State and County Delivered Bridge Replacement Project Analysis: Phase I and Phase II

Summary Report

by

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16. Abstract

The purpose of the study was to compare the cost of state delivered bridge projects and county delivered bridge projects. A total of 190 different bridge replacement projects were analyzed. The first phase of the project focused on whether or not the project delivery type (state or county) was a significant predictor of project cost or project duration. The greatest variability in the cost of bridge replacement projects (79%), was found to be explained by project duration and bridge length, with length being the most influential. Overall, it was found that the duration of state-delivered projects was longer than the duration of county-delivered projects.

In the second phase, analysis was completed to determine if a predictive model could be developed for project costs and project duration. Variables included bridge closure type (on-site detour, off-site detour, and staged build), clearance type (over water, over railroad, over canal/irrigation), number of bids received, and project location. Clearance type was found to impact construction costs, but not be a significant predictor. It was also found that projects built in stages had higher construction costs than projects using onsite or offsite detours. Using the results from Phase I and analysis from Phase II, a model was developed. The model was found to account for 86% of variation in project costs.

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State and County Delivered Bridge Replacement Project Analysis: Phase I and Phase II

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I. Executive Summary

This report summarizes the results of Phase I and Phase II of the State vs. County Delivery Bridge Replacement Analysis project. The data set used in the project included 190 bridge replacement projects. Key attributes of the projects are summarized in Table 1.

Table 1: Bridge Project Characteristics

Total number of bridges	190
# of state-delivered projects	50
# of county-delivered projects	140
Costs ($)	$60,500 – 6,388,217
Bridge Length (ft)	23-680
Duration (days)	106-2,494
Average # of bids	4
% of Projects by Closure Type	21% built in stages 52% offsite detour 27% onsite detour
% of Projects by Clearance Type	92% over water 1% over railroad 7% over canal/irrigation
% of Projects by Region	Region 1 17% Region 2 25% Region 3 26% Region 4 9% Region 5 23%

To enable a valid analysis of the data, the following assumptions and mathematical operations were performed:

1. Costs, duration, length, and width data were transformed using natural logs for all analyses. Testing was completed on the transformed data to verify that the transformed data were robust and satisfied the requirements of normally-distributed errors and equal variances.
2. As design and construction projects spanned multiple years, present values were used for all cost data to enable comparison of bridge costs.
3. Engineering costs were distributed equally from the engineering design start date to the start of construction date.
4. Construction costs were distributed equally across years between the start of construction date and the substantial construction completion date.
5. Right of way costs were not included when calculating total costs.
6. Total duration included both engineering design duration and construction duration.

In the first phase of the project, the focus was determining whether or not the project delivery type (state or county) could be a significant predictor of project cost or project duration. The variables (and associated measurement units) included in Phase I analysis:

- Project delivery type (state or county)
- Engineering and construction costs (dollar amount). Right-of-way costs were not included.
- Engineering design and construction durations (days)
- Bridge length (ft)
- Bridge closure during construction (yes or no)

The significant findings from the Phase I analysis are summarized below.

Phase I, Finding 1:

- In regards to the variability observed in the cost of bridge replacement projects included in the study, 79% can be explained by project duration and bridge length.
- Approximately 7% of this variation is due to project duration, but the largest portion of cost variation (72%) can be explained by bridge length.

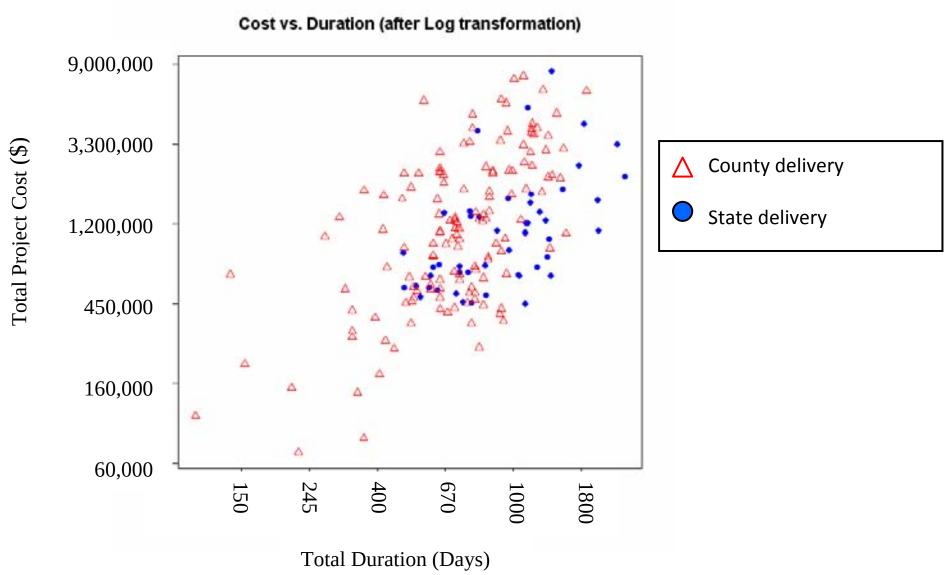


Figure 1: Overall summary of cost vs. duration

(Note: there were no state-delivered projects with total costs < $450,000)

Phase I, Finding 2:

- The average duration of the engineering design portion of state-delivered projects was greater than the average duration of the engineering design portion of county-delivered projects. The difference was statistically significant. The average duration for the engineering design portion of county-delivered projects was 449 days. The average duration for the engineering design portion of state-delivered projects was 774 days. See Figure 2 for a graphical summary of total project duration by delivery type.

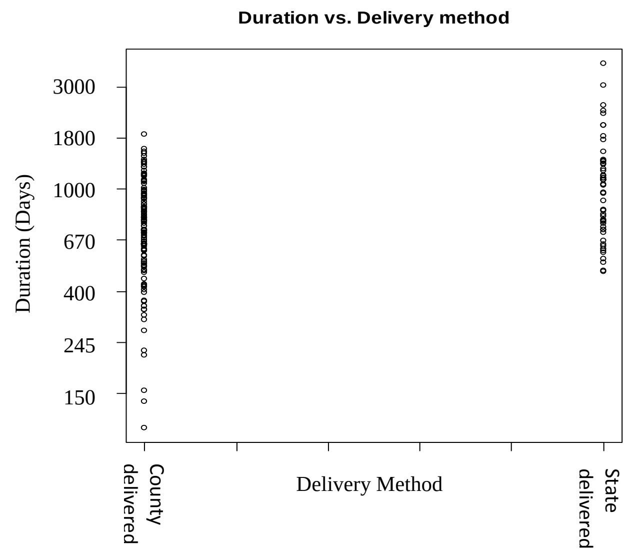


Figure 2: Duration vs. delivery method

Phase I, Finding 3:

- Closing (or not) of the bridge during construction did not provide any additional explanation for variation observed in total bridge replacement costs, for the set of bridges studied. As can be seen in Figure 3, bridge closures are distributed across the entire range of project costs.

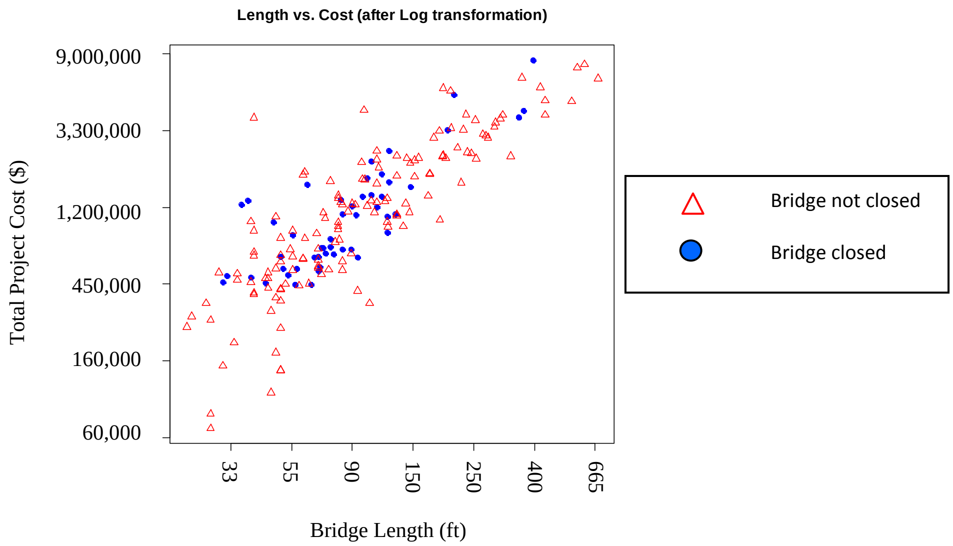


Figure 3: Project cost vs. length with bridge closure type specified

In Phase II, the focus was on completing additional analysis to see if it was possible to create a predictive model for project costs and project duration. Based on the results of Phase I, four additional variables were identified for inclusion in the study. The first two additional variables stratified the bridges based on closure type (on-site detour, off-site detour, and staged build) and clearance type (over water, over railroad, over canal/irrigation). The third variable was the number of bids received for a project. Three levels were defined for the analysis (projects with two or few bids, projects with three to five bids, and projects with six or more bids). The fourth variable was the project location. For purposes of this study, five regions were defined based on the geographical location of the project and population density. The significant findings resulting from the Phase II analysis are summarized in the following section.

Phase II, Finding 1:

- The map used to define the region associated with each project is shown in Figure 4 below. Projects in Region 1 were found to take longer to complete than projects in Region 5.

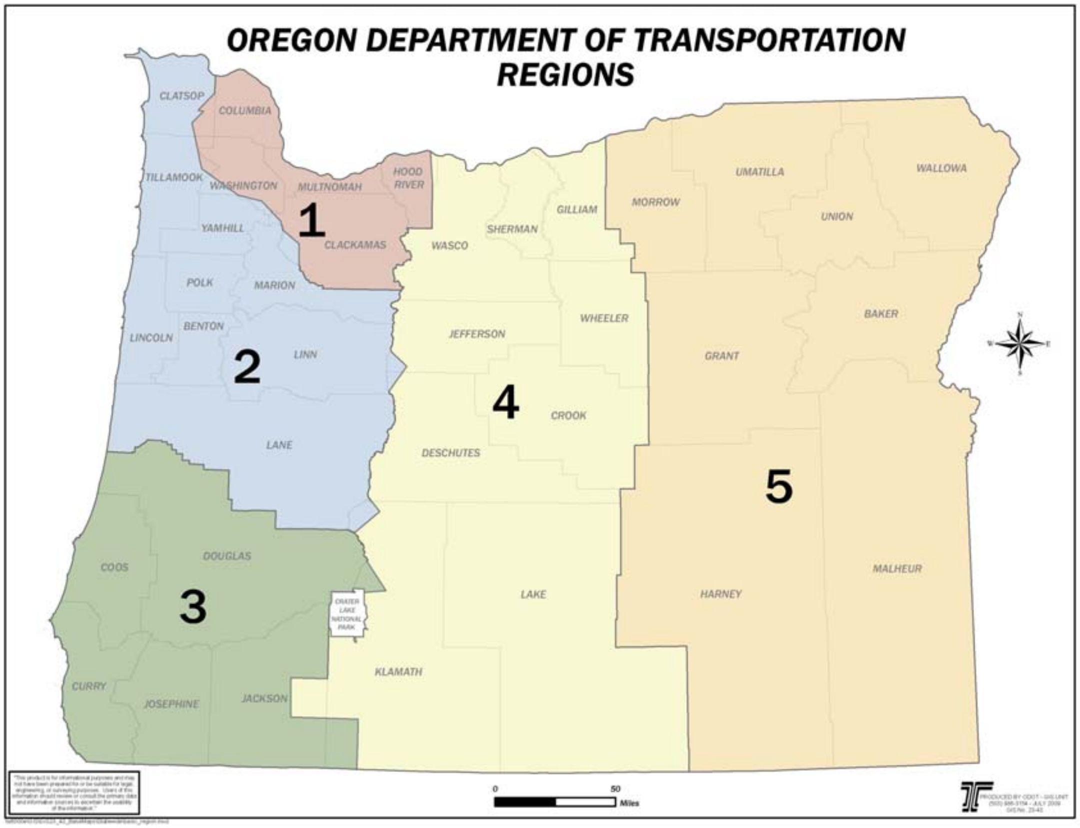


Figure 4: Regions 1 – 5 and associated counties.

Phase II, Finding 2:

- The number of bids was treated as a categorical variable with three levels (two or fewer bids, three to five bids, or more than six bids). The number of bids was not found to be a significant predictor of total project costs.

Phase II, Finding 3:

- Clearance type was found to impact project construction costs. Projects extending over railroads had higher construction costs than projects over water. Projects extending over irrigation or canals had the lowest construction costs (Figure 5). Clearance type, however, was not found to be a significant predictor of overall project costs. Clearance type was found to be correlated with bridge length, which was identified in Phase I as a significant predictor of costs.

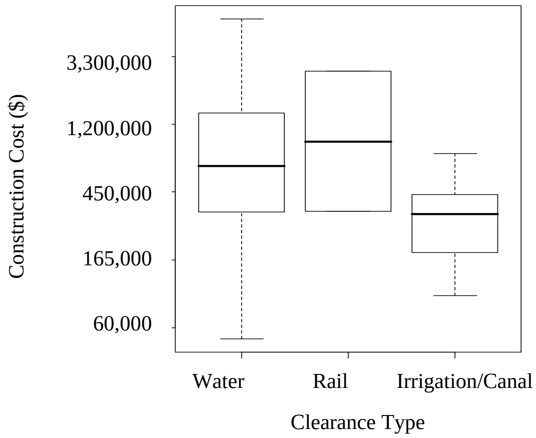


Figure 5: Construction Costs vs. Clearance Type

Phase II, Finding 4:

- The type of closure/detour used for the projects in this study was found to have a significant impact on project construction costs. Projects that were built in stages had higher construction costs than projects using onsite or offsite detours. There was no difference in project construction costs between projects using onsite and offsite detours (Figure 6).

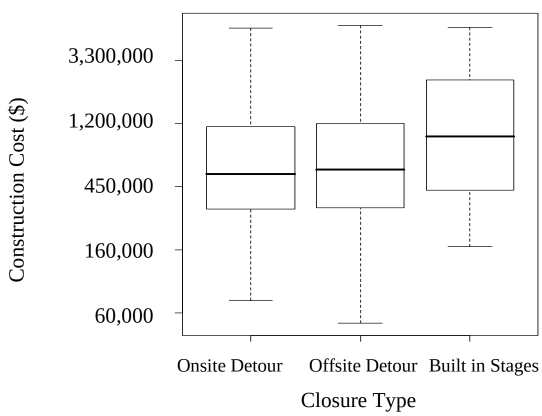


Figure 6: Construction Costs vs. Closure Type

Phase I and Phase II Overall Findings

A mathematical model was developed based on 190 bridge replacement projects. Approximately 86% of the observed variation in total project costs can be accounted for in a model that includes bridge length, project duration, and bridge width. Only 14% of the variation in project costs remains unexplained. The five variables identified as having significant prediction power on project costs and/or project duration include bridge length, bridge width, clearance type, and delivery method. These variables should be considered in estimating project costs for future replacement projects. It is likely that it would take significant amount of time to identify additional variables to explain the remaining variation and to collect the data. It is also likely that the unaccounted for variation (14%) cannot be explained by a single variable and is a result of a large number of variables. The overall relationships between project cost and the significant predictors identified are summarized in Figure 7.

- The length of the bridge was found to be the most significant predictor of construction costs. Bridge length can explain approximately 72% of the variation observed in project costs for the 190 bridge replacement projects included in this study. The type of clearance can explain a small proportion (5%) of the variation observed in bridge length.
- Project duration and bridge width explain an additional 14% of the variation observed in construction costs for the projects studied.
- The project delivery type (county vs. state) was found to explain approximately 10% of the variation observed in project duration, which accounts for approximately 1% of the variation observed in total project cost.

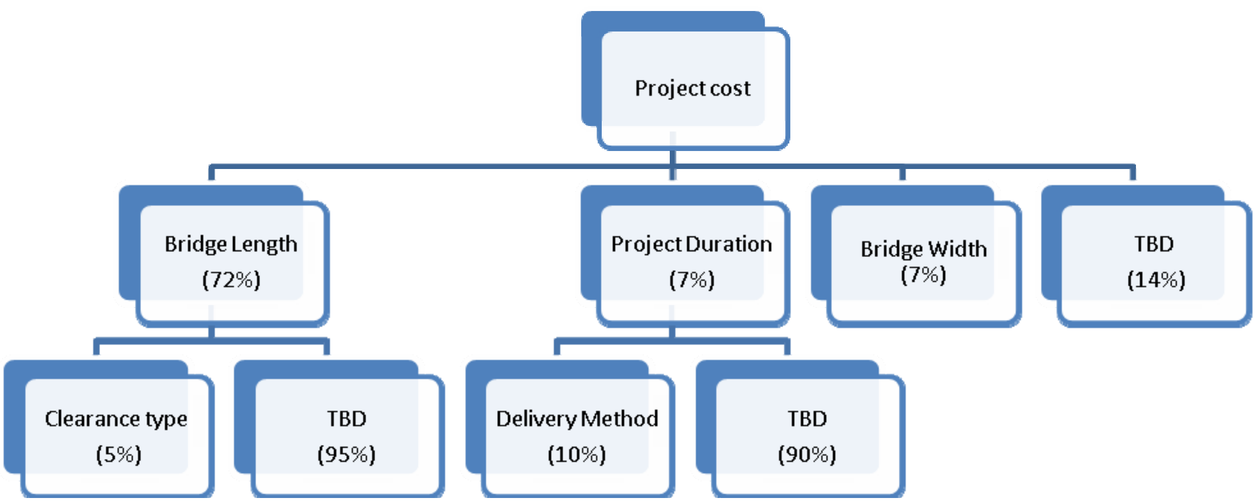


Figure 7: Relationships between project cost and significant predictors, including bridge length, project duration, bridge width, clearance type, and delivery method

II. Introduction

The remaining sections of this report summarize the detailed results of the first and second phase of the State vs. County Delivery Bridge Replacement Analysis study. Data for this study were received from; Jon Oshel, County Road Program Manager; and Holly Winston, Senior Local Bridge Standards Engineer. Initially, data from 226 bridge replacement projects occurring between 1994 and 2008 were collected. Some of the bridge replacement projects were eliminated from the study as the projects did not represent a typical project, e.g. projects having a significant rehabilitation component, or because at the time of data collection the project was not completed. The final data set that was analyzed included 190 bridge replacement projects. Appendix A contains a list of all bridge replacement project included in the study. Appendix B contains a list of the 36 bridge replacement projects excluded from the study, along with the reason for exclusion. Summary information for the 190 bridges included in the analysis is provided is shown in Table 1. Additional data on the "extreme" bridge replacement projects are summarized in Table 2. The data provided for each project included; total project cost, which included both engineering and construction costs; project duration, the total duration of each project was calculated by measuring the elapsed time between the engineering design begin date and substantial construction completion date; bridge length (feet); delivery type (state or county); closure type; bridge clearance type; number of bids received for the project; and project location. The purpose of Phase I of the study was to determine whether or not project delivery type could explain observed variations in project costs and project durations. Phase II was completed to identify the significance of other key variables on project costs and durations.

Table 2: Extreme Bridge Replacement Project Details

	County	Bridge name	Funding source	Begin date	Completion date	Total Cost ($)	Total Duration (days)	Length (ft)
Most expensive	Coos County	Stringtown Overflow	OTIA III	07/08/2004	10/01/2002	6,428,672	1180	610
Least expensive	Benton county	Bottger Creek	Local	02/17/2007	10/01/2007	60,500	226	28
Longest length	Washington County	Tualatin River	OTIA II	09/23/1999	11/15/2004	4,432,497	1880	680
Shortest length	Jackson county	Cottonwood Creek	Local	06/01/2005	10/01/2007	212,900	852	23
Longest duration	Clackamas County	Abernethy Creek	HBP	07/20/1994	05/18/2001	1,185,472	2494	105
Shortest duration	Lake county	Dick's Creek	Local	07/01/2003	10/15/2003	76,067	106	46

Delivery type was defined based on the source of funding for the replacement project, i.e. State or Federal Highway Administration (FHWA). Projects funded by the Federal Highway Bridge Program (HBP) were identified as state-delivered projects; whereas projects funded by the Oregon Transportation Investment Act (OTIA I, OTIA II, or OTIA III), Oregon Watershed Enhancement Board (OWEB), or local sources were identified as county-delivered projects. In this analysis, project cost and duration were the dependent variables under consideration.

Project costs were adjusted to enable comparison of projects that were completed in different years. Standard engineering economic principles were applied to adjust costs for inflationary effects. Project costs were divided into two different categories, design engineering costs and construction costs. Design engineering costs were distributed equally on an annual basis between the project start date and the project construction award date. Construction costs were distributed equally on an annual basis between the construction award date and construction substantial completion date.

Two types of independent variables were included in the analysis, indicator variables and quantitative variables. Indicator variables are variables that take the value of 0 or 1 to indicate the absence or presence of a factor. Delivery type, closure type, clearance type, number of bids, and region were the five independent, indicator variables included in the study. Project duration, bridge length, and bridge width were the independent, quantitative variables included in the analysis.

The remainder of this report summarizes the results of the various statistical and graphical analyses completed to determine which factors, including delivery type, were most significant in explaining bridge replacement project costs and project durations.

III. Background

This section provides some background information on the type of analyses that were performed in this study. Linear regression models and Analysis of Variance (ANOVA) were used to analyze the data. A simple linear regression model is a straight line function that relates the mean of a dependent variable to independent variables. The dependent variable is an output of interest, e.g. project costs. Independent variables are those variables that are believed to drive a dependent variable. A linear regression analysis is used to determine whether or not a linear function can be used to predict the value of the mean of a dependent variable when two quantitative variables are analyzed. ANOVA is used when one of the variables in an indicator variable. In both Phase I and Phase II, the two primary dependent variables of interest were project costs and project duration. The symbol “y” is used to represent dependent variables. In Phase I, bridge length, delivery type, and bridge closure were the independent variables studied. In Phase II, bridge width, bridge closure type, bridge clearance type, number of bids, and region were added as independent variables to the analysis. The symbols, x_1, x_2, …, x_n, are used to represent independent variables in a mathematical model. A simple linear regression model is represented in the following general formula:

$$y = B_0 + B_1 \times x_1 + B_2 \times x_2 + \ldots + B_n \times x_n.$$

In this format, B_0, B_1, …, B_n are the model parameters that have to be estimated. These parameters were estimated using the mean square error method. After estimating the model parameters, the result can be summarized in a table as illustrated in Table 3.

Table 3: General table of results from a linear regression analysis

	Estimate	Pr(>|t|)
B_0	…	…
B_1	…	…
⋮		
B_n	…	…
Adjusted R-squared: …		

The first column includes the names of the parameters. The second column includes the estimated values for each parameter. The third column is the p-value for each parameter. The p-value is a probability value that specifies the significance of the estimate. When the p-value is less than 0.05 it is said that there is sufficient evidence that the parameter estimate is correct. The last row of the table includes the adjusted value of R-squared. R-squared identifies how much variability in the dependent variable can be explained by the independent variables included in the model.

In completing a linear regression analysis, there are four assumptions that must be met. Constant variance is one assumption for a linear regression model to be valid. This assumption can be validated with a fitted value vs. residual plot. A fitted value is the dependent variable value based on the estimated parameters. A residual value is the difference between the true value and estimated value of the dependent variable. To meet the assumption of constant variance, the plot between the fitted and residual values must be dispersed randomly around a value of zero. A second assumption is that the error terms are normally distributed. Normal probability plots of the residuals were reviewed to verify that this assumption was met for each variable included in the analysis. The third assumption is that the data being analyzed vary in a linear fashion. Linearity was verified by plotting each independent variable against each dependent variable. It was found that for each of the quantitative variables included in the study (cost, duration, length, and width), the assumption of linearity was not met unless the data were transformed. A natural log transformation was applied and shown to produce well-behaved data. For the remainder of this report the term "log" will be used when referring to any data where a natural log transformation was applied. The fourth assumption is of independence. There was no evidence of serial or time-based correlation observed in the data used for this study.

IV. Analysis Phase I

A. Project cost vs. delivery type

Project costs were analyzed as a function of delivery type using a linear regression model. The results are summarized in Table 4. The assumption of constant variance of the errors appears to be a valid as the fitted values for cost (when the natural log transformation was applied) are randomly dispersed around the value of 0. Since the p-value for B_1 (0.304) is greater than 0.05, there is no evidence that the delivery method can be used to explain the observed variation in costs. These results indicate that the parameter, B_1, can be set to zero with high confidence. This model indicates that the average cost for a bridge replacement project is approximately $1.65 million, irrespective of whether the project was delivered by a county or by the state. Based on this analysis, the average cost for a bridge replacement project is not directly dependent on delivery type.

In summary, differences observed in project costs cannot be directly attributed to the type of project delivery used (state or county).

Table 4: Project cost vs. delivery type

Model variables

Type	Name	Description
Indicator	Fund	$\begin{cases} 1 & State-delivery \\ 0 & County-delivery \end{cases}$
Dependent	L-cost	Log(cost)

Model

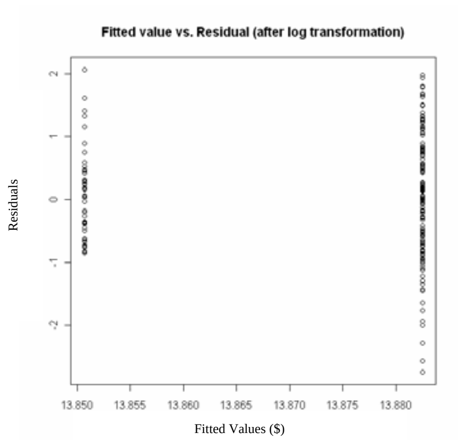
Tested:

Cost = $B_0 + B_1 \times$ Fund

Valid:

Cost=1,640,995

Assumption validation



Linear regression results

	Estimate Std.	Pr(>|t|)
B_0	1640995	<<0.001
B_1	-259305	0.304
Adjusted R-squared: 0.006		

B. Project cost vs. project duration

A plot of project costs against project duration (for the entire set of projects analyzed) is shown in Figure 8. While there appears to be a linear relationship between these data, log transformations were applied to both costs and duration to produce a better behaved distribution for analyses. The plot of the transformed data is shown in Figure 9.

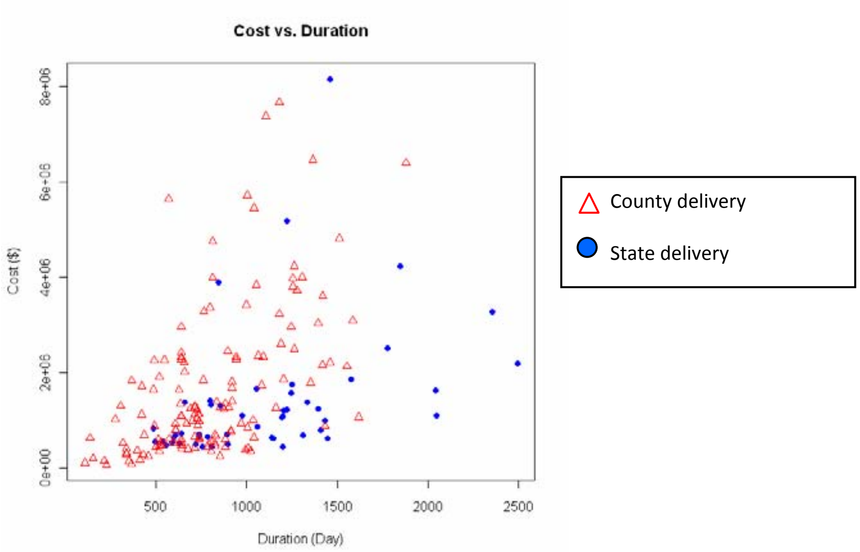


Figure 8: Scatter graph of project costs vs. project duration for untransformed data

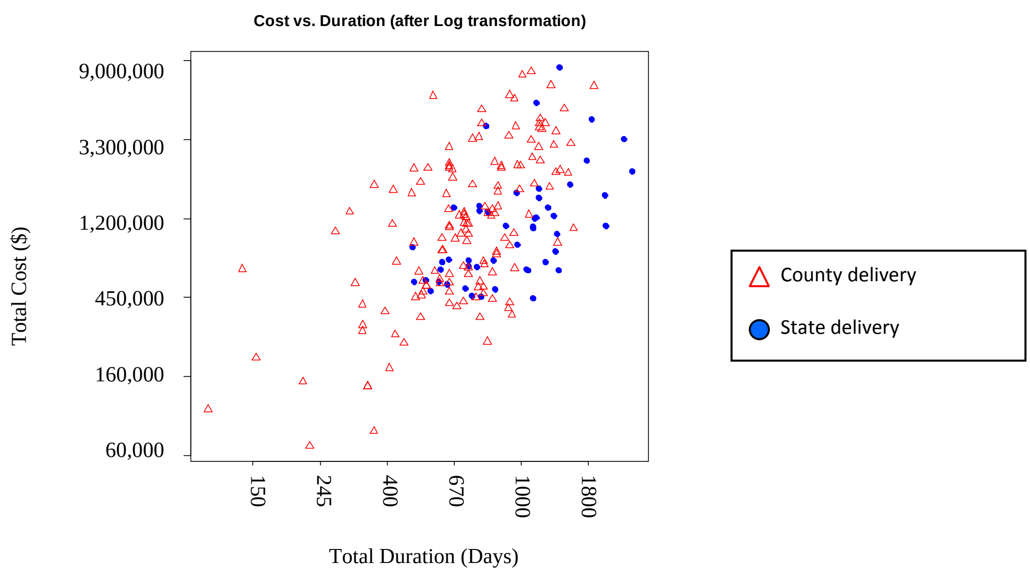


Figure 9: Scatter graph of project cost vs. project duration after log transformation

The relationship between the log of project cost and the log of project duration was analyzed next using linear regression. An indicator variable defining the delivery type used for the project was included in the analysis. The results are summarized in Table 5. The assumption of constant variance of the errors appears to be a valid for this data set when transformed values for project cost and duration are used. Since the p-values for B_2 (0.363) and B_3 (0.252) are greater than 0.05 there is no evidence that either project delivery type or the interaction between project delivery type and project duration can be used to explain the observed variation in costs. This model does support a significant relationship between project duration and project cost, with project duration explaining approximately 38% of the observed variation in project costs as measured by the adjusted R-squared value of 0.38.

In summary, the average cost for a bridge replacement project was found to be correlated with project duration. Duration can explain roughly 38% of the variation observed in project costs for the 190 bridge replacement projects included in the study. Differences observed in project costs were again found to not be attributable to the type of project delivery used (state or county).

Table 5: Project cost vs. project duration

Model variables

Type	Name	Description
Indicator	Fund	$\begin{cases} 1 & State-delivery \\ 0 & County-delivery \end{cases}$
Independent	L-duration	Log(duration)
Dependent	L-cost	Log(cost)

Model

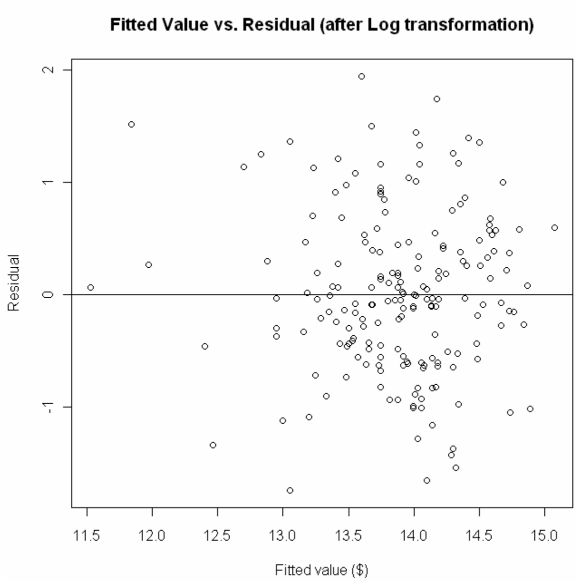
Tested:

L-cost = B_0 + B_1×L-duration+B_2× Fund + B_3× L-duration:Fund

Valid:

L-cost = 5.77 + 1.23 × L-duration

Assumption validation



Linear regression results

	Estimate	Pr(>|t|)
B_0	5.77	<<0.001
B_1	1.23	<<0.001
B_2	1.74	0.363
B_3	0.32	0.252
Adjusted R-squared: 0.38		

C. Project cost vs. bridge length and delivery method

In the next step of the analysis, project costs were analyzed with both bridge length and delivery type included in the model. A scatter graph of project costs against bridge length (for the entire set of projects analyzed) is shown in Figure 10. Similar to project cost and duration, it was necessary to use a natural log transformation to obtain a distribution of data appropriate for linear regression analysis.

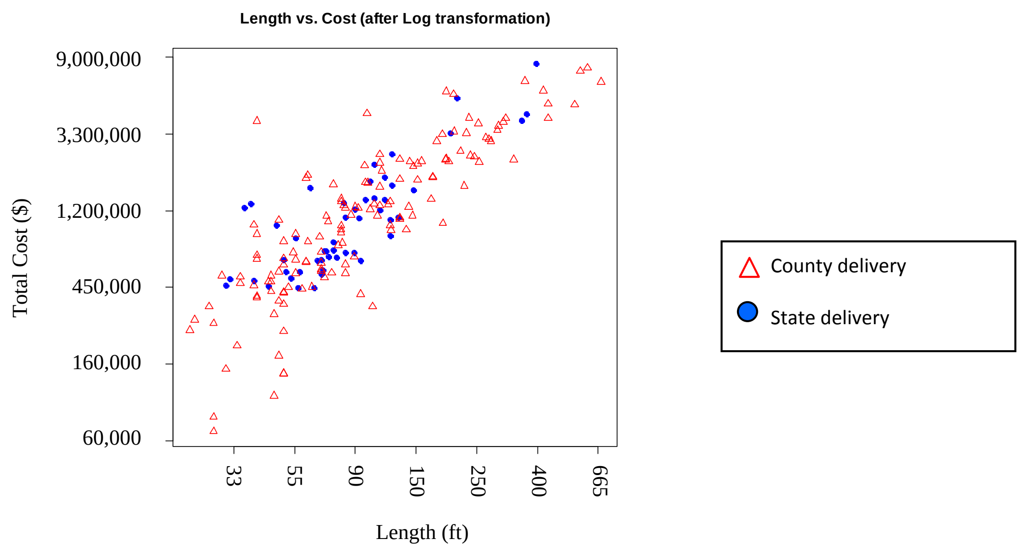


Figure 10: Scatter graph of project cost vs. bridge length

The relationship between the log of project cost and the log of length was analyzed using linear regression. An indicator variable defining the delivery type used for the project was included in the analysis. The results are summarized in Table 6. The assumption of constant variance of the errors appears to be a valid for this data set when transformed values for project cost and length are used. Since the p-values for B_2 (0.38) and B_3 (0.47) are greater than 0.05 there is no evidence that either project delivery type or the interaction between project delivery type and bridge length can be used to explain the observed variation in costs. This model does support a significant relationship between bridge length and project costs, with bridge length explaining a very significant portion (72%) of the observed variation in project costs as measured by the adjusted R-squared value of 0.72.

In summary, the average cost for a bridge replacement project was found to be significantly correlated with bridge length. Length can explain roughly 72% of the variation observed in project costs for the 190 bridge replacement projects included in the study. Differences observed in project costs were again found to not be attributable to the type of project delivery used (state or county).

Table 6: Project cost vs. bridge length and delivery method

Model variables

Type	Name	Description
Indicator	Fund	$\begin{cases} 1 & State-delivery \\ 0 & County-delivery \end{cases}$
Independent	L-length	Log(length)
Dependent	L-cost	Log(cost)

Model

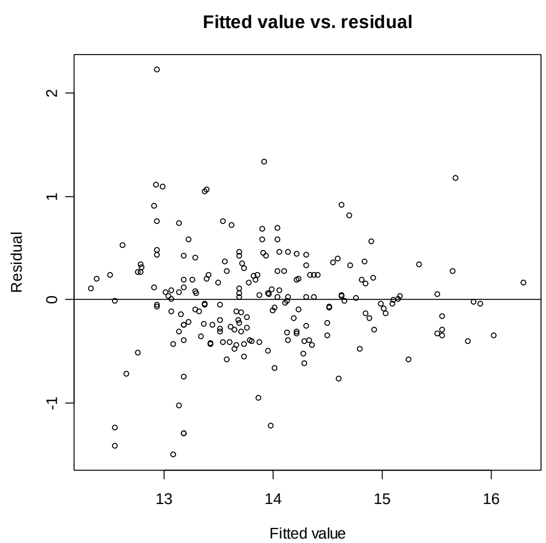
Tested:

L-cost = B_0 + B_1×L-length+B_2× Fund + B_3× L-length:Fund

Valid:

L-cost = 8.93 + 1.09 × L-length

Assumption validation



Linear regression result

	Estimate	Pr(>|t|)
B_0	8.93	<<0.001
B_1	1.09	<<0.001
B_2	0.54	0.38
B_3	-0.098	0.47
Adjusted R-squared: 0.72		

D. Project cost vs. project duration, bridge length and delivery method

A model including three independent variables (delivery type, project duration, and length) and interaction effects between the three variables was built next. The results are summarized in Table 7. The assumption of constant variance of the errors appears to be a valid for this data set when transformed values for project cost, project duration and length are used. Since the p-values for B_3, B_5, B_6, and B_7 are greater than 0.05 there is no evidence that project delivery type or the interaction between project delivery type and project duration or bridge length can be used to explain the observed variation in costs. This model does support a significant relationship between; project duration, bridge length, and project costs, with; duration, length, and the interaction between duration and length explaining a very significant portion (72%) of the observed variation in project costs as measured by the adjusted R-squared value of 0.72. Bridge length and project duration were both found to be significant predictors of project cost. A significant interaction effect between duration and length was also identified.

In summary, a model including project duration, bridge length, and the interaction between duration and length can explain approximately 79% of the variation observed in project costs. Differences observed in project costs were again found to not be attributable to the type of project delivery used (state or county), nor were significant interactions between delivery, duration, and/or length found.

Table 7: Project cost vs. project duration, bridge length and delivery method

Model variables

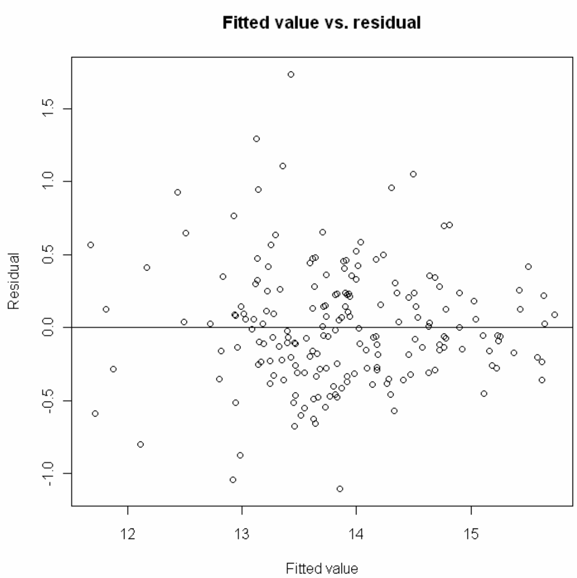
Type	Name	Description
Indicator	Fund	$\begin{cases} 1 & State-delivery \\ 0 & County-delivery \end{cases}$
Independent	L-duration	Log(duration)
Independent	L-length	Log(length)
Dependent	L-cost	Log(cost)

Model

Tested:
L-cost = B_0 + B_1×L-duration + B_2×L-length + B_3×Fund.ind + B_4×L-duration:L-length + B_5×L-length:Fund + B_6×L-duration:Fund+ B_7×L-duration:L-length:Fund

Valid:
L-cost = 1.57×L-duration + 2.51×L-length - 0.24×L-duration:L-length

Assumption validation



Linear regression results

	Estimate	Pr(>|t|)
B_0	-0.78	0.7837
B_1	1.57	0.0002
B_2	2.51	0.0002
B_3	11.71	0.230
B_4	-0.24	0.016
B_5	-2.51	0.256
B_6	-1.70	0.223
B_7	0.36	0.234
Adjusted R-squared: 0.79		

E. Project duration vs. delivery type

The impact of project delivery type (state or county) on bridge engineering design project duration was investigated next. Results are summarized Table 8. Since the p-value for B_0 and B_1 are << 0.001, there is evidence for project delivery being a significant variable in explaining the observed variation in project duration. The total project duration for county delivered projects was 714 days; whereas the total project duration for state delivered projects was 1022 days. A significant difference was also found when only the engineering design portion of projects was compared. While only a small portion of the variation in project duration (slightly less than 10%) can be explained by delivery type, the relationship is statistically significant.

In summary, project delivery type is a significant predictor of project duration. However, project delivery type explains only a very small percentage of the observed variation in project duration.

Table 8: Project duration and delivery method

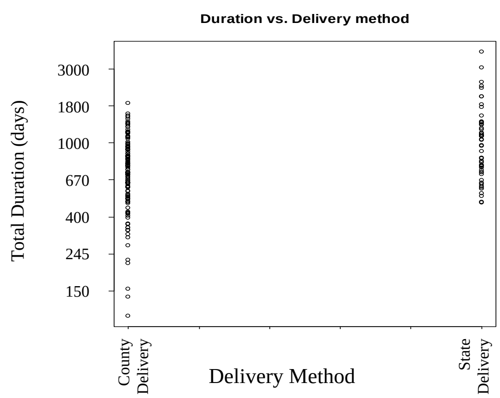
Model variables

Type	Name	Description
Indicator	Fund	$\begin{cases}1 & State-delivery \\ 0 & County-delivery\end{cases}$
Dependent	L-duration	Log (duration)

Model

Tested:
L-duration = $B_0 + B_1 \times$Fund

Valid:
L-duration = $6.57 + 0.36 \times$Fund



ANOVA results

	Estimate	Pr(>|t|)
B_0	6.57	< <0.001
B_1	0.36	<<0.001
Adjusted R-squared: 0.096		

F. Bridge length vs. delivery method

The relationships between project delivery type and bridge length was investigated next. This analysis was needed to determine if the two delivery methods could be distinguished based on bridge length, e.g. if only shorter bridges were built using county delivery and/or if longer bridges were only built using state delivery. The results of this analysis are summarized in Table 9. Since the p-values for B_1 (0.30) is greater than 0.05 there is no evidence that project delivery type is related to bridge length.

In summary, no significant relationship was found, for the bridge replacement projects included in this study, between bridge length and project delivery type.

Table 9: Bridge length vs. delivery method

Model variables

Type	Name	Description
Indicator	Fund	$\begin{cases} 1 & State-delivery \\ 0 & County-delivery \end{cases}$
Dependent	L-length	Log(length)

Model

Tested:
L-length = $B_0 + B_1 \times$Fund

Valid: NA

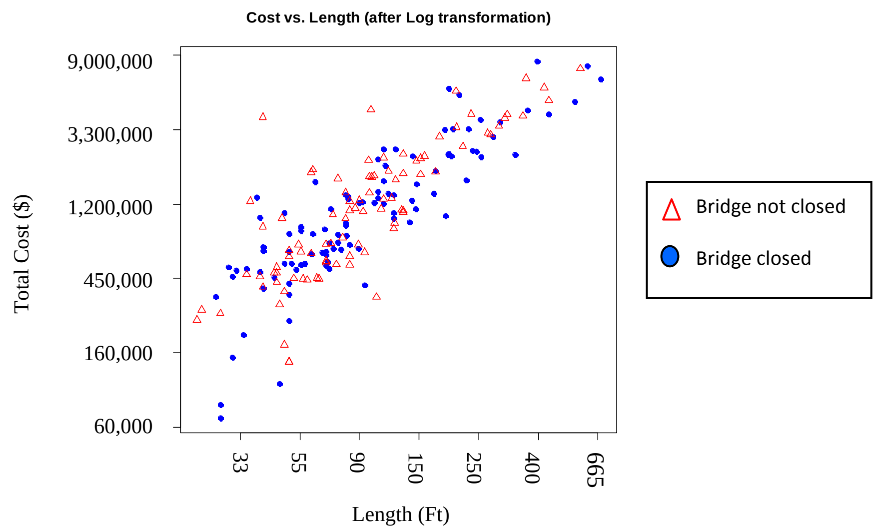
ANOVA results

	Estimate	Pr(>|t|)
B_0	4.56	< <0.001
B_1	-0.12	0.30
Adjusted R-squared: -0.004		

G. Project cost vs. project duration, bridge length, delivery method, and closure type

In the next analysis, a fourth variable, closure type, was included in the model. In the Phase I analysis, bridge closure was defined with an indicator variable, and projects were identified as having required bridge closure or not having required bridge closure. Project costs are plotted against project duration and bridge length for projects requiring closure and projects not requiring closure in Figure 11. It was necessary to use log transformations of cost, duration, and length to obtain a distribution of data appropriate for linear regression analysis.

In summary, the type of bridge closure was not found to have a significant relationship with either project duration or bridge length, with the initial categorization of bridges remaining open or bridges closed during the replacement project.



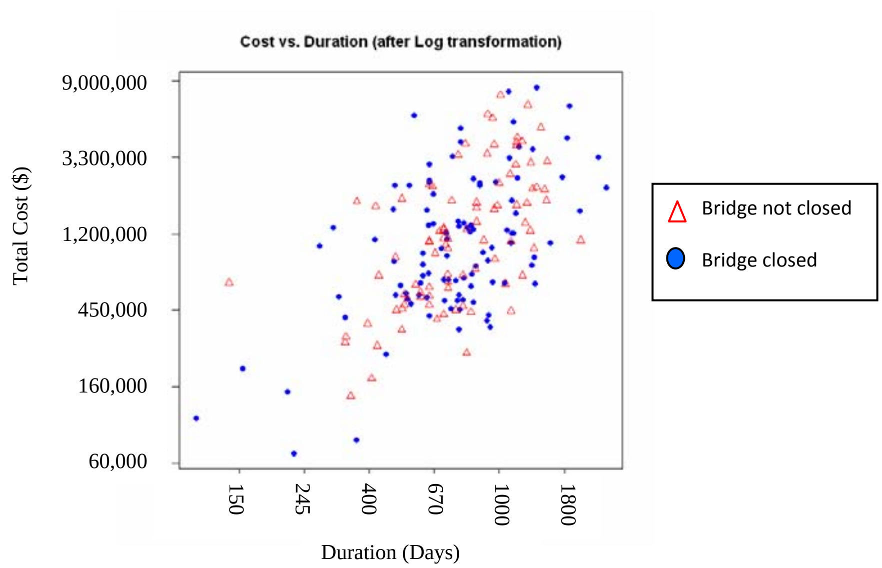


Figure 11: Scatter graph of project cost vs. project duration and vs. bridge length

H. Project cost vs. bridge length after removing upper and lower tails

Because the data set contained only a small number of state-delivered projects for shorter bridges and a small number of county-delivered projects for longer bridges, the upper and lower tails of the data set were removed to determine if a better model could be identified. The bridge projects that were removed from the data set are identified with a number in Figure 12. The results from this analysis are summarized in Table 10. The assumption of constant variance of the errors appears to be a valid assumption for this data set when transformed values for cost and length are used. Since the p-values for B_2 (0.90) and B_3 (0.94) are greater than 0.05 there is no evidence that project delivery type is related to project cost even when extreme points are removed from the data set.

In summary, even with higher and lower cost projects removed from the dataset, there was no indication that project costs could be predicted based on the type of delivery. Thus, data from all 190 bridge replacement projects are used for all remaining Phase I and Phase II analyses.

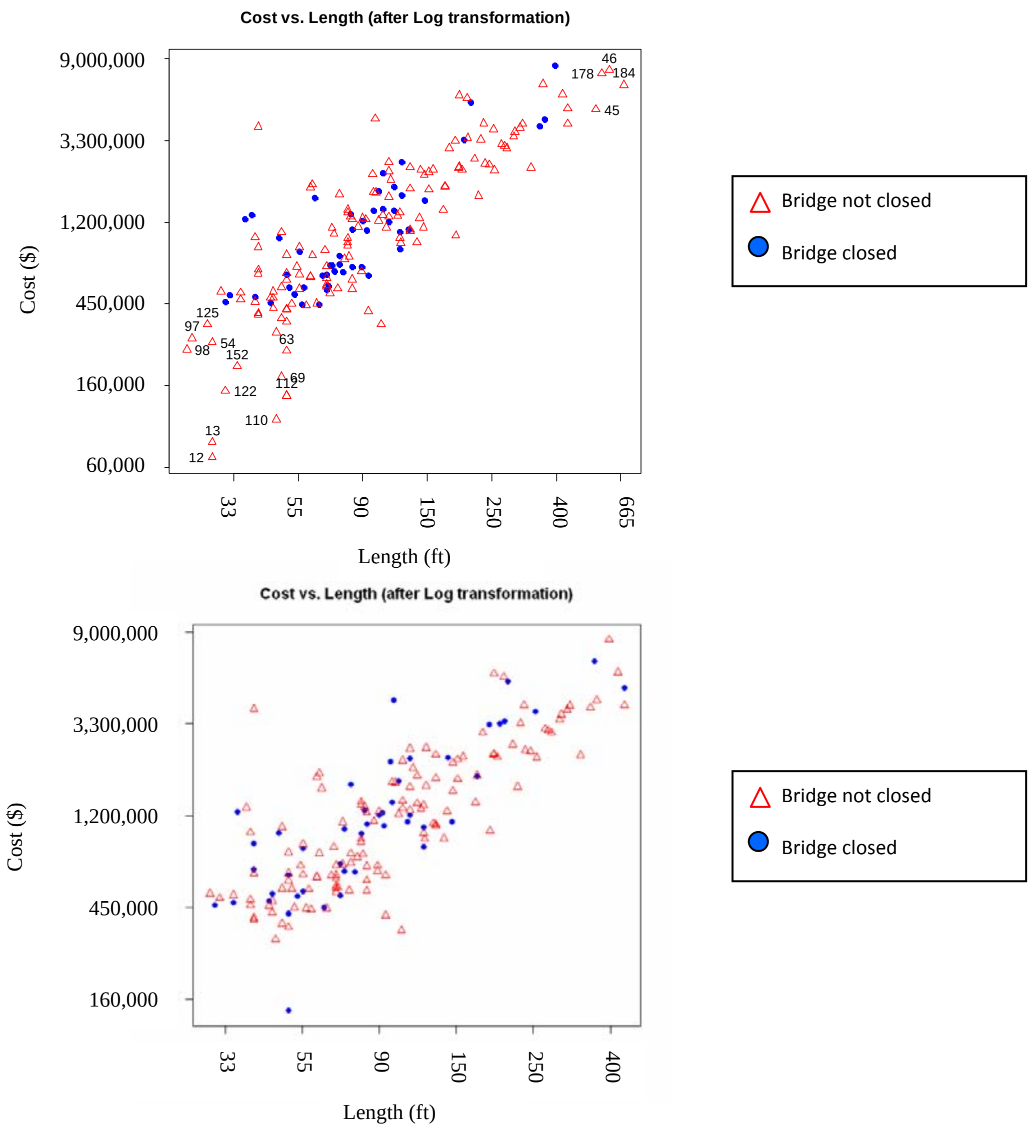


Figure 12: Scatter graphs of project cost vs. length with extreme points identified and after removing the upper and lower tails

Table 10: Project cost vs. bridge length after removing upper and lower tail data

Model variables

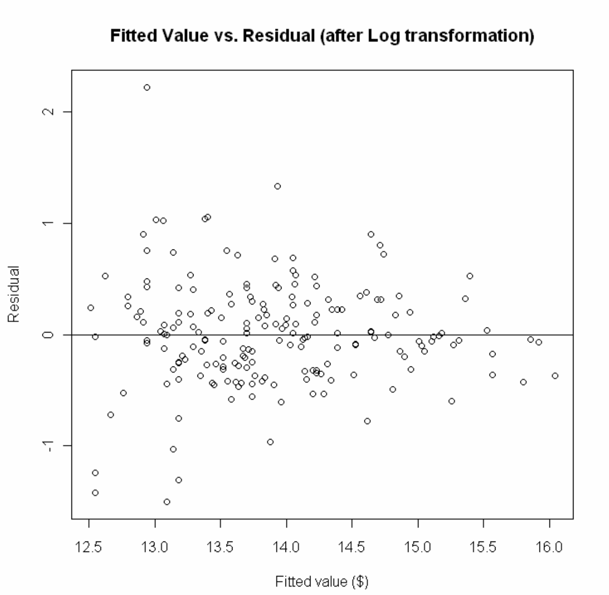
Type	Name	Description
Indicator	Fund	$\begin{cases} 1 & State-delivery \\ 0 & County-delivery \end{cases}$
Independent	L-length	Log(length)
Dependent	L-cost	Log(cost)

Model

Tested:
L-cost = B_0 + B_1×L-length+B_2× Fund + B_3× L-length:Fund

Valid:
L-cost = 9.39 + 0.99 × L-length

Assumption validation



Linear regression result

	Estimate	Pr(>|t|)
B_0	9.39	<<0.001
B_1	0.99	<<0.001
B_2	0.072	0.90
B_3	-0.0095	0.94
Adjusted R-squared: 0.62		

I. Project cost vs. engineering project duration

Project costs were also analyzed looking at only the engineering design portion of the project duration (eduration). As can be seen in Figure 13, log transformation of both engineering design costs and engineering design duration are necessary. After transforming the engineering cost and engineering design duration data, a regression model was tested. Results are summarized in Table 11. The assumption of constant variance of the errors appears to be a valid assumption for this data set when transformed values for cost and engineering design duration are used. Since the p-values for B_2 (0.53) and B_3 (0.50) are greater than 0.05 there is no evidence that either project delivery type or the interaction between project delivery type and the engineering design project duration can be used to explain the observed variation in costs. This model does support a significant relationship between project duration and project costs, with project duration explaining approximately 14% of the observed variation in project costs as measured by the adjusted R-squared value of 0.14. Differences observed in the project costs cannot be attributed to the type of project delivery used (state or county).

In summary, consistent with the total cost analysis, engineering design duration does account for some (approximately 14%) of the observed variation in engineering design costs.

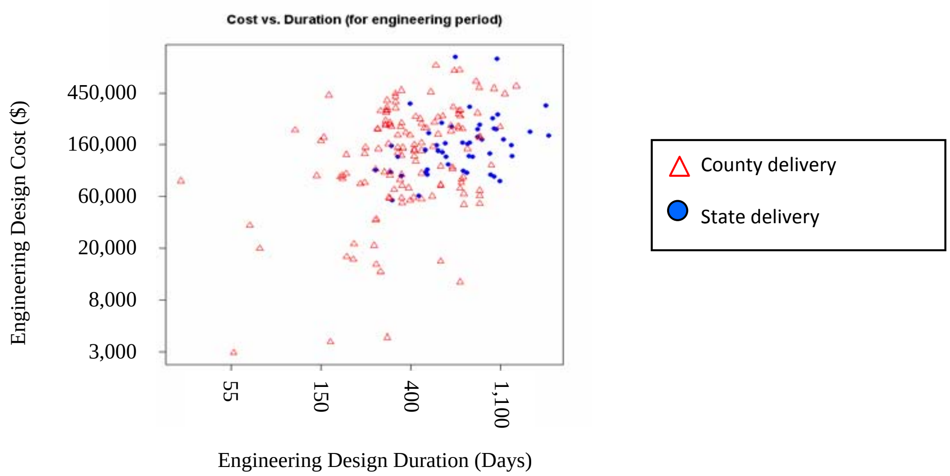


Figure 13: Scatter graph of the engineering design cost vs. engineering design duration

Table 11: Project cost vs. project duration during the engineering phase of the project

Model variables

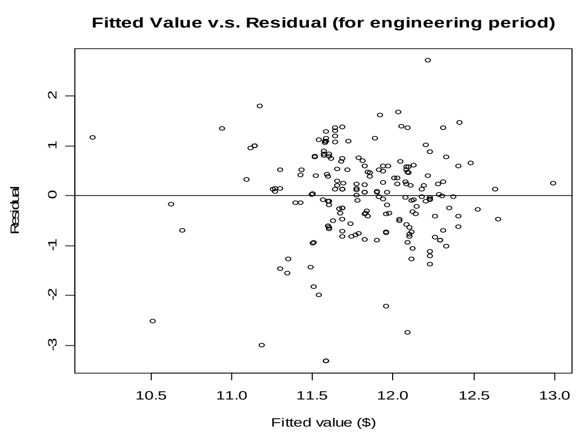
Type	Name	Description
Indicator	Fund	$\begin{cases} 1 & State-delivery \\ 0 & County-delivery \end{cases}$
Independent	L-eduration	Log(duration)
Dependent	L-cost	Log(cost)

Model

Tested:
L-cost = $B_0 + B_1 \times$L-eduration$+B_2\times$ Fund $+ B_3\times$ L-eduration:Fund

Valid:
L-cost = 7.99 + 0.63 × L-eduration

Assumption Validation



Linear regression result

	Estimate	Pr(>|t|)
B_0	7.99	<<0.001
B_1	0.63	<<0.001
B_2	1.25	0.53
B_3	-0.21	0.50
Adjusted R-squared: 0.1436		

V. Analysis Phase II

This section summarizes the findings resulting from the Phase II analyses. In this phase, four new variables (bridge width, clearance type, number of bids, and project location) were added to the study and one variable (bridge closure type) was refined. All of these new variables, except bridge width, were indicator variables. The goal of Phase II was to investigate whether or not these additional variables could be used to explain variation in costs for the 190 bridge replacement projects included in this study. For Phase II analyses, costs and durations were analyzed more closely depending on the variables included in a particular model. Engineering costs, construction costs, or total costs were used as appropriate to the particular analysis being performed. Similarly, engineering design, construction, or total durations were used depending on the variables being studied.

Three clearance types were defined for the study. The projects were divided depending on whether the bridge spanned over water, over a railroad, or over irrigation / canals. The number of bids received for each project was used to create three categories of bridge projects (projects with two or few bids, projects with three to five bids, and projects with six or more bids). Project location was categorized based on the geographical location of the project. Each project was located in one of the five defined regions. A refined bridge closure factor was defined based on whether a project used building stages, onsite detours, or offsite detours. The bridge closure variable used in Phase I categorized bridge projects based on whether or not bridge closure was required during construction. This previous definition led to some ambiguity, thus additional data were obtained to more clearly specify what method was used during construction. The notation used for Phase II variables is summarized in Table 12.

Table 12: Notation for Phase II variables

Item	Definition	Item	Definition
TCOST	Total Cost	L_TCOST	Log transformation of total cost
PCOST*	Preliminary engineering cost	L_PCOST	Log transformation of preliminary engineering cost
CCOST*	Construction cost	L_CCOST	Log transformation of construction cost
TDUR	Total Duration	L_TDUR	Log transformation of total duration
PDUR**	Engineering design duration	L_PDUR	Log transformation of engineering duration
CDUR**	Construction duration	L_CDUR	Log transformation of construction duration
LENGTH	Bridge length	L_LENGTH	Log transformation of length
WIDTH	Bridge width	L_WIDTH	Log transformation of width
REG.FACT	Region factor (1, 2, 3, 4, 5)	BC.FACT	Bridge closure factor (Built in stages, On-site detour, Off-site detour)
CT.FACT	Clearance type factor (Over water, over railroad, over irrigation/canal)		

*: TCOST=PCOST+CCOST **: TDUR=PDUR+CDUR

A. Project cost vs. clearance type

Project costs were analyzed as a function of clearance type. Analysis of variance was completed to determine if clearance type was a significant predictor. Based on the results from the analysis of variance, clearance type was found to be a significant predictor for project costs. Residuals were plotted against fitted values to confirm constant variance. Linear regression models were then built for each category of clearance. The results of these analyses are summarized in Table 13. Since the p-values for the analysis of variance is less than 0.05 there is evidence that clearance type can be used to explain the observed variation in project costs. Since the p-values for B_0 and B_2 are less than 0.05, three different cost equations can be created, one for each type of clearance. This model, however, explains only a very small percentage (3%) of the observed variation (adjusted R-squared = 0.03). The average project cost for bridges built over railroad are higher than projects replacing bridges built over water or irrigation/canals. The least expensive bridge replacement projects are those where the bridge is built over irrigation/canals.

In summary, although the cost models for the clearance type do differ, clearance type explains only a very small portion (3%) of the observed variation in project costs. The same analyses were also completed, using only construction costs as the dependent variable. Parallel results were found.

Table 13: Project cost vs. clearance type

Model variables

Type	Name	Description
Indicator	CT_OR	$\begin{cases} 1 & over-railroad \\ 0 & over-water \end{cases}$
Indicator	CT_OI	$\begin{cases} 1 & over-irr/canal \\ 0 & over-water \end{cases}$
Dependent	L_TCOST	Log(TCOST)

Model

Tested:

$$L\_TCOST = B_0 + B_1 \times CT\_OR + B_2 \times CT\_OI$$

Valid:

L_TCOST1=13.43 (Avg. cost over water)
L_TCOST2=13.74 (Avg. cost over railroad)
L_TCOST3=12.95 (Avg. cost over irrigation/canal)

Analysis of Variance results

	Df	Pr(>F)
CT.FACT	2	0.01420
Residuals	0.92	

Linear regression results

	Estimate	Pr(>|t|)
B_0	13.43	<<0.001
B_1	0.32	0.589
B_2	-0.79	<<0.001
Adjusted R-squared: 0.03427		

B. Construction cost vs. bridge closure

Construction costs were analyzed next as a function of bridge closure type. The results for construction cost are summarized in Table 14. Residuals were plotted against fitted values to confirm constant variance. Analysis of variance was completed to determine if bridge closure type was a significant predictor of construction costs. The p-value was slightly larger than 0.05. Linear regression models were then built for each category of closure (on-site detour, off-site detour, and staged build). Since the p-values for B_0 and B_2 are less than 0.05, two different cost equations can be created, one for on-site or off-site detours and one for projects where staged builds were used. The average project cost for bridges in which a staged build was used are higher than projects using either on or off-site detours. This model, however, explains only a very small percentage (< 2%) of the observed variation (adjusted R-squared = 0.02).

In summary, although the cost models for the closure type do indicate that projects using a staged build have higher construction costs, the observed impact on construction costs was minimal.

Table 14: Construction cost vs. bridge closure type

Model variables

Type	Name	Description
Indicator	BC_OF	$\begin{cases} 1 & \textit{offsite} \\ 0 & \textit{onsite} \end{cases}$
Indicator	BC_BS	$\begin{cases} 1 & \textit{builtinstage} \\ 0 & \textit{onsite} \end{cases}$
Dependent	L_CCOST	Log(CCOST)

Model

Tested:

$$L\_CCOST = B_0 + B_1 \times BC\_OF + B_2 \times BC\_BS$$

Valid:

L_CCOST1=13.28 (Avg. cost on-site detour or off-site detour)

L_CCOST2=13.72 (Avg. cost built in stages)

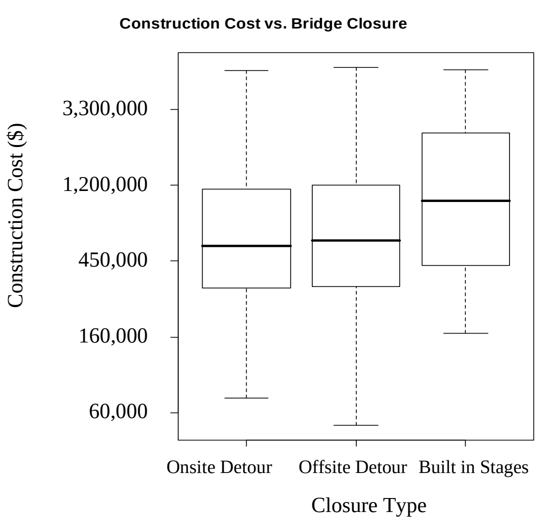
ANOVA

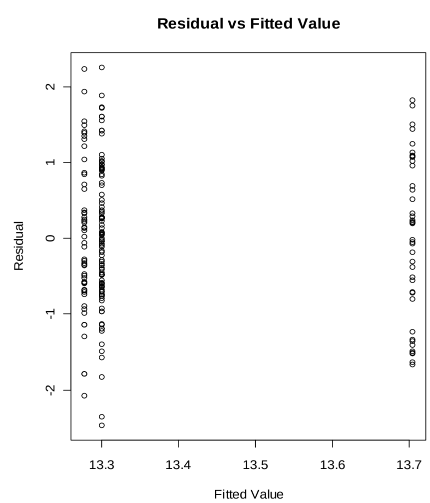
	Df	Pr(>F)
BC.FACT	2	0.05843
Residuals	0.93	

Linear regression results

	Estimate	Pr(>|t|)
B_0	13.28	<<0.001
B_1	0.02288	0.8904
B_2	0.42719	0.0369
Adjusted R-squared: 0.01954		

Results and assumption validation





C. Construction cost vs. number of bids

The next variable that was analyzed was the number of bids received for a bridge replacement project. Construction costs were analyzed vs. number of bids using a linear regression model. The results are summarized in Table 15. Residuals were plotted against fitted values to confirm constant variance. Linear regression models were then built for each of three categories of bids received (two or fewer bids, three to five bids, and six or more bids). Since the p-values for B_0, B_0, and B_2 are less than 0.05, three different construction cost equations can be created, one for category of bids. This model explains approximately 10% of the variation observed in construction costs (adjusted R-squared = 0.10). However, this variable does not explain a significant portion of total project costs.

In summary, the number of bids received for a bridge replacement project is related to the construction costs of the completed project, but is not a significant predictor of total project costs.

Table 15: Construction costs vs. number of bids

Model variables

Type	Name	Description
Indicator	Bids1	$\begin{cases} 1 & three\_to\_five \\ 0 & two\_or\_fewer \end{cases}$
Indicator	Bids2	$\begin{cases} 1 & six\_or\_more \\ 0 & two\_or\_fewer \end{cases}$
Dependent	L_CCOST	Log(CCOST)

Model

Tested:

L_CCOST = $B_0 + B_1 \times$ Bids1 + $B_2 \times$ Bids2

Valid:

Valid model 1:

L_CCOST= 13.04 (Two or fewer bids)

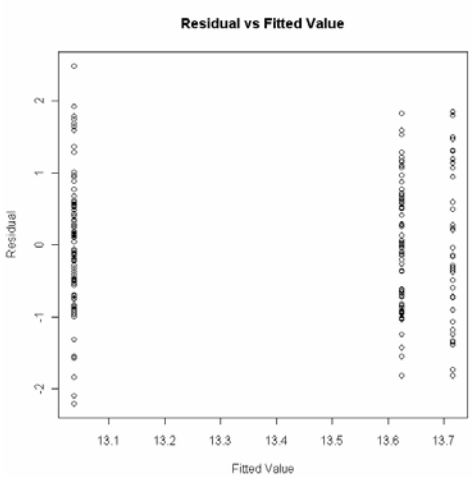
Valid model 2:

L_CCOST=13.63 (Three to five bids)

Valid model 3:

L_CCOST=14.31(Six or more bids)

Assumption Validation



Linear regression results

	Estimate	Pr(>|t|)
B_0	13.04	0.000
B_1	0.59	0.000
B_2	0.68	0.000
Adjusted R-squared: 0.101		

D. Project duration vs. region

Project duration compared to regions was analyzed using linear regression models. Three different durations were analyzed; the design duration, the construction duration, and the total project duration. The results are summarized in Tables 16, 17, and 18, respectively. Residuals were plotted against fitted values to confirm constant variance for all three models. In the first linear regression model analyzing the relationship between design duration and region, the p-values for the parameters were significant for the parameters for four of the five regions. Regions 4 and 5 had the lowest engineering design durations (averaging approximately 345 days). Regions 1 and 2 had the highest average engineering durations (averaging 626 days). The average design duration for Region 3 was 459 days. Approximately 10% (adjusted R-squared = 0.10) of the variation in design duration can be explained by differences due to the location of the bridge replacement project.

Table 16: Design duration vs. region

Model variables

Type	Name	Description
Indicator	Reg2	$\begin{cases} 1 & region\_2 \\ 0 & region\_1 \end{cases}$
Indicator	Reg3	$\begin{cases} 1 & region\_3 \\ 0 & region\_1 \end{cases}$
Indicator	Reg4	$\begin{cases} 1 & region\_4 \\ 0 & region\_1 \end{cases}$
Indicator	Reg5	$\begin{cases} 1 & region\_5 \\ 0 & region\_1 \end{cases}$
Dependent	L_PDUR	Log(PDUR)

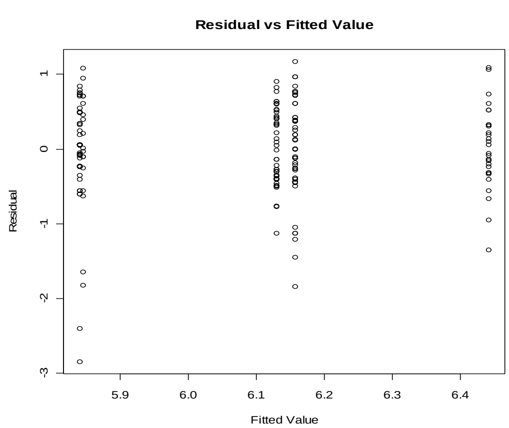
Model

Tested:

$L\_PDUR = B_0 + B_1 \times Reg2 + B_2 \times Reg3 + B_3 \times Reg4 + B_4 \times Reg5$

Valid model 1:
L_PDUR= 6.44 (regions 1 and 2)
Valid model 2:
L_PDUR=6.13 (region 3)
Valid model 3:
L_PDUR= 5.85 (region 4)
Valid model 4:
L_PDUR= 5.84 (region 5)

Assumption Validation



Linear regression results

	Estimate	Pr(>|t|)
B_0	6.44	0.000
B_1	-0.28	0.051
B_2	-0.31	0.031
B_3	-0.59	0.001
B_4	-0.60	0.000
Adjusted R-squared: 0.101		

In the second linear regression model analyzing the relationship between construction duration and region, the p-values for the parameters were significant for only Region 4. Regions 1, 2, 3, and 5 had average construction durations of 305 days; whereas the average construction duration for Region 4 was 194 days. Approximately 10% (adjusted R-squared = 0.10) of the variation in construction duration can be explained by differences due to the location of the bridge replacement project.

Table 17: Construction duration vs. region

Model variables

Type	Name	Description
Indicator	Reg2	$\begin{cases} 1 & region\_2 \\ 0 & region\_1 \end{cases}$
Indicator	Reg3	$\begin{cases} 1 & region\_3 \\ 0 & region\_1 \end{cases}$
Indicator	Reg4	$\begin{cases} 1 & region\_4 \\ 0 & region\_1 \end{cases}$
Indicator	Reg5	$\begin{cases} 1 & region\_5 \\ 0 & region\_1 \end{cases}$
Dependent	L_CDUR	Log(CDUR)

Model

Tested:

L_CDUR = $B_0 + B_1 \times$ Reg2 + $B_2 \times$ Reg3 + $B_3 \times$ Reg4 + $B_4 \times$ Reg5

Valid model 1:

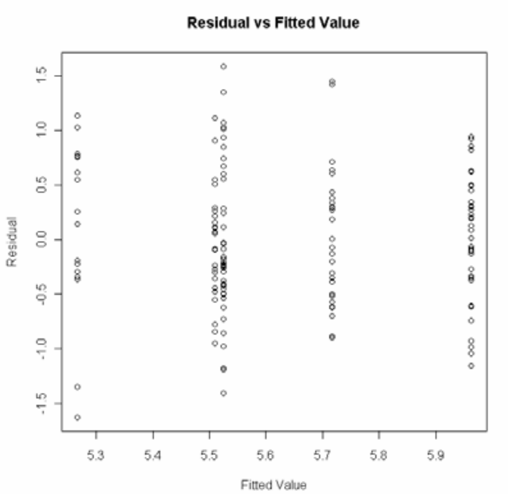
model 1:

L_CDUR= 5.72 (regions 1, 2, 3, and 5)

model 2:

L_CDUR=5.27 (region 4)

Assumption Validation



Linear regression results

	Estimate	Pr(>|t|)
B_0	5.72	0.000
B_1	-0.19	0.170
B_2	0.25	0.083
B_3	-0.45	0.017
B_4	-0.21	0.156
Adjusted R-squared: 0.101		

In the third linear regression model, which analyzed the relationship between the total project duration and region, the p-values for the parameters were significant for only Regions 4 and 5. Regions 1, 2, and 3 had average project durations of 972 days; whereas the average project duration for Region 4 was 584 days and was 633 days for Region 5. Approximately 10% (adjusted R-squared = 0.10) of the variation in project duration can be explained by differences due to the location of the bridge replacement project.

In summary, projects take longer in the Regions 1, 2, and 3 than in Regions 4 and 5.

Table 18: Total project duration vs. region

Model variables

Type	Name	Description
Indicator	Reg2	$\begin{cases}1 & region\_2\\ 0 & region\_1\end{cases}$
Indicator	Reg3	$\begin{cases}1 & region\_3\\ 0 & region\_1\end{cases}$
Indicator	Reg4	$\begin{cases}1 & region\_4\\ 0 & region\_1\end{cases}$
Indicator	Reg5	$\begin{cases}1 & region\_5\\ 0 & region\_1\end{cases}$
Dependent	L_TDUR	Log(TDUR)

Model

Tested:

L_TDUR = $B_0 + B_1 \times$ Reg2 + $B_2 \times$ Reg3 + $B_3 \times$ Reg4 + $B_4 \times$ Reg5

Valid:

model 1:

L_TDUR= 6.88 (regions 1, 2, and 3)

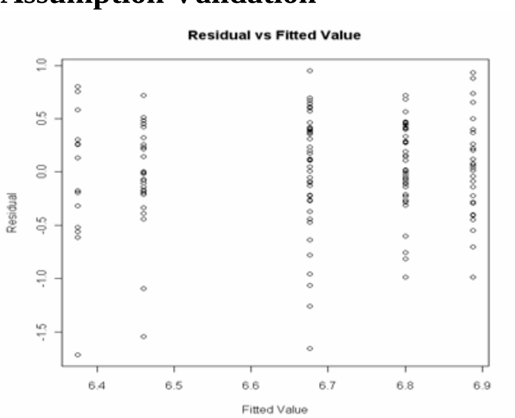
model 2:

L_TDUR=6.37 (region 4)

model 3:

L_DUR= 6.45 (region 5)

Assumption Validation



Linear regression results

	Estimate	Pr(>|t|)
B_0	6.88	0.000
B_1	-0.21	0.052
B_2	-0.09	0.414
B_3	-0.51	0.000
B_4	-0.43	0.000
Adjusted R-squared: 0.102		

VI. Conclusions

This study was focused on determining whether or not the source of funding was a significant factor in determining bridge replacement project costs. A secondary purpose of the study was to identify key variables that could be used to explain observed variations in project costs. Data from 190 bridge replacement projects was used in the analyses described in this report. Based on the analyses completed, variation in total project costs can be explained primarily by the length of the bridge being replaced, the width of the bridge being replaced, and the overall duration of the project. A small amount of the variation observed in project length (approximately 5%) can be attributed to the clearance type (over water, over railroad, or over irrigation/canal). Similarly, a small amount (10%) of the variation observed in project duration can be attributed to the type of delivery.

Overall, it was shown that for the 190 bridges included in this study, the type of delivery (state or county) does not impact project costs directly. There was also no evidence that bridge closure type when treated as a binary (closed or not closed) or indicator variable (built in stages, off-site detour, or on-site detour) can explain the observed variations in project costs.

The number of bids and the location of the bridge replacement project were both found to have a small impact on construction costs but did not explain a significant portion of the observed variation in total project costs.

The best model found, as a result of the analysis, is the model that includes project duration, bridge length, and bridge width (p-value < 0.001, adjusted R-square= 0.86). In this model, project delivery type was found to impact project duration, which in turn impacted project costs. The majority of variation in project costs can be explained by bridge length (adjusted R-square = 0.72). The general relationship between cost and the other independent variables found to be significant is summarized in Figure 7.

VII. Appendix A: Bridges included in analysis

County	Original NBIS #	New NBIS #	Bridge Name	Road Name	Funding Source
Baker County	01C408	20259	Burnt R Clarks Creek Rd.	County Rd. 1121	OTIA III
Baker County	01C227	20258	Cracker Crk/Cracker Cr. R.	C-553 NON-FA	OTIA III
Baker County	01C522	19803	Dixie Creek	Rye Valley Road	OTIA I
Baker County	00741	19280	Pritchard Cr (Old US 30)	County Rd 539	HBP
Benton County	14103	N/A	Bottger Creek	Hoskins Road	Local
Benton County	14185	19616	Flat Creek	Old River Road	OTIA I
Benton County	03C10	19216	Muddy Creek	Airport Road	HBP
Benton County	14401	19862	Muddy Creek	Llewellyn Road	OTIA I
Benton County	14402	18865	Muddy Crk Overflow Channel	Llewellyn Road	HBP
Benton County	14195	19215	Newton Creek	Chapel Drive	HBP
Benton County	14122	20130	Oliver Creek	Bellfountain Rd.	OTIA III
Benton County	14523A	N/A	Stewart Slough	Seavy Ave	Local
Benton County	14528	20731	West Fork Mary's River	Long Road	HBP
Clackamas County	06223	18285	Abernethy Creek	Anchor Way	HBP
Clackamas County	05C09	19119	Abernethy Creek	Washington Street	HBP
Clackamas County	N/A	20793	Bear Creek	Lolo Pass Road	Local
Clackamas County	N/A	20779	Buckner Creek	Beavercreek Road	Local
Clackamas County	06607	18853	Eagle Creek	Rainbow Road	HBP
Clackamas County	06541	20149	Milk Creek	Dhooge Road	OTIA III
Clackamas County	06511	20147	Milk Creek	Mulino Road	OTIA III
Clackamas County	06562	19749	Mill Creek	Graves Road	OTIA I
Clackamas County	00605	20148	Molalla River	Fryrer Park Road	OTIA III
Clackamas County	06429	18095	Oswego Canal	Childs Road	HBP
Clackamas County	06605	19593	Salmon River	East Bridge Road	HBP
Clackamas County	06401	19951	Zigzag River	Lolo Pass Road	HBP
Clatsop County	11158A	18842	Lower Walluski Road	Labiske Road	HBP
Clatsop County	11159A	18843	Upper Walluski Road	Labiske Road	HBP
Columbia County	13378	19118	Beaver Creek	Heath Road	HBP
Columbia County	00157	20059	Beaver Creek	Old Hwy 30 @ MP 4.60	HBP
Columbia County	00155	20058	Beaver Creek	Old Hwy 30 @ MP 5.49	HBP
Columbia County	13771A	20653	East Fork Nehalem River	Scappoose-Vernonia Hwy.	OTIA III
Columbia County	13746A	20655	Lizzie Creek	Chapman Road	OTIA III
Columbia County	13791A	20658	Lost Creek	Lost Creek Road	OTIA III
Columbia County	09C22	20654	North Fork Scappoose Creek	Chapman Grange Road	OTIA III
Columbia County	13764A	20652	North Fork Scappoose Creek	Scappoose-Vernonia Hwy.	OTIA III
Columbia County	9C158	N/A	South Beaver Creek	Old Hwy 30	OTIA III
Columbia County	13626A	20656	Tide Creek	Anliker Road	OTIA III
Coos County	08927	20126	Beaver Slough	Leneve Bridge	OTIA III
Coos County	11C22	19665	Cunningham Creek	Cunningham Road	HBP
Coos County	11C108	18850	Drain Ditch	Benson Creek Road	HBP
Coos County	11C113	20356	Kentuck Slough	County Rd. 45	OTIA III
Coos County	C1101	18821	Larson Creek	County Road 7A	HBP

County	Original NBIS #	New NBIS #	Bridge Name	Road Name	Funding Source
Coos County	11C53	20102	Noble Creek	County Rd. 186	OTIA III
Coos County	01314A	20127	North Fork Coquille River	Cooper	OTIA III
Coos County	08464	20128	North Fork Coquille River	Gravelford Road	OTIA III
Coos County	11C90X	18854	Saunders Lake	County Road 220A	HBP
Coos County	08859	20129	Stringtown Overflow	County Rd. 5A	OTIA III
Coos County	11C78	20205	Upper Rock Creek	County Rd. 21C	OTIA III
Crook County	16636	19913	Crooked River	Conant Basin Road	HBP
Crook County	13C12	19026	Crooked River	Elliot Lane	HBP
Crook County	13C28	20027	Crooked River	Newsom Road	OTIA III
Crook County	371-1	N/A	Irrigation Ditch	Riggs Road East	OTIA III
Crook County	13C36A	18955	Ochocco Creek	Willowdale Road	HBP
Deschutes County	09C35	19610	Johnson Market Bridge	Johnson Market Road	OTIA I
Douglas County	19C067	18903	Bachelor Creek	County Road 50	HBP
Douglas County	19C486	20369	Calapooya Creek	County Rd. 9	OTIA III
Douglas County	19C495	20531	Cow Creek	County Rd. 21	OTIA III
Douglas County	19C472	20317	Days Creek	Tiller-Trail Hwy.	OTIA III
Douglas County	19C023	20154	Deadman Creek	South Umpqua River Road	OTIA III
Douglas County	19C481	20502	Diamond Creek	Tiller-Trail Hwy.	OTIA III
Douglas County	19C431	20411	Emile Creek	Little River Road	OTIA III
Harney County	25E32	N/A	Crane Creek	Crane - Venator	Local
Harney County	25D01	20453	Dry Creek	Catlow Valley Road	OTIA III
Harney County	25C02	N/A	Dunder Und Blitzen	Narrows - Princeton	Local
Harney County	25A82	20455	Ninemile Slough	IRR C106	OTIA III
Harney County	25E10	20279	North Drewsey Slough	Drewsey Road	OTIA III
Harney County	25E24	19624	Pine Creek	Pine Creek Road	HBP
Harney County	25A16	20454	Silver Creek Slough	Silver Creek Road	OTIA III
Harney County	25A22	N/A	Silvies River - West Loop	West Loop	OTIA II
Harney County	25E11	20280	South Drewsey Slough	Drewsey Road	OTIA III
Harney County	25A43	19922	West Fork Silvies River	Greenhouse Lane	OTIA II
Jackson County	29C195	20177	Antelope Creek	E. Antelope Road	Local
Jackson County	29C34	20178	Antelope Creek	Meridan Road	OTIA I
Jackson County	07811	20121	Applegate River	Applegate Road	OTIA III
Jackson County	08038	20122	Applegate River	Applegate Road	OTIA III
Jackson County	07503	20087	Bear Creek	County Road No. 960	OTIA III
Jackson County	06947	19630	Bear Creek	East Pine Street	HBP
Jackson County	07703	18869	BEAR CREEK	Kirtland Road	HBP
Jackson County	07990	20086	Bear Creek	West Valley View Road	OTIA III
Jackson County	07905	20067	Beaver Creek	Applegate Road	OTIA III
Jackson County	29C224	20187	Big Butte Creek	Netherlands Road	OTIA I
Jackson County	N/A	N/A	Cottonwood Creek	Colestin Road	Local
Jackson County	08707	20083	Emigrant Creek	Dead Indian Road	OTIA III
Jackson County	08914	20055	Evans Creek	Evans Creek Road	OTIA III
Jackson County	07229	20056	Evans Creek	Evans Creek Road	OTIA III
Jackson County	29C218	19614	Foots Creek	Right Fork Foots Creed Road	OTIA I
Jackson County	29C185	N/A	Galls Creek	Galls Creek Road	Local

County	Original NBIS #	New NBIS #	Bridge Name	Road Name	Funding Source
Jackson County	07988	20220	Little Applegate River	Applegate Road	HBP
Jackson County	29C198	20105	Pleasant Creek	Pleasant Creek Road	OTIA I
Jackson County	07819	20071	Red Blanket Creek	Butte Falls-Prospect Hwy.	OTIA III
Jackson County	29C220	19615	Right Fork Foots Creek	Foots Creek Road	OTIA I
Jackson County	07708	20072	Snider Creek	Table Rock Road	OTIA III
Jackson County	07989	20068	Star Gulch Creek	Applegate Road	OTIA III
Jackson County	07687	20478	Thompson Creek	Thompson Creek Road	OTIA III
Jackson County	07688	20479	Thompson Creek	Thompson Creek Road	OTIA III
Jackson County	07689	20481	Thompson Creek	Thompson Creek Road	OTIA III
Jackson County	29C79	19780	Wagner Creek	Wagner Creek Road	Local
Jackson County	29C80	20458	Wagner Creek	Wagner Creek Road	Local
Jefferson County	31C50A	20042	Irrigation Canal	Park Lane	OTIA III
Jefferson County	31C071	19779	Trout Creek	Gosner Road	OTIA II
Josephine County	122005	20350	Coyote Creek	Bloom Road	OTIA III
Josephine County	144005	19680	Grave Creek	Beecher Road	HBP
Josephine County	250005	20723	Jones Creek	Foothill Blvd.	OTIA III
Josephine County	33C13	20508	Sucker Creek	Holland Loop Road	OTIA III
Josephine County	420005	18908	West Fork Williams Creek	East Fork Road	HBP
Klamath County	08103	19068	"A" Canal	Homedale Road	HBP
Klamath County	18C025	20363	Lost River	Crystal Springs Road	Local
Klamath County	06745	20380	Sprague River	Sprague River Road	OTIA III
Klamath County	06835B	20382	Sprague River	Sprague River Road	OTIA III
Lake County	37C041	20076	Deep Creek	3-14	OTIA III
Lake County	37C043	19841	Dick's Creek	Crooked Creek	Local
Lake County	N/A	20445	Lower Crane Creek	Crane Creek 1-15	OWEB
Lake County	N/A	20446	Upper Crane Creek	Crane Creek 1-15	OWEB
Lane County	14875A	N/A	Big River	London Road	OTIA III
Lane County	39C224	20354	Row River	Row River Road	OTIA III
Linn County	N/A	19730	Calapooia River	Driver Raod	HBP
Linn County	12240	20257	Calapooia River	Tangent Drive	OTIA III
Linn County	12764	20331	Calapooia River	Wirth Road	OTIA III
Linn County	11965	18963	Hamilton Creek	Plagman Drive	HBP
Linn County	02623	20565	Thomas Creek	Scio-Main Street	OTIA III
Malheur County	45C135	18946	Alkali Creek	Woodbridge Road	HBP
Malheur County	45C121	19697	Bull Creek Canal	Bully Creek Road	OTIA I
Malheur County	15521A	20281	Drain Ditch	Harper-Westfall Road	OTIA III
Malheur County	45R10	19921	Low Lift Canal	Fir Road	OTIA I
Malheur County	45C220	19920	Owyhee Canal	Clark Boulevard	OTIA I
Malheur County	45C119	19676	Vale Main Canal	Reservoir Road	Local
Marion County	47C53	20330	Abiqua Creek	South Abiqua Road	HBP
Marion County	1501	20620	Mill Creek	Marion Road SE	Local
Marion County	47C22	20091	Pudding River	Mt. Angel-Gervais Road	OTIA III
Marion County	47C21	20217	Pudding River (Overflow)	Mt. Angel-Gervais Road	OTIA III
Marion County	01106	20150	Rail Road	Jeffrson-Marion Hwy.	OTIA III
Morrow County	49C23	20073	Rhea Creek	Brenner Canyon Road	OTIA I

County	Original NBIS #	New NBIS #	Bridge Name	Road Name	Funding Source
Multnomah County	04522	N/A	Beaver Creek Bridge	Beaver Creek Bridge	OTIA I
Polk County	53B04	19969	Little Luckiamute River	Bridge Street	OTIA III
Polk County	53C112	18939	Little Luckiamute River	Socialist Valley Road	HBP
Polk County	53C017	19978	Luckiamute River	Airlie Road	OTIA III
Polk County	10307A	19970	Luckiamute River	Buena Vista Road	OTIA III
Polk County	53C013	19976	Luckiamute River	Corvallis Road	OTIA III
Polk County	53C083	19974	Rickreal Creek	Rickreall Road	OTIA III
Polk County	53C029	19975	Rickreall Creek	Greenwood Road	OTIA III
Polk County	53C077	19973	Rock Creek	Fire Hall Road	OTIA III
Polk County	53C110)	20299	Teal Creek	Frost Road	HBP
Polk County	53C113	19972	Willamette River Overflow	Wigrich Road	OTIA III
Tillamook County	57C28	20629	Bewley Creek	Bewley Creek Road	OTIA III
Tillamook County	57C26	19625	Blaser Bridge	Tillamook River Road	OTIA I
Tillamook County	06550	N/A	Earl Bridge	Long Prairie Road	OTIA II
Tillamook County	57C45	20106	East Creek	Moon Creek Road	OTIA III
Tillamook County	57C29	20630	Killam Creek	South Prairie Road	OTIA III
Tillamook County	57C73	18984	Neskowin Creek	Cascade Trace Road	HBP
Tillamook County	11380A	20276	Nestucca River	Blaine Road	OTIA III
Tillamook County	57C35	20625	Wilson River	Kansas Creek Road	OTIA III
Umatilla County	59C636	20284	Despain Gulch	Despain Gulch Road	OTIA III
Umatilla County	59C535	18942	Dry Creek	Harris Rd	HBP
Umatilla County	59C422	20256	Dry Creek	Steen Road	OTIA II
Umatilla County	59C714	20285	Greasewood Creek	Columbia Street	OTIA III
Umatilla County	59C680	20368	Stage Gulch Ditch	Cooper Road	HBP
Umatilla County	59C212	18954	US Feed Canal	Cooper Road	HBP
Umatilla County	59C205	19987	US Feed Canal	Stage Gulch Road	HBP
Umatilla County	59C627	20283	Vansycle Canyon	Butler Grade Road	OTIA III
Umatilla County	59C358	18938	Wildhorse Creek	McCormach Road	HBP
Union County	61C21	20174	Catherine Creek	Badger Flat Lane	OTIA I
Union County	61C19	20176	Grande Ronde River	McKennon Lane	OTIA II
Union County	61C30	20175	Little Creek #5	High Valley Road	OTIA I
Wallowa County	63C13	20588	Bear Creek	Bear Creek Road	OTIA III
Wallowa County	63C01	20587	Bear Creek	Frontage Road	OTIA III
Wallowa County	63C81	20388	Imnaha River	Lower Imnaha Road	HBP
Wallowa County	63C80	20447	Imnaha River	Upper Imnaha Road	OTIA III
Wallowa County	63C79	20448	Imnaha River	Upper Imnaha Road	OTIA III
Wallowa County	063C17	20287	Trout Creek	Golf Course Road	OTIA III
Wallowa County	63C137	19939	Wallowa River	Baily Lane	HBP
Wallowa County	63C35	20288	Wallowa River	Ed Long	OTIA I
Wallowa County	63C36	20289	Wallowa River	Orval Makin	OTIA II
Wallowa County	63C019	18802	Wallowa River	Wade Gulch Road	HBP
Wasco County	00106	18774	Eightmile River	Lower Eightmile Road	HBP
Washington County	671664	N/A	Beaver Creek	Timber Road	OTIA III
Washington County	671367	20437	East Fork Dairy Creek	Greener Road	OTIA III
Washington County	671276	18951	Galls Creek	Clapshaw Hill Road	HBP

County	Original NBIS #	New NBIS #	Bridge Name	Road Name	Funding Source
Washington County	671389	20297	Nehalem River	Timber Road	OTIA III
Washington County	671391	20296	Nehalem River	Vernonia Road	OTIA III
Washington County	01767	20069	Tualatin River	OR 10 (Hwy 142)	HBP
Washington County	671235	19619	Tualatin River	Rood Bridge Road	OTIA II
Washington County	671418	20295	Tualatin River	SW Scholls Ferry Road	OTIA III
Washington County	671234	19193	Tualatin River Overflow	Minter Bridge Road	OTIA I
Yamhill County	11540A	20065	Baker Creek	Baker Creek Road	OTIA III
Yamhill County	11566	20066	North Yamhill River	Meadow Lake Road	OTIA III
Yamhill County	11605	19880	Panther Creek	Rex Brown Road	OTIA I
Yamhill County	11774C	19161	Willamina Creek	Tindle Creek Road	HBP
Yamhill County	01751A	20088	Willamina Creek	Willamina Creek Road	OTIA III
Yamhill County	11493A	20351	Yamhill River	Lafayette Hwy.	OTIA III
Yamhill County	11645	20329	Yamhill River	Moores Valley Road	OTIA III

VIII. Appendix B: Bridges excluded from analysis

County	Original NBIS #	New NBIS #	Bridge Name	Road Name	Funding Source	Reason for Exclusion
Benton County	14538	N/A	Alsea River	Hayden Road	OTIA I	Covered Bridge Rehabilitation
Clackamas County	01446	N/A	Clackamas River	Springwater Road	OTIA III	Project Not Completed
Clackamas County	06135	20408	Johnson Creek	Johnson Ck. Blvd.	OTIA III	Project Not Completed
Clackamas County	06570	20415	Sandy River	Ten Eyck Road	OTIA III	Project Not Completed
Clackamas County	06507	20765	Tualatin River	Boarland Road	OTIA III	Project Not Completed
Clackamas County	02567	N/A	Tualatin River	Stafford Road	OTIA III	Project Not Completed
Columbia County	00136	20057	Beaver Creek	Old Hwy 30 @ MP 7.32	HBP	Bridge Included Whole Corridor Study for Planning Purposes Prior to Design and Construction
Coos County	02300A	19663	Isthmus Slough	Sumner Road	HBP	Over 700 Feet Long with Significant Environmental Issues
Crook County	371-2	N/A	Irrigation Ditch	Riggs Road West	OTIA III	Replaced with culvert -- Not NBIS
Douglas County	19C513	N/A	South Umpqua River	County Rd. 386	OTIA III	Rehabilitation Project
Grant County	23C011	18859	North Fork John Day River	Rudio Road	HBP	Deck Replacement Only
Jackson County	08540B	20558	Bear Creek	Upton road	OTIA III	Project Delivered by ODOT
Jackson County	09089	20054	Evans Creek	West Main Street	OTIA III	Project Not Completed
Jackson County	06970	19273	Rogue River	Depot Street	HBP	Arch Bridge with Accelerated Construction Component
Jackson County	00374	20070	Southern Pacific Railroad	County Road No. 804	OTIA III	Project Costs Include Major Road Approach Work
Klamath County	06746	20381	Sprague River	Sprague River Road	OTIA III	Project Not Completed
Lane County	039C24	N/A	Coast Fork Willamette River	London Road	OTIA III	Rehabilitation Project
Lane County	14868A	N/A	Coast Fork Willamette River	London Road	OTIA III	Rehabilitation Project
Lane County	39C235	20352	Sharps Creek	Sharps Creek Road	OTIA III	Rehabilitation Project
Lincoln County	854A	N/A	Siletz River	Logsden Road	OTIA III	Project Not Completed
Linn County	02373	N/A	Calapooia River	Main Street	OTIA III	Rehabilitation Project
Linn County	43C36	19687	One Horse Slough	One Horse Slough	OTIA I	Incorporated Previously Used Slabs
Malheur County	08754	20282	Vale Canal	Harper-Westfall Road	OTIA III	No data for cost
Malheur County	45C110	N/A	Vale Main Canal	Ninth Avenue West	Local	Project Not Completed
Multnomah County	51C11	N/A	Corbett Hill Viaduct	Corbett Hill Road	OTIA I	Viaduct Replaced with Retaining Wall
Multnomah County	02641	20136	Willamette River Slough	Sauvie Island Road	OTIA III	Bridge Too Large for Study
Polk County	10002A	19977	Rock Creek	East Avenue	OTIA III	Rehabilitation Project

County	Original NBIS #	New NBIS #	Bridge Name	Road Name	Funding Source	Reason for Exclusion
Sherman County	55C010	N/A	Mud Hollow Creek	Mud Hollow Road	Local	Not Built
Tillamook County	01355A	20306	Trask River	Long Prairie Road	OTIA III	Project Not Completed
Umatilla County	59C726	20390	Meacham Creek	Bingham Road	BIA	Funded and Delivered by BIA
Umatilla County	59C727	20452	Umatilla River	Bingham Road	BIA	Funded and Delivered by BIA
Wasco County	65C78	N/A	Chenoweth Creek	River Trail Way	OTIA III	Project Not Completed
Wasco County	003080	N/A	Fifteen Mile Creek	Viewpoint Road	OTIA III	Rehabilitation Project
Wasco County	08327	N/A	Gate Creek	Smock Road	OTIA III	Rehabilitation Project
Washington County	671304	20624	Council Creek	Cornelius Scheflin	OTIA III	Project Not Completed
Washington County	671305	N/A	Council Creek	Spiesschaert Road	OTIA III	Project Not Completed