INFLUENCE OF PRIMARY BRIDGE COMPONENT CONDITION ON OVERALL BRIDGE CONDITION RATING

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1. INTRODUCTION

- Bridge Management Systems (BMSs) of Malaysia have to maintain more than 7000 bridges

- 80 % of these bridge superstructures are made by concrete and more than 9% are made by steel

- Simple supported bridges and culverts are the main structure of these bridges which are

- A BMS classify bridge component in different way for their bridge condition rating systems.

- Many researchers utilized the classification based on the common practice in their home country in their research of bridge assessment

- Sasmal et al., 2006 categorized the deck, superstructure and substructure as the main bridge components.

In the Annual Bridge Inspection Manual (ABIM) of Malaysia, the bridge components are classified as either primary or secondary components.

- The primary components: surfacing, deck slab, beams/girders, piers and abutments
- The secondary components: parapet, expansion joints, bearings, slope protection

- In bridge condition rating system, the inspector generally use visual inspection as the first step of any condition assessment procedure unless a structure cannot be visually assessed.

- The procedure related to the uncertainty and subjective judgment of the bridge inspectors

- Thus, for BMSs optimization, there is a need to develop condition rating models to handle the uncertainty and the subjective judgment

Objective

To investigate the influence of the condition of primary bridge component to overall condition of:

- Pre-stressed concrete beam bridge (PCBB)
- Reinforcement concrete beam bridge (RCBB)
- Steel beam bridge (SBB)

In order to investigate the variance of the bridge condition rating in respect to its condition of primary bridge component, two mathematical models was

2. METHODS

2.1 Type of bridge and bridge components

- The primary components of single span of PCBB, RCBB and SBB bridges are modeled in order to evaluate the bridge condition rating

- Four primary bridge components namely surfacing, deck slab, beam/girder and abutments are used as input parameters

2.2 Bridge condition rating data

- The condition rating of a bridge structure is a process of assessing the overall condition and integrity of the structure

- The structural condition rating of a structure depends on the type of structure and its intended service (Adhikary & Mutsuyoshi, 2002)

- Condition rating of single span bridge is evaluated base on its component condition ratings

Table 1. The condition rating system used in ABIM

Rating scale	General definition
1	No damage is found and no maintenance is required.
2	Damage is detected and it is necessary to record the condition for observation purposes.
3	
4	Damage detected is slightly critical and thus it is necessary to implement routine maintenance work.
5	Damage detected is critical and thus it is necessary to implement repair work or to carry out detailed inspection to determine whether any rehabilitation works are

2.3 Multiple regression analysis (MRA)

- MRA is widely applied in modeling of bridge engineering problems due to its frequent use in predictions and the easy interpretation of the resulting models.

- MRA was used to analyze the relationship between the condition rating of primary bridge components and the entire bridge condition rating.

Two MRA models are explored in this study, namely:

MRA 1 : $y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \ldots + \beta_n x_{ni} + \varepsilon_i$

MRA 2 : $y_i = \beta_0 + \beta_1 x_1{}^2{}_i + \beta_2 x_2{}^2{}_i + \beta_3 x_3{}^2{}_i + \ldots + \beta_n x_n{}^2{}_i + \varepsilon_i$

MRA 1 – simple, MR2 - quardratic

Where:

y = The bridge condition rating

x = The primary bridge conditions

β = The coefficient of primary bridge conditions

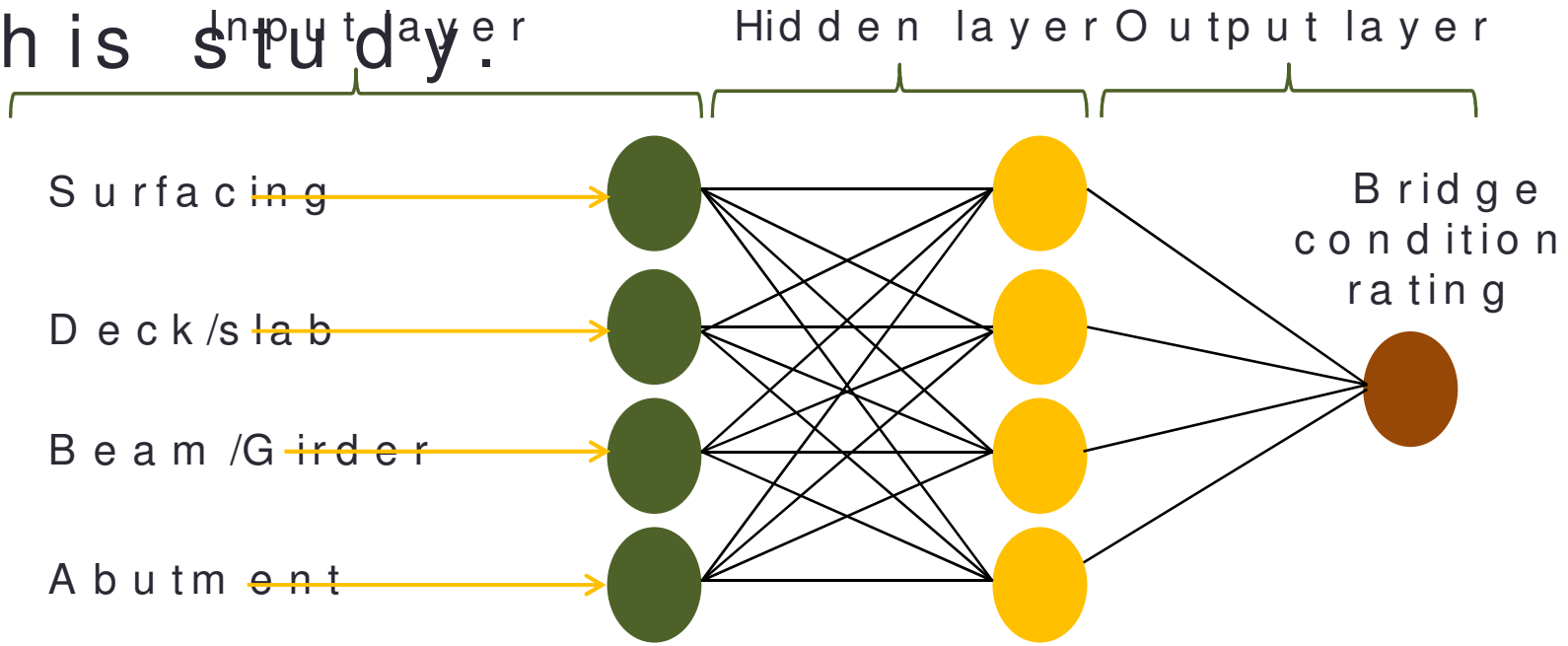
n = The number of primary bridge component,

i = 1, 2, 3, …, N is the number of data sets

ε = represents the error of the

2.4 Artificial Neural Network (ANN)

ANNs which are consist of an input layer, a single of hidden layer and an output layer as shown in Fig.1 was used in this study.



ANN Parameters

- Training algorithm: Levenberg-Marquardt algorithm (*trainlm*)
- Transfer function: nonlinear (tan-sigmoid) in hidden layer and linier in output layer
- Number of neurons in hidden layer was obtained by trial and error

2.5 Model evaluation

Performance of the model was evaluated using:

- Mean square error (MSE)
- Coefficient of determination (R^2)
- Fisher's F Test was considered to evaluate the performance of the model

The evaluation of the model are always related to error,

3. RESULTS AND DISCUSSION

3.1 Performance of MRA models

Table 2. Performance of MRA models for PCBB, RCBB and SBB bridges

Bridge	MRA 1			MRA 2		
	MSE	R^2-Training	R^2-Testing	*MSE*	R^2-Training	R^2-Testing
PCBB	0.1382	0.5963	0.7656	0.1272	0.6283	0.8159
RCBB	0.1098	0.9177	0.8642	0.1514	0.8866	0.8564
SBB	0.1331	0.8618	0.7509	0.1505	0.8438	0.7491

- The best MRA models yield 62.83 %, 91.77 % and 86.18 % variations in the condition rating of PCBB, RCBB and SSB bridges, as accounted for through the combined effects of the primary component condition rating variables
- The MRA2 seems suitable to explain the impact of primary component condition rating on condition rating of entire PCBB.
- Meanwhile, the best model for PCBB and SSB were obtained

- The verification results for the above models fit 76.56 %, 86.42% and 75.09% of the testing data variation in the PCBB, RCBB and SBB bridges using MRA1.

- Meanwhile, MRA2 able to fit 81.59 %, 85.64 % and 74.91 % of the testing data variation in the PCBB, RCBB and SBB bridges.

- Referring to the MRA output show that the relationship between primary component condition and condition rating of PCBB, RCBB and SBB are found to be statistically

3.2 ANN Results

The training results show that an ANN trained with *trainlm* utilizing a single hidden layer with 4, 1 and 1 neurons in the hidden layer for PCBB, RCBB and SBB bridges, respectively, yields the best performance compared to other network structures as shown in Table 4.

Table 4. Performance of network models for PCBB, RCBB and SBB

Bridge	*MSE*	*R2-Training*	*R2-Testing*
PCBB	0.1004	0.6735	0.618 8
RCBB	0.1125	0.9054	0.8 637
S BB	0.1654	0.8 177	0.7655

- The best ANN models are able to fit 67.35%, 90.54% and 81.77% of the impact of the primary bridge component condition on the entire condition rating of PCBB, RCBB and SBB bridges, respectively.

- For the testing set, ANN models were able to fit 61.88 %, 86.37 % and 76.55 % for PCBB, RCBB and SBB, respectively.

- Fig. 2 shows R^2-value of training and testing set data for modeling of PCBB, RCBB and SBB bridges based on its primary component condition

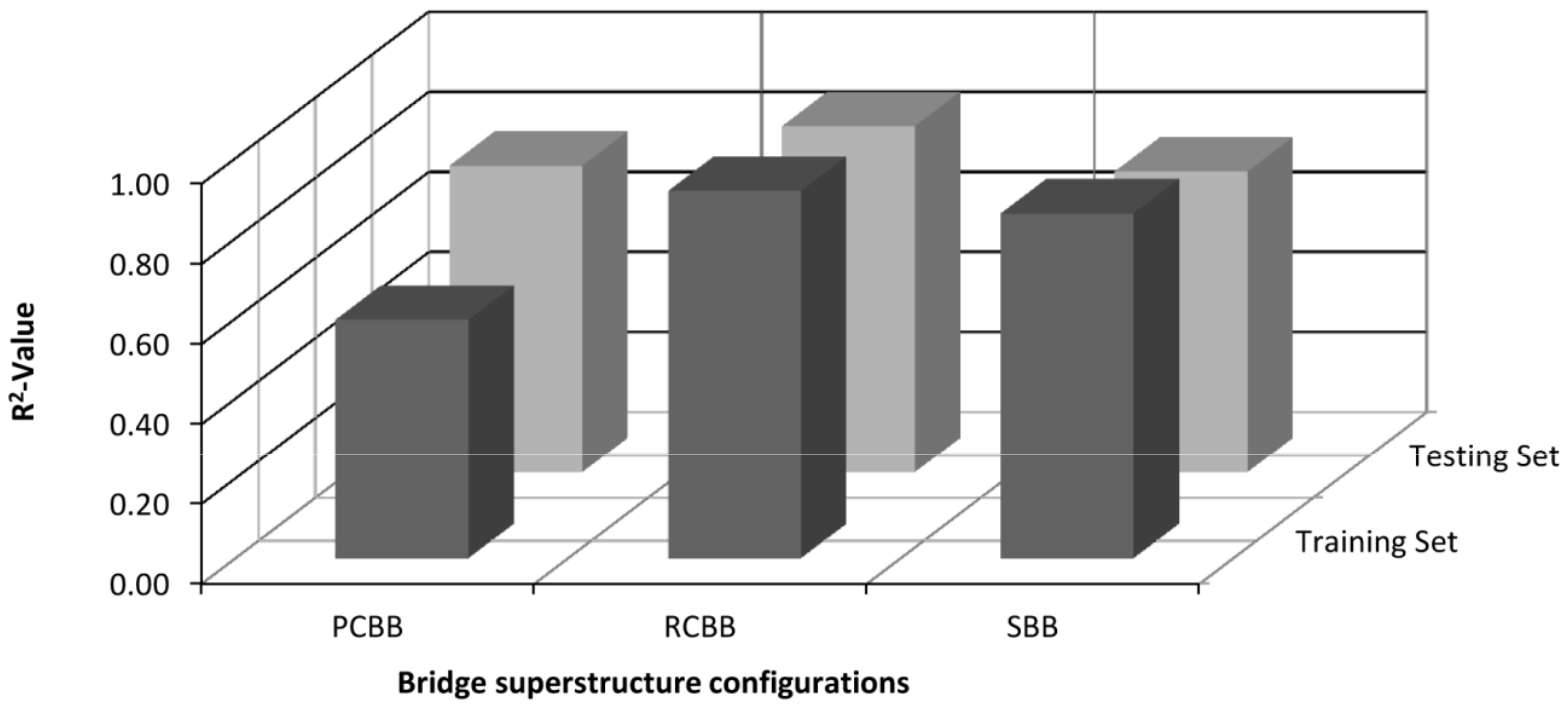


Fig. 2 Performance evaluation of ANN models based on R^2-value

4. CONCLUSION

- Four primary bridge components were used as input parameters in modeling of PCBB, RCBB and SSB bridge condition ratings using MRA and ANN models.

- ANN models are able to fit 67.35%, 90.54% and 81.77% of the impact of the primary bridge component condition on the entire condition rating of PCBB, RCBB and SBB bridges.

- The best MRA models able to fit 62.82%, 91.77% and 86.18% the

- The R^2 values of training set for the PCBB of ANN model was higher than the MRA models. Meanwhile, MRA models yield better result for RCBB and SBB bridges compared with ANN models.

- In terms of errors, the ANN models of PCBB, RCBB and SBB yield 0.1004, 0.1125 and 0.1654, respectively. Meanwhile, the best MRA models yield 0.1272, 0.1098 and 0.1331 for PCBB, RCBB and SBB bridges, respectively

- Referring to R^2-value and *MSE* of training set, the ANN model seems suitable to model PCBB bridge condition rating in

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