# Chapter 4

# Empirical Results

This chapter presents the analysis of 2 proposed hybrid models. The results of hybrid multiple regression-artificial neural network model will be presented in Section 4.1, and the results of hybrid artificial neural network-regression model will be presented in Section 4.2. Then, the comparison results will be demonstrated in Section 4.3.

## 4.1 Results of hybrid multiple regression - artificial neural network model

### 4.1.1 Statistical analysis of the correlated inspection results

As mentioned earlier in Chapter 3, in this research, transportation productivity is considered as a dependent variable. Whereas, seven independent variables are employed to predict transportation productivity, which are concrete volume per trip (Cubic meter: $X_1$), delivery distance (Kilometer: $X_2$), batching time (Minute: $X_3$), travelling time (Minute: $X_4$), waiting time (Minute: $X_5$), pouring time (Minute: $X_6$) and returning time (Minute: $X_7$).

At the beginning step of the research, it is necessary to test whether the model is unaffected multicollinearity issue. As such, correlation values between independent variables were conducted (Table 4.1). In order to reconfirm whether there is no problem with multicollinearity, the Durbin – Watson and VIF test were further investigated. The ranging value of Durbin – Watson should be in between 1.5 and 2.5 (Atici, 2011) and VIF value should lower than 20 (Pao, 2008). Table 4.2 shows the results of VIF test. It is indicated that both Durbin – Watson (1.83) and VIF tests are complied well.

**Table 4.1:** Correlation values between independent variables

| $X_i^a$ | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ |
|---|---|---|---|---|---|---|---|
| $\mathbf{X_1}$ | 1 | | | | | | |
| $\mathbf{X_2}$ | 0.03 | 1 | | | | | |
| $\mathbf{X_3}$ | 0.27 | 0.03 | 1 | | | | |
| $\mathbf{X_4}$ | 0.02 | 0.06 | 0.04 | 1 | | | |
| $\mathbf{X_5}$ | 0.17 | -0.03 | 0.07 | -0.09 | 1 | | |
| $\mathbf{X_6}$ | -0.13 | -0.01 | -0.01 | 0.02 | -0.02 | 1 | |
| $\mathbf{X_7}$ | -0.06 | 0.04 | 0.02 | 0.05 | -0.09 | 0.09 | 1 |

**Table 4.2:** Results of VIF test

| **Variables** | **VIF value** |
|---|---|
| $X_1$: Concrete volume | 1.128 |
| $X_2$: Deliver distance | 1.544 |
| $X_3$: Batching time | 1.080 |
| $X_4$: Travelling time | 1.650 |
| $X_5$: Waiting time | 1.042 |
| $X_6$: Pouring time | 1.028 |
| $X_7$: Returning time | 1.402 |

### 4.1.2 Multiple regression analysis

Multiple regression analysis was then developed in order to be an input in a hybrid model. Table 4.3 shows regression statistic results. $R^2$ value is closely to 1, which can be claimed that the model is acceptable.

**Table 4.3:** Regression statistic results

| **Regression statistics** | **value** |
|---|---|
| Multiple $R^2$ | 0.96356 |
| $R^2$ | 0.92845 |
| Adjust $R^2$ | 0.92674 |
| Standard error | 1.13882 |

Table 4.4 presents the results of statistics summary form multiple regression model. Concrete volume per trip, deliver distance, batching time, travelling time, waiting time, pouring time, and return time variables were performed significant confidence at 99 % level (p - value < 0.01) while distance variable was performed significant confidence at 95 % level (p – value < 0.05).

**Table 4.4:** Results of ANOVA for ready mixed concrete delivery

| | $\beta$ | Standard error | t-value | p-value |
|---|---|---|---|---|
| Concrete volume | 1.2935 | 0.02454 | 36.0942 | 0.00** |
| Deliver distance | - 0.0092 | 0.00598 | -2.1085 | 0.03* |
| Batching time | - 0.0165 | 0.00496 | -10.2694 | 0.00** |
| Travelling time | - 0.0353 | 0.00354 | -14.4371 | 0.00** |
| Waiting time | - 0.0392 | 0.00213 | -20.5561 | 0.00** |
| Pouring time | - 0.0243 | 0.00120 | -27.7891 | 0.00** |
| Returning time | - 0.0223 | 0.00294 | -10.8420 | 0.00** |

Multiple regression model can be written as the following equation:

$$Y = 1.2935*Volume - 0.0092*Distance\ \text{time} - 0.0165*Batching\ time - 0.0353*Travelling\ time - 0.0392*Waiting\ time - 0.0243*Pouring\ time - 0.0223*Return\ time \quad (4.1)$$

### 4.1.3 Development of artificial neural network model

The results from Section 4.1.1 are used as an input in artificial neural network model to optimize ready mixed concrete delivery model. Artificial neural network was analyzed by using multilayer perceptron feed forward structure .The experimental design, presented in Table 3.2 in Chapter 3, was develop to generate the ANN model. The collected data were randomly selected 70% to be the training set of ANN, while the rest 30% were prepared for validation (Kumar et al., 2013). The optimal potential structure of ANN model (in terms of MSE) for ready mixed concrete transportation productivity (Y) is shown in Table 4.5.

**Table 4.5:** Optimal potential structure of ANN model

| Parameters | Optimal potential structure |
|---|---|
| Structure | 7:7:1 |
| Learning rate | 0.3 |
| Momentum | 0.6 |
| Iteration | 50,000 |
| Trained : Tested | 70:30 |

The results from Table 4.5 are then used to predict the value of Y. The comparison between actual and predicted values of transportation productivity is exhibited in Figure 4.1. The result indicates that the relationship between actual and predicted data of this model is not fit well.

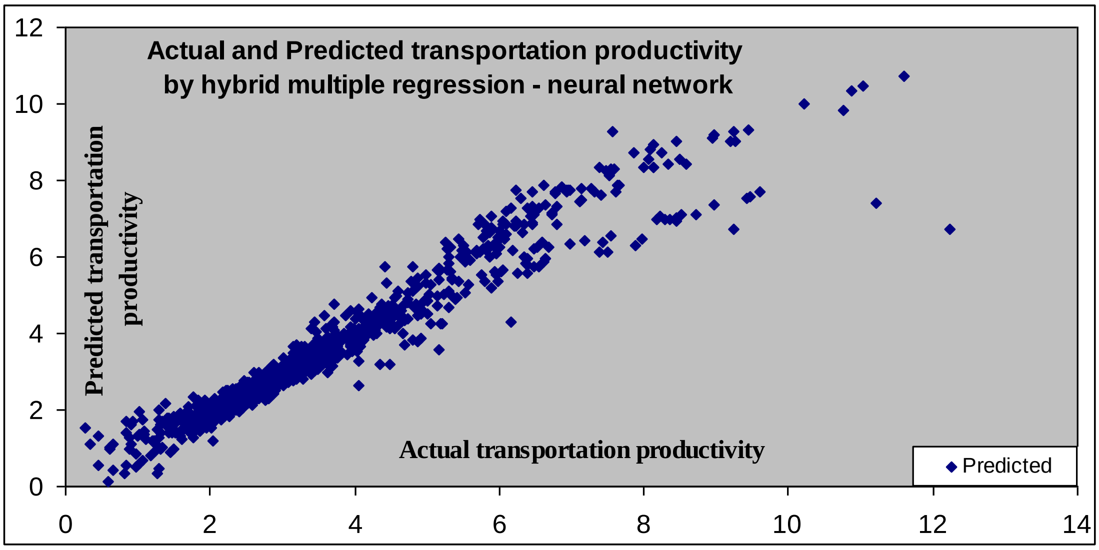


**Figure 4.1:** Performance of hybrid multiple regression– artificial neural network model

## 4.2 Results of hybrid artificial neural network - regression model

### 4.2.1 Development of artificial neural network model

Artificial neural network was analyzed by using multilayer perceptron feed forward structure to optimize ready mixed concrete delivery model. The experimental design presented in Table 3.2 in Chapter 3 was develop to generate the ANN model. The collected data were randomly selected 70% to be trained the proposed ANN, while the rest 30% were prepared for validation (Kumar et al., 2013). The optimal potential structure of ANN model for ready mixed concrete delivery is shown in Table 4.6. The mean square error is used in training the proposed NN architecture, after training the proposed model, the optimal results of ANN model is obtained as shown in Table 4.7.

**Table 4.6:** Optimal potential structure of ANN model

| Parameters | Optimal potential structure |
|---|---|
| Structure | 7:7:1 |
| Learning rate | 0.4 |
| Momentum | 0.7 |
| Iteration | 50,000 |
| Trained : Tested | 70:30 |

**Table 4.7:** Optimal results of ANN model

| Optimal potential structure | |
|---|---|
| Correlation | 0.9995 |
| Mean absolute error | 0.0166 |
| Root mean square error | 0.03299 |
| Relative absolute error | 1.1318% |
| Root relative square error | 1.7718% |

### 4.2.2 Development of Regression Model

For the second proposed hybrid model, the dependent variable is transportation productivity and the independent variable is the output data obtained from ANN model. Tables 4.8 and 4.9 show results from ANOVA and regression statistics, respectively. F ratio was significant indicating the overall explanatory power of this model. The coefficient of determination ($R^2$) was found to be 0.9997 indicating that 99.97 percent of transportation productivity was explained by independent variable. From the regression analysis, independent variable which obtained from ANN model did have a significant influence on transportation productivity.

**Table 4.8:** Measure of variation in regression

| | df | SS | MS | F | p- value |
|---|---|---|---|---|---|
| Regression | 1 | 3294.607611 | 3294.608 | 3983657 | 0.0000*** |
| Residual | 841 | 0.695532982 | 0.000827 | | |
| Total | 842 | 3295.303144 | | | |

**Table 4.9:** Regression output

| Regression Statistics | |
|---|---|
| Multiple R | 0.999894460 |
| R Square | 0.999788932 |
| Adjusted R Square | 0.999788681 |
| Standard Error | 0.028758145 |
| Observations | 843 |

**Table 4.10:** The least-square method result

| | Coefficients | Standard Error | t Stat | p-value |
|---|---|---|---|---|
| Intercept | -0.00783551 | 0.002127647 | -3.68271 | 0.000246*** |
| Predicted | 1.00209456 | 0.000502074 | 1995.91 | 0.000000*** |

Then, the point-to-point comparison between actual and predicted values via using hybrid neural network with regression model is given in Figure 4.2. The results show that the relationship between actual and predicted transportation productivity of hybrid neural network with regression model is closely to linear relationship.

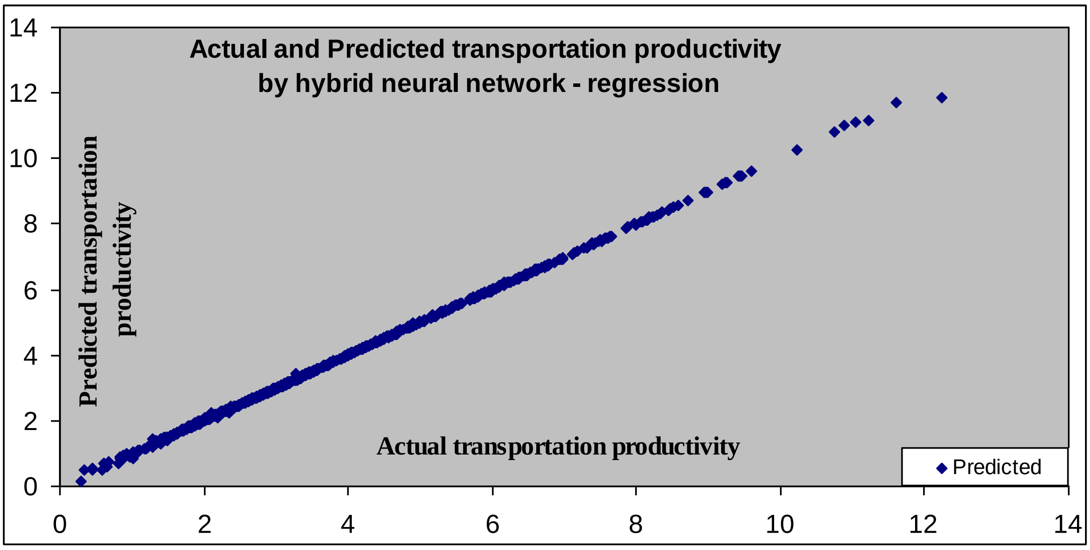


**Figure 4.2:** Performance of hybrid artificial neural network–regression model

### 4.3 Performance evaluation

The performance measurements of transportation productivity from both models are compared by using mean absolute percentage error (MAPE) and root mean square error (RMSE). Table 4.11 shows the comparison results of MAPE and RMSE values of both hybrid models. The result indicates generally that the error from hybrid neural network with regression model is lower than hybrid multiple regression with artificial neural network model. Therefore, it can be summarized that combining hybrid artificial neural network with regression model has a better performance than combining multiple regression with artificial neural network.

**Table 4.11:** Performance comparison

| Models | RMSE | MAPE |
|---|---|---|
| Hybrid artificial neural network–regression model | 0.028724 | 0.860352 |
| Hybrid multiple regression-artificial neural network model | 0.519427 | 10.830478 |