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Model of Predicting the Rating of Bridge Conditions in Indonesia with Regression and K-Fold Cross Validation

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Abstract: Maintenance and repair of the bridge are inevitable in the operation of a bridge to maintain its condition to keep the operation. Indonesia has hundreds of thousands of bridges that are still actively in use. The classic problem with infrastructure management, such as bridges, is that large numbers are generally not balanced with adequate bridge maintenance budgets. Therefore, the strategy of implementing maintenance and repair by preparing priorities becomes the only logical approach. To get a priority scale, a scoring mechanism is needed. The assessment used by the Ministry of Public Works and Public Housing (PUPR) especially the Bina Marga field is based on the bridge management and maintenance system, namely Bridge Management System (BMS) 1993. With BMS 1993, the condition of the bridge is represented by the Condition Value (NK) of the bridge. This study is based on existing NK, prediction of NK value in the future. The predicted model developed is with regression models. Regression models are combined with k-fold cross-validation to improve the accuracy rate of the model. The developed model produces regression models for all variables of condition values with a low error percentage that is in the range of MAPE = 10% and RMSE 0.15. Further significance tests with ANOVA are also conducted to test the effect of independent variables on dependent variables, including testing on fit models to show the resulting model does not overfit and/or underfitting.

Keywords: Bridge maintenance, condition value, regression, cross validation

1. Introduction

Based on detailed data obtained from the Ministry of Public Works and Public Housing (PUPR) in 2019 and 2020 there are 18,649 and 18,916 national bridges spread throughout Indonesia. The bridge is part of the transportation infrastructure that serves as a link to roads that are cut off due to obstacles such as rivers, lakes, valleys, seas, and railway lines that do cross not a plot. The bridge is a complementary building of the road that serves as a traffic lane that must be equipped with a drainage system and space to place utilities (Permen PU No.19 / PRT / M / 2011). The bridge is designed to provide service in terms of the number of traffic crossings and maximum crossing load allowed for a certain period. This is called the age of the bridge. At the end of this period, the benefits of bridge traffic should be higher than the costs associated with its design, construction, and service life (Branco, 2004).

Therefore, maintenance or repair efforts are required with good management with an accurate and effective bridge condition inspection system. Assessment of the condition of the bridge is an effort to maintain the age of the bridge and prevent the destruction of the bridge structure. Research into the maintenance and management of bridges has been going on for decades (Austroads, 2002). Some of the studies conducted in Indonesia are studies conducted by reviewing and evaluating several bridges in Riau with high risk using the Bridge Management System method to get proper repair or maintenance measures (Apriani, 2018). Assessment of the condition of the bridge on the provincial road in Yogyakarta has been researched by (Hariman et al, 2007) which aims to monitor the condition of the bridge so

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that several actions can be determined to ensure that the bridge is a safe condition through the right strategy of maintenance, rehabilitation, strengthening, and replacement of the bridge. The study examined the bridge. The study conducted a systemic examination of the bridge through the Bridge Management Information System (IBMS). Another similar study is by (Sudradjat, 2015). The research aims to find out the existing condition of the bridge, the prediction of the condition of the bridge in the future, and the direction of bridge handling in the study area, namely in East Java.

Evaluation of alternatives to bridge rehabilitation and replacement is one of the main tasks in the field of highway repair programming because bridges play a strategically important role in the well-being of the entire highway network (Saito, 1987). The need for bridge maintenance will get higher as the bridge ages. If depicted, the performance of a bridge will decrease with the increase in time while serving the traffic load on it (Aktan, 1996). The correlation between the decline in bridge performance and the age of the bridge can be presented in the form of the following graph:

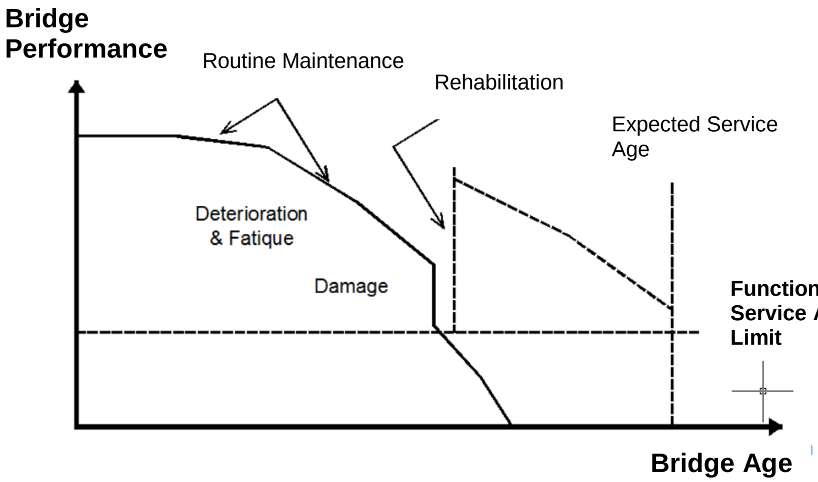


Fig. 1 - Correlation of decreased bridge performance and bridge age (Sudradjat, 2015)

Based on the need to carry out maintenance and repair of the bridge as a result of the decrease in bridge performance, standards or references are also needed in determining the priority of bridge repair to keep the condition of the bridge optimal according to the age of the plan. Prediction of the age of the bridge can be done as in research conducted by (Safana, 2021) which shows that preventive measures and improvements on the Way Gedau bridge in the form of patches on perforated surface layers are needed. This research is one of the efforts to maintain the performance of the bridge until the rehabilitation deadline according to figure 1. In addition, some other approaches such as determining the priority scale can also be done considering conditions of limited development financing budget so that the process may be the initial requirement for the preparation of a bridge maintenance and/or repair activity (Minesa et al, 2014). Moreover, budget constraints are a problem that is always faced by the Public Works Office and Bina Marga bridge maintenance. Prioritization helps stakeholders in determining the roads and bridges to be repaired and the type of handling (Asrul, 2017). This condition makes Bina Marga have priority in determining the implementation of maintenance programs to ensure targeted maintenance (Ompusunggu, 2009).

In determining priorities, an assessment is needed to improve the accuracy of the priority scale. Bridge assessment and condition analysis are regulated in the system which refers to guideline No.005-01/P/BM/2011 on Bridge Inspection Guidelines issued by the Director General of Bina Marga. This guideline refers to BMS or bridge management systems (hereinafter referred to as BMS) which are essential to support bridge management agencies in complex decision-making processes to optimize maintenance, repair, and renovation strategies to improve and maintain optimal bridge network health. BMS provides effective predictive analysis to assess the condition and extent of bridge damage, as well as to make decisions about maintenance budgets, and the best future maintenance strategies (Hariman et al, 2007). BMS is applied and arranged with the function that all bridge handling activities are carried out following general policies and uniform standards (Putra, 2012). (Wiryanto Dewobroto, 2013)

The assessment process is carried out in the form of technical screening to get the value of the condition (NK) of the bridge economically. The results of both assessment processes are used to obtain job program ratings (Ompusunggu, 2009). NK itself is an overview of the value of conditions when surveying the bridge. In BMS the value of NK is used for 5 categories namely NK for Upper Buildings (BA), NK for Lower Buildings (BB), NK for Watersheds (DAS), and NK for Bridge Plate (LNT), and NK for Overall Bridge (JBT). In the preparation of maintenance work programs, this NK information becomes input in decision-making in the form of handling recommendations for maintenance, repair, or even rehabilitation (Princeton, 2007). Assessment of the condition of the bridge involves an inspection which is a procedure for evaluating the elements of the bridge by answering several parameters, namely: S (Structure), damage (R), quantity (K), function (F), influence (P). Rating conditions can work well when damage to the element has been identified. Bridges are made up of several elements that interact with each other and have a hierarchy. Level-1 (bridge as a whole), level-2 (components: upper building, the lower building, river flow), level-3 (elements: foundation, abutment, pillar), level-4 (element section: pillar head, wing wall abutment wall), level-5 (location of element section: Abutment wall A1) (Vaza et al, 2013).

In the context of anticipatory planning, NK data on time can be viewed as historical data on bridge conditions. For this reason, NK data can be used as a process of predicting bridge conditions. NK results of this prediction can be used as the basis for the determination of priorities in handling the bridge, starting from the process of planning maintenance, repair, or rehabilitation to its implementation (Princeton, 2007). One common model used for the prediction process is the regression model approach. However, the resulting regression model cannot necessarily be used directly. There are issues of correlation, accuracy, and overfitting that need to be considered and used as the basis for the validation of the resulting model. For that, in this study in addition to getting the NK prediction model, the prediction model also needs to be validated. One of the methods used in doing validation is to use the cross-validation technique. According to Berrar (2018), the cross-validation technique is one method of resampling data to assess the generalization capabilities of predictive models. The initial idea of cross-validation (CV) was to complete and evaluate each model candidate on the dataset to avoid bias (Lei, 2020). CV is also a popular model assessment method (Berrar, 2018; Lei, 2020).

Basic concepts that need to be understood are about learning sets, training sets, and test sets/validation sets. The data set available to form and evaluate predictive models is called the learning set, the data set is considered a sample of the desired population, then random subsampling techniques will be performed that will result in a training set and test/validation set. The predictive model is then built and trained on a training set that will then be tested on a test set. There are several types of subsampling techniques, which are often used in k-fold validation in this method, learning sets available in partitions into separate k subsets with uniform sizes. The fold is used to indicate the number of subsets produced. Predictive models are trained using a subset of k-1 sets, the rest being validation sets. Examples in this application are k-10 validation, K-1 is a validation set, and the rest is a training set (Berrar, 2018). In its application, there are no specific rules regarding k-fold validation, commonly used is k-5 or k-10 and the determination of the value of k can depend on the size of the data set owned.

This study aims to provide an overview of the predicted condition value (NK) of the bridge based on bridge age variables in Indonesia using regression models that will be validated using the K-Fold Cross Validation method. This method is one of the useful regression model validation techniques for assessing how statistical analysis results from regression models will generalize independent data sets. This technique is mainly used to predict and estimate how accurate the regression model is (Berrar, 2018).

2. Introduction

This work is using data from the Ministry of Public Works and Public Housing of the Republic of Indonesia, which contains information for 18,649 bridge condition ratings (NK) taken on 2019. This data interpretation according to the variable code of the bridge condition value is as follows:

Table 1 - Interpretation of variable code value condition (NK) bridge

Code	Remarks
NK BA	Superstructure Condition Rating
NK BB	Substructure condition Rating
NK LNT	Plate Condition Rating
NK DAS	Watershed Condition Rating
NK JBT	General Condition Rating

2.1 Regression Model Creation with Cross Validation

In this study, regression models were made using the k-fold cross validation method where the data set (data set) is divided into several k parts/folds. This means that each fold is divided into 3 parts, namely 1 part is used as a test set, part 2 is used as a validation set to strengthen the results of the test set, and the rest as a training set. This division is done for each fold of the total fold.

The stages in performing k-fold cross validation are described as follows:

1. Determining the number of K
2. Dividing the data into 3 parts: train set, test set, and validation set
3. Creation of regression model of each K using the train set
4. Choosing the model with the best accuracy using RSQUARED, MAPE, and RMSE Value
5. Performing ANOVA Test and Model Fit Test

2.2 Calculation of Model Accuracy and Error Size

This section will calculate of error size to find out the accuracy of the model using MAPE and RMSE error sizes with calculation formulas already listed in the literature study and interpretation of MAPE and RMSE results as described in Table 1 and Table 2.Table 1 - An example of a table

2.3 Significance Test

In this section will be conducted an ANOVA test to find out the significance of dependent variables in estimating the value of dependent variables. The significance value used is p-value = 0.05. The ANOVA test was conducted with the help of IBM 25 SPSS software and the results were poured into table form.

2.4 Model Fit

In this section will be tested fit models to indicate overfitting and/or underfitting on each model to be made. Testing is done by graphical methods as described in literature studies.

3. Data Analysis

Data has been divided before the creation of regression models to improve the accuracy of the model result. Based on existing data, further interpretation is required for each variable that is assessed. There are five variables included in the bridge assessment criteria as outlined in Table 1.

Data is divided into 3 parts: Train Set (80%), Test Set (15%), and Validation Set (5%). This process is done using a random function. 5-Fold Cross Validation was used in this study which means there are 5 data sets for each variable. The first set is named K1, the second set is named K2, and so on until K5. Here is a table example of the division of datasets into Train Set, Test Set, and Validation Set for cross-validation:

Table 2 - Data sorting for cross validation

	Variable				
	NK BA	**NK BB**	**NK LNT**	**NK DAS**	**NK JBT**
K1	Train Set 1	Train Set 1	Train Set 1	Train Set 1	Train Set 1
	Test 1	Test 1	Test 1	Test 1	Test 1
	Validation Set 1	Validation Set 1	Validation Set 1	Validation Set 1	Validation Set 1
K2	Train Set 2	Train Set 2	Train Set 2	Train Set 2	Train Set 2
	Test 2	Test 2	Test 2	Test 2	Test 2
	Validation Set 2	Validation Set 2	Validation Set 2	Validation Set 2	Validation Set 2
K3	Train Set 3	Train Set 3	Train Set 3	Train Set 3	Train Set 3
	Test 3	Test 3	Test 3	Test 3	Test 3
	Validation Set 3	Validation Set 3	Validation Set 3	Validation Set 3	Validation Set 3
K4	Train Set 4	Train Set 4	Train Set 4	Train Set 4	Train Set 4
	Test 4	Test 4	Test 4	Test 4	Test 4
	Validation Set 4	Validation Set 4	Validation Set 4	Validation Set 4	Validation Set 4
K5	Train Set 5	Train Set 5	Train Set 5	Train Set 5	Train Set 5
	Test 5	Test 5	Test 5	Test 5	Test 5
	Validation Set 5	Validation Set 5	Validation Set 5	Validation Set 5	Validation Set 5

Regression modeling is performed on each dataset from K1 to K5 for all variables. From 5 datasets selected one dataset that produces the model with the best accuracy as measured by RSQUARED values and MAPE and RMSE error sizes. Interpretation of the variable code can be seen in table 1.

3.1 Regression Model

The creation of a regression model with the help of the 5-Fold Cross Validation method is to estimate the Condition Value (NK) of the bridge in the future. The variables used for the model are condition value (NK) variables located on the Y axis and bridge age (age) located on the X-axis. It is based on the poor accuracy of linear regression models. The figures below show the accuracy comparison measured from the RSQUARED value model between the linear regression model and the polynomial regression model for the JBT NK variable with the following results:

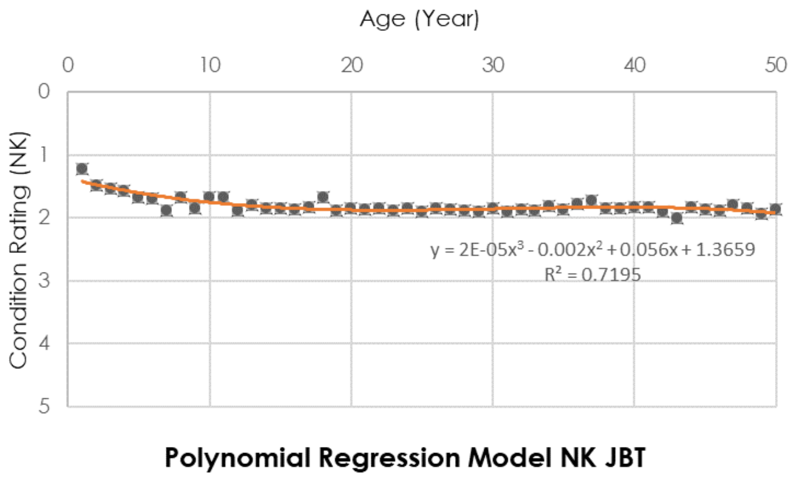


Fig. 2 - Polynomial regression model

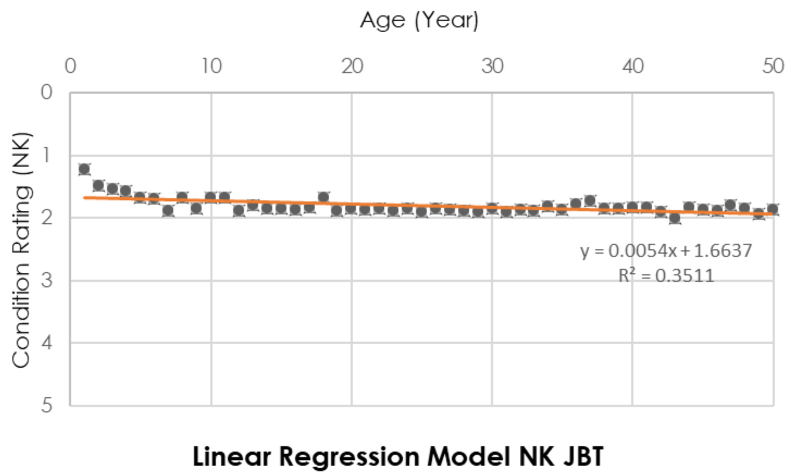


Fig. 3 - Linear regression model

In the linear model, there is an RSQUARED value of 0.3511 and in the polynomial model, there is a value of 0.7195. This shows that the use of polynomial models has better accuracy than the use of linear regression models. In addition to RSQUARED, it is necessary to test the fit model to indicate overfitting on the model that has been made, so that the possibility of overfitting the results of RSQUARED is eliminated. In the next section, the selection of regression models will be used to estimate the value of bridge conditions. Model selection is done by performing a review of the RSQUARED value as well as calculating the size of the absolute percentage error (MAPE) and root mean squared error (RMSE). Model selection results are presented in the following table:

Table 3 - Model selection for NK BA, NK BB, NK LNT, NK DAS, NK JBT

Model	K	RSQUARED	MAPE (%)	RMSE	RANK
NK BA	K1	0.7376	10.0250	1.1609	1
	K2	0.7264	11.3858	0.1739	3
	K3	0.7208	11.2765	0.1763	2
	K4	0.7215	11.6370	0.1798	4

	K5	0.7530	11.6371	0.1770	5
NK BB	K1	0.5535	6.4671	0.1336	5
	K2	0.5715	5.8306	0.1216	1
	K3	0.5644	6.1959	0.1267	3
	K4	0.5349	5.7926	0.1294	4
	K5	0.5709	6.0540	0.1265	2
NK LNT	K1	0.5234	11.7532	0.0946	2
	K2	0.5492	11.4660	0.0967	1
	K3	0.5207	11.7986	0.0954	3
	K4	0.5199	12.1414	0.1006	5
	K5	0.5313	11.9013	0.0945	4
NK DAS	K1	0.6343	8.5788	0.1303	2
	K2	0.6341	9.1384	0.1356	3
	K3	0.6437	9.1486	0.1377	4
	K4	0.6345	8.8950	0.1268	1
	K5	0.6578	8.9807	0.1400	5
NK JBT	K1	0.7195	4.7629	0.1063	1
	K2	0.6861	4.6281	0.1080	2
	K3	0.7001	4.6959	0.1093	4
	K4	0.7319	4.8620	0.1080	3
	K5	0.7505	5.0057	0.1113	5

Table 4 - Selected models

Variable	Remarks	Model Accuracy		
		RSQUARED	MAPE (%)	RMSE
NK BA	Best Accuracy	0.7376	10.0250	0.1609
NK BB	Best Accuracy	0.5715	5.8306	0.1216
NK LNT	Best Accuracy	0.5492	11.466	0.0967
NK DAS	Best Accuracy	0.6345	8.8950	0.1268
NK JBT	Best Accuracy	0.7195	4.7629	0.1063

Regression models for NK BA have an accuracy of 73.96%, NK BB 57.15%, NK LNT 54.96%, NK DAS 63.45%, and NK JBT 91.95% indicated by a good RSQUARED value. Mape calculations obtained for BA are worth 10.03%, BB 5.83%, LNT 11.46%, WATERSHED 8.89%, and JBT 4.76% means the model has good accuracy. In addition, RMSE with a value of 0.16 for NK BA, 0.12 for NK BB, 0.09 for NK LNT, 0.12 for NK DAS, and 0.10 for NK JBT also shows good indications of accuracy.

3.2 Significance Test Using ANOVA

In this section, hypothesis testing is carried out with the ANOVA Test using the help of IBM 25 SPSS software. The ANOVA test aims to find out how much influence age variables as independent variables have on condition value variables as dependent variables. Tests were conducted on each model in this study with a total of 5 tests on 5 existing models. The ANOVA test results table is submitted as follows:

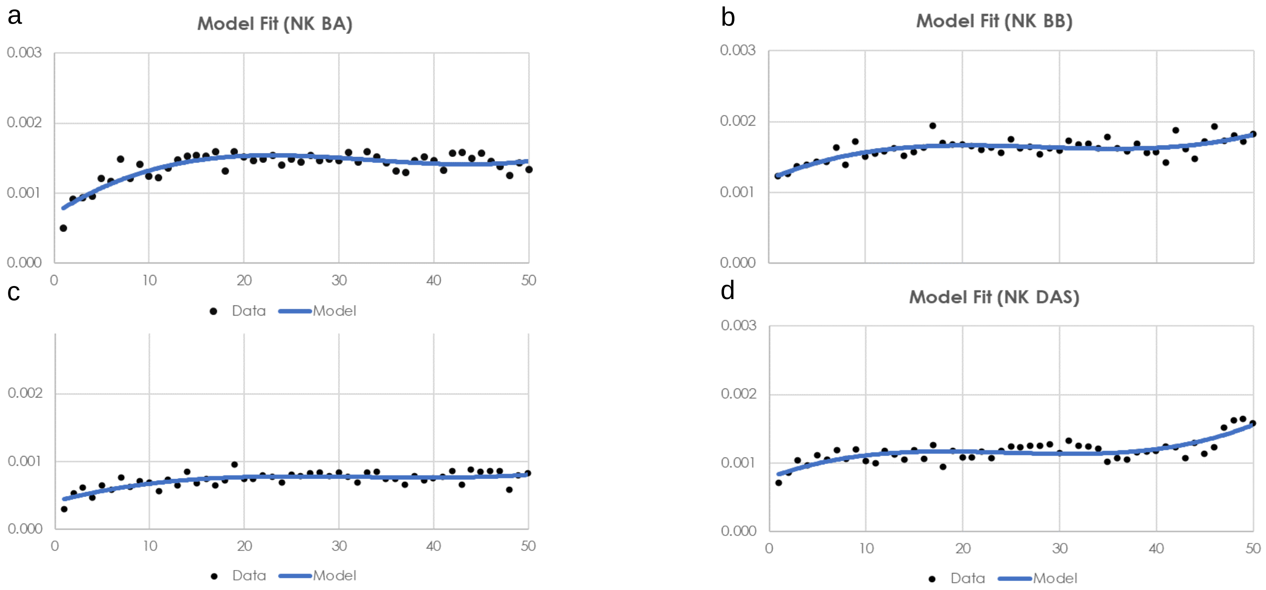
Table 5 - Table of ANOVA test results

		Sum of Squares	df	Mean Squares	F	Sig.
ANOVA Test NK BA	Regression	2.565	3	0.855	65.7	0.000
	Residual	0.599	46	0.013		
	Total	3.164	49			
ANOVA Test NK BB	Regression	5.657	3	1.886	52.3	0.000
	Residual	1.658	46	0.036		
	Total	7.315	49			
ANOVA Test NK LNT	Regression	5.146	3	1.715	56.4	0.000
	Residual	1.399	46	0.03		
	Total	6.544	49			
ANOVA Test NK DAS	Regression	2.682	3	0.894	47.3	0.000
	Residual	0.87	46	0.019		
	Total	3.552	49			
ANOVA Test NK JBT	Regression	1.083	3	0.361	38.1	0.000
	Residual	0.436	46	0.009		
	Total	1.52	49			

Based on the ANOVA test the significance value or p-value of the five models is very small to close to zero which means that the number is smaller than the alpha value of significance which is 0.05. Based on these values it can be interpreted that the age variable (independent variable) can be relied upon to perform its dependent variable estimates, namely: NK BA, NK, BB, NK LNT, NK DAS, and NK JBT. The value of F which ranges from 38,066 to 65,676 which is more than the value of significance, indicates a significant difference in the value of bridge conditions (dependent variables) at each age level of the bridge (independent variable).

3.3 Model Fit

In this section, model fit is checked with graphics methods due to overfitting, and underfitting in data can be easily detected using graphics (Moore, 2001). Overfitting and underfitting checks are performed on train sets and test sets for all variables and are described as follows and found to be fit models for 5 categories.



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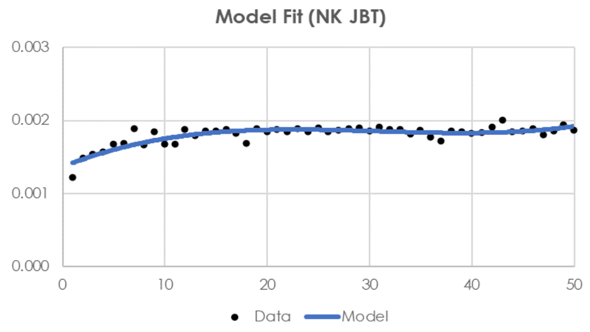

Fig. 4 - Model Fit: (a) NK BA; (b) NK BB; (c) NK LNT; (d) NK DAS; (e) NK JBT

The yield curve of the model shows the distribution of data according to the curve of the model. In addition, the model curve also does not tend to overfit because the curve has a balance between variance and bias. This indicates that the model has a good fit model.

3.4 Model Validation

Models that have been created using train sets are validated with the test sets and validation sets to find out the percentage of errors. MAPE and RMSE value interpretation is presented in table form as follows:

Table 6 - MAPE value interpretation (Lewis, 1982)

MAPE (%)	Interpretation
<10	Highly accurate forecasting
10 – 20	Good forecasting
20 – 50	Reasonable forecasting
>50	Inaccurate forecasting

Table 7 - RMSE value interpretation

RMSE	Interpretation
<0,2	Very good accuracy
0,2 – 0,5	Good accuracy
>0.5	Bad accuracy

Following the interpretation of MAPE and RMSE values, model validation results can be found in the tables below:

Table 8 - Validation of NKBA models

MODEL VALIDATION	NK BA				REMARKS
	MAPE (%)	NOTE	RMSE	NOTE	
TEST DATA VS MODEL PREDICTION	**13.0265**	Good	**0.2014**	Good	**Good**

VAL DATA VS MODEL PREDICTION	**18.1754**	Good	**0.2859**	Good	**Good**

Table 9 - Validation of NKBB models

MODEL VALIDATION	NK BB				REMARKS
	MAPE (%)	NOTE	RMSE	NOTE	
TEST DATA VS MODEL PREDICTION	**9.7228**	Highly Accurate	**0.1926**	Very Good	**Excellent**
VAL DATA VS MODEL PREDICTION	**16.6409**	Good	**0.2967**	Good	**Good**

Table 10 - Validation of NKLNT models

MODEL VALIDATION	NK LNT				REMARKS
	MAPE (%)	NOTE	RMSE	NOTE	
TEST DATA VS MODEL PREDICTION	**18.4240**	Good	**0.1655**	Very Good	**Good**
VAL DATA VS MODEL PREDICTION	**29.9060**	Reasonable	**0.2315**	Good	**Reasonable**

Table 11 - Validation of NKDAS models

MODEL VALIDATION	NK DAS				REMARKS
	MAPE (%)	NOTE	RMSE	NOTE	
TEST DATA VS MODEL PREDICTION	**12.3281**	Good	**0.2345**	Good	**Good**
VAL DATA VS MODEL PREDICTION	**23.3436**	Reasonable	**0.3271**	Good	**Reasonable**

Table 12 - Validation of NKJBT models

MODEL VALIDATION	NK DAS				REMARKS
	MAPE (%)	NOTE	RMSE	NOTE	
TEST DATA VS MODEL PREDICTION	**5.8763**	Highly Accurate	**0.1457**	Very Good	**Excellent**
VAL DATA VS MODEL PREDICTION	**10.0758**	Good	**0.2621**	Good	**Good**

From the results of the validation process, the model shows good accuracy and is suitable to be used to estimate the value of the bridge condition. In general, the results of validation using test data tend to produce better conclusions than using validation data. The accuracy that is not very good (reasonable) in the validation of the model prediction results against the validation data can be caused by the dataset being too small (5%) so that it is not able to represent the entire data modeled by 80% of the dataset. It is proven by using a Test Set of 15% of the total data, it is found that the prediction results are good to very accurate so that the model can be said to be accurate.

4. Conclusions

The study focused on creating regression models to perform estimates of the condition value of bridge elements at a certain age. Regression models are created by the K-Fold Cross Validation method and tested with a predefined test dataset in the process of sorting data for K-Fold Cross Validation. Validation results show that the model has good accuracy and it can be concluded that the model is worth using to perform estimates of the value of bridge conditions. The result of this model is a regression equation and a regression curve. The recommendation for future research is the modeling of comparison using the Bridge Condition Ratio (BCR) method. Additional research can be done to perform an estimate of the value of conditions using other methods.

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