Performance analysis of neural network models for sustainable manufacturing practices (SMP) and economy performances

N.H. Abu[1,*], A.S.M. Jaya[1], M.R. Muhamad[2]

[1)] Faculty of Information Technology and Communication, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: norhashidahabu@gmail.com, m031420010@student.utem.edu.my

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ABSTRACT – This study presents a development of neural network model based on the single hidden layer with 10, 12 and 15 neurons in the hidden layer. 150 data of sustainable manufacturing practices (SMP) were divided into 70% for training (104 data), 15% for validation (23 data) and 15% for testing (23 data). Two performance measures are used to validate the model which is mean square error (MSE) and R valued. It shows that neural network model with 10 neurons in hidden layer give better performance and can be used to predict the target output of sustainability performance.

1. INTRODUCTION

Sustainability is evolutionary concepts that expand to responses the issues of global inequality and arises as a consequence of adaptation to changing circumstances. The previous research focusing on manufacturing management faces a lot of difficulties in a way of gaining reliable data and analysis about manufacturing practices and the performances. Time and cost consuming become the highest problem and it follows by lack of knowledge about the manufacturing practices and performances by the manufacturing firms itself. Instead of applying all the manufacturing practices into the firms directly, it is wisely to provide the statistically evidences through mathematical modeling and analysis before the implementation.

Regarding the issues, ANNs have been recently developed as a powerful modeling tool in comparison to the statistical or numerical methods. ANNs have been used for many engineering applications such as prediction, optimization classification and pattern recognition. They have a highly interconnect structure similar to brain cells of human neural networks. There are eight inputs involves which are cleaner production (CP), eco-efficiency (EE), employee relation (ER), supplier relation (SR), customer relation (CuS), community relation (CoR), closed-loop production (CLP) and industrial ecology (IE). The target output is economic sustainability performance. The objective is to find relationship between SMP and economy performance using neural network approach.

2. METHODOLOGY

Neural network consisted of input, sum function, log-sigmoid activation function and output. Levenberg-Marquardt back propagation as training algorithm is reinforced by this neural network. The input values for neuron are obtained by multiplying the output that connected the neuron by strength of connection.

The structures consist of great number of processing elements call neuron and arranged in different layers of the network. Each network contains an input layer, an output layer and one or more hidden layers. The neurons in the networks are interconnect using weight factors, $c_{j,k}$. A neuron in given layer receives information (i_j) from all the neurons in the preceding layer. It sums up information (net_k) weighted by factors corresponding to the connection and the bias of the layer (θ_k) and transmit output values (y_k) computed through applying a mathematical function (f(.)) to net_k, to all the neurons of the next layer. This process is formulated in equation (1) and (2):

$$net_k = \sum_{i=1}^{n} C_{j,k} W_k + \theta_k \tag{1}$$

$$y_k = f(net_k) = \frac{1}{1+e^{-net_k}} \tag{2}$$

The number of neurons in the ANN layer has an important effect to the network performances [1-2]. The number of neurons in input layer is same with the number of input (independent) variables. While number in neurons in output layer represent the number of output (dependent) variables. However, this situation happen based on cause and effect relationship because currently no explicit rule to detect the number of hidden neuron in the hidden layer(s). Both number of hidden layer and number of neurons in hidden layer are generally detected by process of trial and error.

The influence of the number of neurons in the hidden layer on the performance of the network is quite complicated. The trained network does not have sufficient ability to learn the relationship of inputs and outputs if the architecture of ANN model is too simple. While, if the architecture is too complex the training of the network will be over fitted or the model will not converge to the goal error.

In the abstract, the hidden layer was testing using three different numbers of neurons which are 10, 12,

and 15 neurons as previous study [2-5]. The chosen number of neuron must avoid overfitting and improve neural network generalization [2]. The aim of these steps is to improve the result of the neural network.

3. RESULTS AND DISCUSSION

There are two performance measures is used to validate the neural network model which are mean squared error (MSE) and R value. Mean squared error is the average squared difference between outputs and targets. The lower values the better and zero means no error. The regression R values measure the relationship between outputs and targets. The higher R values the better and value of 1 means that outputs and targets value is close in relationship. Table 1 until Table 3 show the MSE and R values for all the neural network models:

Table 1 Results of MSE and R value for neurons = 10.

Results	MSE	R value
Training	0.2482	0.6574
Validation	0.2228	0.4644
Testing	0.2249	0.5084

Table 2 Results of MSE and R value for neurons = 12.

Results	MSE	R value
Training	0.1377	0.7828
Validation	0.5351	0.0683
Testing	0.3456	0.5867

Table 3 Results of MSE and R value for neurons = 15.

Results	MSE	R value
Training	0.1249	0.8416
Validation	0.3662	0.3208
Testing	0.6089	0.2042

From the Table 1, Table 2 and Table 3, it shows the mean squared error (MSE) and R value for the neural network models. The lowest MSE for training data is the hidden layer with 15 neurons which is 0.1249. Then, the lowest MSE for validation data is the hidden layer with 10 neurons which is 0.2228. Lastly, for the testing data, the lowest MSE is also hidden layer with 10 neurons which is 0.2249 [2].

The R values shows that the highest for training data is hidden layer with 15 neurons which is 0.8416. For validation data is 10 neurons which is 0.4644 and for testing data, the hidden layer with 12 neuron is the highest which is 0.5867 [3].

From this two performance measure, it shows that training set data provide the best results with the lowest mean squared error (MSE) and highest R value [4]. While the best hidden layer is with 10 neurons because consist of average lower MSE and average higher R value [5].

4. CONCLUSION

In this research we have demonstrated the use of neural network analysis for the prediction of economy sustainability performance based on sustainable manufacturing practices (SMP). The analysis shows that the predicted model consists of all the manufacturing practices give a lot of information regarding the economy sustainability. It was concluded that neural network model can provide accurate prediction of economy sustainability performance from sustainable manufacturing practices (SMP).

Hence, the result can provide guidelines, statistical evidence and analysis for manufacturing engineers and firms. It is crucial before implementing sustainable manufacturing practices (SMP) into the manufacturing firms and management

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