DEVELOPMENT OF LINEAR MODELS TO PREDICT SUPERSTRUCTURE RATINGS OF STEEL AND PRESTRESSED CONCRETE BRIDGES

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To my lovely wife and son. Thank you for being next to me during this goal.

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Title of Study: DEVELOPMENT OF LINEAR MODELS TO PREDICT SUPERSTRUCTURE RATINGS OF STEEL AND PRESTRESSED CONCRETE BRIDGES.

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Abstract: Due to the importance of estimating costs and approving budgets of maintenance and construction bridges, it is necessary to evaluate how some variables, such as structure material, average daily traffic, and length of spans, interacts among them, and how that relationship affects the costs. Therefore, this study is focused on the analysis of the longevity through the relationship among the different variables that the National Bridge Inventory (NBI) has in order to understand more of bridge superstructure rating. Particularly, this research is centered on what happens with Oklahoma's steel and pre-stressed concrete bridges and what variables are determinant of the bridge superstructure rating. To do that, by using the NBI database of 2010 and applying statistical methods such as Pearson's Correlation and Multiple Regression, linear models for predicting the superstructure rating of each material are developed. Although the bridge age and the average daily traffic have been the principal variables of deterioration in previous studies, the superstructure material has not been identified as an important determinant.

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CHAPTER I

INTRODUCTION

Bridges are one of the most important infrastructure assets, but usually making a decision of building a new bridge is mainly based on a bid price. As a result, some bridges may have a useful life that is compromised sooner than anticipated. This situation may cause bridge owners to spend part of their budgets in an inefficient way. Due to this and the need of research on bridge superstructure performance, there is the interest to start analyzing the overall impact of a bridge's superstructure material type and the elements that affect the superstructure rating.

1.1. Background

Although there are some previous studies related to the bridge superstructure performance, the majority of those studies have not been focused on analyzing the situation and condition of the bridges in the state of Oklahoma. Also, the dominant interest of early studies was to evaluate the overall condition of the bridges or the deterioration rate of the bridge deck. Therefore, there is a gap that needs to be closed in order to allow government agencies, with more information and research, to optimize the funds assigned for maintenance and construction of bridges. Furthermore, designer, construction companies, and material fabricators will be interested in knowing the causes of deterioration in bridge superstructures.

According to the scope of this thesis, the National Bridge Inventory (NBI) databases will be the source of information. Specifically, the NBI-2010 is the database used in this study. Thus, it is imperative to do a data quality assurance process in order to identify and remove unnecessary variables and outliers, if appropriate. Then possible determinants of the superstructure rating will be established. Hence, statistical methods as Pearson's Correlation and Multiple Regression will be applied in order to develop the final linear model for different materials.

Finally, the results of this study may be helpful for all parties involved in the process of building new bridges or providing maintenance to current structures. We expect this research to give more information and methodologies required when the accurate assignment of limited funds is a priority. Furthermore, both designers and constructors of bridges will better understand the determinants of low bridge superstructures ratings. Therefore, they can improve designs and construction methods to develop a superior bridge plus possible higher profits.

Although this study has some limitations in data, there are expectations to continue developing this research with the integration of more information from different agencies such as the Oklahoma Department of Transportation (ODOT). For example, combining the NBI database and the financial story of bridges would help improve the accuracy of any model developed until now. Also, it would open another path to keep researching and finding new useful tools for the engineering world and its related fields.

1.2. Scope

Due to the amount of bridges that the NBI tracks, it was necessary to set different research parameters. This focuses the number of bridges according to the interests of this study. Some of the parameters selected to choose the bridges were the bridge state (location), the bridge year built, the type of design, and deck type.

Thus, this research will focus on bridges in the state of Oklahoma. Furthermore, there are two main materials that have been commonly used to build the superstructure of bridges in the state of Oklahoma since 1980s. These materials are pre-stressed concrete and steel. Also, each of these materials has two structure types. Hence, this research will study the following superstructure materials: pre-stressed concrete, pre-stressed concrete continuous, steel, and steel continuous.

Also, the construction period of the group of bridges to be analyzed is from 1955 to 2010. This condition was set because nearly all pre-stressed concrete bridges were built in this period. In order to compare them with steel bridges, both groups of materials should have been built in the same interval.

1.3. Objective

Some researches have studied the deterioration of bridges, but none of them has focused on analyzing the superstructure rating specifically. Therefore, the purpose of this research is to study the superstructure rating and develop a linear model for each material. Thus, the objective of these models is to predict the bridge superstructure rating and to help evaluate its future performance.

Models may be of interests not just for bridge owners, but also designers, construction products companies, and other governmental agencies. Also, the prediction of the superstructure rating may give the opportunity to estimate time (when) and amount of money (how much) a bridge would need to be maintained or reconstructed. This would allow to having bridges in good conditions, which means better traffic flow and no tragedies (collapse of structures).

CHAPTER II

REVIEW OF LITERATURE

The different studies developed for understanding and predicting the condition of bridges in the U.S. may be classified by the kind of technique used in them. Some of these techniques are simple regression analysis, multiple regression analysis, and Markovian modeling. Although there is not a clear tendency of using one of those methods, there is an inclination of what data would be analyzed. It is the National Bridge Inventory (NBI); therefore it has been an essential source of information for several bridge studies. For example, Veshosky, Beidleman, Buetow, and Demir (1994) developed a non-linear model in order to predict the superstructure condition rating for each material (steel and pre-stressed concrete), and their single information reference was NBI-1990 (all the U.S.). Their main conclusion was that superstructure bridge deterioration decays faster during the first years, and then it slows down. Moreover, this study shows the bridge age as the most important determinant for both materials analyzed.

Similar to Veshosky et al. (1994), Lee (2012) analyzed the state of bridge deterioration in the U.S. Although the author did not develop any model to predict bridge ratings or conditions, he conduct a statistical analysis of variables contained in the NBI-2010 for three materials (concrete, steel, and pre-stressed concrete). He highlights that while steel bridges are sensitive to the span length, pre-stressed concrete bridges are not at all. Also, he calls attention to the fact that pre-stressed concrete bridge deterioration is more serious than the other two kinds of bridges (steel and concrete). The reason of this is that the pre-stressed concrete bridges have the highly stressed strands embedded or enclosed in ducts, which is a fundamental element of their structural design. Due to this, the visual inspection is demanding and in some cases impossible; therefore, when a corrosion issue is presumed to be considerable, the most reasonable criterion is to replace the affected member.

Another study that uses NBI databases was made by Tang, Kanaan, Wnag, Oh, and Kwigizile (2012). The authors focused on frequencies of explanatory data items (variables) for five regions in the U.S. In order to obtain the variable frequencies, they used the following statistical methods: Pearson’s correlation, multiple regression, and Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Finally, the study showed that the year the bridge was built and the inspection frequency were the most important variables for explaining the bridge ratings. Nevertheless, the Average Daily Traffic (ADT) was not significant explanatory parameter of bridge ratings as it was concluded by Veshosky et al. (1994).

Also, Dekelbab, Al-Wazeer, and Harris (2008) analyzed the deterioration cycles of bridge decks applying the Kaplan-Meir method, which is a time-based model usually used in the medical field. According to the researchers, their interest was the deck deterioration because the deck is the principal consideration related to service and maintenance. Due to the results, the authors said that bridges with low ADT have low probability of condition change. Also, they concluded that at the early age of decks the detection of deterioration is difficult, so the inspectors do not notice it and modify the deck rating. Yet when the deck deterioration is visualized, the deck rating drops quickly.

Nevertheless, although NBI databases have been a vital source of data for collection of studies, some authors as Dekelbab et al. (2008), Tang et al. (2012), and Veshosky et al. (1994) agree that it is necessary to complement the NBI databases with more information such as environmental conditions. Even more, according to Bruschi (1996), the NBI databases are not the correct data resource to develop models to predict the bridge ratings.

On the other hand, other techniques and sources of information have been used to obtain models to understand the bridge condition. For example, the artificial neural network (ANN) approach was used by Huang (2010). This study pointed to predict the deck deterioration using a database of Wisconsin, some of the variables identified as significant were age and ADT as Veshosky et al. (1994) found for superstructure bridge deterioration. Due to this, some researches may apply this technique to predict superstructure rating and deterioration in future studies.

CHAPTER III

METHODOLOGY

This chapter will discuss relevant elements of how the research was developed such as the selection of databases, the generation of a usable dataset, and building of summary statistics and linear models. Also, this will be useful for understanding the assumptions and techniques applied in this study.

3.1. Data Collection

The database, National Bridge Inventory (NBI), used in this research was developed by the Office of Engineering – Bridge Division of the U.S. Department of Transportation, and it was obtained from the National Steel Bridge Alliance (NSBA). Although there was the opportunity to have 19 databases from 1992 to 2010, the final decision was to analyze the most recent database, NBI-2010. One of the reasons for making that decision is that the NBI-2010 database contains the highest amount of bridges (25,844) than the other 18 databases. Also, it is the most recent database that could be used which incorporates the bridges' condition from just three years ago.

After the selection of the database, a usable dataset needed to be developed. This was done according to the research preference (e.g. bridge materials, age) and the definition of each variable (Weseman, 1995). Thus, the population of interest was selected based on the parameters shown in Table 1. Because of that, the number of bridges decreased notably from 25,844 bridges to 7,428 bridges.

Table 1. Parameters of the Research

Item or Variable	Reseach Parameters
27: Year built	Bridges build from 1955 to 2010
43A: Kind of material and/or design	Pre-stressed Concrete
	Pre-stressed Concrete Continuous
	Steel
	Steel Continuous
43B: Type of design and/or construction	Stringer/Multibeam or girder
106: Year reconstructed	Not reconstructed bridges
107: Deck type	Concrete Cast-in-place

Nevertheless, items (variables) were evaluated because the NBI database contains non-valid parameters for some bridges and redundant items (Tang et al., 2012). First, again in accordance to the definition of each item (Weseman, 1995), and previous studies (Tang et al., 2012; Veshosky et al., 1994), there was a selection of variables which may be determinants for the superstructure rating (see Table 2). The reason why some items were not selected as "possible" determinants is because they were classified as repetitive or needless variables for predicting the superstructure rating. For example, item 6A (Features Intersected) and item 7 (Facility Carried by Structure) were classified as needless because they are unimportant to the objective of the study. After that, the cleaning process whose objective was to erase all the records (bridges) that had non-valid parameters such as "blanks" was completed. As a result of these processes, the obtained dataset contains 7,077 bridges, which 3,881bridges have as superstructure material steel or steel continuous, and 3,196 bridges have as superstructure material pre-stressed concrete or pre-stressed concrete continuous.

Table 2. Determinants of Superstructure Rating

Item 21: Maint Responsibility	Item 46: Spans Approach
Item 26: FC of Inventory Rte	Item 48: Length of Max Span
Item 27: Year Built	Item 49: Structure Length
Item 29: ADT	Item 51: Bridge Roadway Curb-to-Curb
Item 31: Design Load	Item 52: Deck Width O/O
Item 41: Structure Status	Item 67: Structural Evaluation
Item 42B: TOS under Bridge	Item 68: Deck Geometry
Item 44A: Approach Material/Design	Item 69: Underclear
Item 44B: Approach Design/Construction	Item 71: Water Adequacy
Item 45: Spans Main Unit	Item 72: Approach Alignment

However, because the new dataset had qualitative and quantitative variables (determinants), it was necessary to convert the qualitative variables to “dummy variables” (Hardy, 1993). According to Hardy (1993), the binary (0,1) coding was used to create the new dummy variables in order to not miss any parameter included in the initial qualitative variables. Therefore, all the content of the qualitative variables were decoded; thus there were unique parameters for all those variables. Then, Minitab 16 was used in order to create the dummy variables as Bower (2013) explains in his paper. This software is well known for its user-friendly environment, and students in the School of Civil and Environmental Engineering at Oklahoma State University have access to it.

On the other hand, the variable “Age” was created because it was useful to know how old the bridges were compared to when they were built (item 27). To calculate “Age”, it is just the subtraction between 2010, which is the reference year, and item 27 (Year Built) as it is showed in equation (1).

$$Age = 2010 - Item\ 27\text{:}\ Year\ Built \quad (1)$$

Moreover, although item 31 (Design Load) and item 59 (Superstructure Rating) were codified as qualitative variables, it was necessary to have them as quantitative variables. To do this, their parameters were modified according to Table 3 and Table 4 (Weseman, 1995).

Table 3. Superstructure Condition Rating

Rating	Value
Failed Condition	0
"Imminent" Failure Condition	1
Critical Condition	2
Serious Condition	3
Poor Condition	4
Fair Condition	5
Satisfactory Condition	6
Good Condition	7
Very Good Condition	8
Excellent Condition	9

Table 4. Live Load for which the Structure was Designed

Design	Value
Other or Unknown	0
M 9 / H 10	1
M 13.5 / H 15	2
MS 13.5 / HS 15	3
M 18 / H 20	4
MS 18 / HS 20	5
MS 18+Mod / HS 20+Mod	6
Pedestrian	7
Railroad	8
MS 22.5 / HS 25	9

Due to the research objective, the dataset was divided into two datasets. One dataset was for all the bridges whose superstructure material is steel or steel continuous (S-SC) with 3,881bridges, and the other dataset was for all the bridges whose superstructure material is pre-stressed concrete or pre-stressed concrete continuous (PC-PCC) with 3,196 bridges.

3.2. Data Analysis

A general statistical analysis was conducted to visualize the tendency of the data. Both Pearson's Correlation and Multiple Regression statistical methods were used in order to determine which variables have the greatest influence on bridge superstructure rating. Models to predict the superstructure rating were developed; and finally, validation of the final models for each material was done.

3.2.1. Summary Statistics

Summary statistics including mean, standard deviation, minimum, maximum, and quartiles for the quantitative variables such as Age, Average Daily Traffic, and Design Load. Each of these numerical descriptive statistics (Freund, 2010) were calculated for both materials (S-SC and PC-PCC) in order to have an idea of their central tendency and dispersion.

In addition, the deficient superstructure bridges, which are the bridges whose superstructure ratings are less or equal to 4, were selected from the dataset. Having this information, a comparison of statistics between the 7,077 bridges (General) and 160 bridges (deficient superstructure bridges) was done.

3.2.2. Variable Selection

In order to select the variables (parameters) which have the greatest influence on superstructure rating, the Pearson's Correlation coefficient was used. The Pearson's Correlation gives the strength of the linear relationship between two variables by the correlation coefficient. As stated by Freund (2010), there is a strong correlation if its coefficient is close to 1 or -1. However, a value of zero (0) in the correlation coefficient tells that there is no linear relationship between the two variables. Thus, the correlation coefficient was calculated for each relationship between superstructure rating and the determinants for both groups of materials. Also, the correlation coefficient was calculated between superstructure rating and the other four (4) ratings in order to know how strong their correlation is

3.2.3. Model Development

After the analysis of the Pearson's Correlation coefficients was completed, the multiple regression concept was applied to find a model to predict the superstructure rating. According to Freund (2010), the simple linear regression and the multiple regression differ in that the second one has more than one parameter β_i and one intercept β_0 in order to predict the value of y, which is the dependent variable (see equation 2).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m + \varepsilon \ (2)$$

Moreover, multiple regression has different approaches such as variable selection and stepwise regression. Therefore, in this instance the stepwise approach was used. This approach adds one variable to the model each time and then analyzes what type of contribution the variable makes, if any. If there is minimal or no contribution, the variable is eliminated from the model. Due to this, two models were developed for each group of materials. One is based on the highest 10 Pearson's correlations, and the second one is based on all the variables contained in each group dataset.

In addition, according to the multiple regression concepts (Freund, 2010), it is necessary to check that the p-values for the t-test (student's distribution) are less than the alpha-value (α). This alpha-value (α) was chosen as 0.05 because of the kind of study. Furthermore, Minitab 16 allows the user to set the alpha-value and check it before any variable is added.

3.2.4. Model Validation

In order to verify the final models developed above, two different checks were made: a validation using Excel and a multi-collinearity test using the variance inflation factor (VIF) Minitab 16. The first check, Excel validation, consisted of taking the equation from the final model and the respective data for the parameters in each material dataset. Then, the superstructure rating (predicted superstructure rating) was calculated for each bridge. Finally, this predicted rating was compared with the superstructure rating contained in the dataset, "actual rating", to determine accuracy of the model. This comparison may help interpret the models' limitations, and it should contribute to the improvement of future studies on this topic.

The other check, multicollinearity test or VIF as it is known (Minitab 16), inspected whether or not there are dependencies among the independent parameters (variables) as Simon (2008) mentioned. If the test shows that there is any dependence, values greater than 5.0, the variables of the model were highly correlated. In such cases, one of the highly correlated variables was removed.

3.3. Data Dissemination

The increasing demand of building and maintaining infrastructure assets such as bridges with limited budgets has created the necessity of bridge owners to predict when to have funds available to be spent in construction or maintenance. Due to this premise, there is the belief that spreading the results of this research, would be useful for bridge owners and researchers who could be interested in continuing future studies on this matter. Therefore, different ways to disseminate the findings of the study such as a research summary document, a poster, a paper, or a conference presentation have been considered. However, writing a paper for a magazine and giving a speech in a conference are the favored ones. For example, the Steel Conference, NASCC, which is hosted by the American Institute of Steel Construction (AISC) every year, would be a good place to present the methodology, results, and conclusions of this study. Nevertheless, the results of this research will be presented to NSBA for their review before disseminating the results in the broader public arena.

Also, another place to present the findings of this research could be during a meeting with engineers and workers of the Bridge Section of any Department of Transportation (DOT), especially the Oklahoma DOT. This may open the opportunity to share knowledge from the field in order to complement this research. Also, this could be the beginning of a close relationship between the academia and the field facilitating the flow of knowledge and experience to each other.

CHAPTER IV

RESULTS

This section contains the results obtained in this research, such as summary statistics of each material dataset, variables selected as parameters that have the greatest impact on superstructure rating, final models to predict the superstructure rating, and the values obtained using the combination of finals models and the data of each material. Also, the VIF values are shown in this section. Those values verify if the variables are not dependent among each other.

4.1. Data Collection

The result of the data collection and its quality assurance process was two datasets; one dataset for each group of superstructure bridge material. These datasets, which have more than 90 variables each, were used to develop this research, and they can be seen in Figure 1 below. Also, while the S-SC dataset contains 3,881 bridges, the PC-PCC dataset contains 3,196 bridges. However, since the two datasets do not have a substantial difference in number of bridges, this study could be developed without having any issues related to comparing unequal size datasets. Also, these datasets were exported to Minitab 16 in order to create all the statistical calculations, the creation of dummy variables, and the development of the linear models.

Figure 1. Dataset Visualization

4.2. Data Analysis

This section contains the results of each process described in the methodology, such as the superstructure rating models for both groups of materials and their validations. Furthermore, it shows in detail some relevant facts found in the study related to the R-square values of the linear models.

4.2.1. Summary Statistics

Table 5 and Table 6 summarize the numerical statistics for both groups of materials. Due to the research interest, one important comparison to highlight is that while S-SC bridges have a higher mean age (24.7 years) than PC-PCC (18.3 years), PC-PCC bridges have a higher superstructure rating mean (7.9) than S-SC (6.1). As it was mentioned, S-SC bridges have higher means in age but also in spans approach. Yet PC-PCC bridges have higher means in the rest of the variables and ratings. Although one may say that PC-PCC bridges have higher mean ratings (deck, superstructure, substructure, and sufficiency) and so they have a better performance, it is too early to conclude it. Also, it is too soon to infer it because NBI does not show any information about investment in maintenance or reconstruction of the bridges, which are critical facts that need to be analyzed as well.

In addition, Table 7 and Table 8 summarize the averages of age and superstructure rating between the general bridges and the deficient superstructure bridges, respectively. While S-SC bridges are 93.1% of the total deficient superstructure bridges, PC-PCC bridges are just 6.9% of them. Furthermore, while S-SC deficient bridges are 3.84% of the total S-SC bridges (3,881), PC-PCC deficient bridges are only 0.34% of the total PC-PCC bridges (3,196). Therefore, unquestionably S-SC bridges have both the higher number of deficient bridges and the higher relation, and the number of deficient superstructure bridges versus number of bridges for material, in comparison to PC-PCC bridges.

Table 5. Steel and Steel Continuous Bridges Summary Statistics, n = 3,881

Variable	Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Age	24.7	16.148		10.0	22.0	41.0	55.0
Item 29: ADT	1,988.8	4,926.000	10.0	50.0	100.0	684.0	32,600.0
Item 45: Spans Main Unit	1.9	1.955	1.0	1.0	1.0	3.0	32.0
Item 46: Spans Approach	0.1	0.793					23.0
Item 48: Length of Max S	152.2	94.650		88.0	128.0	183.0	1,067.0
Item 49: Structure Lengt	345.9	582.400	61.0	94.0	152.0	436.0	16,538.0
Item 51: Bridge Roadway	83.9	28.632	43.0	72.0	77.0	85.0	389.0
Item 52: Deck Width O/O	90.7	56.200	43.0	73.0	80.0	94.0	2,195.0
Item 58: Deck Rating N	6.5	1.072		6.0	7.0	7.0	9.0
Item 59: Superstructure	6.1	1.086		5.0	6.0	7.0	9.0
Item 60: Substructure Ra	6.0	1.192		5.0	6.0	7.0	9.0
Sufficiency Rating	799.9	171.200	76.0	703.5	847.0	950.0	1,000.0

Table 6. Pre-stressed Concrete and Pre-stressed Concrete Continuous Bridges Summary Statistics, n = 3,196

Variable	Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Age	18.3	11.489		10.0	17.0	25.0	55.0
Item 29: ADT	2,817.9	4,675.200	1.0	100.0	620.0	3,650.0	32,500.0
Item 45: Spans Main Unit	3.0	3.507	1.0	1.0	3.0	3.0	57.0
Item 46: Spans Approach	0.0	0.902					48.0
Item 48: Length of Max S	248.3	69.680		198.0	247.0	305.0	1,200.0
Item 49: Structure Lengt	704.5	1,046.000	70.0	305.0	466.0	680.0	17,008.0
Item 51: Bridge Roadway	106.8	38.470	40.0	82.0	98.0	122.0	370.0
Item 52: Deck Width O/O	115.5	42.040	41.0	87.0	104.0	128.0	426.0
Item 58: Deck Rating N	7.2	0.829	3.0	7.0	7.0	8.0	9.0
Item 59: Superstructure	7.9	0.707	3.0	8.0	8.0	8.0	9.0
Item 60: Substructure Ra	7.2	0.987	3.0	7.0	7.0	8.0	9.0
Sufficiency Rating	929.3	97.160	98.0	901.0	968.0	1,000.0	1,000.0

Table 7. Average of Age and Superstructure Rating - All Dataset Bridges

Material	Frequency (Bridges)	Percentage (%)	Average of Age	Average of SS Rating
Prestressed Concrete (PC-PCC)	3196	45.2%	18.3	7.9
Steel (S-SC)	3881	54.8%	24.7	6.1
Total	**7077**	**100%**	**21.9**	**6.9**

Table 8. Average of Age and Superstructure rating - Deficient Bridges

Material	Frequency (Bridges)	Percentage (%) Total Deficient SS Bridges	Percentage (%) Material	Average of Age	Average of SS Rating
Prestressed Concrete (PC-PCC)	11	6.9%	0.34%	36.9	3.8
Steel (S-SC)	149	93.1%	3.84%	43.6	3.8
Total	**160**	**100%**		**43.1**	**3.8**

Nevertheless, Figure 2 illustrates the number of bridges for both groups of superstructure materials and classifications in which one can see that the deficient superstructure PC-PCC bridges have the lowest mean age (36.9 years) in comparison to the deficient superstructure S-SC bridges (43.6 years). In addition, both groups have the same mean superstructure rating (3.8) for deficient superstructure bridges.

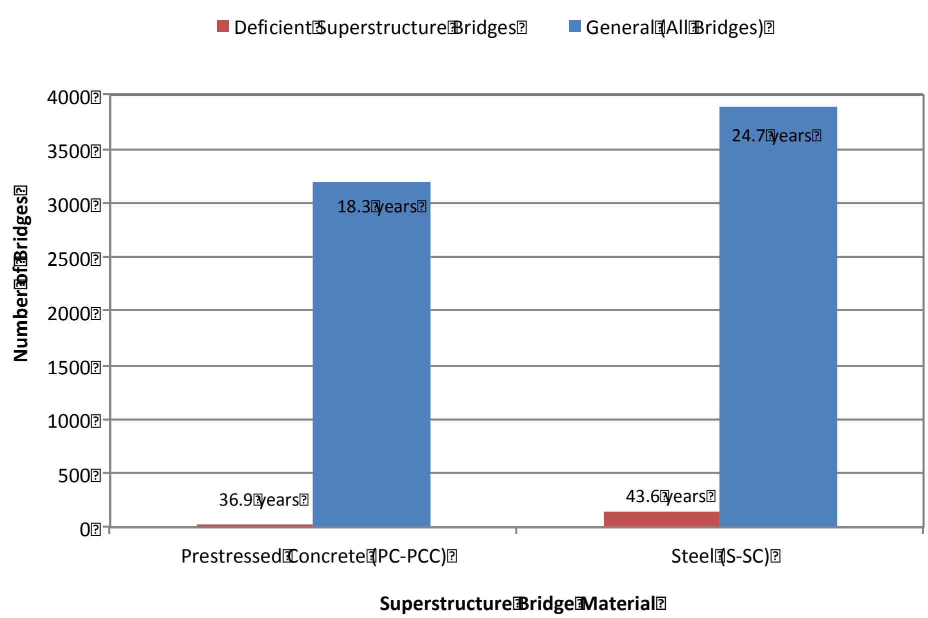

Figure 2. General Bridges vs Deficient Superstructure Bridges

Furthermore, Table 9 and Table 10 contain the summary of frequency (number of bridges) and the relative frequency of the general bridges and deficient superstructure bridges, respectively, according to age intervals. Table 9 shows that the total amount of bridges built has been increasing in almost all the intervals except for 0-6 and 28-34. Also, the total amount of deficient superstructure bridges increases among the age intervals.

Since 30 years ago, PC-PCC bridges have clearly won space in the construction bridge field; however, they have not totally taken the place of S-SC bridges (see Figure 3). For example, in the age intervals since 34 years, the number of PC-PCC bridges is higher than S-SC bridges, yet in the age interval 0-6 the number of S-SC bridges is a little bit higher.

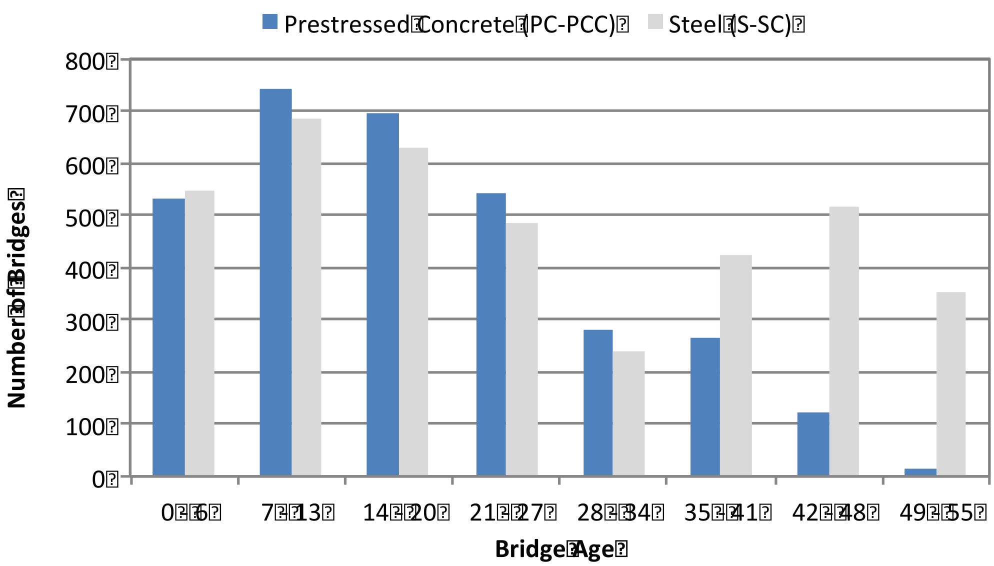

Figure 3. Frequency of General Bridges by Age Intervals and Superstructure Material

On the other hand, Figure 4 reveals that more than 90% of the deficient superstructure PC-PCC bridges occur between 28 and 41 years old. As a contrast, deficient superstructure S-SC bridges only reached the 90% in the last interval, 49 – 55 years old. It may be interpreted as PC-PCC superstructure bridges deteriorate earlier than S-SC superstructure bridges.

Table 9. Frequency of General Bridges and Deficient Superstructure Bridges by Age Intervals and Superstructure Material

	General (All Bridges)									Deficient Superstructure Bridges							
Material	**0–6**	**7–13**	**14–20**	**21–27**	**28–34**	**35–41**	**42–48**	**49–55**	**Total**	**7–13**	**14–20**	**21–27**	**28–34**	**35–41**	**42–48**	**49–55**	**Total**
Prestressed Concrete (PC-PCC)	532	744	696.0	544	279	266.0	121	14	3196.0				5	5		1	11.0
Steel (S-SC)	545	687	627.0	487	241	425.0	518	351	3881.0	2	2	5.0	11	25	53.0	51	149.0
Total	**1077**	**1431**	**1323.0**	**1031**	**520**	**691.0**	**639**	**365**	**7077.0**	**2**	**2**	**5.0**	**16**	**30**	**53.0**	**52**	**160.0**

Table 10. Relative Frequency of General Bridges and Deficient Superstructure Bridges by Age Intervals and Superstructure Material

	General (All Bridges)									Deficient Superstructure Bridges							
Material	**0–6**	**7–13**	**14–20**	**21–27**	**28–34**	**35–41**	**42–48**	**49–55**	**Total**	**7–13**	**14–20**	**21–27**	**28–34**	**35–41**	**42–48**	**49–55**	**Total**
Prestressed Concrete (PC-PCC)	16.6%	23.3%	21.8%	17.0%	8.7%	8.3%	3.8%	0.4%	100.0%	0.0%	0.0%	0.0%	45.5%	45.5%	0.0%	9.1%	100.0%
Steel (S-SC)	14.0%	17.7%	16.2%	12.5%	6.2%	11.0%	13.3%	9.0%	100.0%	1.3%	1.3%	3.4%	7.4%	16.8%	35.6%	34.2%	100.0%

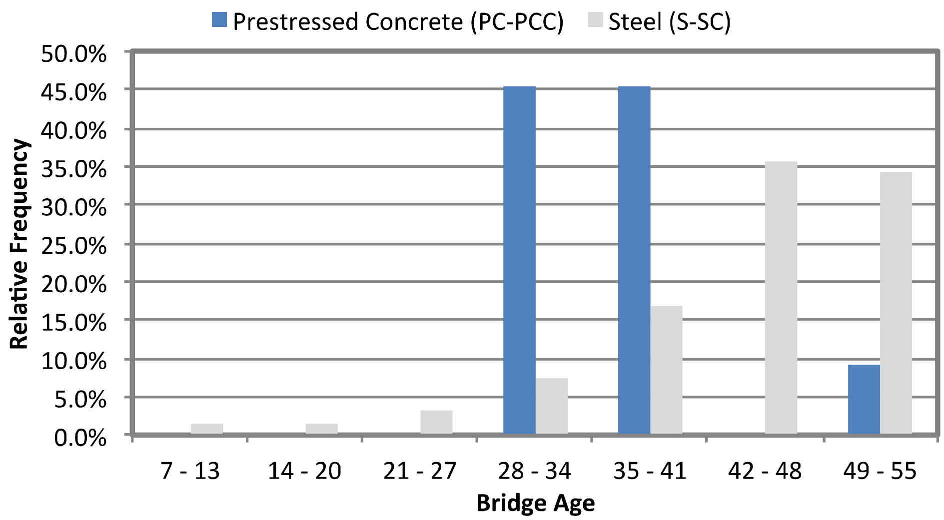

Figure 4. Relative Frequency of Deficient Superstructure Bridges by Age Intervals and Superstructure Material

4.2.2. Variable Selection

Due to the creation of dummy variables, the Pearson's Correlation coefficients table is too extensive to show here; therefore, the tables of both material groups are attached as **Error! Reference source not found.Error! Reference source not found.** and Appendix 2. However, Table 11 shows the ten highest Pearson's Correlation coefficients for S-SC superstructure bridges. The first four coefficients are for the other ratings contained in NBI databases. It proves that there is a strong linear relationship between the superstructure rating and other ratings, especially with substructure, deck, and sufficiency ratings.

Table 11. The Highest Ten Pearson's Correlation Coefficients of S-SC Superstructure Bridges

Rank	Kind	Variable	Description	Pearson's Coefficient
1	Rating	Item 60 Substructure Rating	Item 60 Substructure Rating	0.706
2	Rating	Item 58 Deck Rating	Item 58 Deck Rating	0.570
3	Rating	Sufficiency Rating	Sufficiency Rating	0.568
4	Rating	Status_Structura	Structurally deficient	-0.386
5	Num	Age	Age	-0.383
6	Rating	Status_Not defic	Not deficient	0.319
7	Num	Item 31 Design Load	Item 31 Design Load	0.266
8	QLT	ITEM 41-2 Structure Status	Open, no restriction	0.211
9	QLT	ITEM 68-4 Deck Geometry	Equal to present minimum criteria	0.203
10	QLT	ITEM 41-5 Structure Status	Posted for load (may include other restrictions such a temporary bridges which are load posted)	-0.188

Nevertheless, because of the interest of this study, just variables were used to predict the deterioration of the superstructure. It means ratings were not used at all to develop the linear models because a rating is not considered as a variable (determinant). Consequently, the highest ten possible determinants were selected and showed in Table 12. According to this table, just three of the determinants are quantitative variables, and the other seven are qualitative (“dummy” variables). One of the numeric variables is age, and its Pearson’s coefficient confirms that the superstructure rating decreases as the bridges age.

Table 12. The Ten Possible Determinants of S-SC Superstructure Bridges

Rank	Kind	Variable	Description	Pearson's Coefficient
1	Num	Age	Age	-0.383
2	Num	Item 31 Design Load	Item 31 Design Load	0.266
3	QLT	ITEM 41-2 Structure Status	Open, no restriction	0.211
4	QLT	ITEM 68-4 Deck Geometry	Equal to present minimum criteria	0.203
5	QLT	ITEM 41-5 Structure Status	Posted for load (may include other restrictions such a temporary bridges which are load posted)	-0.188
6	QLT	ITEM 68-5 Deck Geometry	Meets minimum tolerable limits to be left in place as is	-0.150
7	QLT	ITEM 68-7 Deck Geometry	Somewhat better than minimum adequacy to tolerate being left in place as is	-0.134
8	QLT	ITEM 21-7 Maint Responsibility	State Highway Agency	-0.117
9	Num	Item 45 Spans Main Unit	Item 45 Spans Main Unit	-0.117
10	QLT	Item 26 Rural Local	Rural Local	0.116

Likewise, the same process was done for PC-PCC superstructure bridges. Table 13 and Table 14 summarize the highest 10 correlation coefficients for determinants and ratings, and just the determinants, respectively. One can notice that the determinants of PC-PCC superstructure bridges are more quantitative than qualitative which is the opposite of S-SC superstructure bridges.

Table 13. The Highest Ten Pearson's Correlation Coefficients of PC-PCC Superstructure Bridges

Rank	Kind	Variable	Description	Pearson's Coefficient
1	Rating	Item 60 Substructure Rating	Item 60 Substructure Rating	0.615
2	Rating	Item 58 Deck Rating	Item 58 Deck Rating	0.572
3	Num	Age	Age	-0.519
4	Rating	Sufficiency	Sufficiency Rating	0.360
5	Rating	Status_Structura	Structurally deficient	-0.323
6	Rating	Status_Not defic	Not deficient	0.228
7	QLT	Item 26 Rural Local	Rural Local	0.206
8	QLT	ITEM 21-5 Maint Responsibility	County Highway Agency	0.202
9	QLT	ITEM 21-7 Maint Responsibility	State Highway Agency	-0.190
10	Num	Item 45 Spans Main Unit	Item 45 Spans Main Unit	-0.181

Table 14. The Ten Possible Determinants of PC-PCC Superstructure Bridges

Rank	Kind	Variable	Description	Pearson's Coefficient
1	Num	Age	Age	-0.519
2	QLT	Item 26 Rural Local	Rural Local	0.206
3	QLT	ITEM 21-5 Maint Responsibility	County Highway Agency	0.202
4	QLT	ITEM 21-7 Maint Responsibility	State Highway Agency	-0.190
5	Num	Item 45 Spans Main Unit	Item 45 Spans Main Unit	-0.181
6	Num	Item 49 Structure Length	Item 49 Structure Length	-0.159
7	Num	Item 31 Design Load	Item 31 Design Load	0.145
8	Num	Item 52 Deck Width O/O	Item 52 Deck Width O/O	-0.132
9	Num	Item 51 Bridge Roadway Curb-to-Curb	Item 51 Bridge Roadway Curb-to-Curb	-0.121
10	QLT	ITEM 68-4 Deck Geometry	Equal to present minimum criteria	0.110

Although the Pearson's Correlation coefficients of the ratings for both groups, S-SC bridges and PC-PCC bridges, are similar (see Table 11 and Table 13), the possible determinants for both groups are not exactly the same (see Table 12 and Table 14). Furthermore, seven of the ten highest correlation coefficients of PC-PCC superstructure bridges are quantitative variables while there are just three quantitative variables for S-SC superstructure bridges. Therefore, it shows that the two groups of materials are affected by different variables and different levels of severity. For example, although Age is the highest correlation coefficient of both S-SC superstructure bridges (-0.383) and PC-PCC superstructure bridges (-0.519), PC-PCC is more sensitive to it. As a contrast, S-SC superstructure bridges have item 31 (Design Load) as the second highest correlation coefficient (0.266), but PC-PCC superstructure bridges have it in the seventh position (0.145).

4.2.3. Model Development

Multiple Regression

As a result of the stepwise approach in Minitab 16, two models for each group of material were obtained. The first two models (see Equations 3 and 4) were created using the ten possible determinants tables of each superstructure material group, Table 12 and Table 14 respectively. One can notice that neither of the models is composed of the ten possible determinants. To clarify, while the S – SC model just uses seven variables and the constant term to predict the superstructure rating, the PC – PCC model only uses six variables and the constant term. However, this is not used to make any comparison.

(3)

(4)

In order to measure how well these models fit the data, their R-squares (R^2) are analyzed. Although the S-SC model has a higher R^2 than that which was obtained by Veshosky et al. (1994), 25.92% and 13.6% respectively, the S-SC model developed in this research is not as high as one would expect in order to explain the original variability.

On the other hand, the model obtained for PC-PCC bridges has a R^2 of 31.58%, which is higher than Veshosky et al. (1994)'s model for pre-stressed concrete (12.90%). Again, one may have expected a higher value to predict the superstructure rating with the original variability.

Appendix 3 and Appendix 4 contain the Minitab 16 outcomes for the two groups of materials from where the models and R-squares were taken.

In addition, the other two models were developed using the totality dataset of each group of material, which have more than 90 predictors (variables). Minitab 16 ran more than 20 steps for each group in order to get the final model (see Appendix 7 and Appendix 8). For simplicity, it was decided to work with 6 variables for both groups of materials instead of 27 variables for PC-PCC and 31 variables for S-SC. Also, due to the R-square (R^2) values and its increments through the steps, the complexity of using the model with 27 or the model with 31 variables was not considered pertinent. The increment of R^2 value is just 6%, as it is the case for PC-PCC bridges' model, and 4% for the S-SC bridges' model. However, if someone would prefer to use the complete models, he or she can obtain the coefficients from the Minitab 16 outcomes, Appendix 7 and Appendix 8. In addition, the residual plots of these two models were printed out, and they can be seen in Appendix 9 and Appendix 10.

These final stepwise models for the S-SC bridges and PC-PCC bridges are summarized in equations 5 and 6, respectively. Also, according to these new results, the R^2 values increased in both cases, and there were some differences in the determinants in comparison to the variable selection approach models. Therefore, the comparison between both approaches of multiple regression technique where one can read the difference in both determinants and coefficients of determinants are condensed in Table 15 and Table 16.

(5)

(6)

Table 15. PC-PCC Bridge Superstructure Rating Models Comparison

Possible Determinants because of their Pearson's Correlation Coefficient	Coefficient	All Variables of the Dataset	Coefficient
Constant	8.483	Constant	8.317
Age	-0.30000	Age	-0.03057
Item 21-5 Maintenance Responsibility - County Highway Agency	-0.12000	It is not a determinant for this approach	
Item 21-7 Maintenance Responsibility - State Highway Agency	-0.32900	Item 21-7 Maintenance Responsibility - State Highway Agency	-0.26700
Item 49 Structure Length	-0.00007	Item 49 Structure Length	-0.00007
Item 31 Design Load	0.04470	Item 31 Design Load	0.04630
Item 52 Deck Width, Out-to-Out	-0.00069	It is not a determinant for this approach	
It is not a determinant for this approach		Item 26 Functional Classification of Inventory Route - Urban Collector	-0.34900
It is not a determinant for this approach		Item 68-1 Deck Geometry - Basically intolerable requiring high priority of replacement	0.44600
R^2	31.58%	R^2	33.03%

Table 16. S-SC Bridge Superstructure Rating Models Comparison

Possible Determinants because of their Pearson's Correlation Coefficient	Coefficient	All Variables of the Dataset	Coefficient
Constant	6.032	Constant	6.399
Age	-0.0272	Age	-0.03355
Item 31 Design Load	0.1335	Item 31 Design Load	0.14470
Item 41-2 Structure Open, Posted, or Closed to Traffic – Open, no restriction	0.2480	It is not a determinant for this approach	
Item 68-4 Deck Geometry – Equal to present minimum criteria	-0.1380	It is not a determinant for this approach	
Item 68-2 Deck Geometry – Meets minimum tolerable limits to be left in place as is	-0.3870	It is not a determinant for this approach	
Item 68-7 Deck Geometry – Somewhat better than minimum adequacy to tolerate being left in place as is	-0.3550	It is not a determinant for this approach	
Item 26 Functional Classification of Inventory Route – Rural Local	-0.0830	It is not a determinant for this approach	
It is not a determinant for this approach		Item 21-0 Maintenance Responsibility – NA	0.91400
It is not a determinant for this approach		Item 71-4 Water Adequacy – Equal to present minimum criteria	-0.35100
It is not a determinant for this approach		Item 71-7 Water Adequacy – Somewhat better than minimum adequacy to tolerate being left in place as is	-0.49900
It is not a determinant for this approach		Item 71-6 Water Adequacy – N/A	0.28700
R^2	25.92%	R^2	30.98%

4.2.4. Model Validation

The results of the model validation are divided into two main stages: Excel validation, and multi-collinearity test (VIF). Also, the Excel validation was only conducted for the linear models with the highest R-squares because these were considered the best models in which the data would fit. It means one model for each group of superstructure material was validated using Excel. Thus, Figure 5 and Figure 6 summarize this process with the trendline and trendline equations of the "Predicted Superstructure Rating" of both groups of materials.

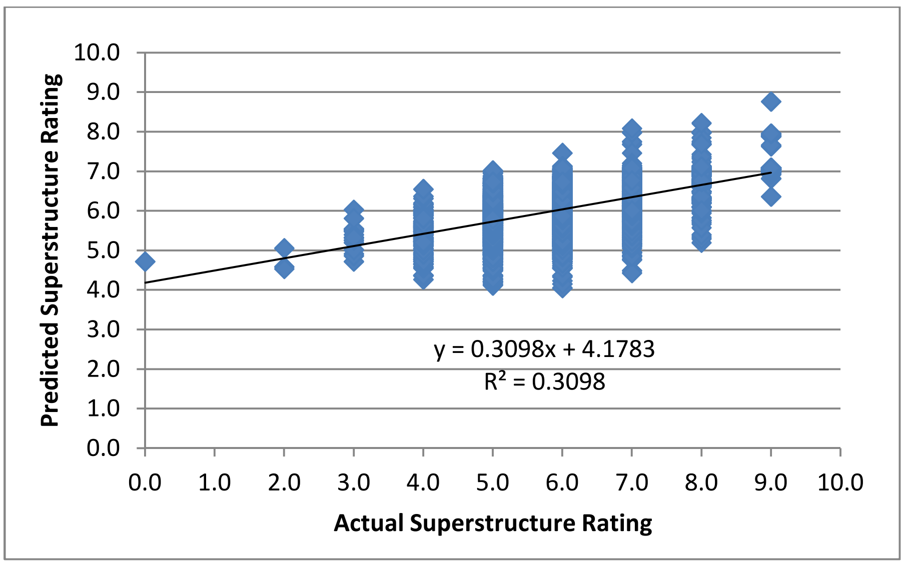

Figure 5. Model Validation for S-SC Bridge Superstructure Rating

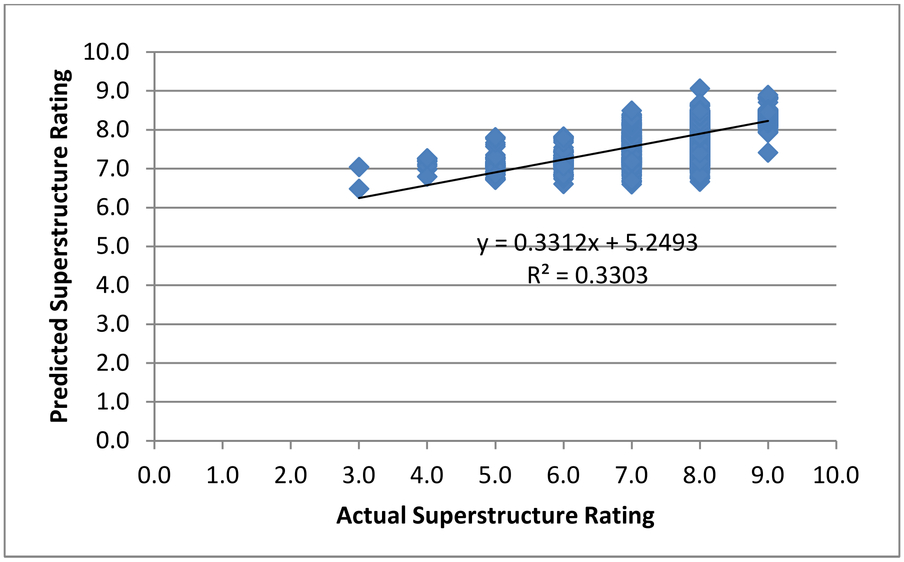

Figure 6. Model Validation for PC-PCC Bridge Superstructure Rating

According to the equations mentioned above, the accuracy of both models, which is the slope of the trendlines, is very similar to each other, with 31% for S-SC Superstructure Bridges and 33% for PC-PCC Superstructure Bridges. Moreover, their precision, which is the R-square value, is also very similar to each other, with 31% and 33%, for S-SC Superstructure Bridges and PC-PCC Superstructure Bridges respectively. Those results show that there is a lot of variation in the data used.

Furthermore, when the "Predicted Superstructure Rating" values obtained were analyzed for both models, it was found that the PC-PCC Superstructure Bridges' model values coincided with the "actual" rating of 71% of the time while the S-SC Superstructure Bridges' model values coincided just 39% of the time. Also, the percentages of overestimating the superstructure ratings were 11% and 31%, PC-PCC and S-SC respectively. In addition, the percentages of the superstructure ratings were 19% and 30%, for PC-PCC and S-SC respectively. This could mean that the PC-PCC Superstructure Bridges' model is more accurate than the S-SC Superstructure Bridges' model.

Nevertheless, it was found that "actual" low rating values (1, 2, 3, and 4) were considerably different. To clarify, when applying the S-SC Superstructure Bridges' model, 97% of the "actual" low rating values obtained were predicted at a value of 5 or more. However, for the PC-PCC Superstructure Bridges' model 100% of the "actual" low rating values were 6 or more. It means that both models should be improved in order to decrease their bias.

On the other hand, although the VIF verification was conducted for the four models, in Figure 7 and Figure 8 just show the Minitab 16 outcomes of the two models with the highest R-squares (equation 5 and equation 6). Because the VIF values of the two models are less than 5, one can conclude that there is not dependence among the parameters included in the models. If someone is interested in seeing the results of this verification for the other two models, those results are in Appendix 5 and Appendix 6; however, the VIF values obtained were less than 5 as well.

Regression Analysis: Item 59 versus Age, Item 31, ...

```
The regression equation is
Item 59 = 6.40 - 0.0335 Age + 0.145 Item 31 + 0.914 ITEM 21-0 - 0.351 ITEM 71-4
          - 0.499 ITEM 71-7 + 0.287 ITEM 71-6
```

Predictor	Coef	SE Coef	T	P	VIF
Constant	6.39940	0.03771	169.71	0.000	
Age	-0.0335493	0.0009922	-33.81	0.000	1.222
Item 31	0.144694	0.007180	20.15	0.000	1.049
ITEM 21-0	0.91398	0.08459	10.80	0.000	1.185
ITEM 71-4	-0.35101	0.03855	-9.10	0.000	1.080
ITEM 71-7	-0.49859	0.05708	-8.73	0.000	1.045
ITEM 71-6	0.28737	0.04709	6.10	0.000	1.450

```
S = 0.902886   R-Sq = 31.0%   R-Sq(adj) = 30.9%
```

Figure 7. VIF Verification for S-SC Superstructure Bridges

Regression Analysis: Item 59 versus Age, ITEM 21-7, ...

```
The regression equation is
Item 59 = 8.32 - 0.0306 Age - 0.267 ITEM 21-7 - 0.000066 Item 49
          + 0.0463 Item 31 - 0.349 Urban Collector + 0.446 ITEM 68-1
```

Predictor	Coef	SE Coef	T	P	VIF
Constant	8.31750	0.04396	189.22	0.000	
Age	-0.0305703	0.0009629	-31.75	0.000	1.167
ITEM 21-7	-0.26685	0.02421	-11.02	0.000	1.278
Item 49	-0.00006606	0.00000999	-6.61	0.000	1.041
Item 31	0.046281	0.007355	6.29	0.000	1.310
Urban Collector	-0.34922	0.06441	-5.42	0.000	1.013
ITEM 68-1	0.44618	0.05925	7.53	0.000	1.065

S = 0.578709   R-Sq = 33.0%   R-Sq(adj) = 32.9%

Figure 8. VIF Verification for PC-PCC Superstructure Bridge

CHAPTER V

CONCLUSIONS

According to the research parameters, there are a total of 160 deficient superstructure bridges for both groups of materials, which make up 2.26% of the total (7,077 bridges). Although S-SC bridges are 93.1% (149 bridges) of the deficient superstructure bridges, their average age is higher than PC-PCC, 43.6 years and 36.9 years, respectively. Additionally, both deficient S-SC and deficient PC-PCC bridges have the same average superstructure rating, which is 3.8. This means that although S-SC bridges are the majority of the deficient bridges, deficient S-SC bridges have the same performance in comparison to deficient PC-PCC bridges, which are younger on average.

Also, according to the analysis of deficient superstructure bridge relative frequency, the PC-PCC bridges deteriorate earlier than S-SC bridges. The reason is that more than 90% of the deficient superstructure PC-PCC bridges are between 28 and 41 years old while during the same period just 24.2% of the deficient superstructure S-SC bridges are. Also, if one wants to reach 90% of the deficient superstructure S-SC bridges, one must look at the last interval, 49 – 55 years old.

Moreover, the same conclusion was made by analyzing all the bridges in the dataset developed for this research (7,077 bridges). The superstructure rating average for PC-PCC bridges (7.9) is higher than for S-SC bridges (6.1). However, the Age average for S-SC bridges

(24.7 years) is higher than PC-PCC bridges (18.3 years). Moreover, there is a lack of information of which maintenance and reconstruction regulations are applied by the bridge owner or the agency responsible for the maintenance. Therefore, it is not possible to conclude which material is better or what conditions affect these two groups of materials.

On the other hand, although the NBI databases have a lot of information on every bridge in its inventory, the databases used in this research do not contain all the variables possible. Therefore, this could have been a reason why the obtained linear models had low adjusted coefficients of multiple correlation (R^2-adj), 30.97% for S-SC bridges, and 32.90% for PC-PCC bridges.

However, the variable Age, which represents the variable Year Built (Item 27), is the most significant variable for the superstructure deterioration for both groups of materials. As it was expected, Age and Superstructure Rating have an inverse relationship, which means the greater the age, the lower the Superstructure Rating. Nevertheless, the PC-PCC bridges are more sensitive to effects of Age than S-SC bridges. The Pearson's Correlation coefficients were -0.519 and -0.383 respectively. Also, this argument was confirmed by the coefficients for the multi-regression models even though to a lesser extent.

Although the Design Load (Item 31) was established as another sensitive variable for both groups of materials, it had more impact on the S-SC bridges. While it is the second highest correlation coefficient for S-SC bridges (0.266), it is the seventh highest correlation coefficient for PC-PCC bridges (0.145). Also, the Design Load (Item 31) coefficients of the multi-regression models show an important difference between them, 0.043 and 0.134, PC-PCC bridges and S-SC bridges, respectively. However, Design load and Superstructure Rating ratio vary proportionately. It means that if the bridge was designed with a high load Design Load, it had a better Superstructure Rating.

Moreover, according to the validation process made in Excel, the PC-PCC Superstructure Bridges' model is more precise than the S-SC Superstructure Bridges' model, 33% and 31% respectively. Those results can be considered as good because of the high variability that the data has. Also, because it is considered the first step for future studies, it is believed that applying this methodology the research group would obtain higher precision for new models.

CHAPTER VI

RECOMMENDATIONS

In order to continue developing the topic of interest in this research, it is important to gain access to the totality of the NBI databases. This could give to future researchers the opportunity to improve the multiple regression models found in this research and develop new models using different kinds of regression techniques such as logarithmic or exponential.

In addition to the NBI databases, it would be interesting to track a sample of both groups of bridges in order to develop a similar analysis to what was done in this research. This allows the comparison of the results of Pearson's Correlation and the multiple regression models obtained in both cases.

However, it is imperative to obtain information about both the maintenance and reconstruction protocols used for the bridges' owners, and the financial history of the bridges. All this information integrated with the NBI databases may help determine which group of superstructure material would have a better performance. Also, there would be the beginning of new analysis such as what conditions favor or deteriorate each group of superstructure bridges. Therefore, both Federal and Local governments and designers and builders would be interested in applying the results of those studies.

Furthermore, it is also recommended to combine all the above data with environmental conditions and natural hazards factors that are impacting the bridges. Some of the external factors to integrate could be temperature fluctuations, tornados, earthquakes, and floods. Moreover, this may give more information to the designers and bridge owners (Federal and Local governments) at the moment of making a decision about what material and design would be best for a bridge project under specific conditions and budget.

Finally, replicating the methodology developed in this study in addition to grouping the bridges according to different parameters, such as age, design load, bridge owner, and structure length, the research group is confident that those future superstructure rating models may be more precise and accurate. It means there would be more tools for better maintenance and management of bridges.

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APPENDICES

Appendix 1. S-SC Superstructure Bridges' Pearson's Correlation Coefficient

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
1	Rating	Item 60 Substructure Rating	Item 60 Substructure Rating - Numebric	0.706	No
2	Rating	Item 58 Deck Rating	Item 58 Deck Rating - Numeric	0.570	No
3	Rating	Sufficiency Rating	Sufficiency Rating	0.568	No
4	Rating	Status_Structura	Structurally deficient	-0.386	No
5	Num	Age	Age	-0.383	No
6	Rating	Status_Not defic	Not deficient	0.319	No
7	Num	Item 31 Design Load	Item 31 Design Load	0.266	No
8	QLT	ITEM 41-2 Structure Status	Open, no restriction	0.211	No
9	QLT	ITEM 68-4 Deck Geometry	Equal to present minimum criteria	0.203	No
10	QLT	ITEM 41-5 Structure Status	Posted for load (may include other restrictions such a temporary bridges which are load posted)	-0.188	No
11	QLT	ITEM 68-5 Deck Geometry	Meets minimum tolerable limits to be left in place as is	-0.150	No
12	QLT	ITEM 68-7 Deck Geometry	Somewhat better than minimum adequacy to tolerate being left in place as is	-0.134	No
13	QLT	Area_OTHER	Area_OTHER	0.130	No
14	QLT	ITEM 21-7 Maint Responsibility	State Highway Agency	-0.117	No
15	QLT	ITEM 22-7 Owner	State Highway Agency	-0.117	No
16	Num	Item 45 Spans Main Unit	Item 45 Spans Main Unit	-0.117	No
17	QLT	Item 26 Rural Local	Rural Local	0.116	No
18	QLT	ITEM 71-7 Water Adequacy	Somewhat better than minimum adequacy to tolerate being left in place as is	-0.115	No
19	QLT	ITEM 71-4 Water Adequacy	Equal to present minimum criteria	-0.113	No
20	QLT	ITEM 71-3 Water Adequacy	Equal to present desirable criteria	0.105	No
21	QLT	Area_OKC	Area_OKC	-0.102	No

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
22	QLT	ITEM 22-5 Owner	County Highway Agency	0.095	No
23	QLT	ITEM 21-5 Maint Responsibility	County Highway Agency	0.092	No
24	QLT	ITEM 71-5 Water Adequacy	Meets minimum tolerable limits to be left in place as is	-0.090	No
25	Num	Item 52 Deck Width O/O	Item 52 Deck Width O/O	0.087	No
26	QLT	ITEM 69-7 Underclear	Superior to present desirable criteria	0.085	No
27	QLT	ITEM 21-0 Maint Responsibility	NA	0.083	No
28	QLT	ITEM 22-0 Owner	NA	0.083	No
29	QLT	ITEM 71-0 Water Adequacy	Basically intolerable requiring high priority of corrrective action	-0.081	No
30	QLT	ITEM 41-0 Structure Status	Bridge closed to all traffic	-0.080	No
31	Num	Item 51 Bridge Roadway Curb-to-Curb	Item 51 Bridge Roadway Curb-to-Curb	0.076	No
32	Num	Item 49 Structure Length	Item 49 Structure Length	-0.073	No
33	QLT	ITEM 68-2 Deck Geometry	Better than present minimum criteria	0.068	No
34	QLT	ITEM 44A-5 Approach Material/Design	Steel	-0.065	No
35	QLT	ITEM 68-0 Deck Geometry	Basically intolerable requiring high priority of corrrective action	-0.064	No
36	QLT	ITEM 44A-3 Approach Material/Design	Prestressed Concrete	0.063	No
37	QLT	Item 26 Rural Minor Arte	Rural Minor Arterial	-0.062	No
38	QLT	ITEM 72-3 Approach Alignment	Equal to present desirable criteria	0.058	No
39	QLT	Item 26 Rural Major Coll	Rural Major Collector	-0.057	No
40	QLT	ITEM 22-3 Owner	City or Municipal Highway Agency	-0.056	No
41	QLT	Item 26 Al Pripl Arteria	Rural Principal Arterial - Other	-0.056	No
42	QLT	ITEM 42B-0 TOS under Bridge	Highway, with or without pedestrian	0.054	No
43	QLT	ITEM 71-2 Water Adequacy	Better than present minimum criteria	0.053	No
44	QLT	ITEM 21-3 Maint Responsibility	City or Municipal Highway Agency	-0.052	No
45	Num	Item 29: ADT	Item 29: ADT	-0.052	No
46	QLT	ITEM 41-6 Structure Status	Posted for other load-capacity restriction (speed, number of vehicles on bridge, etc.)	-0.052	No
47	QLT	ITEM 69-3 Underclear	Equal to present minimum criteria	0.051	No
48	QLT	ITEM 44A-2 Approach Material/Design	Other	0.048	No
49	QLT	ITEM 44B-3 Approach Design/Construction	Other	0.046	No
50	QLT	ITEM 69-1 Underclear	Better than present minimum criteria	0.046	No
51	QLT	ITEM 44B-1 Approach Design/Construction	Culvert	-0.045	No

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
52	QLT	ITEM 71-6 Water Adequacy	N/A	0.042	No
53	QLT	ITEM 21-1 Maint Responsibility	Air Force	0.041	No
54	QLT	ITEM 22-1 Owner	Air Force	0.041	No
55	QLT	ITEM 44B-5 Approach Design/Construction	Stringer/Multi-beam or girder	-0.041	No
56	QLT	ITEM 69-5 Underclear	N/A	-0.041	No
57	QLT	Area_TULSA	Area_TULSA	-0.040	No
58	QLT	ITEM 68-8 Deck Geometry	Superior to present desirable criteria	0.039	No
59	QLT	Item 26 An Pripl Arter F	Urban Principal Arterial - Other Freeways or Expressways	-0.037	No
60	QLT	ITEM 42B-1 TOS under Bridge	Highway-railroad	-0.035	No
61	QLT	ITEM 72-5 Approach Alignment	Meets minimum tolerable limits to be left in place as is	-0.035	No
62	QLT	ITEM 42B-5 TOS under Bridge	Pedestrian-bicycle	-0.033	No
63	QLT	ITEM 68-6 Deck Geometry	N/A	0.033	No
64	QLT	ITEM 42B-2 TOS under Bridge	Highway-waterway	-0.031	Yes
65	QLT	ITEM 72-4 Approach Alignment	Equal to present minimum criteria	-0.031	Yes
66	QLT	Area_NA	Area_NA	0.030	Yes
67	QLT	ITEM 42B-4 TOS under Bridge	Other	-0.030	Yes
68	QLT	ITEM 42B-8 TOS under Bridge	Relief for waterway	-0.030	Yes
69	QLT	ITEM 72-0 Approach Alignment	Basically intolerable requiring high priority of corrrective action	-0.030	Yes
70	QLT	ITEM 72-7 Approach Alignment	Superior to present desirable criteria	0.030	Yes
71	QLT	ITEM 44A-4 Approach Material/Design	Prestressed Concrete Continuous	0.029	Yes
72	QLT	ITEM 72-2 Approach Alignment	Better than present minimum criteria	-0.029	Yes
73	QLT	Item 26 Urban Collector	Urban Collector	-0.028	Yes
74	QLT	ITEM 69-4 Underclear	Meets minimum tolerable limits to be left in place as is	-0.028	Yes
75	QLT	ITEM 41-4 Structure Status	Open, temporary structure in place to carry legal loads while original structure is closed and awaiting replacement or rehabilitation	-0.027	Yes
76	QLT	ITEM 42B-3 TOS under Bridge	Highway-waterway-railroad	-0.027	Yes
77	QLT	ITEM 68-3 Deck Geometry	Equal to present desirable criteria	0.026	Yes
78	QLT	ITEM 68-1 Deck Geometry	Basically intolerable requiring high priority of replacement	-0.025	Yes
79	QLT	Item 26 Urban Other Prip	Urban Other Principal Arterial	-0.024	Yes
80	Num	Item 46 Spans Approach	Item 46 Spans Approach	-0.024	Yes

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
81	QLT	ITEM 69-6 Underclear	Somewhat better than minimum adequacy to tolerate being left in place as is	0.024	Yes
82	QLT	ITEM 21-6 Maint Responsibility	Other State Agencies	-0.022	Yes
83	QLT	ITEM 22-6 Owner	Other State Agencies	-0.022	Yes
84	QLT	ITEM 41-3 Structure Status	Open, posting recommended but not legally implemented (all signs not in place or not correctly implemented)	-0.022	Yes
85	QLT	ITEM 42B-7 TOS under Bridge	Railroad-waterway	-0.022	Yes
86	QLT	ITEM 44A-6 Approach Material/Design	Steel Continuous	-0.022	Yes
87	QLT	Item 26 Urban Minor Arte	Urban Minor Arterial	-0.021	Yes
88	QLT	ITEM 21-2 Maint Responsibility	Army	0.020	Yes
89	QLT	ITEM 22-2 Owner	Army	0.020	Yes
90	QLT	ITEM 42B-9 TOS under Bridge	Waterway	-0.020	Yes
91	QLT	ITEM 71-8 Water Adequacy	Superior to present desirable criteria	0.017	Yes
92	QLT	ITEM 44A-0 Approach Material/Design	Concrete	-0.016	Yes
93	QLT	ITEM 44B-2 Approach Design/Construction	Girder and floorbeam system	-0.016	Yes
94	QLT	ITEM 72-1 Approach Alignment	Basically intolerable requiring high priority of replacement	-0.016	Yes
95	QLT	ITEM 44A-7 Approach Material/Design	Wood or Timber	0.014	Yes
96	QLT	ITEM 44B-6 Approach Design/Construction	Tee beam	-0.012	Yes
97	QLT	ITEM 42B-6 TOS under Bridge	Railroad	0.011	Yes
98	QLT	ITEM 21-4 Maint Responsibility	Corps of Engineers (Civil)	-0.010	Yes
99	QLT	ITEM 22-4 Owner	Corps of Engineers (Civil)	-0.010	Yes
100	QLT	ITEM 72-6 Approach Alignment	Somewhat better than minimum adequacy to tolerate being left in place as is	-0.009	Yes
101	QLT	ITEM 69-2 Underclear	Equal to present desirable criteria	0.008	Yes
102	Num	Item 48 Length of Max Span	Item 48 Length of Max Span	0.007	Yes
103	QLT	Item 26 Al_Pripl Arteria	Rural Principal Arterial - Interstate	0.006	Yes
104	QLT	Item 26 Rural Minor Coll	Rural Minor Collector	0.006	Yes
105	QLT	ITEM 69-0 Underclear	Basically intolerable requiring high priority of replacement	-0.005	Yes
106	QLT	Item 26 Urban Local	Urban Local	-0.004	Yes
107	Rating	Status_Functiona	Functionally obsolete	0.004	Yes
108	QLT	Item 26 An Pripl Arteria	Urban Principal Arterial - Interstate	-0.003	Yes
109	QLT	ITEM 44B-4 Approach Design/Construction	Slab	-0.001	Yes

Appendix 2. PC-PCC Superstructure Bridges' Pearson's Correlations Coefficients

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
1	Rating	Item 60 Substructure Rating	Item 60 Substructure Rating - Numebric	0.615	No
2	Rating	Item 58 Deck Rating	Item 58 Deck Rating - Numeric	0.572	No
3	Num	Age	Age	-0.519	No
4	Rating	Sufficiency Rating	Sufficiency Rating	0.360	No
5	Rating	Status_Structura	Structurally deficient	-0.323	No
6	Rating	Status_Not defic	Not deficient	0.228	No
7	QLT	Item 26 Rural Local	Rural Local	0.206	No
8	QLT	ITEM 22-5 Owner	County Highway Agency	0.203	No
9	QLT	ITEM 21-5 Maint Responsibility	County Highway Agency	0.202	No
10	QLT	ITEM 21-7 Maint Responsibility	State Highway Agency	-0.190	No
11	QLT	ITEM 22-7 Owner	State Highway Agency	-0.190	No
12	Num	Item 45 Spans Main Unit	Item 45 Spans Main Unit	-0.181	No
13	Num	Item 49 Structure Length	Item 49 Structure Length	-0.159	No
14	Num	Item 31 Design Load	Item 31 Design Load	0.145	No
15	Num	Item 52 Deck Width O/O	Item 52 Deck Width O/O	-0.132	No
16	Num	Item 51 Bridge Roadway Curb-to-Curb	Item 51 Bridge Roadway Curb-to-Curb	-0.121	No
17	QLT	ITEM 68-4 Deck Geometry	Equal to present minimum criteria	0.110	No
18	QLT	Item 26 Al Pripl Arteria	Rural Principal Arterial - Other	-0.102	No
19	Num	Item 29: ADT	Item 29: ADT	-0.099	No
20	QLT	ITEM 71-3 Water Adequacy	Equal to present desirable criteria	0.092	No
21	QLT	Area_TULSA	Area_TULSA	-0.083	No
22	QLT	Item 26 Urban Collector	Urban Collector	-0.082	No
23	QLT	ITEM 41-1 Structure Status	New structure not yet open to traffic	0.081	No
24	QLT	ITEM 68-0 Deck Geometry	Basically intolerable requiring high priority of corrrective action	-0.080	No
25	QLT	ITEM 71-2 Water Adequacy	Better than present minimum criteria	-0.080	No
26	QLT	ITEM 41-5 Structure Status	Posted for load (may include other restrictions such a temporary bridges which are load posted)	-0.078	No
27	QLT	ITEM 69-0 Underclear	Basically intolerable requiring high priority of replacement	-0.078	No

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
28	QLT	ITEM 22-4 Owner	Corps of Engineers (Civil)	-0.070	No
29	QLT	ITEM 42B-9 TOS under Bridge	Waterway	0.070	No
30	QLT	ITEM 72-2 Approach Alignment	Better than present minimum criteria	-0.070	No
31	QLT	ITEM 21-4 Maint Responsibility	Corps of Engineers (Civil)	-0.068	No
32	QLT	ITEM 41-6 Structure Status	Posted for other load-capacity restriction (speed, number of vehicles on bridge, etc.)	-0.068	No
33	QLT	ITEM 69-6 Underclear	Somewhat better than minimum adequacy to tolerate being left in place as is	-0.068	No
34	QLT	ITEM 21-3 Maint Responsibility	City or Municipal Highway Agency	-0.063	No
35	QLT	Area_NA	Area_NA	0.062	No
36	QLT	ITEM 68-2 Deck Geometry	Better than present minimum criteria	-0.060	No
37	QLT	ITEM 68-5 Deck Geometry	Meets minimum tolerable limits to be left in place as is	-0.060	No
38	QLT	Item 26 Urban Other Prip	Urban Other Principal Arterial	-0.060	No
39	QLT	ITEM 22-3 Owner	City or Municipal Highway Agency	-0.059	No
40	QLT	ITEM 72-7 Approach Alignment	Superior to present desirable criteria	0.059	No
41	Num	Item 48 Length of Max Span	Item 48 Length of Max Span	0.055	No
42	QLT	ITEM 69-5 Underclear	N/A	0.055	No
43	QLT	Item 26 Rural Major Coll	Rural Major Collector	-0.054	No
44	QLT	ITEM 68-8 Deck Geometry	Superior to present desirable criteria	-0.053	No
45	QLT	ITEM 42B-3 TOS under Bridge	Highway-waterway-railroad	-0.052	No
46	QLT	ITEM 42B-8 TOS under Bridge	Relief for waterway	-0.052	No
47	QLT	Item 26 Urban Minor Arte	Urban Minor Arterial	-0.051	No
48	QLT	ITEM 71-8 Water Adequacy	Superior to present desirable criteria	0.050	No
49	QLT	Item 26 Urban Local	Urban Local	-0.049	No
50	QLT	ITEM 71-6 Water Adequacy	N/A	-0.048	No
51	QLT	ITEM 41-2 Structure Status	Open, no restriction	0.044	No
52	QLT	ITEM 42B-2 TOS under Bridge	Highway-waterway	-0.042	No

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
53	QLT	ITEM 71-7 Water Adequacy	Somewhat better than minimum adequacy to tolerate being left in place as is	-0.039	No
54	Rating	Status_Functiona	Functionally obsolete	-0.039	No
55	QLT	ITEM 68-3 Deck Geometry	Equal to present desirable criteria	0.035	No
56	QLT	Item 26 Al Pripl Arteria	Al Pripl Arteria	0.035	Yes
57	QLT	ITEM 42B-1 TOS under Bridge	Highway-railroad	-0.034	Yes
58	QLT	Item 26 An Pripl Arteria	Urban Principal Arterial - Interstate	0.029	Yes
59	QLT	ITEM 71-0 Water Adequacy	Basically intolerable requiring high priority of corrrective action	0.029	Yes
60	QLT	ITEM 72-6 Approach Alignment	Somewhat better than minimum adequacy to tolerate being left in place as is	0.028	Yes
61	QLT	ITEM 21-0 Maint Responsibility	NA	0.027	Yes
62	QLT	ITEM 22-0 Owner	NA	0.027	Yes
63	QLT	ITEM 42B-0 TOS under Bridge	Highway, with or without pedestrian	-0.026	Yes
64	QLT	ITEM 71-4 Water Adequacy	Equal to present minimum criteria	-0.025	Yes
65	QLT	ITEM 44A-3 Approach Material/Design	Prestressed Concrete	0.022	Yes
66	QLT	ITEM 21-2 Maint Responsibility	Army	-0.021	Yes
67	QLT	ITEM 22-2 Owner	Army	-0.021	Yes
68	QLT	ITEM 41-0 Structure Status	Bridge closed to all traffic	-0.021	Yes
69	QLT	ITEM 71-1 Water Adequacy	Basically intolerable requiring high priority of replacement	-0.021	Yes
70	QLT	ITEM 44A-7 Approach Material/Design	Wood or Timber	0.020	Yes
71	QLT	ITEM 72-3 Approach Alignment	Equal to present desirable criteria	0.020	Yes
72	QLT	ITEM 44A-0 Approach Material/Design	Concrete	-0.015	Yes
73	QLT	ITEM 44A-6 Approach Material/Design	Steel Continuous	-0.013	Yes
74	QLT	ITEM 44B-5 Approach Design/Construction	Stringer/Multi-beam or girder	0.013	Yes
75	QLT	ITEM 71-5 Water Adequacy	Meets minimum tolerable limits to be left in place as is	-0.013	Yes
76	QLT	ITEM 72-0 Approach Alignment	Basically intolerable requiring high priority of corrrective action	-0.013	Yes

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
77	QLT	Item 26 An Pripl Arter F	Urban Principal Arterial - Other Freeways or Expressways	-0.012	Yes
78	QLT	ITEM 42B-6 TOS under Bridge	Railroad	-0.011	Yes
79	QLT	ITEM 42B-7 TOS under Bridge	Railroad-waterway	-0.011	Yes
80	QLT	Area_OKC	Area_OKC	0.010	Yes
81	QLT	ITEM 44A-2 Approach Material/Design	Other	-0.010	Yes
82	QLT	ITEM 44B-3 Approach Design/Construction	Other	-0.010	Yes
83	QLT	ITEM 69-3 Underclear	Equal to present minimum criteria	-0.010	Yes
84	QLT	ITEM 69-7 Underclear	Superior to present desirable criteria	0.010	Yes
85	QLT	ITEM 72-4 Approach Alignment	Equal to present minimum criteria	0.010	Yes
86	QLT	Area_OTHER	Area_OTHER	-0.009	Yes
87	QLT	Item 26 Rural Minor Arte	Rural Minor Arterial	-0.009	Yes
88	QLT	ITEM 69-1 Underclear	Better than present minimum criteria	-0.008	Yes
89	QLT	ITEM 42B-4 TOS under Bridge	Other	0.007	Yes
90	QLT	ITEM 44B-4 Approach Design/Construction	Slab	-0.007	Yes
91	QLT	ITEM 68-1 Deck Geometry	Basically intolerable requiring high priority of replacement	0.006	Yes
92	QLT	ITEM 21-6 Maint Responsibility	Other State Agencies	-0.005	Yes
93	QLT	ITEM 22-6 Owner	Other State Agencies	-0.005	Yes
94	QLT	ITEM 44B-6 Approach Design/Construction	Tee beam	0.005	Yes
95	QLT	ITEM 72-5 Approach Alignment	Meets minimum tolerable limits to be left in place as is	0.005	Yes
96	QLT	ITEM 21-8 Maint Responsibility	State Park, Forest, or Reservation Agency	0.004	Yes
97	QLT	ITEM 44A-1 Approach Material/Design	Concrete Continuous	0.004	Yes
98	QLT	ITEM 44B-0 Approach Design/Construction	Box Beam or girders - Single or Spread	0.004	Yes
99	Num	Item 46 Spans Approach	Item 46 Spans Approach	0.004	Yes
100	QLT	ITEM 68-7 Deck Geometry	Somewhat better than minimum adequacy to tolerate being left in place as is	-0.004	Yes
101	QLT	Item 26 Rural Minor Coll	Rural Minor Collector	0.004	Yes

	Kind	Variable	Description	Pearson's Coefficient	p-value > 0.05
102	QLT	ITEM 68-6 Deck Geometry	N/A	0.003	Yes
103	QLT	ITEM 69-2 Underclear	Equal to present desirable criteria	-0.002	Yes
104	QLT	ITEM 44A-5 Approach Material/Design	Steel	0.000	Yes
105	QLT	ITEM 69-4 Underclear	Meets minimum tolerable limits to be left in place as is	0.000	Yes

Appendix 3. Minitab Outcome of Multiple Regression for S-SC Superstructure Bridges

Stepwise Regression: Item 59 versus Age, Item 31, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.05

Response is Item 59 on 10 predictors, with N = 3881

Step	1	2	3	4	5	6
Constant	6.692	6.185	6.257	6.035	6.072	6.219
Age	-0.02579	-0.02721	-0.02688	-0.02615	-0.02489	-0.02601
T-Value	-25.86	-28.71	-28.49	-27.62	-25.70	-25.36
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
Item 31		0.1550	0.1512	0.1382	0.1363	0.1356
T-Value		20.94	20.50	18.08	17.89	17.81
P-Value		0.000	0.000	0.000	0.000	0.000
ITEM 68-7			-0.223	-0.208	-0.259	-0.371
T-Value			-6.74	-6.30	-7.59	-7.70
P-Value			0.000	0.000	0.000	0.000
ITEM 41-2				0.284	0.268	0.264
T-Value				6.14	5.81	5.73
P-Value				0.000	0.000	0.000
ITEM 68-5					-0.289	-0.392
T-Value					-5.73	-6.61
P-Value					0.000	0.000
ITEM 68-4						-0.156
T-Value						-3.29
P-Value						0.001
S	1.00	0.951	0.945	0.941	0.937	0.936
R-Sq	14.70	23.37	24.26	24.99	25.62	25.82
R-Sq(adj)	14.68	23.33	24.20	24.91	25.52	25.71
Mallows Cp	586.1	134.7	90.3	54.1	23.1	14.3

Step	7
Constant	6.302
Age	-0.0272
T-Value	-23.44
P-Value	0.000
Item 31	0.1335
T-Value	17.42
P-Value	0.000
ITEM 68-7	-0.355
T-Value	-7.28
P-Value	0.000
ITEM 41-2	0.248
T-Value	5.32
P-Value	0.000
ITEM 68-5	-0.387
T-Value	-6.52
P-Value	0.000
ITEM 68-4	-0.138
T-Value	-2.87
P-Value	0.004
Rural Local	-0.083
T-Value	-2.22
P-Value	0.027
S	0.936
R-Sq	25.92
R-Sq(adj)	25.78
Mallows Cp	11.3

Appendix 4. Minitab Outcome of Multiple Regression for PC-PCC Superstructure Bridges

Stepwise Regression: Item 59 versus Age, Item 45, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.05

Response is Item 59 on 10 predictors, with N = 3196

Step	1	2	3	4	5	6
Constant	8.440	8.512	8.546	8.309	8.392	8.483
Age	-0.03193	-0.03134	-0.03103	-0.02926	-0.02999	-0.03000
T-Value	-34.33	-34.24	-34.09	-30.75	-30.46	-30.50
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ITEM 21-7		-0.236	-0.208	-0.270	-0.325	-0.329
T-Value		-10.73	-9.37	-11.09	-10.42	-10.53
P-Value		0.000	0.000	0.000	0.000	0.000
Item 49			-0.00007	-0.00007	-0.00007	-0.00007
T-Value			-6.82	-6.92	-7.29	-7.14
P-Value			0.000	0.000	0.000	0.000
Item 31				0.0450	0.0434	0.0447
T-Value				6.05	5.83	5.98
P-Value				0.000	0.000	0.000
ITEM 21-5					-0.085	-0.120
T-Value					-2.84	-3.57
P-Value					0.004	0.000
Item 52						-0.00069
T-Value						-2.27
P-Value						0.023
S	0.604	0.593	0.589	0.586	0.585	0.585
R-Sq	26.95	29.49	30.50	31.29	31.47	31.58
R-Sq(adj)	26.93	29.45	30.44	31.21	31.36	31.45
Mallows Cp	215.4	98.8	53.7	19.0	12.9	9.7

Appendix 5. VIF Verification for S-SC Superstructure Bridges

Regression Analysis: Item 59 versus Age, Item 31, ...

```
The regression equation is
Item 59 = 6.06 - 0.0269 Age + 0.135 Item 31 - 0.129 ITEM 68-7 + 0.259 ITEM 41-2
          + 0.264 ITEM 68-2 + 0.0896 ITEM 68-4 - 0.0912 Rural  Local
```

Predictor	Coef	SE Coef	T	P	VIF
Constant	6.06205	0.07577	80.00	0.000	
Age	-0.026947	0.001173	-22.98	0.000	1.578
Item 31	0.134510	0.007696	17.48	0.000	1.115
ITEM 68-7	-0.12856	0.04455	-2.89	0.004	1.848
ITEM 41-2	0.25896	0.04674	5.54	0.000	1.134
ITEM 68-2	0.26398	0.07239	3.65	0.000	1.223
ITEM 68-4	0.08956	0.04471	2.00	0.045	2.157
Rural Local	-0.09122	0.03735	-2.44	0.015	1.519

```
S = 0.939026   R-Sq = 25.4%   R-Sq(adj) = 25.2%
```

Appendix 6. VIF Verification for PC-PCC Superstructure Bridges

Regression Analysis: Item 59 versus Age, Item 49, ...

```
The regression equation is
Item 59 = 8.50 - 0.0301 Age - 0.000072 Item 49 + 0.0444 Item 31
          - 0.000748 Item 52 + 0.0170 Rural  Local - 0.108 ITEM 21-5
          - 0.324 ITEM 21-7 - 0.0472 ITEM 68-4
```

Predictor	Coef	SE Coef	T	P	VIF
Constant	8.50048	0.06857	123.97	0.000	
Age	-0.030121	0.001006	-29.94	0.000	1.248
Item 49	-0.00007240	0.00001024	-7.07	0.000	1.071
Item 31	0.044376	0.007480	5.93	0.000	1.327
Item 52	-0.0007480	0.0003076	-2.43	0.015	1.562
Rural Local	0.01705	0.02884	0.59	0.555	1.652
ITEM 21-5	-0.10803	0.03626	-2.98	0.003	3.053
ITEM 21-7	-0.32387	0.03141	-10.31	0.000	2.106
ITEM 68-4	-0.04721	0.02389	-1.98	0.048	1.311

```
S = 0.584770   R-Sq = 31.7%   R-Sq(adj) = 31.5%
```

Appendix 7. Minitab Outcome of Multiple Regession - All Variables for S-SC Bridge Superstructure Rating

Stepwise Regression: Item 59 versus Age, Item 29: ADT, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.05

Response is Item 59 on 91 predictors, with N = 3881

Step	1	2	3	4	5	6
Constant	6.692	6.185	6.206	6.304	6.373	6.399
Age	-0.02579	-0.02721	-0.03051	-0.03119	-0.03146	-0.03355
T-Value	-25.86	-28.71	-32.03	-32.97	-33.63	-33.81
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
Item 31		0.1550	0.1600	0.1556	0.1527	0.1447
T-Value		20.94	22.16	21.71	21.54	20.15
P-Value		0.000	0.000	0.000	0.000	0.000
ITEM 21-0			1.173	1.119	1.072	0.914
T-Value			14.25	13.70	13.25	10.80
P-Value			0.000	0.000	0.000	0.000
ITEM 71-4				-0.341	-0.394	-0.351
T-Value				-8.95	-10.35	-9.10
P-Value				0.000	0.000	0.000
ITEM 71-7					-0.546	-0.499
T-Value					-9.61	-8.73
P-Value					0.000	0.000
ITEM 71-6						0.287
T-Value						6.10
P-Value						0.000
S	1.00	0.951	0.927	0.918	0.907	0.903
R-Sq	14.70	23.37	27.18	28.66	30.32	30.98
R-Sq(adj)	14.68	23.33	27.13	28.58	30.23	30.87

Step	7	8	9	10
Constant	6.417	6.413	6.311	6.313
Age	-0.03334	-0.03340	-0.03186	-0.03164
T-Value	-33.71	-33.87	-30.86	-30.70
P-Value	0.000	0.000	0.000	0.000
Item 31	0.1429	0.1450	0.1433	0.1426
T-Value	19.95	20.27	20.08	20.03
P-Value	0.000	0.000	0.000	0.000
ITEM 21-0	0.907	0.897	0.914	0.911
T-Value	10.76	10.68	10.90	10.89
P-Value	0.000	0.000	0.000	0.000
ITEM 71-4	-0.367	-0.368	-0.365	-0.370
T-Value	-9.54	-9.58	-9.54	-9.68
P-Value	0.000	0.000	0.000	0.000

ITEM 71-7	-0.515	-0.509	-0.498	-0.502
T-Value	-9.05	-8.96	-8.78	-8.88
P-Value	0.000	0.000	0.000	0.000
ITEM 71-6	0.270	0.326	0.335	0.328
T-Value	5.75	6.77	6.97	6.85
P-Value	0.000	0.000	0.000	0.000
ITEM 71-5	-0.68	-0.68	-0.66	-0.66
T-Value	-5.44	-5.46	-5.29	-5.35
P-Value	0.000	0.000	0.000	0.000
An Pripl Arter Freeways Express		-0.53	-0.52	-0.52
T-Value		-5.04	-4.94	-4.95
P-Value		0.000	0.000	0.000
ITEM 68-4			0.152	0.154
T-Value			4.90	4.95
P-Value			0.000	0.000
ITEM 71-0				-1.83
T-Value				-4.59
P-Value				0.000
ITEM 21-1				
T-Value				
P-Value				
ITEM 71-2				
T-Value				
P-Value				
S	0.900	0.897	0.894	0.892
R-Sq	31.50	31.95	32.37	32.73
R-Sq(adj)	31.38	31.81	32.21	32.56

Step	11	12
Constant	6.317	6.401
Age	-0.03187	-0.03214
T-Value	-30.94	-31.18
P-Value	0.000	0.000
Item 31	0.1423	0.1414
T-Value	20.02	19.92
P-Value	0.000	0.000
ITEM 21-0	0.912	0.902
T-Value	10.93	10.83
P-Value	0.000	0.000
ITEM 71-4	-0.368	-0.442
T-Value	-9.64	-10.32
P-Value	0.000	0.000
ITEM 71-7	-0.500	-0.573
T-Value	-8.86	-9.62
P-Value	0.000	0.000
ITEM 71-6	0.334	0.268
T-Value	6.98	5.27

P-Value	0.000	0.000
ITEM 71-5	-0.66	-0.74
T-Value	-5.34	-5.87
P-Value	0.000	0.000
An Pripl Arter Freeways Express	-0.52	-0.53
T-Value	-4.96	-5.04
P-Value	0.000	0.000
ITEM 68-4	0.152	0.149
T-Value	4.89	4.80
P-Value	0.000	0.000
ITEM 71-0	-1.83	-1.90
T-Value	-4.58	-4.76
P-Value	0.000	0.000
ITEM 21-1	2.66	2.59
T-Value	4.21	4.12
P-Value	0.000	0.000
ITEM 71-2		-0.145
T-Value		-3.79
P-Value		0.000
S	0.890	0.888
R-Sq	33.04	33.29
R-Sq(adj)	32.85	33.08

Step	13	14	15	16	17
Constant	6.399	6.330	6.304	6.302	6.287
Age	-0.0319	-0.0320	-0.0313	-0.0313	-0.0310
T-Value	-30.97	-31.05	-29.71	-29.70	-29.40
P-Value	0.000	0.000	0.000	0.000	0.000
Item 31	0.1401	0.1372	0.1399	0.1402	0.1394
T-Value	19.74	19.19	19.44	19.49	19.38
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-0	0.903	0.906	0.899	0.876	0.872
T-Value	10.84	10.90	10.82	10.50	10.46
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-4	-0.441	-0.431	-0.435	-0.435	-0.428
T-Value	-10.32	-10.08	-10.17	-10.17	-10.02
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-7	-0.573	-0.561	-0.567	-0.567	-0.560
T-Value	-9.63	-9.42	-9.53	-9.53	-9.41
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-6	0.247	0.222	0.264	0.291	0.288
T-Value	4.83	4.31	4.95	5.37	5.31
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-5	-0.74	-0.72	-0.73	-0.73	-0.72
T-Value	-5.88	-5.78	-5.85	-5.85	-5.78
P-Value	0.000	0.000	0.000	0.000	0.000

An Pripl Arter Freeways Express	-0.53	-0.54	-0.42	-0.43	-0.42
T-Value	-5.04	-5.16	-3.81	-3.89	-3.76
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-4	0.152	0.155	0.154	0.156	0.174
T-Value	4.92	5.01	4.99	5.06	5.51
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-0	-1.90	-1.88	-1.90	-1.90	-1.89
T-Value	-4.78	-4.73	-4.78	-4.78	-4.77
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-1	2.59	2.56	2.61	2.61	2.62
T-Value	4.12	4.08	4.16	4.16	4.18
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-2	-0.144	-0.138	-0.141	-0.141	-0.137
T-Value	-3.77	-3.60	-3.70	-3.70	-3.58
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 69-7	0.71	0.69	0.75	0.75	0.71
T-Value	3.44	3.36	3.64	3.61	3.43
P-Value	0.001	0.001	0.000	0.000	0.001
Item 52		0.00087	0.00104	0.00103	0.00095
T-Value		3.24	3.81	3.79	3.46
P-Value		0.001	0.000	0.000	0.001
Item 29: ADT			-0.00001	-0.00001	-0.00001
T-Value			-3.06	-2.90	-2.96
P-Value			0.002	0.004	0.003
ITEM 42B-1				-0.40	-0.39
T-Value				-2.78	-2.71
P-Value				0.005	0.007
ITEM 68-2					0.171
T-Value					2.65
P-Value					0.008
Al Pripl Arterial - Other					
T-Value					
P-Value					
S	0.887	0.886	0.885	0.884	0.884
R-Sq	33.49	33.67	33.83	33.97	34.08
R-Sq(adj)	33.27	33.43	33.58	33.69	33.79

Step	18
Constant	6.278
Age	-0.0306
T-Value	-28.83
P-Value	0.000
Item 31	0.1408
T-Value	19.55
P-Value	0.000
ITEM 21-0	0.863
T-Value	10.36
P-Value	0.000

ITEM 71-4	-0.429
T-Value	-10.06
P-Value	0.000
ITEM 71-7	-0.566
T-Value	-9.52
P-Value	0.000
ITEM 71-6	0.284
T-Value	5.25
P-Value	0.000
ITEM 71-5	-0.73
T-Value	-5.84
P-Value	0.000
An Pripl Arter Freeways Express	-0.44
T-Value	-3.92
P-Value	0.000
ITEM 68-4	0.175
T-Value	5.54
P-Value	0.000
ITEM 71-0	-1.90
T-Value	-4.80
P-Value	0.000
ITEM 21-1	2.59
T-Value	4.14
P-Value	0.000
ITEM 71-2	-0.140
T-Value	-3.66
P-Value	0.000
ITEM 69-7	0.74
T-Value	3.55
P-Value	0.000
Item 52	0.00097
T-Value	3.53
P-Value	0.000
Item 29: ADT	-0.00001
T-Value	-2.89
P-Value	0.004
ITEM 42B-1	-0.38
T-Value	-2.68
P-Value	0.007
ITEM 68-2	0.195
T-Value	3.00
P-Value	0.003
Al Pripl Arterial - Other	-0.275
T-Value	-2.88
P-Value	0.004
S	0.883

R-Sq	34.23
R-Sq(adj)	33.92

Step	19	20	21	22
Constant	6.225	6.225	6.224	6.219
Age	-0.0310	-0.0310	-0.0311	-0.0310
T-Value	-28.95	-28.93	-29.00	-28.93
P-Value	0.000	0.000	0.000	0.000
Item 31	0.1387	0.1391	0.1394	0.1397
T-Value	19.17	19.23	19.28	19.33
P-Value	0.000	0.000	0.000	0.000
ITEM 21-0	0.888	0.888	0.867	0.847
T-Value	10.60	10.60	10.29	10.02
P-Value	0.000	0.000	0.000	0.000
ITEM 71-4	-0.420	-0.420	-0.420	-0.420
T-Value	-9.80	-9.81	-9.81	-9.82
P-Value	0.000	0.000	0.000	0.000
ITEM 71-7	-0.553	-0.553	-0.551	-0.553
T-Value	-9.27	-9.28	-9.25	-9.28
P-Value	0.000	0.000	0.000	0.000
ITEM 71-6	0.261	0.261	0.277	0.300
T-Value	4.77	4.77	5.03	5.37
P-Value	0.000	0.000	0.000	0.000
ITEM 71-5	-0.71	-0.67	-0.67	-0.67
T-Value	-5.66	-5.30	-5.30	-5.33
P-Value	0.000	0.000	0.000	0.000
An Pripl Arter Freeways Express	-0.45	-0.45	-0.49	-0.51
T-Value	-4.07	-4.07	-4.34	-4.53
P-Value	0.000	0.000	0.000	0.000
ITEM 68-4	0.181	0.181	0.176	0.171
T-Value	5.74	5.72	5.57	5.42
P-Value	0.000	0.000	0.000	0.000
ITEM 71-0	-1.87	-1.87	-1.87	-1.87
T-Value	-4.71	-4.72	-4.71	-4.72
P-Value	0.000	0.000	0.000	0.000
ITEM 21-1	2.62	2.61	2.73	2.74
T-Value	4.18	4.18	4.36	4.37
P-Value	0.000	0.000	0.000	0.000
ITEM 71-2	-0.128	-0.128	-0.128	-0.129
T-Value	-3.35	-3.35	-3.35	-3.36
P-Value	0.001	0.001	0.001	0.001
ITEM 69-7	0.72	0.72	0.68	0.68
T-Value	3.45	3.45	3.29	3.26
P-Value	0.001	0.001	0.001	0.001
Item 52	0.00090	0.00089	0.00091	0.00098
T-Value	3.25	3.24	3.30	3.56
P-Value	0.001	0.001	0.001	0.000

Item 29: ADT	-0.00001	-0.00001	-0.00001	-0.00001
T-Value	-3.09	-3.10	-2.79	-2.91
P-Value	0.002	0.002	0.005	0.004
ITEM 42B-1	-0.38	-0.38	-0.36	-0.36
T-Value	-2.63	-2.63	-2.49	-2.48
P-Value	0.009	0.009	0.013	0.013
ITEM 68-2	0.186	0.186	0.200	0.194
T-Value	2.86	2.86	3.07	2.97
P-Value	0.004	0.004	0.002	0.003
Al Pripl Arterial - Other	-0.306	-0.307	-0.325	-0.340
T-Value	-3.18	-3.19	-3.37	-3.52
P-Value	0.001	0.001	0.001	0.000
Item 48	0.00048	0.00047	0.00049	0.00051
T-Value	2.71	2.68	2.78	2.88
P-Value	0.007	0.007	0.005	0.004
ITEM 44B-1		-2.12	-2.12	-2.12
T-Value		-2.38	-2.38	-2.38
P-Value		0.017	0.017	0.017
Urban Other Pripl Arterial			-0.26	-0.28
T-Value			-2.36	-2.57
P-Value			0.019	0.010
Urban Collector				-0.25
T-Value				-2.46
P-Value				0.014
ITEM 68-0				
T-Value				
P-Value				
ITEM 21-2				
T-Value				
P-Value				
S	0.882	0.882	0.881	0.880
R-Sq	34.35	34.45	34.54	34.64
R-Sq(adj)	34.03	34.11	34.18	34.27

Step	23	24
Constant	6.212	6.214
Age	-0.0311	-0.0313
T-Value	-29.04	-29.14
P-Value	0.000	0.000
Item 31	0.1398	0.1395
T-Value	19.35	19.32
P-Value	0.000	0.000
ITEM 21-0	0.858	0.860
T-Value	10.14	10.17
P-Value	0.000	0.000
ITEM 71-4	-0.422	-0.420
T-Value	-9.88	-9.82

P-Value	0.000	0.000
ITEM 71-7	-0.554	-0.552
T-Value	-9.32	-9.27
P-Value	0.000	0.000
ITEM 71-6	0.300	0.303
T-Value	5.37	5.43
P-Value	0.000	0.000
ITEM 71-5	-0.68	-0.68
T-Value	-5.42	-5.40
P-Value	0.000	0.000
An Pripl Arter Freeways Express	-0.50	-0.51
T-Value	-4.48	-4.49
P-Value	0.000	0.000
ITEM 68-4	0.182	0.181
T-Value	5.69	5.67
P-Value	0.000	0.000
ITEM 71-0	-1.86	-1.86
T-Value	-4.71	-4.70
P-Value	0.000	0.000
ITEM 21-1	2.75	2.76
T-Value	4.40	4.41
P-Value	0.000	0.000
ITEM 71-2	-0.130	-0.128
T-Value	-3.41	-3.34
P-Value	0.001	0.001
ITEM 69-7	0.68	0.67
T-Value	3.26	3.25
P-Value	0.001	0.001
Item 52	0.00100	0.00100
T-Value	3.63	3.62
P-Value	0.000	0.000
Item 29: ADT	-0.00001	-0.00001
T-Value	-2.99	-2.96
P-Value	0.003	0.003
ITEM 42B-1	-0.36	-0.36
T-Value	-2.54	-2.54
P-Value	0.011	0.011
ITEM 68-2	0.207	0.207
T-Value	3.16	3.17
P-Value	0.002	0.002
Al Pripl Arterial - Other	-0.360	-0.357
T-Value	-3.71	-3.69
P-Value	0.000	0.000
Item 48	0.00050	0.00050
T-Value	2.83	2.86
P-Value	0.005	0.004

ITEM 44B-1	-2.28	-2.28
T-Value	-2.56	-2.56
P-Value	0.011	0.011
Urban Other Pripl Arterial	-0.29	-0.29
T-Value	-2.61	-2.61
P-Value	0.009	0.009
Urban Collector	-0.26	-0.26
T-Value	-2.62	-2.61
P-Value	0.009	0.009
ITEM 68-0	0.187	0.188
T-Value	2.35	2.36
P-Value	0.019	0.018
ITEM 21-2		1.46
T-Value		2.34
P-Value		0.019
S	0.880	0.879
R-Sq	34.74	34.83
R-Sq(adj)	34.35	34.42

Step	25	26	27	28
Constant	6.134	6.128	6.127	6.130
Age	-0.0308	-0.0308	-0.0308	-0.0307
T-Value	-28.20	-28.23	-28.19	-28.13
P-Value	0.000	0.000	0.000	0.000
Item 31	0.1356	0.1355	0.1355	0.1353
T-Value	18.29	18.28	18.29	18.27
P-Value	0.000	0.000	0.000	0.000
ITEM 21-0	0.845	0.825	0.817	0.830
T-Value	9.98	9.69	9.60	9.72
P-Value	0.000	0.000	0.000	0.000
ITEM 71-4	-0.419	-0.417	-0.418	-0.420
T-Value	-9.82	-9.78	-9.80	-9.84
P-Value	0.000	0.000	0.000	0.000
ITEM 71-7	-0.541	-0.539	-0.539	-0.541
T-Value	-9.06	-9.04	-9.05	-9.08
P-Value	0.000	0.000	0.000	0.000
ITEM 71-6	0.293	0.318	0.327	0.372
T-Value	5.24	5.59	5.73	6.15
P-Value	0.000	0.000	0.000	0.000
ITEM 71-5	-0.66	-0.66	-0.66	-0.66
T-Value	-5.26	-5.25	-5.26	-5.28
P-Value	0.000	0.000	0.000	0.000
An Pripl Arter Freeways Express	-0.50	-0.52	-0.52	-0.52
T-Value	-4.46	-4.61	-4.64	-4.64
P-Value	0.000	0.000	0.000	0.000
ITEM 68-4	0.176	0.171	0.173	0.170
T-Value	5.51	5.34	5.40	5.31

P-Value	0.000	0.000	0.000	0.000
ITEM 71-0	-1.78	-1.78	-1.78	-1.78
T-Value	-4.50	-4.49	-4.50	-4.50
P-Value	0.000	0.000	0.000	0.000
ITEM 21-1	2.74	2.75	2.75	2.75
T-Value	4.38	4.40	4.41	4.41
P-Value	0.000	0.000	0.000	0.000
ITEM 71-2	-0.121	-0.118	-0.118	-0.119
T-Value	-3.16	-3.08	-3.08	-3.11
P-Value	0.002	0.002	0.002	0.002
ITEM 69-7	0.69	0.68	0.68	0.63
T-Value	3.32	3.29	3.27	3.05
P-Value	0.001	0.001	0.001	0.002
Item 52	0.00099	0.00106	0.00106	0.00106
T-Value	3.57	3.80	3.82	3.80
P-Value	0.000	0.000	0.000	0.000
Item 29: ADT	-0.00001	-0.00001	-0.00001	-0.00001
T-Value	-3.06	-3.22	-3.25	-3.24
P-Value	0.002	0.001	0.001	0.001
ITEM 42B-1	-0.36	-0.37	-0.38	-0.38
T-Value	-2.54	-2.60	-2.65	-2.63
P-Value	0.011	0.009	0.008	0.009
ITEM 68-2	0.204	0.201	0.202	0.194
T-Value	3.12	3.07	3.09	2.97
P-Value	0.002	0.002	0.002	0.003
Al Pripl Arterial - Other	-0.367	-0.383	-0.369	-0.374
T-Value	-3.79	-3.95	-3.79	-3.85
P-Value	0.000	0.000	0.000	0.000
Item 48	0.00049	0.00051	0.00050	0.00048
T-Value	2.76	2.91	2.82	2.71
P-Value	0.006	0.004	0.005	0.007
ITEM 44B-1	-2.22	-2.24	-2.24	-2.24
T-Value	-2.49	-2.51	-2.52	-2.52
P-Value	0.013	0.012	0.012	0.012
Urban Other Pripl Arterial	-0.29	-0.31	-0.31	-0.32
T-Value	-2.62	-2.82	-2.85	-2.89
P-Value	0.009	0.005	0.004	0.004
Urban Collector	-0.26	-0.28	-0.28	-0.26
T-Value	-2.60	-2.84	-2.80	-2.59
P-Value	0.009	0.005	0.005	0.010
ITEM 68-0	0.189	0.211	0.214	0.217
T-Value	2.39	2.64	2.69	2.72
P-Value	0.017	0.008	0.007	0.007
ITEM 21-2	1.44	1.44	1.43	1.43
T-Value	2.31	2.31	2.30	2.30
P-Value	0.021	0.021	0.021	0.021

ITEM 41-2	0.101	0.103	0.104	0.107
T-Value	2.26	2.30	2.32	2.38
P-Value	0.024	0.021	0.020	0.017
Urban Minor Arterial		-0.23	-0.24	-0.24
T-Value		-2.27	-2.31	-2.31
P-Value		0.023	0.021	0.021
ITEM 42B-4			-0.75	-0.78
T-Value			-2.23	-2.33
P-Value			0.026	0.020
ITEM 69-4				-0.174
T-Value				-2.23
P-Value				0.026
ITEM 69-0				
T-Value				
P-Value				
ITEM 42B-5				
T-Value				
P-Value				
S	0.879	0.878	0.878	0.878
R-Sq	34.92	35.00	35.09	35.17
R-Sq(adj)	34.49	34.56	34.63	34.70

Step	29	30
Constant	6.132	6.135
Age	-0.0305	-0.0305
T-Value	-27.95	-27.97
P-Value	0.000	0.000
Item 31	0.1349	0.1348
T-Value	18.23	18.23
P-Value	0.000	0.000
ITEM 21-0	0.904	0.900
T-Value	10.05	10.01
P-Value	0.000	0.000
ITEM 71-4	-0.421	-0.422
T-Value	-9.88	-9.89
P-Value	0.000	0.000
ITEM 71-7	-0.543	-0.543
T-Value	-9.12	-9.13
P-Value	0.000	0.000
ITEM 71-6	0.439	0.450
T-Value	6.68	6.82
P-Value	0.000	0.000
ITEM 71-5	-0.67	-0.67
T-Value	-5.31	-5.32
P-Value	0.000	0.000
An Pripl Arter Freeways Express	-0.52	-0.53
T-Value	-4.58	-4.68
P-Value	0.000	0.000

ITEM 68-4	0.169	0.168
T-Value	5.29	5.24
P-Value	0.000	0.000
ITEM 71-0	-1.79	-1.79
T-Value	-4.52	-4.52
P-Value	0.000	0.000
ITEM 21-1	2.75	2.75
T-Value	4.41	4.41
P-Value	0.000	0.000
ITEM 71-2	-0.120	-0.120
T-Value	-3.13	-3.14
P-Value	0.002	0.002
ITEM 69-7	0.57	0.55
T-Value	2.70	2.65
P-Value	0.007	0.008
Item 52	0.00102	0.00101
T-Value	3.67	3.64
P-Value	0.000	0.000
Item 29: ADT	-0.00001	-0.00001
T-Value	-3.23	-3.06
P-Value	0.001	0.002
ITEM 42B-1	-0.34	-0.35
T-Value	-2.37	-2.41
P-Value	0.018	0.016
ITEM 68-2	0.181	0.178
T-Value	2.75	2.71
P-Value	0.006	0.007
Al Pripl Arterial - Other	-0.382	-0.385
T-Value	-3.93	-3.96
P-Value	0.000	0.000
Item 48	0.00045	0.00044
T-Value	2.55	2.48
P-Value	0.011	0.013
ITEM 44B-1	-2.25	-2.25
T-Value	-2.53	-2.53
P-Value	0.011	0.011
Urban Other Pripl Arterial	-0.32	-0.33
T-Value	-2.95	-3.02
P-Value	0.003	0.003
Urban Collector	-0.26	-0.26
T-Value	-2.54	-2.58
P-Value	0.011	0.010
ITEM 68-0	0.222	0.221
T-Value	2.79	2.77
P-Value	0.005	0.006
ITEM 21-2	1.43	1.43

T-Value	2.29	2.30
P-Value	0.022	0.022
ITEM 41-2	0.111	0.112
T-Value	2.48	2.49
P-Value	0.013	0.013
Urban Minor Arterial	-0.25	-0.25
T-Value	-2.40	-2.44
P-Value	0.017	0.015
ITEM 42B-4	-0.83	-0.84
T-Value	-2.47	-2.49
P-Value	0.014	0.013
ITEM 69-4	-0.261	-0.272
T-Value	-3.08	-3.20
P-Value	0.002	0.001
ITEM 69-0	-0.242	-0.252
T-Value	-2.60	-2.70
P-Value	0.009	0.007
ITEM 42B-5		-1.45
T-Value		-2.33
P-Value		0.020
S	0.877	0.876
R-Sq	35.28	35.37
R-Sq(adj)	34.80	34.87

Step	31
Constant	6.137
Age	-0.0308
T-Value	-28.04
P-Value	0.000
Item 31	0.1348
T-Value	18.23
P-Value	0.000
ITEM 21-0	0.905
T-Value	10.07
P-Value	0.000
ITEM 71-4	-0.424
T-Value	-9.95
P-Value	0.000
ITEM 71-7	-0.547
T-Value	-9.19
P-Value	0.000
ITEM 71-6	0.443
T-Value	6.71
P-Value	0.000
ITEM 71-5	-0.66
T-Value	-5.30
P-Value	0.000

An Pripl Arter Freeways Express	-0.53
T-Value	-4.68
P-Value	0.000
ITEM 68-4	0.171
T-Value	5.34
P-Value	0.000
ITEM 71-0	-1.78
T-Value	-4.50
P-Value	0.000
ITEM 21-1	2.75
T-Value	4.42
P-Value	0.000
ITEM 71-2	-0.124
T-Value	-3.23
P-Value	0.001
ITEM 69-7	0.56
T-Value	2.69
P-Value	0.007
Item 52	0.00102
T-Value	3.68
P-Value	0.000
Item 29: ADT	-0.00001
T-Value	-2.96
P-Value	0.003
ITEM 42B-1	-0.35
T-Value	-2.45
P-Value	0.014
ITEM 68-2	0.178
T-Value	2.71
P-Value	0.007
Al Pripl Arterial - Other	-0.380
T-Value	-3.92
P-Value	0.000
Item 48	0.00040
T-Value	2.26
P-Value	0.024
ITEM 44B-1	-2.24
T-Value	-2.52
P-Value	0.012
Urban Other Pripl Arterial	-0.32
T-Value	-2.93
P-Value	0.003
Urban Collector	-0.25
T-Value	-2.44
P-Value	0.015
ITEM 68-0	0.221

T-Value	2.77
P-Value	0.006
ITEM 21-2	1.44
T-Value	2.32
P-Value	0.021
ITEM 41-2	0.112
T-Value	2.50
P-Value	0.012
Urban Minor Arterial	-0.24
T-Value	-2.32
P-Value	0.020
ITEM 42B-4	-0.84
T-Value	-2.51
P-Value	0.012
ITEM 69-4	-0.271
T-Value	-3.20
P-Value	0.001
ITEM 69-0	-0.248
T-Value	-2.65
P-Value	0.008
ITEM 42B-5	-1.49
T-Value	-2.39
P-Value	0.017
ITEM 72-2	0.105
T-Value	1.99
P-Value	0.047
S	0.876
R-Sq	35.44
R-Sq(adj)	34.92

Appendix 8. Minitab Outcome of Multiple Regression - All Variables for PC-PCC Bridge Superstructure Rating

Stepwise Regression: Item 59 versus Age, Item 29: ADT, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.05

Response is Item 59 on 88 predictors, with N = 3196

Step	1	2	3	4	5	6
Constant	8.440	8.512	8.521	8.553	8.315	8.317
Age	-0.03193	-0.03134	-0.03289	-0.03255	-0.03077	-0.03057
T-Value	-34.33	-34.24	-35.28	-35.10	-31.84	-31.75
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ITEM 21-7		-0.236	-0.220	-0.193	-0.255	-0.267
T-Value		-10.73	-10.03	-8.72	-10.53	-11.02
P-Value		0.000	0.000	0.000	0.000	0.000
ITEM 68-1			0.441	0.431	0.433	0.446
T-Value			7.32	7.20	7.27	7.53
P-Value			0.000	0.000	0.000	0.000
Item 49				-0.00007	-0.00007	-0.00007
T-Value				-6.69	-6.80	-6.61
P-Value				0.000	0.000	0.000
Item 31					0.0453	0.0463
T-Value					6.13	6.29
P-Value					0.000	0.000
Urban Collector						-0.349
T-Value						-5.42
P-Value						0.000
S	0.604	0.593	0.589	0.585	0.581	0.579
R-Sq	26.95	29.49	30.66	31.62	32.41	33.03
R-Sq(adj)	26.93	29.45	30.59	31.53	32.31	32.90

Step	7	8	9	10	11	12
Constant	8.318	8.341	8.341	8.343	8.360	8.387
Age	-0.03154	-0.03152	-0.03190	-0.03168	-0.03154	-0.03127
T-Value	-32.39	-32.51	-32.80	-32.58	-32.46	-32.19
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ITEM 21-7	-0.228	-0.235	-0.230	-0.241	-0.259	-0.266
T-Value	-9.09	-9.41	-9.20	-9.58	-10.13	-10.41
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ITEM 68-1	0.343	0.357	0.317	0.321	0.317	0.304
T-Value	5.55	5.79	5.08	5.15	5.11	4.90
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
Item 49	-0.00007	-0.00007	-0.00007	-0.00007	-0.00007	-0.00007
T-Value	-7.21	-6.96	-6.93	-6.96	-6.96	-7.22
P-Value	0.000	0.000	0.000	0.000	0.000	0.000

Item 31	0.0439	0.0424	0.0425	0.0434	0.0441	0.0431
T-Value	5.99	5.81	5.83	5.96	6.06	5.95
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
Urban Collector	-0.373	-0.382	-0.367	-0.374	-0.385	-0.390
T-Value	-5.80	-5.96	-5.74	-5.85	-6.03	-6.12
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ITEM 21-0	0.203	0.234	0.215	0.206	0.185	0.156
T-Value	5.63	6.42	5.85	5.62	4.98	4.13
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ITEM 72-2		-0.181	-0.167	-0.171	-0.171	-0.153
T-Value		-5.24	-4.79	-4.94	-4.93	-4.40
P-Value		0.000	0.000	0.000	0.000	0.000
ITEM 72-6			0.306	0.298	0.293	0.296
T-Value			3.82	3.72	3.67	3.71
P-Value			0.000	0.000	0.000	0.000
Urban Local				-0.283	-0.301	-0.298
T-Value				-3.55	-3.77	-3.74
P-Value				0.000	0.000	0.000
ITEM 71-4					-0.124	-0.150
T-Value					-3.66	-4.37
P-Value					0.000	0.000
ITEM 71-2						-0.117
T-Value						-4.02
P-Value						0.000
S	0.576	0.574	0.572	0.571	0.570	0.569
R-Sq	33.69	34.26	34.56	34.81	35.09	35.41
R-Sq(adj)	33.54	34.09	34.37	34.61	34.86	35.17

Step	13	14	15	16	17
Constant	8.384	8.387	8.384	8.380	8.378
Age	-0.03109	-0.03102	-0.03110	-0.03101	-0.03122
T-Value	-32.02	-31.98	-32.10	-32.04	-32.19
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-7	-0.271	-0.277	-0.305	-0.314	-0.321
T-Value	-10.61	-10.81	-11.22	-11.52	-11.75
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-1	0.299	0.300	0.314	0.318	0.284
T-Value	4.83	4.85	5.07	5.13	4.52
P-Value	0.000	0.000	0.000	0.000	0.000
Item 49	-0.00007	-0.00007	-0.00007	-0.00008	-0.00007
T-Value	-7.14	-7.32	-7.43	-7.60	-7.44
P-Value	0.000	0.000	0.000	0.000	0.000
Item 31	0.0439	0.0425	0.0419	0.0423	0.0432
T-Value	6.06	5.86	5.79	5.84	5.97
P-Value	0.000	0.000	0.000	0.000	0.000
Urban Collector	-0.391	-0.392	-0.392	-0.390	-0.409
T-Value	-6.16	-6.18	-6.18	-6.16	-6.43

P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-0	0.149	0.153	0.149	0.146	0.102
T-Value	3.95	4.06	3.97	3.88	2.52
P-Value	0.000	0.000	0.000	0.000	0.012
ITEM 72-2	-0.150	-0.153	-0.152	-0.151	-0.152
T-Value	-4.30	-4.40	-4.38	-4.34	-4.38
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 72-6	0.315	0.313	0.315	0.316	0.308
T-Value	3.95	3.94	3.97	3.99	3.88
P-Value	0.000	0.000	0.000	0.000	0.000
Urban Local	-0.301	-0.308	-0.322	-0.324	-0.324
T-Value	-3.79	-3.88	-4.05	-4.07	-4.09
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-4	-0.154	-0.151	-0.147	-0.145	-0.143
T-Value	-4.48	-4.41	-4.28	-4.23	-4.19
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-2	-0.120	-0.118	-0.119	-0.118	-0.115
T-Value	-4.14	-4.08	-4.13	-4.10	-3.98
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-4	-1.08	-1.08	-1.09	-1.09	-1.09
T-Value	-3.80	-3.78	-3.83	-3.84	-3.83
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-3		0.168	0.197	0.206	0.203
T-Value		2.90	3.37	3.52	3.48
P-Value		0.004	0.001	0.000	0.001
ITEM 68-2			0.086	0.092	0.096
T-Value			3.05	3.29	3.42
P-Value			0.002	0.001	0.001
An Pripl Arterial - Inters				0.35	0.34
T-Value				3.17	3.06
P-Value				0.002	0.002
ITEM 69-3					0.141
T-Value					2.77
P-Value					0.006
Item 48					
T-Value					
P-Value					
S	0.568	0.567	0.566	0.565	0.565
R-Sq	35.71	35.88	36.06	36.26	36.42
R-Sq(adj)	35.44	35.59	35.76	35.94	36.08

Step	18
Constant	8.491
Age	-0.03182
T-Value	-32.11
P-Value	0.000
ITEM 21-7	-0.324

T-Value	-11.84
P-Value	0.000
ITEM 68-1	0.272
T-Value	4.32
P-Value	0.000
Item 49	-0.00007
T-Value	-6.42
P-Value	0.000
Item 31	0.0440
T-Value	6.08
P-Value	0.000
Urban Collector	-0.401
T-Value	-6.30
P-Value	0.000
ITEM 21-0	0.115
T-Value	2.81
P-Value	0.005
ITEM 72-2	-0.151
T-Value	-4.36
P-Value	0.000
ITEM 72-6	0.307
T-Value	3.88
P-Value	0.000
Urban Local	-0.328
T-Value	-4.14
P-Value	0.000
ITEM 71-4	-0.145
T-Value	-4.25
P-Value	0.000
ITEM 71-2	-0.117
T-Value	-4.06
P-Value	0.000
ITEM 21-4	-1.11
T-Value	-3.92
P-Value	0.000
ITEM 68-3	0.204
T-Value	3.49
P-Value	0.000
ITEM 68-2	0.093
T-Value	3.31
P-Value	0.001
An Pripl Arterial - Inters	0.34
T-Value	3.10
P-Value	0.002
ITEM 69-3	0.152
T-Value	2.99
P-Value	0.003

Item 48	-0.00045
T-Value	-2.88
P-Value	0.004
S	0.564
R-Sq	36.58
R-Sq(adj)	36.23

Step	19	20	21	22	23
Constant	8.485	8.479	8.482	8.477	8.475
Age	-0.03167	-0.03148	-0.03131	-0.03116	-0.03090
T-Value	-31.93	-31.70	-31.48	-31.30	-30.93
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-7	-0.328	-0.350	-0.352	-0.349	-0.341
T-Value	-11.98	-12.21	-12.27	-12.18	-11.85
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-1	0.272	0.267	0.263	0.262	0.282
T-Value	4.32	4.24	4.18	4.17	4.47
P-Value	0.000	0.000	0.000	0.000	0.000
Item 49	-0.00007	-0.00007	-0.00007	-0.00007	-0.00007
T-Value	-6.46	-6.62	-6.65	-6.67	-6.81
P-Value	0.000	0.000	0.000	0.000	0.000
Item 31	0.0446	0.0440	0.0433	0.0431	0.0424
T-Value	6.17	6.09	5.99	5.98	5.88
P-Value	0.000	0.000	0.000	0.000	0.000
Urban Collector	-0.402	-0.400	-0.394	-0.393	-0.386
T-Value	-6.33	-6.30	-6.21	-6.19	-6.09
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-0	0.113	0.111	0.108	0.110	0.133
T-Value	2.77	2.73	2.66	2.71	3.20
P-Value	0.006	0.006	0.008	0.007	0.001
ITEM 72-2	-0.152	-0.152	-0.152	-0.152	-0.150
T-Value	-4.40	-4.39	-4.42	-4.40	-4.34
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 72-6	0.303	0.301	0.309	0.309	0.332
T-Value	3.82	3.81	3.91	3.91	4.18
P-Value	0.000	0.000	0.000	0.000	0.000
Urban Local	-0.323	-0.323	-0.315	-0.313	-0.306
T-Value	-4.08	-4.07	-3.98	-3.95	-3.88
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-4	-0.143	-0.141	-0.140	-0.137	-0.140
T-Value	-4.19	-4.13	-4.10	-4.03	-4.11
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-2	-0.112	-0.110	-0.111	-0.109	-0.114
T-Value	-3.88	-3.82	-3.86	-3.80	-3.96
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-4	-0.99	-1.02	-1.02	-1.02	-1.03

T-Value	-3.46	-3.54	-3.56	-3.56	-3.60
P-Value	0.001	0.000	0.000	0.000	0.000
ITEM 68-3	0.209	0.208	0.208	0.209	0.209
T-Value	3.58	3.57	3.57	3.59	3.61
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-2	0.094	0.093	0.092	0.089	0.088
T-Value	3.36	3.31	3.28	3.19	3.14
P-Value	0.001	0.001	0.001	0.001	0.002
An Pripl Arterial - Inters	0.34	0.37	0.37	0.37	0.39
T-Value	3.11	3.31	3.32	3.33	3.49
P-Value	0.002	0.001	0.001	0.001	0.000
ITEM 69-3	0.152	0.155	0.153	0.152	0.119
T-Value	2.99	3.05	3.01	2.99	2.30
P-Value	0.003	0.002	0.003	0.003	0.022
Item 48	-0.00044	-0.00042	-0.00042	-0.00041	-0.00041
T-Value	-2.83	-2.68	-2.69	-2.68	-2.62
P-Value	0.005	0.007	0.007	0.007	0.009
ITEM 41-6	-0.48	-0.48	-0.49	-0.49	-0.49
T-Value	-2.66	-2.66	-2.68	-2.69	-2.69
P-Value	0.008	0.008	0.007	0.007	0.007
Rural Minor Arterial		0.103	0.104	0.105	0.103
T-Value		2.61	2.63	2.66	2.60
P-Value		0.009	0.009	0.008	0.009
ITEM 41-5			-0.52	-0.52	-0.53
T-Value			-2.58	-2.59	-2.65
P-Value			0.010	0.010	0.008
ITEM 41-1				0.50	0.67
T-Value				2.50	3.22
P-Value				0.012	0.001
ITEM 69-6					-0.193
T-Value					-2.82
P-Value					0.005
ITEM 42B-1					
T-Value					
P-Value					
S	0.564	0.563	0.563	0.562	0.562
R-Sq	36.73	36.86	36.99	37.12	37.27
R-Sq(adj)	36.35	36.46	36.58	36.68	36.82

Step	24
Constant	8.478
Age	-0.03109
T-Value	-31.05
P-Value	0.000
ITEM 21-7	-0.343
T-Value	-11.94
P-Value	0.000

ITEM 68-1	0.291
T-Value	4.61
P-Value	0.000
Item 49	-0.00007
T-Value	-6.92
P-Value	0.000
Item 31	0.0424
T-Value	5.88
P-Value	0.000
Urban Collector	-0.385
T-Value	-6.07
P-Value	0.000
ITEM 21-0	0.132
T-Value	3.18
P-Value	0.001
ITEM 72-2	-0.147
T-Value	-4.27
P-Value	0.000
ITEM 72-6	0.339
T-Value	4.27
P-Value	0.000
Urban Local	-0.304
T-Value	-3.85
P-Value	0.000
ITEM 71-4	-0.138
T-Value	-4.05
P-Value	0.000
ITEM 71-2	-0.112
T-Value	-3.88
P-Value	0.000
ITEM 21-4	-1.03
T-Value	-3.59
P-Value	0.000
ITEM 68-3	0.213
T-Value	3.67
P-Value	0.000
ITEM 68-2	0.088
T-Value	3.17
P-Value	0.002
An Pripl Arterial - Inters	0.39
T-Value	3.56
P-Value	0.000
ITEM 69-3	0.114
T-Value	2.20
P-Value	0.028
Item 48	-0.00041
T-Value	-2.64

P-Value	0.008
ITEM 41-6	-0.49
T-Value	-2.69
P-Value	0.007
Rural Minor Arterial	0.104
T-Value	2.64
P-Value	0.008
ITEM 41-5	-0.53
T-Value	-2.64
P-Value	0.008
ITEM 41-1	0.69
T-Value	3.29
P-Value	0.001
ITEM 69-6	-0.210
T-Value	-3.06
P-Value	0.002
ITEM 42B-1	0.25
T-Value	2.43
P-Value	0.015
S	0.561
R-Sq	37.39
R-Sq(adj)	36.92

Step	25	26	27	28	29
Constant	8.470	8.476	8.477	8.477	8.477
Age	-0.0311	-0.0309	-0.0309	-0.0308	-0.0309
T-Value	-31.08	-30.71	-30.75	-30.65	-30.72
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-7	-0.338	-0.352	-0.351	-0.345	-0.348
T-Value	-11.72	-11.92	-11.90	-11.65	-11.73
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-1	0.294	0.308	0.309	0.309	0.311
T-Value	4.66	4.85	4.87	4.88	4.91
P-Value	0.000	0.000	0.000	0.000	0.000
Item 49	-0.00007	-0.00007	-0.00007	-0.00007	-0.00007
T-Value	-7.19	-7.00	-7.15	-7.14	-7.12
P-Value	0.000	0.000	0.000	0.000	0.000
Item 31	0.0414	0.0419	0.0418	0.0415	0.0417
T-Value	5.73	5.81	5.79	5.76	5.78
P-Value	0.000	0.000	0.000	0.000	0.000
Urban Collector	-0.382	-0.337	-0.350	-0.346	-0.345
T-Value	-6.03	-5.05	-5.24	-5.17	-5.17
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 21-0	0.136	0.119	0.121	0.127	0.124
T-Value	3.28	2.83	2.88	3.01	2.94
P-Value	0.001	0.005	0.004	0.003	0.003

ITEM 72-2	-0.146	-0.150	-0.154	-0.153	-0.152
T-Value	-4.24	-4.35	-4.47	-4.44	-4.42
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 72-6	0.334	0.326	0.324	0.323	0.324
T-Value	4.20	4.11	4.08	4.08	4.10
P-Value	0.000	0.000	0.000	0.000	0.000
Urban Local	-0.297	-0.238	-0.236	-0.236	-0.236
T-Value	-3.76	-2.85	-2.82	-2.83	-2.83
P-Value	0.000	0.004	0.005	0.005	0.005
ITEM 71-4	-0.125	-0.131	-0.130	-0.132	-0.131
T-Value	-3.64	-3.80	-3.78	-3.84	-3.81
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 71-2	-0.100	-0.102	-0.101	-0.102	-0.101
T-Value	-3.44	-3.49	-3.45	-3.51	-3.47
P-Value	0.001	0.000	0.001	0.000	0.001
ITEM 21-4	-1.09	-1.10	-1.10	-1.10	-1.10
T-Value	-3.79	-3.83	-3.83	-3.83	-3.83
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-3	0.214	0.214	0.216	0.214	0.215
T-Value	3.68	3.69	3.72	3.69	3.71
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 68-2	0.088	0.090	0.090	0.087	0.088
T-Value	3.15	3.21	3.23	3.11	3.14
P-Value	0.002	0.001	0.001	0.002	0.002
An Pripl Arterial - Inters	0.40	0.40	0.40	0.39	0.40
T-Value	3.59	3.61	3.62	3.58	3.60
P-Value	0.000	0.000	0.000	0.000	0.000
ITEM 69-3	0.121	0.118	0.119	0.110	0.113
T-Value	2.32	2.27	2.30	2.11	2.17
P-Value	0.020	0.023	0.022	0.035	0.030
Item 48	-0.00040	-0.00041	-0.00041	-0.00041	-0.00040
T-Value	-2.58	-2.65	-2.64	-2.63	-2.62
P-Value	0.010	0.008	0.008	0.009	0.009
ITEM 41-6	-0.49	-0.50	-0.50	-0.50	-0.50
T-Value	-2.68	-2.77	-2.78	-2.78	-2.78
P-Value	0.007	0.006	0.005	0.005	0.005
Rural Minor Arterial	0.099	0.099	0.099	0.099	0.101
T-Value	2.52	2.52	2.52	2.51	2.56
P-Value	0.012	0.012	0.012	0.012	0.011
ITEM 41-5	-0.52	-0.50	-0.49	-0.50	-0.49
T-Value	-2.61	-2.47	-2.46	-2.48	-2.47
P-Value	0.009	0.013	0.014	0.013	0.013
ITEM 41-1	0.69	0.78	0.78	0.79	0.78
T-Value	3.32	3.66	3.67	3.72	3.70
P-Value	0.001	0.000	0.000	0.000	0.000
ITEM 69-6	-0.202	-0.202	-0.201	-0.212	-0.209
T-Value	-2.94	-2.95	-2.94	-3.09	-3.04

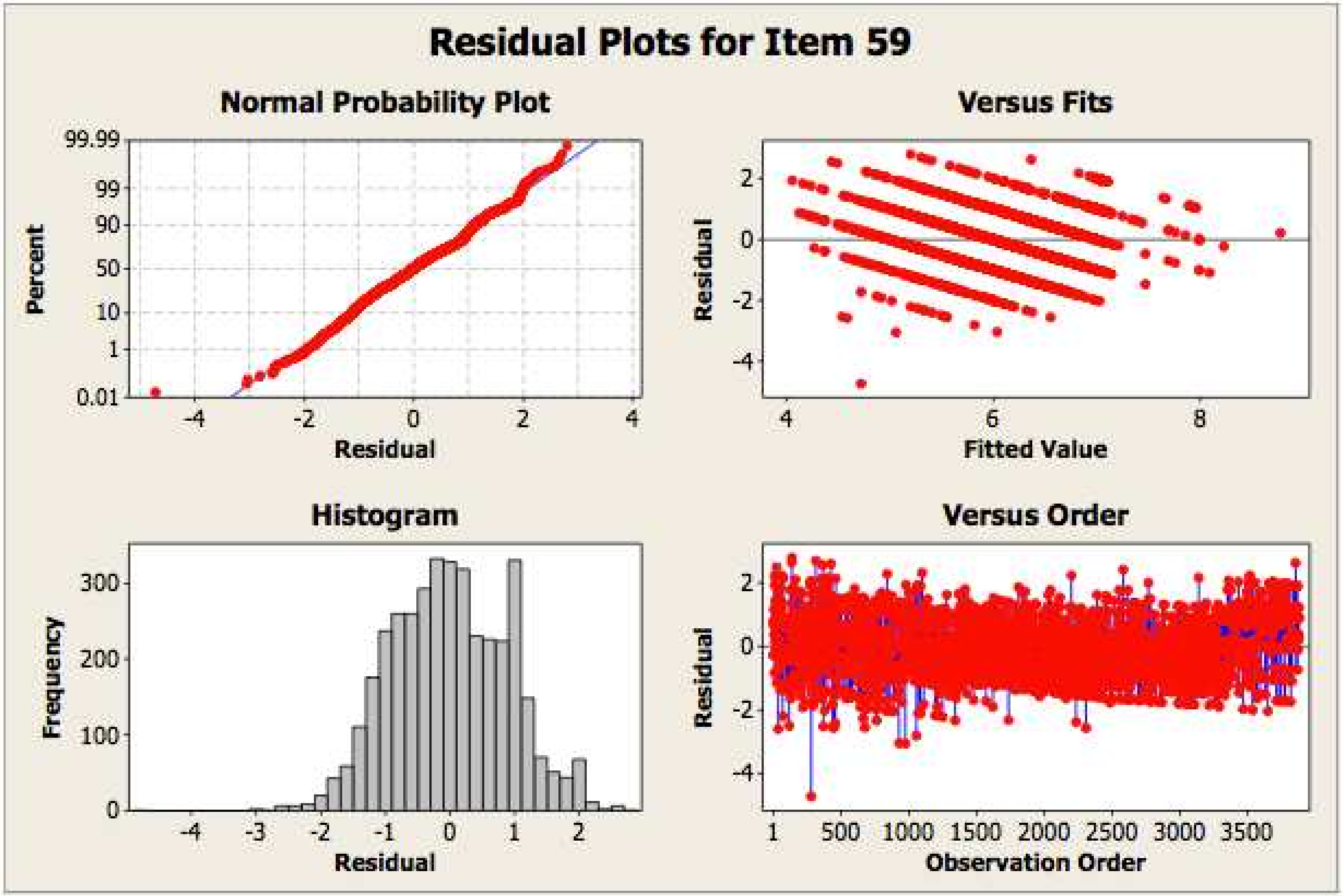
P-Value	0.003	0.003	0.003	0.002	0.002
ITEM 42B-1	0.26	0.27	0.27	0.30	0.30
T-Value	2.52	2.58	2.59	2.90	2.92
P-Value	0.012	0.010	0.010	0.004	0.004
ITEM 71-8	0.081	0.082	0.084	0.080	0.081
T-Value	2.29	2.33	2.38	2.28	2.31
P-Value	0.022	0.020	0.017	0.022	0.021
ITEM 21-3		-0.102	-0.106	-0.104	-0.105
T-Value		-2.17	-2.24	-2.22	-2.22
P-Value		0.030	0.025	0.026	0.026
ITEM 44B-0			1.24	1.47	1.47
T-Value			2.20	2.57	2.56
P-Value			0.028	0.010	0.011
ITEM 69-0				-0.24	-0.24
T-Value				-2.38	-2.36
P-Value				0.017	0.018
ITEM 42B-4					0.59
T-Value					2.10
P-Value					0.036
ITEM 71-7					
T-Value					
P-Value					
S	0.561	0.560	0.560	0.560	0.559
R-Sq	37.49	37.59	37.68	37.79	37.88
R-Sq(adj)	37.00	37.07	37.15	37.24	37.31

Step	30
Constant	8.482
Age	-0.0307
T-Value	-30.53
P-Value	0.000
ITEM 21-7	-0.352
T-Value	-11.85
P-Value	0.000
ITEM 68-1	0.309
T-Value	4.89
P-Value	0.000
Item 49	-0.00007
T-Value	-7.13
P-Value	0.000
Item 31	0.0416
T-Value	5.78
P-Value	0.000
Urban Collector	-0.343
T-Value	-5.13
P-Value	0.000
ITEM 21-0	0.115

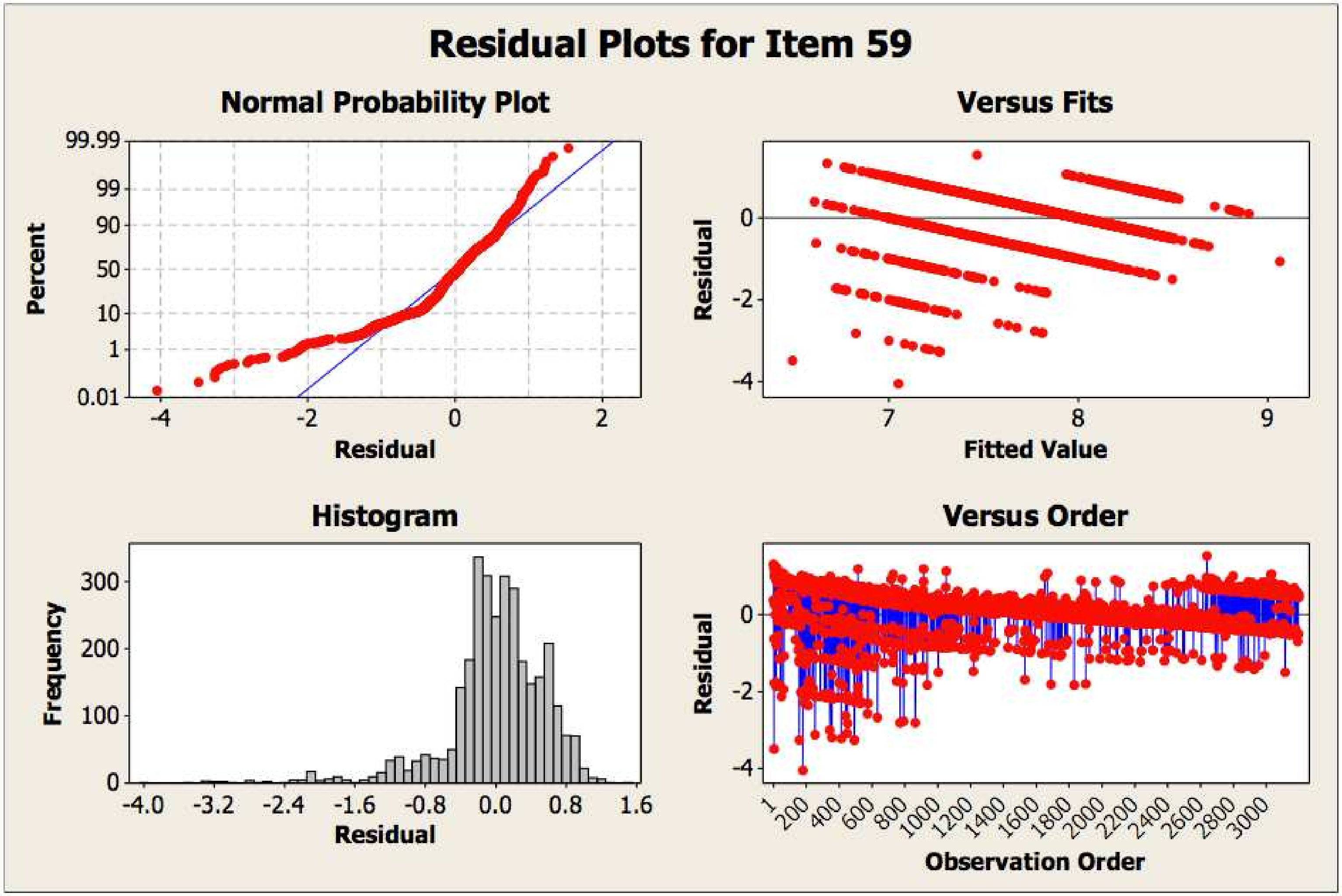
T-Value	2.73
P-Value	0.006
ITEM 72-2	-0.146
T-Value	-4.22
P-Value	0.000
ITEM 72-6	0.330
T-Value	4.17
P-Value	0.000
Urban Local	-0.239
T-Value	-2.87
P-Value	0.004
ITEM 71-4	-0.139
T-Value	-4.01
P-Value	0.000
ITEM 71-2	-0.108
T-Value	-3.68
P-Value	0.000
ITEM 21-4	-1.10
T-Value	-3.86
P-Value	0.000
ITEM 68-3	0.212
T-Value	3.66
P-Value	0.000
ITEM 68-2	0.087
T-Value	3.11
P-Value	0.002
An Pripl Arterial - Inters	0.40
T-Value	3.60
P-Value	0.000
ITEM 69-3	0.110
T-Value	2.11
P-Value	0.035
Item 48	-0.00040
T-Value	-2.62
P-Value	0.009
ITEM 41-6	-0.50
T-Value	-2.79
P-Value	0.005
Rural Minor Arterial	0.101
T-Value	2.56
P-Value	0.010
ITEM 41-5	-0.50
T-Value	-2.51
P-Value	0.012
ITEM 41-1	0.79
T-Value	3.71
P-Value	0.000

ITEM 69-6	-0.213
T-Value	-3.10
P-Value	0.002
ITEM 42B-1	0.30
T-Value	2.90
P-Value	0.004
ITEM 71-8	0.076
T-Value	2.17
P-Value	0.030
ITEM 21-3	-0.108
T-Value	-2.29
P-Value	0.022
ITEM 44B-0	1.46
T-Value	2.54
P-Value	0.011
ITEM 69-0	-0.24
T-Value	-2.39
P-Value	0.017
ITEM 42B-4	0.59
T-Value	2.09
P-Value	0.037
ITEM 71-7	-0.161
T-Value	-2.03
P-Value	0.042
S	0.559
R-Sq	37.96
R-Sq(adj)	37.37

Appendix 9. Residual Plots for S-SC Superstructure Bridges



Appendix 10. Residual Plots for PC-PCC Superstructure Bridges



VITA

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