Evaluation Pavement Deteriorating Condition on Surface Distress Index (SDI) Data Using Radial Basis Function Neural Networks (RBFNN)

By Amrina Rosada

Journal of Physics: Conference Series

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Amrina Rosada, Joni Arliansyah* and Erika Buchari

Department of Civil Engineering of Faculty of Engineering of Sriwijaya University, Palembang, Indonesia

*)Corresponding author : joniarliansyah@yahoo.com

Abstract. A pavement deterioration model (PDM) by using Surface Distress Index data applying Radial Basis Function Neural Networks (RBFNN) is presented in this paper. RBFNN architectures is designed as sequential PDM where the future pavement condition can be predicted using only information about present SDI value and age of pavements. The data used in this study were retrieved from road condition survey data of at pavement section between Betung region to Palembang. The pavement condition prediction results are compared with actual measured SDI value and other existing methods. The comparison is made between RBFNN model and Regression model. The comparison was also made to evaluate the flexibility of RBFNN by starting from a point that located along the actual deterioration curve. The results indicate that RBFNN model have better capability than regression model to be used to predict future condition of pavements, and the application is very flexible.

Key Words: Surface Distress Index, Prediction, Radial Basis Function Neural Networks.

1. Introduction

As one of the land transportation infrastructure, road/highway has an important role in supporting and developing the life of nation and state. In addition, the road is also part of the inter-regional transportation system that has a role in the economics, social and cultural fields of a region so as to achieve equity and balance of development between regions. The availability of a qualified road infrastructure is one of the factors determining the attractiveness of a region, the road has a very important function in the distribution of goods traffic, the people of a region both locally and nationally and determining the competitiveness of investment as well as increasing economic growth that affects equity community. Road infrastructure burdened with high traffic volume repeatedly will cause a decrease in the quality of roads that may affect safety, comfort, and the economy. An area and government should conduct continuous road checks and maintenance to obtain a quality road.

Pavements are complex structures involving many variables, such as materials, construction, loads, environment, performance, maintenance, and economics. Thus, various technical and economic factors must be well understood to design pavements, to build pavements, and to maintain better pavements [1].

One of the most common functional road function parameters is the Surface Distress Index (SDI) value obtained from the Road Condition Survey (RCS) survey to find out whether the pavement structure is still well evaluated and capable of supporting the load and volume of traffic which exists.

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Assessment of road surface condition was conducted with a system of assessment of pavement conditions according to Bina Marga. The most dominant damage is usually found potholes, cracking, ruts, upheaval, bumpy road, raveling and grade depression.

Several predictive deterioration models describe friction behavior of road pavements. Friction data, along with macrotexture, were proved to be effective indicators to monitor pavement conditions [2]. Factors influencing the performance of a pavement are traffic, moisture (water), subgrade, construction quality, maintenance [3], climate [4]. The factors affecting the performance of pavement preservation models which could be used to predict the performance of these treatments the most important factors as: Condition of existing pavement prior to treatment, quality of construction, quality of materials, proper design of preservation treatment materials, traffic volume, climate [5]. These factors influence the pavement conditions. To better understand the mechanism and to predict future pavement conditions, a model of pavement deterioration is required. Decreasing model of pavement condition is a mathematical relationship between pavement conditions with the factors mentioned above. This model is used to predict future pavement conditions, where the results of these predictions are useful in the development of road maintenance management model or Maintenance Priority Index (MPI). This index can then be used to determine the priority of pavement repair schedule based on the level of road damage.

This research tries to apply Radial Basis Function Neural Networks (RBFNN) in pavement drop model. RBFNN applictaion is designed to develop pavement drop model using limited historical condition data and can be used for all climatic conditions, materials, construction techniques, and others [6]. So far, a study on the prediction of Surface Distress Index (SDI) values using Radial Basis Function Neural Networks (RBFNN) has not been done so that the study is expected to be done so that it can increase the knowledge and research in the field of transportation in order to predict the decrease of pavement on next year.

The purposes of this research are: to make a model of road pavement deterioration by using Radial Basis Function Neural Networks (RBFNN) based on Surface Distress Index data from the report road condition survey report at pavement section between the Betung regions to Palembang, and to Compare the results of deterioration condition model to the actual conditions.

2. Material and Method

2.1. Surface Distress Index (SDI) Data

SDI data were taken from Road Condition Survey (RCS) through the visual inspection of the road pavement deterioration, the result of visual inspection indicates the pavement condition that defined in the data and calculated by certain procedures and stages. SDI (Surface Distress Index) describes structural condition but only based on subjective visual observations or experience of the surveyor to determine whether distress with an indication of pavement shape change is cracked, the wheel and hole traces only occur on the surface structure of the pavement or are already extending below the coating, SDI value is basically a description of road functional condition by using road deterioration data.

2.2. *Radial Basis Neural Function Network (RBFNN)*

Radial Basis Function Neural Networks (RBFNN) is one of the approach methods used to calculate the decrease in road pavement. RBFNN is designed to improve pavement deterioration model based on existing database of road historical condition value. Beside that RBFNN also designed to predict the future road pavement condition by using only information of the actual pavement condition data and pavement age. The result of road pavement condition prediction then compared to the value of existing data. RBFNN is the type of neural network that consists of three layers including input layer, hidden layer and output layer. The architechture of a RBFNN is shown in figure 1.

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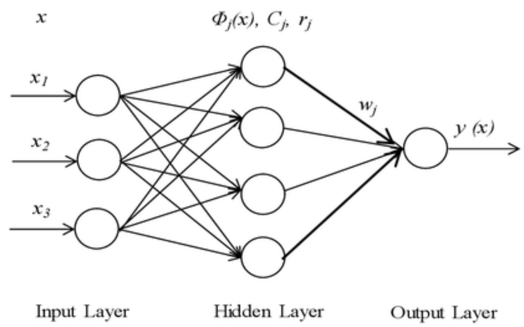

Figure 1. Radial Basis Function Neural Network

The Input layer node only pass the data input into the hidden layer, therefore there's no calculation in the input layer node. The input layer is consist of n_s nodes which the input vector $\boldsymbol{x} = (x_1, x_2, \ldots, x_{ns})$. While the hidden layer is consist of n node and each of hidden node $j = 1, 2, \ldots, n$ has a center value c_j. Every hidden layer node is performing a non-linear transformation of the input data into new space through the radial basis function. The most common choice for the radial basis function is a Gaussian function, given by the following equation:

$$\phi_j(\boldsymbol{x}) = \exp(-\| \boldsymbol{x} - c_j \|^2 / r_j^2) \quad (1)$$

Where the $\| \boldsymbol{x} - c_j \|$ is represent the Euclidean distance between the input vector ($\boldsymbol{x}$) and the center of radial basis function (c_j). While r_j is the width of radial basis function. The output layer node operation is linear, given by the following equation:

$$y(\boldsymbol{x}) = \sum_{j=1}^{n} w_j . \phi_j(\boldsymbol{x}) \quad (2)$$

Where w_j is the weight connection of hidden layer to output layer and n is number of hidden node. The RBFNN has a simple linear combination output, the parameter solution can be achieved by using a linear optimization methods. Therefore, RBFNN has fast convergence time and is guaranteed to converge to global optimum parameter. The radial basis function networks learn faster than multi layer percepton network [7]. Theoretically the radial basis function network are capable of universal approximation and learning without local minima [8], therefore it is guaranteed to converge to global optimum parameter.

The training of RBFNN involves determination of the following parameters.

- The number of hidden layer nodes.
- The center and the width of each radial basis function in each node.
- The connection weight of hidden layer to output layer.

2.3. Variable and Analysis

The variable that used in this research is preceeding SDI data value and Δ age. The age is a time of life duration of pavements since its construction, reconstruction or overlay. The preceding SDI is the SDI value at this age. The Δ age is the interval time or the age difference between the preceding SDI and the next SDI when optimum RBFNN is used to predict the future pavement condition. In PMS, the same interval analysis period is commonly used.

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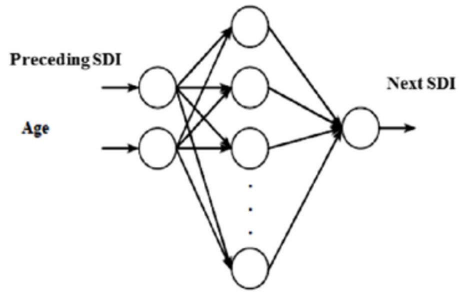

Figure 2. RBFNN for database with the same time interval

The data used in this research were collected from road condition survey data of at pavement section between Betung region to Palembang. The datasets include pavement condition data, maintenance history, pavement material types, traffic, pavement geometric, and road map. The datasets of Betung region to Palembang is constructed by only one type of pavement. A total of about 100 pavement sections data of route Betung region to Palembang were retrieved to develop the model. Datasets were randomly divided into three subsets, which are; training, validation and testing. The dataset divided into two subset of 80% for training, and 10% for testing. The training subset is used for training the model. While the validation subset is used to check the network validity, and testing set is using the remaining 10% of total data.

In analysis, comparison between the ordinary regression and radial basis function network (RBFNN) models were made using the SPSS statistical software. The data then standardized by using the following equation:

$$x = \frac{x-\mu}{\sigma} \tag{3}$$

Where x is observed value, μ is the mean, and σ is the standard deviation. This standardization process generates variable Z with zero mean and unit variance.

3. Result and Discussion

3.1. Analysis Result Deterioration Model by Regression and RBFNN

The regression analysis gives coefficients to all predictor as shown in Table 1. By using stepwise procedure give the equation as following:

$$Y = 0.545 + 0.634x \tag{4}$$

With $R^2 = 0.6922$ ($F = 266.45$, $p = 0.000$). This means number of variable can explain 69.22% of variation in the pavement deteriorating.

Table 1. Coefficients of predictors in regression analysis

	Unstandardized Coefficients		Standardized Coefficients			
	B	Std. Error	Beta	Std. Error	t	Sig.
(Constant)	-0.314	0.367			-0.855	0.395
SDI_1	-2.673	0.411	-1.027	0.158	-6.497	0
SDI_2	4.642	0.561	1.308	0.158	8.277	0

In the radial

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basis function analysis, 80% datasets were assigned to the training sample, and 20% to the testing sample.

After training and testing the network, the result showed that the RBF network error reach 0.002 and the correlation coefisien equal to 0.82.

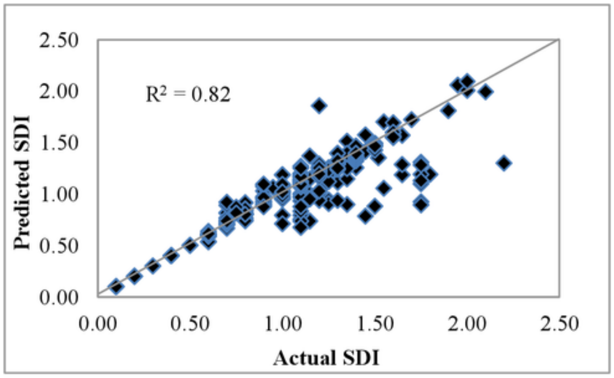

Figure 3. Prediction SDI value vs actual SDI value

The graph shows that RBF performs better and obtain better result than ordinary regression in term of the amoun of variation in dependend variable explained in the model. This is because of the flexibility of RBF model. The predicted SDI values of training data, along with the actual SDI values shown in Figure 3**.** The coefficient of correlation is 0.82.

3.2. Comparison between the result of testing data with actual data and regression analysis

The figure 4 shown that the trend of RBFNN deterioration prediction result, started from age = 0 and SDI value = 0,6, has a good agreement with the actual SDI value, and the general trend of RBFNN model can give better results comparing with regression model. The same condition is found in the next testing value. The pavement sections in a pavement family that have the same age and the same initial SDI value, might have the different pavement condition deterioration in the future.

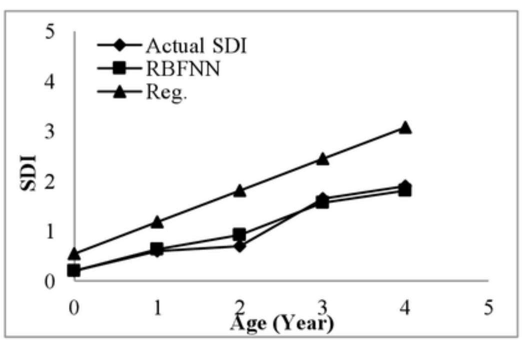

Figure 4. Pavement performance curve data section1

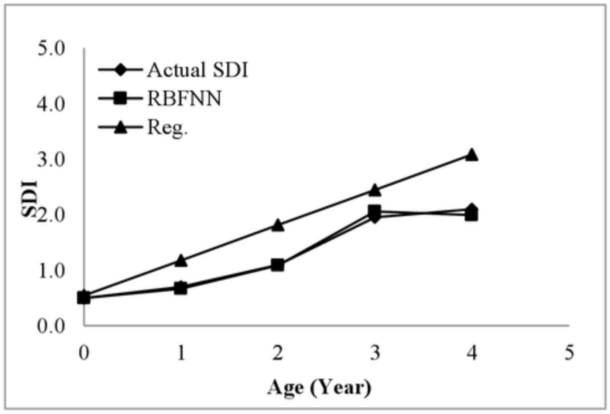

Figure 5. Pavement performance curve data section 2

The RBFNN is learning from the training data and then able to represent the existing data patterns in the training data. Because the training data contains a range of pavement ages with various SDI values, the optimum RBFNN can be used to predict the future condition of pavement sections using only information about age of pavement and its SDI value.

3.3. Flexibility of deteriorating model by using RBFNN

To evaluate this flexibility, the future condition of the testing sections data determined by using RBFNN, it started from a point that located along the actual deterioration curve, was compared with the actual pavement deterioration. The location of the starting point was selected randomly that shown in Figure 6 and Figure 7.

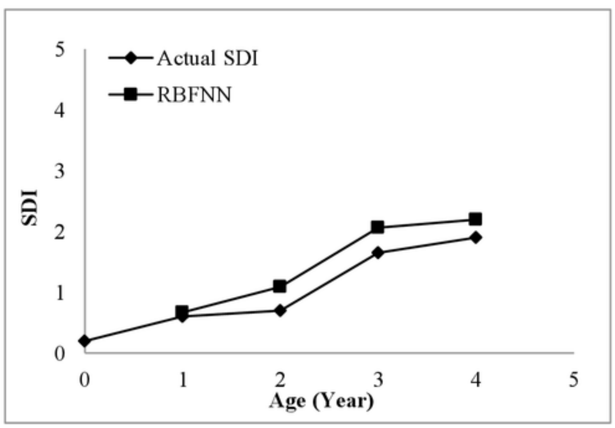

Figure 6. Pavement performance curve data section1

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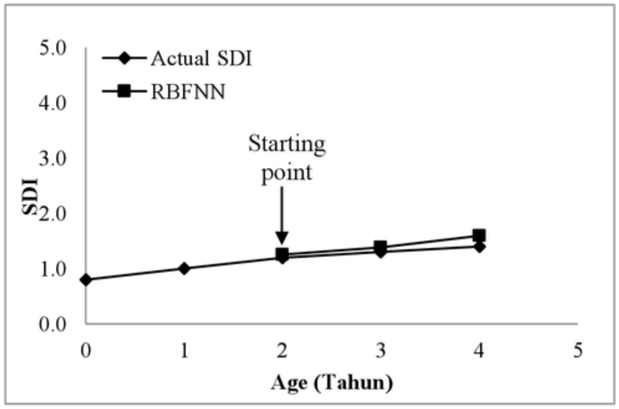

Figure 7. Pavement performance curve data section1

The results indicate that deterioration predictions, which started from a point located along the actual deterioration curve, are in a good agreement with the actual measurement SDI. This indicates that the proposed pavement deterioration model using RBFNN can be used to determine the future pavement condition using only information about the present MCI value and the age of pavements.

4. Conclusion

In this study, The RBFNN model was trained to make prediction of pavement deterioration of SDI datasets. RBFNN has performed better result with $R^2 = 0.82$ than regression model. The validation and testing the datasets were determined by trial and error. The normality of error and the linearity might be one of the reasons of worse performance of regression model. However, the result of RBFNN model has showed a good capability and very good flexibility of pavement deterioration condition prediction.

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