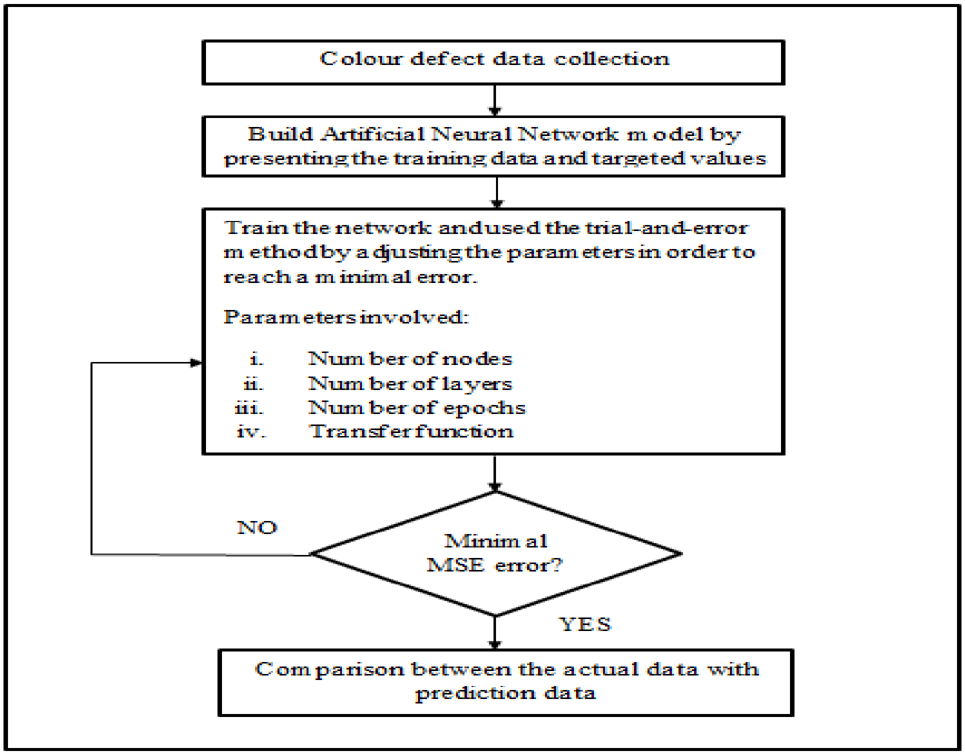

Figure 3: Process of developing an Artificial Neural Network model

The back-propagation algorithm of the Artificial Neural Network as follow (Tan *et al*., 2015):

$$\Delta W(k) = n\left(-\nabla E\left(W(k)\right) + \beta \Delta W(k-1)\right) \qquad (3.1a)$$

$$\Delta b(k) = n\left(-\nabla E\left(b(k)\right) + \beta \Delta b(k-1)\right) \qquad (3.1b)$$

Where,

W = Network weight

$\nabla E\left(W(k)\right)$ = Gradient of E at $W(k)$, with κ = 1, 2, 3, …, M

$\nabla E\left(b(k)\right)$ = Gradient of E at $b(k)$, with κ = 1, 2, 3, …, M

n = Learning rate

β = Momentum factor

3.2 Mean Square Error (MSE)

In order to obtain the best performance of Artificial Neural Network model, measurement of Mean Square Error will be conducted. An optimum neural network model will accompany by the minimal MSE value. The equation showed as below is used to calculate the mean error value.

$$\text{MSE}=\frac{\sum(error)^2}{n} \qquad (3.2)$$

Where,
Error = Actual value – Prediction value (3.3)

n = amount of data

4.0 Result and Discussions

According to fellow previous studies, a feed-forward neural network model which conducted in Levenberg-Marquard back-propagation (LM-BP) algorithm with a single hidden layer was a well suited method to train the network (Kabir & Sumi, 2012; Moustafa, 2011; Afrand *et al*., 2016). Figure 4 showed the architecture of neural network.

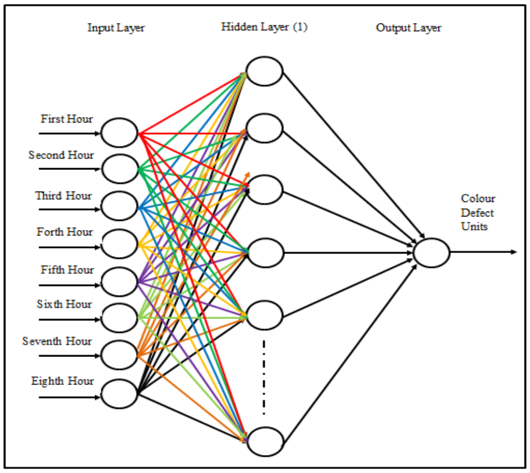

Figure 4: Architecture of the neural network

The neural network analysis carried out by the MATLAB R2015a application that using the neural network toolbox. There would be involved as many of 112 data entries and randomly divided up 100% of data in three sections which were 70% for the section training, 15% used in section validation and 15% for the section testing. Trial-and-error method was developed in order to determine the number of neuron with the minimize Mean Square Error (MSE). The training process would be started with one (1) neuron in hidden layer until seventeen (17) neurons with tangent sigmoid transfer function 'tansig' and train in as many as 1000 epochs, 5000 epochs and 10,000 epochs. Table 1 showed the result of each epoch set after training the network. From the Table 4.1, the optimum number of neurons in hidden layer was nine (9) where it produced a smallest MSE value at 10,000 epochs compared to the others two (2) epoch sets.

Table 1: Result of each epoch set

Number of Neurons	MSE value		
	1000 Epochs	**5000 Epochs**	**10000 Epochs**
1	1.5164	0.014561	0.54848
2	1.0424	0.21855	0.67086
3	0.70511	0.27881	1.5593
4	4.6795	1.0864	0.54623
5	2.0582	2.8239	2.4688
6	16.3816	0.2176	2.0012
7	2.2588	17.3917	4.4267
8	0.07351	0.0020005	0.00010802
9	14.7182	4.0399	**0.0000010801**
10	2.8317	0.50775	0.00010343
11	1.3892	0.018879	0.0056403
12	1.3454	0.011129	0.38934
13	7.5442	2.9781	0.80833
14	9.607	0.082556	1.2056
15	0.022352	2.3915	0.0095978
16	1.7126	0.6457	0.1855
17	2.1321	16.1439	0.0016503

The optimal neural network model was found out at nine (9) neurons in hidden layer at 10,000 epochs with a minimize MSE value, 0.0000010801. Figure 5 showed the neural network architecture where presented by the neural network toolbox and Figure 6 showed an opened window of the network when it was reached the minimum gradient.

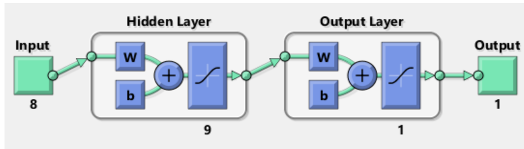

Figure 5: Neural Network Architecture

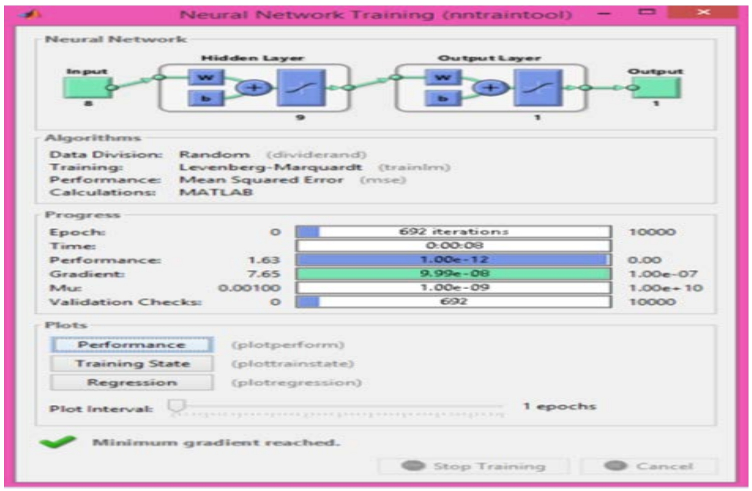

Figure 6: The opened window of network

The performance plot shown in Figure 7 was presented to the minimum MSE which dropped at an epoch of 0 and the value was 0.0000010801 or 1.0801e^{-6} for the validation dataset. The training process stopped when MSE of validation dataset stared to increase.

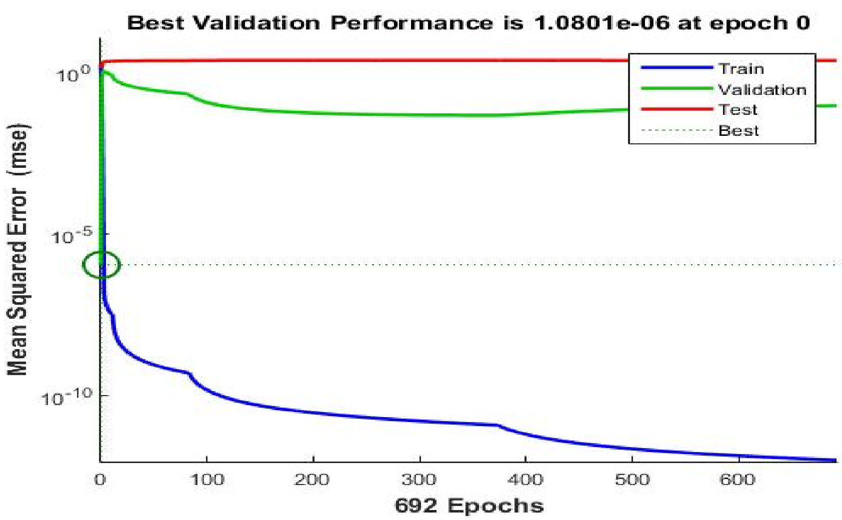

Figure 7: The best validation performance plot

For this study, an over fitting situation may occurred when the test curve higher than the validation curve (Khamis & Wahab, 2016; Ahmadloo & Azizi, 2016). However, according to Karia *et al*. (2013), there had no evidence to show that it was an over fitting situation due to the following condition of the performance plot. First, the test plot was similar with the validation plot and also the test plot was not raise significantly than the validation plot. Second, there was indicate an evidence showed that the performance of validation errors improve with the training errors due to the MSE were small enough. MSE is represented how close a set of point in regression line and also the difference between predicted value and measure value. From the result, the MSE value is very close to zero (0). Thus, it can be generated a best fit regression line where the regression line showed in Figure 8.

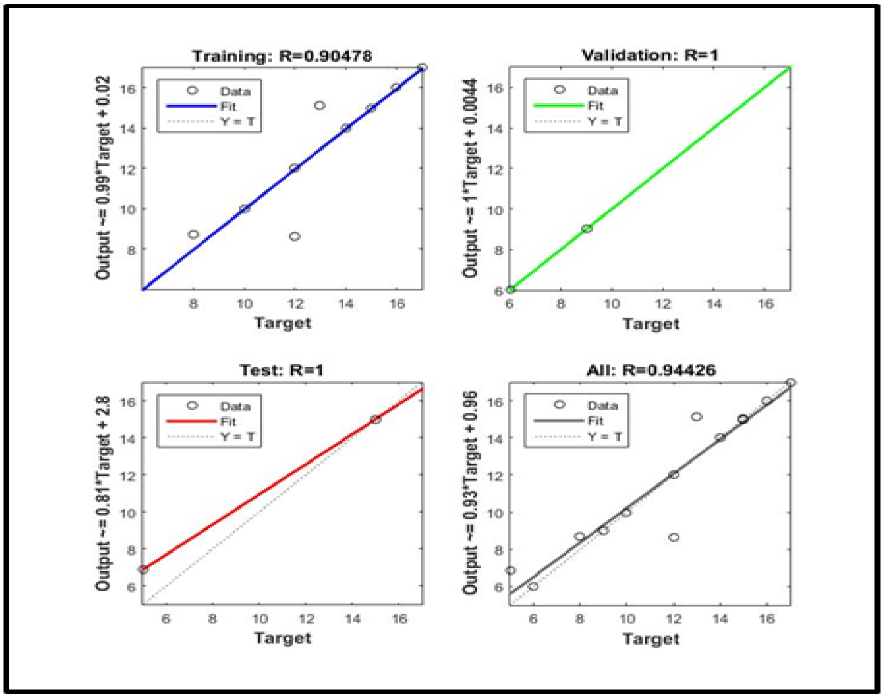

Figure 8: The regression plot

Figure 9 showed a training state plot which involved in three (3) different types of graph. The training state plot was indicated the difference between the testing dataset and training dataset. The gradient graph represented about each of the iteration of gradient value of back-propagation in logarithmic scale. The minimum gradient value was obtained in number of 9.9858e^(-08) at 692 epochs. Third graph indicated the validation fail when increases the validation MSE value. It would automatically stop at 692 iterations after obtained the validation MSE value in performance graph.

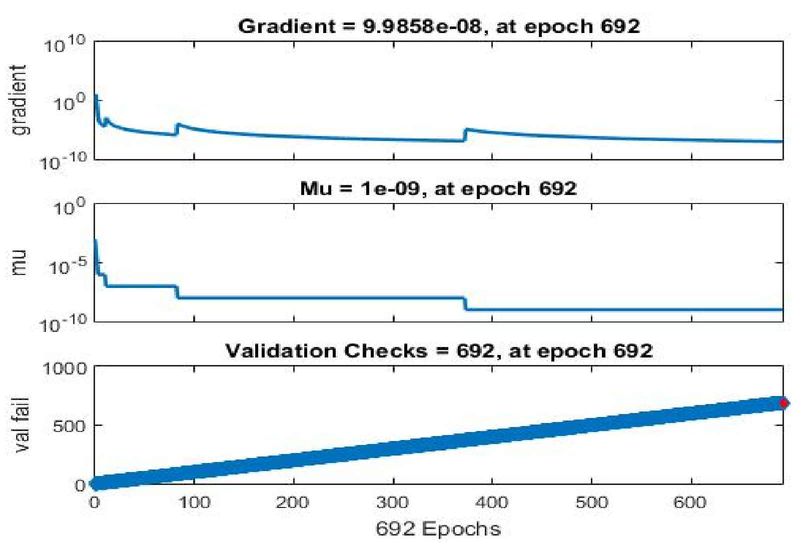

Figure 9: Training state plot

The neural network model is created after training the network and it is able to capture the well suited network properties for the model. Table 2 showed a summary of neural network model that was used to forecast the colour defect units.

Table 2: Summary of neural network model

Neural Network Model Properties

Neural Network Type	Multi layer feed-forward back-propagation neural network
Learning Algorithm	Levenberg-Marquardt (LM)
Hidden Layer	1
Hidden Neurons	9
Input Neurons	Production Time 1. First hour 2. Second hour 3. Third hour 4. Forth hour 5. Fifth hour 6. Sixth hour 7. Seventh hour 8. Eighth hour
Output Neuron(s)	Colour defect units
Data Division	70% for training, 15% for validation, 15% for testing (as default in NN toolbox)
Epoch(s)	10,000
Transfer Function	Tangent sigmoid (tansig)
Evaluate Neural Network Performance	Mean Square Error (MSE)
Training Termination	Stop training when reaches minimum gradient value / maximum 10,000 epochs

Figure 10 showed a plot graph that was plotted from the actual data and the prediction data that were obtained through the neural network model with desired properties as stated in Table 4.2. The red line represented to the prediction data meanwhile the blue line represented to the actual data. From observing Figure 4.7, it is a good fitting diagram where the prediction plot was well matched with the actual plot and two curves were much similar. Thus, it indicated that the performance of neural network model was good enough to forecast the colour defect units.

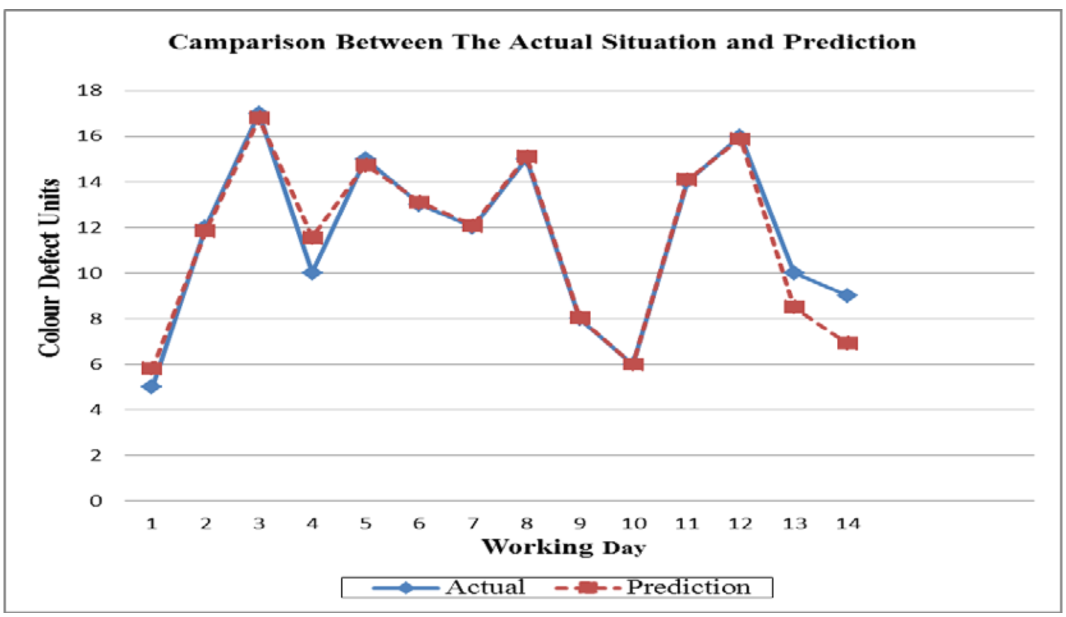

Figure 10: A comparison graph between the actual situation and prediction

5.0 Conclusion

The neural network model with a series of desired properties which stated in Table 4.2 produced a best validation performance, the smallest MSE value equal to 0.0000010801 or 1.0801e^(-06) and this value very close to zero (0). The smallest MSE value was able to create a best fit regression line with the R value of 0.94426 where it was closely to one (1). Hence, a non-linear variable which was represented by the colour defect unit for this study can be explained by the neural network model and show as much as 94% change in units meanwhile only remaining the 6% redound to unknown. The result of the comparison process was showed that there was well matched between the actual situation and predicted value. The company could use this model and applied to their actual work for their management purpose. A high accuracy result gained from the forecasting method was important for the management purpose because the result was capable to effect the company performance (Kerkkänen, 2010; GhasemiGol *et al*., 2015).

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Biography

Dr. Abdul Talib Bon is Professor of Technology Management in the Department of Production and Operations Management at the Universiti Tun Hussein Onn Malaysia. He has a PhD in Computer Science, which he obtained from the Universite de La Rochelle, France. His doctoral thesis was on topic Process Quality Improvement on Beltline Moulding Manufacturing. He studied Business Administration in the Universiti Kebangsaan Malaysia for which he was awarded the MBA. He’s bachelor degree and diploma in Mechanical Engineering which his obtained from the Universiti Teknologi Malaysia. He received his postgraduate certificate in Mechatronics and Robotics from Carlisle, United Kingdom. He had published more 150 International Proceedings and International Journals and 8 books. His research interests include manufacturing, forecasting, simulation, optimization, TQM and Green Supply Chain. He is a member of IEOMS, IIE, IIF, TAM, MIM and council member’s of MSORSM.