AN ARTIFICIAL NEURAL NETWORK MODEL FOR ROAD ACCIDENT PREDICTION: A CASE STUDY OF KHULNA METROPOLITAN CITY

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ABSTRACT

Highway related accidents are considered one of the most serious problems in the modern world as traffic accidents cause serious threat to human life worldwide. The increase in the number of vehicles and inefficient drivers on the road, as well as to the poor conditions and maintenance of the roads, are responsible for accident crisis in Khulna Metropolitan city, Bangladesh. Prediction of future traffic accidents is therefore of utmost importance in order to appreciate the magnitude of the problem and speed up the decision making towards its alleviation. In this study, it was developed a design of an Artificial Neural Network (ANN) model with the aim of identifying its suitability for prediction of traffic accidents under Khulna cities conditions.In the ANN model development, the sigmoid activation function was employed with Levenberg-Marquardt algorithm. This model was developed using the data from the year 2000 to 2013. In the design, vehicle type, accidents type, junction type and collision type were selected and used as model parameters. The model results indicate that the junction point is the most important parameter that affects the number of accidents on highways. The results demonstrated that the estimated traffic accidents, based on sufficient data, are close enough to actual traffic accidents and thus are reliable to predict future traffic accidents in Khulna Metropolitan city. The performance evaluation of the model signified that the ANN model is better than other statistical methods in use.

Keywords: *Artificial neural network, road, accident, back propagation, vehicles*

1. INTRODUCTION

Road accidents are one of the major causes of death, injury and disability all over the world both in developed and developing countries. With a broad estimation, in every one minute, two people are killed and 95 people are severely injured or permanently disabled in traffic accidents worldwide. Traffic accident related deaths and injuries result is not only substantial economic losses but also serious physical and mental sufferings. Developing countries are much more affected from traffic accidents than developed countries. According to the world health organization (WHO) statistics, 75% of deaths resulted from traffic accidents occur in developing countries, although they own only 32% of the motor vehicles in the world. While the annual fatality per 10,000 vehicles ranges from 20 to 200 in low or middle income countries, it varies between 1.5 and 5.0 in industrialized countries. Each year more than 500000 people die in road accidents around the world (Mannan & Karim ,1999).

There has been an alarming rise in road accidents, significantly highway accidents, in Bangladesh over the past few years. According to a study conducted by the Accident Research Institute (ARI) of BUET, road accidents claim on average 12,000 lives annually and lead to about 35,000 injuries. According to World Bank statistics, annual fatality rate from road accidents is found to be 85.6 fatalities per 10,000 vehicles. Hence, the roads in Bangladesh have become deadly.

The number of injured and killed people is currently increasing rapidly in Khulna Metropolitan city. If until 2020 the trends in RTAs continue, it will be considered as the second most noted cause of fatalities in Bangladesh. RTAs contribute greatly in huge economic overheads, extreme human distress and disaster. A long term sustainable road traffic system can be achieved if the traffic safety work is developed and intensified.

Artificial Neural Network (ANN) systems have been applied in different information technology problems, such as traffic in communication and transportation engineering (Ozgan & Demirci, 2008). ANN has been widely applied in travel behaviour, flow and management (Himanen, V.1998). The use of artificial neural networks can reveal the relationship that exists between vehicle, roadway and environment characteristics and driver injury severity (Abdelwahab & Abdel-At, 2001). Traffic forecasting problems involving complex interrelationships between variables of traffic system can be efficiently solved using ANN. They provide realistic and fast ways for developing models with enough data (Riviere et al., 2006). Considering this high capability researchers are researching on new generations of ANN with more power and precision. This study explains the use of neural networks in the modeling of the number of persons fatally injured in motor vehicle accidents in data sets of the Khulna Metropolitan city. The ANN models help us to compare the cities road safety performance by the number of motor vehicle fatalities.

The advantage of ANN over conventional programming depends on its ability to solve complex and non-algorithmic problems. ANN uses past experience to learn how to deal with the new and unexpected situations. The statistical distribution of the data does not need to be known when developing an ANN model. There is no need for prior knowledge about the relationships amongst the variables being modeled. ANN has the ability to model complex, nonlinear relationships without previous assumptions of the nature of the relationship, like a black box. The most important key element of ANN paradigm is the novel structure of the information processing system. The synapses associated with irrelevant variables readily show negligible weight values; relevant variables present significant synapse weight values. Neural networks, which are good at broad and flat transformation of data, are nonlinear, able to relate input with output, and are error tolerant. Another advantage of ANN analysis is that it allows the inclusion of a large number of variables. Traffic forecasting problems involving complex interrelationships between variables of traffic system can be efficiently solved using ANN.

The traffic accident situation in Khulna city as well as Bangladesh is really alarming and the loss of lives and property damages are expected to continue if suitable corrective measures are not taken accordingly by applying proper engineering measures through extensive research and investigations. This situation is very dangerous particularly in metropolitan cities. About 20 percent of road accident occurred in metropolitan cities viz. Dhaka, Chittagong, Khulna and Rajshahi (Hoque, M.M., 1991). Because of the alarming increase of the road traffic accident at Khulna metropolitan city, it is important to prediction of road accident considering the basic factors of those causing accident in this area. Therefore, it is important that accident prediction should be carried out for these cities on a priority basis.

2. METHODOLOGY

2.1 STUDY AREA

The study area is under the five police stations of Khulna Metropolitan City, which are: Khulna Sadar, Daulatpur, Khalishpur, Khanjahan Ali and Sonadanga.

2.2 DATA COLLECTION

In the current study, highways of Khulna Metropolitan city has been considered as a case study. The road traffic accidents (RTA) data from 2000 to 2013 were collected from the Accident Research Institute (ARI) of BUET.

2.3 DEVELOPMENT OF ANN PREDICTION MODEL

To estimate the ANN model, there are a number of software packages ready to perform the Levenberg Marquardt algorithm was chosen for this study. In the ANN model, independent variables are named as the input, and dependent variables are named as the output. The input importance chart shows the relative importance of each input column. The data is divided into three sets; training data. (About 70% of the total data), validation data (about 15% of the total data), and testing data (about15% of the total data). Training, validation and testing of the network was performed using MATLAB .Multi-layer perceptron ANN adopts different learning algorithms; and one the most well-known techniques is back propagation and it was used in this study. The years, accident types, collision types, junction types and vehicle types used as model factors. The designed Multi-Layer Perceptron Neural Network (MLPNN) consists of the input layers, hidden layers and an output layer, as shown in Figure 1.

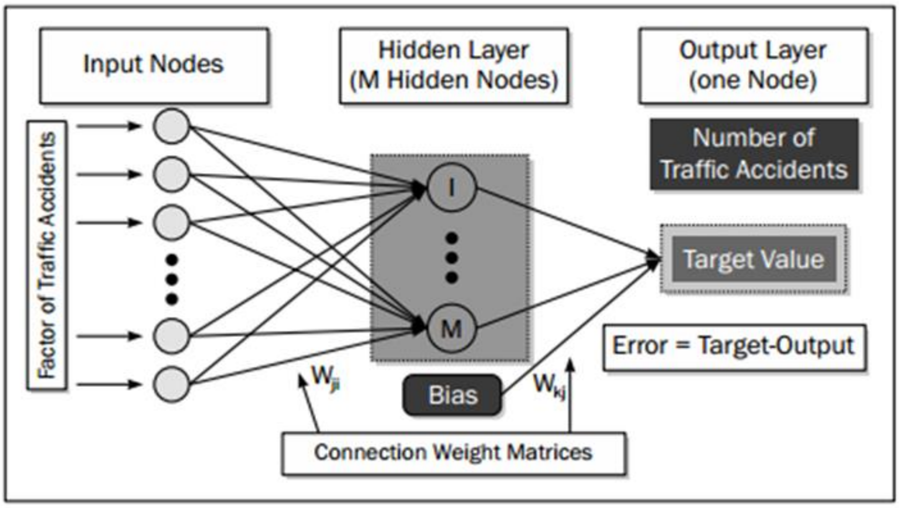

Figure 1: Structure of artificial neural network model for traffic accidents

The Selected transfer functions were

- Input hidden layer: Tan-sigmoid transfer function
- Output hidden layer: Linear transfer function
- The training process includes the following operations:
- Setting initial values for weights
- Evaluating the output based on initial weights.
- Measuring the error (mean square error or any function to calculate the error)
- Adjusting the weights using rate of learn(usually small value such as 0.01)
- The weights continue to be modified as each error is computed. If the network is capable and the learning rate is set correctly, the error is eventually driven to zero.
- In the validation phase, no adjustment occurs to the weights. Validation is necessary to measure the performance of the network model where the predicted values are compared with the actual as given by the validation data. This process can be integrated with training process to improve the performance of the model.
- Through the testing process, the predicted values are compared with the input values using testing data that was not used in training or validation process.

The Multi-Layer Perceptron Neural Network (MLPNN), which is also called the multilayer feed-forward neural network, was chosen and used in this study. Figure 2 is a graphical representation of the overall architecture of the proposed system.

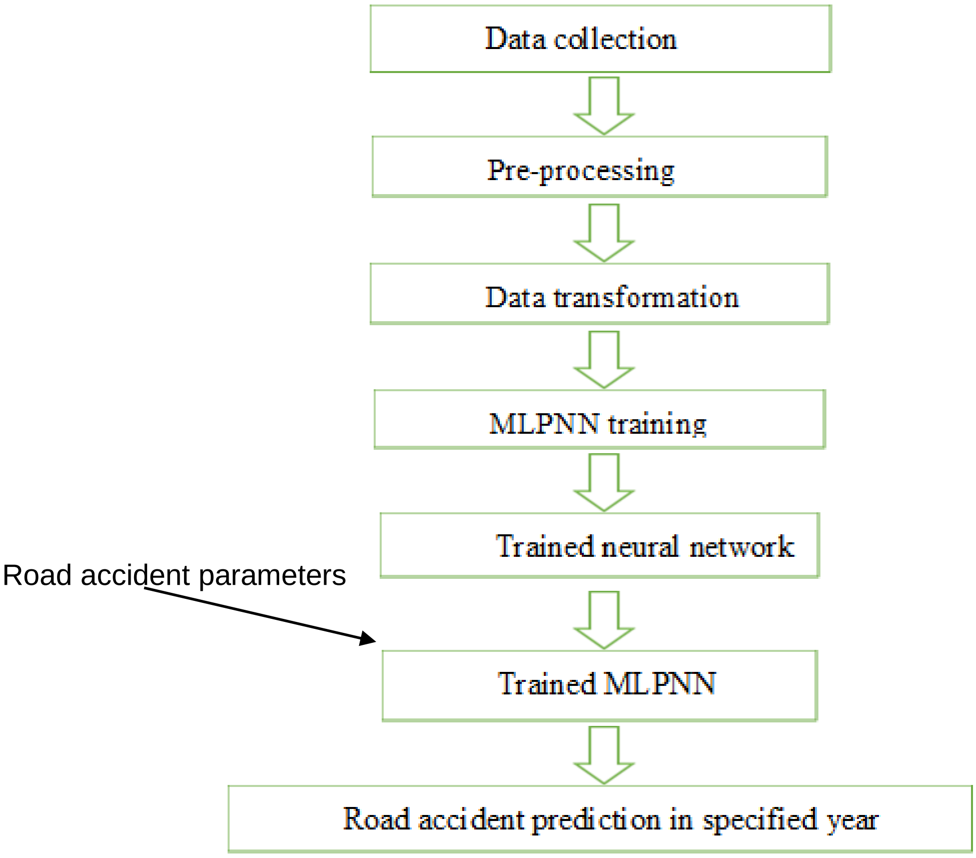

Figure 2: The Training Architecture

The major aim for carrying out training in a multilayer feed-forward network is to obtain ANN output weight values to match the actual target values very closely. To design and train multilayer perceptron network involves several challenges, which include determining the number of hidden layers to be used in the network, determining the number of neurons to be used in each hidden layer, establishing a general acceptable solution that avoids local minima, converging to an optimal solution as and when due or in good time, and validating the neural network to test for over fitting. Though there exist errors and noise in the training set, ANN still possesses the capability to find the dependencies that are hidden and are not linear, and it also learns from past experience as it completes its training.

In this study, the adjustment of the weight value was carried out using conjugated gradient algorithm with help of gradient during backward propagation of errors in the network. The conjugate gradients algorithm uses more paths that are direct to best group of weight values when compared with the gradient descent.

3. RESULTS AND DISCUSSION

The designed Multilayer Perceptron Neural Networks (MLPNN) contains three input layers with two hidden layers and one output layer. The output layer carries out the prediction of the RTA rate when presented with the factors.

Table 1: Summary of 2007 and 2013 RTA

Year	2007	2013	Remarks
Person dead	48	22	54% reduction in the number of persons dead
Person injured	40	11	73% reduction of persons injured

It was observed that 2007 has the higher number of persons dead and also number of persons injured between the year 2007 and 2013 RTA.

The comparative analysis of 2007 against 2013 made the prediction of RTA for 2013 to 2020 using primary source collected data capable of allowing an accurate and good data model. The multilayer feed-forward neural network with its learning technique worked through the output value comparison with the accurate answer and also performed the computation of the already established error function. The error is inputted back to the ANN algorithm and it adjusts the weight values of every connection to bring down the values of the error function to minimal. From the analysis of 2007 against 2013 the RTA target verses actual from 2000-2020 were obtained through prediction from collected data.

Table 2: Actual and predicted number of accidents using ANN

Year	Actual	Predicted	Residual	Year	Actual	Predicted	Residual
2000	69	76	7	2007	78	82	4
2001	55	62	7	2008	38	44	6
2002	56	55	9	2009	52	55	7
2003	38	45	7	2010	54	55	3
2004	20	27	7	2011	34	40	6
2005	35	42	7	2012	21	25	4
2006	59	58	9	2013	31	33	2

The Neural Networks allow the development of different alternatives by changing the number of hidden layers. Three model was developed for three different parameters to determine the coefficient of determination. The results were found to be very satisfactory with relatively small residuals especially in recent years where more reliable data bases are available through using more advanced data compilation techniques.

The following regression plots display the network outputs with respect to targets for training, validation, and test sets. For a perfect fit, the data should fall along a 45 degree line, where the network outputs are equal to the targets.

Figure 3 shows the accident type parameter where the fit is reasonably good for all data sets, with R values in each case of 0.99987.

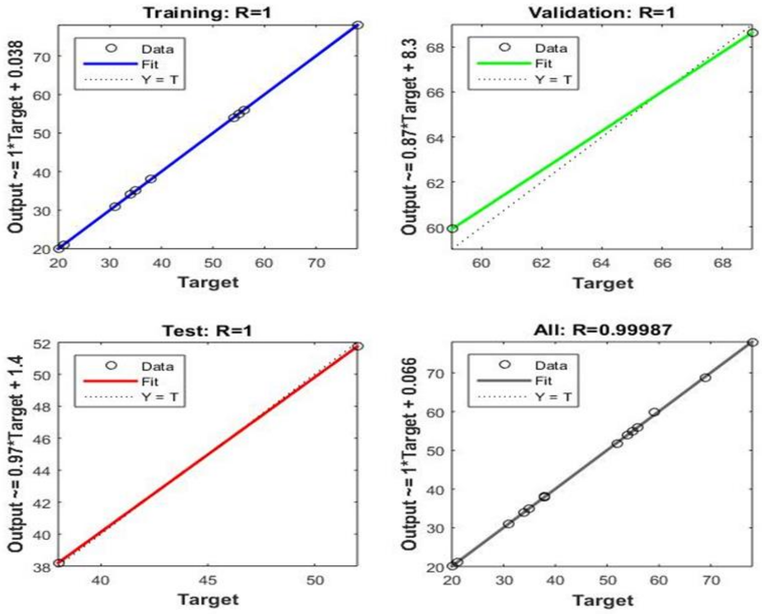

Figure 3: ANN Output for Different Types of Accident

Figure 4 shows the collision type parameter where the fit is reasonably good for all data sets, with R values in each case of 0.993 or above.

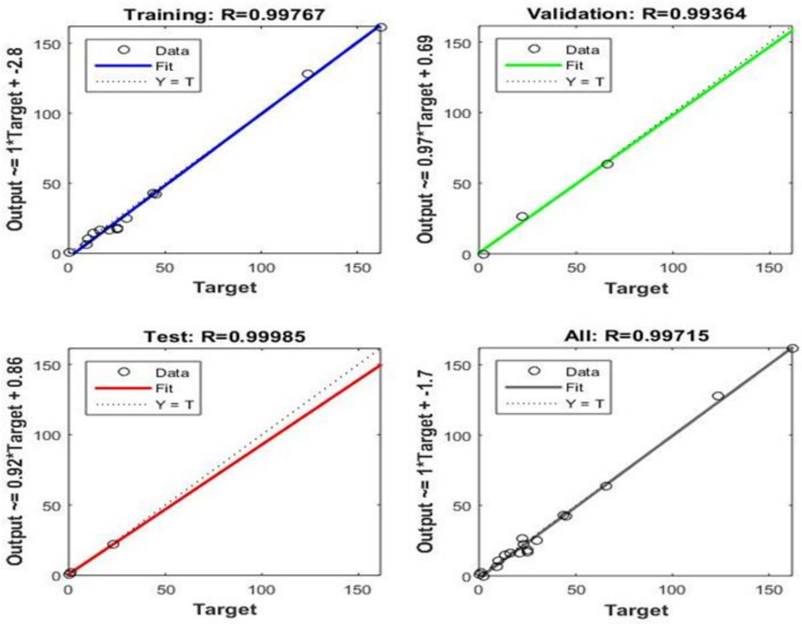

Figure 4: ANN Output for Different Types of Collision

Figure 5 shows the accident type parameter where the fit is reasonably good for all data sets, with R values in each case of 0.999 or above.

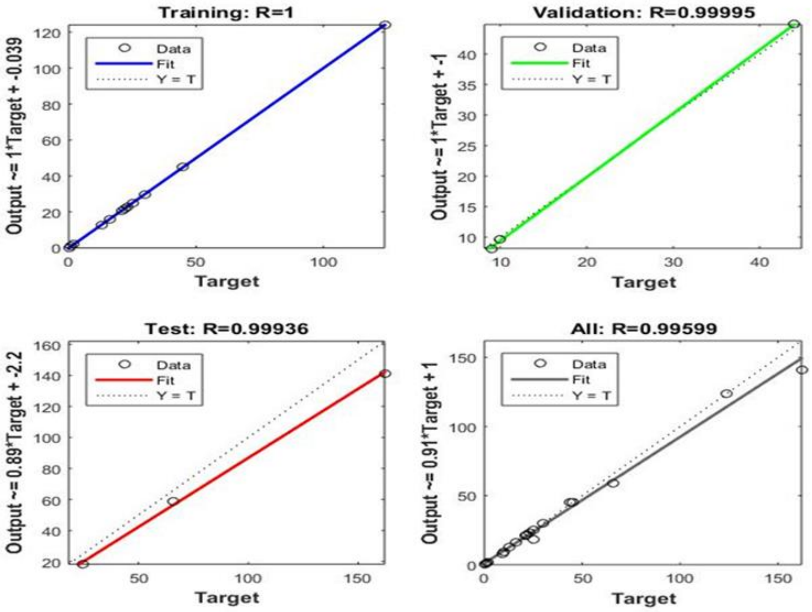

Figure 5: ANN Output for Different Types of Junction

This training stopped when the validation error increased for two iterations, which occurred at iteration 31. For finding the Performance in the training window, a plot of the training errors, validation errors, and test errors appears, as shown in the following Figure 6. In this study, the result is reasonable because of the following considerations:

- The final mean-square error is small.
- The test set error and the validation set error have similar characteristics.
- No significant over fitting has occurred by iteration 27 (where the best validation performance occurs)

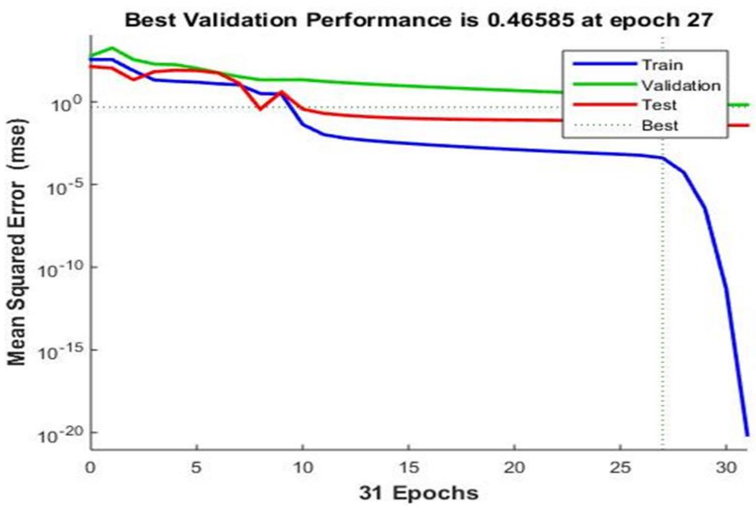

Figure 6. Error graph versus learning epochs for Different Types of Accident

Each time a neural network is trained, can result in a different solution due to different initial weight and bias values and different divisions of data into training, validation, and test sets. As a result, different neural networks trained on the study problem can give different outputs for the same input. To ensure that a neural network of good accuracy has been found, retrain several times. The difference between actual and estimated values in case of injury cases was not as higher as in case of total accident cases and that indicates a further scope of improvement of the injury prevention measures which have been taken by the respective authorities.

The multilayer feed-forward neural network with its learning technique worked through the output value comparison with the accurate answer and also performed the computation of the already established error function. The error is inputted back to the ANN algorithm and it adjusts the weight values of every connection to bring down the values of the error function to minimal.

4. CONCLUSIONS

In this study, the factors which cause accidents have been investigated, for providing road safety, and accident prediction models which include relations between these factors have been established. In this study the obtained data from the database have been investigated with ANN as a tool of forecasting techniques. Since ANN method is a more flexible and assumption-free methodology and furthermore, capable of evaluating/comparing all of the traffic accident characteristics, it is selected for modelling the traffic accidents data. The low values of mean squared error indicate superiority of the model. The results demonstrated that the predicted traffic accidents, based on sufficient data, are close enough to actual traffic accidents and thus are reliable to predict future traffic accidents in Khulna Metropolitan City.

ANN showed its advantage over conventional programming in this study. This is due to its capability to provide solutions to non-algorithmic problems and can learn how to deal with the new and unexpected situations by the help of past experience. Neural networks are able to relate input with output, allow large number of variables and are error tolerant.

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