FAC 8513 VEHICLE BRIDGE

FY24 SUC:	$31.99 / SY
Source:	Inflated from previous FY using ENR labor and material cost indices to measure actual inflation
Original Source:	Three studies were used to revise the unit cost:\n\n The “Historical Life Cycle (LC) Costs of Steel and Girder Bridges” report was prepared for the American Iron and Steel Institute and the Short Span Steel Bridge Alliance by Dr. Michael Barker, Professor of Civil Engineering at the University of Wyoming, May 2016, using data for multiple bridges (PennDOT Database), projected to 2014.\n\n A Connecticut DOT life cycle cost study of the Moses Wheeler Bridge provides cost in 2009 dollars.\n\n A Kentucky life cycle cost study (dissertation) of the bridge carrying Huntertown Road over the Bluegrass Parkway provides a cost estimate from 2015.

The resulting average of these three studies is:

Study	Cost/SF	Cost/SY	Year	Inflation	FY17 SUC
Michael Baker		$ 3.52	2014	1.070819	3.76607
Connecticut	$ 2.91	$ 26.20	2009	1.163282	30.47799
Kentucky	$ 3.72	$ 33.50	2015	1.046557	35.05966
				Average	23.10124

Note: The Barker study is based data extracted from the Pennsylvania DOT database.

HISTORICAL LIFE CYCLE COSTS OF

STEEL & CONCRETE GIRDER BRIDGES

Prepared For
American Iron & Steel Institute
Steel Marketing Development Institute
Short Span Steel Bridge Alliance
National Steel Bridge Alliance
American Galvanizers Association

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May 31, 2016

The opinions, findings and conclusions in this
report are not necessarily those of SMDI, NSBA or the AGA

Executive Summary

Since the early 1990's, the Federal Highway Administration (FHWA) has promoted the consideration of Life Cycle Costs Analysis (LCCA) in the design and engineering of bridges. LCCA determines the "true cost" of bridge alternatives considering the time value of money. The Life Cycle Cost analyses employed in this study uses the Perpetual Present Value Cost (PPVC) of bridge alternatives for an equivalent comparison between the alternatives.

Over the years, the author has worked with state departments of transportations and local county engineers on effective and economical bridge construction. A frequent question that arises during meetings is the difference in Life Cycle Costs between steel and concrete girder bridges. Both the concrete industry and the steel industry site various anecdotal advantage above the other for the Life Cycle Costs over the life of the bridge. There has historically been a healthy competition between material types for new bridge construction. However, there is industry and owner confusion on how the different types of bridges compare on a Life Cycle Cost basis.

This study developed useful owner information on historical Life Cycle Costs for typical steel and concrete state bridges in Pennsylvania. Typical bridges are defined in the study as those with concrete decks supported by steel rolled beams, steel plate girders, precast concrete boxes, or precast concrete beams. PennDOT historical records for bridges built between 1960 and 2010 were used to develop a database for the Life Cycle Cost study. Initial and maintenance costs considered include total project costs (more than just superstructure) as recorded in the PennDOT records. The PennDOT database used for the Life Cycle Cost analyses only includes a subset of the total bridge inventory due to missing cost and date data for a majority of the individual bridges. The database consists of 1186 state bridges out of 6587 (18% of the eligible inventory) built between 1960 and 2010.

The initial costs, Life Cycle Costs, and future costs of the 1186 bridges in the database are examined with respect to variability in bridge type, bridge length, number of spans, and bridge life. The steel bridges in the database are also examined with respect to protective coating systems. Consideration of the specific numbers and any conclusions must be taken in the context that the results represent the bridges that made it into the database, and the database is not as comprehensive as desirable for drawing conclusions. Therefore, interpreting the tables and figures showing comparisons of initial costs, Perpetual Present Value Costs, maintenance and future costs, and bridge life is left to the reader.

A conclusion that can be drawn is that all the types of bridges are fairly competitive in both Initial Costs and Perpetual Present Value Costs. The average initial costs vary from \$174/ft^2 to \$226/ft^2 and the average Perpetual Present Value Costs vary between \$218/ft^2 (Pretressed I Beam) and \$278/ft^2 (Prestressed Adjacent Box). For bridge life, the lowest average life was 73 years (Pretressed I Beam) and the longest was 82 years (Steel I Beam). The coefficient of variation (standard deviation / mean) of the PPVC was approximately 20%, which is considerably high. With the relatively small differences in the PPVC averages, given the dispersion of the PPVC costs (standard deviation), any of the bridge types may have the least Perpetual Present Value Cost for a given project.

Even though this research was limited to only a subset of PennDOT bridges, the analyses demonstrate the potential benefits of LCC analysis for bridge construction and management. A study of a more comprehensive database of bridges on the initial costs, Life Cycle Costs and future costs of different types of bridges over a diverse set of circumstances would be very useful for bridge owners and managers. With a more comprehensive database, not only would there be a more accurate comparison of bridge types, an accurate comparison of design details, such as jointless decks, rebar coatings, steel protection systems, and other construction details could be completed.

Acknowledgements

This study is a result of the author's discussions with state and county bridge engineers' questions on Life Cycle Costs of bridges. The work is an attempt to give bridge owners Life Cycle Cost data so that they can make informed decisions in their bridge programs.

The author would like to acknowledge financial support from the Steel Marketing Development Institute, the National Steel bridge Alliance, and the American Galvanizers Association.

The professionals of the Pennsylvania Department of Transportation deserve special thanks. PennDOT Bridge Engineer Tom Macioce eagerly agreed to be part of the study, a welcome agreement given the difficulty the author had in securing bridge data. Gathering the necessary historical data was a daunting task. The engineers at PennDOT, and especially Civil Engineer Katherine Schopman, devoted many hours mining and verifying historical records so the author could develop an accurate bridge database for the Life Cycle Cost study.

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1 - Introduction

1.1 Background

Since the early 1990's, the Federal Highway Administration (FHWA) has promoted the consideration of Life Cycle Costs Analysis (LCCA) in the design and engineering of bridges. LCCA is an economic method to compare design alternatives over the entire life of the structure. The method considers not only initial costs, but also the future costs, their timing, and the service life of the bridge. LCCA determines the "true cost" of bridge alternatives, considering the time value of money, for an equivalent monetary comparison.

For instance, if one alternative has a high initial cost and no futures costs, LCCA can compare this to an alternative that has a lower initial cost and a major costly rehabilitation at 40 years. LCCA methods discount future costs to equivalent today costs for a direct economic comparison.

There has historically been a healthy competition between material types for new bridge construction. The most prevalent material types being used for typical bridges (those considered in this study) include steel rolled beams or plate girders and precast concrete box or beam superstructures with concrete decks. However, there is industry and owner confusion on how the different types of bridges compare on a Life Cycle Cost basis.

Both the concrete industry and the steel industry site various anecdotal advantage above the other for the Life Cycle Costs over the life of the bridge, and both are correct. Yes, given the competition between steel and concrete, different characteristics across the country's regions, diverse design and construction techniques employed by owners, varied maintenance program efforts, etc, sometimes steel may show an advantage and sometimes concrete may show an advantage. This is especially true for a bridge at an individual site, in a specific region, and with particular environmental characteristics.

Over the years, the author has worked with state departments of transportations and local county engineers on effective and economical bridge construction. A frequent question that arises during meetings is the difference in Life Cycle Costs between steel and concrete girder bridges. The discussion entails anecdotal information from the concrete industry and the steel industry. The concrete industry, using their projected maintenance and rehabilitation assumptions, can show that a precast beam bridge with integral abutments has lower Life Cycle Costs than a painted steel beam bridge with end deck joints in a northern state that uses road salt. The steel industry can show, with their assumptions, that a galvanized steel bridge with a jointless deck has a lower Life Cycle Cost in that same environment. Although the discussions are helpful, the issue remains unsettled. Owners want to consider LCC in bridge design decisions, but many are uncomfortable with this anecdotal discussion.

1.2 Objectives

The objective of this study was to develop useful owner information on historical Life Cycle Costs for typical bridges across the country. A database of bridges across the country was to be developed for the

Life Cycle Cost analyses. For each bridge in the database, the LCC analysis requires: the year built and the initial cost; dates and costs for repairs, maintenance and rehabilitations, and the reasons for the work; and the end-of-service life that may be actual or estimated. The intent was to develop historical Life Cycle Cost data for bridges owned by state departments of transportation (state) and those owned by counties (local). There is a significant difference between state and local bridges in both initial costs and maintenance costs.

The typical bridges in the study are simple- and multi-span "regular type" rolled steel, plate girder, precast I-beam, and precast box beam bridges. The years of inclusion were set to bridges built between 1960 (modern era for prestressed concrete and steel construction techniques) and 2010. Different geographical regions were to be included to examine wet and dry, cold and warm, and various environmental condition climates. For the steel bridges, the plan was to examine the influence of painted, weathering steel and galvanized protection systems. It was also desired to study the impact of other characteristics that would have an influence such as type of construction, deck material and joint details, deck rebar coatings, traffic volume and original design loads.

As stated above, the objective of this study was to develop useful owner information on historical Life Cycle Costs for typical state owned and local owned bridges across the country. The author worked with several select states and various select counties to develop a comprehensive database of bridges. However, the effort was, for the most part, unsuccessful. The data collection requirement of knowing each bridge's entire life of initial costs and future costs and dates was problematic for the owners due to the high amount of time and resources required to collect the data. Of the states contacted, only the Pennsylvania Department of Transportation had the necessary complete data for a subset of their bridge inventory. At the local level, although some counties had complete data for a few of their bridges, the number of bridges was small and using only a few bridges from a wide range of counties would not result in a consistent study, nor would the result be representative of county bridges.

Therefore, although the study was intended to examine state and local bridges across the country, the study was limited to state owned bridges in Pennsylvania. Also, the PennDOT database used for the Life Cycle Cost analyses only includes a subset of the total bridge inventory due to missing data for the majority of the individual bridges. The final Life Cycle Cost database consists of 1186 state bridges out of 6587 built between 1960 and 2010. This means the database represents 18% of the inventory. The report describes the criteria applied to development of the PennDOT bridge database that is used for the Life Cycle Cost analyses.

1.3 Summary of Results

The report presents the Life Cycle Cost analyses for the bridge database. The initial costs, Life Cycle Costs, and future costs of the 1186 bridges in the database are examined with respect to variability in bridge type, bridge length, number of spans, and bridge life. The steel bridges in the database are also examined with respect to protective coating systems.

The database must be considered only a snapshot of the total PennDOT bridge inventory. The criteria removed 82% of the eligible bridges built between 1960 and 2010, mostly due to incomplete initial cost, maintenance records and external contract records. If these records were complete, the database would be much larger and the resulting Life Cycle Cost analyses would more accurately represent the PennDOT bridge inventory. Consideration of the specific numbers and any conclusions must be taken in the context that the results represent the bridges that made it into the database, and the database is not as comprehensive as one would like.

However, the study shows that all the types of steel and concrete bridges are fairly competitive in both average Initial Costs and average Life Cycle Costs. With the dispersion of costs (standard deviation) any of the bridge types may have the least Life Cycle Cost for a given project.

1.4 Benefits and Future Work

This historical Life Cycle Cost study was limited to state bridges in Pennsylvania. Even though this research was limited to only a subset of PennDOT bridges, the analyses demonstrate the potential benefits of LCC analysis for bridge construction and management. A study of a more comprehensive database of bridges on the initial costs, Life Cycle Costs and future costs of different types of bridges over a diverse set of circumstances would be very useful for bridge owners and managers. Although extending this work would take considerable effort, other states and counties could be contacted in an effort to obtain a comprehensive bridge database.

2 - Life Cycle Costs

2.1 Introduction

Life Cycle Costs (LCC) analysis is an economic tool that allows comparison of competing project alternatives. For instance, does spending additional funds now that will reduce future maintenance costs make economic sense? A difficulty in comparing alternatives, even when represented in the same terms such as dollars, is that when the dollars are spent has an influence on equivalency due to inflation and discounting.

2.2 Time Value of Money and Discount Rate

Expenditures that occur at various times in the future will have values that depend on the time of the expenditure. A dollar in 1990 has more purchasing power than a dollar in 2014. This is called inflation. Expenditures that occur at various times in the future also must consider the opportunity value of time. Delayed expenditures (future) have the opportunity for economic return (for instance interest) that could be earned on the delayed monies. A dollar today is worth significantly more than a dollar in ten years because the dollar today could be invested and earn interest. This is called discounting. An effective Discount Rate (DR) that considers the effect of inflation (removes inflation) can be determined so that initial and future expenditures can be used to discount cash flow (time value of money) using constant (today) dollars. The DR (effective) will take care of the inflation (due to using constant today dollars) and the discounting for value of time (opportunity for economic return). The present value cost of a future cost (in today's constant dollars) occurring at year N with an effective discount rate of DR is:

$$Present\ Value\ Cost = Future\ Cost(1 + DR)^{-N}$$

For instance, if a concrete deck repair would cost \$1000 today, but it occurs 20 years in the future, at a discount rate of 2.3% the present value cost of that repair in the future is:

$$Present\ Value\ Cost = \$1000(1 + 0.023)^{-20} = \$634.58$$

With inflation, the actual cost in 20 years will exceed the constant dollar today cost of \$1000, but the \$634.58 invested today will grow over the 20 years at an interest rate (greater than the discount rate) that will be able to pay for the inflated actual cost at year 20. The effective Discount Rate allows Time Value of Money analysis using today's costs (constant dollars) and removes the need to consider inflation and discounting separately.

Discount rate has various meanings for different industries such as banking, the Federal Reserve, pensions and insurance companies. For LCC analysis, the discount rate represents the effective interest rate, accounting for inflation, used to discount cash flow (time value of money). The discount rate used in this work is taken from the Federal Office of Management and Budget Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, Appendix C.

The OMB Circular No A-94 defines nominal and real discount rates for current and past years. The real discount rate is the effective discount rate that accounts for inflation. Table 1 presents historical real discount rates based on interest rates on treasury notes and bonds of specified maturities.

Table 1: OMB Circular A-94 Historical Real Discount Rates

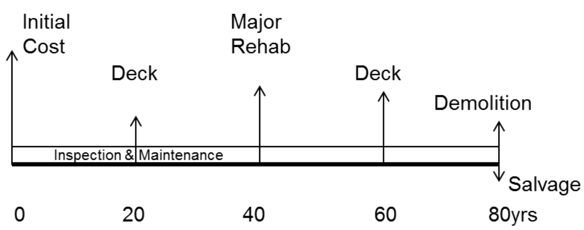
Year	Treasury Notes and Bonds Maturity					
	3 Year	5 Year	7 Year	10 Year	20 Year	30 Year
1979	2.8	3.4	4.1	4.6	#N/A	5.4
1980	2.1	2.4	2.9	3.3	#N/A	3.7
1981	3.6	3.9	4.3	4.4	#N/A	4.8
1982	6.1	7.1	7.5	7.8	#N/A	7.9
1983	4.2	4.7	5	5.3	#N/A	5.6
1984	5	5.4	5.7	6.1	#N/A	6.4
1985	5.9	6.5	6.8	7.1	#N/A	7.4
1986	4.6	5.1	5.6	5.9	#N/A	6.7
1987	2.8	3.1	3.5	3.8	#N/A	4.4
1988	3.5	4.2	4.7	5.1	#N/A	5.6
1989	4.1	4.8	5.3	5.8	#N/A	6.1
1990	3.2	3.6	3.9	4.2	#N/A	4.6
1991	3.2	3.5	3.7	3.9	#N/A	4.2
1992	2.7	3.1	3.3	3.6	#N/A	3.8
1993	3.1	3.6	3.9	4.3	#N/A	4.5
1994	2.1	2.3	2.5	2.7	#N/A	2.8
1995	4.2	4.5	4.6	4.8	#N/A	4.9
1996	2.6	2.7	2.8	2.8	#N/A	3
1997	3.2	3.3	3.4	3.5	#N/A	3.6
1998	3.4	3.5	3.5	3.6	#N/A	3.8
1999	2.6	2.7	2.7	2.7	#N/A	2.9
2000	3.8	3.9	4	4	#N/A	4.2
2001	3.2	3.2	3.2	3.2	#N/A	3.2
2002	2.1	2.8	3	3.1	#N/A	3.9
2003	1.6	1.9	2.2	2.5	#N/A	3.2
2004	1.6	2.1	2.4	2.8	3.4	3.5
2005	1.7	2	2.3	2.5	3	3.1
2006	2.5	2.6	2.7	2.8	3	3
2007	2.5	2.6	2.7	2.8	3	3
2008	2.1	2.3	2.4	2.6	2.8	2.8
2009	0.9	1.6	1.9	2.4	2.9	2.7
2010	0.9	1.6	1.9	2.2	2.7	2.7
2011	0	0.4	0.8	1.3	2.1	2.3
2012	0	0.4	0.7	1.1	1.7	2
2013	-1.4	-0.8	-0.4	0.1	0.8	1.1
2014	-0.7	0	0.5	1	1.6	1.9
2015	0.1	0.4	0.7	0.9	1.2	1.4

Table 1 shows that the discount rate was fairly high in the 1980s, lower in the 1990s, and considerably low in recent years. This work uses (somewhat arbitrarily) the discount rates from 2011 in the Life Cycle Cost analyses. The thought is that 2011 is fairly recent and the very recent discount rates (2015) will tend to increase as the economy improves. It is acknowledged that this selection is subjective, but realizing that as long as the discount rate is consistent across the bridge database, the difference between small changes of discount rate would be minimal. Where the value of the discount rate would have a significant impact would be where one bridge has a higher initial cost and lower future costs compared to a bridge with lower initial cost and higher future costs. These situations are not prevalent in the final LCC bridge database. This work also assumes a long term investment outlook and uses the 30 year maturity level. Therefore, from Table 1, the discount rate used for the Life Cycle Cost analyses in this work is 2.3%.

2.3 Life Cycle Cost Analysis

Life cycle cost analysis represents the "total" cost of a bridge over the life of the bridge and results in an equivalent life cycle cost amount. The cost amount is typically represented by either an Equivalent Uniform Annual Cost (EUAC) or a Present Value Cost (PCV). The EUAC is the life cycle cost amount annualized over the life of the bridge. The PVC represents a present amount that, at a given discount rate (DR), will be enough to pay the initial cost of the bridge and all future costs that are associated with the bridge over its life. This study uses the Present Value Cost in the Life Cycle Cost Analyses.

The data required for the LCC analysis are the initial cost and any future costs and their time frames associated with the bridge over the life of the bridge. Figure 1 demonstrates a LCC analysis for an academic bridge example that has an 80 year life. It assumes future maintenance and rehabilitation costs and the timing of those costs as shown in Figure 1.



For an Initial Cost (IC)
Assume:

Deck	=	5%	IC (every 20 years)
Rehab	=	20%	IC (every 40 years)
Demo	=	10%	IC
Salvage	=	-3%	IC
Main/Ins	=	0.1%	IC per year

Figure 1: Life Cycle Cost Analysis Example Bridge

The initial cost of the bridge is IC. Deck repair is assumed to cost 5% of the initial cost and to occur every 20 years (except for a major rehabilitation year). The major rehabilitation occurs at 40 years and costs 20% of the initial cost. Demolishing the bridge at 80 years costs 10% of the initial, but there is salvage materials that return 3% of the initial cost (negative is to make the salvage a benefit). Yearly regular maintenance and inspection costs are assumed to be 0.1% of the initial cost. These cost numbers are only used here to demonstrate the LCC analysis and do not necessarily represent a real bridge example. The time value of money equations can be found in any economics book.

The present value cost for all costs associated with this example bridge is:

$$PVC = IC[1 + 0.05(1 + 0.023)^{-20} + 0.05(1 + 0.023)^{-60} + 0.20(1 + 0.023)^{-40} + 0.10(1 + 0.023)^{-80} - 0.03(1 + 0.023)^{-80} + 0.001\frac{(1 + 0.023)^{-80} - 1}{0.023(1 + 0.023)^{-80}}] = 1.17IC$$

The idea is that if the owner invested 1.17 times the initial cost now, the bridge could be built and all future costs would be covered with the extra 17% of the initial cost for a bridge lasting 80 years.

However, when comparing bridges that have different bridge lives, a present value cost by itself is not sufficient. For instance, if this bridge lasts 80 years with a PVC = 1.17IC, it cannot be directly compared to the present value cost of a bridge that lasts only 60 years. Therefore, a common method to directly compare bridges with different life spans is to use either Equivalent Uniform Annual Costs (EUAC) or a Perpetual Present Value Cost (PPVC). Both are equivalent in terms of use for alternative comparisons and the PPVC is used in this work.

The Perpetual Present Value Cost (PPVC) is determined by assuming that at the end of the bridge's life, it is replaced by an identical bridge into perpetuity. This is demonstrated in Figure 2.

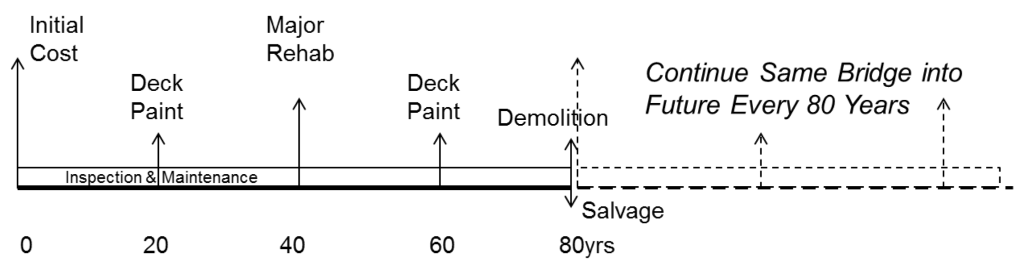


Figure 2: Perpetual Life Cycle Cost Analysis Example Bridge

The PPVC for all costs associated with this bridge into perpetuity is:

$$PPVC = PVC\left[\frac{(1 + 0.023)^{80}}{(1 + 0.023)^{80} - 1}\right] = 1.17IC[1.19] = 1.40IC$$

The idea is that if the owner invested 1.40 times the initial cost now, the bridge could be built and all future costs, including replacing the bridge every 80 years, would be covered with the extra 40% of the initial cost for a bridge lasting into perpetuity. The benefit of using the PPVC is that it allows direct comparisons between any set of bridges.

2.4 Sensitivity of PPVC

The Perpetual Present Value Cost will be sensitive to several variables in the Life Cycle Cost analysis. The primary variables are:

- Bridge Life
- Future Costs
    - Magnitude of Future Costs
    - Timing of Future Costs
- Discount Rate
- Within Steel Bridges – Coating Systems (Weathering Steel , Galvanized & Painted)

The next sections demonstrate the sensitivity using the example bridge from above. The Life Cycle Cost analysis of the PennDOT final LCC bridge database will attempt to examine these variables.

2.4.1 Bridge Life

Assuming the same generic future deck (5%IC @ 20 years), rehabilitation (20%IC @ 40 years), maintenance and inspection (0.1%IC yearly), demolition (10%IC) and salvage costs (-3%IC), Figure 3 shows the PPVC for bridges with a bridge life from 40 to 120 years.

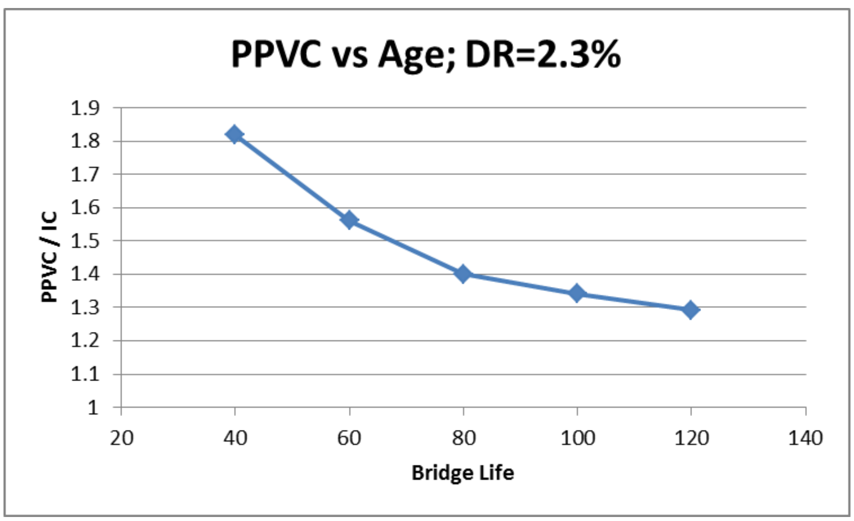


Figure 3: Perpetual Present Value Cost vs. bridge Life

It is clear that bridge life has a large impact on the PPVC. A bridge that lasts 80 years (previous example) has a PPVC of 1.40IC. But, if that bridge only lasts 40 years due to poor performance, the PPVC is over 1.80IC, a significantly large increase in Life Cycle Costs. However, if the bridge life can be extended to 120 years, the PPVC is lower than 1.30IC. This type of analysis can be used to analyze bridge preservation efforts.

2.4.2 Magnitude of Future Costs

To examine the sensitivity to the magnitude of future costs, Figure 4 compares the PPVC with 100% of all future costs considered to the PPVC where the future costs are assigned to be only 90% of the assumed values. The difference is rather small meaning that the PPVC is not all that sensitive to changes in the cost of the future cost.

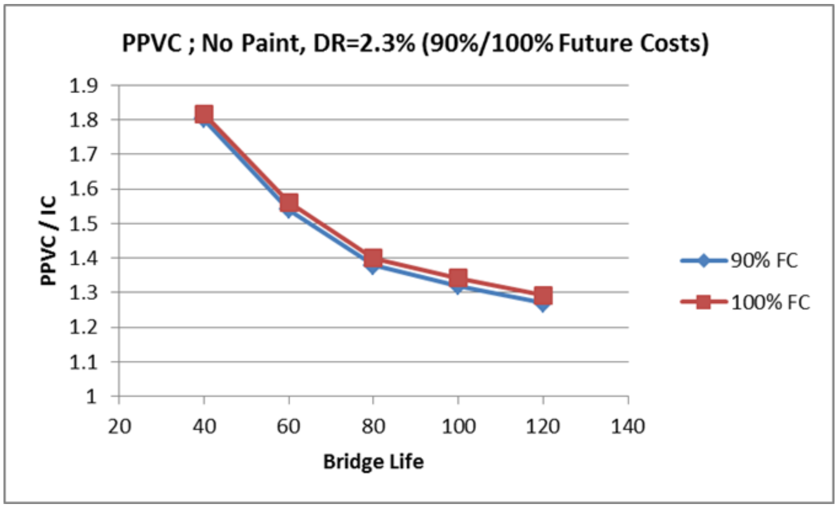


Figure 4: Perpetual Present Value Cost vs. Amount of Future Cost

2.4.3 Timing of Future Costs

Bridge preservation efforts and regular simple maintenance can extend bridge life and delay major rehabilitations and significant required maintenance. Life Cycle Cost analysis can determine the impact. Figure 5 demonstrates the effect for the example bridge.

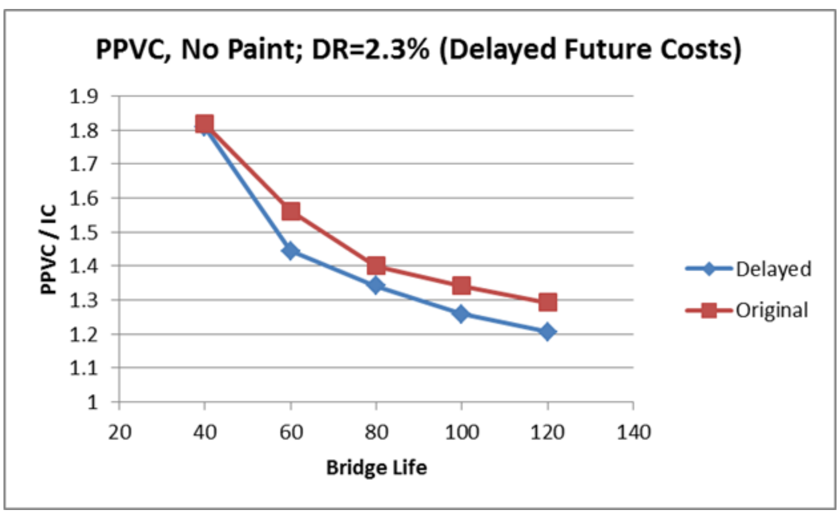


Figure 5: Perpetual Present Value Cost vs. Delayed Future Costs

If deck repair and major rehabilitation is delayed 50% (deck at 30 years vs. 20 and Rehab at 60 years vs. 40), the PPVC is significantly lowered. Of course at 40 years there is little difference since there is little future cost.

2.4.4 Discount Rate

The discount rate used for the PennDOT database is 2.3%. The decision to use 2.3% was explained earlier. However, there would be a direct impact on PPVC if the rate varied. Figure 6 illustrates a comparison of the PPVC between a discount rate of 2.3% and a rate of 5%. The 5% rate represents a similar set of circumstances used to select the 2.3% rate, except for the year 1995. In Figure 6, only the future costs (deck repair, rehabilitation, demolition and salvage) are considered to better show the comparison since initial costs would not change.

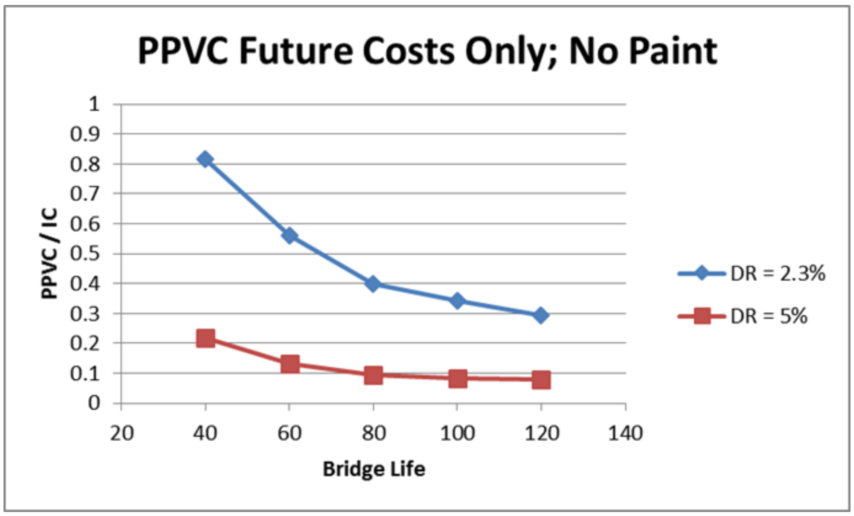


Figure 6: Perpetual Present Value Cost vs. Discount rate

The present value costs for the future maintenance significantly decrease with the higher discount rate. Using an accurate discount rate would be important for examining maintenance and rehabilitation alternatives within a bridge structure. However, when comparing bridges in a database, as long as the bridge histories are somewhat similar, the difference would be consistent over the bridge database. Where the value of the discount rate would have a significant impact in a database comparison analysis would be when one bridge has a higher initial cost and lower future costs compared to a bridge with lower initial cost and higher future costs. These situations are not prevalent in the final LCC bridge database.

2.4.5 Steel Bridge Coating Systems

Coating systems for steel bridges is an important maintenance and preservation issue. Using weathering steel, galvanizing or painting are required to protect the steel from corrosion. Each method of protection has initial costs and possibly required maintenance. Life Cycle Cost analysis can be used to examine the overall effectiveness of the different protection systems. For instance, galvanizing may have a higher initial cost, but if there is little to no future maintenance required, galvanizing may have a lower Life Cycle Cost than a lower initial cost system like painting that requires re-painting costs in the future. For the example bridge, Figure 7 compares the cost of future painting costs to the previous PPVC bridge. It is assumed that re-painting the bridge costs 7% of the initial cost and that is occurs every 20 years, except during the major rehabilitation year. This is not a true comparison of painted vs. galvanized or weathering steel since no difference in the initial cost was considered. However, it does demonstrate the impact from having to re-paint the bridge every 20 years.

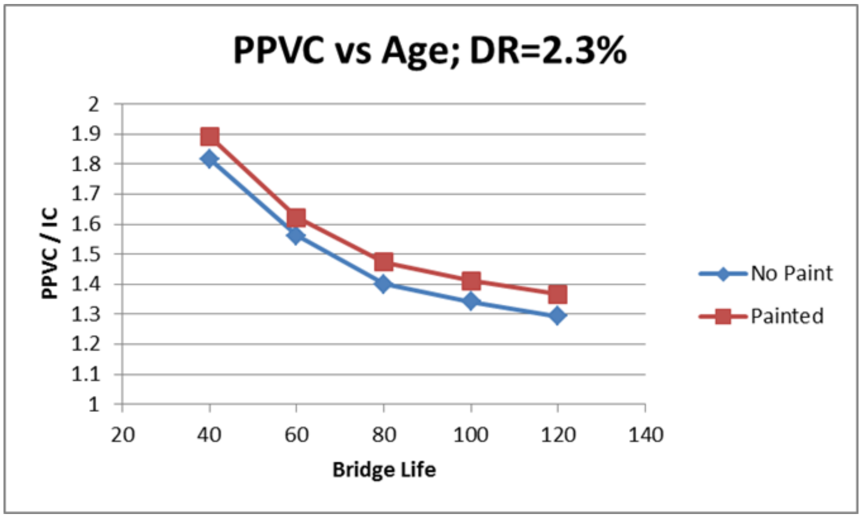


Figure 7: Perpetual Present Value Painted vs. Non-Painted

For a bridge that has an 80 year life, the PPVC for a non-painted bridge was 1.40IC. With a re-painting model of a 7%IC cost` every 20 years, the PPVC increases to 1.47IC, a 5% increase. Using Life Cycle Cost analysis, one can examine what additional initial cost would be "worth" not having to re-paint the bridge.

2.5 Summary of Life Cycle Costs

The Life Cycle Cost procedures developed in this chapter will be applied to the bridge database developed in Chapter 3. An example bridge was used here to study the sensitivity of the Perpetual Present Value Cost to variables that may have a significant impact on the PPVC. It is noted here that the example was not very realistic in terms of maintenance and rehabilitation that actually occurs on the nation's bridges. However, it develops considerations and concepts that will be applied to the PennDOT bridge database. The Life Cycle Cost analyses in Chapter 4 will examine different bridge types for the variables discussed in the sensitivity study as much as is possible for the bridge database developed in Chapter 3.

3 - The PennDOT Database

3.1 PennDOT Database Criteria

The database is developed from files supplied by the PennDOT Bridge Division. Inventory files, PennDOT performed department maintenance files, and external contractor maintenance and rehabilitation files were combined to develop the final database to use in the Life Cycle Cost study. Initial and maintenance costs considered include total project costs as represented in PennDOT records. Therefore, non-superstructure costs are included even though the study pertains to the superstructure only. It is assumed that the non-superstructure costs even out over the large database so the relative comparisons between bridge types is not affected. The following describes the development of the final LCC database. The final LCC database used for this Life Cycle Cost study was limited to the following criteria:

- Modern typical bridge structures
  - Precast I-Beam, Box Adjacent, and Box Spread bridges
  - Steel Rolled Shape and Welded Plate Girder bridges
- Bridges built between 1960 and 2010
- Bridges with complete and accurate department maintenance records
  - Known dates
  - Known costs
  - Consider any maintenance cost that is equal to or greater than $\$0.25/ft^2$
- Bridges with known initial costs
- Bridges with complete and accurate external contractor maintenance and rehabilitation records
  - Known dates
  - Known costs
- Initial cost limitation to bridges with initial cost less than $\$500/ft^2$ and greater than $\$100/ft^2$

For a bridge to be included in the final LCC database, all of the above criteria must be satisfied. If any one of the criterion are not, the bridge is not included in the LCC study. Although care was exercised in developing the database, errors may be present due to inaccurate or missing data in the PennDOT inventory and maintenance files. Individual bridge information was not reviewed by PennDOT state or district personnel for accuracy. It is assumed that any errors cancel out over the database so relative comparisons between bridge types is not affected. The following demonstrates the application of the criteria to develop the final LCC database.

3.2 Initial Database

The PennDOT inventory database includes 25,403 structures of which there are 8466 classified as Precast Box Beam – Spread, Precast Box Beam – Adjacent, Precast I Beam, Steel I Beam – Rolled Shape, and Steel I Welded Girder – Plate Girder bridges. All other types of bridge structures were not considered in this work. The Life Cycle Cost study examined the modern era of bridge construction defined as bridges built from 1960 to the present. The study is also limited to bridges built up to 2010. Table 2 shows the total number of bridges in each category in the PennDOT inventory file and also the number of bridges in each category built between 1960 and 2010. This initial database was the starting point in the process to develop the final database for the LCC study.

Table 2: PennDOT Bridge Inventory Initial Database

Bridge Type	Total Number of Bridges	Number of Bridges 1960 - 2010
Steel I Beam	1347	550
Steel I Girder	1112	1017
P/S Box - Adjacent	1814	1440
P/S Box - Spread	2648	2196
P/S I Beam	1545	1384
Total	8466	6587

3.2.1 Department Performed Maintenance Criterion

The initial bridge database was compared to PennDOT's department performed maintenance files. The criteria are that the maintenance performed must have valid dates and costs for all maintenance performed and that the maintenance costs are equal to or greater than $0.25/ft^2. This removes a great portion of bridges in each category since there are many examples of maintenance that was performed that did not have accurate records. For example, a bridge may have 3 valid maintenance records, but one that did not have a valid date. This bridge would not be included in the final LCC database. One caveat to the acceptance is that any maintenance performed in 2015 was considered a valid date, but the date of that maintenance event was defined to be December of 2014. This is because the LCC study is based on the year 2014 (due to the Construction Cost Indices used) and any error in the time value of money conversions would be miniscule. There are also many bridges that did not have any department maintenance that are included in the intermediate database. The remaining bridges in this intermediate database are shown in Table 3.

Table 3: Intermediate Database with Valid Department Maintenance Records

Bridge Type	Number of Bridges with Valid Maintenance	Number of Bridges with No Maintenance	Intermediate Database Totals
Steel I Beam	99	362	461
Steel I Girder	131	574	705
P/S Box - Adjacent	151	1177	1328
P/S Box - Spread	381	1684	2065
P/S I Beam	204	937	1141
Total	966	4734	5700

There were 1853 bridges that had documented department maintenance that exceeded $0.25/ft^2 performed. Of those, 966 had maintenance records that had known dates and known costs associated with the maintenance efforts. This means that 887 bridges were removed from the database due to incomplete department maintenance information. These are bridges that would certainly have an impact on the Life Cycle Cost analysis averages. Lower percentages of bridges with valid maintenance records would tend to decrease LCC averages over the database. However, the impact on the averages will be relatively small since future discounted maintenance costs are small compared to initial costs as will be demonstrated in the LCC analyses. Table 4 illustrates the number of bridges with documented department maintenance and those that had valid maintenance information.

Table 4: Department Maintenance Bridge Database Numbers

Bridge Type	Number of Bridges with Maintenance	Number of Bridges with Valid Maintenance	Percentage of Bridges with Valid Maintenance
Steel I Beam	188	99	52.7%
Steel I Girder	443	131	29.6%
P/S Box - Adjacent	263	151	57.4%
P/S Box - Spread	512	381	74.41%
P/S I Beam	447	204	45.6%
Total	1853	966	52.1%

There were also 4734 bridges that had no documented department maintenance that exceeded $0.25/ft^2. This results in 83% (4734/5700) of the bridge database will be bridges where only the initial cost will be used in the LCC analyses. Higher percentages of no maintenance bridges will tend to lower Life Cycle Cost averages across the database. However, the impact on the averages will be relatively small since future discounted maintenance costs are small compared to initial costs as will be demonstrated in the LCC analyses. Table 5 presents the number of bridges with no documented department maintenance and the percentage of the total intermediate database.

Table 5: No Department Maintenance Bridge Database Numbers

Bridge Type	Bridges in Intermediate Database	Number of Bridges with No Maintenance	Percentage of No Maintenance Bridges in Database
Steel I Beam	461	362	78.5%
Steel I Girder	705	574	81.4%
P/S Box - Adjacent	1328	1177	88.6%
P/S Box - Spread	2065	1684	81.6%
P/S I Beam	1141	937	82.1%
Total	5700	4734	83.1%

The bridges considered in the database were built between 1960 and 2010. The department maintenance performed considered was any maintenance exceeding \$0.25/ft^2 up to the year 2014 (with a few in early 2015 back-dated to end of 2014). Any maintenance that may be performed on a bridge in the future, while a certainty, is not considered in the LCC analyses. This means that each bridge is assumed to have no additional future maintenance until its end-of-life. The impact of this will be a lowering of LCC cost averages across the database. However, each bridge type would have a similar impact as long as the average year built is similar (newer bridges would tend to have no early maintenance). It will be shown in the final LCC database that the average year built is similar for the different types of bridges.

3.2.2 Initial Cost Criterion

PennDOT records were searched to determine if the initial cost for the bridges in this intermediate database were available. This criterion also removed additional bridges from the database since there were many examples where initial costs could not be determined. Table 6 presents the number of bridges in the intermediate database that did have initial cost records that results in a new intermediate database.

Table 6: Intermediate Database with Valid initial Costs

Bridge Type	Number of Bridges with Valid Maintenance and Initial Costs	Number of Bridges with No Maintenance and Initial Costs	Number of Bridges with Valid Maintenance and Initial Costs
Steel I Beam	27	139	166
Steel I Girder	89	367	456
P/S Box - Adjacent	56	431	487
P/S Box - Spread	151	617	768
P/S I Beam	101	447	548
Total	424	2001	2425

The intermediate database has 5700 bridges with valid department maintenance records or bridges with no department maintenance. Of these 5700 bridges, the initial bridge cost for 2425 (42.5%) could be determined. As would be expected, many of the older bridges had incomplete records and were removed from the database. The removed bridges included a representative number from each bridge type. Therefore, the average year built was not affected and the impact of the reduction should be similar for all bridge types.

3.2.3 External Contract Maintenance and Rehabilitation Criterion

In terms of the Life Cycle Cost Analyses, there is no difference between department performed maintenance and external contract maintenance and rehabilitation. In the PennDOT records, the two types of efforts are located in different databases. The development of the final LCC database applied them separately as shown herein. To be included in the final LCC database, the criteria is that the external contract records must have valid dates and costs. The intermediate database that includes bridges with valid or no department maintenance and valid initial costs includes 2425 bridges (Table 6). There were 603 instances of bridges in the intermediate database that had external contracts performed. Of these 603, there were only 26 that had known dates and known costs associated with the work. This means that 565 of the 2425 had to be removed from the database resulting in a final eligible database of 1860 bridges. Table 7 presents the database number of bridges for each category.

Table 7: Intermediate Database that Meets External Contract Criteria

Bridge Type	Number of Bridges with Valid Maintenance and Initial Costs	Number of Bridges Removed due to Missing External Contract Information	Number of Bridges with Valid Maintenance, Initial Costs, and Contracts
Steel I Beam	166	81	85
Steel I Girder	456	192	264
P/S Box - Adjacent	487	63	424
P/S Box - Spread	768	149	619
P/S I Beam	548	80	468
Total	2425	565	1860

The impact of the removal of bridges with documented contracts, but not valid dates and costs, would be similar to the impact from bridges with invalid department maintenance. Also, the same rule that any future contracts that may be performed on a bridge is not considered. With department maintenance, as discussed above, the discounted future costs are usually small compared to the initial costs. For external contracts that involve major rehabilitation, this is not as prevalent and the discounted future rehabilitation costs may be significant. This would result in the average Life Cycle Costs would increase since many of these bridges have been removed from the database. However, there is no manner to predict major rehabilitation dates or costs for the database bridges. Therefore, it is assumed that the different types of bridges would be impacted similarly.

3.2.4 Initial Cost Limitation Criterion

There are bridges built that have unrealistic initial costs due to project specific characteristics. A bridge may have unreasonably high costs due to extremely complicated site characteristics or lower than normal costs due to existing abutments or other atypical beneficial characteristics. To consider typical bridges of the different types, it was decided to remove bridges from the database that had initial costs exceeding $500/ft^2 and those with costs less than $100/ft^2. The limits were selected in consultation with the PennDOT Bridge Engineer where the remaining bridges were considered "typical" in his estimation. The criteria removed 155 bridges from the database

3.3 Final LCC Bridge Database

Table 8 presents the final LCC database that will be used for the Life Cycle Cost analyses and the percentage compared to the total number of bridges built from 1960 to 2010 from Table 2.

Table 8: Final LCC Database that Meets All Criteria

Bridge Type	Number of Bridges that Meet All criteria	Percentage of 1960 – 2010 database
Steel I Beam	82	14.9%
Steel I Girder	230	22.6%
P/S Box - Adjacent	400	27.8%
P/S Box - Spread	581	26.5%
P/S I Beam	412	29.8%
Total	1705	25.9%

There were 6587 Precast Box Beam – Spread, Precast Box Beam – Adjacent, Precast I Beam, Steel I Beam – Rolled Shape, and Steel I Welded Girder – Plate Girder eligible bridges identified as being built between 1960 and 2010. Of those, 1705 were found to meet the criteria for the final LCC database. This represents 25.9% of the eligible bridges, a decent percentage of the total. However, the database must be considered only a snapshot of the total PennDOT bridge inventory for the bridge types. The criteria removed nearly 75% of the eligible bridges built between 1960 and 2010, mostly due to incomplete initial cost, maintenance records and external contract records. If these records were complete, the database would be much larger and the resulting Life Cycle Cost analyses would more accurately represent the PennDOT bridge inventory.

3.4 End Of Life Prediction

In the Life Cycle Cost Analyses, the end of life of the bridge (when the bridge needs replacement) defines the life cycle of the bridge. Since the bridges in the final LCC database are all currently in service, it was necessary to estimate an end of life date for each bridge. This was accomplished through the use of average deterioration rates based on the Condition Ratings of the superstructure. This study is interested in the Life Cycle Costs of the superstructure only, so the condition ratings of the deck and substructure were not considered.

3.4.1 Deterioration Rates

To model the deterioration rate, it was assumed that the condition rating decreased linearly over time and the bridge is assumed to be replaced when the condition rating reached 3.0. Also it is assumed that the condition rating is 9.0 when the structure was built. Thus, for a given bridge in the year 2014, the deterioration rate is:

$$Deterioration\ Rate = \frac{(2014\ Condition\ Rating) - 9}{2014 - (Year\ Built)}$$

This has many drawbacks such as deterioration rates are not necessarily linear, rehabilitations tend to raise condition ratings, there is no consideration of average daily traffic, and preservation (maintenance) efforts are not represented.

All 6587 of the bridges built between 1960 and 2010 were used to determine the average deterioration rates for the different types of bridges. Table 9 presents the average deterioration rates and the coefficient of variation of the data within each bridge type.

Table 9: Average Deterioration Rates

Bridge Type	Number of Bridges 1960 - 2010	Deterioration Rate (Condition Rating Loss/Year)	Coefficient of Variation (Mean/St. Deviation)
Steel I Beam	550	-0.07114	54.7%
Steel I Girder	1017	-0.08144	57.4%
P/S Box - Adjacent	1440	-0.08125	50.9%
P/S Box - Spread	2196	-0.07988	70.9%
P/S I Beam	1384	-0.08383	63.3%

It is clear that the variation of the deterioration rate is very high. This is somewhat expected given the variation of bridge characteristics and environments. Other models were considered for deterioration rates. PennDOT assumes certain remaining life based on a non-linear deterioration rate and a Business Plan Network. These were considered for this study, but were found to be difficult to apply and draw conclusions given the limited database of bridges. However, a side-study (not shown here) showed that the differences were small for the averages in Table 9 and the PennDOT method for the bridges in a Business Plan Network of 1. Therefore, given little alternative, the average deterioration rates in Table 9 were used to estimate the remaining life of each bridge in the final LCC database.

3.4.2 Remaining Life and Bridge Life

To estimate the remaining life for each bridge, it is assumed that the bridge will be replaced when the superstructure condition rating reaches 3.0 for the deterioration rates from Table 9:

$$Remaining\ Life = \frac{3 - \ (2014\ Condition\ Rating)}{(Average\ Deterioration\ Rate)}$$

The bridge life becomes:

$$Bridge\ Life = 2014 - (Year\ Built) + Remaining\ Life$$

Table 10 presents the average year built and the average bridge life for the different bridge types in the final LCC database.

Table 10: Final LCC Database that Meets All Criteria

Bridge Type	**Number of Bridges in Final LCC Database**	**Average Year Built**	**Average Bridge Life (years)**
Steel I Beam	82	1981	81.3
Steel I Girder	230	1977	79.2
P/S Box - Adjacent	400	1985	74.0
P/S Box - Spread	581	1984	79.9
P/S I Beam	412	1984	74.5

3.4.3 End of Life Year

The life cycle starts at the year the bridge is built and goes through the year it is replaced (end of life year). The Life Cycle Cost Analyses for each bridge in the final LCC database requires discounting future costs to current value. This means that the year for the bridge replacement (end of life) is necessary for the analyses. Given the remaining life, the end of life year becomes:

$$End\ of\ Life\ Year = 2014 + Remaining\ Life$$

3.5 Summary

Table 11 presents a summary of the final LCC bridge database to be used in Life Cycle Costs studies in the next chapter.

Table 11: Final LCC Bridge Database Summary

Bridge Type	**Number of Bridges in Final LCC Database**	**Percentage of 1960 – 2010 database**	**Average Year Built**	**Average Bridge Life (years)**
Steel I Beam	82	14.9%	1981	81.3
Steel I Girder	230	22.6%	1977	79.2
P/S Box - Adjacent	400	27.8%	1985	74.0
P/S Box - Spread	581	26.5%	1984	79.9
P/S I Beam	412	29.8%	1984	74.5
Total	1705	25.9%		

Appendix A lists the bridges in the database used for the Life Cycle Cost Analyses. Not all of the 1705 bridges in Table 11 were included in the LCC database as explained in the next section. In the appendix, there are three tables for each type of bridge type. The first lists the general information for each bridge. For the steel bridges, the first table also lists the rebar, geometry, and material characteristics since this study examined variations within steel bridge types. The second table lists the initial cost for the bridge, maintenance costs, year from year built, and type of maintenance, and external contract work. All costs are reduced to dollars/ft^2 of surface deck area. The monetary values are all in constant 2014 dollars as will be explained in the next chapter. The third table presents the Life Cycle Cost results for each bridge. It presents the Perpetual Life Cycle costs, initial costs, maintenance plus external contract costs, along with the basic bridge characteristics. The third table also presents the averages and standard deviations for the bridge data.

4 - PennDOT Database Life Cycle Cost Analyses

4.1 Database Life Cycle Costs

The final LCC bridge database is analyzed for Life Cycle Costs according to the procedures previously demonstrated in Chapter 2. However, the Chapter 2 example was generic with all costs associated with the bridge known. The bridge database, of course, is missing some of the variables used in the example. For instance, there was no data on demolition costs or salvage costs. Also, there is no attempt to add routine maintenance and inspection costs. The database includes the initial cost for the structure, valid maintenance costs, and valid external contract costs. These costs are listed in the second table in Appendix A for each bridge type in constant 2014 dollars. The Life Cycle Cost analyses conducted in this study use constant 2014 dollars.

4.2 Constant 2014 Dollars

The database presented in Appendix A was developed from the criteria previously discussed. The valid initial costs, maintenance costs and external contract costs collected were actual dollars spent at the time of the cost. Therefore, they must be inflated to an equivalent amount in 2014. The dollars at the time expended are transformed into constant 2014 dollars using the Construction Cost Indices (CCI) provided by Engineering News Record publications. Given an expenditure in a past year 19XX, the equivalent 2014 dollars can be determined by:

$$2014\ Dollars = \frac{CCI\ 2014}{CCI\ 19XX} 19XX\ Dollars$$

Table 12 Shows the Historical Construction Cost Indices from 1960 to 2014.

As an example, if a bridge's initial cost is \$330,000 and it is built in 1994, the equivalent 2014 initial cost for the bridge is:

$$2014\ Bridge\ Initial\ Cost = \frac{9806}{5408} \$330{,}000 = 1.813(330{,}000) = \$598{,}370$$

In terms of inflation, this means a bridge built in 2014 costs 81.3% more than a bridge built in 1994.

The cost data for all the bridges in Appendix A are in constant 2014 dollars. Therefore, the study assumes that all of the bridges are built in 2014 for the Life Cycle Cost analyses. The constant 2014 dollars is necessary to (1) account for inflation to transform past built bridges to 2014 using the Construction Cost Index and (2) the discount rate for all future costs considers future inflation and discounting future costs with the discount rate is applied to constant 2014 dollars.

Table 12: Historical Construction Cost Indices from 1960 to 2014 (Engineering News Record)

Year	CCI	Year	CCI	Year	CCI
2014	9806	1995	5471	1976	2401
2013	9547	1994	5408	1975	2212
2012	9308	1993	5210	1974	2020
2011	9070	1992	4985	1973	1895
2010	8799	1991	4835	1972	1753
2009	8570	1990	4732	1971	1581
2008	8310	1989	4615	1970	1381
2007	7966	1988	4519	1969	1269
2006	7751	1987	4406	1968	1155
2005	7446	1986	4295	1967	1074
2004	7115	1985	4195	1966	1019
2003	6694	1984	4146	1965	971
2002	6538	1983	4066	1964	936
2001	6343	1982	3825	1963	901
2000	6221	1981	3535	1962	872
1999	6059	1980	3237	1961	847
1998	5920	1979	3003	1960	824
1997	5826	1978	2776		
1996	5620	1977	2576		

4.3 Life Cycle Cost Example PennDOT Bridge 30570

The Life Cycle Cost analysis will be demonstrated using Precast Box Beam – Spread PennDOT Bridge 30570. The results are shown in Appendix A.

BrKey: 30570

Bridge Type: P/S, Box Beam (Spread)

County: Shuylkill

Location: 0.75 mi. N of Exit 107(33)

Year Built: 1969

Spans: 3

Length: 176 ft

Deck Area: 7621 ft^2

Super Cond Rating: 5

Using the average Precast Box Beam – Spread bridge deterioration rate of -0.07988 from Table 9, with a superstructure condition rating of 5, the remaining life is:

$$Remaining\ Life = \frac{(3-5)}{-0.07988} = 25\ years$$

The bridge life is estimated to be:

$$Bridge\ Life = 2014 + 25 - 1969 = 70\ years$$

There were two incidents of department maintenance and one external contract. For this example, total costs and costs/ft^2 of deck area are shown. The remainder of this report will use costs/ft^2 for direct comparisons. The costs at the time of the work and year of the work are:

Initial Cost:	Year = 1969	Cost = \$141475 (\$18.56/ft^2)	Work: Bridge Construction
External Contract:	Year = 1988	Cost = \$58401 (\$7.66/ft^2)	Work: Latex Overlay
Maintenance 1:	Year = 2009	Cost = \$1891 (\$0.25/ft^2)	Work: Repair Concrete Deck
Maintenance 2:	Year = 2013	Cost = \$2510 (\$0.33/ft^2)	Work: Repair Concrete Deck

To transform the costs to constant 2014 dollars, the Construction Cost Indices are applied. To set the time frame for the Life Cycle Cost analysis, the date of maintenance from the built date is determined. The inputs for the LCC analysis are:

Initial Cost:	Year = 0	Cost = \$18.56/ft^2(9806/1269)	= \$143.45/ft^2
External Contract:	Year = 19	Cost = \$7.66/ft^2(9806/4519)	= \$ 16.63/ft^2
Maintenance 1:	Year = 40	Cost = \$0.25/ft^2(9806/8570)	= \$ 0.28/ft^2
Maintenance 2:	Year = 44	Cost = \$0.33/ft^2(9806/9547)	= \$ 0.34/ft^2

The bridge life timeline is shown in Figure 8.

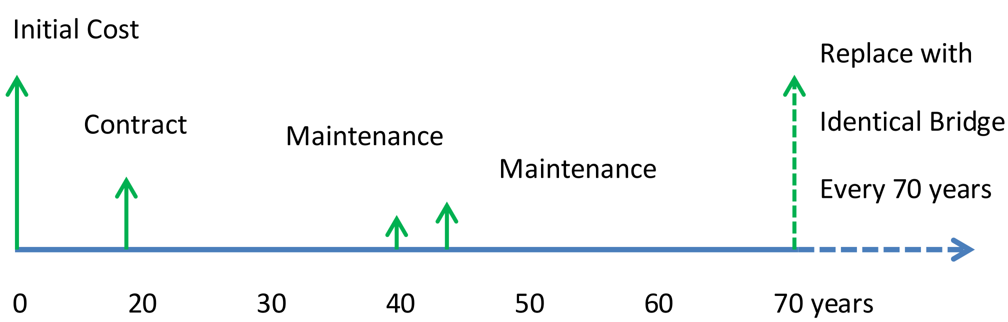


Figure 8: PennDOT Bridge 30750 Life Cycle Cost Timeline

To determine the Present Value Cost, the future costs are discounted to year 0 with a discount rate of 2.3% and added to the initial cost:

$$PVC = \$143.45 + \$16.63(1.023)^{-19} + \$0.28(1.023)^{-40} + \$0.34(1.023)^{-44} = \$154.49/ft^2$$

The Present Value Cost of only the future costs (maintenance and contracts) is:

$$Maintenance\ PVC = 16.63(1.023)^{-19} + 0.28(1.023)^{-40} + 0.34(1.023)^{-44} = \$11.04/ft^2$$

Finally, to compare this bridge with others in the PennDOT database, the Perpetual Present Value Cost for Bridge 30570 is:

$$PPVC = \$154.49\left[\frac{(1+0.023)^{70}}{(1+0.023)^{70}-1}\right] = 1.256(\$154.49) = \$193.97/ft^2$$

4.4 Removal of Non-Typical Bridges

There are 1705 bridges in Table 11 that met the database selection criteria. However, there are only 1186 that are used for the Life Cycle Cost comparisons. For the Life Cycle Cost analyses, bridges were removed based on Perpetual Present Value Costs that were considered non-typical. The idea is to compare typical bridges based on the bridge type averages. Therefore, working with the PennDOT Bridge Engineer, a removal criterion was set to be bridges that have a Perpetual Present Value Costs exceeding plus or minus one standard deviation from the mean of the entire bridge type group. This removes bridges that have either unreasonably high or low PPVC due to complicated or simple projects and keeps what is considered typical bridges. Table 13 shows the original number of bridges in the Table 11 database and the number of bridges used for the Life Cycle Cost study.

Table 13: Final Life Cycle Cost Database

Bridge Type	Number of Bridges in Table 11 Database	Number of Bridges in LCC Study Database	Percentage Removed with "Typical Bridge" Criterion
Steel I Beam	82	54	34%
Steel I Girder	230	144	37%
P/S Box - Adjacent	400	282	30%
P/S Box - Spread	581	397	32%
P/S I Beam	412	309	25%
	1705	1186	30%

From Table 13, the percentage of bridges removed with the "Typical Bridge" criterion is fairly consistent over the bridge types. The opinion is that the final Life Cycle Cost database represents typical bridges for the different bridge types and that the averages can be used for comparison. Appendix A contains the 1186 individual bridge results for each bridge type for the final Life Cycle Cost database.

4.5 Life Cycle Cost Results

For each bridge type, the third table in Appendix A lists the PPVC, Initial and present value of all future maintenance costs. Each bridge can be compared to any other within a bridge type or over different bridge types using the PPVC. The third table also lists year built, bridge life, length and number of spans. At the top of the third table are averages and standard deviations for all of these quantities.

Table 14 presents the results of the Life Cycle Cost study for the averages over the database. The PPVC is the quantity to equally compare over different bridge types. The least expensive alternative is the P/S I Beam, followed by the Steel I Beam. Another important consideration for bridge owners is bridge life. Both of the steel bridge types (rolled and girder) have the longest average bridge life. However, since the standard deviations, average length, average number of spans, and average life all vary considerably between the bridge types, it is worth studying these variables a little closer.

Table 14: Life Cycle Cost Results Using Total Database

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Length	Avg # Spans	Avg Year Built	Avg Life
Steel I Beam	54	$232.78	$194.78	$0.42	166	2.19	1980	82
Steel I Girder	144	$273.71	$226.10	$0.21	406	4.07	1976	80
P/S Box - Adjacent	282	$278.30	$223.74	$0.96	89	1.31	1987	74
P/S Box - Spread	397	$256.11	$210.65	$2.06	89	1.56	1986	79
P/S I Beam	309	$217.50	$174.10	$0.20	212	2.43	1985	73

4.5.1 Variability in Perpetual Present Value Cost

Table 15 repeats the averages for PPVC for the different bridge types, but it also presents the standard deviation in the PPVC.

Table 15: Statistical Characteristics of Perpetual Present Value Cost

	Mean	St. Dev	Pr(PPVC<$300)
Steel I Beam	$232.78	$57.51	87.9%
Steel I Girder	$273.71	$65.60	65.6%
P/S Box - Adjacent	$278.30	$48.02	67.4%
P/S Box - Spread	$256.11	$53.51	79.4%
P/S I Beam	$217.50	$54.85	93.4%

Assuming that the behavior follows a Normal distribution, Figure 9 demonstrates the Probability Density Function (PDF) PPVC behavior of the different bridge types. The PDF shows the mean and the standard deviation characteristics. All of the bridge types are similar in both mean and standard deviation. There is no one type of bridge that is clearly less expensive or more uncertain in the cost than another. This is especially true given the limited database that is used in the Life Cycle Cost study.

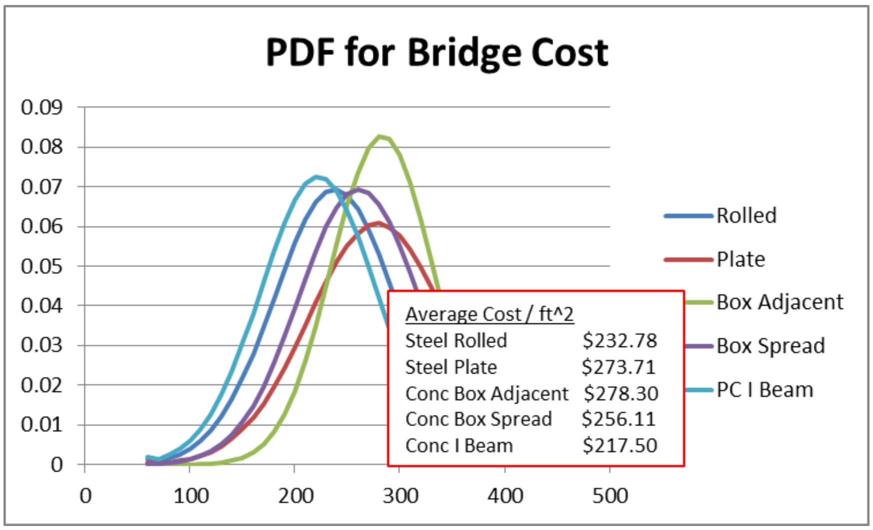


Figure 9: Probability Density Function for Perpetual Present Value Cost

A useful way to use such data is to ask the question, what is the probability that the PPVC is less than $300/ft^2 for the different bridge types? Still assuming the probability distribution is Normal, any statistics textbook can determine that the probability (shown in Table 15) is:

$$Probability(PPVC < \$300/ft^2) = \Phi\left(\frac{300 - Mean}{St.\,Deviation}\right)$$

This analysis is demonstrated in Figure 10 where the Cumulative Density Function (CDF) is plotted for the different bridge types. There is a 93% probability (confidence for bridge owners) that a Precast I Beam bridge, and an 88% probability that a Steel I Shape Beam bridge, will have a Perpetual Present Value Cost less than $300/ft^2. The probabilities decrease for the other types of bridges.

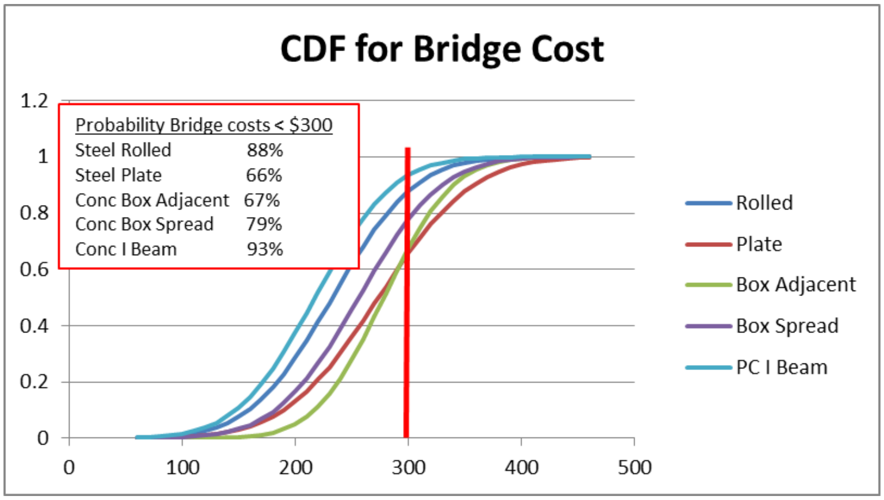


Figure 10: Cumulative Density Function for Perpetual Present Value Cost

4.5.2 Variability in Bridge Life

A similar analysis can be conducted for bridge life. Table 16 repeats the averages for bridge life for the different bridge types, but it also presents the standard deviation in the bridge life.

Table 16: Statistical Characteristics of Bridge Life

	Mean	St. Dev.	Pr(Life>75yrs)
Steel I Beam	82	10.83	73.0%
Steel I Girder	80	15.40	62.7%
P/S Box - Adjacent	74	10.47	45.6%
P/S Box - Spread	79	11.15	65.6%
P/S I Beam	73	11.91	44.3%

Assuming that the behavior follows a Normal distribution, Figure 11 demonstrates the Probability Density Function (PDF) bridge life behavior of the different bridge types. The PDF shows the mean and the standard deviation characteristics. All of the bridge types are similar in mean bridge life and standard deviation (with some differences). There is no one type of bridge that clearly has a significantly longer bridge life (except there is a difference between steel and concrete as a whole) or more uncertain bridge life than another.

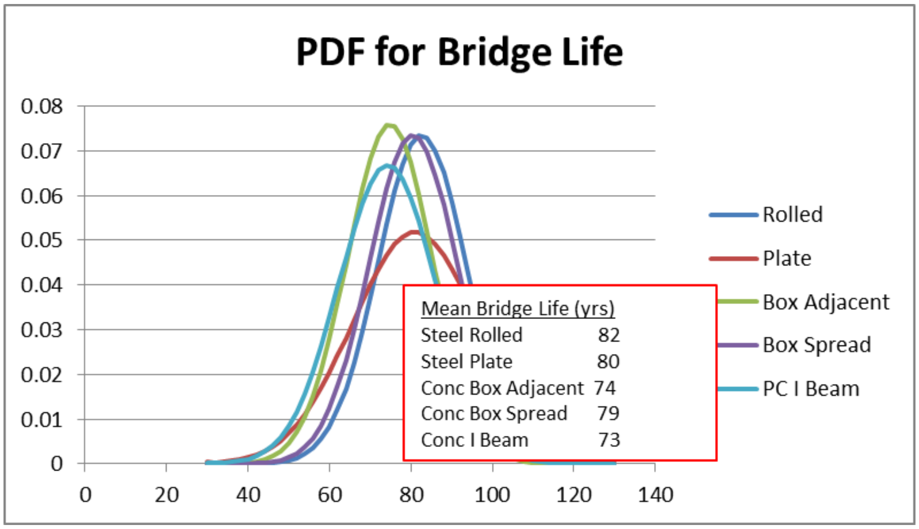


Figure 11: Probability Density Function for Bridge Life

Again, a useful way to use such data is to ask the question, what is the probability that the Bridge Life exceeds 75 years for the different bridge types? Still assuming the probability distribution is Normal, any statistics textbook can determine that the probability (shown in Table 16) is:

$$Probability(Life > 75\ years) = 1 - \Phi\left(\frac{75 - Mean}{St.Deviation}\right)$$

This analysis (assuming Normal distribution) is demonstrated in Figure 12 where the Cumulative Density Function (CDF) is plotted for the different bridge types.

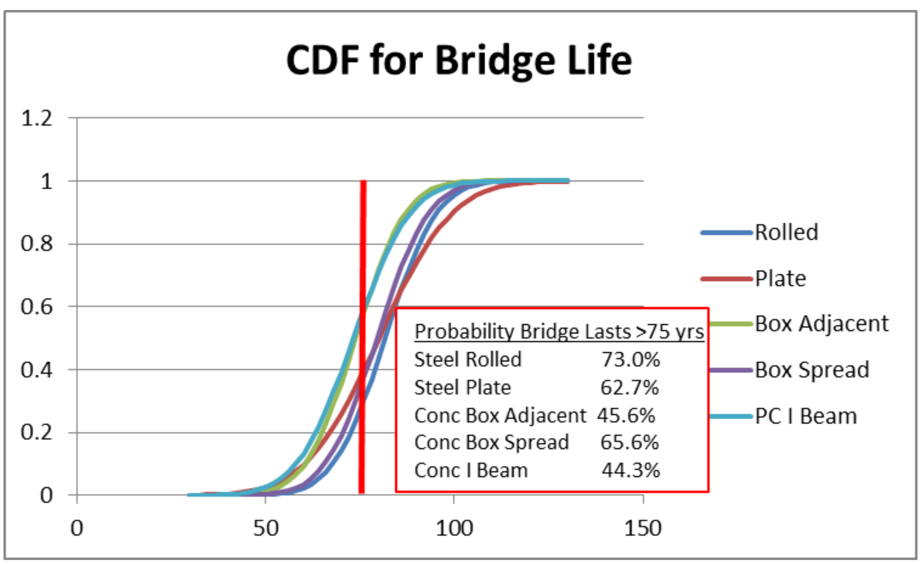


Figure 12: Cumulative Density Function for Bridge Life

There is a 73% probability (confidence for bridge owners) that a Steel I Shape Beam bridge, but only a 44% probability that a Precast I Beam bridge, will have a Bridge Life that exceeds 75 years. The probabilities are between the two for the other types of bridges.

4.5.3 Variability in Average Number of Spans

There is a significant difference in average number of spans between the bridge types. The following examines sub-groups of the bridge types for various numbers of spans. Table 17 shows the results for simple-span bridges. There are 608 simple span bridges that meet the criteria and the re-application of the "Typical Bridge" PPVC criterion.

Table 17: Life Cycle Cost Results for Simple Span Bridges

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Length	Avg # Spans	Avg Year Built	Avg Life
Steel I Beam	22	$302.38	$253.90	$0.13	90	1.00	1981	84
Steel I Girder	21	$318.73	$263.02	$0.25	128	1.00	1979	81
P/S Box - Adjacent	215	$300.74	$241.81	$1.00	65	1.00	1987	74
P/S Box - Spread	245	$294.67	$245.40	$1.06	54	1.00	1988	81
P/S I Beam	105	$287.24	$234.67	$0.04	108	1.00	1989	76

For all the bridge types, the PPVC increases compared to the entire database results. This is expected since most of the time simple-span bridges have higher cost per ft^2. The ranking also changes some with the three concrete bridge types being the least expensive. However, all the bridge types are fairly competitive as they were for the entire database.

Table 18 presents the results for 2-span bridges. There are 184 two-span bridges that meet the criteria and the re-application of the "Typical Bridge" PPVC criterion. For 2-span bridges, some of the PPVC increase and some decrease compared to the overall results. Steel I Girder bridges have the least PPVC, followed by Precast Box Beam – Spread bridges. However, like in previous examples, all of the bridge types are competitive.

Table 18: Life Cycle Cost Results for 2-Span Bridges

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Length	Avg # Spans	Avg Year Built	Avg Life
Steel I Beam	16	$234.04	$193.99	$0.05	198	2.00	1988	81
Steel I Girder	24	$210.49	$175.04	$0.24	243	2.00	1976	81
P/S Box - Adjacent	32	$242.74	$191.74	$1.53	155	2.00	1987	72
P/S Box - Spread	59	$226.78	$183.55	$0.08	127	2.00	1989	74
P/S I Beam	53	$230.78	$183.02	$0.18	209	2.00	1985	71

To consider any bridge that exceeds a simple span, Table 19 has the results for all the bridges that have a number of spans that exceed one (all multi-span bridges). There are 614 multi-span bridges that meet the criteria and the re-application of the "Typical Bridge" PPVC criterion.

Table 19: Life Cycle Cost Results for All Multi-Span Bridges (Number of Spans > 1)

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Length	Avg # Spans	Avg Year Built	Avg Life
Steel I Beam	35	$213.82	$177.00	$0.62	213	2.80	1980	80
Steel I Girder	123	$262.12	$217.78	$0.19	460	4.66	1976	80
P/S Box - Adjacent	70	$214.90	$170.96	$1.21	181	2.63	1983	73
P/S Box - Spread	170	$190.13	$152.34	$3.29	158	2.82	1980	77
P/S I Beam	216	$193.38	$153.66	$0.21	260	3.15	1983	73

All of the different bridge type average PPVC decreases compared to the overall database for multi-span bridges. Here Precast Box Beam – Spread bridges have the least PPVC, but, again, all of the bridge types are competitive with Steel I Girder (high average number of spans) bridges on the high end of PPVC.

4.5.4 Variability in Average Bridge Length

The Steel Marketing Development Institute, through the Short Span Steel Bridge Alliance, defines short span bridges as those with a length of 140 ft or less. To consider short span bridge behavior, Table 20 presents the results for all bridges that have a maximum span of 140 ft. There are 708 multi-span bridges (most of them precast concrete boxes) that meet the criteria and the re-application of the "Typical Bridge" PPVC criterion. Here the Steel I Beam bridges are the least expensive with Precast Box Beam – Spread next. All of the average PPVC are greater than those of the entire database.

Table 20: Life Cycle Cost Results for Bridge Length Maximum = 140 ft

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Length	Avg # Spans	Avg Year Built	Avg Life
Steel I Beam	27	$266.24	$222.08	$0.16	84	1.26	1978	82
Steel I Girder	18	$311.26	$257.19	$0.29	119	1.00	1977	81
P/S Box - Adjacent	240	$292.38	$235.03	$0.95	69	1.09	1987	74
P/S Box - Spread	325	$272.20	$225.14	$2.16	64	1.23	1986	81
P/S I Beam	98	$281.64	$231.20	$0.05	104	1.08	1987	77

For bridges that have bridge length greater than 140 ft, Table 21 presents the results. There are 479 multi-span bridges (most of them precast concrete boxes) that meet the criteria and the re-application of the "Typical Bridge" PPVC criterion. The three concrete bridge types have the least average PPVC.

Table 21: Life Cycle Cost Results for Bridge Length > 140 ft

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Length	Avg # Spans	Avg Year Built	Avg Life
Steel I Beam	28	$216.25	$180.08	$0.69	234	2.86	1982	80
Steel I Girder	96	$256.79	$213.34	$0.19	281	3.02	1975	80
P/S Box - Adjacent	48	$214.14	$170.45	$1.41	213	2.77	1983	73
P/S Box - Spread	75	$191.14	$153.59	$0.90	206	3.16	1981	74
P/S I Beam	232	$195.38	$154.71	$0.25	258	3.05	1984	72

4.5.5 Summary of PPVC Comparisons

Drawing absolute Life Cycle Cost conclusions between different bridge types is difficult given the PennDOT database used in the analyses. The database comprises bridges that met all of the criteria, including known dates and costs for all maintenance performed, known dates and costs for all external contracts performed, and known initial costs. There were many bridges that had maintenance and external contracts, but without known dates or costs. These bridges were removed from the database. There were many bridges with most of the information known, but one item missing. These bridges were removed from the database. Therefore, the database is biased towards bridges that did not have maintenance or external contracts since these would not have been removed as long as they had initial costs. The results do not include a large number of bridges that have maintenance. So, consideration of the specific numbers must be taken in context that the numbers represent the bridges that made it into the database, and the database is not as comprehensive as one would like.

However, a conclusion that can be drawn is that all the types of bridges are fairly competitive in both Initial Costs and Perpetual Present Value Costs. With the dispersion of costs (standard deviation) any of the bridge types may be least expensive for a given project.

4.5.6 Future Costs

The benefit in considering Life Cycle Costs in bridge project decisions is that a LCC analysis considers future costs and bridge life. Both are important aspects for bridge management. Bridge life was addressed above with the steel bridge types having a slight advantage over the concrete types. One indicator of how much future maintenance costs and bridge life impact Life Cycle Costs would be the ratio of PPVC and Initial Cost. The ratio would contain an influence from bridge life since the PPVC assumes the bridge is replaced into perpetuity. Table 22 presents the average PPVC, Initial Cost, the present value cost of all future maintenance costs, bridge life, and the ratio of PPVC and Initial Cost. The average Future Cost is the sum of all maintenance and external contract work for each bridge type divided by the number of bridges for that bridge type.

Table 22: Life Cycle Costs and PPVC/Initial Cost for Total Database

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Life	PPVC/Initial Cost
Steel I Beam	54	$232.78	$194.78	$0.42	82	1.20
Steel I Girder	144	$273.71	$226.10	$0.21	80	1.21
P/S Box - Adjacent	282	$278.30	$223.74	$0.96	74	1.24
P/S Box - Spread	397	$256.11	$210.65	$2.06	79	1.22
P/S I Beam	309	$217.50	$174.10	$0.20	73	1.25

For instance, for Steel I Beam bridges, the result indicates that, for this database, on average it takes 20% more than the initial cost to take care of all future maintenance costs and replace the bridge into perpetuity. The reason that the above statement states “for this database” is that the database is biased towards bridges with no maintenance costs.

When comparing the bridge types, the steel type bridges have a lower future cost component (1.20 and 1.21 vs. 1.22 – 1.25). This is a combination of future maintenance costs and bridge life. Precast I beam bridges have the lowest Future Cost of $0.20, but an average bridge life of only 73 years, whereas Steel I Beam bridges have a higher Future Cost of $0.42, but the average bridge life is 82 years. The combination of the two variables results in Steel I Beam bridges having a lower PPVC/Initial Cost of 1.20 while the Precast I Beam bridges have a ratio 0f 1.25.

4.5.7 Maintenance and External Contracts

The second table in Appendix A lists the maintenance and external contracts that were performed on each bridge for each bride type in the database. Table 23 lists the types of maintenance that are included in the database.

Table 23: Maintenance Definitions for the Database

Group	PennDOT Designation	Description
1 - Concrete Deck	6-D744303-RPR.CONC.DECK	Concrete Deck (Repair)
2 - Deck Joints	20-D744102-RPR.STL.EXP.DAM	Steel Dams (Repair/Rehab)
	2-A743301-RESEAL DK.JOINT	Reseal Deck Joint
	33-B744102-RPR/RPLCOMPR.SEAL	Compression Seal (Repair/Rehab)
	4-A744101-REPAIR DK.JOINT	Repair/Reseal Deck Joint
3 - Structure Framing	25-A744602-RPR/RPL.STEEL BEAM	Stringer (Repair/Replace) - Steel
	54-D744602-RPR/RPLSTLDIAPHRAM	Diaphragm/Lateral Bracing (Repair/Replace) - Steel
	49-C744602-RPR.STEELGIRDER	Girder (Repair) - Steel
	42-A744603-RPR/RPL.CONC.BEAM	Stringer (Repair/Replace) - Concrete
	69-B744603-RPR/RPLCONC DIAPHRAM	Diaphragm (Repair/Replace) - Concrete
	45-D744503-RPL.BRGPED/SEAT	Pedestal Seat (Reconstruct)
	EXTERNAL CONTRACT WORK	Various Superstructure Work
4 - Painting	57-A743201-SPOT PAINT SUPERSTR	Superstucture Spot Painting
	65-C743201-PAINT SUPERSTRUCTURE	Superstructure Full Painting
5 - Protection	80-A743401-PROT.CTG.TO SUPERSTR	Superstructure Protective Coating

The maintenance work is divided into five groups: Concrete Deck, Deck Joints, Structure Framing, Painting and Protection. Noting that the database has concerns in terms of completeness of information, Tables 24 through 26 present maintenance characteristics for the Concrete Deck, Deck Joints and Structure Framing groups.

Table 24: Maintenance Characteristics for Concrete Deck Repair

	# Bridges	# Occurrences	Avg Age to Repair	Average Cost per ($/ft^2)	% of Bridges Repaired	Avg Cost over all Bridges
Steel Rolled	54	12	42	$0.29	22.22%	$0.06
Steel Plate	144	22	39	$0.89	15.28%	$0.14
Concrete Box Adjacent	282	32	35	$6.95	11.35%	$0.79
Concrete Box Spread	397	82	37	$1.15	20.65%	$0.24
Concrete I-beam	309	78	40	$0.46	25.24%	$0.12

Table 25: Maintenance Characteristics for Deck Joints

	# Bridges	# Occurrences	Avg Age to Repair	Average Cost per ($/ft^2)	% of Bridges Repaired	Avg Cost over all Bridges
Steel Rolled	54	16	37	$0.32	29.63%	$0.09
Steel Plate	144	42	36	$0.64	29.17%	$0.19
Concrete Box Adjacent	282	25	32	$3.43	8.87%	$0.30
Concrete Box Spread	397	51	33	$0.91	12.85%	$0.12
Concrete I-beam	309	51	35	$0.94	16.50%	$0.16

Table 26: Maintenance Characteristics for Structure Framing

	# Bridges	# Occurrences	Avg Age to Repair	Average Cost per ($/ft^2)	% of Bridges Repaired	Avg Cost over all Bridges
Steel Rolled	54	4	38	$9.87	7.41%	$0.73
Steel Plate	144	19	38	$1.08	13.19%	$0.14
Concrete Box Adjacent	282	2	27	$63.81	0.71%	$0.45
Concrete Box Spread	397	18	25	$44.04	4.53%	$2.00
Concrete I-beam	309	6	39	$0.51	1.94%	$0.01

The number of occurrences is the total number of maintenance events that were performed for that bridge type. The average cost per event is the total cost of all occurrences divided by the number of occurrences. The percentage of bridges repaired is the number of occurrences divided by the number of bridges. However, this may have some inaccuracy since the same repair may have been applied to a bridge more than once. The same inaccuracy may be present in the average cost over all bridges in that the average cost of each repair times the number of occurrences is divided by the number of bridges in the database for each bridge type.

The results shown are for the database as developed and the number of maintenance occurrences is fairly low. With the limited number of bridges in the database that have valid maintenance records, it is difficult to draw meaningful conclusions. However, the Concrete Box type bridges, when maintenance is required, have high maintenance costs for deck repair and structure framing. Concrete Box type bridges are configured to where the deck is part of the structure framing, so there is a cross-over when trying to separate the deck from the box.

So, again, consideration of the specific numbers must be taken with the context that the numbers represent the bridges that made it into the database, and the database is not as comprehensive as one would like. However, if the database was comprehensive, such a study could be very beneficial to bridge owners and managers.

4.5.8 PennDOT Steel Bridge Database

Within the steel type bridge database, additional characteristics were examined. For instance, curved steel bridge construction is more complicated than straight bridges. Fracture-critical bridges, having additional scrutiny over non-fracture-critical bridges, may result in additional initial and future costs. Also, coating systems can have an influence on initial and future costs. Table 27 examines these variables. The following discusses the results within the limited steel bridge PennDOT database.

Table 27: Steel I Beam and Steel I Girder Bridges

	# Bridges	PPVC	Initial Cost	Future Cost	Avg Length	Avg # Spans	Avg Year Built	Avg Life
Steel Rolled - All	54	$232.78	$194.78	$0.42	166	2.19	1980	82
Steel Rolled - Straight	46	$229.94	$193.19	$0.48	160	2.22	1979	82
Steel Rolled - Weathering	15	$242.75	$203.95	$0.07	164	1.47	1983	83
Steel Girder - All	144	$273.71	$226.10	$0.21	406	4.07	1976	80
Steel Girder - Straight	100	$273.54	$225.58	$0.21	330	3.18	1976	80
Steel Girder - Weathering	11	$254.04	$215.76	$0.03	263	2.45	1974	83
Steel Girder - Non Fract. Crit.	132	$272.53	$225.11	$0.23	359	3.50	1976	80

4.5.8.1 Curved vs. Straight Steel Bridges

When comparing the results for straight bridges and the results for all of the bridges, for both the Steel I Beam and Steel I Girder bridges in the database, there is little difference between curved and straight bridges for PPVC, Initial Costs, Future Costs, or Bridge Life. Although there are not that many curved bridges in the database (8 I beam (15%) and 44 I Girder (30%)), the additional costs associated with curved bridges does not increase the all bridge data significantly (($232.78-$229.94)/$229.94 = 1.2% for I Beam and nearly nothing for I Girder).

4.5.8.2 Fracture-Critical Steel Bridges

There were 12 fracture-critical bridges in the Steel I Girder database. The PPVC for the fracture-critical bridges is actually lower than the PPVC for all I Girder bridges. From this database analysis, it does not appear that fracture-critical designation has a significant impact on Life Cycle Costs.

4.5.8.3 Painted vs. Weathering Steel

The database includes 15 I Beam and 11 I Girder bridges that used weathering steel. The remainder of the bridges are assumed to be painted. When comparing the painted to the weathering steel bridges, the results are mixed. For PPVC, the weathering steel I Beam bridges have a higher (4.3%) PPVC than the overall PPVC, but the I Girder weathering steel bridges have a lower (0.4%) PPVC. However, what is consistent is that future costs are significantly less for weathering steel bridges than for painted bridges. Also, the bridge life increased slightly.

4.5.8.4 Galvanizing

There were no galvanized bridges that made it into the Life Cycle Cost database. This is unfortunate because protective coating systems is an important aspect of steel bridges and galvanizing has become an economical and effective protection system. Recent information shows that Hot Dipped Galvanizing initial costs are approximately equal to or even less than a quality 3-coat paint system. Of course paint systems need maintenance over the bridge life, whereas galvanizing usually does not, or it may require a zinc-rich spot painting at about 60 years. Group 4 in Table 23 shows the painting maintenance for the steel bridges. Table 28 lists the number of paint maintenance events where there were 4 I Beam and 11 I Girder paint maintenance records. The present value of the average future painting costs for these bridges are \$1.44/ft^2 and \$0.21/ft^2, respectively. If galvanizing was an option, these future costs would be eliminated. However, since there were no galvanized bridges in the database, no direct comparisons can be made in this study.

Table 28: Painted Steel I Beam and Steel I Girder Bridges

	# Bridges	# Occurrences	Avg Age to Repair	Average Cost per (\$/ft^2)
Steel Rolled	54	4	34	\$1.44
Steel Plate	144	11	39	\$0.21

4.5.8.5 Summary of PennDOT Steel Bridge Database

The discussion on characteristics of steel bridges, whether it is curved vs. straight, fracture-critical, or painted vs. weathering steel vs. galvanizing, is based on the limited PennDOT database developed herein. Hard conclusions are difficult to discern due to the limitations within the database. However, with a more comprehensive database, these types of studies would be beneficial to bridge owners and managers.

4.6 Summary

This chapter determined the Life Cycle Costs for the Life Cycle Cost bridge database. The initial costs, Life Cycle Costs, and future costs of the 1186 bridges in the database are examined with respect to variability in bridge type, bridge length, number of spans, and bridge life. The steel bridges in the database are also examined with respect to protective coating systems. Drawing hard conclusions from the results is difficult knowing that the database is limited with respect to the PennDOT bridge inventory. Chapter 5 presents a summary of the study and conclusions from the results.

5 - Summary and Conclusions

5.1 Review of Objectives and Life Cycle Cost Database

The objective of this study was to examine historical Life Cycle Costs of typical steel and concrete bridges across the United States. This requires collecting the life histories of bridges, including initial costs, maintenance, rehabilitation and bridge life. Unfortunately, except for the Pennsylvania Department of Transportation, the select number of states and counties contacted for this study were not able to provide the required data on their bridges due to the large amount of time and resources required to collect this data. Therefore the Life Cycle Cost study contained in this report is limited to state bridges in the PennDOT inventory. Even within the PennDOT inventory, only 18% (1186 bridges out of a possible 6587) of the bridges built between 1960 and 2010 had complete historical records and are included in the Life Cycle Cost analyses. The database must be considered only a snapshot of the total PennDOT bridge inventory. The criteria applied removed 82% of the eligible bridges, mostly due to incomplete initial cost, maintenance records and external contract records. If these records were complete, the database would be much larger and the resulting Life Cycle Cost analyses would more accurately represent the PennDOT bridge inventory.

5.2 Interpreting Results and Conclusions

The report examines the initial costs, Life Cycle Costs, and future costs of the bridges in the database with respect to variability in bridge type, bridge length, number of spans, and bridge life. The types of bridges in the database include steel rolled shape beam, steel plate girder, precast box, and precast beam bridges. The steel bridges in the database are also examined with respect to protective coating systems.

Therefore, given the nature of the database used, interpreting the tables and figures showing comparisons of initial costs, Perpetual Present Value Costs, maintenance and future costs, and bridge life is left to the reader. Consideration of the specific numbers and any conclusions must be taken in the context that the results represent the bridges that made it into the database, and the database is not as comprehensive as desirable for drawing conclusions.

A conclusion that can be drawn, however, is that all the types of bridges are fairly competitive in both Initial Costs and Perpetual Present Value Costs. The average initial costs vary from \$174/ft^2 to \$226/ft^2 and the average Perpetual Present Value Costs vary between \$218/ft^2 (Pretressed I Beam) and \$278/ft^2 (Prestressed Adjacent Box). For bridge life, the lowest average life was 73 years (Pretressed I Beam) and the longest was 82 years (Steel I Beam).

The coefficient of variation (standard deviation / mean) of the PPVC was approximately 20%, which is considerably high. With the relatively small differences in the PPVC averages, given the dispersion of the PPVC costs (standard deviation), any of the bridge types may have the least Perpetual Present Value Cost for a given project.

5.3 Future Work

Even though this research was limited to only a subset of PennDOT bridges, the analyses demonstrate the potential benefits of LCC analysis for bridge construction and management. A study of a more comprehensive database of bridges on the initial costs, Life Cycle Costs and future costs of different types of bridges over a diverse set of circumstances would be very useful for bridge owners and managers. With a more comprehensive database, not only would there be a more accurate comparison of bridge types, an accurate comparison of design details, such as jointless decks, rebar coatings, steel protection systems, and other construction details could be completed. The author worked with several states and many counties to try to develop a broad database of bridges across the country. However, these particular states and local owners could not provide the necessary historical data. Although extending this work would take considerable effort, other states and counties could be contacted in an effort to obtain a comprehensive bridge database.

Appendix A - PennDOT Bridge Database

The PennDOT Bridge Database is Divided by Bridge Type:

- **Steel I-Beam**
- **Steel I Welded Girder**
- **Precast Box Beam – Adjacent**
- **Precast Box Beam – Spread**
- **Precast I Beam**

For Each Bridge Type, the Data is Presented as:

- **General Information**
- **Initial Cost, Maintenance and External Contracts**
- **Life Cycle Cost Results**

2015

LIFE-CYCLE COST ANALYSIS OF REINFORCED CONCRETE BRIDGES REHABILITATED WITH CFRP

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LIFE-CYCLE COST ANALYSIS OF REINFORCED CONCRETE BRIDGES REHABILITATED WITH CFRP

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Engineering at the University of Kentucky

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ABSTRACT OF DISSERTATION

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The deterioration of highway bridges and structures and the cost of repairing, rehabilitating, or replacing deteriorated structures is a major issue for bridge owners. An aging infrastructure as well as the need to upgrade structural capacity for heavier trucks adds to problem. Life-cycle cost analysis (LCCA) is a useful tool for determining when the deployment of fiber-reinforced polymer (FRP) composite components is an economically viable alternative for rehabilitating deteriorated concrete bridges.

The use of LCCA in bridge design and rehabilitation has been limited. The use of LCCA for bridges on a project level basis has often been limited to the non-routine design of major bridges where the life-cycle cost model is customized.

LCCA has historically been deterministic. The deterministic analysis uses discrete values for inputs and is fairly simple and easy to do. It does not give any indication of risk, i.e. the probability that the input values used in the analysis and the resulting life-cycle cost will actually occur.

Probabilistic analysis accounts for uncertainty and variability in input variables. It requires more effort than a deterministic analysis because probability distribution functions are required, random sampling is used, and a large number of iterations of the life-cycle cost calculations are carried out. The data needed is often not available.

The significance of this study lies in its identification of the parameters that had the most influence on life-cycle costs of concrete bridge and how those parameters interacted. The parameters are: (1) Time to construct the new bridge; (2) traffic volume under bridge (when applicable); (3) value of time for cars; and (4) delay time under the bridge during new bridge construction (when applicable). Using these parameters the analyst can now "simulate" a probabilistic analysis by using the deterministic approach and reducing the number of iterations. This study also extended the use of LCCA to bridge rehabilitations and to bridges with low traffic volumes. A large number of bridges in the United States have low traffic volumes. For the highway bridge considered in the parametric study, rehabilitation using FRP had a lower life-cycle cost when compared to the new bridge alternative.

KEYWORDS: life-cycle cost analysis, bridge rehabilitation, reinforced concrete t-beam bridges, fiber-reinforced polymer

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CHAPTER ONE: INTRODUCTION

The deterioration of highway bridges and structures is a major problem worldwide. In 2010 about 25.9 percent of the 604,493 bridges in the United States are deficient (USDOT 2013a). This includes both structurally deficient and functionally obsolete bridges. About 11.7 percent of the bridges are structurally deficient.

There are various reasons to replace or rehabilitate deficient bridges (Seible et al. 1991; Arduini and Nanni 1997; Weissmann and Harrison 1998; Lees et al. 2002; Aidoo et al. 2004; Nezamian and Setunge 2007; Choi et al. 2008; Kim and Harries 2013). The reasons may be design, construction, or operation related. Design related reasons include design errors, changes in design specifications, and deficiencies in design specifications. Construction related reasons include construction errors and deficiencies in construction specifications. Operation related reasons include element deterioration, increases in traffic volumes, truck collisions, earthquakes, and increases in legal loads (commercial vehicle sizes and weights) and permit loads.

There are three alternatives for dealing with deficient bridges (Klaiber et al. 1988; Alkhrdaji et al. 2000; Deniaud and Cheng 2003; Flowers et. al. 2010). One alternative is to do nothing. This often leads to load posting the bridge for weight restrictions. Load posting imposes financial hardships on those who then must detour around the posted bridge and can increase congestion on the alternate routes. Another alternative is to rehabilitate the bridge to increase the live load capacity. A third alternative is to replace the bridge.

Bridge Strengthening

There are some advantages to bridge strengthening in lieu of replacement or load posting (Klaiber et al. 1988; Reed et al. 2002; Tavakkolizadeh and Saadatmanesh 2003; Jones et al. 2004; Flowers et. al. 2010; Okeil et al. 2013). Bridge rehabilitation extends the service life of existing bridges. It can cost less to strengthen a bridge than to replace it. The reduced construction time can minimize construction-related impacts such as an increase in traffic delay and congestion, the disruption to local businesses, and environmental impacts (i.e. noise and air quality).

There are several traditional methods to increase the live load capacity of existing bridges (Berger and Gorgon 1978; Klaiber et al. 1988; Nezamian and Setunge 2007). One method is to add supplemental supports or members. Another is to strengthen critical members by increasing their cross section or replacing them. Live load capacity can be increased by reducing dead load, usually by replacing the normal weight concrete deck with a lightweight concrete one. Another is to change the behavior of the structural system by making simple spans continuous or making non-composite beams composite. Most of these methods require closing the bridge or limiting traffic. This has an economic impact on the travelling public (Carolin et al. 2005; Hoult and Lees 2009). One alternative that can minimize these impacts is the addition of external reinforcement.

One traditional method for adding external reinforcement is externally bonded steel plates (Klaiber et al. 1988; Reed et al. 2002; Petrou et al. 2008). It can be accomplished with minimal disruption to traffic (Carolin et al. 2005). However, problems with using steel have led to the search for alternate materials (Bakis et al. 2002; Deniaud and Cheng 2003; Petrou et al. 2008). The two primary issues with using steel plates are corrosion of the steel and the heavy weight of the plates. Fiber-reinforced polymer (FRP) plates can be used in place of steel (Arduini and Nanni 1997; Chaallal et al. 1998; Malek and Patel 2002; Monti and Santini 2002; Alagusundaramoorthy et al. 2003; Choi et al. 2008; Petrou et al. 2008; Hoult and Lees 2009).

Fiber-reinforced Polymers

Fiber-reinforced polymers (FRPs) are being used to strengthen concrete bridges (Alkhrdaji et al. 2000; Shekar et al. 2003; Ekenel et al. 2005; Catbas et al. 2006; Täljsten et al. 2007). The benefits and advantages of FRP composites are widely reported in the published literature (Spadea et al. 1998; Bakis et al. 2002; Alagusundaramoorthy et al. 2003; Deniaud and Cheng 2003; Tavakkolizadeh and Saadatmanesh 2003; Aidoo et al. 2004; Shahrooz and Boy 2004; El Maaddawy and Soudki 2005; Kim et al. 2008; Allen and Atadero 2012; Kim and Harries 2013; Wang et al. 2013). They include a high strength-to-weight ratio, a high tensile strength, superior fatigue resistance, excellent corrosion resistance, strong chemical resistance, advantageous electromagnetic properties, and versatility of use.

The FRP strengthening technique has several advantages (Shahawy et al. 2000; Malek and Patel 2002; Deniaud and Cheng 2003; Wang et al. 2004; Nezamian and Setunge 2007; Soudki et al. 2007; Kim et al. 2008; Allen and Atadero 2012; Kim and Harries 2013; Wang et al. 2013). One of the primary advantages is its lightweight. As a result it is easy to install, requires a minimum amount of equipment to support, and can be installed quickly. This simplifies construction and reduces the amount of time required for installation which can lower the cost. FRP systems can be installed without disrupting traffic on the bridge which decreases the impact on the travelling public. They can increase the ductility, shear resistance, and flexural strength of bridge members. The system can be designed to provide strength where needed. It may be possible to bond FRPs to surfaces that are curved and wrap them to match member geometry. Some other advantages include reduced maintenance costs, minimal reduction in clearances, and minimal changes in member dimensions.

Life-cycle Cost Analysis

The cost of repairing, rehabilitating, or replacing deteriorated structures is a major issue for State Departments of Transportation (DOT). The National Bridge Investment Analysis System model estimates a backlog of bridge investments in 2010 of $106.4 billion (USDOT 2013a). It is estimated that $20.5 billion annually is needed to eliminate the backlog of deficient bridges by the year 2028, which is a 60 percent increase over the $12.8 billion currently being spent (ASCE 2013). An aging infrastructure as well as the need to upgrade structural capacity for heavier live loads (trucks) adds to the backlog. FRP can be used to repair and rehabilitate existing concrete bridges (Bae et al. 2013). Life-cycle cost analysis (LCCA) is a useful tool for determining when FRP is an economically viable method for rehabilitating deteriorated concrete bridges.

The Federal Highway Administration (FHWA) defines Life-Cycle Cost Analysis as “an engineering economic analysis tool useful in comparing the relative merit of competing project implementation alternatives” (FHWA 2002). All costs are considered, both agency and user. The effects of agency activities such as construction on user costs are accounted for. The alternative with the lowest life-cycle cost is identified.

LCCA has historically been deterministic (FHWA 2002, Pittenger et al. 2012). The deterministic analysis uses discrete values for inputs and is fairly simple and easy to do. Published tables of discount factors simplified computational effort required. Since a deterministic analysis gives only a single life-cycle cost it does not give any indication of risk, i.e. the probability that the input values used in the analysis and the resulting life-cycle cost will actually occur (FHWA 2002). Costs and timings do however vary and this variability can affect the choice of alternative.

Probabilistic analysis accounts for uncertainty and variability in input variables (FHWA 2002, Reigle and Zaniewski 2002, Smith et al. 2005). It allows for simultaneous variations in more than one input parameter. A probabilistic analysis requires more effort than a deterministic analysis because probability distribution functions are required, random sampling is used, and a large number of iterations of the life-cycle cost calculations are carried out. In addition the results are tracked and stored for further statistical analysis.

A deterministic sensitivity analysis can be done to partially address the uncertainty and variability of input parameters. However the analysis only varies one parameter at a time and the “compounding” effect of changes in multiple inputs is not addressed. Some changes when individually applied increase life-cycle costs and others decrease life-cycle costs. When taken together the changes may additive or subtractive.

Dissertation Objective and Tasks

The objective of this study is to determine when rehabilitating a reinforced concrete bridge with externally applied fiber reinforced polymer composites had a lower life-cycle cost than bridge replacement.

In order to achieve the objective of this study, the following tasks are carried out:

1) Conduct a literature search to identify the current state-of -the-art in life cycle cost analysis for highway bridges to identify areas needing further research (Chapters 2 and 3);
2) Comparison of the life-cycle cost of reinforced concrete bridges rehabilitated using externally applied FRP composites with a new replacement bridge (Chapter 4);
3) Conduct a sensitivity analysis to identify the variables that primarily influence the life-cycle costs (Chapter 5); and
4) Determine the probability when rehabilitation has the lower life-cycle cost (Chapter 6);

Tasks 2, 3, and 4 were accomplished by applying the methodology to a reinforced concrete T-beam bridge.

Dissertation Significance

The significance of this study lies in its identification of the parameters that had the most influence on life-cycle costs of concrete bridge and how those parameters interacted. The identification of those parameters with the most influence can allow analysts to “simulate” a probabilistic analysis by using the deterministic approach but with a reduced number of iterations. The study extended the use of LCCA to bridge rehabilitations and to bridges with low traffic volumes. A large number of bridges in the United States have low traffic volumes. The study introduced the use of time declining discount rates for longer analysis periods.

Parametric studies included a bridge over a highway, a bridge over a highway with modified construction time and cost, a bridge over a highway with a limited number of random variables, a bridge over a waterway, and a bridge over a waterway with modified construction time and cost. The bridge included in the studies was a reinforced concrete bridge that was either rehabilitated with fiber reinforced polymer composites or replaced with a new bridge.

The methodology can be easily programmed in a spreadsheet. Bridge owners can then perform these analyses to assist with the decision making process as it relates to rehabilitating or replacing a concrete bridge. The methodology can easily be applied to other bridge types.

CHAPTER TWO: LITERATURE REVIEW

A historical background on life-cycle cost analysis (LCCA) is presented by Ozbay et al. (2004). The use of economic analysis in highway engineering was first introduced in the 19th century. In 1847 Gillespie published the *Manual of the Principles and Practices of Road Making*. In this manual the cheapest road is not necessarily the one that costs the least but the one with the greatest return on investment. In 1960 the American Association of State Highway Officials (AASHO) Redbook introduced LCCA to transportation. In 1969 the engineering economist Winfrey published *Economic Analysis for Highways*. During this time research began on user and vehicle operating costs. The American Association of State Highway and Transportation Officials (AASHTO) pavement design guides, 1983 and 1993, included LCCA for economic analysis. Sections 1024 and 1025 of the Intermodal Surface Transportation Efficiency Act of 1992 contain provisions for life cycle costs of bridges, tunnels, and pavements. Federal Executive Order 12893 was issued in 1994 and stated that "Benefits and costs should be measured and appropriately discounted over the full life cycle of each project." The National Highway System (NHS) Designation Act of 1995 required the use of LCCA on NHS projects that cost $25 million or more. The FHWA issued its policy on LCCA in 1996. To assist in the implementation of LCCA for pavements FHWA Demonstration Project 115, "Life-Cycle Cost Analysis in Pavement Design," was made available in 1998. In conjunction with this workshop a technical bulletin (Walls III and Smith 1998) and a spreadsheet based program were developed. National Cooperative Highway Research

Program Report 483 (Hawk 2003) provides a methodology and guidance manual for the LCCA of individual bridges in a project level analysis.

A three-stage survey on LCCA usage was conducted in 2001 and 2002. It obtained information from 39 state DOTs (Ozbay et al. 2004). The results were reported by offices or divisions using LCCA and by the types of projects on which LCCA is used. Of the respondents 68 percent of the design and research offices, 37.5 percent of the materials and pavement offices, and 12.5 percent of bridges offices reported using LCCA. All of the respondents reported using LCCA for pavement projects and only 25 percent reported using LCCA for bridge projects.

Life-cycle Cost Analysis for Pavements

As shown by the results of the LCCA survey most of the usage has been for pavements. It has been used to evaluate design alternatives on a project-level basis (Kulkarni 1984; Beg et al. 2000; Safronetz and Sparks 2003; Lee et al. 2011). The California Department of Transportation (Caltrans) has mandated the use of LCCA to evaluate pavement design alternatives (Lee et. al. 2011). It has been used to evaluate rehabilitation, preventive maintenance, preservation alternatives, and construction techniques (Reigle and Zaniewski 2002; Smith et al. 2005; Gerbrandt and Berthelot 2007; Praticò et al. 2011; Pittenger et al. 2011 and 2012; Pour and Jeong 2012). LCCA has been used to optimize the timing and location of road infrastructure (pavements and bridges) maintenance projects (Evdorides et al. 2002), optimize resource allocation (Gerbrandt and Berthelot 2007), and to estimate annualized life-cycle costs of constructing and maintaining representative road segments that included pavements, bridges, and other road infrastructure components (Swan et al. 2007). Katz (2004) used LCCA to compare FRP reinforced concrete pavement to steel reinforced concrete pavement.

Life-cycle Cost Analysis for Bridges

Many bridge management systems (BMS) use some form of life-cycle cost analysis on a network level (Safi et al. 2012). A BMS typically includes deterioration, life-cycle cost, and budget optimization procedures (Saito and Sinha 1987; Al-Subhi et al. 1990; Shirole et al. 1991; James et al. 1991; Frangopol et al. 2000; Patidar et al. 2007). Chen and Johnston (1990) reported on using economic analysis of alternatives to optimize bridge management decisions (time and cost) for maintenance, rehabilitation, and replacement. Elbehairy et al. (2009) reported on a bridge management system that uses decisions made on the project-level and network-level to optimize bridge repairs. Johnson et al. (1998) reported on using economic analysis to make a preliminary selection of a rehabilitation option, compare the cost and benefits of various rehabilitation alternatives to the no rehabilitation alternative, and establish priorities. Cady (1985) reported on using minimum life-cycle costs for bridge deck protection, repair, rehabilitation, and replacement strategies for the Pennsylvania Department of Transportation. LCCA was used to optimize maintenance of a reinforced concrete bridge deck (Mullard and Stewart 2012) and a reinforced concrete girder bridge (Zhu and Liu 2013).

The use of LCCA in bridge design and rehabilitation has been limited. Fagen and Phares (2000) used LCCA to evaluate a bridge-replacement alternative for low-volume county roads. Okasha et al. (2012) used LCCA to compare steel bridges fabricated with a new maintenance-free steel and conventional painted carbon steel. Ehlen and Marshall (1996) used LCCA to compare concrete beams reinforced with FRP to beams reinforced with conventional steel. Ehlen (1997, 1999) used LCCA to compare FRP bridge decks to reinforced concrete decks. Grace et al. (2012) used LCCA to compare bridge decks reinforced with carbon fiber-reinforced polymer (CFRP) to bridge decks reinforced with conventional steel. The use of LCCA for bridges on a project level basis has been limited to the non-routine design of major bridges where the life-cycle cost model is customized (Thompson, 2004). Meiarashi et al. (2002) compared the life-cycle costs of a CFRP suspension bridge and a steel bridge.

Life-cycle Cost Analysis for Bridge Rehabilitation

LCCA tools for evaluating and comparing bridge rehabilitation strategies, especially fiber reinforced polymers, on a project level are needed. Klaiber et al. (1987) recommended using a life-cycle cost analysis to compare strengthening and replacement options on a project level. Limited information on life-cycle costs and the lack of simple LCCA tools have kept FRP from being used more (Hastak and Halpin 2000; Thompson 2004; Trejo and Reinschmidt 2007a). Cosenza and Manfredi (2002) and Porter and Harries (2007) identified and reported on the need for life-cycle analysis tools for FRP. These tools would allow designers to justify the use of high performance materials such as FRP even though initial costs are higher (Trejo and Reinschmidt 2007b).

The rehabilitation of reinforced concrete bridges with FRP extends the service life of the bridge which postpones the need for replacement. Since FRP can be installed without major impact on traffic it can reduce the user costs due to the repair or rehabilitation. When it increases the live load capacity of a bridge it also reduces user costs for those vehicles that no longer need to detour around the bridge. LCCA tools would allow designers to justify the use of high performance materials such as FRP even though initial costs are higher (Trejo and Reinschmidt 2007b).

CHAPTER THREE: LIFE-CYCLE COST ANALYSIS

In a life-cycle cost analysis future costs are discounted to their present value. Costs (initial and future) can be either nominal or real (constant) dollars. While nominal dollars directly include the effect of inflation real dollars do not. Although either can be used in a LCCA they should not be combined in the same analysis and the use of real dollars is recommended (FHWA 2002). Three types of analyses were used in the study: deterministic, sensitivity, and probabilistic.

Discount Factors

Discount factors are used to calculate the present value of future costs (Blank and Tarquin 1998). The discount factor for a single amount (P/F) depends on the discount rate, *i*, and the time that the cost occurs, *n*:

$$(P/F, i, n) = \frac{1}{(1+i)^n} \tag{3.1}$$

The discount factor for a uniform series (P/A) depends on the discount rate and the time over which the costs occur, *n*:

$$(P/A, i, n) = \frac{(1+i)^n - 1}{i(1+i)^n} \tag{3.2}$$

In order to conduct the LCCA an appropriate discount rate must be selected. This allows future and present costs to be combined (James et al. 1991). For analysis periods longer than 50 years the use of a time declining discount rate is recommended (Boardman et al. 2011). A discount rate of 3.5 percent was used for costs occurring 50 or less years in the future and 2.5 percent for costs occurring more than 50 years in the future (Boardman et al. 2011).

Bridge Alternatives

The bridge used in the study is based on an existing bridge located in Woodford County in Central Kentucky. It is a four span continuous reinforced concrete T-beam structure that carries Huntertown Road over the Bluegrass Parkway. There are two lanes on the bridge and four lanes, two in each direction, under the bridge. The maximum span length is 60 feet (18.3 m) and the total bridge length is 204.1 feet (62.2 m). The typical cross section of the existing bridge is shown in Figure 3.1a.

Two alternatives were considered, rehabilitation and replacement. Since the alternatives need to achieve the same level of service or utility, comparable benefits and no externalities, the rehabilitation alternative included deck restoration and safety work. Otherwise LCCA is not appropriate for comparing alternatives and a Benefit-Cost Analysis should be done instead (FHWA 2002). The first alternative was to rehabilitate the existing bridge. The rehabilitation consisted of externally applied CFRP to strengthen it for shear, latex modified concrete (LMC) overlay to improve the deck condition, and retrofitting the existing bridge rail with thrie beam for safety. The second alternative was to replace the existing bridge with a two span prestressed concrete I-beam bridge. The total length of the new bridge is 204 feet (62.2 m). The typical cross section of the replacement bridge is shown in Figure 3.1b. A typical installation of thrie beam retrofit is shown in Figure 3.2.

The analysis period is the time interval used to evaluate all future costs. The length of the analysis period was selected to include at least one major rehabilitation activity after any initial construction (FHWA 2002) and was the same for both alternatives in order to fairly compare results. The analysis period for this study was 75 years which is the designated service life for new bridges designed using the AASHTO Load and Resistance Factor Design specifications (AASHTO 2010a).

Remaining Service Life

The remaining service life (RSL) is the amount of service life remaining for an alternative at the end of the analysis period. In this study this occurs only for the rehabilitation alternative. The RSL is to account for remaining service life of the new bridge constructed at the end of the service life of the bridge rehabilitation. RSL is not the same as salvage value. With RSL the bridge remains in service while with a salvage value the bridge is demolished and materials reused.

The value of any remaining service life depends on when the activity occurs relative to the end of the analysis period. The value of the RSL was determined using activity cost and the amount of service life remaining past the end of the analysis period (Walls III and Smith 1998). The value was assumed to linearly decrease from the full value at the time of its construction to zero at the end of its service life. An RSL was calculated when the construction of an activity occurred before the end of the analysis period but the end of its service life occurred after. When timing of an activity was greater than or equal to the analysis period the RSL and the cost of the activity are equal and there was no net change in life-cycle cost.

In the probabilistic analysis the service lives of the replacement bridge, deck overly, and deck replacement varied. As a result the activity timings also varied and more than one deck overlay and deck replacement may occur in an analysis period. In addition any activity that would possibly occur five years or closer to the end of the bridge replacement service life was assumed to not have occurred since replacement would most likely be planned. Expressions were developed to calculate the RSL value for the possible timings of deck overlays and replacements and 21 test examples were used to verify the expressions.

Deck overlay number 1

$$RSL = \left(\frac{T_{DR1} - SL_{BR}}{T_{DR1} - T_{OV1}}\right)(C_{OV}) = \left(\frac{T_{DR1} - SL_{BR}}{SL_{OV}}\right)(C_{OV}) \tag{3.3}$$

Deck replacement number 1

If $T_{DR2} < T_{BR} + SL_{BR}$

$$RSL = \left(\frac{T_{DR2} - SL_{BR}}{T_{DR2} - T_{DR1}}\right)(C_{DR}) \tag{3.4}$$

If $T_{DR2} \geq T_{BR} + SL_{BR}$

$$RSL = \left(\frac{T_{BR} + SL_{BR} - SL_{BR}}{T_{BR} + SL_{BR} - T_{DR1}}\right)(C_{DR}) = \left(\frac{T_{BR}}{T_{BR} + SL_{BR} - T_{DR1}}\right)(C_{DR}) \tag{3.5}$$

Deck overlay number 2

If $T_{DR2} < T_{BR} + SL_{BR}$

$$RSL = \left(\frac{T_{DR2} - SL_{BR}}{T_{DR2} - T_{OV2}}\right)(C_{OV}) = \left(\frac{T_{DR2} - SL_{BR}}{SL_{OV}}\right)(C_{OV}) \tag{3.6}$$

If $T_{DR2} \geq T_{BR} + SL_{BR}$

$$RSL = \left(\frac{T_{BR} + SL_{BR} - SL_{BR}}{T_{BR} + SL_{BR} - T_{OV2}}\right)(C_{OV}) = \left(\frac{T_{BR}}{T_{BR} + SL_{BR} - T_{OV2}}\right)(C_{OV}) \tag{3.7}$$

Deck replacement number 2

$$RSL = \left(\frac{T_{BR}}{T_{BR} + SL_{BR} - T_{DR2}}\right)(C_{DR}) \tag{3.8}$$

Deck overlay number 3

$$RSL = \left(\frac{T_{BR}}{T_{BR} + SL_{BR} - T_{OV3}}\right)(C_{OV}) \tag{3.9}$$

where:

T_{BR} = timing of bridge replacement (years)

T_{DR1} = timing of deck replacement number 1 (years)

T_{DR2} = timing of deck replacement number 2 (years)

T_{OV1} = timing of deck overlay number 1 (years)

T_{OV2} = timing of deck overlay number 2 (years)

T_{OV3} = timing of deck overlay number 3 (years)

SL_{BR} = service life of bridge replacement (years)

SL_{OV} = service life of deck overlay (years)

C_{DR} = cost of bridge deck replacement ($)

C_{OV} = cost of deck overlay ($)

RSL test examples used included:

1. 75-year Bridge Service Life (Mean), T_{BR} = 20 years, T_{OV1} = 40 years, T_{DR1} = 60 years, T_{OV2} = 80 years, T_{DR2} = 100 years (Mean Activity Timings)
2. 70-year Bridge Service Life (Minimum), T_{BR} = 20 years, T_{OV1} = 40 years, T_{DR1} = 60 years, T_{OV2} = 80 years, T_{DR2} = 100 years (Mean Activity Timings)
3. 90-year Bridge Service Life (Maximum), T_{BR} = 20 years, T_{OV1} = 40 years, T_{DR1} = 60 years, T_{OV2} = 80 years, T_{DR2} = 100 years, T_{OV3} = 120 years (Mean Activity Timings)
4. 70-year Bridge Service Life (Minimum), T_{BR} = 10 years, T_{OV1} = 25 years, T_{DR1} = 40 years, T_{OV2} = 55 years, T_{DR2} = 70 years, T_{OV3} = 85 years (Minimum Activity Timings)

5. 90-year Bridge Service Life (Maximum), T_{BR} = 10 years, T_{OV1} = 25 years, T_{DR1} = 40 years, T_{OV2} = 55 years, T_{DR2} = 70 years, T_{OV3} = 85 years (Minimum Activity Timings)

6. 70-year Bridge Service Life (Minimum), T_{BR} = 25 years, T_{OV1} = 50 years, T_{DR1} = 75 years, T_{OV2} = 100 years (Maximum Activity Timings)

7. 90-year Bridge Service Life (Maximum), T_{BR} = 25 years, T_{OV1} = 50 years, T_{DR1} = 75 years, T_{OV2} = 100 years, T_{DR2} = 125 years (Maximum Activity Timings)

8. 80-year Bridge Service Life, T_{BR} = 20 years, T_{OV1} = 40 years, T_{DR1} = 60 years, T_{OV2} = 80 years, T_{DR2} = 100 years, T_{OV3} = 120 years (Mean Activity Timings)

9. 75-year Bridge Service Life, T_{BR} = 10 years, T_{OV1} = 25 years, T_{DR1} = 40 years, T_{OV2} = 55 years, T_{DR2} = 70 years, T_{OV3} = 85 years (Minimum Activity Timings)

10. 85-year Bridge Service Life, T_{BR} = 20 years, T_{OV1} = 40 years, T_{DR1} = 60 years, T_{OV2} = 80 years, T_{DR2} = 100 years, T_{OV3} = 120 years (Mean Activity Timings)

11. 75-year Bridge Service Life, T_{BR} = 20 years, T_{OV1} = 45 years, T_{DR1} = 70 years, T_{OV2} = 95 years, T_{DR2} = 120 years

12. 90-year Bridge Service Life, T_{BR} = 25 years, T_{OV1} = 45 years, T_{DR1} = 70 years, T_{OV2} = 90 years, T_{DR2} = 115 years

13. 75-year Bridge Service Life, T_{BR} = 15 years, T_{OV1} = 35 years, T_{DR1} = 55 years, T_{OV2} = 75 years, T_{DR2} = 95 years

14. 80-year Bridge Service Life, T_{BR} = 15 years, T_{OV1} = 35 years, T_{DR1} = 55 years, T_{OV2} = 75 years, T_{DR2} = 95 years

15. 80-year Bridge Service Life, T_{BR} = 10 years, T_{OV1} = 30 years, T_{DR1} = 50 years, T_{OV2} = 70 years, T_{DR2} = 90 years

16. 90-year Bridge Service Life, T_{BR} = 10 years, T_{OV1} = 30 years, T_{DR1} = 50 years, T_{OV2} = 70 years, T_{DR2} = 90 years, T_{OV3} = 110 years

17. 75-year Bridge Service Life, T_{BR} = 15 years, T_{OV1} = 30 years, T_{DR1} = 45 years, T_{OV2} = 60 years, T_{DR2} = 75 years, T_{OV3} = 90 years

18. 85-year Bridge Service Life, T_{BR} = 15 years, T_{OV1} = 35 years, T_{DR1} = 50 years, T_{OV2} = 70 years, T_{DR2} = 85 years, T_{OV3} = 105 years

19. 90-year Bridge Service Life, T_{BR} = 20 years, T_{OV1} = 45 years, T_{DR1} = 65 years, T_{OV2} = 90 years, T_{DR2} = 110 years

20. 85-year Bridge Service Life, T_{BR} = 15 years, T_{OV1} = 30 years, T_{DR1} = 50 years, T_{OV2} = 65 years, T_{DR2} = 85 years, T_{OV3} = 100 years

21. 75-year Bridge Service Life, T_{BR} = 15 years, T_{OV1} = 35 years, T_{DR1} = 60 years, T_{OV2} = 80 years, T_{DR2} = 105 years

Bridge Activities and Costs

All activities associated with each alternative (initial construction, rehabilitation, and routine maintenance) are identified. The number of activities can be different for each alternative. Activities include routine maintenance (on an annual basis unless detailed data is available), preventive maintenance (preservation), repair, and rehabilitation. A schedule of activity timing includes the performance period or service life of each activity, when work zones and detours will be used, how long work zones will be in place, and the length of detours. The activity timings used in this study are summarized in Table 3.1.

Expenditure stream diagrams show all activities, costs associated with those activities, and activity and cost timing in a single graphic. This can be a visual aid for the analyst and when presenting the LCCA results. Any remaining service life for the rehabilitation alternative is shown at the end of the analysis period as a negative cost. Example expenditure stream diagrams for the replacement and rehabilitation alternatives are shown in Figure 3.

The estimated time to construct the bridge replacement and deck restoration are based on an analysis of contract completion dates included in Kentucky Transportation Cabinet (KYTC) bridge and deck restoration projects let from January 2013 to October 2014. A listing of the projects used is contained in Appendix A. Details of the time analysis are contained in Appendix B.

There are two general categories of costs, agency and user costs (Zimmerman et al. 2000, Beg et al. 2000, FHWA 2002). Costs that were similar for both alternatives were eliminated from the analysis. These are typically user costs during normal operations, i.e. no maintenance or construction activities that require a work zone with traffic restrictions.

Agency Costs

Agency costs include the costs of new construction, repair, rehabilitation, and maintenance of bridges and bridge components. Other agency costs include the cost of design, condition assessment of existing structures, right-of-way acquisition, utility adjustments, and any salvage value. Some costs can be estimated on a unit cost basis, i.e. bridge replacement, deck replacement, repairs, and routine annual maintenance.

However, some of these costs are only for the actual construction. The cost of preliminary engineering (PE), construction engineering (CE), maintenance of traffic (MOT), and any demolition are added to the cost of actual construction. The agency cost parameters used are summarized in Table 3.2.

Agency cost data was obtained from bridge replacement, deck restoration, and guardrail projects constructed in Kentucky and published data. The bid data analysis herein is from the Kentucky Transportation Cabinet (KYTC) projects let from January 2013 to October 2014. The bid data analysis determined unit costs for prestressed concrete girder bridges, deck replacement, bridge removal, deck removal, latex modified concrete (LMC) overlays, bridge overlay approach pavement, bridge rail retrofit, and maintenance of traffic. Details of the analyses are contained in Appendix C for unit construction costs and Appendix D for maintenance of traffic costs.

Bridge replacement projects and roadway projects that included new and replacement bridges were used to determine the unit costs for prestressed concrete girder bridges, deck replacement, and the percentage of the contract price for maintenance of traffic during bridge replacement. The analysis used the bid data (116 bidders) for 30 prestressed concrete I-beam bridges to determine the cost of bridge and deck replacement and the bid data (93 bidders) for 27 bridge projects to determine the percentage of contract price for maintenance of traffic costs. The bridge removal cost was determined using the bid data (23 bidders) for the removal of 10 continuous reinforced concrete T-beam bridges. The deck removal cost used the bid data (three bidders) for two bridges.

Bridge deck restoration projects were used to determine the unit costs for LMC overlays, bridge overlay approach pavement, and the percentage of the contract price for maintenance of traffic costs during bridge rehabilitation. The analysis used the bid data (595 bidders) for 108 bridges.

Guardrail projects were used to determine the unit cost for bridge rail retrofit with thrie beam. The analysis used the bid data (six bidders) for two bridges.

The unit cost for carbon fiber-reinforced polymer (CFRP) wrap was based on published cost data (e.g. O'Conner et al. 1999). O'Connor et al. (1999) reported costs of CFRP used to strengthen a reinforced concrete pier cap of a bridge in New York. Hag-Elsafi et al. (2001) reported costs of CFRP used to strengthen a reinforced concrete T-beam bridge in New York. Wipf et al. (2004) reported costs of CFRP used to repair impact damaged prestressed concrete beams in Iowa.

A survey by the Washington State Department of Transportation (DOT) in 2002 collected engineering cost data from 25 states. The average cost of PE was 10.3 percent and for CE was 11.2 percent. These values tend to be higher for more complex urban projects than for rural projects (Alam et al. 2005).

Annual routine bridge maintenance costs are the sum of annual maintenance costs for the various bridge components. Wipf et al. (1987) reported annual maintenance costs using data provided by some states. The average annual cost for reinforced concrete deck girders (old bridge) and prestressed concrete beams (new bridge) were converted to 2013 dollars using gross domestic product (GDP) deflators (U.S. Department of Commerce).

Bridge Replacement Cost

The total cost to replace the existing bridge included the costs for PE, CE, removing the existing bridge, constructing the new bridge and approaches, and maintaining traffic during the construction. The cost of bridge removal and construction were estimated using unit costs and estimated bridge areas. The cost of approach roadway construction was estimated as a percent of the bridge construction cost. The cost of maintenance of traffic was estimated as a percent of the cost of bridge removal, bridge construction, and approach roadway construction. The cost of PE was estimated as a percentage of bridge and approach roadway construction costs. The cost of CE was estimated as a percentage of bridge removal, bridge construction, and approach roadway construction costs.

Bridge Deck Replacement Cost

The total cost to replace the existing bridge deck included the costs for PE, CE, removing the existing reinforced concrete bridge deck and rails, constructing the new reinforced concrete bridge deck and rails, and maintaining traffic during the construction. The cost of bridge deck removal and construction were estimated using unit costs and estimated bridge areas. The cost of maintenance of traffic was estimated as a percent of the cost of bridge deck removal and bridge deck construction. The bridge deck construction unit cost was developed using a subset of bridge construction bid items, those items used to construct the reinforced concrete deck and rails. The cost of PE was estimated as a percentage of bridge deck construction cost. The cost of CE was estimated as a percentage of bridge deck removal and construction costs.

Bridge Deck Restoration Cost

The total cost to construct the bridge deck restoration included the costs for PE, CE, constructing the deck overlay, construct the overlay approach pavement, and maintaining traffic during construction. The costs for PE and CE were estimated as a percentage of deck overlay and overlay approach pavement costs. The quantity of deck overlay for the existing bridge was estimated to be 5,100 ft^2 (474 m^2) and for the replacement bridge to be 5,712 ft^2 (531 m^2). The quantity of overlay approach pavement for the existing bridge was estimated to be 278 yd^2 (232 m^2) and for the replacement bridge to be 355 yd^2 (297 m^2).

Bridge Rehabilitation Cost

The total cost to rehabilitate the existing bridge included the costs for PE, CE, applying the CFRP, restoring the bridge deck, retrofiting the existing bridge rail with thrie beam rail, and maintaining traffic during construction. The cost of CFRP application, bridge deck restoration, and bridge deck approach pavement construction were estimated using unit costs and estimated areas or lengths as appropriate. The cost of maintenance of traffic was estimated as a percent of the cost of bridge rehabilitation construction. The costs of PE and CE were estimated as a percentage of CFRP, deck restoration, and bridge rail retrofit costs. The quantity of CFRP wrap was estimated assuming the girder stems are wrapped with two plies on the bottom and both faces of each stem from the supports to the quarter points in the adjacent spans. An additional ply is added longitudinally near the top of both stem faces for anchorage of the wrapped plies. This resulted in an estimated quantity of single ply CFRP of 5,700 ft^2 (530 m^2).

User Costs

User costs include the costs of time delays (value of time), vehicle operation, and crashes (FHWA 2002, AASHTO 2010b, Watts et al. 2012). Crash costs include costs for property damage only, injury, and fatality crashes. The user cost parameters used are summarized in Table 3.3.

Long term user costs are those costs due to load limits, height restrictions, narrow widths, and poor horizontal alignment. Load limits and height restrictions cause some vehicles to detour around a bridge. Detours lead to an increase in travel lime, vehicle operating costs, and accident rates. Narrow bridge widths lead to an increase in travel time due to reduced operating speeds and crashes (Son and Sinha 1997). Deck condition, functional classification, bridge width, and approach roadway alignment can influence accident risks (Thompson et al. 2000). A very badly spalled deck increases user costs as drivers tend to slow down which increases travel time as well as vehicle operating costs (Markow et al. 1993).

Short term user costs are those costs due to work zones for bridge maintenance, repair, rehabilitation, or replacement. When a bridge is closed all traffic must detour around the bridge. When one or more lanes are closed there are increases in travel time and crash rates. Sufficient data to determine any increase in crash rates may not be available. Drivers may also opt to detour around a work zone, where possible, to avoid work zone congestion.

Vehicle operating costs can be broken down by vehicle class, passenger cars and heavy trucks as a minimum, and could also include busses and utility trucks (dos Santos et al. 2011). In order to use a variety of vehicle types the number of each vehicle type needs to be known. Since this is typically not known, this study used an average value for automobiles, pickups, vans, and sport utility vehicles and another value for commercial trucks (Barnes and Langworthy 2004). The “baseline” case is based on a fuel price of $1.50 per gallon ($0.40 per liter) and costs for maintenance/repair, tires, and depreciation in 2003 dollars. This study adjusted the fuel cost using $3.25 per gallon ($0.86 per liter) and converted the other costs to 2013 dollars using GDP deflators. The average cost to operate personal vehicles is then 27.25 cents per mile (16.9 cents per kilometer) and the cost to operate commercial trucks is 73.4 cents per mile (45.6 cents per kilometer). The baseline costs and the adjusted costs are summarized in Table 3.4.

The value of time can be broken down by personal and business travel (USDOT 2012). The values are per person-hour. Two weighted averages for automobiles are given: one for local travel and one for intercity travel. The weighted averages were determined using distributions of travel by trip purpose on various modes. This study assumed an equal distribution and used the average of the two.

Crash costs depend on traffic volumes, crash rates, crash distribution by severity level, and the cost associated with each level. This study used the Abbreviated Injury Scale (AIS), National Highway Traffic Safety Administration guidance for the distribution of injuries to the different injury levels, the value of property damage only crashes (AIS 0), and the Value of a Statistical Life (VSL) to calculate the cost of a non-fatal crash, Table 3.5 (USDOT 2012, USDOT 2013b).

User Cost Calculations

In order to calculate user costs it is necessary to estimate traffic volumes, travel delays, additional travel distance, crash rate, and fatality rate. The value of time (VOT), traffic volumes, and vehicle operating costs (VOC) were then used with the estimated amount of delay and vehicle occupancy rates to calculate additional user costs. The vehicle occupancy rates used are from AASHTO (2010b). Traffic volumes, additional travel distance, and crash and fatality rates were used to calculate crash costs. The nine combinations of initial traffic volumes on and under the bridge, average daily traffic (ADT) cases, are shown in Table 3.6. The rates for total crashes and fatalities are from the Kentucky Strategic Highway Safety Plan, 2011-2014 (KYTC 2011). The rates used are for the year 2011 which was the latest year for which rates were given.

This study used the following assumptions in calculating user costs:

- User costs under normal operating conditions are the same for existing and replacement bridges, no delays or additional travel distance
- User costs for identical activities under work zone conditions may be the same (lane closures, delays, or detours, additional travel time and distance) but generally occur at different times
- Crash and fatality rates under normal operating conditions are the same for existing and replacement bridges
- Crash and fatality rates in work zones are the statewide rates due to lack of work zone specific data

The vehicle operating costs (VOC) were calculated using:

$$C_{VOC} = [(ADT)(VOC_C) + (ADTT)(VOC_T)](\Delta D) \tag{3.10}$$

where:

C_{VOC} = total vehicle operating cost per day, \$

VOC_C = vehicle operating cost for cars, \$/vehicle

VOC_T = vehicle operating cost for trucks, \$/vehicle

ADT = average daily traffic, vehicles per day

ADTT = average daily truck traffic, vehicles per day

ΔD = additional distance travelled, mi (km)

The value of time (VOT) costs were calculated using:

$$C_{VOT} = [(ADT)(VOT_C) + (ADTT)(VOT_T)](\Delta T) \quad (3.11)$$

where:

C_{VOC} = total value of time cost per day, \$

VOT_C = value of time for cars, \$/hr

VOT_T = value of time for trucks, \$/hr

ADT = average daily traffic, vehicles per day

ADTT = average daily truck traffic, vehicles per day

ΔT = time delay per vehicle

The crash costs were calculated using:

$$C_{crash} = [(CR)(cost/crash) + (FR)(cost/fatality)](ADT)(D)/1,000,000 \quad (3.12)$$

where:

C_{crash} = total crash cost per day, \$

CR = crash rate, number of crashes per million vehicle-miles (crashes per million vehicle-kilometers)

FR = fatality rate, number of fatalities per million vehicle-miles (crashes per million vehicle-kilometers)

ADT = average daily traffic, vehicles per day

D = distance travelled, mi (km)

Table 3.1-Bridge activity timing

Activity	Timing (year)	Duration (days)	Detour
Replacement Alternative			
Construct new bridge	0	240	Yes
Place deck overlay	20	30	No
Replace deck	40	45	Yes
Place deck overlay	60	30	No
End service life	75	--	--
Rehabilitation Alternative			
Apply FRP, place deck overlay, retrofit bridge rail	0	30	No
Construct new bridge	20	240	Yes
Place deck overlay	40	30	No
Replace deck	60	45	Yes
Remaining service life new bridge	75	--	--

Table 3.2-Agency cost parameters

Parameter	Value
Prestressed concrete girder bridge, $/ft^2 ($/m^2)	107.52 (1,157.33)
Deck overlay-new bridge, $/ft^2 ($/m^2)	16.54 (178.03)
Deck overlay-old bridge, $/ft^2 ($/m^2)	16.54 (178.03)
Bridge overlay approach pavement-new bridge, $/yd^2 ($/m^2)	40.01 (47.85)
Bridge overlay approach pavement-old bridge, $/yd^2 ($/m^2)	54.83 (65.58)
Deck replacement, $/ft^2 ($/m^2)	38.17 (410.86)
CFRP wrap (one layer), $/ft^2 ($/m^2)	54.39 (585.45)
Bridge rail retrofit with thrie beam, $/ft ($/m)	76.99 (252.59)
Bridge removal, $/ft^2 ($/m^2)	14.13 (152.09)
Deck removal, $/ft^2 ($/m^2)	4.87 (52.42)
Bridge annual maintenance-new bridge, $/ft^2 ($/m^2)	0.10 (1.08)
Bridge annual maintenance-old bridge, $/ft^2 ($/m^2)	0.15 (1.61)
Maintenance of traffic-replacement, percent	3.41
Maintenance of traffic-rehabilitation, percent	15.12
Preliminary Engineering, percent	10
Construction Engineering, percent	11

Table 3.3-User cost parameters

Parameter	Value
Length of detour, miles (km)	2 (3.2)
Duration of bridge work, days	30 to 240
Average daily traffic on bridge-initial, vehicles/day	100 to 5,000
Truck traffic on bridge, percent	5
Average daily traffic under bridge-initial, vehicles/day	5,000 to 25,000
Truck traffic under bridge, percent	12
Annual traffic growth rate on bridge, percent	1
Annual traffic growth rate under bridge, percent	2
Value of time-cars, $/hour	16.28
Value of time-trucks, $/hour	25.30
Vehicle operating cost-cars, $/mile ($/km)	0.27 (0.17)
Vehicle operating cost-trucks	0.74 (0.46)
Vehicle occupancy rate-cars, persons/vehicle	1.5
Vehicle occupancy rate-trucks, persons/vehicle	1.05
Estimated travel delay per vehicle on bridge	
Bridge replacement, minutes	10
Bridge rehabilitation, minutes	5
Deck overlay, minutes	5
Deck replacement, minutes	10
Estimated travel delay per vehicle under bridge	
Bridge replacement, minutes	5
Bridge rehabilitation, minutes	5
Deck overlay, minutes	0
Deck replacement, minutes	0
Cost per non-fatal accident, $	126,870
Cost per fatal accident, $	9,100,000
Non-fatal crash rate per million vehicle miles	2.65
Fatality rate per million vehicle miles	0.015

Table 3.4-Baseline vehicle operating costs

Cost Category	Automobile		Pickup/Van/SUV		Commercial Truck	
	$2003	$2013	$2003	$2013	$2003	$2013
Total Marginal Costs cents/mi (cents/km)	15.3 (9.5)	23.6 (14.7)	19.2 (11.9)	30.9 (19.2)	43.4 (27.0)	73.4 (15.6)
Fuel cents/mi (cents/km)	5.1 (3.2)	11.1 (6.9)	7.8 (4.8)	16.9 (10.5)	21.4 (13.3)	46.4 (28.8)
Maintenance/Repair cents/mi (cents/km)	3.1 (1.9)	3.8 (2.4)	3.7 (2.3)	4.6 (2.9)	10.5 (6.5)	12.9 (8.0)
Tires cents/mi (cents/km)	0.9 (0.6)	1.1 (0.7)	1.0 (0.6)	1.2 (0.7)	3.5 (2.2)	4.3 (2.7)
Depreciation cents/mi (cents/km)	6.2 (3.9)	7.6 (4.7)	6.7 (4.2)	8.2 (5.1)	8.0 (5.0)	9.8 (6.1)

Table 3.5-Cost for a non-fatal crash

Fraction Crashes		Fraction VSL	Unit Value	Estimated cost per non-fatal crash
AIS 0	0.43676		$3,465	$1,513.37
AIS 1	0.41739	0.003	$9,100,000	$11,394.75
AIS 2	0.08872	0.047	$9,100,000	$37,945.54
AIS 3	0.04817	0.105	$9,100,000	$46,026.44
AIS 4	0.00617	0.266	$9,100,000	$14,935.10
AIS 5	0.00279	0.593	$9,100,000	$15,055.68
	1.00000	1.000		$126,870.88

AIS = Abbreviated Injury Scale

Table 3.6-Initial average daily traffic, ADT, volume

Case	ADT on bridge, vehicles per day		ADT under bridge, vehicles per day	
1	100	Low	5,000	Low
2	100	Low	10,000	Medium
3	100	Low	25,000	High
4	1,000	Medium	5,000	Low
5	1,000	Medium	10,000	Medium
6	1,000	Medium	25,000	High
7	5,000	High	5,000	Low
8	5,000	High	10,000	Medium
9	5,000	High	25,000	High

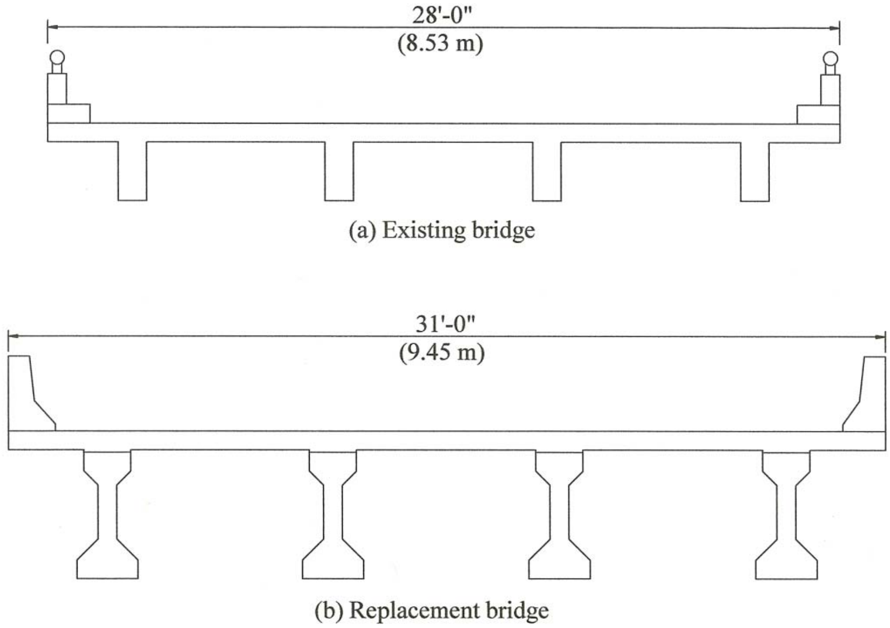
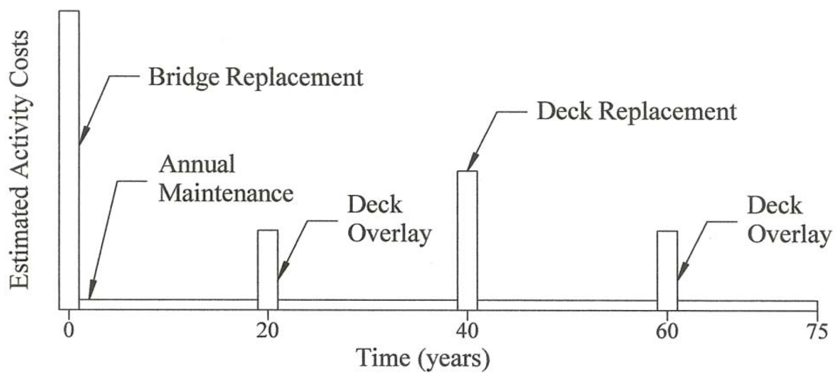
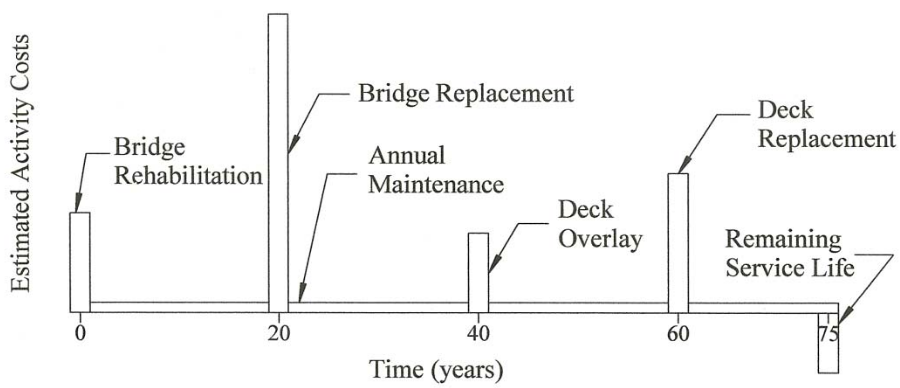


Figure 3.1-Typical sections

Figure 3.2-Bridge rail retrofit with thrie beam



(a) Bridge Replacement Alternative



(b) Bridge Rehabilitation Alternative

Figure 3.3-Expenditure stream diagrams

CHAPTER FOUR: DETERMINISTIC ANALYSIS

In this study deterministic analyses were carried out to determine the life-cycle costs of the replacement and rehabilitation alternatives and which had the lower life-cycle cost. Analyses were carried out for 1) a bridge over a highway, 2) a bridge over a highway with modified bridge construction time and cost, 3) a bridge over a waterway, and 4) a bridge over a waterway with modified bridge construction time and cost. Each analysis used the agency and user cost parameters shown in Table 3.1, Table 3.2 and Table 3.3. Each analysis used a range of initial traffic volumes, both on and under the bridge.

Bridge over Highway

Deterministic analyses were carried out for each of the nine ADT cases (Table 3.6). The agency, user, and total life-cycle costs for the replacement and rehabilitation alternatives of the bridge over a highway are summarized in Table 4.1.

In all the traffic cases the rehabilitation alternative had the lower life-cycle cost. Although the agency costs for both alternatives were almost equal the user costs were not. For this example the agency cost for the replacement alternative is only 1.6 percent more than the rehabilitation. Since agency costs do not depend on traffic volumes they were the same for all traffic cases and the increases in life-cycle costs were primarily due to user costs. The user costs for lower traffic volumes were relatively close and the difference dramatically increased as the traffic volumes increased. The impact of traffic volume on user costs was especially significant for traffic under the bridge for the estimated delays, i.e. ADT cases 3, 6, and 9 (Table 3.6).

As the traffic volume increased, both on and under the bridge, the difference in total life-cycle cost between the alternatives also increased. The differences in total life-cycle costs are summarized in Table 4.2. The smallest difference was for case 1, 100 vehicles per day (vpd) on the bridge and 5,000 vpd under the bridge. The second smallest difference was for case 2, 100 vpd on the bridge and 10,000 vpd under the bridge. This is followed by cases 4 and 5 with 1,000 vpd on the bridge and 5,000 to 10,000 vpd under the bridge. These are followed by cases 3 and 6 with 25,000 vpd under the bridge and 100 to 1,000 vpd on the bridge. The next two are cases 7 and 8 with 5,000 vpd on the bridge and 5,000 to 10,000 vpd under the bridge. The largest difference was for case 9, 5,000 vpd on the bridge and 25,000 vpd under the bridge.

Agency, user, and total life-cycle costs for all the activities and for each traffic case are summarized in Table 4.3 for the replacement alternative and Table 4.4 for the rehabilitation alternative. Agency costs for the replacement alternative are the same for each of the traffic cases. Agency costs for the rehabilitation alternative are the same for each of the traffic cases.

User life-cycle costs for the replacement alternative is summarized in Table 4.5 and for the rehabilitation alternative is summarized in Table 4.6. Two activities had no impact on traffic under the bridge: deck replacement and deck overlay. For these activities the user costs are the same for those traffic cases where traffic on the bridge is the same. For the remaining activities, user costs increase as traffic on and under the bridge increases.

Bridge over Highway with Modified Bridge Construction Time and Cost

The deterministic analysis of the bridge over a highway showed that user costs were frequently high and also a significant portion of the life-cycle costs, Table 4.7. The percentage of life-cycle costs that were due to user costs for the two alternatives did not differ by much, about three percent or less. For low traffic volumes the user costs ranged from 68.7 to 91.3 percent of total life-cycle costs for the replacement alternative and from 65.8 to 90.3 percent of total life-cycle costs for the rehabilitation alternative. For medium traffic volumes the user costs ranged from 76.9 to 92.1 percent of total life-cycle costs for the replacement alternative and from 73.0 to 90.9 percent of total life-cycle costs for the rehabilitation alternative. For high traffic volumes the user costs ranged from 89.4 to 94.3 percent of total life-cycle costs for the replacement alternative and from 86.0 to 93.1 percent of total life-cycle costs for the rehabilitation alternative. The percentage of life-cycle costs due to user costs increased as traffic volumes increased.

The sensitivity analysis showed that the time to construct the new bridge was one of the four parameters that had the most influence on life-cycle costs. Therefore, two modifications to the bridge construction time were investigated. In the first modification the most likely time to construct the bridge was decreased by 25 percent. In the second modification it was decreased by 50 percent. The times used are summarized in Table 4.8.

Since decreases in construction time would most likely increase the cost three cost variations were used with each time modification. For the first time modification the unit cost to construct the bridge was increased by zero, five, and ten percent. For the second time modification they were increased by zero, ten, and twenty percent. The unit costs used are summarized in Table 4.9.

The combinations of modified times and costs used are summarized in Table 4.10. Even though no increase in cost is likely to occur it was included as a base line or limiting value.

Six additional deterministic analyses using the modified bridge construction times and costs were carried out for each of the nine traffic cases. The agency, user, and total life-cycle costs for the six modifications are summarized in Tables 4.11 to 4.16. Although the decrease in construction time reduced the difference in life-cycle costs between the replacement and rehabilitation alternative, the rehabilitation alternative still had the lower life-cycle cost. The decrease in construction time had the larger influence on life-cycle costs than subsequent increases in unit costs.

Bridge over Waterway

Since a large number of bridges cross waterways the effect of no vehicular traffic under the bridge was investigated. This reduced the number of traffic cases to just three: low (100 vpd), medium (1,000 vpd), and high (5,000 vpd) traffic volumes on the bridge.

Three additional deterministic analyses were carried out. The agency, user, and total life-cycle costs for the three cases are summarized in Table 4.17. The rehabilitation alternative still had the lower life-cycle cost. However the difference for the low traffic case was only 5.3 percent. This cost difference maybe small enough for some decision makers to choose the replacement alternative. Although the difference in total life-cycle costs between the alternatives decreased, there was a significant decrease for some traffic cases.

Bridge over Waterway with Modified Bridge Construction Time and Cost

The effect of reducing bridge construction time on bridge with no vehicular traffic under the bridge was investigated. Six additional deterministic analyses were carried out for each three traffic volume cases. The agency, user, and total life-cycle costs for the six modifications are summarized in Tables 4.18 to 4.23.

Although the decrease in construction time reduced the difference in life-cycle costs between the replacement and rehabilitation alternative, the rehabilitation alternative still had the lower life-cycle cost. For the lower traffic cases the difference is small enough for one to consider using accelerated bridge technologies for bridge construction as long as any increases in construction costs are minimal. A five percent increase in the bridge construction unit cost, however, resulted in an increase in the difference. The reduced construction time had an adverse effect on the difference.

Deterministic Analysis Summary

Deterministic analyses were carried out for a highway bridge, a highway bridge with modified bridge construction time and cost, a waterway bridge, and a waterway bridge with modified bridge construction time and cost. The percent difference in total life-cycle costs from all the analyses are summarized in Table 4.24.

The rehabilitation alternative had the lower life-cycle cost in all analyses. However there were instances where the difference in life-cycle cost has been reduced enough for a decision maker to consider accelerated bridge construction technologies for low and medium traffic volumes. If it were possible to obtain a 50 percent decrease in bridge construction time without any increase in cost the life-cycle costs are almost the same, 0.8 percent difference.

When the bridge is over a waterway the differences in life-cycle costs are all reduced. For 100 vpd the difference was 5.3 percent or less. When combined with accelerated bridge construction technologies a further decrease in the difference was possible. For the low traffic volumes the difference was less than five percent for some combinations of decreased construction time and increased cost. However, increases in bridge construction cost negated any decrease in the difference and in some cases increased the difference.

Table 4.1-Summary of life-cycle costs for highway bridge

ADT Case[1]	Life-cycle Costs, Dollars						Percent Difference[2]
	Replacement Alternative			Rehabilitation Alternative			
	Agency	User	Total	Agency	User	Total	
1	1,191,515	2,618,430	3,809,944	1,172,788	2,252,939	3,425,727	11.1
2	1,191,515	5,086,170	6,277,684	1,172,788	4,404,281	5,577,069	12.5
3	1,191,515	12,489,390	13,680,904	1,172,788	10,858,308	12,031,096	13.7
4	1,191,515	3,974,636	5,166,151	1,172,788	3,167,309	4,340,097	19.1
5	1,191,515	6,442,376	7,633,891	1,172,788	5,318,651	6,491,439	17.6
6	1,191,515	13,845,596	15,037,111	1,172,788	11,772,678	12,945,466	16.1
7	1,191,515	10,002,220	11,193,735	1,172,788	7,231,176	8,403,964	33.2
8	1,191,515	12,469,960	13,661,475	1,172,788	9,382,519	10,555,307	29.4
9	1,191,515	19,873,180	21,064,695	1,172,788	15,836,546	17,009,334	23.8

[1]Refer to Table 3.6 for ADT cases

[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.2-Comparison of total life-cycle costs for highway bridge

ADT Case[1]	Life-cycle Costs, Dollars		
	Replacement Alternative	Rehabilitation Alternative	Difference
1	3,809,944	3,425,727	384,217
2	6,277,684	5,577,069	700,615
4	5,166,151	4,340,097	826,054
5	7,633,891	6,491,439	1,142,452
3	13,680,904	12,031,096	1,649,808
6	15,037,111	12,945,466	2,091,645
7	11,193,735	8,403,964	2,789,771
8	13,661,475	10,555,307	3,106,168
9	21,064,695	17,009,334	4,055,361

[1]Refer to Table 3.6 for ADT cases

Table 4.3-Life-cycle costs replacement alternative highway bridge

ADT Case[1]	Category	Bridge Replacement	Deck Overlay	Deck Replacement	Deck Overlay	Annual Routine Maintenance	Total
		Life-Cycle Cost, Dollars					
1	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	2,602,627	3,760	9,511	2,532		2,618,430
	Total	3,583,198	78,107	94,260	36,155	18,223	3,809,944
2	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	5,070,367	3,760	9,511	2,532		5,086,170
	Total	6,050,938	78,107	94,260	36,155	18,223	6,277,684
3	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	12,473,587	3,760	9,511	2,532		12,489,390
	Total	13,454,158	78,107	94,260	36,155	18,223	13,680,904
4	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	3,816,609	37,602	95,107	25,319		3,974,636
	Total	4,797,180	111,949	179,856	58,942	18,223	5,166,151
5	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	6,284,349	37,602	95,107	25,319		6,442,376
	Total	7,264,920	111,949	179,856	58,942	18,223	7,633,891
6	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	13,687,569	37,602	95,107	25,319		13,845,596
	Total	14,668,140	111,949	179,856	58,942	18,223	15,037,111
7	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	9,212,083	188,009	475,534	126,593		10,002,220
	Total	10,192,655	262,357	560,284	160,216	18,223	11,193,735
8	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	11,679,823	188,009	475,534	126,593		12,469,960
	Total	12,660,395	262,357	560,284	160,216	18,223	13,661,475
9	Agency	980,572	74,347	84,750	33,623	18,223	1,191,515
	User	19,083,043	188,009	475,534	126,593		19,873,180
	Total	20,063,615	262,357	560,284	160,216	18,223	21,064,695

[1]Refer to Table 3.6 for ADT cases

Table 4.4-Life-cycle costs rehabilitation alternative highway bridge

ADT Case[1]	Life-Cycle Cost, Dollars							
	Category	Bridge Rehabilitation	Bridge Replacement	Deck Overlay	Deck Replacement	Remaining Service Life	Annual Routine Maintenance	Total
1	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	314,599	1,925,591	2,306	10,443			2,252,939
	Total	917,552	2,418,393	39,670	86,707	-57,083	20,489	3,425,727
2	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	623,067	3,768,466	2,306	10,443			4,404,281
	Total	1,226,019	4,261,268	39,670	86,707	-57,083	20,489	5,577,069
3	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	1,548,469	9,297,090	2,306	10,443			10,858,308
	Total	2,151,422	9,789,892	39,670	86,707	-57,083	20,489	12,031,096
4	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	369,786	2,670,036	23,058	104,429			3,167,309
	Total	972,738	3,162,838	60,423	180,693	-57,083	20,489	4,340,097
5	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	678,253	4,512,911	23,058	104,429			5,318,651
	Total	1,281,205	5,005,713	60,423	180,693	-57,083	20,489	6,491,439
6	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	1,603,656	10,041,535	23,058	104,429			11,772,678
	Total	2,206,608	10,534,337	60,423	180,693	-57,083	20,489	12,945,466
7	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	615,058	5,978,681	115,292	522,145			7,231,176
	Total	1,218,010	,471,482	152,657	598,409	-57,083	20,489	8,403,964
8	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	923,526	7,821,556	115,292	522,145			9,382,519
	Total	1,526,478	8,314,357	152,657	598,409	-57,083	20,489	10,555,307
9	Agency	602,952	492,802	37,364	76,264	-57,083	20,489	1,172,788
	User	1,848,928	13,350,180	115,292	522,145			15,836,546
	Total	2,451,880	13,842,982	152,657	598,409	-57,083	20,489	17,009,334

[1]Refer to Table 3.6 for ADT cases

Table 4.5-User life-cycle cost summary highway bridge replacement alternative

ADT Case[1]	Life-cycle Cost, Dollars				
	Bridge replacement	Deck overlay	Deck replacement	Deck overlay	Total
1	2,602,627	3,760	9,511	2,532	2,618,430
2	5,070,367	3,760	9,511	2,532	5,086,170
3	12,473,587	3,760	9,511	2,532	12,489,390
4	3,816,609	37,602	95,107	25,319	3,974,636
5	6,284,349	37,602	95,107	25,319	6,442,376
6	13,687,569	37,602	95,107	25,319	13,845,596
7	9,212,083	188,009	475,534	126,593	10,002,220
8	11,679,823	188,009	475,534	126,593	12,469,960
9	19,083,043	188,009	475,534	126,593	19,873,180

[1]Refer to Table 3.6 for ADT cases

Table 4.6-User life-cycle cost summary highway bridge rehabilitation alternative

ADT Case[1]	Life-cycle Cost, Dollars				
	Bridge rehabilitation	Bridge replacement	Deck overlay	Deck replacement	Total
1	314,599	1,925,591	2,306	10,443	2,252,939
2	623,067	3,768,466	2,306	10,443	4,404,281
3	1,548,469	9,297,090	2,306	10,443	10,858,308
4	369,786	2,670,036	23,058	104,429	3,167,309
5	678,253	4,512,911	23,058	104,429	5,318,651
6	1,603,656	10,041,535	23,058	104,429	11,772,678
7	615,058	5,978,681	115,292	522,145	7,231,176
8	923,526	7,821,556	115,292	522,145	9,382,519
9	1,848,928	13,350,180	115,292	522,145	15,836,546

[1]Refer to Table 3.6 for ADT cases

Table 4.7-Percent user costs for highway bridge

ADT Case[1]	Replacement Alternative			Rehabilitation Alternative		
	User Costs	Total Costs	Percent User	User Costs	Total Costs	Percent User
1	2,618,430	3,809,944	68.7	2,252,939	3,425,727	65.8
2	5,086,170	6,277,684	81.0	4,404,281	5,577,069	79.0
3	12,489,390	13,680,904	91.3	10,858,308	12,031,096	90.3
4	3,974,636	5,166,151	76.9	3,167,309	4,340,097	73.0
5	6,442,376	7,633,891	84.4	5,318,651	6,491,439	81.9
6	13,845,596	15,037,111	92.1	11,772,678	12,945,466	90.9
7	10,002,220	11,193,735	89.4	7,231,176	8,403,964	86.0
8	12,469,960	13,661,475	91.3	9,382,519	10,555,307	88.9
9	19,873,180	21,064,695	94.3	15,836,546	17,009,334	93.1

[1]Refer to Table 3.6 for ADT cases

Table 4.8-Bridge construction times

	Most Likely, days
Initial	240
Initial minus 25%	180
Initial minus 50%	120

Table 4.9-Bridge construction unit costs

	Mean, $\$/ft^2$ ($\$/m^2$)
Initial	107.52 (1,157.33)
Initial plus 5%	112.90 (1,215.20)
Initial plus 10%	118.27 (1,273.04)
Initial plus 20%	129.02 (1,388.75)

Table 4.10-Modified bridge construction time and cost

Modification	Decrease in Time	Increase in Costs
1a	25%	0%
1b	25%	5%
1c	25%	10%
2a	50%	0%
2b	50%	10%
2c	50%	20%

Table 4.11-Summary of life-cycle costs for highway bridge with modification 1a

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1	1,191,515	1,967,773	3,159,288	1,172,788	1,771,541	2,944,329	7.3
2	1,191,515	3,818,578	5,010,093	1,172,788	3,462,165	4,634,953	8.1
3	1,191,515	9,370,993	10,562,508	1,172,788	8,534,036	9,706,824	8.8
4	1,191,515	3,020,484	4,211,999	1,172,788	2,499,800	3,672,588	14.7
5	1,191,515	4,871,289	6,062,804	1,172,788	4,190,424	5,363,212	13.0
6	1,191,515	10,423,704	11,615,219	1,172,788	9,262,295	10,435,082	11.3
7	1,191,515	7,699,199	8,890,714	1,172,788	5,736,506	6,909,294	28.7
8	1,191,515	9,550,004	10,741,519	1,172,788	7,427,130	8,599,918	24.9
9	1,191,515	15,102,419	16,293,934	1,172,788	12,499,001	13,671,789	19.2

[1]Refer to Table 3.6 for ADT cases
[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.12-Summary of life-cycle costs for highway bridge with modification 1b

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1	1,235,959	1,967,773	3,203,732	1,193,264	1,771,541	2,964,805	8.1
2	1,235,959	3,818,578	5,054,537	1,193,264	3,462,165	4,655,429	8.6
3	1,235,959	9,370,993	10,606,952	1,193,264	8,534,036	9,727,300	9.0
4	1,235,959	3,020,484	4,256,443	1,193,264	2,499,800	3,693,064	15.3
5	1,235,959	4,871,289	6,107,248	1,193,264	4,190,424	5,383,688	13.4
6	1,235,959	10,423,704	11,659,663	1,193,264	9,262,295	10,455,559	11.5
7	1,235,959	7,699,199	8,935,158	1,193,264	5,736,506	6,929,770	28.9
8	1,235,959	9,550,004	10,785,963	1,193,264	7,427,130	8,620,394	25.1
9	1,235,959	15,102,419	16,338,378	1,193,264	12,499,001	13,692,265	19.3

[1]Refer to Table 3.6 for ADT cases
[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.13-Summary of life-cycle costs for highway bridge with modification 1c

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1	1,280,321	1,967,773	3,248,094	1,213,703	1,771,541	2,985,244	8.8
2	1,280,321	3,818,578	5,098,899	1,213,703	3,462,165	4,675,867	9.1
3	1,280,321	9,370,993	10,651,314	1,213,703	8,534,036	9,747,738	9.3
4	1,280,321	3,020,484	4,300,805	1,213,703	2,499,800	3,713,503	15.8
5	1,280,321	4,871,289	6,151,610	1,213,703	4,190,424	5,404,126	13.8
6	1,280,321	10,423,704	11,704,025	1,213,703	9,262,295	10,475,997	11.7
7	1,280,321	7,699,199	8,979,520	1,213,703	5,736,506	6,950,209	29.2
8	1,280,321	9,550,004	10,830,325	1,213,703	7,427,130	8,640,832	25.3
9	1,280,321	15,102,419	16,382,740	1,213,703	12,499,001	13,712,703	19.5

[1]Refer to Table 3.6 for ADT cases
[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.14-Summary of life-cycle costs for highway bridge with modification 2a

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1	1,191,515	1,317,116	2,508,631	1,172,788	1,290,144	2,462,931	1.9
2	1,191,515	2,550,986	3,742,501	1,172,788	2,520,048	3,692,836	1.3
3	1,191,515	6,252,596	7,444,111	1,172,788	6,209,763	7,382,551	0.8
4	1,191,515	2,066,332	3,257,846	1,172,788	1,832,291	3,005,079	8.4
5	1,191,515	3,300,202	4,491,716	1,172,788	3,062,196	4,234,984	6.1
6	1,191,515	7,001,812	8,193,326	1,172,788	6,751,911	7,924,699	3.4
7	1,191,515	5,396,178	6,587,693	1,172,788	4,241,836	5,414,624	21.7
8	1,191,515	6,630,048	7,821,563	1,172,788	5,471,741	6,644,529	17.7
9	1,191,515	10,331,658	11,523,173	1,172,788	9,161,456	10,334,244	11.5

[1]Refer to Table 3.6 for ADT cases
[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.15-Summary of life-cycle costs for highway bridge with modification 2b

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1	1,280,321	1,317,116	2,597,437	1,213,703	1,290,144	2,503,846	3.7
2	1,280,321	2,550,986	3,831,307	1,213,703	2,520,048	3,733,751	2.6
3	1,280,321	6,252,596	7,532,917	1,213,703	6,209,763	7,423,466	1.5
4	1,280,321	2,066,332	3,346,653	1,213,703	1,832,291	3,045,994	9.9
5	1,280,321	3,300,202	4,580,523	1,213,703	3,062,196	4,275,899	7.1
6	1,280,321	7,001,812	8,282,133	1,213,703	6,751,911	7,965,613	4.0
7	1,280,321	5,396,178	6,676,499	1,213,703	4,241,836	5,455,539	22.4
8	1,280,321	6,630,048	7,910,369	1,213,703	5,471,741	6,685,443	18.3
9	1,280,321	10,331,658	11,611,979	1,213,703	9,161,456	10,375,158	11.9

[1]Refer to Table 3.6 for ADT cases
[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.16-Summary of life-cycle costs for highway bridge with modification 2c

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1	1,369,128	1,317,116	2,686,244	1,254,617	1,290,144	2,544,761	5.6
2	1,369,128	2,550,986	3,920,114	1,254,617	2,520,048	3,774,666	3.9
3	1,369,128	6,252,596	7,621,724	1,254,617	6,209,763	7,464,380	2.1
4	1,369,128	2,066,332	3,435,459	1,254,617	1,832,291	3,086,908	11.3
5	1,369,128	3,300,202	4,669,329	1,254,617	3,062,196	4,316,813	8.2
6	1,369,128	7,001,812	8,370,939	1,254,617	6,751,911	8,006,528	4.6
7	1,369,128	5,396,178	6,765,306	1,254,617	4,241,836	5,496,453	23.1
8	1,369,128	6,630,048	7,999,176	1,254,617	5,471,741	6,726,358	18.9
9	1,369,128	10,331,658	11,700,786	1,254,617	9,161,456	10,416,073	12.3

[1]Refer to Table 3.6 for ADT cases
[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.17-Summary of life-cycle costs for waterway bridge

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1,2,3	1,191,515	150,690	1,342,204	1,172,788	101,597	1,274,384	5.3
4,5,6	1,191,515	1,506,896	2,698,411	1,172,788	1,015,967	2,188,755	23.3
7,8,9	1,191,515	7,534,480	8,725,995	1,172,788	5,079,834	6,252,622	39.6

[1]Refer to Table 3.6 for ADT cases
[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.18-Summary of life-cycle costs for waterway bridge with modification 1a

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1,2,3	1,191,515	116,968	1,308,483	1,172,788	80,918	1,253,705	4.4
4,5,6	1,191,515	1,169,679	2,361,194	1,172,788	809,177	1,981,964	19.1
7,8,9	1,191,515	5,848,394	7,039,909	1,172,788	4,045,883	5,218,670	34.9

[1]Refer to Table 3.6 for ADT cases

[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.19-Summary of life-cycle costs for waterway bridge with modification 1b

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1,2,3	1,235,959	116,968	1,352,927	1,193,264	80,918	1,274,182	6.2
4,5,6	1,235,959	1,169,679	2,405,638	1,193,264	809,177	2,002,441	20.1
7,8,9	1,235,959	5,848,394	7,084,353	1,193,264	4,045,883	5,239,147	35.2

[1]Refer to Table 3.6 for ADT cases

[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.20-Summary of life-cycle costs for waterway bridge with modification 1c

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1,2,3	1,280,321	116,968	1,397,289	1,213,703	80,918	1,294,620	7.9
4,5,6	1,280,321	1,169,679	2,450,000	1,213,703	809,177	2,022,879	21.1
7,8,9	1,280,321	5,848,394	7,128,715	1,213,703	4,045,883	5,259,585	35.5

[1]Refer to Table 3.6 for ADT cases

[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.21-Summary of life-cycle costs for waterway bridge with modification 2a

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1,2,3	1,191,515	83,246	1,274,761	1,172,788	60,239	1,233,026	3.4
4,5,6	1,191,515	832,462	2,023,976	1,172,788	602,386	1,775,174	14.0
7,8,9	1,191,515	4,162,308	5,353,823	1,172,788	3,011,931	4,184,719	27.9

[1]Refer to Table 3.6 for ADT cases

[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.22-Summary of life-cycle costs for waterway bridge with modification 2b

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1,2,3	1,280,321	83,246	1,363,567	1,213,703	60,239	1,273,941	7.0
4,5,6	1,280,321	832,462	2,112,783	1,213,703	602,386	1,816,089	16.3
7,8,9	1,280,321	4,162,308	5,442,629	1,213,703	3,011,931	4,225,634	28.8

[1]Refer to Table 3.6 for ADT cases

[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.23-Summary of life-cycle costs for waterway bridge with modification 2c

ADT Case[1]	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars			Percent Difference[2]
	Agency	User	Total	Agency	User	Total	
1,2,3	1,369,128	83,246	1,452,374	1,254,617	60,239	1,314,856	10.5
4,5,6	1,369,128	832,462	2,201,589	1,254,617	602,386	1,857,003	18.6
7,8,9	1,369,128	4,162,308	5,531,436	1,254,617	3,011,931	4,266,548	29.6

[1]Refer to Table 3.6 for ADT cases

[2]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

Table 4.24-Summary of difference in total life-cycle costs for all bridges

Analysis	Percent Difference[1]								
	ADT Case 1[2]	ADT Case 2[2]	ADT Case 3[2]	ADT Case 4[2]	ADT Case 5[2]	ADT Case 6[2]	ADT Case 7[2]	ADT Case 8[2]	ADT Case 9[2]
Highway	11.1	12.5	13.7	19.1	17.6	16.1	33.2	29.4	23.8
Highway + Mod 1a	7.3	8.1	8.8	14.7	13.0	11.3	28.7	24.9	19.2
Highway + Mod 1b	8.1	8.6	9.0	15.3	13.4	11.5	28.9	25.1	19.3
Highway + Mod 1c	8.8	9.1	9.3	15.8	13.8	11.7	29.2	25.3	19.5
Highway + Mod 2a	1.9	1.3	0.8	8.4	6.1	3.4	21.7	17.7	11.5
Highway + Mod 2b	3.7	2.6	1.5	9.9	7.1	4.0	22.4	18.3	11.9
Highway + Mod 2c	5.6	3.9	2.1	11.3	8.2	4.6	23.1	18.9	12.3
Waterway	5.3	5.3	5.3	23.3	23.3	23.3	39.6	39.6	39.6
Water + Mod 1a	4.4	4.4	4.4	19.1	19.1	19.1	34.9	34.9	34.9
Water + Mod 1b	6.2	6.2	6.2	20.1	20.1	20.1	35.5	35.5	35.5
Water + Mod 1c	7.9	7.9	7.9	21.1	21.1	21.1	35.5	35.5	35.5
Water + Mod 2a	3.4	3.4	3.4	14.0	14.0	14.0	27.9	27.9	27.9
Water + Mod 2b	7.0	7.0	7.0	16.3	16.3	16.3	28.8	28.8	28.8
Water + Mod 2c	10.5	10.5	10.5	18.6	18.6	18.6	29.6	29.6	29.6

[1]Percent difference = (Total Replacement - Total Rehabilitation)/Total Rehabilitation

[2]Refer to Table 3.6 for ADT cases

CHAPTER FIVE: SENSITIVITY ANALYSIS

A sensitivity analysis can be used to improve the results of a deterministic analysis (FHWA 2002) by providing a limited measure of the effects of input parameter variability on life-cycle costs. The sensitivity analysis is used to determine which input parameters the life-cycle costs are the most sensitive to. This can assist decision-makers in understanding any variability in the analysis results of the design alternatives. It can also be used to identify which input values need a more refined estimate and which do not. Changes in only one input parameter are made while all the others are held constant. The life-cycle cost is sensitive to an input parameter when a small change in that parameter results in a relatively large change in the life-cycle cost (Trejo and Reinschmidt 2007a). However, since only one input parameter is changed at a time the analysis cannot measure the impact of simultaneous changes in more than one parameter. It also does not give any indication of risk (Pittenger et al. 2012).

The sensitivity analysis in this study used the 26 parameters presented in Table 5.1. Each parameter was changed by plus and minus ten percent from the mean input values. An analysis was done for each of the nine ADT cases. Changes in life-cycle costs were converted to a percentage of the mean life-cycle cost for each ADT case. Except for changes in the service life of the CFRP rehabilitation, both plus and minus changes in parameter mean values of ten percent resulted in the same magnitude, but different sign, of change in life-cycle costs. All parameters had changes less than ten percent.

Although the ranking of parameters varied depending on the alternative and the ADT case, the same four parameters had the most impact on life-cycle cost, user costs in particular, for both alternatives. They were bridge replacement duration, ADT under bridge, VOT cars, and delay time under the bridge during bridge replacement.

Three summaries of the analysis results are presented. The first one is for the replacement alternative, the second one is for the rehabilitation alternative, and the third one is for both alternatives combined.

The degree of sensitivity depended on the initial traffic volume. Some parameters had changes greater than one percent for all ADT cases. For other parameters some ADT cases had changes less than one percent and other ADT cases had changes greater than one percent. Four categories of changes in life-cycle cost, as a function of initial ADT, were found. Categories A, B, C, and D are described as follows:

- Category A: percent change in life-cycle cost increased as ADT on bridge increased (ADT under bridge constant) and as ADT under bridge increased (ADT on bridge constant)
- Category B: percent change in life-cycle cost decreased as ADT on bridge increased (ADT under bridge constant) and increased as ADT under bridge increased (ADT on bridge constant)
- Category C: percent change in life-cycle cost increased as ADT on bridge increased (ADT under bridge constant) and decreased as ADT under bridge increased (ADT on bridge constant)
- Category D: percent change in life-cycle cost decreased as ADT on bridge increased (ADT under bridge constant) and as ADT under bridge increased (ADT on bridge constant)

The categories of each input parameter for the replacement and rehabilitation alternatives are summarized in Table 5.2

Replacement Alternative

The results of the sensitivity analysis for the replacement alternative are summarized in Table 5.3.

Nine parameters had changes greater than one percent for at least two ADT cases. Four of these had changes greater than one percent for all nine ADT cases: bridge replacement duration (Category A), ADT under bridge (Category B), delay time under the bridge during bridge replacement (Category B), and VOT cars (Category A). Two of these had the same impact on life-cycle cost: ADT under bridge and delay time under the bridge during bridge replacement. The remaining five parameters had changes greater than one percent for the number of ADT cases shown. Category B included one parameter: VOT trucks (3 cases). Category C included three parameters: ADT on bridge (6 cases), delay time on the bridge during bridge replacement (5 cases), and detour length during replacement (2 cases). Category D included one parameter: bridge replacement cost (4 cases).

The remaining 17 parameters had changes less than one percent for all nine ADT cases. Two parameters had the same impact on life-cycle cost: deck overlay duration and delay time on the bridge during deck overlay. Category C included six parameters: VOC cars, deck replacement duration, delay time on the bridge during deck replacement, deck overlay duration, delay time on the bridge during deck overlay, and VOC trucks. Category D included four parameters: deck overlay cost for the new bridge, deck replacement cost, MOT during replacement, and MOT during rehabilitation. The seven rehabilitation specific parameters had no impact on the life-cycle cost of the replacement alternative.

Rehabilitation Alternative

The results of the sensitivity analysis for the rehabilitation alternative are summarized in Table 5.4.

Fifteen parameters had changes greater than one percent for at least one ADT case. Five of these had changes greater than one percent for all nine ADT cases: ADT under bridge (Category B), VOT cars (Category A), bridge replacement duration (Category A), delay time under the bridge during bridge replacement (Category B) and service life of the CFRP rehabilitation (Category C). The remaining ten parameters had changes greater than one percent for the number of ADT cases shown. Category B included four parameters: deck overlay duration (5 cases), bridge rehabilitation duration (5 cases), delay time under the bridge during bridge rehabilitation (3 cases), and VOT trucks (3 cases). Category C included three parameters: ADT on bridge (5 cases), delay time on the bridge during bridge replacement (4 cases), and detour length during replacement (2 cases). Category D included three parameters: Bridge replacement cost (1 case), FRP strengthening cost (1 case), and quantity of CFRP (1 case). Two parameters had the same impact on LCC: FRP strengthening cost and the quantity of CFRP.

The remaining 11 parameters had changes less than one percent for all nine ADT cases. Category C included six parameters: deck replacement duration, VOC cars, delay time on the bridge during deck replacement, delay time on the bridge during bridge rehabilitation, delay time on the bridge during deck overlay, and VOC trucks. Category D included five parameters: deck overlay cost for the old bridge, MOT during rehabilitation, deck replacement cost, deck overlay cost for the new bridge, and MOT during replacement.

Replacement and Rehabilitation Alternatives

A comparison of the sensitivity analysis results for both alternatives show some similarities in which parameters have the most influence on the life-cycle cost for each of the nine ADT cases. The same four parameters had the most impact on life-cycle cost, user costs in particular. They were bridge replacement duration, ADT under bridge, VOT cars, and delay time under bridge-bridge replacement. In addition, two of these parameters had changes in life-cycle cost greater than five percent for all nine ADT cases: bridge replacement duration and VOT cars. The other two parameters had changes greater than five percent in six of the nine ADT cases. The ADT on bridge parameter also had changes greater than five percent but only for two ADT cases with the replacement alternative and only one ADT case with the rehabilitation alternative.

The 11 parameters that had changes less than one percent for all ADT cases for the rehabilitation alternative also had changes less than one percent for all ADT cases for the replacement alternative. The deck overlay duration parameter had changes less than one percent for all ADT cases for the replacement alternative but not for the rehabilitation alternative.

The five parameters that had changes greater than one percent for some ADT cases for the replacement alternative also had changes greater than one percent for some

ADT cases for the rehabilitation alternative. Four other parameters had changes greater than one percent for some ADT cases for only the rehabilitation alternative: bridge rehabilitation duration, delay time under bridge-bridge rehabilitation, FRP strengthening cost, and quantity of CFRP. The service life of the CFRP rehabilitation had changes greater than one percent for all ADT cases for the rehabilitation alternative.

Sensitivity Analysis Summary

Although only one parameter at a time is varied in a sensitivity analysis multiple parameters can vary simultaneously in a probabilistic analysis. Individually some parameters had a positive effect on life-cycle costs, an increase in the value of the parameter resulted in an increase in life-cycle costs. Other parameters had a negative effect, an increase in the value of the parameter resulted in a decrease in life-cycle costs. When the individual changes are combined and applied simultaneously the overall effect may be positive, negative, or about neutral.

Four parameters had the most influence on life-cycle costs: bridge replacement duration, ADT under the bridge, VOT cars, and delay time under the bridge during bridge replacement. Two of these were Category A: bridge replacement duration and VOT cars. The other two were Category B: ADT under the bridge and delay time under the bridge during bridge replacement. For increases in traffic volume on the bridge the two categories had the opposite effect on the percent change in life-cycle costs. For increases in traffic volume under the bridge they had the same effect.

For the high traffic volume on the bridge cases the influence was similar to the four parameters that had the most influence, i.e. for high traffic volumes there were five parameters with the most influence on life-cycle costs. It was a Category C parameter:

ADT on the bridge. Increases in traffic volume on the bridge increased the percent change in life-cycle costs and increases in traffic volume under the bridge decreased the percent change in life-cycle costs. Traffic volume under the bridge had the opposite effect. When combined the influence of one of the parameters offset the influence of the other, especially for high traffic volumes.

Table 5.1-Sensitivity analysis parameters

No.	Parameter	No.	Parameter
1	Bridge replacement cost	14	Initial ADT on bridge
2	Deck replacement cost	15	Initial ADT under bridge
3	FRP strengthening cost	16	VOT cars
4	Deck overlay cost-new bridge	17	VOT trucks
5	Deck overlay cost-old bridge	18	VOC cars
6	Bridge replacement duration	19	VOC trucks
7	Bridge rehabilitation duration	20	Delay time on bridge-bridge replacement
8	Deck overlay duration	21	Delay time under bridge-bridge replacement
9	Deck replacement duration	22	Delay time on bridge-bridge rehabilitation
10	Quantity of CFRP	23	Delay time under bridge-bridge rehabilitation
11	MOT-replacement	24	Delay time on bridge-deck overlay
12	MOT-rehabilitation	25	Delay time on bridge-deck replacement
13	Detour length-replacement	26	Service life CFRP rehabilitation

Table 5.2-Sensitivity analysis categories

No.	Parameter	Replacement Category	Rehabilitation Category
1	Bridge replacement cost	D	D
2	Deck replacement cost	D	D
3	FRP strengthening cost	NA	D
4	Deck overlay cost-new bridge	D	D
5	Deck overlay cost-old bridge	NA	D
6	Bridge replacement duration	A	A
7	Bridge rehabilitation duration	NA	B
8	Deck overlay duration	C	B
9	Deck replacement duration	C	C
10	Quantity of CFRP	NA	D
11	MOT-replacement	D	D
12	MOT-rehabilitation	D	D
13	Detour length-replacement	C	C
14	Initial ADT on bridge	C	C
15	Initial ADT under bridge	B	B
16	VOT cars	A	A
17	VOT trucks	B	B
18	VOC cars	C	C
19	VOC trucks	C	C
20	Delay time on bridge-bridge replacement	C	C
21	Delay time under bridge-bridge replacement	B	B
22	Delay time on bridge-bridge rehabilitation	NA	C
23	Delay time under bridge-bridge rehabilitation	NA	B
24	Delay time on bridge-deck overlay	C	C
25	Delay time on bridge-deck replacement	C	C
26	Service life CFRP rehabilitation	NA	C

NA=not applicable

Table 5.3-Sensitivity analysis summary highway bridge replacement alternative

No.	Percent Change Life-cycle Costs								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
1	2.331	1.415	0.649	1.719	1.163	0.591	0.793	0.650	0.422
2	0.199	0.121	0.055	0.147	0.099	0.050	0.068	0.056	0.036
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.283	0.172	0.079	0.209	0.141	0.072	0.096	0.079	0.051
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	6.831	8.077	9.118	7.388	8.232	9.103	8.230	8.549	9.059
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.017	0.010	0.005	0.122	0.082	0.042	0.281	0.230	0.149
9	0.025	0.015	0.007	0.184	0.125	0.063	0.425	0.348	0.226
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.077	0.047	0.021	0.057	0.038	0.020	0.026	0.021	0.014
12	0.031	0.019	0.009	0.023	0.016	0.008	0.011	0.009	0.006
13	0.103	0.063	0.029	0.762	0.516	0.262	1.759	1.441	0.935
14	0.396	0.240	0.110	2.917	1.974	1.002	6.731	5.515	3.577
15	6.477	7.862	9.019	4.777	6.465	8.205	2.205	3.613	5.858
16	5.924	7.023	7.941	6.205	7.018	7.855	6.631	7.008	7.609
17	0.853	1.025	1.169	0.734	0.914	1.100	0.554	0.687	0.900
18	0.038	0.023	0.011	0.283	0.192	0.097	0.654	0.536	0.348
19	0.005	0.003	0.001	0.035	0.024	0.012	0.080	0.066	0.043
20	0.258	0.156	0.072	1.899	1.285	0.652	4.382	3.591	2.329
21	6.477	7.862	9.019	4.777	6.465	8.205	2.205	3.613	5.858
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.017	0.010	0.005	0.122	0.082	0.042	0.281	0.230	0.149
25	0.018	0.011	0.005	0.134	0.091	0.046	0.309	0.253	0.164
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

[1]Refer to Table 3.6 for ADT cases

Table 5.4-Sensitivity analysis summary highway bridge rehabilitation alternative

No.	Percent Change Life-cycle Costs								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
1	1.194	0.734	0.340	0.943	0.630	0.316	0.487	0.388	0.241
2	0.157	0.097	0.045	0.124	0.083	0.042	0.064	0.051	0.032
3	1.232	0.757	0.351	0.973	0.650	0.326	0.502	0.400	0.248
4	0.109	0.067	0.031	0.086	0.057	0.029	0.044	0.035	0.022
5	0.395	0.243	0.112	0.312	0.208	0.105	0.161	0.128	0.080
6	5.621	6.757	7.728	6.152	6.952	7.757	7.114	7.410	7.849
7	0.918	1.117	1.287	0.852	1.045	1.239	0.732	0.875	1.087
8	0.925	1.121	1.289	0.905	1.080	1.257	0.869	0.984	1.155
9	0.030	0.019	0.009	0.241	0.161	0.081	0.621	0.495	0.307
10	1.232	0.757	0.351	0.972	0.650	0.326	0.502	0.400	0.248
11	0.041	0.025	0.012	0.033	0.022	0.011	0.017	0.013	0.008
12	0.207	0.127	0.059	0.164	0.109	0.055	0.085	0.067	0.042
13	0.074	0.046	0.021	0.585	0.391	0.196	1.511	1.203	0.747
14	0.297	0.182	0.084	2.341	1.565	0.785	6.045	4.813	2.986
15	6.280	7.715	8.941	4.957	6.628	8.309	2.560	4.076	6.324
16	5.686	6.856	7.855	5.984	6.891	7.802	6.525	6.972	7.635
17	0.823	1.004	1.158	0.735	0.920	1.105	0.576	0.722	0.938
18	0.028	0.017	0.008	0.218	0.146	0.073	0.562	0.448	0.278
19	0.003	0.002	0.001	0.027	0.018	0.009	0.069	0.055	0.034
20	0.176	0.108	0.050	1.386	0.927	0.465	3.579	2.850	1.769
21	5.380	6.609	7.659	4.246	5.678	7.118	2.193	3.492	5.417
22	0.018	0.011	0.005	0.141	0.094	0.047	0.365	0.290	0.180
23	0.900	1.106	1.282	0.711	0.950	1.191	0.367	0.584	0.907
24	0.007	0.004	0.002	0.053	0.036	0.018	0.137	0.109	0.068
25	0.022	0.014	0.006	0.175	0.117	0.059	0.452	0.360	0.223
26a[2]	2.838	2.722	2.623	3.100	2.914	2.726	3.574	3.363	3.050
26b[3]	-2.716	-2.619	-2.536	-2.962	-2.797	-2.632	-3.409	-3.216	-2.931

[1]Refer to Table 3.6 for ADT cases
[2]CFRP service life minus 10%
[3]CFRP service life plus 10%

CHAPTER SIX: PROBABILISTIC ANALYSIS

In a probabilistic analysis multiple parameters are varied at the same time to account for variability and uncertainty. The Monte Carlo simulation is commonly used to perform the probabilistic analysis. The two main parameters with uncertainties are related to costs and service life (Pittenger et al. 2012). Probability distribution functions and random sampling were used to select a discrete value for inputs that varied. The process was repeated and a range of life-cycle costs was generated for each alternative. A statistical analysis of the results was performed to determine the cumulative probability of the life-cycle costs for each alternative (Reigle and Zaniewski 2002).

Two common probability distributions were used in this study to represent the variability of some input parameters (Walls III and Smith 1998, Pittenger et al. 2012). Agency unit costs represented by a normal distribution with mean and standard deviation values are summarized in Table 6.1. In order to avoid the possibility of low or negative unit costs minimum values were included. Parameters represented by a triangular distribution with minimum, most likely, and maximum values, are summarized in Table 6.2. Minimum traffic volumes were assumed to be 80% of the most likely traffic volume and maximum traffic volumes were 110% of the most likely traffic volume. The Palisades @Risk software (Palisades Corporation) was used within spreadsheets to calculate life-cycle costs using the ranges and distributions of input values.

Each life-cycle cost analysis consisted of 100,000 iterations of the life-cycle cost model. Latin Hypercube sampling was used when generating random number as it has quicker convergence (Walls III and Smith, 1998). Each analysis used the same initial seed number for each ADT case in order to be able to compare the impact of traffic volume on the results.

The risk profile basic statistics from each probabilistic analysis included the minimum life-cycle cost, maximum life-cycle cost, mean life-cycle cost, median life-cycle cost, standard deviation of the life-cycle costs, and distribution of life-cycle costs by percentile. Cumulative probability curves for each alternative were then developed using the distribution of life-cycle costs. The decision-maker can use this information to select an alternative based on the level of risk that they are most comfortable with and not rely only on mean life-cycle costs (FHWA 2002).

In this study probabilistic analyses were carried out to determine the probability when rehabilitation had the lower life-cycle cost. Analyses were carried out for 1) a bridge over a highway, 2) a bridge over a highway with limited random variables, 3) a bridge over a highway with modified bridge construction time and cost, 4) a bridge over a waterway, and 5) a bridge over a waterway with modified bridge construction time and cost. Each analysis used the agency and user cost parameters shown in Table 3.1, Table 3.2 and Table 3.3. Each analysis used a different initial traffic volume, both on and under the bridge.

Bridge over Highway

Nine probabilistic analyses were carried out. The risk profile statistics from the probabilistic analyses and the cumulative probability curves are contained in Appendix E for each of the nine ADT cases.

The typical results of a simulation, ADT case 1, presented as ascending cumulative probability curves for each alternative are shown in Figure 6.1. Each curve shows the cumulative probability of life-cycle cost, i.e. the probability that the life-cycle cost is less than or equal to any given value. Although the curves for the other ADT cases are similar there are two main differences. The first one is the range of life-cycle costs. The second is the point where the two curves intersect, when they do intersect. This is the point at which the alternative with the lower life-cycle cost changes from replacement to rehabilitation.

The minimum, maximum, and range of life-cycle costs are summarized in Table 6.3. As the traffic volumes increased the minimum life-cycle cost, maximum life-cycle cost, and the range in life-cycle costs all increased. For a fixed traffic volume on the bridge the increases in maximum values was larger than the increases in minimum values. For a fixed traffic volume under the bridge the increases in minimum values was larger than the increases in maximum values. This holds for both the replacement and rehabilitation alternatives.

Changes in traffic volumes for the replacement alternative resulted in different percent changes in the minimum and maximum life-cycle costs. Two analyses were done. In the first one the traffic on the bridge was held constant and traffic under the bridge was increased, Table 6.4. For 100 vpd on the bridge, traffic under the bridge was increased first from 5,000 to 10,000 vpd and then from 10,000 to 25,000 vpd. Increasing traffic under the bridge from 5,000 to 10,000 vpd increased the minimum value 8.74 percent and the maximum value 82.70 percent. Increasing traffic under bridge from 10,000 to 25,000 vpd increased the minimum value 11.73 percent and the maximum value 135.79 percent.

For 1,000 vpd on the bridge, traffic under the bridge was also increased first from 5,000 to 10,000 vpd and then from 10,000 to 25,000 vpd. Increasing traffic under bridge from 5,000 to 10,000 vpd increased the minimum value 6.83 percent and the maximum value 62.39 percent. Increasing traffic under bridge from 10,000 to 25,000 vpd increased the minimum value 4.75 percent and the maximum value 115.26 percent. For 5,000 vpd on the bridge, traffic under the bridge was also increased first from 5,000 to 10,000 vpd and then from 10,000 to 25,000 vpd. Increasing traffic under bridge from 5,000 to 10,000 vpd increased the minimum value 3.07 percent and the maximum value 22.97 percent. Increasing traffic under bridge from 10,000 to 25,000 vpd increased the minimum value 8.92 percent and the maximum value 68.94 percent.

In the second analysis for the replacement alternative the traffic under the bridge was held constant and traffic on the bridge was increased, Table 6.5. For 5,000 vpd under the bridge increasing traffic on bridge from 100 to 1,000 vpd increased the minimum value 72.85 percent and the maximum value 32.54 percent. Increasing traffic on the bridge from 1,000 to 5,000 vpd increased the minimum value 131.73 percent and the maximum value 120.79 percent. For 10,000 vpd under the bridge increasing traffic on the bridge from 100 to 1,000 vpd increased the minimum value 69.81 percent and the maximum value 17.81 percent. Increasing traffic on the bridge from 1,000 to 5,000 vpd increased the minimum value 123.57 percent and the maximum value 67.19 percent. For 25,000 vpd under the bridge, increasing traffic on the bridge from 100 to 1,000 vpd increased the minimum value 59.21 percent and the maximum value 7.55 percent. Increasing traffic on the bridge from 1,000 to 5,000 vpd increased the minimum value 132.47 percent and the maximum value 31.21 percent.

Changes in traffic volumes for the rehabilitation alternative also resulted in different percent changes in the minimum and maximum life-cycle costs. Two same two analyses were done. In the first analysis the traffic on the bridge was held constant and traffic under the bridge was increased, Table 6.4. For 100 vpd on the bridge increasing traffic under the bridge from 5,000 to 10,000 vpd increased the minimum value 24.11 percent and the maximum value 81.43 percent. Increasing traffic under the bridge from 10,000 to 25,000 vpd increased the minimum value 52.35 percent and the maximum value 134.65 percent. For 1,000 vpd on the bridge increasing traffic under the bridge from 5,000 to 10,000 vpd increased the minimum value 22.41 percent and the maximum value 66.70 percent. Increasing traffic under the bridge from 10,000 to 25,000 vpd increased the minimum value 39.36 percent and the maximum value 120.04 percent. For 5,000 vpd on the bridge increasing traffic under the bridge from 5,000 to 10,000 vpd increased the minimum value 9.09 to 23.65 percent. Increasing traffic under the bridge from 10,000 to 25,000 vpd increased the minimum value 23.19 percent and the maximum value 71.80 percent.

In the second analysis for the rehabilitation alternative the traffic under the bridge was held constant and traffic on the bridge was increased, Table 6.5. For low traffic under the bridge increasing traffic on the bridge from 100 to 1,000 vpd increased the minimum value 37.47 percent and the maximum value 22.09 percent. Increasing traffic on the bridge from 1,000 to 5,000 vpd increased the minimum value 100.07 percent and the maximum value 110.51 percent. For 10,000 vpd under the bridge increasing traffic on the bridge from 100 to 1,000 vpd increased the minimum value 35.59 percent and the maximum value 12.17 percent. Increasing traffic on the bridge from 1,000 to 5,000 vpd increased the minimum value 78.30 percent and the maximum value 56.15 percent. For 25,000 vpd under the bridge increasing traffic on the bridge from 100 to 1,000 vpd increased the minimum value 24.03 percent and the maximum value 5.19 percent. Increasing traffic on the bridge from 1,000 to 5,000 vpd increased the minimum value 57.61 percent and the maximum value 21.92 percent.

The point where the cumulative probability curves intersect indicates the life-cycle cost and probability at which the alternative with the lower life-cycle cost changes from one alternative to the other. At this point the probabilities that either replacement or rehabilitation will have the lower life-cycle cost are the same. For the highway bridge and life-cycle costs less than this value there is a higher probability that replacement will have the lower life-cycle cost. For life-cycle costs greater than this value there is a higher probability that rehabilitation will have the lower life-cycle cost. The life-cycle costs and probabilities where the curves intersect were estimated using the risk profile statistics and straight line interpolation.

The point where the two curves intersect varied depending on the traffic volume. For ADT case 1 (Table 3.6) this point is at 17.02 percent and 2.54 million dollars. For ADT case 2 (Table 3.6) this point is at 17.85 percent and 3.80 million dollars. For ADT case 3 (Table 3.6) this point is at 17.99 percent and 7.52 million dollars. For ADT case 4 (Table 3.6) this point is at 0.23 percent and 2.00 million dollars. For ADT case 5 (Table 3.6) this point is at 2.52 percent and 3.37 million dollars. For ADT case 6 (Table 3.6) this point is at 9.34 percent and 7.07 million dollars. For ADT case 9 (Table 3.6) this point is at 0.30 percent and 5.86 million dollars. For ADT cases 7 and 8 (Table 3.6) the curves did not intersect. For these ranges of traffic there is a zero percent probability that the replacement life-cycle cost is lower.

The agency, user, and total life-cycle costs from the deterministic analysis and the mean and median values from the probabilistic analyses are compared in Table 6.6. Some values are close to the deterministic values but never equal. This shows that deterministic life-cycle costs are mean values. In some cases the deterministic values are lower and in the others they are higher. The deterministic values tended to be higher with low traffic volumes and lower with increased traffic volume. For the replacement alternative the deterministic values ranged from 7.2 percent lower to 5.3 percent higher than mean values and from 5.2 percent lower to 9.9 percent higher than the median values. For the rehabilitation alternative the deterministic values ranged from 8.8 percent lower to 2.4 percent higher than mean values and from 6.7 percent lower to 5.3 percent higher than the median values.

The results of the probabilistic analysis show some trends with respect to increases in traffic volumes. As the traffic volumes on the bridge increased, with traffic volume under the bridge constant, the probability that replacement has the lower life-cycle cost decreased. As the traffic volume under bridge increased, with traffic volume on the bridge constant, the probability that replacement has the lower life-cycle cost increased. This increase in probability became more significant with increases in traffic volumes on the bridge. These opposing trends can make it difficult to predict the effect of different combinations of traffic volume on and under the bridge.

Bridge over Highway with Limited Random Variables

The probabilistic analyses for the highway bridge used either normal distributions or triangular distributions of more variables that what the sensitivity analysis indicated are necessary. The sensitivity analysis showed that four variables had the most influence on life-cycle costs: bridge replacement duration, traffic under the bridge, VOT cars, and delay time under the bridge during bridge replacement. Therefore, nine probabilistic analyses were carried out using probability distributions for only these four variables. The risk profile statistics and cumulative probability curves for the highway bridge with limited random variables are contained in Appendix E. The estimated probabilities at which replacement has the lower life-cycle cost are compared with the highway bridge analysis that used more random variables in Table 6.7. The associated estimated life-cycle costs are compared in Table 6.8.

The effect of using the limited random variables on probabilities depended on traffic volumes. For the low traffic volumes on the bridge the probabilities that replacement had the lower life-cycle cost all decreased. The decrease was more significant for ADT case 1 (Table 3.6). For the medium traffic volumes the effect was mixed. ADT cases 4 and 5 (Table 3.6) showed a slight increase in probability while ADT case 6 (Table 3.6) showed a slight decrease. For the high traffic volumes the results were also mixed. For ADT cases 7 and 8 (Table 3.6) there was no change. For ADT case 9 (Table 3.6) there was a slight increase. Although the other random variables individually had a small influence on life-cycle costs collectively they had more influence.

The effect of using the limited random variables on the associated life-cycle cost also depended on traffic volumes. For the low traffic volumes on the bridge the life-cycle costs all decreased. For the medium traffic volumes the effect was mixed. ADT cases 4 and 6 (Table 3.6) showed an increase while ADT case 5 (Table 3.6) showed a decrease. For the high traffic volumes the results were also mixed. For ADT cases 7 and 8 (Table 3.6) there was no change. For ADT case 9 (Table 3.6) there was an increase.

These changes in probabilities and costs mostly likely would not change which alternative is selected. If the decision maker was not going to select the replacement alternative at 17 to 18 percent probability, for low traffic volume on the bridge, they would most likely not select the replacement alternative at lower probability.

Bridge over Highway with Modified Bridge Construction Time and Cost

As done in the deterministic analysis two modifications to the bridge construction time were investigated. In the first modification the initial value of the most likely time to construct the bridge was decreased by 25 percent. In the second modification it was decreased by 50 percent. The maximum times were adjusted by about the same percentages. Since minimum times would most likely not decrease as much as the other two times a nominal decrease of five and ten days was selected. The times used are summarized in Table 6.9.

Three variations of the unit bridge construction cost were used with each modification. For the first time modification the initial mean and minimum values of unit cost to construct the bridge was increased by zero, five, and ten percent. For the second time modification they were increased by zero, ten, and twenty percent. The value of the standard deviation was not changed. The unit costs used are summarized in Table 6.10.

The combinations of modified times and costs are summarized in Table 6.11. Even though no increase in cost is likely to occur it was also included in the probabilistic analyses as a base line or limiting value.

Six additional probabilistic analyses using the modified bridge construction times and costs were done for each of the nine traffic cases. The estimated probabilities at which replacement had the lower life-cycle cost are summarized in Table 6.12. The associated estimated life-cycle costs are summarized in Table 6.13. The risk profile statistics and cumulative probability curves for the highway bridge with modified construction time and costs are contained in Appendix E.

Decreasing the time to construct the new bridge generally increased the probability at which the replacement alternative had the lower life-cycle cost. However, for the higher traffic volumes the decrease in time had no effect, ADT cases 7 and 8 (Table 3.6), or little effect, ADT case 9 (Table 3.6). It also had little effect on ADT case 4 (Table 3.6). Decreasing the construction time without any increase in the unit cost had the most effect. For the low traffic volume on the bridge cases the probability increased to more than 50 percent. Although subsequent increases in unit cost negated most of the increase in probability, the resulting probabilities were still more than those for the corresponding highway bridge. The associated life-cycle costs changed very little.

Bridge over Waterway

Three additional probabilistic analyses using no vehicular traffic under the bridge were carried out. The risk profile statistics and cumulative probability curves for the bridge over waterway are contained in Appendix E. The estimated probabilities at which replacement has the lower life-cycle cost are compared with the highway bridge in Table 6.14. The associated estimated life-cycle costs are compared in Table 6.15.

Changing the traffic volume under the bridge to zero resulted in two significant changes in probabilities. For medium and high traffic volumes there was now a zero percent probability that the replacement alternative had the lower life-cycle cost. For the low traffic volume case the relative positions of the two cumulative probability curves was reversed, Figure 6.2. Below the intersection point of the curves the rehabilitation alternative now had the lower life-cycle cost instead of the replacement alternative. The intersection point also shifted upwards to about 74 percent, i.e. the probability that the rehabilitation alternative had the lower life-cycle cost was about 74 percent. The associated life-cycle cost was also reduced. The amount it decreased was relatively small for ADT case 1 (Table 3.6) but was more significant for ADT case 3 (Table 3.6). This was due to the removal of more traffic from under the bridge in case 3 (Table 3.6) and the subsequent reduction in user costs.

Bridge over Waterway with Modified Bridge Construction Time and Cost

Six additional probabilistic analyses using no vehicular traffic under the bridge together with the modified bridge construction times and costs were carried out for the same three traffic volume cases used for a bridge over a waterway. The risk profile statistics and cumulative probability curves for the bridge over waterway with modified construction time and cost are contained in Appendix E. The estimated probabilities at which replacement has the lower life-cycle cost are compared with the highway bridge and the waterway bridge in Table 6.16. The associated estimated life-cycle costs are compared in Table 6.17.

Modifying the bridge construction time and cost for a bridge over a waterway only had an impact for the low traffic volume case. As with the bridge over water analysis the relative position of the two cumulative probability curves was reversed. It also raised the point where the two cumulative probability curves intersect. The probability that the rehabilitation alternative had the lower life-cycle cost increased to about 81 percent with modification 1b to as much as 96 percent for modification 2c. There was a corresponding increase in the associated life-cycle cost.

This was not the case for modifications 1a and 2a, Figures 6.3 and 6.4. The two curves were close enough for them to intersect in three places. For modification 1a the curves intersected at 0.82, 6.12, and 59.03 percent. The associated life-cycle costs were 0.97, 1.09, and 1.37 million dollars. For modification 2a the curves intersected at 0.59, 18.18, and 32.59 percent. The associated life-cycle costs were 0.92, 1.15, and 1.23 million dollars. The difference in life-cycle costs were generally less than five percent.

Modifying the bridge construction time and cost for a bridge over a waterway made no difference in which alternative had the lower life-cycle cost for the medium and high traffic volume cases. The rehabilitation alternative continued to have the lower life-cycle cost. It did however increase the difference in life-cycle costs for all probabilities, i.e. increased the distance between the two curves.

Probabilistic Analysis Summary

Probabilistic analyses were carried out for a highway bridge, a highway bridge with limited random variables, a highway bridge with modified bridge construction time and cost, a waterway bridge, and a waterway bridge with modified bridge construction time and cost. The estimated probabilities at which replacement has the lower life-cycle cost are compared for all the analyses in Table 6.18. The associated estimated life-cycle costs are compared in Table 6.19.

The rehabilitation alternative generally had the higher probability of having the lower life-cycle cost. However there were instances where the difference between the two alternatives had been reduced enough for a decision maker to consider using accelerated bridge construction technologies. This was for a bridge over a waterway with low traffic volumes. If it were possible to obtain a 50 percent decrease in bridge construction time without any increase in bridge construction cost the life-cycle costs are close. However this may not be likely to occur.

The effect of the different bridge options on life-cycle costs and the difference in life-cycle costs between the two alternatives depended on the traffic volumes. They had the most effect on the low traffic volume cases. For the low traffic volume cases modification of bridge construction time and cost had a wide range of effect on probabilities. Some of these probabilities may be high enough for a decision maker to choose replacement instead of rehabilitation. For bridges over a waterway the results favored the rehabilitation alternative. As the traffic volumes increased the probability that the replacement alternative had the lower life-cycle cost decreased and eventually went to zero.

Table 6.1-Probabilistic analysis input-normal distribution

Parameter	Mean	Std. Dev.	Minimum
Prestressed concrete girder bridge, $/ft^2 ($/m^2)	107.52 (1,157.33)	18.28 (196.76)	72.00 (775.00)
Deck overlay-new bridge, $/ft^2 ($/m^2)	16.54 (178.03)	4.79 (51.56)	7.00 (75.35)
Deck overlay-old bridge, $/ft^2 ($/m^2)	16.54 (178.03)	4.79 (51.56)	7.00 (75.35)
Bridge overlay approach pavement-new bridge, $/yd^2 ($/m^2)	40.01 (47.85)	12.25 (14.65)	20.00 (23.92)
Bridge overlay approach pavement-old bridge, $/yd^2 ($/m^2)	54.83 (65.58)	16.45 (19.67)	20.00 (23.92)
Deck construction, $/ft^2 ($/m^2)	38.17 (410.86)	7.19 (77.39)	24.00 (258.33)
CFRP wrap (one layer), $/ft^2 ($/m^2)	54.39 (585.45)	21.24 (228.62)	39.00 (419.79)
Bridge rail retrofit with thrie beam, $/ft ($/m)	$76.99 (252.59)	14.52 (47.64)	65.00 (213.25)
Bridge removal, $/ft^2 ($/m^2)	14.13 (152.09)	4.03 (43.38)	8.00 (86.11)
Deck removal, $/ft^2 ($/m^2)	4.87 (52.42)	2.61 (28.09)	2.00 (21.53)

Table 6.2-Probabilistic analysis input-triangular distribution

Parameter	Minimum	Most Likely	Maximum
Construct new bridge-duration, days	90	240	370
Service life new bridge, years	70	75	90
Service life bridge deck (time to overlay), years	15	20	25
Service life bridge deck overlay, years	15	20	25
Service life CFRP strengthening, years	10	20	25
Value of time-cars, $/hour	13.34	16.28	19.21
Delay time on bridge-bridge replacement, minutes	8	10	20
Delay time under bridge-bridge replacement, minutes	0	5	10

Table 6.3-Total life-cycle costs for highway bridge

ADT Case[1]	Total Life-cycle Costs, millions of Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Minimum	Maximum	Range	Minimum	Maximum	Range
1	1.05	9.42	8.37	1.34	8.12	6.78
2	1.14	17.20	16.06	1.66	14.73	13.07
3	1.27	40.56	39.29	2.54	34.55	32.01
4	1.81	12.48	10.67	1.84	9.91	8.07
5	1.93	20.27	18.34	2.26	16.52	14.26
6	2.02	43.63	41.61	3.14	36.34	33.20
4	4.19	27.55	23.36	3.69	20.86	17.17
8	4.32	33.88	29.56	4.02	25.79	21.77
9	4.70	57.24	52.54	4.96	44.31	39.35

[1]Refer to Table 3.6 for ADT cases
Range = Maximum - Minimum

Table 6.4-Change in minimum and maximum life-cycle cost (LCC) with constant traffic on bridge

Traffic on, vehicles per day	Change in traffic under, vehicles per day	Replacement		Rehabilitation	
		Minimum	Maximum	Minimum	Maximum
100	From 5,000 to 10,000[1]	8.74%	82.70%	24.11%	81.43%
	From 10,000 to 25,000[2]	11.73%	135.79%	52.35%	134.65%
1,000	From 5,000 to 10,000[1]	6.83%	62.39%	22.41%	66.70%
	From 10,000 to 25,000[2]	4.75%	115.26%	39.36%	120.04%
5,000	From 5,000 to 10,000[1]	3.07%	24.45%	9.09%	23.70%
	From 10,000 to 25,000[2]	8.92%	68.94%	23.19%	71.80%

[1]Percent change = $(LCC_{10000}-LCC_{5000})/LCC_{5000}$
[2]Percent change = $(LCC_{25000}-LCC_{10000})/LCC_{10000}$

Table 6.5-Change in minimum and maximum life-cycle cost (LCC) with constant traffic under bridge

Traffic under, vehicles per day	Changes in traffic on, vehicles per day	Replacement		Rehabilitation	
		Minimum	Maximum	Minimum	Maximum
5,000	From 100 to 1,000[1]	72.85%	32.54%	37.47%	22.09%
	From 1,000 to 5,000[2]	131.73%	120.79%	100.07%	110.51%
10,000	From 100 to 1,000[1]	69.81%	17.81%	35.59%	12.17%
	From 1,000 to 5,000[2]	123.57%	67.19%	78.30%	56.15%
25,000	From 100 to 1,000[1]	59.21%	7.55%	24.03%	5.19%
	From 1,000 to 5,000[2]	132.47%	31.21%	57.61%	21.92%

[1]Percent change = $(LCC_{1000}-LCC_{100})/LCC_{100}$
[2]Percent change = $(LCC_{5000}-LCC_{1000})/LCC_{1000}$

where:
LCC_{100} = life cycle cost when traffic volume is 100 vehicles per day
LCC_{1000} = life cycle cost when traffic volume is 1,000 vehicles per day
LCC_{5000} = life cycle cost when traffic volume is 5,000 vehicles per day
LCC_{10000} = life cycle cost when traffic volume is 10,000 vehicles per day
LCC_{25000} = life cycle cost when traffic volume is 25,000 vehicles per day

Table 6.6-Comparision of life-cycle costs for highway bridge, deterministic and probabilistic analysis

ADT Case[1]	LCC	Replacement Alternative, Dollars			Rehabilitation Alternative, Dollars		
		Agency	User	Total	Agency	User	Total
1	D	1,191,515	2,618,430	3,809,944	1,172,788	2,252,939	3,425,727
	P1	1,203,146	2,487,246	3,690,392	1,250,889	2,190,694	3,441,584
	P2	1,201,069	2,356,742	3,560,778	1,235,173	2,088,005	3,340,833
2	D	1,191,515	5,086,170	6,277,684	1,172,788	4,404,281	5,577,069
	P1	1,203,146	4,805,013	6,008,159	1,250,889	4,265,064	5,515,954
	P2	1,201,069	4,548,437	5,748,648	1,235,173	4,062,532	5,315,901
3	D	1,191,515	12,489,390	13,680,904	1,172,788	10,858,308	12,031,096
	P1	1,203,146	11,758,315	12,961,461	1,250,889	10,488,175	11,739,065
	P2	1,201,069	11,119,865	12,320,279	1,235,173	9,985,899	11,237,070
4	D	1,191,515	3,974,636	5,166,151	1,172,788	3,167,309	4,340,097
	P1	1,203,146	4,012,556	5,215,702	1,250,889	3,237,609	4,488,499
	P2	1,201,069	3,865,747	5,071,344	1,235,173	3,120,120	4,372,410
5	D	1,191,515	6,442,376	7,633,891	1,172,788	5,318,651	6,491,439
	P1	1,203,146	6,330,323	7,533,469	1,250,889	5,311,980	6,562,869
	P2	1,201,069	6,043,843	7,250,388	1,235,173	5,085,968	6,339,431
6	D	1,191,515	13,845,596	15,037,111	1,172,788	11,772,678	12,945,466
	P1	1,203,146	13,283,624	14,486,770	1,250,889	11,535,090	12,785,980
	P2	1,201,069	12,609,807	13,817,945	1,235,173	11,002,411	12,255,098
7	D	1,191,515	10,002,220	11,193,735	1,172,788	7,231,176	8,403,964
	P1	1,203,146	10,791,710	11,994,856	1,250,889	7,890,566	9,141,455
	P2	1,201,069	10,575,930	11,778,008	1,235,173	7,713,306	8,963,475
8	D	1,191,515	12,469,960	13,661,475	1,172,788	9,382,519	10,555,307
	P1	1,203,146	13,109,477	14,312,623	1,250,889	9,964,936	11,215,825
	P2	1,201,069	12,798,769	14,002,997	1,235,173	9,697,881	10,945,213
9	D	1,191,515	19,873,180	21,064,695	1,172,788	15,836,546	17,009,334
	P1	1,203,146	20,062,778	21,265,924	1,250,889	16,188,047	17,438,936
	P2	1,201,069	19,328,734	20,532,299	1,235,173	15,600,600	16,847,351

[1]Refer to Table 3.6 for ADT cases
LCC=life-cycle cost
D=deterministic
P1=probabilistic, mean values
P2=probabilistic, median values

Table 6.7-Estimated probability for highway bridge with limited variables

Analysis	Estimated Probability, Percent								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	17.02	17.85	17.99	0.23	2.52	9.34	NA	NA	0.30
Limited	10.57	13.31	14.82	0.42	2.62	8.45	NA	NA	0.51

[1]Refer to Table 3.6 for ADT cases
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.8-Estimated life-cycle costs for highway bridge with limited variables

Analysis	Life-cycle Costs, Millions of Dollars								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	2.54	3.80	7.52	2.00	3.37	7.07	NA	NA	5.86
Limited	2.25	3.42	6.89	2.18	3.24	6.61	NA	NA	6.44

[1]Refer to Table 3.6 for ADT cases
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.9-Modified bridge construction times

	Time, Days		
	Minimum	Most Likely	Maximum
Initial	90	240	370
Initial minus 25%	85	180	280
Initial minus 50%	80	120	180

Table 6.10-Modified bridge construction unit costs

	Unit Costs, $\$/ft^2$ ($\$/m^2$)		
	Mean	Std Deviation	Minimum
Initial	107.52 (1,157.33)	18.28 (196.76)	72.00 (775.00)
Initial plus 5%	112.90 (1,215.20)	18.28 (196.76)	75.60 (813.75)
Initial plus 10%	118.27 (1,273.04)	18.28 (196.76)	79.20 (852.50)
Initial plus 20%	129.02 (1,388.75)	18.28 (196.76)	86.40 (930.00)

Table 6.11-Bridge construction time and cost modifications

Modification	Decrease in Time	Increase in Costs
1a	25%	0%
1b	25%	5%
1c	25%	10%
2a	50%	0%
2b	50%	10%
2c	50%	20%

Table 6.12-Estimated probability for highway bridge with modified construction time and cost

	Estimated Probability, Percent								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	17.02	17.85	17.99	0.23	2.52	9.34	NA	NA	0.30
Mod 1a	28.77	28.60	28.28	0.07	5.29	16.97	NA	NA	0.54
Mod 1b	24.03	26.39	27.33	NA	4.58	16.38	NA	NA	0.50
Mod 1c	19.80	24.27	26.40	NA	4.03	15.79	NA	NA	0.46
Mod 2a	59.84	56.29	54.29	2.09	19.47	39.25	NA	NA	2.37
Mod 2b	44.62	49.25	51.41	0.25	14.83	36.42	NA	NA	1.85
Mod 2c	28.06	42.27	48.72	NA	10.57	33.63	NA	NA	1.29

[1]Refer to Table 3.6 for ADT cases
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.13-Estimated life-cycle costs for highway bridge with modified construction time and cost

	Life-cycle Costs, Millions of Dollars								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	2.54	3.80	7.52	2.00	3.37	7.07	NA	NA	5.86
Mod 1a	2.58	3.83	7.55	1.82	3.43	7.20	NA	NA	6.09
Mod 1b	2.51	3.77	7.48	NA	3.38	7.17	NA	NA	6.03
Mod 1c	2.44	3.71	7.42	NA	3.33	7.12	NA	NA	5.96
Mod 2a	2.68	3.93	7.72	2.23	3.63	7.49	NA	NA	6.70
Mod 2b	2.53	3.81	7.59	1.84	3.52	7.36	NA	NA	6.61
Mod 2c	2.36	3.69	7.48	NA	3.40	7.24	NA	NA	6.52

[1]Refer to Table 3.6 for ADT cases
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.14-Estimated probability for waterway bridge

Analysis	Estimated Probability, Percent								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	17.02	17.85	17.99	0.23	2.52	9.34	NA	NA	0.30
Waterway	73.59[2]	73.59[2]	73.59[2]	NA	NA	NA	NA	NA	NA

[1]Refer to Table 3.6 for ADT cases
[2]Probability that rehabilitation life-cycle costs less than replacement life-cycle costs
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.15-Estimated life-cycle costs for waterway bridge

Analysis	Life-cycle Costs, Millions of Dollars								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	2.54	3.80	7.52	2.00	3.37	7.07	NA	NA	5.86
Waterway	1.48	1.48	1.48	NA	NA	NA	NA	NA	NA

[1]Refer to Table 3.6 for ADT cases
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.16-Estimated probability for waterway bridge with modified construction time and cost

Analysis	Estimated Probability, Percent								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	17.02	17.85	17.99	0.23	2.52	9.34	NA	NA	0.30
Waterway	73.59[2]	73.59[2]	73.59[2]	NA	NA	NA	NA	NA	NA
Water + Mod 1a	--[3]	--[3]	--[3]	NA	NA	NA	NA	NA	NA
Water + Mod 1b	80.73[2]	80.73[2]	80.73[2]	NA	NA	NA	NA	NA	NA
Water + Mod 1c	90.60[2]	90.60[2]	90.60[2]	NA	NA	NA	NA	NA	NA
Water + Mod 2a	--[3]	--[3]	--[3]	NA	NA	NA	NA	NA	NA
Water + Mod 2b	85.12[2]	85.12[2]	85.12[2]	NA	NA	NA	NA	NA	NA
Water + Mod 2c	95.81[2]	95.81[2]	95.81[2]	NA	NA	NA	NA	NA	NA

[1]Refer to Table 3.6 for ADT cases
[2]Probability that rehabilitation life-cycle costs less than replacement life-cycle costs
[3]More than one intersection point
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.17-Estimated life-cycle costs for waterway bridge with modified construction time and cost

Analysis	Life-cycle Costs, Millions of Dollars								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	2.54	3.80	7.52	2.00	3.37	7.07	NA	NA	5.86
Waterway	1.48	1.48	1.48	NA	NA	NA	NA	NA	NA
Water + Mod 1a	--[2]	--[2]	--[2]	NA	NA	NA	NA	NA	NA
Water + Mod 1b	1.53	1.53	1.53	NA	NA	NA	NA	NA	NA
Water + Mod 1c	1.65	1.65	1.65	NA	NA	NA	NA	NA	NA
Water + Mod 2a	--[2]	--[2]	--[2]	NA	NA	NA	NA	NA	NA
Water + Mod 2b	1.56	1.56	1.56	NA	NA	NA	NA	NA	NA
Water + Mod 2c	1.77	1.77	1.77	NA	NA	NA	NA	NA	NA

[1]Refer to Table 3.6 for ADT cases
[2]More than one intersection point
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.18-Estimated probability for all bridges

Analysis	Estimated Probability, Percent								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	17.02	17.85	17.99	0.23	2.52	9.34	NA	NA	0.30
Mod 1a	28.77	28.60	28.28	0.07	5.29	16.97	NA	NA	0.54
Mod 1b	24.03	26.39	27.33	NA	4.58	16.38	NA	NA	0.50
Mod 1c	19.80	24.27	26.40	NA	4.03	15.79	NA	NA	0.46
Mod 2a	59.84	56.29	54.29	2.09	19.47	39.25	NA	NA	2.37
Mod 2b	44.62	49.25	51.41	0.25	14.83	36.42	NA	NA	1.85
Mod 2c	28.06	42.27	48.72	NA	10.57	33.63	NA	NA	1.29
Limited	10.57	13.31	14.82	0.42	2.62	8.45	NA	NA	0.51
Waterway	73.59[2]	73.59[2]	73.59[2]	NA	NA	NA	NA	NA	NA
Water + Mod 1a	--[3]	--[3]	--[3]	NA	NA	NA	NA	NA	NA
Water + Mod 1b	80.73[2]	80.73[2]	80.73[2]	NA	NA	NA	NA	NA	NA
Water + Mod 1c	90.60[2]	90.60[2]	90.60[2]	NA	NA	NA	NA	NA	NA
Water + Mod 2a	--[3]	--[3]	--[3]	NA	NA	NA	NA	NA	NA
Water + Mod 2b	85.12[2]	85.12[2]	85.12[2]	NA	NA	NA	NA	NA	NA
Water + Mod 2c	95.81[2]	95.81[2]	95.81[2]	NA	NA	NA	NA	NA	NA

[1]Refer to Table 3.6 for ADT cases
[2]Probability that rehabilitation life-cycle costs less than replacement life-cycle costs
[3]More than one intersection point
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

Table 6.19-Estimated life-cycle costs for all bridges

Analysis	Life-cycle Costs, Millions of Dollars								
	ADT Case 1[1]	ADT Case 2[1]	ADT Case 3[1]	ADT Case 4[1]	ADT Case 5[1]	ADT Case 6[1]	ADT Case 7[1]	ADT Case 8[1]	ADT Case 9[1]
Highway	2.54	3.80	7.52	2.00	3.37	7.07	NA	NA	5.86
Mod 1a	2.58	3.83	7.55	1.82	3.43	7.21	NA	NA	6.09
Mod 1b	2.51	3.77	7.48	NA	3.38	7.17	NA	NA	6.03
Mod 1c	2.44	3.71	7.42	NA	3.33	7.12	NA	NA	5.96
Mod 2a	2.68	3.93	7.72	2.23	3.63	7.49	NA	NA	6.70
Mod 2b	2.53	3.81	7.59	1.84	3.52	7.36	NA	NA	6.61
Mod 2c	2.36	3.69	7.48	NA	3.40	7.24	NA	NA	6.52
Limited	2.25	3.42	6.89	2.18	3.24	6.61	NA	NA	6.44
Waterway	1.48	1.48	1.48	NA	NA	NA	NA	NA	NA
Water + Mod 1a	--[2]	--[2]	--[2]	NA	NA	NA	NA	NA	NA
Water + Mod 1b	1.53	1.53	1.53	NA	NA	NA	NA	NA	NA
Water + Mod 1c	1.65	1.65	1.65	NA	NA	NA	NA	NA	NA
Water + Mod 2a	--[2]	--[2]	--[2]	NA	NA	NA	NA	NA	NA
Water + Mod 2b	1.56	1.56	1.56	NA	NA	NA	NA	NA	NA
Water + Mod 2c	1.77	1.77	1.77	NA	NA	NA	NA	NA	NA

[1]Refer to Table 3.6 for ADT cases
[2]More than one intersection point
NA-Rehabilitation life-cycle costs less than replacement life-cycle costs

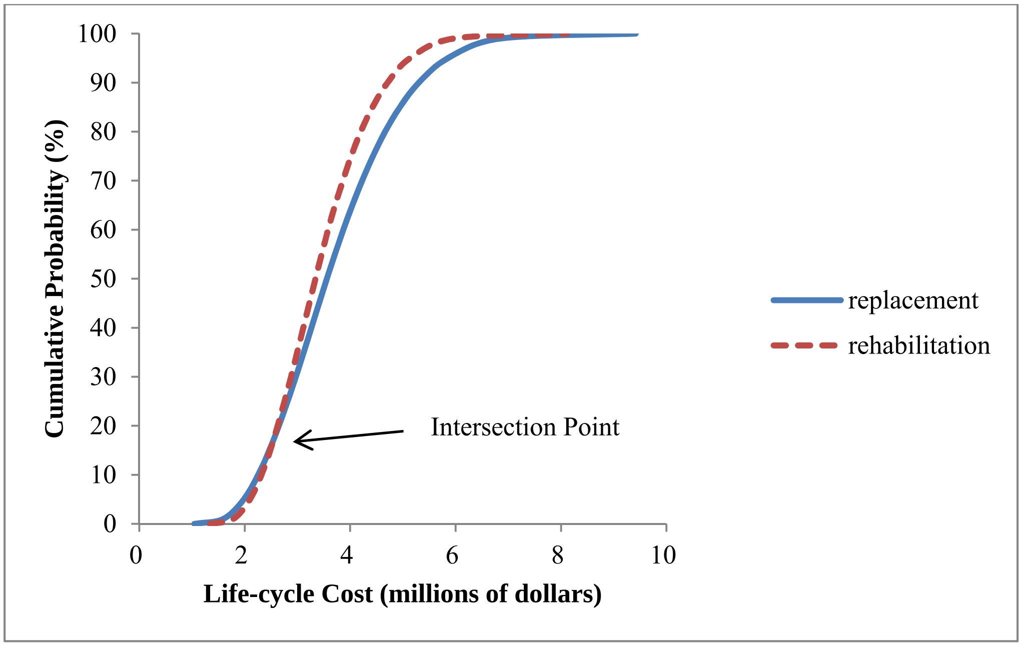


Figure 6.1-Ascending cumulative probability distributions for highway bridge, ADT case 1 (Table 3.6)

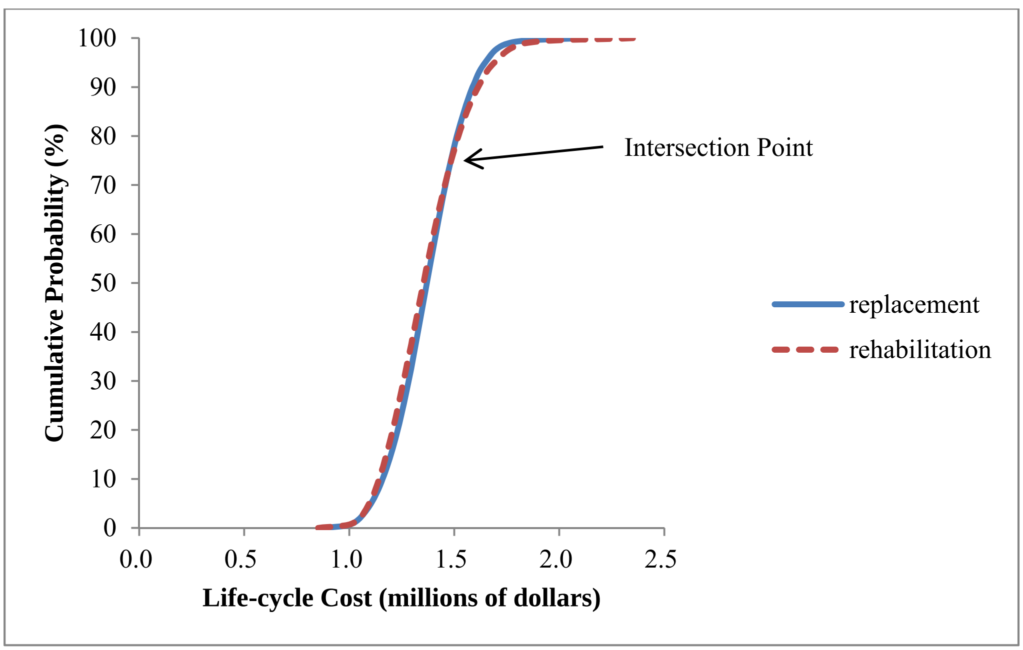


Figure 6.2-Ascending cumulative probability distributions for waterway bridge, ADT case 1, 2, 3 (Table 3.6)

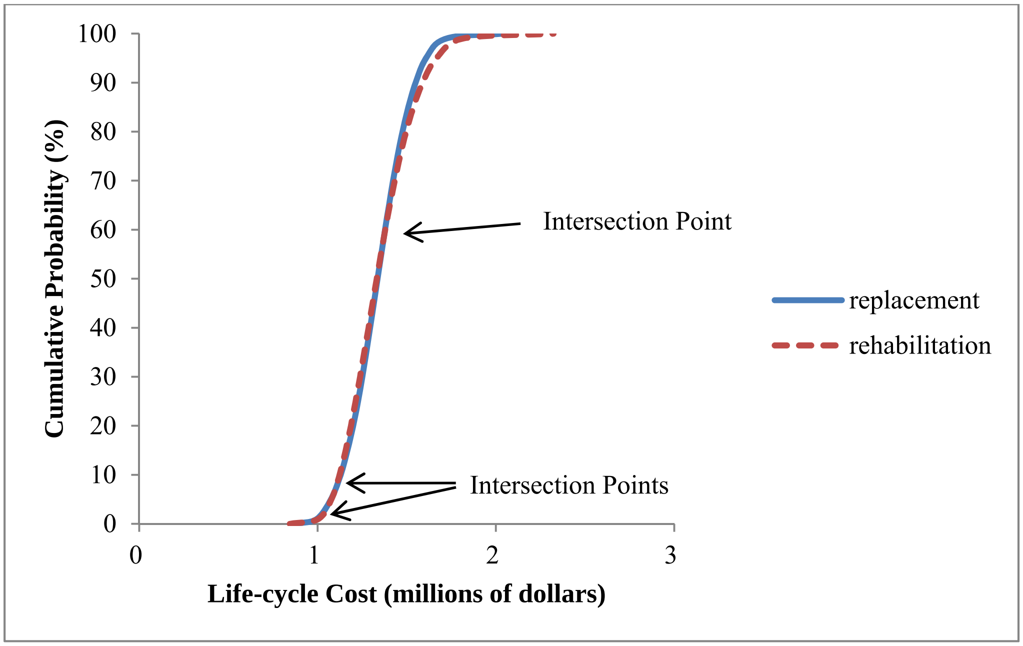


Figure 6.3-Ascending cumulative probability distributions for waterway bridge with modification 1a, ADT case 1 (Table 3.6)

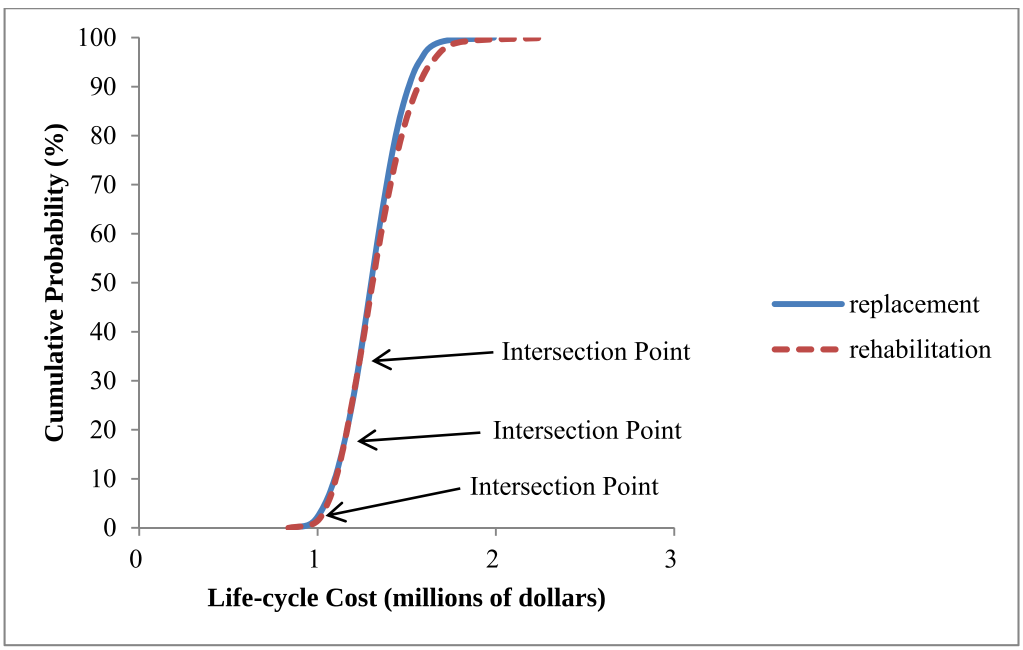


Figure 6.4-Ascending cumulative probability distributions for waterway bridge with modification 2a, ADT case 1 (Table 3.6)

CHAPTER SEVEN: SUMMARY AND CONCLUSIONS

This dissertation presents the results of a study to identify the parameters that had the most influence on life-cycle costs for reinforced concrete bridges rehabilitated with fiber reinforced polymer composites and how those parameters interacted. The use of LCCA was extended to bridge rehabilitation and lower traffic volumes. The study also introduced the use of time declining discount rates for longer analysis periods.The methodology was then used to determine and compare the life-cycle cost of a reinforced concrete tee-beam bridge rehabilitated with CFRP and a bridge replacement. Both a deterministic and probabilistic analysis was used to determine when the life-cycle cost of the replacement alternative is less than the rehabilitation alternative. Nine combinations of traffic volumes on and under the bridge were used to determine the effect of traffic volumes on life-cycle costs.

Sensitivity Analysis

The sensitivity analysis showed which parameters had the most influence on life-cycle costs. Most parameters had a small influence. Four parameters had the most influence: time to construct the new bridge, traffic volume under bridge, value of time for cars, and delay time under bridge during new bridge construction. By using a limited number of variations in these four parameters a "simulated" probabilistic analysis can be done with less effort than that needed to do a probabilistic analysis.

These four parameters individually had different influences on life-cycle costs. For the time to construct the new bridge and the value of time for cars the change in life-cycle costs increased as traffic volumes on and under the bridge increased. For the other two parameters the change in life-cycle costs decreased as traffic volume on the bridge increased and increased as traffic volume under the bridge increased. Although traffic volume on the bridge did not have as much influence on life-cycle costs it increased life-cycle costs as traffic volumes on the bridge increased and decreased life-cycle costs as traffic volumes under the bridge increased. Taken individually traffic volume under the bridge had a larger influence on life-cycle costs. However, when both are varied at the same time the traffic volume on the bridge had more of an influence. For high traffic volumes on the bridge the change in life-cycle costs did not vary much even though traffic volume under the bridge increased from 5,000 to 25,000 vehicles per day.

Bridge over Highway

For bridges over a highway the deterministic analysis showed that the rehabilitation alternative life-cycle cost is always less than the replacement alternative. This occurred for all traffic combinations. The analysis also showed that increases in traffic volumes, both on and under a bridge, significantly increased life-cycle costs for both alternatives as well as the difference in life-cycle costs.

Although life-cycle costs always increased as traffic volumes increased the percent difference in life-cycle costs between the replacement and rehabilitation alternatives did not. For low traffic volume on the bridge the percent increased slightly as traffic volume under the bridge increased. For medium and high traffic volume on the bridge the percent difference decreased as traffic volume under the bridge increased. For a constant traffic volume under the bridge the percent difference significantly increased as traffic volume on the bridge increased. This would indicate that traffic volumes on the bridge had more influence on life-cycle costs than traffic volume under the bridge.

The probabilistic analysis for a bridge over a highway showed that there is a small probability that the replacement alternative life-cycle cost is less than the rehabilitation alternative. The probability varied and depended on the traffic volume. The life-cycle costs were primarily driven by the traffic volume on the bridge. For low traffic volume on the bridge, the probability that the replacement life-cycle cost is lower ranged from 17.02 to 17.99 percent. For medium traffic volume on the bridge, the probability that the replacement life-cycle cost is lower ranged from 0.23 to 9.34 percent. For high traffic volume on the bridge, the probability that the replacement life-cycle cost is lower ranged from zero to 0.30 percent.

The probabilistic analysis showed different trends in the influence of traffic volumes than from the deterministic analysis. For low and high traffic volumes on the bridge the probability that replacement had the lower life-cycle costs varied very little, the range was one percent or less. For medium traffic volumes on the bridge the probability that replacement had the lower life-cycle cost increased significantly as traffic under the bridge increased. However, for a constant traffic volume under the bridge the probability that replacement had the lower life-cycle cost decreased significantly as traffic volume on the bridge decreased. This occurred for all levels of traffic.

Bridge over Highway with Limited Random Variables

Using more random variables that the four that had the most influence on life-cycle costs did not have a consistent impact on the results. This only applies to the probabilistic analysis. In some ADT cases the probabilities increased and in others they decreased. For low traffic volumes on the bridge the probabilities decreased. For medium traffic volumes on the bridge the probabilities increased slightly for ADT cases 4 and 5 (Table 3.6) but decreased for the ADT case 6 (Table 3.6). For high traffic volume on the bridge there was no change in probability for ADT cases 7 and 8 (Table 3.6) and a slightly increased probability for ADT case 9 (Table 3.6). The changes in probability transitioned from a decrease at low traffic volumes to no or slight increases at high traffic volumes.

Bridge over Highway with Modified Bridge Construction Time and Cost

Since user costs are a significant portion of the life-cycle costs and the time to construct the new bridge was one of the four parameters with the most influence on life-cycle costs the use of an accelerated bridge construction technology to reduce the time to construct the bridge may be considered. Any additional costs to construct the bridge (agency costs) would have to be weighed against the time savings and decreases in user costs.

For bridges over a highway with modified bridge construction time and cost the results were similar to those for the bridge over a highway. The only differences were the values of the life-cycle costs and the percent differences between the alternatives. The amount of reduction depended on traffic volume. If the bridge construction time can be reduced by 50 percent the percent difference in life-cycle costs can be significantly reduced. The reduction was largest for low traffic volumes on the bridge. For a constant traffic volume on the bridge the amount of reduction increased as traffic under the bridge increased. For a constant traffic volume under the bridge the amount of reduction decreased as traffic on the bridge increased.

Bridge over Waterway

For bridges over waterways the deterministic analysis results are both similar to the bridge over a highway and different. Since there is no vehicular traffic under the bridge all life-cycle costs are reduced. Like the bridge over a highway the percent difference in life-cycle costs also increased as traffic on the bridge increased. When compared to the bridge over highway the percent difference in life-cycle costs decreased significantly for the low traffic volume case. However, for the medium and high traffic volume cases the difference increased.

When compared to the bridge over a highway the probability distribution curves reversed position. The probability that rehabilitation, instead of replacement, had the lower life-cycle cost was about 74 percent for the low traffic volume on the bridge cases. For the other traffic cases the curves did not intersect and the rehabilitation alternative had the lower life-cycle cost. This is different than the bridge over highway where the curves did intersect for ADT cases 4, 5, 6, and 9 (Table 3.6) but at a low probability.

Bridge over Waterway with Modified Bridge Construction Time and Cost

For the bridge over a waterway with modifications to the bridge construction time and cost the deterministic analysis results are similar and different than other results. Like the bridge over waterway the percent difference in life-cycle costs increased as the traffic volume on the bridge increased. Like the modified bridge over highway the percent differences decreased when compared to the waterway bridge. However, unlike the modified bridge over highway the percent difference increased enough with the increased construction cost to be larger than the bridge over waterway. This shows that using accelerated bridge techniques had an adverse effect on life-cycle costs.

For the bridge over a waterway with modifications to the bridge construction time and cost the probability distribution curves also reversed position. The probability that rehabilitation, instead of replacement, had the lower life-cycle cost increased to about 81 to 96 percent for the low traffic volume on the bridge cases. The actual probability depended on the amount the bridge construction time was reduced and the amount the bridge construction cost increased. For the unlikely case where there is no increase in bridge construction cost the curves were close enough to have two or three intersection points and it was not possible to make any definitive conclusions. For the other traffic cases the curves also did not intersect and the rehabilitation alternative had the lower life-cycle cost.

Conclusions and Recommendations

LCCA is another tool that can be used to evaluate alternatives of equal utility to help select the preferred alternative for implementation. The results provide the decision maker with additional economic information to help in selecting the preferred alternative. However there may be other considerations that may cause a decision maker to not select the alternative with the lower life-cycle cost.

The sensitivity analysis showed that it is possible to simulate a probabilistic analysis using the deterministic approach if the right variables are chosen. Using minimum and maximum values for these variables a range of life-cycle costs can be obtained with a reduced number of iterations of the life-cycle cost model. A methodology to automate this analysis would make this approach viable.

Additional research to make the methodology used in this study more of an assessment tool is recommended. Such an extended methodology would fit in with the ever growing field of sustainability.

APPENDIX A: KYTC PROJECTS

Appendix A contains listings of KYTC projects that were used to determine the construction unit costs for the following:

- Prestressed concrete beam bridge
- Reinforced concrete deck
- Reinforced concrete bridge deck restoration
- Bridge removal
- Bridge deck removal
- Bridge rail retrofit

It also contains listings of KYTC projects that were used to determine the maintenance of traffic costs during the following:

- Bridge construction
- Bridge deck restoration

It also contains listings of KYTC projects that were used to determine the construction time for the following:

- Bridge construction
- Bridge deck restoration

The following items are used in the project listings:

- Date Let: The date the contractor's bids are opened
- Call: Identifies the project during project advertising and bid opening
- Contract ID: Identifies the project during construction for contract administration
- County: Identifies the county where the project is located
- District: Identifies the State highway district where the project is located
- SYP: Identifies the project in the State's six year improvement plan
- Proposal Description: Usually the State or Federal project number

A summary of which projects were used in each analysis is shown in Table A.1.

Date Let: 01-25-13 Call: 103 Contract ID: 13-1003
Bridge with Grade, Drain & Surface Brown Badgett Loop (CR 1092)
County: Hopkins District: 02 SYP: 02-01067.00
Proposal Description: BRZ 0203(305)

Date Let: 01-25-13 Call: 317 Contract ID: 13-2650
Bridge Deck Overlay Butler County (WN 9007)
County: Butler District: 03 SYP:
Proposal Description: FE02 016 9007 B00061N

Date Let: 02-22-13 Call: 100 Contract ID: 13-2903
Bridge Deck Restoration & Waterproofing Interstate 64
County: Jefferson District: 05 SYP: 05-01072.00
Proposal Description: IM 0642 (181)

Date Let: 02-22-13 Call: 104 Contract ID: 13-1009
Bridge with Grade, Drain & Surface KY 1428
County: Floyd District: 12 SYP: 12-01071.00
Proposal Description: BRZ 1203(345)

Date Let: 02-22-13 Call: 311 Contract ID: 13-2652
Bridge Deck Restoration & Waterproofing Campbell County (KY 9)
County: Campbell District: 06 SYP:
Proposal Description: FE02 019 0009 B00033N

Date Let: 03-22-13 Call: 104 Contract ID: 13-1318
Bridge with Grade, Drain & Surface Fulton-Fulgham Road (KY 307)
County: Hickman District: 01 SYP: 01-01018.00
Proposal Description: BRO 5005 (007)

Date Let: 03-22-13 Call: 332 Contract ID: 13-2913
Bridge Deck Restoration & Waterproofing Bridge over North Fork of Triplett Creek
County: Rowan District: 09 SYP:
Proposal Description: FE02 103 0377 B00027N

Date Let: 03-22-13 Call: 434 Contract ID: 13-2653
Bridge Deck Restoration & Waterproofing Wayne & McCreary Cos. Bridge Overlays and Joint Replacements
County: Various District: 08 SYP:
Proposal Description: 121GR13M073-FE02

Date Let: 04-19-13 Call: 101 Contract ID: 13-1306
Grade, Drain & Surface with Bridge Georgetown Northwest Bypass
County: Scott District: 07 SYP: 07-00102.10
Proposal Description: HPP 0122 (008)

Date Let: 04-19-13 Call: 406 Contract ID: 13-2654
Bridge Deck Overlay Hancock County
County: Hancock District: 02 SYP:
Proposal Description: 046GR13M082-FE02

Date Let: 04-19-13 Call: 425 Contract ID: 13-1020
Asphalt Rehab with Bridge(s) Martha Layne Collins Parkway (BG 9002)
County: Various District: 04 SYP: 04-02046.00
Proposal Description: 121GR13D020-FD04 SPP

Date Let: 04-19-13 Call: 426 Contract ID: 13-2907
Bridge Deck Restoration & Waterproofing New Circle Road Bridges
County: Fayette District: 07 SYP:
Proposal Description: 034GR13M058-FE02

Date Let: 05-24-13 Call: 352 Contract ID: 13-1034
Bridge with Grade, Drain & Surface Low Water Drive (CR 1336)
County: Harlan District: 11 SYP: 11-08510.00
Proposal Description: JL03 048 1336 000-001

Date Let: 05-24-13 Call: 368 Contract ID: 13-2914
Bridge Replacement Bridge over Little Goose Creek (MP 13.476)
County: Clay District: 11 SYP:
Proposal Description: CB01 026 0687 B00041N

Date Let: 05-24-13 Call: 369 Contract ID: 13-2909
Bridge Deck Restoration & Waterproofing Bridge over Levisa Fork of Big Sandy
County: Floyd District: 12 SYP:
Proposal Description: FE02 036 0023 B00038L,R

Date Let: 05-24-13 Call: 406 Contract ID: 13-2656
Bridge Deck Overlay KY 838 Crittenden and Livingston Countys
County: Various District: 01 SYP:
Proposal Description: 121GR13M093-FE01

Date Let: 05-24-13 Call: 420 Contract ID: 13-2904
Bridge Deck Restoration & Waterproofing KY 80 over KY 9006
County: Clay District: 11 SYP:
Proposal Description: 026GR13M092-FE02

Date Let: 06-14-13 Call: 200 Contract ID: 13-1033
Bridge Replacement Old Tunnel Mill Road (KY 458)
County: Washington District: 04 SYP: 04-01079.00
Proposal Description: 121GR13D033-NHPP BRO

Date Let: 06-14-13 Call: 201 Contract ID: 13-2911
Bridge Deck Restoration & Waterproofing Bridges over I-64
County: Bath District: 09 SYP: 09-02030.00
Proposal Description: 121GR13M096 - IM

Date Let: 06-14-13 Call: 202 Contract ID: 13-4106
Guardrail Russell - Greenup (US 23)
County: Greenup District: 09 SYP:
Proposal Description: 121GR13T006

Date Let: 06-14-13 Call: 405 Contract ID: 13-2917
Bridge Deck Restoration & Waterproofing Bridges Over Mountain Parkway
County: Wolfe District: 10 SYP:
Proposal Description: 119GR13M097-FE02

Date Let: 07-12-13 Call: 200 Contract ID: 13-1040
Bridge with Grade, Drain & Surface Ray Road (CR 1060)
County: Daviess District: 02 SYP: 02-01066.00
Proposal Description: 121GR13D040

Date Let: 07-12-13 Call: 366 Contract ID: 13-1041
Grade, Drain & Surface with Bridge Hooker Branch Road (CR 1276)
County: Clay District: 11 SYP: 11-08633.00
Proposal Description: JL04 026 1276 000-001

Date Let: 08-16-13 Call: 103 Contract ID: 13-1309
Bridge with Grade, Drain & Surface Huddy-Mcveigh Road (KY 199)
County: Pike District: 12 SYP: 12-01076.00
Proposal Description: BRO 5365 (012)

Date Let: 08-16-13 Call: 106 Contract ID: 13-1051
Bridge with Grade, Drain & Surface Dahl Road (KY 1677)
County: Pulaski District: 08 SYP: 08-01042.00
Proposal Description: BRZ 0803(173)

Date Let: 08-16-13 Call: 201 Contract ID: 13-2916
Bridge Deck Restoration & Waterproofing I-64 Bridges
County: Franklin District: 05 SYP: 05--02069
Proposal Description: 121GR13M095 - IM

Date Let: 08-16-13 Call: 202 Contract ID: 13-1203
Bridge with Grade, Drain & Surface Woodbine-Barbourville Road (KY 6)
County: Knox District: 11 SYP: 11--1076.00, 11-1075.00
Proposal Description: 061GR13D003-BRZ

Date Let: 08-16-13 Call: 344 Contract ID: 13-1206
Bridge with Grade & Drain Bridge Connector
County: Martin District: 12 SYP:
Proposal Description: FD39 080 NEW ROUTE

Date Let: 08-16-13 Call: 410 Contract ID: 13-2658
Bridge Deck Restoration & Waterproofing Robertson County KY 165 and KY 616
County: Robertson District: 06 SYP:
Proposal Description: 101GR13M123-FE02

Date Let: 08-16-13 Call: 430 Contract ID: 13-2657
Bridge Deck Overlay Boone County KY 8 and KY 536--Gallatin County KY 35
County: Various District: 06 SYP:
Proposal Description: 121GR13M104-FE02

Date Let: 09-27-13 Call: 101 Contract ID: 13-1208
Bridge with Grade, Drain & Surface Wilson Creek Bridge (KY 945)
County: Graves District: 01 SYP: 01--1058.00
Proposal Description: STP BRZ 0103 (324)

Date Let: 09-27-13 Call: 102 Contract ID: 13-1063
Bridge Replacement East Union-Carlisle Road (KY-1285)
County: Nicholas District: 09 SYP: 09-08503.00
Proposal Description: STP BRZ 0903(187)

Date Let: 09-27-13 Call: 105 Contract ID: 13-1053
Bridge with Grade, Drain & Surface KY 476
County: Perry District: 10 SYP: 10-01087.00
Proposal Description: BRO 5375(036)

Date Let: 09-27-13 Call: 111 Contract ID: 13-1061
Bridge Replacement KY-502
County: Hopkins District: 02 SYP: 02-01070.00
Proposal Description: STP BRZ 0203(318)

Date Let: 09-27-13 Call: 200 Contract ID: 13-1211
Asphalt Rehab with Bridge(s) Louisville-Cincinnati Road (1-71)
County: Henry District: 05 SYP: 05-02063.00
Proposal Description: 121GR13D011-NHPP IM

Date Let: 09-27-13 Call: 201 Contract ID: 13-1204
Grade, Drain & Surface with Bridge Richmond-Lancaster Road (KY 52)
County: Various District: 07 SYP: 07-00201.01
Proposal Description: 121GR13D004-FE02 STP

Date Let: 09-27-13 Call: 311 Contract ID: 13-2661
Bridge Deck Overlay Outerloop (KY 1065)
County: Jefferson District: 05 SYP:
Proposal Description: FE02 056 1065 B00290N

Date Let: 09-27-13 Call: 317 Contract ID: 13-1209
Grade, Drain & Surface with Bridge Kuttawa-Princeton Road (US 62)
County: Lyon District: 01 SYP: 01-00307.01
Proposal Description: FD04 SPP 072 0062 009-013

Date Let: 09-27-13 Call: 320 Contract ID: 13-2923
Bridge Deck Restoration & Waterproofing KY 1773 Bridge over Grassy Creek
County: Carter District: 09 SYP:
Proposal Description: FE02 022 1773 B00135N

Date Let: 09-27-13 Call: 322 Contract ID: 13-2924
Bridge Deck Restoration & Waterproofing KY 386 Bridge over McBride Creek
County: Nicholas District: 09 SYP:
Proposal Description: FE02 091 0386 B00033N

Date Let: 09-27-13 Call: 323 Contract ID: 13-2921
Bridge Deck Restoration & Waterproofing KY 699 Bridge over Leatherwood Creek
County: Perry District: 10 SYP:
Proposal Description: FE02 097 0699 B00045N

Date Let: 10-25-13 Call: 109 Contract ID: 13-1066
Bridge Replacement Anthoston-Niagara Road (KY-136)
County: Henderson District: 02 SYP: 02-01069.00
Proposal Description: STP BRZ 0203(319)

Date Let: 10-25-13 Call: 301 Contract ID: 13-2660
Bridge Deck Restoration & Waterproofing Henderson County KY 285
County: Henderson District: 02 SYP:
Proposal Description: CB06 051 0285 B00029N

Date Let: 10-25-13 Call: 304 Contract ID: 13-2659
Bridge Deck Restoration & Waterproofing Ohio County KY 1245
County: Ohio District: 02 SYP:
Proposal Description: CB06 092 1245 B00112N

Date Let: 10-25-13 Call: 321 Contract ID: 13-2663
Bridge Deck Restoration & Waterproofing Union County KY 359
County: Union District: 02 SYP:
Proposal Description: FE02 113 0359 B00009N

Date Let: 10-25-13 Call: 400 Contract ID: 13-2664
Bridge Deck Restoration & Waterproofing Davies County KY 3143, KY 554 and US 431
County: Daviess District: 02 SYP:
Proposal Description: 030GR13M136 - FE02

Date Let: 10-25-13 Call: 404 Contract ID: 13-2918
Bridge Deck Restoration & Waterproofing Bridge Overlays in Powell County
County: Powell District: 10 SYP:
Proposal Description: 099GR13M121 - FE02

Date Let: 10-25-13 Call: 406 Contract ID: 13-2920
Bridge Deck Restoration & Waterproofing District 9 Bridge Overlays
County: Various District: 09 SYP:
Proposal Description: 121GR13M132 - FE02

Date Let: 11-22-13 Call: 104 Contract ID: 13-1076
Bridge Replacement Stanton-Slade Road (KY 11)
County: Powell District: 10 SYP: 10-01085.00
Proposal Description: STP BRO 5260(035)

Date Let: 11-22-13 Call: 105 Contract ID: 13-1214
Bridge with Grade, Drain & Surface Gray-Indian Creek Road (KY 3437)
County: Knox District: 11 SYP: 11-01082.00
Proposal Description: STP BRZ 1103 (273)

Date Let: 11-22-13 Call: 106 Contract ID: 13-1219
Bridge with Grade, Drain & Surface Beaver Dam - Leitchfield Road (US 62)
County: Ohio District: 02 SYP: 02-01071.00
Proposal Description: STP BRO 5038 (101)

Date Let: 11-22-13 Call: 107 Contract ID: 13-1220
Bridge with Grade, Drain & Surface Sedalia to Mayfield Road (KY 79)
County: Graves District: 01 SYP: 01-01060.00
Proposal Description: STP BRZ 0103 (325)

Date Let: 11-22-13 Call: 108 Contract ID: 13-1221
Bridge with Grade, Drain & Surface Glomawr to Hazard Road (KY 451)
County: Perry District: 10 SYP: 10-1088.00
Proposal Description: STP BRZ 1003 (229)

Date Let: 11-22-13 Call: 109 Contract ID: 13-1218
Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
County: Hart District: 04 SYP: 04-00013.00
Proposal Description: NHPP IM 0652 (089)

Date Let: 11-22-13 Call: 111 Contract ID: 13-1073
Bridge with Grade, Drain & Surface Buffalo Branch Road (CR-1327)
County: Bell District: 11 SYP: 11-01083.00
Proposal Description: STP BRZ 1103(274)

Date Let: 11-22-13 Call: 304 Contract ID: 13-2925
Bridge Deck Restoration & Waterproofing Bluegrass Parkway
County: Nelson District: 04 SYP:
Proposal Description: FE02 090 9002 B00017L,R

Date Let: 11-22-13 Call: 406 Contract ID: 13-2919
Bridge Deck Restoration & Waterproofing District 10 Bridge Overlays
County: Various District: 10 SYP:
Proposal Description: 121GR13M122 - FE02

Date Let: 12-13-13 Call: 105 Contract ID: 13-1015
Bridge with Grade, Drain & Surface Patty Loveless Drive (KY 80)
County: Pike District: 12 SYP: 12-01070.00
Proposal Description: STP BRO 0806(042)

Date Let: 12-13-13 Call: 106 Contract ID: 13-1080
Grade, Drain & Surface with Bridge Gratz-Moxley Road (KY-355)
County: Owen District: 06 SYP: 06-01066.00
Proposal Description: STP BRZ 0603(237)

Date Let: 12-13-13 Call: 113 Contract ID: 13-1235
Grade & Drain with Bridge Partridge to Oven Fork Road (US 119, Section 3B)
County: Letcher District: 12 SYP: 12-00311.37
Proposal Description: APD 1191 (040)

Date Let: 12-13-13 Call: 300 Contract ID: 13-1213
Grade, Drain & Surface with Bridge Morgantown Road (KY 79)
County: Logan District: 03 SYP: 03-01068.00
Proposal Description: FD04 SPP 071 0079 006-007

Date Let: 12-13-13 Call: 303 Contract ID: 13-2666
Bridge Deck Restoration & Waterproofing Warren County KY 185
County: Warren District: 03 SYP:
Proposal Description: FE02 114 0185 B00003N

Date Let: 12-13-13 Call: 306 Contract ID: 13-1056
Grade, Drain & Surface with Bridge US-68 and Louie B. Nunn Parkway
County: Metcalfe District: 03 SYP: 03-08505.00
Proposal Description: JL03 085 0068 009-011

Date Let: 12-13-13 Call: 307 Contract ID: 13-1081
Grade, Drain & Surface with Bridge New Moody Lane-Commerce Parkway (New Route)
County: Oldham District: 05 SYP: 05-08201.01
Proposal Description: FD04 SPP 093 new route

Date Let: 12-13-13 Call: 401 Contract ID: 13-2926
Bridge Deck Restoration & Waterproofing District 4 Bridge Overlays
County: Various District: 04 SYP:
Proposal Description: 121GR13M135-FE02

Date Let: 12-13-13 Call: 402 Contract ID: 13-1227
Bridge with Grade, Drain & Surface Baizetown-Windy Hill Road (KY 505 over Western KY Parkway)
County: Ohio District: 02 SYP: 02-04015.00
Proposal Description: 121GR13D027 - CB01 & FE02

Date Let: 01-24-14 Call: 101 Contract ID: 14-1006
Bridge with Grade, Drain & Surface KY 1505
County: Rockcastle District: 08 SYP: 08-01052.00
Proposal Description: STP BRZ 0803(181)

Date Let: 01-24-14 Call: 301 Contract ID: 14-1004
Bridge Replacement Daniel Boone Drive (KY-11)
County: Knox District: 11 SYP: 11-00150.00
Proposal Description: FD04 SPP 061 0011 009-011

Date Let: 01-24-14 Call: 313 Contract ID: 14-1208
Grade, Drain & Surface with Bridge Morgantown Road (KY 79)
County: Logan District: 03 SYP: 03-01068.00
Proposal Description: FD04 SPP 071 0079 006-007

Date Let: 03-28-14 Call: 112 Contract ID: 14-1013
Bridge Replacement Pacies Branch Road (CR 1245)
County: Letcher District: 12 SYP: 12-01091.00
Proposal Description: STP BRZ 1203 (370)

Date Let: 03-28-14 Call: 300 Contract ID: 14-2904
Bridge Deck Restoration & Waterproofing Bridge over Harrods Creek
County: Oldham District: 05 SYP:
Proposal Description: CB06 093 1694 B00025N

Date Let: 04-25-14 Call: 104 Contract ID: 14-1214
Bridge Replacement US 42 (East Main Street) over Beargrass Creek
County: Jefferson District: 05 SYP: 05-01052.00
Proposal Description: NHPP BRO 8703 (003)

Date Let: 04-25-14 Call: 105 Contract ID: 14-1017
Bridge Replacement Bloomfield Road (US 62)
County: Nelson District: 04 SYP: 04-01075.00
Proposal Description: STP BRO 5038 (102)

Date Let: 04-25-14 Call: 302 Contract ID: 14-1218
Grade, Drain & Surface with Bridge Cumberland Parkway (9008) and US 127 Interchange
County: Russell District: 08 SYP: 08-08504.00
Proposal Description: FD04 SPP 104 0127 017-018

Date Let: 04-25-14 Call: 328 Contract ID: 14-2908
Bridge Deck Restoration & Waterproofing Bridge over Culp Creek Rd
County: Greenup District: 09 SYP:
Proposal Description: FE02 045 0067 B00077N

Date Let: 04-25-14 Call: 329 Contract ID: 14-2901
Bridge Deck Restoration & Waterproofing US 31E
County: Nelson District: 04 SYP:
Proposal Description: FE02 090 0031 B00044N

Date Let: 04-25-14 Call: 403 Contract ID: 14-2907
Bridge Deck Restoration & Waterproofing Fleming County Bridge Overlays
County: Fleming District: 09 SYP:
Proposal Description: 035GR14M058-FE02

Date Let: 05-30-14 Call: 100 Contract ID: 14-1226
Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
County: Warren District: 03 SYP: 03-0016.03
Proposal Description: HPP STP 0150 (012)

Date Let: 05-30-14 Call: 103 Contract ID: 14-1027
Bridge with Grade, Drain & Surface Outland School Road (KY-1536)
County: Calloway District: 01 SYP: 01-01061.00
Proposal Description: BRZ 0103 (331)

Date Let: 05-30-14 Call: 108 Contract ID: 14-1225
Bridge Replacement Tousey Road (CR 1872) Over Spring Fork
County: Grayson District: 04 SYP: 04-01071.00
Proposal Description: STP BRZ 0403 (190)

Date Let: 05-30-14 Call: 109 Contract ID: 14-1021
Bridge with Grade & Drain Stinson Road (CR-1700)
County: Wayne District: 08 SYP: 08-01051.00
Proposal Description: STP BRZ 0803 (182)

Date Let: 05-30-14 Call: 110 Contract ID: 14-1224
Bridge Replacement Elk Lick Creek Road (CR 1224)
County: Lee District: 10 SYP: 10-01091.00
Proposal Description: STP BRZ 1003 (221)

Date Let: 05-30-14 Call: 200 Contract ID: 14-1028
Asphalt Rehab Interstate/Parkway Edward T. Breathitt Parkway (PW 9004)
County: Hopkins District: 02 SYP: 02-00232.00, 02-00232.10
Proposal Description: 121GR14D019-NHPP

Date Let: 05-30-14 Call: 352 Contract ID: 14-2657
Bridge Deck Restoration & Waterproofing Davies County
County: Daviess District: 02 SYP:
Proposal Description: FE02 030 0060 00069R

Date Let: 05-30-14 Call: 353 Contract ID: 14-2658
Bridge Deck Restoration & Waterproofing Hopkins
County: Hopkins District: 02 SYP:
Proposal Description: FE02 054 9004 00014

Date Let: 05-30-14 Call: 354 Contract ID: 14-2912
Bridge Deck Restoration & Waterproofing Bridge over Licking River
County: Morgan District: 10 SYP:
Proposal Description: FE02 088 0772 B00070N

Date Let: 05-30-14 Call: 355 Contract ID: 14-2913
Bridge Deck Restoration & Waterproofing Bridge over Middle Fork of Red River
County: Powell District: 10 SYP:
Proposal Description: FE02 099 9000 B00011L

Date Let: 05-30-14 Call: 440 Contract ID: 14-2909
Bridge Deck Restoration & Waterproofing KY 114 Overlays
County: Floyd District: 12 SYP:
Proposal Description: 036GR14M064-FE02

Date Let: 05-30-14 Call: 444 Contract ID: 14-2655
Bridge Deck Restoration & Waterproofing Davies County US 231
County: Daviess District: 02 SYP:
Proposal Description: 030GR14M072-FE02

Date Let: 05-30-14 Call: 445 Contract ID: 14-2656
Bridge Deck Restoration & Waterproofing Ballard County
County: Ballard District: 01 SYP:
Proposal Description: 004GR14M071-FE02

Date Let: 05-30-14 Call: 446 Contract ID: 14-2914
Bridge Deck Restoration & Waterproofing Bridges over Mountain Parkway
County: Powell District: 10 SYP:
Proposal Description: 121GR14M068-FE02

Date Let: 06-27-14 Call: 101 Contract ID: 14-1232
Bridge with Grade, Drain & Surface Bent Branch Road (KY-1426)
County: Pike District: 12 SYP: 12-01102.00
Proposal Description: STP BRZ 1203 (374)

Date Let: 06-27-14 Call: 109 Contract ID: 14-1222
Bridge with Grade, Drain & Surface Frenchburg to Owingsville Road (KY 36)
County: Menifee District: 10 SYP: 10-01090.00
Proposal Description: STP BRO 1003 (238)

Date Let: 06-27-14 Call: 110 Contract ID: 14-1031
Bridge with Grade, Drain & Surface KY 32 over Seas Branch
County: Rowan District: 09 SYP: 09-01076.00
Proposal Description: STP BRO 5253(023)

Date Let: 06-27-14 Call: 207 Contract ID: 14-1033
Bridge with Grade, Drain & Surface Lower Johns Creek Road (KY-194)
County: Floyd District: 12 SYP: 12-01075.00
Proposal Description: 121GR14D033-STP

Date Let: 06-27-14 Call: 316 Contract ID: 14-2917
Bridge Deck Restoration & Waterproofing Bridge over Wilson Creek
County: Nelson District: 04 SYP:
Proposal Description: FE02 090 0061 B00062N

Date Let: 07-11-14 Call: 100 Contract ID: 14-2915
Bridge Deck Restoration & Waterproofing Interstate 64
County: Franklin District: 05 SYP: 05-00520.00
Proposal Description: IM 0643 (052)

Date Let: 07-11-14 Call: 107 Contract ID: 14-1026
Bridge Replacement Hacker Branch Road (CR-1136)
County: Owsley District: 10 SYP: 10-01093.00
Proposal Description: STP BRZ 1003 (227)

Date Let: 07-11-14 Call: 108 Contract ID: 14-1223
Bridge Replacement Rye Branch Road (CR 1756)
County: Magoffin District: 10 SYP: 10-01092.00
Proposal Description: STP BRZ 1003 (239)

Date Let: 07-11-14 Call: 109 Contract ID: 14-1237
Bridge with Grade, Drain & Surface KG Estates Road (CR 1162)
County: Lawrence District: 12 SYP: 12-01106.00
Proposal Description: STP BRZ 1203 (373)

Date Let: 07-11-14 Call: 113 Contract ID: 14-1024
Bridge with Grade, Drain & Surface Hazard-Hyden Road (KY-80)
County: Perry District: 10 SYP: 10-01082.00
Proposal Description: STP BRO 5271 (039)

Date Let: 07-11-14 Call: 115 Contract ID: 14-1037
Bridge with Grade & Drain Stinson Road (CR-1700)
County: Wayne District: 08 SYP: 08-01051.00
Proposal Description: STP BRZ 0803 (182)

Date Let: 08-22-14 Call: 106 Contract ID: 14-1045
Bridge with Grade, Drain & Surface Morehead-Grayson Road (US-60)
County: Rowan District: 09 SYP: 09-01061.00
Proposal Description: STP BRO 5211(106)

Date Let: 08-22-14 Call: 107 Contract ID: 14-1253
Bridge Replacement Glasgow Street (CS 1053)
County: Metcalfe District: 03 SYP: 03-01075.00
Proposal Description: STP BRZ 0303 (256)

Date Let: 08-22-14 Call: 108 Contract ID: 14-1252
Bridge Replacement Mobley Mill Road (CR 1327)
County: Nelson District: 04 SYP: 04-01083.00
Proposal Description: STP BRZ 0403 (194)

Date Let: 08-22-14 Call: 109 Contract ID: 14-1228
Bridge with Grade, Drain & Surface Upper Wolf Creek Road (CR 1134)
County: Owsley District: 10 SYP: 10-01108.00
Proposal Description: STP BRZ 1003 (240)

Date Let: 08-22-14 Call: 111 Contract ID: 14-1255
Bridge with Grade & Drain Curtis Road (CR 1226)
County: Boyle District: 07 SYP: 07-01133.00
Proposal Description: STP BRZ 0703 (322)

Date Let: 08-22-14 Call: 200 Contract ID: 14-1029
Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
County: Hart District: 04 SYP: 04-00015.00, 04-00016.00, 04-00017.00
Proposal Description: 121GR14D029-NHPP

Date Let: 08-22-14 Call: 203 Contract ID: 14-1241
Asphalt Pavement & Roadway Rehab Julian M. Carroll Parkway (9003)
County: Graves District: 01 SYP: 01-00234.00
Proposal Description: 121GR14D041-NHPP

Date Let: 08-22-14 Call: 313 Contract ID: 14-1043
Bridge with Grade, Drain & Surface KY-49
County: Marion District: 04 SYP: 04-08304.00
Proposal Description: FD04 SPP 078 0049 013-016

Date Let: 08-22-14 Call: 319 Contract ID: 14-2660
Bridge Deck Restoration & Waterproofing Anderson County US 62 Tyron Bridge
County: Anderson District: 07 SYP:
Proposal Description: FE02 003 0062 B00003N

Date Let: 08-22-14 Call: 435 Contract ID: 14-2923
Bridge Deck Restoration & Waterproofing Bridge Overlays in Harlan County
County: Harlan District: 11 SYP:
Proposal Description: 048GR14M083 - FE02

Date Let: 08-22-14 Call: 445 Contract ID: 14-2922
Bridge Deck Restoration & Waterproofing Bridge Overlays in Perry County
County: Perry District: 10 SYP:
Proposal Description: 097GR14M081 - FE02

Date Let: 09-26-14 Call: 100 Contract ID: 14-2980
Bridge Deck Restoration & Waterproofing Bridge over Ohio River
County: Boone District: 06 SYP: 06-02039.00
Proposal Description: IM 2759 (130)

Date Let: 09-26-14 Call: 103 Contract ID: 14-1048
Bridge Replacement Tebb's Bend (CR-1236)
County: Taylor District: 04 SYP: 04-01058.00
Proposal Description: STP BRZ 0403 (195)

Date Let: 09-26-14 Call: 104 Contract ID: 14-1018
Bridge with Grade, Drain & Surface Oscar Bowling Road (CR 1113A)
County: Clay District: 11 SYP: 11-01069
Proposal Description: STP BRZ 1103 (280)

Date Let: 09-26-14 Call: 112 Contract ID: 14-1209
Grade, Drain & Surface with Bridge Kenneth Barrett Road (KY 30)
County: Owsley District: 10 SYP: 10-01084.00
Proposal Description: STP BRO 0302 (018)

Date Let: 09-26-14 Call: 113 Contract ID: 14-1262
Bridge with Grade, Drain & Surface Booneville-Jackson Road (KY 30)
County: Breathitt District: 10 SYP: 10-01096.00
Proposal Description: STP BRO 5263 (020)

Date Let: 09-26-14 Call: 116 Contract ID: 14-1261
Bridge Replacement Hade Bell Road (CR 1167)
County: Allen District: 03 SYP: 03-01081.00
Proposal Description: STP BRZ 0303 (263)

Date Let: 09-26-14 Call: 117 Contract ID: 14-1049
Bridge with Grade, Drain & Surface Wildie Road (CR-1071)
County: Rockcastle District: 08 SYP: 08-01058.00
Proposal Description: STP BRZ 0803 (186)

Date Let: 09-26-14 Call: 118 Contract ID: 14-1256
Bridge with Grade, Drain & Surface KG Estates Road (CR 1162)
County: Lawrence District: 12 SYP: 12-01106.00
Proposal Description: STP BRZ 1203 (373)

Date Let: 09-26-14 Call: 119 Contract ID: 14-1047
Grade & Drain with Bridge KY 343
County: Letcher District: 12 SYP: 12-01097.00
Proposal Description: STP BRZ 1203 (376)

Date Let: 09-26-14 Call: 306 Contract ID: 14-1053
Bridge with Grade, Drain & Surface 10th Street (KY-2386)
County: Whitley District: 11 SYP: 11-08306.00
Proposal Description: FD04 SPP 118 2386 000-001

Date Let: 09-26-14 Call: 404 Contract ID: 14-2926
Bridge Deck Restoration & Waterproofing Western Kentucky Parkway Bridge Overlays
County: Hardin District: 04 SYP:
Proposal Description: 047GR14M085 - FE02

Bridge Replacement Pryorsburg to Dublin Road (KY 1748)
Date Let: 10-24-14 Call: 108 Contract ID: 14-1271
County: Graves District: 01 SYP: 01-01134.00
Proposal Description: STP BRZ 0103 (335)

Date Let: 10-24-14 Call: 110 Contract ID: 14-1274
Bridge with Grade, Drain & Surface Upper Wolf Creek Road (CR 1134)
County: Owsley District: 10 SYP: 10-01108.00
Proposal Description: STP BRZ 1003 (240)

Date Let: 10-24-14 Call: 111 Contract ID: 14-1278
Bridge Replacement Wildie Road (CR 1071)
County: Rockcastle District: 08 SYP: 08-01057.00
Proposal Description: STP BRZ 0803 (191)

Date Let: 10-24-14 Call: 118 Contract ID: 14-1280
Grade & Drain with Bridge Simpsonville - Buck Creek Road (KY 1848)
County: Shelby District: 05 SYP: 05-00348.01
Proposal Description: STP 5389 (003)

Date Let: 10-24-14 Call: 302 Contract ID: 14-1061
Bridge Replacement Hemp Patch Branch Road (CR-1002)
County: Knott District: 12 SYP: 12-04092.00
Proposal Description: FD04 SPP 060 1002 000-001

Date Let: 10-24-14 Call: 304 Contract ID: 14-1276
Grade & Drain with Asphalt Surface Chalybeate School Road (KY 743)
County: Edmonson District: 03 SYP: 03-08602.00
Proposal Description: FD04 SPP 031 0743 003-006

Date Let: 10-24-14 Call: 306 Contract ID: 14-1282
Asphalt Rehab with Bridge(s) Louie B. Nunn Cumberland Parkway (9008)
County: Barren District: 03 SYP: 03-02037.00
Proposal Description: FD04 SPP 005 9008 000-009

Date Let: 10-24-14 Call: 319 Contract ID: 14-2903
Bridge Deck Restoration & Waterproofing Bridge over Tygarts Creek
County: Carter District: 09 SYP:
Proposal Description: FE02 022 6062 B00035N

Date Let: 10-24-14 Call: 403 Contract ID: 14-2927
Bridge Deck Restoration & Waterproofing Bridge Overlays in Wayne County
County: Wayne District: 08 SYP:
Proposal Description: 116GR14M087 - FE02

Table A.1-Summary of KYTC projects

Date Let	Call	Bridge Construction	Deck Construction	Deck Restoration	Bridge Removal	Deck Removal	Bridge Rail Retrofit	MOT Bridge Construction	MOT Deck Restoration	Bridge Construction Time	Bridge Restoration Time
01-25-13	103	X	X		X			X		X	
01-25-13	317			X					X		X
02-22-13	100			X					X		X
02-22-13	104	X	X		X					X	
02-22-13	311			X					X		X
03-22-13	104				X			X			
03-22-13	332			X					X		X
03-22-13	434			X					X		X
04-19-13	101	X	X					X			
04-19-13	406			X					X		X
04-19-13	425					X		X			
04-19-13	426			X					X		X
05-24-13	352				X			X			
05-24-13	368				X						
05-24-13	369			X					X		X
05-24-13	406			X					X		X
05-24-13	420			X					X		X
06-14-13	200									X	
06-14-13	201			X					X		X
06-14-13	202						X				
06-14-13	405								X		
07-12-13	200				X			X			
07-12-13	366	X	X					X		X	
08-16-13	103				X			X			
08-16-13	106	X	X		X			X		X	
08-16-13	201			X					X		X
08-16-13	202				X						
08-16-13	344							X			
08-16-13	410			X					X		X
08-16-13	430			X					X		X
09-27-13	101				X			X			
09-27-13	102				X			X			
09-27-13	105	X	X		X			X		X	
09-27-13	111				X			X			
09-27-13	200			X			X				X
09-27-13	201			X							X
09-27-13	311			X					X		X
09-27-13	317	X	X					X		X	
09-27-13	320			X					X		X
09-27-13	322			X					X		X
09-27-13	323			X					X		X

Table A.1-Summary of KYTC projects (continued)

Date Let	Call	Bridge Construction	Deck Construction	Deck Restoration	Bridge Removal	Deck Removal	Bridge Rail Retrofit	MOT Bridge Construction	MOT Deck Restoration	Bridge Construction Time	Bridge Restoration Time
10-25-13	109				X			X			
10-25-13	301			X					X		X
10-25-13	304			X					X		X
10-25-13	321			X					X		X
10-25-13	400			X					X		X
10-25-13	404			X					X		X
10-25-13	406			X					X		X
11-22-13	104	X	X		X			X		X	
11-22-13	105				X			X			
11-22-13	106	X	X		X			X		X	
11-22-13	107				X			X			
11-22-13	108	X	X		X			X		X	
11-22-13	109	X	X		X						
11-22-13	111	X	X		X			X		X	
11-22-13	304			X					X		X
11-22-13	406			X					X		X
12-13-13	105				X						
12-13-13	106	X	X		X			X		X	
12-13-13	113	X	X					X			
12-13-13	300							X		X	
12-13-13	303			X					X		X
12-13-13	306	X	X					X		X	
12-13-13	307	X	X					X			
12-13-13	401			X					X		X
12-13-13	402							X			
01-24-14	101							X			
01-24-14	301							X			
01-24-14	313	X	X		X			X		X	
03-28-14	112				X			X			
03-28-14	300								X		
04-25-14	104									X	
04-25-14	105				X			X			
04-25-14	302			X							X
04-25-14	328			X					X		X
04-25-14	329			X					X		X
04-25-14	403			X					X		X
05-30-14	100	X	X								
05-30-14	103				X			X			
05-30-14	108							X			
05-30-14	109							X			
05-30-14	110				X			X			

Table A.1-Summary of KYTC projects (continued)

Date Let	Call	Bridge Construction	Deck Construction	Deck Restoration	Bridge Removal	Deck Removal	Bridge Rail Retrofit	MOT Bridge Construction	MOT Deck Restoration	Bridge Construction Time	Bridge Restoration Time
05-30-14	200			X							X
05-30-14	352			X					X		X
05-30-14	353			X					X		X
05-30-14	354			X					X		X
05-30-14	355			X					X		X
05-30-14	440			X					X		X
05-30-14	444			X					X		X
05-30-14	445			X					X		X
05-30-14	446			X					X		X
06-27-14	101				X						
06-27-14	109	X	X		X			X		X	
06-27-14	110				X			X			
06-27-14	207				X			X			
06-27-14	316			X					X		X
07-11-14	100			X					X		X
07-11-14	107				X			X			
07-11-14	108	X	X		X			X		X	
07-11-14	109							X			
07-11-14	113	X	X		X			X		X	
07-11-14	115				X			X			
08-22-14	106				X			X			
08-22-14	107				X			X			
08-22-14	108				X			X			
08-22-14	109							X			
08-22-14	111				X			X			
08-22-14	200	X	X		X			X			
08-22-14	203			X							X
08-22-14	313	X	X		X			X		X	
08-22-14	319								X		
08-22-14	435			X					X		X
08-22-14	445			X					X		X
09-26-14	100			X					X		X
09-26-14	103				X						
09-26-14	104				X			X		X	
09-26-14	112				X			X		X	
09-26-14	113				X			X		X	
09-26-14	116				X			X			
09-26-14	117				X			X			
09-26-14	118				X			X			
09-26-14	119				X			X			
09-26-14	306							X			
09-26-14	404			X					X		X

Table A.1-Summary of KYTC projects (continued)

Date Let	Call	Bridge Construction	Deck Construction	Deck Restoration	Bridge Removal	Deck Removal	Bridge Rail Retrofit	MOT Bridge Construction	MOT Deck Restoration	Bridge Construction Time	Bridge Restoration Time
10-24-14	108				X			X			
10-24-14	110				X			X			
10-24-14	111				X			X			
10-24-14	118							X			
10-24-14	302				X			X		X	
10-24-14	304							X			
10-24-14	306			X							X
10-24-14	319			X					X		X
10-24-14	403			X					X		X

APPENDIX B: CONSTRUCTION TIME

Appendix E contains summaries of construction times for the following:

- Prestressed concrete beam bridge
- Reinforced concrete bridge deck restoration

Bridge Construction Time

An analysis of the contract time for completion of prestressed concrete beam bridge projects was done for projects with a calendar completion date, Table B.1, and one for projects with a specified number of working days for completion, Table B.2.

Table B.1-Projects with calendar date completion

Date Let	Call	County	District	Date Let	Completion Date	Time (days)
Jan 2013	103	Hopkins	2	1/25/2013	10/30/2013	278
Feb 2013	104	Floyd	12	2/22/2013	10/31/2013	251
Jun 2013	200	Washington	4	6/14/2013	10/31/2013	139
Jul 2013	366	Clay	11	7/12/2013	7/30/2014	383
Aug 2013	106	Pulaski	8	8/16/2013	11/30/2013	106
Nov 2013	106	Ohio	2	11/22/2013	9/1/2014	283
Nov 2013	111	Bell	11	11/22/2013	7/1/2014	221
Dec 2013	106	Owen	6	12/13/2013	8/30/2014	260
Dec 2013	300	Logan	3	12/13/2013	11/1/2014	323
Jan 2014	313	Logan	3	1/24/2014	11/1/2014	281
Apr 2014	104	Jefferson	5	4/25/2014	10/1/2014	159
Sep 2014	104	Clay	11	9/26/2014	7/30/2015	307
Oct 2014	302	Knott	12	10/24/2014	8/31/2015	311

The average time from bid opening to completion date is 254 days. Assuming two weeks used to award contract and issue a notice to proceed, the average completion time is 240 calendar days. The time from bid opening to completion date ranges from 106 to 383 days or from 92 to 369 days adjusted.

Table B.2-Projects with working days completion

Date Let	Call	County	District	Date Let	Time (days)
Sep 2013	105	Perry	10	9/27/2013	135
Sep 2013	317	Lyon	1	9/27/2013	150
Nov 2013	104	Powell	10	11/22/2013	85
Nov 2013	108	Perry	10	11/22/2013	220
Dec 2013	306	Metcalfe	3	12/13/2013	270
Jun 2014	109	Menifee	10	6/27/2014	150
Jul 2014	108	Magoffin	10	7/11/2014	50
Jul 2014	113	Perry	10	7/11/2014	240
Aug 2014	313	Marion	4	8/22/2014	170
Sep 2014	112	Owsley	10	9/26/2014	165
Sep 2014	113	Breathitt	10	9/26/2014	220

The average completion time is 168.6 working days. Assuming five working days per week, the average completion time is 236.1 calendar days. The completion time ranges from 50 to 270 working days or from 70 to 378 working days adjusted.

Bridge Deck Overlay Construction Time

An analysis of the contract time for completion of concrete deck restoration projects was done. The completion dates were working days, calendar days, weekends, or not specified. Bridges without a specified completion date were usually part of a larger project where the overall completion date controlled. The completion dates are summarized in Table B.3. The completion dates specified in the project proposals are summarized in Tables B.4, B.5, and B.6. The most common completion date was 30 calendar days, for 65 percent of the bridges where a date was specified and 77 percent of the bridges where calendar days were specified. The average calendar day completion date was 30.8 days. The study used 30 calendar days.

Table B.3-Bridge deck restoration completion date summary

Completion Date	Number Times Used
20 working days	2
30 working days	2
40 working days	1
2 weekends	9
14 calendar days	1
20 calendar days	8
25 calendar days	1
30 calendar days	60
40 calendar days	1
45 calendar days	4
60 calendar days	3
Sub total	92
None specified	16
Total	108

Table B.4-Specified completion dates, working days

Letting	Call	Bridge Number	Completion Date
Jan 2013	317	016B00061N	40 working days
Mar 2013	434	074B00011N	30 working days
Mar 2013	434	116B00001N	20 working days
Apr 2013	406	046B00030N	20 working days
Apr 2013	406	046B00013N	30 working days

Table B.5-Specified completion dates, calendar days

Letting	Call	Bridge Number	Completion Date
Feb 2013	100	056B00040R	2 weekends
Feb 2013	311	019B00033N	60 calendar days
Mar 2013	332	103B00027N	45 calendar days
Apr 2013	426	034B00027L	2 weekends
Apr 2013	426	034B00027R	2 weekends
Apr 2013	426	034B00028L	2 weekends
Apr 2013	426	034B00028R	2 weekends
Apr 2013	426	034B00029L	2 weekends
Apr 2013	426	034B00029R	2 weekends
Apr 2013	426	034B00031L	2 weekends
Apr 2013	426	034B00031R	2 weekends
May 2013	369	036B00038L	30 calendar days
May 2013	369	036B00038R	30 calendar days
May 2013	406	028B00047N	20 calendar days
May 2013	406	028B00048N	20 calendar days
May 2013	406	070B00058N	20 calendar days
May 2013	420	026B00061N	30 calendar days
May 2013	420	026B00067N	30 calendar days
Jun 2013	201	006B00017N	30 calendar days
Jun 2013	201	006B00042N	30 calendar days
Jun 2013	201	103B00029N	30 calendar days
Aug 2013	410	101B00009N	30 calendar days
Aug 2013	430	008B00036N	30 calendar days
Aug 2013	430	039B00010N	30 calendar days
Aug 2013	430	008B00021N	25 calendar days
Sep 2013	311	056B00290N	60 calendar days
Oct 2013	301	051B00029N	30 calendar days
Oct 2013	304	092B00112N	30 calendar days
Oct 2013	321	092B00112N	40 calendar days
Oct 2013	400	030B00115N	30 calendar days
Oct 2013	400	030B00084N	20 calendar days
Oct 2013	400	030B00048N	14 calendar days
Oct 2013	404	099B00009R	30 calendar days
Oct 2013	404	099B00017N	30 calendar days
Oct 2013	404	099B00042N	30 calendar days
Oct 2013	406	022B00106N	30 calendar days
Oct 2013	406	068B00030N	30 calendar days
Oct 2013	406	068B00031N	30 calendar days
Oct 2013	406	091B00035N	30 calendar days
Nov 2013	304	090B00017L	30 calendar days
Nov 2013	304	090B00017R	30 calendar days
Nov 2013	406	013B00026N	30 calendar days
Nov 2013	406	077B00026N	30 calendar days
Nov 2013	406	088B00042N	30 calendar days
Nov 2013	406	097B00036N	30 calendar days
Dec 2013	303	114B00003N	60 calendar days
Dec 2013	401	078B00038N	30 calendar days
Dec 2013	401	109B00004N	30 calendar days
Dec 2013	401	109B00025N	30 calendar days

Table B.5-Specified completion dates, calendar days (continued)

Letting	Call	Bridge Number	Completion Date
Apr 2014	328	045B00077N	30 calendar days
Apr 2014	329	090B00044N	30 calendar days
Apr 2014	403	035B00022N	30 calendar days
Apr 2014	403	035B00025N	30 calendar days
May 2014	352	030B00069R	30 calendar days
May 2014	353	054B00014L	30 calendar days
May 2014	353	054B00014R	30 calendar days
May 2014	354	088B00070N	30 calendar days
May 2014	355	099B00011L	30 calendar days
May 2014	440	036B00021N	30 calendar days
May 2014	440	036B00022N	30 calendar days
May 2014	444	030B00034N	30 calendar days
May 2014	444	030B00033N	30 calendar days
May 2014	444	030B00032N	30 calendar days
May 2014	445	004B00032N	30 calendar days
May 2014	445	004B00051N	30 calendar days
May 2014	445	004B00050N	30 calendar days
May 2014	446	099B00033N	30 calendar days
May 2014	446	119B00019N	30 calendar days
Jul 2014	100	037B00057L	30 calendar days
Jul 2014	100	037B00057R	30 calendar days
Aug 2014	435	048B00065N	45 calendar days
Aug 2014	435	048B00147N	45 calendar days
Aug 2014	435	048B00129N	30 calendar days
Aug 2014	445	097B00042N	30 calendar days
Aug 2014	445	097B00089N	45 calendar days
Sep 2014	404	047B00092L	30 calendar days
Sep 2014	404	047B00092R	30 calendar days
Sep 2014	404	047B00093L	30 calendar days
Sep 2014	404	047B00093R	30 calendar days
Oct 2014	319	022B00035N	30 calendar days
Oct 2014	403	116B00009N	30 calendar days
Oct 2014	403	116B00010N	30 calendar days
Oct 2014	403	116B00020N	30 calendar days
May 2014	200	051B00062L	20 calendar days
May 2014	200	051B00062R	20 calendar days
May 2014	200	117B00071L	20 calendar days
May 2014	200	117B00071R	20 calendar days

Table B.6-Specified completion dates, not specified

Letting	Call	Bridge Number	Completion Date
Aug 2013	201	037B00055L	None specified
Aug 2013	201	037B00055R	None specified
Aug 2013	201	037B00056L	None specified
Aug 2013	201	106B00059L	None specified
Sep 2013	320	022B00135N	None specified
Sep 2013	322	091B00033N	None specified
Sep 2013	323	097B00045N	None specified
Jun 2014	316	090B00062N	None specified
Sep 2014	100	008B00052N	None specified
Sep 2013	200	052B00001N	None specified
Sep 2013	200	052B00038N	None specified
Sep 2013	200	052B00051L	None specified
Sep 2013	201	040B00004N	None specified
Apr 2014	302	104B00022N	None specified
Aug 2014	203	079B00075L	None specified
Oct 2014	306	005B00068R	None specified

APPENDIX C: CONSTRUCTION UNIT COSTS

Appendix C contains summaries of bid items and construction unit costs for the following:

- Prestressed concrete beam bridge
- Reinforced concrete deck
- Reinforced concrete bridge deck restoration
- Bridge removal
- Bridge deck removal
- Bridge rail retrofit

Precast Prestressed Concrete I-Beam Bridges

The cost analysis for the construction of precast prestressed concrete I-beam bridges included the following bid items:

- Approach Slab
- Armored Edge for Concrete
- Bridge Chain Link Fence-4 ft
- Bridge Chain Link Fence-6 ft
- Bridge Chain Link Fence-8 ft
- Bridge Chain Link Fence-9 ft
- Concrete-Class A
- Concrete-Class AA
- Crushed Aggregate Slope Protection
- Cyclopean Stone Rip Rap
- Deck Drain
- Drilled Shaft-Common 54 in
- Drilled Shaft-Rock 48 in
- Expansion Dam-4 in Neoprene
- Fabric-Geotextile Type IV
- Guardrail-Steel W Beam-S Face Br
- High Strength Geotextile Fabric
- Masonry Coating
- Mechanical Reinforcement Coupler #5
- Mechanical Reinforcement Coupler #7
- Mechanical Reinforcement Coupler #8
- Mechanical Reinforcement Coupler #9
- Mechanical Reinforcement Coupler #10
- Mechanical Reinforcement Coupler #11
- Mechanical Reinforcement Coupler-#5 Epoxy Coated
- Mechanical Reinforcement Coupler-#6 Epoxy Coated
- Mechanical Reinforcement Coupler-#8 Epoxy Coated
- Pile Points-12 in
- Pile Points-14 in
- Piles-Steel HP12X53
- Piles-Steel HP14X73
- Piles-Steel HP14X89
- Precast PC I-Beam Type 3
- Precast PC I-Beam Type 4
- Precast PC I-Beam Type 5
- Precast PC I-Beam Type 6
- Precast PC I-Beam Type 7
- Precast PC I-Beam Type 8
- Precast PC I-Beam Type 9
- Precast PC I-Beam Type HN 42-49
- Precast PC I-Beam Type HN 54-49

- Precast PC I-Beam Type HN 60-49
- Precast PC I-Beam Type NH 66-61 Hybrid
- Precast PC I-Beam Type HN 72-49
- Pre-drilling For Piles
- Protective Fence
- Rail System Type III
- Reinforced Concrete Slope Wall-6 in
- Steel Reinforcement
- Steel Reinforcement-Epoxy Coated
- Structural Steel
- Structure Excavation-Common
- Structure Excavation-Solid Rock
- Structure Excavation-Unclassified
- Structure Granular Backfill
- Test Piles

All the items were not used with every bridge. The results of the analysis are summarized in Table C.1.

Table C.1-Bridge construction unit costs analysis summary

Cost Analysis Case	n	Unit Cost, $/ft^2 ($/m^2)	
		Mean	Standard Deviation
Excluding costs greater than $160.00/ft^2 ($1,722.22/m^2)	116	107.52 (1,157.33)	18.28 (196.76)
Excluding costs greater than $200.00/ft^2 ($2,152.77/m^2)	129	115.00 (1,237.84)	28.55 (307.31)
Excluding costs greater than $300.00/ft^2 ($3,229.16/m^2)	139	122.20 (1,315.34)	38.00 (409.03)
All costs included	140	123.61 (1,330.52)	41.35 (445.09)

The following are summaries of unit costs for each project used in the analysis.

Bridge with Grade, Drain & Surface Brown Badgett Loop (CR 1092)
Date Let: 01-25-13 Call: 103 County: Hopkins District: 02
Precast PC I Beam Type: HN42-49 Bridge Area: 7,754 ft^2 (720.4 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	983,665.96	126.86 (1,365.50)
Bidder 2	981,309.92	126.56 (1,362.28)
Bidder 3	977,545.41	126.07 (1,357.00)
Bidder 4	1,017,754.23	131.26 (1,412.87)
Bidder 5	1,221,990.50	157.59 (1,696.28)
Bidder 6	1,545,127.00	199.27 (2,144.92)

Bridge with Grade, Drain & Surface KY 1428
Date Let: 02-22-13 Call: 104 County: Floyd District: 12
Precast PC I Beam Type: HN 54 49 Bridge Area: 4,247 ft^2 (394.6 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	540,809.24	127.34 (1,370.67)
Bidder 2	660,500.16	155.52 (1,674.00)

Grade, Drain & Surface with Bridge Georgetown Northwest Bypass
Date Let: 04-19-13 Call: 101 County: Scott District: 07
Precast PC I Beam Type: 7 Bridge Area: 23,005 ft^2 (2,137.2 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,593,598.05	112.74 (1,213.52)
Bidder 2	2,363,143.85	102.72 (1,105.66)
Bidder 3	2,566,733.50	111.57 (1,200.92)
Bidder 4	2,363,143.85	102.72 (1,105.66)
Bidder 5	2,666,685.96	115.92 (1,247.75)
Bidder 6	2,531,536.50	110.04 (1,184.46)

Grade, Drain & Surface with Bridge Hooker Branch Road (CR 1276)
Date Let: 07-12-13 Call: 366 County: Clay District: 11
Precast PC I Beam Type: HN60-49 Bridge Area: 4,394 ft^2 (408.2 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	409,850.90	93.28 (1,004.05)
Bidder 2	468,446.40	106.61 (1,147.54)
Bidder 3	528,910.00	120.37 (1,295.65)
Bidder 4	468,446.40	106.61 (1,147.54)
Bidder 5	610,850.80	139.02 (1,496.39)

Bridge with Grade, Drain & Surface Dahl Road (KY 1677)
Date Let: 08-16-13 Call: 106 County: Pulaski District: 08
Precast PC I Beam Type: 4 Bridge Area: 3,033 ft^2 (281.8 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	388,415.12	128.06 (1,378.42)
Bidder 2	378,227.30	124.70 (1,342.25)
Bidder 3	377,942.10	124.61 (1,341.29)
Bidder 4	467,270.30	154.06 (1,658.28)
Bidder 5	461,502.81	152.16 (1,637.83)

Bridge with Grade, Drain & Surface KY 476
Date Let: 09-27-13 Call: 105 County: Perry District: 10
Precast PC I Beam Type: HN42-49 Bridge Area: 9,131 ft^2 (848.3 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	953,767.85	104.45 (1,124.29)
Bidder 2	1,073,528.50	117.57 (1,265.51)
Bidder 3	1,207,156.65	132.20 (1,422.98)
Bidder 4	1,228,610.40	134.55 (1,448.28)
Bidder 5	1,197,482.40	131.14 (1,411.57)

Grade, Drain & Surface with Bridge Kuttawa-Princeton Road (US 62)
Date Let: 09-27-13 Call: 317 County: Lyon District: 01
Precast PC I Beam Type: HN42-49 Bridge Area: 21,250 ft^2 (1,974.2 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,656,685.48	125.02 (1,345.70)
Bidder 2	3,136,758.70	147.61 (1,588.85)

Bridge Replacement Stanton-Slade Road (KY 11)
Date Let: 11-22-13 Call: 104 County: Powell District: 10
Precast PC I Beam Type: HN42-49 Bridge Area: 3,094 ft^2 (287.4 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	314,411.95	101.62 (1,093.82)
Bidder 2	350,178.40	113.18 (1,218.25)
Bidder 3	346,511.15	111.99 (1,205.45)
Bidder 4	425,193.50	137.43 (1,479.28)

Bridge with Grade, Drain & Surface Beaver Dam - Leitchfield Road (US 62)
Date Let: 11-22-13 Call: 106 County: Ohio District: 02
Precast PC I Beam Type: HN 54 49 Bridge Area: 5,891 ft^2 (547.3 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	592,289.20	100.54 (1,082.20)
Bidder 2	677,616.50	115.03 (1,238.17)
Bidder 3	681,994.58	115.77 (1,246.13)
Bidder 4	740,171.61	125.64 (1,352.37)
Bidder 5	733,344.00	124.49 (1,339.99)

Bridge with Grade, Drain & Surface Glomawr to Hazard Road (KY 451)
Date Let: 11-22-13 Call: 108 County: Perry District: 10
Precast PC I Beam Type: 8 Bridge Area: 14,457 ft^2 (1,343.1 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	1,408,871.81	97.45 (1,048.94)
Bidder 2	1,556,763.50	107.68 (1,159.05)
Bidder 3	1,688,817.80	116.82 (1,257.44)
Bidder 4	1,730,651.40	119.71 (1,288.54)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
I 65 over CSX
Precast PC I Beam Type: HN60-49 Bridge Area: 17,868 ft^2 (1,660.0 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	1,662,428.24	93.04 (1,001.47)
Bidder 2	1,918,818.37	107.39 (1,155.93)
Bidder 3	1,785,208.22	99.91 (1,075.42)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
KY 88 over I 65
Precast PC I Beam Type: HN60-49 Bridge Area: 12,450 ft^2 (1,156.6 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	1,057,793.56	84.96 (914.50)
Bidder 2	1,229,649.65	98.77 (1,063.15)
Bidder 3	1,070,577.12	85.99 (925.59)

Bridge with Grade, Drain & Surface Buffalo Branch Road (CR-1327)
Date Let: 11-22-13 Call: 111 County: Bell District: 11
Precast PC I Beam Type: 3 Bridge Area: 1,560 ft^2 (144.9 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	281,673.40	180.56 (1,943.52)
Bidder 2	318,622.80	204.25 (2,198.52)
Bidder 3	353,081.80	226.33 (2,436.19)
Bidder 4	381,694.47	244.68 (2,633.70)

Grade, Drain & Surface with Bridge Gratz-Moxley Road (KY-355)
Date Let: 12-13-13 Call: 106 County: Owen District: 06
Precast PC I Beam Type: 3 Bridge Area: 5,946 ft^2 (552.4 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	992,004.30	166.84 (1,795.84)
Bidder 2	1,068,053.04	179.63 (1,933.51)
Bidder 3	1,123,253.00	188.91 (2,033.40)
Bidder 4	1,027,904.07	172.87 (1,860.75)
Bidder 5	1,073,563.91	180.55 (1,943.42)
Bidder 6	1,193,574.50	200.74 (2,160.74)
Bidder 7	1,082,909.97	182.12 (1,960.32)
Bidder 8	1,059,069.04	178.11 (1,917.15)
Bidder 9	1,227,857.03	206.50 (2,222.74)

Grade & Drain with Bridge Partridge to Oven Fork Road (US 119, Section 3B)
Date Let: 12-13-13 Call: 113 County: Letcher District: 12
Precast PC I Beam Type: 5 Bridge Area: 19,487 ft^2 (1,810.4 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	1,793,854.84	92.05 (990.81)
Bidder 2	1,722,941.60	88.41 (951.63)
Bidder 3	1,725,437.71	88.54 (953.03)
Bidder 4	1,736,084.00	89.09 (958.95)

Grade, Drain & Surface with Bridge US-68 and Louie B. Nunn Parkway
Date Let: 12-13-13 Call: 306 County: Metcalfe District: 03
Precast PC I Beam Type: NH 66 61-hybrid Bridge Area: 10,833 ft^2 (1,006.4 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	1,109,589.75	102.43 (1,102.54)
Bidder 2	1,207,097.72	111.43 (1,199.42)
Bidder 3	1,192,771.23	110.11 (1,185.21)

Grade, Drain & Surface with Bridge New Moody Lane-Commerce Parkway (New Route)
Date Let: 12-13-13 Call: 307 County: Oldham District: 05
Precast PC I Beam Type: 9 Bridge Area: 70,013 ft^2 (6,504.4 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	5,027,348.20	71.81 (772.95)
Bidder 2	5,023,597.00	71.75 (772.31)
Bidder 3	4,931,802.20	70.44 (758.21)
Bidder 4	5,726,496.80	81.79 (880.38)
Bidder 5	5,319,013.65	75.97 (817.73)
Bidder 6	4,911,871.39	70.16 (755.19)
Bidder 7	5,900,494.25	84.28 (907.18)
Bidder 8	6,201,200.45	88.57 (953.36)

Grade, Drain & Surface with Bridge Morgantown Road (KY 79)
Date Let: 01-24-14 Call: 313 County: Logan District: 03
Precast PC I Beam Type: 4 Bridge Area: 10,101 ft^2 (938.4 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	1,068,699.60	105.80 (1,138.82)
Bidder 2	1,157,056.51	114.55 (1,233.00)
Bidder 3	1,070,175.60	105.95 (1,140.43)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over Commonwealth
Precast PC I Beam Type: HN 7249 Bridge Area: 6,956 ft^2 (646.2 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	601,307.18	86.44 (930.43)
Bidder 2	631,882.20	90.84 (977.79)
Bidder 3	430,103.74	61.83 (665.53)
Bidder 4	750,060.00	107.83 (1,160.67)
Bidder 5	631,765.00	90.82 (977.57)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over US 68 / KY80 / RR
Precast PC I Beam Type: 3 and 5 Bridge Area: 21,549 ft^2 (2,002.0 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	1,940,838.98	90.07 (969.50)
Bidder 2	1,883,527.05	87.41 (940.87)
Bidder 3	2,014,000.83	93.46 (1,005.99)
Bidder 4	2,243,972.40	104.13 (1,120.84)
Bidder 5	2,192,051.65	101.72 (1,094.90)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over I-65
Precast PC I Beam Type: 4 Bridge Area: 30,634 ft^2 (2,846.0 m^2)

	Total Bridge Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	2,974,736.68	97.11 (1,045.28)
Bidder 2	3,006,586.90	98.15 (1,056.47)
Bidder 3	3,526,927.89	115.13 (1,239.24)
Bidder 4	3,350,120.80	109.36 (1,177.14)
Bidder 5	3,110,601.58	101.54 (1,092.96)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
Kelly Road over US 31W Connector
Precast PC I Beam Type: 4 Bridge Area: 8,375 ft^2 (778.1 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	867,698.02	103.61 (1,115.24)
Bidder 2	885,617.00	105.75 (1,138.28)
Bidder 3	810,713.61	96.80 (1,041.94)
Bidder 4	1,003,107.85	119.77 (1,289.19)
Bidder 5	954,296.82	113.95 (1,226.54)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over CSX Railroad
Precast PC I Beam Type: 6 Bridge Area: 23,789 ft^2 (2,210.1 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,436,053.06	102.40 (1,102.22)
Bidder 2	2,444,569.55	102.76 (1,106.10)
Bidder 3	2,716,159.60	114.18 (1,229.02)
Bidder 4	2,849,711.05	119.79 (1,289.40)
Bidder 5	2,474,524.83	104.02 (1,119.66)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over CSX Railroad
Precast PC I Beam Type: 6 Bridge Area: 19,983 ft^2 (1,856.5 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,157,217.14	107.95 (1,161.96)
Bidder 2	2,125,711.10	106.38 (1,145.06)
Bidder 3	2,594,414.26	129.83 (1,397.47)
Bidder 4	2,464,408.75	123.33 (1,327.51)
Bidder 5	2,180,766.94	109.13 (1,174.66)

Bridge with Grade, Drain & Surface Frenchburg to Owingsville Road (KY 36)
Date Let: 06-27-14 Call: 109 County: Menifee District: 10
Precast PC I Beam Type: 4 Bridge Area: 3,266 ft^2 (303.4 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	632,362.40	193.62 (2,084.10)
Bidder 2	664,557.10	203.48 (2,190.23)
Bidder 3	704,802.05	215.80 (2,322.84)
Bidder 4	696,419.65	213.23 (2,295.18)
Bidder 5	755,729.70	231.39 (2,490.65)
Bidder 6	669,235.62	204.91 (2,205.62)
Bidder 7	1,041,093.57	318.77 (3,431.20)

Bridge Replacement Rye Branch Road (CR 1756)
Date Let: 07-11-14 Call: 108 County: Magoffin District: 10
Precast PC I Beam Type: 3 Bridge Area: 1,225 ft^2 (113.8 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	196,067.76	160.06 (1,722.86)
Bidder 2	229,058.00	186.99 (2,012.74)
Bidder 3	237,249.50	193.67 (2,084.64)

Bridge with Grade, Drain & Surface Hazard-Hyden Road (KY-80)
Date Let: 07-11-14 Call: 113 County: Perry District: 10
Precast PC I Beam Type: HN 54 49 Bridge Area: 19,127 ft^2 (1,777.0 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,101,305.10	109.86 (1,182.52)
Bidder 2	2,075,194.30	108.50 (1,167.88)
Bidder 3	2,222,734.40	116.21 (1,250.87)
Bidder 4	2,174,378.91	113.68 (1,223.64)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
US 31W Over I-65
Precast PC I Beam Type: HN 54 49 Bridge Area: 18,511 ft^2 (1,719.7 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,140,669.33	115.64 (1,244.73)
Bidder 2	2,150,760.60	116.19 (1,250.65)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
BRIDGE-25019
Precast PC I Beam Type: HN42-49 Bridge Area: 28,193 ft^2 (2,619.2 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,480,276.07	87.97 (946.90)
Bidder 2	2,346,756.95	83.24 (895.98)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
Old Sonora Bridge over I-65
Precast PC I Beam Type: HN42-49 Bridge Area: 9,415 ft^2 (874.6 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	930,306.37	98.81 (1,063.58)
Bidder 2	966,810.45	102.69 (1,105.34)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
KY-84 over I-65
Precast PC I Beam Type: HN42-49 Bridge Area: 21,172 ft^2 (1,967.0 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	1,975,288.03	93.30 (1,004.27)
Bidder 2	2,004,266.30	94.67 (1,019.02)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
BRIDGE-25021
Precast PC I Beam Type: 3 Bridge Area: 12,079 ft^2 (1,122.2 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	1,331,592.97	110.24 (1,186.61)
Bidder 2	1,219,610.70	100.97 (1,086.83)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
BRIDGE-25020
Precast PC I Beam Type: 4 Bridge Area: 13,135 ft^2 (1,220.3 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	1,174,748.09	89.44 (962.72)
Bidder 2	1,126,785.90	85.78 (923.32)

Bridge with Grade, Drain & Surface KY-49
Date Let: 08-22-14 Call: 313 County: Marion District: 04
Precast PC I Beam Type: HN60-49 Bridge Area: 4,518 ft^2 (419.7 m^2)

	Total Bridge Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	489,029.27	108.24 (1,165.08)
Bidder 2	466,779.00	103.32 (1,112.12)
Bidder 3	489,029.27	108.24 (1,165.08)

Reinforced Concrete Decks

The cost analysis for the construction of a cast in place reinforced concrete bridge deck used the bid data for the precast prestressed concrete I-beam bridges but included only the following bid items:

- Armored Edge for Concrete
- Concrete-Class AA
- Guardrail-Steel W Beam-S Face Br
- Masonry Coating
- Mechanical Reinforcement Coupler-#5 Epoxy Coated
- Mechanical Reinforcement Coupler-#6 Epoxy Coated
- Mechanical Reinforcement Coupler-#8 Epoxy Coated
- Rail System Type III
- Steel Reinforcement-Epoxy Coated
- Structural Steel

These are the items used to construct a reinforced concrete bridge deck and rails. All the items were not used with every bridge. The results of the analysis are summarized in Table C.2.

Table C.2-Bridge deck construction unit costs analysis summary

Cost Analysis Case	n	Unit Cost, $/ft^2 ($/m^2)	
		Mean	Standard Deviation
Excluding costs greater than $60.00/ft^2 ($645.8/m^2)	117	38.17 (410.86)	7.19 (77.39)
Excluding costs greater than $70.00/ft^2 ($753.47/m^2)	133	41.46 (446.27)	11.25 (121.09)
Excluding costs greater than $90.00/ft^2 ($968.75/m^2)	139	43.16 (464.57)	13.65 (146.93)
All costs included	140	43.55 (468.77)	14.35 (154.46)

The following are summaries of unit costs for each project used in the analysis.

Bridge with Grade, Drain & Surface Brown Badgett Loop (CR 1092)
Date Let: 01-25-13 Call: 103 County: Hopkins District: 02
Bridge Area: 7,754 ft^2 (720.4 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	374,562.74	48.31 (520.00)
Bidder 2	320,991.08	41.40 (445.62)
Bidder 3	322,714.70	41.62 (447.99)
Bidder 4	328,259.30	42.33 (455.63)
Bidder 5	385,821.70	49.76 (535.61)
Bidder 6	502,134.00	64.76 (697.07)

Bridge with Grade, Drain & Surface KY 1428
Date Let: 02-22-13 Call: 104 County: Floyd District: 12
Bridge Area: 4,247 ft^2 (394.6 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	188,594.24	44.41 (478.02)
Bidder 2	193,942.16	45.67 (491.59)

Grade, Drain & Surface with Bridge Georgetown Northwest Bypass
Date Let: 04-19-13 Call: 101 County: Scott District: 07
Bridge Area: 23,005 ft^2 (2,137.2 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	789,544.06	34.32 (369.42)
Bidder 2	696,445.40	30.27 (325.82)
Bidder 3	848,473.40	36.88 (396.97)
Bidder 4	696,445.40	30.27 (325.82)
Bidder 5	823,942.16	35.82 (385.56)
Bidder 6	774,779.00	33.68 (362.53)

Grade, Drain & Surface with Bridge Hooker Branch Road (CR 1276)
Date Let: 07-12-13 Call: 366 County: Clay District: 11
Bridge Area: 4,394 ft^2 (408.2 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	160,080.90	36.43 (392.13)
Bidder 2	173,152.40	39.41 (424.20)
Bidder 3	206,638.00	47.03 (506.22)
Bidder 4	173,152.40	39.41 (424.20)
Bidder 5	289,514.80	65.89 (709.23)

Bridge with Grade, Drain & Surface Dahl Road (KY 1677)
Date Let: 08-16-13 Call: 106 County: Pulaski District: 08
Bridge Area: 3,033 ft^2 (281.8 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	169,285.62	55.81 (600.73)
Bidder 2	141,644.80	46.70 (502.67)
Bidder 3	140,723.10	46.40 (499.44)
Bidder 4	189,435.30	62.46 (672.31)
Bidder 5	167,441.80	55.21 (594.27)

Bridge with Grade, Drain & Surface KY 476
Date Let: 09-27-13 Call: 105 County: Perry District: 10
Bridge Area: 9,131 ft^2 (848.3 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	370,598.60	40.59 (436.91)
Bidder 2	404,720.00	44.32 (477.05)
Bidder 3	451,054.40	49.40 (531.74)
Bidder 4	447,115.40	48.97 (527.11)
Bidder 5	439,449.28	48.13 (518.07)

Grade, Drain & Surface with Bridge Kuttawa-Princeton Road (US 62)
Date Let: 09-27-13 Call: 317 County: Lyon District: 01
Bridge Area: 21,250 ft^2 (1,974.2 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	929,414.09	43.74 (470.81)
Bidder 2	1,030,090.70	48.47 (521.72)

Bridge Replacement Stanton-Slade Road (KY 11)
Date Let: 11-22-13 Call: 104 County: Powell District: 10
Bridge Area: 3,094 ft^2 (287.4 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	134,704.00	43.54 (468.66)
Bidder 2	140,863.40	45.53 (490.08)
Bidder 3	163,743.15	52.92 (569.62)
Bidder 4	183,640.50	59.35 (638.84)

Bridge with Grade, Drain & Surface Beaver Dam - Leitchfield Road (US 62)
Date Let: 11-22-13 Call: 106 County: Ohio District: 02
Bridge Area: 5,891 ft^2 (547.3 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	197,055.80	33.45 (360.05)
Bidder 2	208,444.00	35.38 (380.83)
Bidder 3	228,546.58	38.80 (417.64)
Bidder 4	272,236.18	46.21 (497.40)
Bidder 5	226,501.60	38.45 (413.87)

Bridge with Grade, Drain & Surface Glomawr to Hazard Road (KY 451)
Date Let: 11-22-13 Call: 108 County: Perry District: 10
Bridge Area: 14,457 ft^2 (1,343.1 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	479,784.14	33.19 (357.25)
Bidder 2	553,461.60	38.28 (412.04)
Bidder 3	544,464.80	37.66 (405.37)
Bidder 4	628,118.90	43.45 (467.69)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
I 65 over CSX
Bridge Area: 17,868 ft^2 (1,660.0 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	552,841.61	30.94 (333.03)
Bidder 2	653,784.74	36.59 (393.85)
Bidder 3	626,778.27	35.08 (377.60)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
KY 88 over I 65
Bridge Area: 12,450 ft^2 (1,156.6 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	434,348.06	34.89 (375.55)
Bidder 2	491,563.06	39.48 (424.96)
Bidder 3	427,794.26	34.36 (369.85)

Bridge with Grade, Drain & Surface Buffalo Branch Road (CR-1327)
Date Let: 11-22-13 Call: 111 County: Bell District: 11
Bridge Area: 1,560 ft^2 (144.9 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	93,996.80	60.25 (648.52)
Bidder 2	102,298.80	65.58 (705.89)
Bidder 3	88,843.80	56.95 (613.00)
Bidder 4	107,388.68	68.84 (740.98)

Grade, Drain & Surface with Bridge Gratz-Moxley Road (KY-355)
Date Let: 12-13-13 Call: 106 County: Owen District: 06
Bridge Area: 5,946 ft^2 (552.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	394,310.20	66.32 (713.86)
Bidder 2	494,948.64	83.24 (895.98)
Bidder 3	415,842.00	69.94 (752.82)
Bidder 4	396,160.00	66.63 (717.20)
Bidder 5	469,930.44	79.03 (850.67)
Bidder 6	476,207.40	80.09 (862.08)
Bidder 7	356,904.54	60.02 (646.05)
Bidder 8	414,673.02	69.74 (750.67)
Bidder 9	513,881.10	86.42 (930.21)

Grade & Drain with Bridge Partridge to Oven Fork Road (US 119, Section 3B)
Date Let: 12-13-13 Call: 113 County: Letcher District: 12
Bridge Area: 19,487 ft^2 (1,810.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	660,790.19	33.91 (365.00)
Bidder 2	595,658.00	30.57 (329.05)
Bidder 3	611,642.00	31.39 (337.88)
Bidder 4	613,430.00	31.48 (338.85)

Grade, Drain & Surface with Bridge US-68 and Louie B. Nunn Parkway
Date Let: 12-13-13 Call: 306 County: Metcalfe District: 03
Bridge Area: 10,833 ft^2 (1,006.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	396,517.75	36.60 (393.96)
Bidder 2	421,614.70	38.92 (418.93)
Bidder 3	449,834.00	41.52 (446.92)

Grade, Drain & Surface with Bridge New Moody Lane-Commerce Parkway (New Route)
Date Let: 12-13-13 Call: 307 County: Oldham District: 05
Bridge Area: 70,013 ft^2 (6,504.4 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	1,682,584.50	24.03 (258.66)
Bidder 2	1,988,200.00	28.40 (305.69)
Bidder 3	1,955,443.50	27.93 (300.63)
Bidder 4	1,930,523.00	27.57 (296.76)
Bidder 5	2,121,907.75	30.31 (326.25)
Bidder 6	1,729,120.75	24.70 (265.87)
Bidder 7	2,237,843.25	31.96 (344.01)
Bidder 8	2,072,025.25	29.59 (318.50)

Grade, Drain & Surface with Bridge Morgantown Road (KY 79)
Date Let: 01-24-14 Call: 313 County: Logan District: 03
Bridge Area: 10,101 ft^2 (938.4 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	371,972.90	36.83 (396.43)
Bidder 2	411,978.60	40.79 (439.06)
Bidder 3	371,972.90	36.83 (396.43)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over Commonwealth
Bridge Area: 6,956 ft^2 (646.2 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	223,066.30	32.07 (345.20)
Bidder 2	222,886.60	32.04 (344.87)
Bidder 3	273,223.54	39.28 (422.80)
Bidder 4	265,272.80	38.14 (410.53)
Bidder 5	230,975.40	33.21 (357.47)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over US 68 / KY80 / RR
Bridge Area: 21,549 ft^2 (2,002.0 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	624,505.90	28.98 (311.94)
Bidder 2	620,306.95	28.79 (309.89)
Bidder 3	750,441.56	34.82 (374.80)
Bidder 4	778,171.10	36.11 (388.68)
Bidder 5	706,382.55	32.78 (352.84)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over I-65
Bridge Area: 30,634 ft^2 (2,846.0 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	898,475.20	29.33 (315.70)
Bidder 2	909,123.30	29.68 (319.47)
Bidder 3	1,090,286.74	35.59 (383.09)
Bidder 4	1,092,353.60	35.66 (383.84)
Bidder 5	948,302.98	30.96 (333.25)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
Kelly Road over US 31W Connector
Bridge Area: 8,375 ft^2 (778.1 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	302,192.70	36.08 (388.36)
Bidder 2	313,699.35	37.46 (403.21)
Bidder 3	371,265.58	44.33 (477.16)
Bidder 4	374,129.30	44.67 (480.82)
Bidder 5	337,891.17	40.35 (434.32)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over CSX Railroad
Bridge Area: 23,789 ft^2 (2,210.1 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	671,408.20	28.22 (303.76)
Bidder 2	700,294.60	29.44 (316.89)
Bidder 3	831,716.36	34.96 (376.30)
Bidder 4	912,564.90	38.36 (412.90)
Bidder 5	712,685.38	29.96 (322.49)

Bridge with Grade & Drain I-65 to US 31W Connector (KY 3145)
Date Let: 05-30-14 Call: 100 County: Warren District: 03
US 31W Connector over CSX Railroad
Bridge Area: 19,983 ft^2 (1,856.5 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	583,108.80	29.18 (314.09)
Bidder 2	590,965.25	29.57 (318.29)
Bidder 3	725,392.67	36.30 (390.73)
Bidder 4	764,209.90	38.24 (411.61)
Bidder 5	631,280.89	31.59 (340.03)

Bridge with Grade, Drain & Surface Frenchburg to Owingsville Road (KY 36)
Date Let: 06-27-14 Call: 109 County: Menifee District: 10
Bridge Area: 3,266 ft^2 (303.4 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	200,295.40	61.33 (660.15)
Bidder 2	197,115.60	60.35 (649.60)
Bidder 3	227,349.80	69.61 (749.27)
Bidder 4	141,010.90	43.18 (464.78)
Bidder 5	228,554.20	69.98 (753.26)
Bidder 6	178,867.82	54.77 (589.54)
Bidder 7	259,361.00	79.41 (854.76)

Bridge Replacement Rye Branch Road (CR 1756)
Date Let: 07-11-14 Call: 108 County: Magoffin District: 10
Bridge Area: 1,225 ft^2 (113.8 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	81,495.30	66.53 (716.12)
Bidder 2	94,896.00	77.47 (833.88)
Bidder 3	118,925.00	97.08 (1,044.96)

Bridge with Grade, Drain & Surface Hazard-Hyden Road (KY-80)
Date Let: 07-11-14 Call: 113 County: Perry District: 10
Bridge Area: 19,127 ft^2 (1,777.0 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	759,953.90	39.73 (427.65)
Bidder 2	709,489.70	37.09 (399.23)
Bidder 3	771,836.00	40.35 (434.32)
Bidder 4	729,488.55	38.14 (410.53)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
US 31W over I-65
Bridge Area: 18,511 ft^2 (1,719.7 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	763,114.63	41.22 (443.69)
Bidder 2	664,422.95	35.89 (386.32)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
BRIDGE-25019
Bridge Area: 28,193 ft^2 (2,619.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	1,029,149.37	36.50 (392.88)
Bidder 2	901,926.55	31.99 (344.34)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
Old Sonora Bridge over I-65
Bridge Area: 9,415 ft^2 (874.6 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	367,202.37	39.00 (419.79)
Bidder 2	374,662.55	39.79 (428.29)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
KY-84 over I-65
Bridge Area: 21,172 ft^2 (1,967.0 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	724,093.73	34.20 (368.12)
Bidder 2	677,549.45	32.00 (344.44)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
BRIDGE-25021
Bridge Area: 12,079 ft^2 (1,122.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	590,611.37	48.90 (526.35)
Bidder 2	513,926.05	42.55 (458.00)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
BRIDGE-25020
Bridge Area: 13,135 ft^2 (1,220.3 m^2)

	Total Deck Items, \$	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	516,154.59	39.30 (423.02)
Bidder 2	457,776.85	34.85 (375.12)

Bridge with Grade, Drain & Surface KY-49
Date Let: 08-22-14 Call: 313 County: Marion District: 04
Bridge Area: 4,518 ft^2 (419.7 m^2)

	Total Deck Items, \$	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	192,216.07	42.54 (457.89)
Bidder 2	191,335.00	42.35 (455.85)
Bidder 3	192,216.07	42.54 (457.89)

Bridge Deck Restorations

The cost analysis for bridge deck restoration work included the following bid items:

- Armored Edge For Concrete
- Blast Cleaning
- Concrete Class M Full Depth Patch
- Concrete Overlay-Latex
- Epoxy Sand Slurry
- Hydrodemolition
- Machine Preparation Of Slab
- Partial Depth Patching

These are the items that KYTC used to prepare and apply a latex modified concrete overlay to an existing bridge deck that does not have an existing overlay. Hydrodemolition was not used with most of the bridges included in the analysis. The calculated unit costs are per unit of overlay area and are summarized in Table C.3. In the statistical analysis the bridges were grouped by overlay area. As the overlay area increased the mean unit cost decreased. The standard deviation also decreased.

Table C.3-Bridge deck restoration unit costs summary

Overlay Area, A, ft^2 (m^2)	Number bridges	n	Unit Costs, $\$/ft^2$ ($\$/m^2$)	
			Mean	Standard Deviation
A < 1,000 (A < 92.9)	2	13	41.75 (449.39)	7.93 (85.36)
1,000 ≤ A < 3,000 (92.9 ≤ A < 278.7)	16	83	31.55 (339.60)	7.80 (83.96)
3,000 ≤ A < 5,000 (278.7 ≤ A < 464.5)	24	146	22.24 (239.39)	6.55 (70.50)
5,000 ≤ A < 10,000 (464.5 ≤ A < 929.0)	47	250	16.54 (178.03)	4.79 (51.56)
10,000 ≤ A < 20,000 (929.0 ≤ A < 1,858.1)	14	72	13.47 (144.99)	3.11 (33.48)
20,000 ≤ A < 30,000 (1,858.1 ≤ A < 2,787.1)	3	18	12.33 (132.72)	2.12 (22.82)
54,578 (5,070.5)	1	8	10.17 (109.47)	1.25 (13.45)
242,904 (22,566.6)	1	5	9.04 (97.31)	1.17 (12.59)

The following are summaries of unit costs for each project used in the analysis.

Bridge Deck Overlay Butler County (WN 9007)
Date Let: 01-25-13 Call: 317 County: Butler District: 03
Bridge Number: 016B00061N, NB only Overlay Area: 24,115 ft^2 (2,240.4 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	226,110.00	9.38 (100.97)
Bidder 2	216,069.20	8.96 (96.44)
Bidder 3	252,862.00	10.49 (112.91)
Bidder 4	233,310.00	9.67 (104.09)
Bidder 5	226,604.00	9.40 (101.18)
Bidder 6	274,630.00	11.39 (122.60)
Bidder 7	378,625.00	15.70 (168.99)

Bridge Deck Restoration & Waterproofing Interstate 64
Date Let: 02-22-13 Call: 100 County: Jefferson District: 05
Bridge Number: 056B00040R Overlay Area: 11,384 ft^2 (1,057.6 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	196,818.00	17.29 (186.11)
Bidder 2	194,986.00	17.13 (184.39)
Bidder 3	215,921.00	18.97 (204.19)
Bidder 4	172,151.50	15.12 (162.75)
Bidder 5	192,894.00	16.94 (182.34)
Bidder 6	198,961.00	17.48 (188.15)

Bridge Deck Restoration & Waterproofing Campbell County (KY 9)
Date Let: 02-22-13 Call: 311 County: Campbell District: 06
Bridge Number: 019B00033N Overlay Area: 28,512 ft^2 (2,648.9 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	316,951.90	11.12 (119.69)
Bidder 2	361,645.00	12.68 (136.49)
Bidder 3	378,254.00	13.27 (142.84)
Bidder 4	360,743.80	12.65 (136.16)
Bidder 5	437,256.00	15.34 (165.12)
Bidder 6	365,085.00	12.80 (137.78)

Bridge Deck Restoration & Waterproofing Bridge over North Fork of Triplett Creek
Date Let: 03-22-13 Call: 332 County: Rowan District: 09
Bridge Number: 103B00027N Overlay Area: 1,980 ft^2 183.9 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	73,187.50	36.96 (397.83)
Bidder 2	66,938.40	33.81 (363.93)
Bidder 3	72,960.00	36.85 (396.65)
Bidder 4	84,126.00	42.49 (457.36)
Bidder 5	103,042.00	52.04 (560.15)

Bridge Deck Restoration & Waterproofing Wayne & McCreary Cos. Bridge Overlays and Joint Replacements
Date Let: 03-22-13 Call: 434 County: Various District: 08
Bridge Number: 074B00011N Overlay Area: 3,360 ft^2 (312.2 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	59,040.80	17.57 (189.12)
Bidder 2	59,270.00	17.64 (189.87)
Bidder 3	62,695.00	18.66 (200.85)
Bidder 4	78,150.00	23.26 (250.37)
Bidder 5	79,846.00	23.76 (255.75)
Bidder 6	102,094.00	30.39 (327.11)

Bridge Deck Restoration & Waterproofing Wayne & McCreary Cos. Bridge Overlays and Joint Replacements
Date Let: 03-22-13 Call: 434 County: Various District: 08
Bridge Number: 116B00001N Overlay Area: 1,760 ft^2 (163.5 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	53,907.20	30.63 (329.70)
Bidder 2	49,405.00	28.07 (302.14)
Bidder 3	62,430.00	35.47 (381.79)
Bidder 4	76,500.00	43.47 (467.91)
Bidder 5	80,807.00	45.91 (494.17)
Bidder 6	106,666.00	60.61 (652.40)

Bridge Deck Overlay Hancock County
Date Let: 04-19-13 Call: 406 County: Hancock District: 02
Bridge Number: 046B00030N Overlay Area: 8,895 ft^2 (826.4 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	141,040.00	15.86 (170.71)
Bidder 2	139,144.00	15.64 (168.35)
Bidder 3	180,160.00	20.25 (217.97)
Bidder 4	150,860.00	16.96 (182.56)
Bidder 5	196,100.00	22.05 (237.34)

Bridge Deck Overlay Hancock County
Date Let: 04-19-13 Call: 406 County: Hancock District: 02
Bridge Number: 046B00013N Overlay Area: 2,880 ft^2 (267.6 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	82,486.00	28.64 (308.28)
Bidder 2	90,432.00	31.40 (337.99)
Bidder 3	104,253.50	36.20 (389.65)
Bidder 4	98,380.00	34.16 (367.69)
Bidder 5	95,610.00	33.20 (357.36)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00027L Overlay Area: 5,111 ft^2 (474.8 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	98,277.40	19.23 (206.99)
Bidder 2	107,070.80	20.95 (225.50)
Bidder 3	121,356.00	23.74 (255.53)
Bidder 4	131,036.60	25.64 (275.99)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00027R Overlay Area: 5,111 ft^2 (474.8 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	98,277.40	19.23 (206.99)
Bidder 2	107,070.80	20.95 (225.50)
Bidder 3	121,356.00	23.74 (255.53)
Bidder 4	131,036.60	25.64 (275.99)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00028L Overlay Area: 5,859 ft^2 (544.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	98,138.30	16.75 (180.29)
Bidder 2	98,520.60	16.82 (181.05)
Bidder 3	107,052.00	18.27 (196.66)
Bidder 4	111,114.20	18.96 (204.08)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00028R Overlay Area: 5,859 ft^2 (544.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	98,138.30	16.75 (180.29)
Bidder 2	98,520.60	16.82 (181.05)
Bidder 3	107,052.00	18.27 (196.66)
Bidder 4	111,114.20	18.96 (204.08)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00029L Overlay Area: 5,282 ft^2 (490.7 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	91,930.70	17.40 (187.29)
Bidder 2	93,212.40	17.65 (189.98)
Bidder 3	100,871.00	19.10 (205.59)
Bidder 4	103,387.30	19.57 (210.65)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00029R Overlay Area: 5,282 ft^2 (490.7 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	91,930.70	17.40 (187.29)
Bidder 2	93,212.40	17.65 (189.98)
Bidder 3	100,871.00	19.10 (205.59)
Bidder 4	103,387.30	19.57 (210.65)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00031L Overlay Area: 7,103 ft^2 (659.9 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	118,720.50	16.71 (179.86)
Bidder 2	119,089.00	16.77 (180.51)
Bidder 3	129,482.00	18.23 (196.23)
Bidder 4	134,504.50	18.94 (203.87)

Bridge Deck Restoration & Waterproofing New Circle Road Bridges
Date Let: 04-19-13 Call: 426 County: Fayette District: 07
Bridge Number: 034B00031R Overlay Area: 7,103 ft^2 (659.9 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	118,720.50	16.71 (179.86)
Bidder 2	119,089.00	16.77 (180.51)
Bidder 3	129,482.00	18.23 (196.23)
Bidder 4	134,504.50	18.94 (203.87)

Bridge Deck Restoration & Waterproofing Bridge over Levisa Fork of Big Sandy
Date Let: 05-24-13 Call: 369 County: Floyd District: 12
Bridge Number: 036B00038L Overlay Area: 15,390 ft^2 (1,429.8 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	149,266.80	9.70 (104.41)
Bidder 2	118,243.50	7.68 (82.67)
Bidder 3	170,171.50	11.06 (119.05)
Bidder 4	208,984.80	13.58 (146.17)
Bidder 5	222,013.20	14.43 (155.32)
Bidder 6	219,462.40	14.26 (153.49)

Bridge Deck Restoration & Waterproofing Bridge over Levisa Fork of Big Sandy
Date Let: 05-24-13 Call: 369 County: Floyd District: 12
Bridge Number: 036B00038R Overlay Area: 15,390 ft^2 (1,429.8 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	149,266.80	9.70 (104.41)
Bidder 2	118,243.50	7.68 (82.67)
Bidder 3	170,171.50	11.06 (119.05)
Bidder 4	208,984.80	13.58 (146.17)
Bidder 5	222,013.20	14.43 (155.32)
Bidder 6	219,462.40	14.26 (153.49)

Bridge Deck Overlay KY 838 Crittenden and Livingston Countys
Date Let: 05-24-13 Call: 406 County: Various District: 01
Bridge Number: 028B00047N Overlay Area: 2,520 ft^2 (234.1 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	78,950.00	31.33 (337.23)
Bidder 2	62,225.00	24.69 (265.76)
Bidder 3	72,210.00	28.65 (308.38)
Bidder 4	78,150.00	31.01 (333.79)
Bidder 5	100,150.00	39.74 (427.76)

Bridge Deck Overlay KY 838 Crittenden and Livingston Countys
Date Let: 05-24-13 Call: 406 County: Various District: 01
Bridge Number: 028B00048N Overlay Area: 2,160 ft^2 (200.7 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	69,325.00	32.09 (345.41)
Bidder 2	55,950.00	25.90 (278.78)
Bidder 3	64,730.00	29.97 (322.59)
Bidder 4	70,345.00	32.57 (350.58)
Bidder 5	87,790.00	40.64 (437.44)

Bridge Deck Overlay KY 838 Crittenden and Livingston Countys
Date Let: 05-24-13 Call: 406 County: Various District: 01
Bridge Number: 070B00058N Overlay Area: 2,520 ft^2 (234.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	78,950.00	31.33 (337.23)
Bidder 2	62,225.00	24.69 (265.76)
Bidder 3	72,210.00	28.65 (308.38)
Bidder 4	78,150.00	31.01 (333.79)
Bidder 5	100,150.00	39.74 (427.76)

Bridge Deck Restoration & Waterproofing KY 80 over KY 9006
Date Let: 05-24-13 Call: 420 County: Clay District: 11
Bridge Number: 026B00061N Overlay Area: 15,308 ft^2 (1,422.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	190,382.00	12.44 (133.90)
Bidder 2	206,123.20	13.47 (144.99)
Bidder 3	208,883.00	13.65 (146.93)
Bidder 4	248,457.90	16.23 (174.70)
Bidder 5	235,408.00	15.38 (165.55)
Bidder 6	200,501.00	13.10 (141.01)
Bidder 7	231,608.00	15.13 (162.86)

Bridge Deck Restoration & Waterproofing KY 80 over KY 9006
Date Let: 05-24-13 Call: 420 County: Clay District: 11
Bridge Number: 026B00067N Overlay Area: 5,940 ft^2 (551.8 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	76,706.00	12.91 (138.96)
Bidder 2	79,218.90	13.34 (143.59)
Bidder 3	80,648.00	13.58 (146.17)
Bidder 4	102,467.90	17.25 (185.68)
Bidder 5	91,280.00	15.37 (165.44)
Bidder 6	78,866.50	13.28 (142.94)
Bidder 7	92,652.50	15.60 (167.92)

Bridge Deck Restoration & Waterproofing Bridges over I-64
Date Let: 06-14-13 Call: 201 County: Bath District: 09
Bridge Number: 006B00017N Overlay Area: 8,040 ft^2 (746.9 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	71,136.00	8.85 (95.26)
Bidder 2	75,540.00	9.40 (101.18)
Bidder 3	92,251.00	11.47 (123.46)
Bidder 4	55,350.00	6.88 (74.06)
Bidder 5	80,700.00	10.04 (108.07)
Bidder 6	120,887.60	15.04 (161.89)
Bidder 7	123,906.00	15.41 (165.87)
Bidder 8	115,592.00	14.38 (154.78)
Bidder 9	115,640.00	14.38 (154.78)

Bridge Deck Restoration & Waterproofing Bridges over I-64
Date Let: 06-14-13 Call: 201 County: Bath District: 09
Bridge Number: 006B00042N Overlay Area: 8,528 ft^2 (792.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	110,282.50	12.93 (139.18)
Bidder 2	107,992.00	12.66 (136.27)
Bidder 3	144,802.80	16.98 (182.77)
Bidder 4	93,457.00	10.96 (117.97)
Bidder 5	118,890.50	13.94 (150.05)
Bidder 6	176,764.46	20.73 (223.13)
Bidder 7	188,213.00	22.07 (237.56)
Bidder 8	177,563.50	20.82 (224.10)
Bidder 9	221,990.00	26.03 (280.18)

Bridge Deck Restoration & Waterproofing Bridges over I-64
Date Let: 06-14-13 Call: 201 County: Bath District: 09
Bridge Number: 103B00029N Overlay Area: 8,658 ft^2 (804.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	88,174.50	10.18 (109.58)
Bidder 2	88,090.50	10.17 (109.47)
Bidder 3	115,304.70	13.32 (143.37)
Bidder 4	75,838.00	8.76 (94.29)
Bidder 5	96,648.50	11.16 (120.12)
Bidder 6	143,742.58	16.60 (178.68)
Bidder 7	149,040.00	17.21 (185.25)
Bidder 8	141,916.00	16.39 (176.42)
Bidder 9	175,412.50	20.26 (218.08)

Bridge Deck Restoration & Waterproofing I-64 Bridges
Date Let: 08-16-13 Call: 201 County: Franklin District: 05
Bridge Number: 037B00055L Overlay Area: 4,770 ft^2 (443.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	173,197.50	36.31 (390.84)
Bidder 2	148,853.00	31.21 (335.94)
Bidder 3	159,960.00	33.53 (360.91)
Bidder 4	164,700.00	34.53 (371.68)
Bidder 5	95,620.00	20.05 (215.82)

Bridge Deck Restoration & Waterproofing I-64 Bridges
Date Let: 08-16-13 Call: 201 County: Franklin District: 05
Bridge Number: 037B00055R Overlay Area: 4,700 ft^2 (436.6 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	173,197.50	36.31 (390.84)
Bidder 2	148,853.00	31.21 (335.94)
Bidder 3	159,960.00	33.53 (360.91)
Bidder 4	164,700.00	34.53 (371.68)
Bidder 5	95,620.00	20.05 (215.82)

Bridge Deck Restoration & Waterproofing I-64 Bridges
Date Let: 08-16-13 Call: 201 County: Franklin District: 05
Bridge Number: 037B00056L Overlay Area: 4,500 ft^2 (418.1 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	163,535.00	36.34 (391.16)
Bidder 2	140,550.00	31.23 (336.16)
Bidder 3	151,070.00	33.57 (361.34)
Bidder 4	155,500.00	34.56 (372.00)
Bidder 5	90,280.00	20.06 (215.92)

Bridge Deck Restoration & Waterproofing I-64 Bridges
Date Let: 08-16-13 Call: 201 County: Franklin District: 05
Bridge Number: 106B00059L Overlay Area: 6,780 ft^2 (629.9 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	246,410.75	36.34 (391.16)
Bidder 2	211,795.30	31.24 (336.26)
Bidder 3	227,660.00	33.58 (361.45)
Bidder 4	234,310.00	34.56 (372.00)
Bidder 5	136,050.00	20.07 (216.03)

Bridge Deck Restoration & Waterproofing Robertson County KY 165 and KY 616
Date Let: 08-16-13 Call: 410 County: Robertson District: 06
Bridge Number: 101B00009N Overlay Area: 7,560 ft^2 (702.3 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	101,846.00	13.47 (144.99)
Bidder 2	102,990.00	13.62 (146.60)
Bidder 3	108,271.00	14.32 (154.14)
Bidder 4	101,165.00	13.38 (144.02)
Bidder 5	122,425.00	16.19 (174.27)
Bidder 6	141,524.00	18.72 (201.50)
Bidder 7	163,096.00	21.57 (232.18)

Bridge Deck Overlay Boone County KY 8 and KY 536--Gallatin County KY 35
Date Let: 08-16-13 Call: 430 County: Various District: 06
Bridge Number: 008B00036N Overlay Area: 4,920 ft^2 (457.1 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	59,935.00	12.18 (131.10)
Bidder 2	50,680.00	10.30 (110.87)
Bidder 3	63,317.50	12.87 (138.53)
Bidder 4	76,690.00	15.59 (167.81)
Bidder 5	84,872.50	17.25 (185.68)
Bidder 6	82,230.00	16.71 (179.86)

Bridge Deck Overlay Boone County KY 8 and KY 536--Gallatin County KY 35
Date Let: 08-16-13 Call: 430 County: Various District: 06
Bridge Number: 039B00010N Overlay Area: 11,200 ft^2 (1,040.5 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	116,584.00	10.41 (112.05)
Bidder 2	123,600.00	11.04 (118.83)
Bidder 3	124,038.60	11.07 (119.16)
Bidder 4	131,568.00	11.75 (126.48)
Bidder 5	150,274.00	13.42 (144.45)
Bidder 6	197,455.00	17.63 (189.77)

Bridge Deck Overlay Boone County KY 8 and KY 536--Gallatin County KY 35
Date Let: 08-16-13 Call: 430 County: Various District: 06
Bridge Number: 008B00021N Overlay Area: 9,540 ft^2 (886.3 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	117,875.00	12.36 (133.04)
Bidder 2	107,410.00	11.26 (121.20)
Bidder 3	136,392.50	14.30 (153.92)
Bidder 4	154,390.00	16.18 (174.16)
Bidder 5	167,007.50	17.51 (188.48)
Bidder 6	166,270.00	17.43 (187.61)

Bridge Deck Overlay Outerloop (KY 1065)
Date Let: 09-27-13 Call: 311 County: Jefferson District: 05
Bridge Number: 056B00290N Overlay Area: 54,578 ft^2 (5,070.5 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	542,275.50	9.94 (106.99)
Bidder 2	531,847.00	9.74 (104.84)
Bidder 3	458,843.00	8.41 (90.52)
Bidder 4	555,711.00	10.18 (109.58)
Bidder 5	573,765.00	10.51 (113.13)
Bidder 6	508,018.00	9.31 (100.21)
Bidder 7	575,630.00	10.55 (113.56)
Bidder 8	694,372.00	12.72 (136.92)

Bridge Deck Restoration & Waterproofing KY 1773 Bridge over Grassy Creek
Date Let: 09-27-13 Call: 320 County: Carter District: 09
Bridge Number: 022B00135N Overlay Area: 3,784 ft^2 (351.5 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	100,185.00	26.48 (285.03)
Bidder 2	114,988.00	30.39 (327.11)
Bidder 3	128,957.00	34.08 (366.83)

Bridge Deck Restoration & Waterproofing KY 386 Bridge over McBride Creek
Date Let: 09-27-13 Call: 322 County: Nicholas District: 09
Bridge Number: 091B00033N Overlay Area: 2,178 ft^2 (202.3 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	56,052.80	25.74 (277.06)
Bidder 2	89,783.80	41.22 (443.69)

Bridge Deck Restoration & Waterproofing KY 699 Bridge over Leatherwood Creek
Date Let: 09-27-13 Call: 323 County: Perry District: 10
Bridge Number: 097B00045N Overlay Area: 2,904 ft^2 (269.8 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	93,368.00	32.15 (346.06)
Bidder 2	115,983.70	39.94 (429.91)
Bidder 3	127,867.00	44.03 (473.93)
Bidder 4	128,447.00	44.23 (476.09)

Bridge Deck Restoration & Waterproofing Henderson County KY 285
Date Let: 10-25-13 Call: 301 County: Henderson District: 02
Bridge Number: 051B00029N Overlay Area: 2,772 ft^2 (257.5 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	67,190.00	24.24 (260.92)
Bidder 2	74,022.00	26.70 (287.40)
Bidder 3	92,995.00	33.55 (361.13)
Bidder 4	107,180.00	38.67 (416.24)
Bidder 5	77,116.00	27.82 (299.45)
Bidder 6	118,650.00	42.80 (460.69)

Bridge Deck Restoration & Waterproofing Ohio County KY 1245
Date Let: 10-25-13 Call: 304 County: Ohio District: 02
Bridge Number: 092B00112N Overlay Area: 7,332 ft^2 (681.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	89,627.50	12.22 (131.53)
Bidder 2	104,580.50	14.26 (153.49)
Bidder 3	112,245.00	15.31 (164.79)
Bidder 4	130,044.50	17.74 (190.95)
Bidder 5	118,889.00	16.22 (174.59)
Bidder 6	148,890.00	20.31 (218.61)

Bridge Deck Restoration & Waterproofing Union County KY 359
Date Let: 10-25-13 Call: 321 County: Union District: 02
Bridge Number: 092B00112N Overlay Area: 6,248 ft^2 (580.5 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	85,264.00	13.65 (146.93)
Bidder 2	93,633.00	14.99 (161.35)
Bidder 3	109,429.00	17.51 (188.48)
Bidder 4	113,342.00	18.14 (195.26)

Bridge Deck Restoration & Waterproofing Davies County KY 3143, KY 554 and US 431
Date Let: 10-25-13 Call: 400 County: Daviess District: 02
Bridge Number: 030B00115N Overlay Area: 2,736 ft^2 (254.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	45,263.00	16.54 (178.03)
Bidder 2	45,761.00	16.73 (180.08)
Bidder 3	50,896.00	18.60 (200.21)
Bidder 4	57,810.50	21.13 (227.44)
Bidder 5	69,201.50	25.29 (272.22)
Bidder 6	63,418.00	23.18 (249.51)
Bidder 7	71,670.00	26.20 (282.01)
Bidder 8	81,814.00	29.90 (321.84)

Bridge Deck Restoration & Waterproofing Davies County KY 3143, KY 554 and US 431
Date Let: 10-25-13 Call: 400 County: Daviess District: 02
Bridge Number: 030B00084N Overlay Area: 6,750 ft^2 (627.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	100,530.00	14.89 (160.27)
Bidder 2	106,334.00	15.75 (169.53)
Bidder 3	116,358.00	17.24 (185.57)
Bidder 4	124,393.00	18.43 (198.38)
Bidder 5	145,747.00	21.59 (232.39)
Bidder 6	137,887.00	20.43 (219.91)
Bidder 7	165,306.00	24.49 (263.61)
Bidder 8	186,606.00	27.65 (297.62)

Bridge Deck Restoration & Waterproofing Davies County KY 3143, KY 554 and US 431
Date Let: 10-25-13 Call: 400 County: Daviess District: 02
Bridge Number: 030B00048N Overlay Area: 4,400 ft^2 (408.8 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	63,089.00	14.34 (154.35)
Bidder 2	61,265.00	13.92 (149.83)
Bidder 3	75,698.00	17.20 (185.14)
Bidder 4	85,617.50	19.46 (209.46)
Bidder 5	102,584.50	23.31 (250.91)
Bidder 6	91,180.00	20.72 (223.03)
Bidder 7	108,938.00	24.76 (266.51)
Bidder 8	119,155.00	27.08 (291.49)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Powell County
Date Let: 10-25-13 Call: 404 County: Powell District: 10
Bridge Number: 099B00009R Overlay Area: 4,770 ft^2 (443.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	44,413.50	9.31 (100.21)
Bidder 2	66,670.50	13.98 (150.48)
Bidder 3	69,943.00	14.66 (157.80)
Bidder 4	78,126.00	16.38 (176.31)
Bidder 5	76,864.00	16.10 (173.41)
Bidder 6	79,103.00	16.58 (178.46)
Bidder 7	73,981.00	15.51 (166.95)
Bidder 8	108,884.00	22.83 (245.74)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Powell County
Date Let: 10-25-13 Call: 404 County: Powell District: 10
Bridge Number: 099B00017N Overlay Area: 4,246 ft^2 (394.5 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	45,292.50	10.67 (114.85)
Bidder 2	65,107.50	15.33 (165.01)
Bidder 3	71,434.00	16.82 (181.05)
Bidder 4	80,256.00	18.90 (203.44)
Bidder 5	79,872.00	18.81 (202.47)
Bidder 6	81,702.00	19.24 (207.10)
Bidder 7	95,541.00	22.50 (242.19)
Bidder 8	115,169.00	27.12 (291.92)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Powell County
Date Let: 10-25-13 Call: 404 County: Powell District: 10
Bridge Number: 099B00042N Overlay Area: 6,240 ft^2 (579.7 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	62,524.50	10.02 (107.85)
Bidder 2	92,035.50	14.75 (158.77)
Bidder 3	96,098.80	15.40 (165.76)
Bidder 4	108,950.00	17.46 (187.94)
Bidder 5	110,808.00	17.76 (191.17)
Bidder 6	114,449.00	18.34 (197.41)
Bidder 7	134,451.00	21.55 (231.96)
Bidder 8	153,515.40	24.60 (264.79)

Bridge Deck Restoration & Waterproofing District 9 Bridge Overlays
Date Let: 10-25-13 Call: 406 County: Various District: 09
Bridge Number: 022B00106N Overlay Area: 5,760 ft^2 (535.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	99,885.00	17.34 (186.65)
Bidder 2	97,942.00	17.00 (182.99)
Bidder 3	106,405.00	18.47 (198.81)
Bidder 4	105,610.00	18.34 (197.41)
Bidder 5	119,840.00	20.81 (224.00)
Bidder 6	105,330.00	18.29 (196.87)
Bidder 7	106,980.00	18.57 (199.89)

Bridge Deck Restoration & Waterproofing District 9 Bridge Overlays
Date Let: 10-25-13 Call: 406 County: Various District: 09
Bridge Number: 068B00030N Overlay Area: 3,612 ft^2 (335.6 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	66,413.00	18.39 (197.95)
Bidder 2	66,421.00	18.39 (197.95)
Bidder 3	71,770.00	19.87 (213.88)
Bidder 4	69,175.00	19.15 (206.13)
Bidder 5	81,799.00	22.65 (243.80)
Bidder 6	72,646.00	20.11 (216.46)
Bidder 7	70,244.00	19.45 (209.36)

Bridge Deck Restoration & Waterproofing District 9 Bridge Overlays
Date Let: 10-25-13 Call: 406 County: Various District: 09
Bridge Number: 068B00031N Overlay Area: 5,200 ft^2 (483.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	86,947.00	16.72 (179.97)
Bidder 2	83,524.00	16.06 (172.87)
Bidder 3	92,695.00	17.83 (191.92)
Bidder 4	91,120.00	17.52 (188.58)
Bidder 5	101,727.00	19.56 (210.54)
Bidder 6	91,656.00	17.63 (189.77)
Bidder 7	92,264.00	17.74 (190.95)

Bridge Deck Restoration & Waterproofing District 9 Bridge Overlays
Date Let: 10-25-13 Call: 406 County: Various District: 09
Bridge Number: 091B00035N Overlay Area: 3,840 ft^2 (356.7 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	71,089.00	18.51 (199.24)
Bidder 2	72,163.00	18.79 (202.25)
Bidder 3	76,540.00	19.93 (214.52)
Bidder 4	73,570.00	19.16 (206.24)
Bidder 5	87,792.00	22.86 (246.06)
Bidder 6	78,320.00	20.40 (219.58)
Bidder 7	75,142.00	19.57 (210.65)

Bridge Deck Restoration & Waterproofing Bluegrass Parkway
Date Let: 11-22-13 Call: 304 County: Nelson District: 04
Bridge Number: 090B00017L Overlay Area: 4,180 ft^2 (388.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	75,600.50	18.09 (194.72)
Bidder 2	80,099.00	19.16 (206.24)
Bidder 3	81,242.00	19.44 (209.25)
Bidder 4	83,138.00	19.89 (214.09)
Bidder 5	55,643.00	13.31 (143.27)
Bidder 6	74,313.00	17.78 (191.38)
Bidder 7	77,967.00	18.65 (200.75)
Bidder 8	84,885.00	20.31 (218.61)

Bridge Deck Restoration & Waterproofing Bluegrass Parkway
Date Let: 11-22-13 Call: 304 County: Nelson District: 04
Bridge Number: 090B00017R Overlay Area: 4,180 ft^2 (388.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	75,600.50	18.09 (194.72)
Bidder 2	80,099.00	19.16 (206.24)
Bidder 3	81,242.00	19.44 (209.25)
Bidder 4	83,138.00	19.89 (214.09)
Bidder 5	55,643.00	13.31 (143.27)
Bidder 6	74,313.00	17.78 (191.38)
Bidder 7	77,967.00	18.65 (200.75)
Bidder 8	84,885.00	20.31 (218.61)

Bridge Deck Restoration & Waterproofing District 10 Bridge Overlays
Date Let: 11-22-13 Call: 406 County: Various District: 10
Bridge Number: 013B00026N Overlay Area: 990 ft^2 (92.0 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	43,878.80	44.32 (477.05)
Bidder 2	48,699.20	49.19 (529.47)
Bidder 3	38,193.00	38.58 (415.27)
Bidder 4	46,453.00	46.92 (505.04)
Bidder 5	40,766.60	41.18 (443.26)
Bidder 6	55,335.00	55.89 (601.59)

Bridge Deck Restoration & Waterproofing District 10 Bridge Overlays
Date Let: 11-22-13 Call: 406 County: Various District: 10
Bridge Number: 077B00026N Overlay Area: 2,640 ft^2 (245.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	66,095.20	25.04 (269.53)
Bidder 2	70,418.70	26.67 (287.07)
Bidder 3	60,558.00	22.94 (246.92)
Bidder 4	71,736.00	27.17 (292.45)
Bidder 5	73,462.90	27.83 (299.56)
Bidder 6	80,190.00	30.38 (327.01)

Bridge Deck Restoration & Waterproofing District 10 Bridge Overlays
Date Let: 11-22-13 Call: 406 County: Various District: 10
Bridge Number: 088B00042N Overlay Area: 5,580 ft^2 (518.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	103,268.50	18.51 (199.24)
Bidder 2	103,758.20	18.59 (200.10)
Bidder 3	97,296.00	17.44 (187.72)
Bidder 4	110,341.50	19.77 (212.80)
Bidder 5	116,521.00	20.88 (224.75)
Bidder 6	126,000.00	22.58 (243.05)

Bridge Deck Restoration & Waterproofing District 10 Bridge Overlays
Date Let: 11-22-13 Call: 406 County: Various District: 10
Bridge Number: 097B00036N Overlay Area: 2,574 ft^2 (239.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	70,449.00	27.37 (294.61)
Bidder 2	71,260.10	27.68 (297.94)
Bidder 3	72,633.00	28.22 (303.76)
Bidder 4	68,254.50	26.52 (285.46)
Bidder 5	86,026.50	33.42 (359.73)
Bidder 6	87,525.00	34.00 (365.97)

Bridge Deck Restoration & Waterproofing Warren County KY 185
Date Let: 12-13-13 Call: 303 County: Warren District: 03
Bridge Number: 114B00003N Overlay Area: 17,440 ft^2 (1,620.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	152,990.00	8.77 (94.40)
Bidder 2	205,218.00	11.77 (126.69)
Bidder 3	194,020.00	11.13 (119.80)
Bidder 4	222,468.00	12.76 (137.35)
Bidder 5	237,557.00	13.62 (146.60)
Bidder 6	251,700.00	14.43 (155.32)
Bidder 7	301,906.00	17.31 (186.32)

Bridge Deck Restoration & Waterproofing District 4 Bridge Overlays
Date Let: 12-13-13 Call: 401 County: Various District: 04
Bridge Number: 078B00038N Overlay Area: 5,082 ft^2 (472.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	82,059.00	16.15 (173.84)
Bidder 2	85,860.00	16.89 (181.80)
Bidder 3	92,283.00	18.16 (195.47)
Bidder 4	100,722.00	19.82 (213.34)
Bidder 5	45,562.00	8.97 (96.55)
Bidder 6	96,307.00	18.95 (203.98)
Bidder 7	100,110.00	19.70 (212.05)

Bridge Deck Restoration & Waterproofing District 4 Bridge Overlays
Date Let: 12-13-13 Call: 401 County: Various District: 04
Bridge Number: 109B00004N Overlay Area: 858 ft^2 (79.7 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	25,458.90	29.67 (319.36)
Bidder 2	33,722.40	39.30 (423.02)
Bidder 3	29,520.70	34.41 (370.38)
Bidder 4	37,274.20	43.44 (467.58)
Bidder 5	23,974.00	27.94 (300.74)
Bidder 6	42,173.50	49.15 (529.04)
Bidder 7	36,641.00	42.71 (459.72)

Bridge Deck Restoration & Waterproofing District 4 Bridge Overlays
Date Let: 12-13-13 Call: 401 County: Various District: 04
Bridge Number: 109B00025N Overlay Area: 3,096 ft^2 (287.6 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	61,216.00	19.77 (212.80)
Bidder 2	64,897.00	20.96 (225.61)
Bidder 3	68,126.00	22.00 (236.81)
Bidder 4	75,872.00	24.51 (263.82)
Bidder 5	35,450.00	11.45 (123.25)
Bidder 6	83,568.00	26.99 (290.52)
Bidder 7	87,670.00	28.32 (304.83)

Bridge Deck Restoration & Waterproofing Bridge over Culp Creek Rd
Date Let: 04-25-14 Call: 328 County: Greenup District: 09
Bridge Number: 045B00077N Overlay Area: 11,328 ft^2 (1,052.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	164,093.00	14.49 (155.97)
Bidder 2	171,420.50	15.13 (162.86)
Bidder 3	172,398.00	15.22 (163.83)
Bidder 4	205,479.00	18.14 (195.26)
Bidder 5	235,419.00	20.78 (223.67)

Bridge Deck Restoration & Waterproofing US 31E
Date Let: 04-25-14 Call: 329 County: Nelson District: 04
Bridge Number: 090B00044N Overlay Area: 6,390 ft^2 (593.7 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	93,112.80	14.57 (156.83)
Bidder 2	123,845.80	19.38 (208.60)
Bidder 3	126,313.08	19.77 (212.80)
Bidder 4	107,798.00	16.87 (181.59)

Bridge Deck Restoration & Waterproofing Fleming County Bridge Overlays
Date Let: 04-25-14 Call: 403 County: Fleming District: 09
Bridge Number: 035B00022N Overlay Area: 5,040 ft^2 (468.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	53,587.10	10.63 (114.42)
Bidder 2	62,480.60	12.40 (133.47)
Bidder 3	81,521.53	16.17 (174.05)
Bidder 4	74,219.50	14.73 (158.55)
Bidder 5	89,191.00	17.70 (190.52)

Bridge Deck Restoration & Waterproofing Fleming County Bridge Overlays
Date Let: 04-25-14 Call: 403 County: Fleming District: 09
Bridge Number: 035B00025N Overlay Area: 4,200 ft^2 (390.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	45,100.50	10.74 (115.60)
Bidder 2	53,160.00	12.66 (136.27)
Bidder 3	69,058.57	16.44 (176.96)
Bidder 4	63,098.50	15.02 (161.67)
Bidder 5	75,645.00	18.01 (193.86

Bridge Deck Restoration & Waterproofing Davies County
Date Let: 05-30-14 Call: 352 County: Daviess District: 02
Bridge Number: 030B00069R Overlay Area: 8,635 ft^2 (802.2 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	130,874.00	15.16 (163.18)
Bidder 2	191,254.00	22.15 (238.42)
Bidder 3	170,172.00	19.71 (212.16)
Bidder 4	208,061.00	24.10 (259.41)
Bidder 5	183,927.00	21.30 (229.27)
Bidder 6	185,470.00	21.48 (231.21)

Bridge Deck Restoration & Waterproofing Hopkins
Date Let: 05-30-14 Call: 353 County: Hopkins District: 02
Bridge Number: 054B00014L Overlay Area: 5,966 ft^2 (554.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	75,190.00	12.60 (135.62)
Bidder 2	95,654.00	16.03 (172.54)
Bidder 3	97,488.00	16.34 (175.88)
Bidder 4	103,324.50	17.32 (186.43)
Bidder 5	112,621.00	18.88 (203.22)
Bidder 6	114,708.00	19.23 (206.99)

Bridge Deck Restoration & Waterproofing Hopkins
Date Let: 05-30-14 Call: 353 County: Hopkins District: 02
Bridge Number: 054B00014R Overlay Area: 5,966 ft^2 (554.3 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	73,822.85	12.37 (133.15)
Bidder 2	95,654.00	16.03 (172.54)
Bidder 3	97,388.00	16.32 (175.67)
Bidder 4	103,324.50	17.32 (186.43)
Bidder 5	112,621.00	18.88 (203.22)
Bidder 6	110,908.00	18.59 (200.10)

Bridge Deck Restoration & Waterproofing Bridge over Licking River
Date Let: 05-30-14 Call: 354 County: Morgan District: 10
Bridge Number: 088B00070N Overlay Area: 11,592 ft^2 (1,076.9 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	144,884.00	12.50 (134.55)
Bidder 2	179,175.00	15.46 (166.41)
Bidder 3	189,522.00	16.35 (175.99)
Bidder 4	167,753.50	14.47 (155.75)
Bidder 5	232,763.00	20.08 (216.14)
Bidder 6	201,475.00	17.38 (187.08)

Bridge Deck Restoration & Waterproofing Bridge over Middle Fork of Red River
Date Let: 05-30-14 Call: 355 County: Powell District: 10
Bridge Number: 099B00011L Overlay Area: 6,210 ft^2 (576.9 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	78,533.00	12.65 (136.16)
Bidder 2	100,762.00	16.23 (174.70)
Bidder 3	84,875.00	13.67 (147.14)
Bidder 4	77,810.00	12.53 (134.87)
Bidder 5	105,507.50	16.99 (182.88)

Bridge Deck Restoration & Waterproofing KY 114 Overlays
Date Let: 05-30-14 Call: 440 County: Floyd District: 12
Bridge Number: 036B00021N Overlay Area: 5,016 ft^2 (466.0 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	90,262.75	17.99 (193.64)
Bidder 2	101,227.40	20.18 (217.21)
Bidder 3	95,070.00	18.95 (203.98)
Bidder 4	94,805.00	18.90 (203.44)
Bidder 5	91,467.00	18.24 (196.33)

Bridge Deck Restoration & Waterproofing KY 114 Overlays
Date Let: 05-30-14 Call: 440 County: Floyd District: 12
Bridge Number: 036B00022N Overlay Area: 4,770 ft^2 (443.1 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	86,767.75	18.19 (195.79)
Bidder 2	96,766.80	20.29 (218.40)
Bidder 3	91,209.00	19.12 (205.81)
Bidder 4	90,670.50	19.01 (204.62)
Bidder 5	87,413.50	18.33 (197.30)

Bridge Deck Restoration & Waterproofing Davies County US 231
Date Let: 05-30-14 Call: 444 County: Daviess District: 02
Bridge Number: 030B00034N Overlay Area: 3,960 ft^2 (367.9 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	68,322.50	17.25 (185.68)
Bidder 2	85,820.00	21.67 (233.25)
Bidder 3	85,820.00	21.67 (233.25)
Bidder 4	80,680.00	20.37 (219.26)
Bidder 5	96,720.00	24.42 (262.85)
Bidder 6	94,525.00	23.87 (256.93)
Bidder 7	88,120.00	22.25 (239.50)

Bridge Deck Restoration & Waterproofing Davies County US 231
Date Let: 05-30-14 Call: 444 County: Daviess District: 02
Bridge Number: 030B00033N Overlay Area: 4,440 ft^2 (412.5 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	75,625.50	17.03 (183.31)
Bidder 2	95,732.00	21.56 (232.07)
Bidder 3	91,187.00	20.54 (221.09)
Bidder 4	89,693.00	20.20 (217.43)
Bidder 5	107,340.75	24.18 (260.27)
Bidder 6	104,505.75	23.54 (253.38)
Bidder 7	97,606.00	21.98 (236.59)

Bridge Deck Restoration & Waterproofing Davies County US 231
Date Let: 05-30-14 Call: 444 County: Daviess District: 02
Bridge Number: 030B00032N Overlay Area: 3,960 ft^2 (367.9 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	64,360.00	16.25 (174.91)
Bidder 2	85,820.00	21.67 (233.25)
Bidder 3	80,690.00	20.38 (219.37)
Bidder 4	80,680.00	20.37 (219.26)
Bidder 5	95,920.00	24.22 (260.70)
Bidder 6	92,790.00	23.43 (252.20)
Bidder 7	88,120.00	22.25 (239.50)

Bridge Deck Restoration & Waterproofing Ballard County
Date Let: 05-30-14 Call: 445 County: Ballard District: 01
Bridge Number: 004B00032N Overlay Area: 3,960 ft^2 (367.9 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	83,937.00	21.20 (228.19)
Bidder 2	88,775.00	22.42 (241.33)
Bidder 3	105,725.00	26.70 (287.40)
Bidder 4	135,006.00	34.09 (366.94)
Bidder 5	110,117.00	27.81 (299.34)

Bridge Deck Restoration & Waterproofing Ballard County
Date Let: 05-30-14 Call: 445 County: Ballard District: 01
Bridge Number: 004B00051N Overlay Area: 2,376 ft^2 (220.7 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	52,165.00	21.95 (236.27)
Bidder 2	56,820.00	23.91 (257.36)
Bidder 3	66,775.00	28.10 (302.46)
Bidder 4	83,547.00	35.16 (378.46)
Bidder 5	82,742.00	34.82 (374.80)

Bridge Deck Restoration & Waterproofing Ballard County
Date Let: 05-30-14 Call: 445 County: Ballard District: 01
Bridge Number: 004B00050N Overlay Area: 2,376 ft^2 (220.7 m^2)

	Total Deck Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	53,013.00	22.31 (240.14)
Bidder 2	54,480.00	22.93 (246.82)
Bidder 3	67,405.00	28.37 (305.37)
Bidder 4	82,833.00	34.86 (375.23)
Bidder 5	91,590.00	38.55 (414.95)

Bridge Deck Restoration & Waterproofing Bridges over Mountain Parkway
Date Let: 05-30-14 Call: 446 County: Powell District: 10
Bridge Number: 099B00033N Overlay Area: 10,436 ft^2 (969.5 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	170,896.00	16.38 (176.31)
Bidder 2	160,302.00	15.36 (165.33)
Bidder 3	177,654.60	17.02 (183.20)
Bidder 4	180,838.00	17.33 (186.54)
Bidder 5	158,673.80	15.20 (163.61)

Bridge Deck Restoration & Waterproofing Bridges over Mountain Parkway
Date Let: 05-30-14 Call: 446 County: Powell District: 10
Bridge Number: 119B00019N Overlay Area: 8,288 ft^2 (770.0 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	122,440.00	14.77 (158.98)
Bidder 2	107,510.00	12.97 (139.61)
Bidder 3	124,245.00	14.99 (161.35)
Bidder 4	102,130.00	12.32 (132.61)
Bidder 5	116,345.00	14.04 (151.12)

Bridge Deck Restoration & Waterproofing Bridge over Wilson Creek
Date Let: 06-27-14 Call: 316 County: Nelson District: 04
Bridge Number: 090B00062N Overlay Area: 6,150 ft^2 (571.4 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	59,893.00	9.74 (104.84)
Bidder 2	94,819.00	15.42 (165.98)
Bidder 3	87,856.00	14.29 (153.82)
Bidder 4	90,041.00	14.64 (157.58)
Bidder 5	123,084.00	20.01 (215.39)

Bridge Deck Restoration & Waterproofing Interstate 64
Date Let: 07-11-14 Call: 100 County: Franklin District: 05
Bridge Number: 037B00057L Overlay Area: 4,770 ft^2 (443.1 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	148,480.00	31.13 (335.08)
Bidder 2	160,300.00	33.61 (361.77)
Bidder 3	166,570.00	34.92 (375.87)
Bidder 4	148,130.00	31.05 (334.22)
Bidder 5	152,080.00	31.88 (343.15)

Bridge Deck Restoration & Waterproofing Interstate 64
Date Let: 07-11-14 Call: 100 County: Franklin District: 05
Bridge Number: 037B00057R Overlay Area: 4,770 ft^2 (443.1 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2$ ($/m^2$)
Bidder 1	148,480.00	31.13 (335.08)
Bidder 2	160,300.00	33.61 (361.77)
Bidder 3	166,570.00	34.92 (375.87)
Bidder 4	148,130.00	31.05 (334.22)
Bidder 5	152,080.00	31.88 (343.15)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Harlan County
Date Let: 08-22-14 Call: 435 County: Harlan District: 11
Bridge Number: 048B00065N Overlay Area: 13,830 ft^2 (1,284.9 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	202,984.50	14.68 (158.01)
Bidder 2	191,187.00	13.82 (148.76)
Bidder 3	195,393.50	14.13 (152.09)
Bidder 4	201,785.00	14.59 (157.04)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Harlan County
Date Let: 08-22-14 Call: 435 County: Harlan District: 11
Bridge Number: 048B00147N Overlay Area: 9,152 ft^2 (850.3 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	122,432.00	13.38 (144.02)
Bidder 2	107,691.50	11.77 (126.69)
Bidder 3	139,840.00	15.28 (164.47)
Bidder 4	117,290.00	12.82 (137.99)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Harlan County
Date Let: 08-22-14 Call: 435 County: Harlan District: 11
Bridge Number: 048B00129N Overlay Area: 7,520 ft^2 (698.6 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	126,851.60	16.87 (181.59)
Bidder 2	121,111.40	16.11 (173.41)
Bidder 3	120,557.00	16.03 (172.54)
Bidder 4	122,410.00	16.28 (175.24)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Perry County
Date Let: 08-22-14 Call: 445 County: Perry District: 10
Bridge Number: 097B00042N Overlay Area: 6,986 ft^2 (649.0 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	192,580.60	27.57 (296.76)
Bidder 2	188,308.00	26.96 (290.19)
Bidder 3	180,060.50	25.77 (277.38)
Bidder 4	262,902.50	37.63 (405.04)
Bidder 5	170,101.20	24.35 (262.10)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Perry County
Date Let: 08-22-14 Call: 445 County: Perry District: 10
Bridge Number: 097B00089N Overlay Area: 20,672 ft^2 (1,920.5 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	271,794.50	13.15 (141.54)
Bidder 2	274,015.00	13.26 (142.73)
Bidder 3	294,015.00	14.22 (153.06)
Bidder 4	306,895.00	14.85 (159.84)
Bidder 5	282,292.00	13.66 (147.03)

Bridge Deck Restoration & Waterproofing Bridge over Ohio River
Date Let: 09-26-14 Call: 100 County: Boone District: 06
Bridge Number: 008B00052N Overlay Area: 242,904 ft^2 (22,566.6 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	1,751,140.00	7.21 (77.61)
Bidder 2	2,383,350.00	9.81 (105.59)
Bidder 3	2,202,850.00	9.07 (97.63)
Bidder 4	2,491,337.50	10.26 (110.44)
Bidder 5	2,152,700.00	8.86 (95.37)

Bridge Deck Restoration & Waterproofing Western Kentucky Parkway Bridge Overlays
Date Let: 09-26-14 Call: 404 County: Hardin District: 04
Bridge Number: 047B00092L Overlay Area: 5,190 ft^2 (482.2 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	62,953.45	12.13 (130.57)
Bidder 2	50,207.50	9.67 (104.09)
Bidder 3	51,749.10	9.97 (107.32)
Bidder 4	62,977.40	12.13 (130.57)
Bidder 5	72,664.50	14.00 (150.69)
Bidder 6	84,094.00	16.20 (174.37)

Bridge Deck Restoration & Waterproofing Western Kentucky Parkway Bridge Overlays
Date Let: 09-26-14 Call: 404 County: Hardin District: 04
Bridge Number: 047B00092R Overlay Area: 5,190 ft^2 (482.2 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	62,953.45	12.13 (130.57)
Bidder 2	50,207.50	9.67 (104.09)
Bidder 3	51,749.10	9.97 (107.32)
Bidder 4	62,977.40	12.13 (130.57)
Bidder 5	72,664.50	14.00 (150.69)
Bidder 6	84,094.00	16.20 (174.37)

Bridge Deck Restoration & Waterproofing Western Kentucky Parkway Bridge Overlays
Date Let: 09-26-14 Call: 404 County: Hardin District: 04
Bridge Number: 047B00093L Overlay Area: 6,270 ft^2 (582.5 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	74,357.20	11.86 (127.66)
Bidder 2	59,958.00	9.56 (102.90)
Bidder 3	62,031.60	9.89 (106.45)
Bidder 4	74,720.80	11.92 (128.31)
Bidder 5	85,550.00	13.64 (146.82)
Bidder 6	99,890.00	15.93 (171.47)

Bridge Deck Restoration & Waterproofing Western Kentucky Parkway Bridge Overlays
Date Let: 09-26-14 Call: 404 County: Hardin District: 04
Bridge Number: 047B00093R Overlay Area: 6,270 ft^2 (582.5 m^2)

	Total Deck Items, $	Unit Cost, $\$/ft^2$ ($\$/m^2$)
Bidder 1	74,357.20	11.86 (127.66)
Bidder 2	59,958.00	9.56 (102.90)
Bidder 3	62,031.60	9.89 (106.45)
Bidder 4	74,720.80	11.92 (128.31)
Bidder 5	85,550.00	13.64 (146.82)
Bidder 6	99,890.00	15.93 (171.47)

Bridge Deck Restoration & Waterproofing Bridge over Tygarts Creek
Date Let: 10-24-14 Call: 319 County: Carter District: 09
Bridge Number: 022B00035N Overlay Area: 7,840 ft^2 (728.4 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	123,668.50	15.77 (169.75)
Bidder 2	121,139.00	15.45 (166.30)
Bidder 3	146,880.00	18.73 (201.61)
Bidder 4	131,227.40	16.74 (180.19)
Bidder 5	90,260.00	11.51 (123.89)
Bidder 6	118,462.60	15.11 (162.64)
Bidder 7	202,561.00	25.84 (278.14)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Wayne County
Date Let: 10-24-14 Call: 403 County: Wayne District: 08
Bridge Number: 116B00009N Overlay Area: 3,816 ft^2 (354.5 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	71,358.00	18.70 (201.28)
Bidder 2	98,020.00	25.69 (276.52)
Bidder 3	113,131.10	29.65 (319.15)
Bidder 4	141,528.50	37.09 (399.23)
Bidder 5	97,926.80	25.66 (276.20)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Wayne County
Date Let: 10-24-14 Call: 403 County: Wayne District: 08
Bridge Number: 116B00010N Overlay Area: 2,736 ft^2 (254.2 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	55,004.00	20.10 (216.35)
Bidder 2	76,455.00	27.94 (300.74)
Bidder 3	87,926.30	32.14 (345.95)
Bidder 4	107,372.50	39.24 (422.37)
Bidder 5	78,709.40	28.77 (309.68)

Bridge Deck Restoration & Waterproofing Bridge Overlays in Wayne County
Date Let: 10-24-14 Call: 403 County: Wayne District: 08
Bridge Number: 116B00020N Overlay Area: 1,320 ft^2 (122.6 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	28,364.00	21.49 (231.32)
Bidder 2	40,230.00	30.48 (328.08)
Bidder 3	46,245.80	35.03 (377.06)
Bidder 4	55,644.00	42.15 (453.70)
Bidder 5	42,637.40	32.30 (347.67)

The following roadway projects also included bridge deck restoration work.

Asphalt Rehab with Bridge(s) Louisville-Cincinnati Road (1-71)
Date Let: 09-27-13 Call: 200 County: Henry District: 05
Bridge Number: 052B00001N Overlay Area: 8,040 ft^2 (746.9 m^2)

	Total Deck Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	75,910.00	9.44 (101.61)
Bidder 2	97,879.00	12.17 (131.00)
Bidder 3	82,249.20	10.23 (110.11)
Bidder 4	93,034.00	11.57 (124.54)

Asphalt Rehab with Bridge(s) Louisville-Cincinnati Road (1-71)
Date Let: 09-27-13 Call: 200 County: Henry District: 05
Bridge Number: 052B00038N Overlay Area: 9,482 ft^2 (880.9 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	80,785.00	8.52 (91.71)
Bidder 2	89,842.50	9.48 (102.04)
Bidder 3	87,553.00	9.23 (99.35)
Bidder 4	96,349.00	10.16 (109.36)

Asphalt Rehab with Bridge(s) Louisville-Cincinnati Road (1-71)
Date Let: 09-27-13 Call: 200 County: Henry District: 05
Bridge Number: 052B00051L Overlay Area: 13,868 ft^2 (1,288.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	123,265.00	8.89 (95.69)
Bidder 2	137,309.50	9.90 (106.56)
Bidder 3	133,616.60	9.63 (103.66)
Bidder 4	146,901.00	10.59 (113.99)

Grade, Drain & Surface with Bridge Richmond-Lancaster Road (KY 52)
Date Let: 09-27-13 Call: 201 County: Various District: 07
Bridge Number: 040B00004N Overlay Area: 3,080 ft^2 (286.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	58,960.00	19.14 (206.02)
Bidder 2	72,649.38	23.59 (253.92)
Bidder 3	88,352.00	28.69 (308.82)
Bidder 4	87,778.00	28.50 (306.77)

Grade, Drain & Surface with Bridge Cumberland Parkway (9008) and US 127 Interchange
Date Let: 04-25-14 Call: 302 County: Russell District: 08
Bridge Number: 104B00022N Overlay Area: 17,216 ft^2 (1,599.4 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	206,665.38	12.00 (129.17)
Bidder 2	200,646.00	11.65 (125.40)
Bidder 3	200,646.00	11.65 (125.40)
Bidder 4	236,609.00	13.74 (147.90)

Asphalt Rehab Interstate/Parkway Edward T. Breathitt Parkway (PW 9004)
Date Let: 05-30-14 Call: 200 County: Hopkins District: 02
Bridge Number: 051B00062L Overlay Area: 6,954 ft^2 (646.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	87,186.50	12.54 (134.98)
Bidder 2	81,049.80	11.66 (125.51)
Bidder 3	89,475.75	12.87 (138.53)

Asphalt Rehab Interstate/Parkway Edward T. Breathitt Parkway (PW 9004)
Date Let: 05-30-14 Call: 200 County: Hopkins District: 02
Bridge Number: 051B00062R Overlay Area: 6,954 ft^2 (646.1 m^2)

	Total Deck Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	87,186.50	12.54 (134.98)
Bidder 2	81,049.80	11.66 (125.51)
Bidder 3	89,475.75	12.87 (138.53)

Asphalt Rehab Interstate/Parkway Edward T. Breathitt Parkway (PW 9004)
Date Let: 05-30-14 Call: 200 County: Hopkins District: 02
Bridge Number: 117B00071L Overlay Area: 11,040 ft^2 (1,025.7 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	94,819.50	8.59 (92.46)
Bidder 2	95,236.65	8.63 (92.89)
Bidder 3	109,586.50	9.93 (106.89)

Asphalt Rehab Interstate/Parkway Edward T. Breathitt Parkway (PW 9004)
Date Let: 05-30-14 Call: 200 County: Hopkins District: 02
Bridge Number: 117B00071R Overlay Area: 11,040 ft^2 (1,025.7 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	94,819.50	8.59 (92.46)
Bidder 2	95,236.65	8.63 (92.89)
Bidder 3	109,586.50	9.93 (106.89)

Asphalt Pavement & Roadway Rehab Julian M. Carroll Parkway (9003)
Date Let: 08-22-14 Call: 203 County: Graves District: 01
Bridge Number: 079B00075L, SB only Overlay Area: 8,726 ft^2 (810.7 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	93,975.00	10.77 (115.93)
Bidder 2	95,366.30	10.93 (117.65)

Asphalt Rehab with Bridge(s) Louie B. Nunn Cumberland Parkway (9008)
Date Let: 10-24-14 Call: 306 County: Barren District: 03
Bridge Number: 005B00068R, EB only Overlay Area: 8,558 ft^2 (795.1 m^2)

	Total Deck Items, $	Unit Cost, $/ft^2 ($/m^2)
Bidder 1	122,270.00	14.29 (153.82)

Bridge Removals

The cost analysis for structure removal included the following bid items:

- Remove structure
- Remove exist superstructure and abutment

The length and width of the structures used to calculate the area of the structures that were removed were taken from the National Bridge Inventory (NBI) database for Kentucky. The calculated unit costs are summarized in Table C.4.

Table C.4-Bridge removal costs summary

Structure type-main	Number of bridges	n	Unit Costs, $/ft² ($/m²)	
			Mean	Standard Deviation
101	4	14	28.75 (310.46)	21.83 (235.74)
104	17	69	28.37 (306.36)	15.83 (170.94)
204	10	23	14.13 (152.59)	4.03 (43.52)
122	4	15	22.20 (218.13)	12.20 (131.74)
119	1	4	10.66 (115.11)	6.35 (68.57)
505	8	19	24.51 (264.68)	18.76 (202.58)
302	12	32	19.45 (210.04)	9.29 (100.32)
402	3	10	23.36 (252.26)	17.64 (190.49)
403	2	6	25.39 (274.18)	7.69 (83.04)
310	6	23	23.95 (258.63)	12.84 (138.66)
702	1	6	26.52 (286.38)	11.00 (119.22)
All	68	221	23.73 (256.25)	14.69 (158.63)

Structure Type Codes
101 = concrete slab
104 = concrete tee beam
204 = continuous concrete tee beam
122 = concrete channel beam
119 = concrete culvert
505 = prestressed concrete box beam or girders - multiple
302 = steel stringer/multi-beam or girder
402 = continuous steel stringer/multi-beam or girder
403 = continuous steel girder and floorbeam system
310 = steel thru truss
702 = timber stringer/multi-beam or girder

The following are summaries of unit costs for each project used in the analysis. Unit costs marked with an asterisk were not used in the cost analysis.

Concrete Slab Bridges (NBI Item 43=101)

Bridge Replacement East Union-Carlisle Road (KY-1285)
Date Let: 09-27-13 Call: 102 County: Nicholas District: 09
NBI Structure Number: 091B00005N Bridge Area: 417 ft^2 (38.7 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	9,000.00	21.57 (232.18)
Bidder 2	5,000.00	11.98 (128.95)
Bidder 3	5,000.00	11.98 (128.95)
Bidder 4	50,000.00	119.84 (1,289.94) *
Bidder 5	10,000.00	23.97 (258.01)
Bidder 6	28,500.00	68.31 (735.28)

Bridge with Grade, Drain & Surface Bent Branch Road (KY-1426)
Date Let: 06-27-14 Call: 101 County: Pike District: 12
NBI Structure Number: 098B00015N Bridge Area: 841 ft^2 (78.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	70,000.00	83.27 (896.31)

Bridge with Grade, Drain & Surface Wildie Road (CR-1071)
Date Let: 09-26-14 Call: 117 County: Rockcastle District: 08
NBI Structure Number: 102C00009N Bridge Area: 1,024 ft^2 (95.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	41,500.00	40.52 (436.15)
Bidder 2	22,500.00	21.97 (236.48)
Bidder 3	10,000.00	9.76 (105.06)

Bridge Replacement Wildie Road (CR 1071)
Date Let: 10-24-14 Call: 111 County: Rockcastle District: 08
NBI Structure Number: 102C00008N Bridge Area: 991 ft^2 (92.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	16,000.00	16.15 (173.84)
Bidder 2	22,500.00	22.71 (244.45)
Bidder 3	34,000.00	34.32 (369.42)
Bidder 4	21,000.00	21.20 (228.19)
Bidder 5	14,662.50	14.80 (159.31)

Concrete Tee Beam Bridges (NBI Item 43=104)

Bridge with Grade, Drain & Surface KY 1428
Date Let: 02-22-13 Call: 104 County: Floyd District: 12
NBI Structure Number: 036B00003N Bridge Area: 2,344 ft^2 (217.8 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	70,000.00	29.86 (321.41)
Bidder 2	130,000.00	55.46 (596.96)

Bridge with Grade, Drain & Surface Fulton-Fulgham Road (KY 307)
Date Let: 03-22-13 Call: 104 County: Hickman District: 01
NBI Structure Number: 053B00014N Bridge Area: 2,813 ft^2 (261.3 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	80,000.00	28.44 (306.12)
Bidder 2	500,000.00	177.77 (1,913.49) *

Bridge with Grade, Drain & Surface Fulton-Fulgham Road (KY 307)
Date Let: 03-22-13 Call: 104 County: Hickman District: 01
NBI Structure Number: 053B00015N Bridge Area: 3,519 ft^2 (326.9 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	70,000.00	19.89 (214.09)
Bidder 2	500,000.00	142.08 (1,529.33) *

Bridge with Grade, Drain & Surface Fulton-Fulgham Road (KY 307)
Date Let: 03-22-13 Call: 104 County: Hickman District: 01
NBI Structure Number: 053B00016N Bridge Area: 2,540 ft^2 (236.0 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	60,000.00	23.62 (254.24)
Bidder 2	500,000.00	196.87 (2,119.08) *

Bridge with Grade, Drain & Surface Huddy-McVeigh Road (KY 199)
Date Let: 08-16-13 Call: 103 County: Pike District: 12
NBI Structure Number: 098B00033N Bridge Area: 1,151 ft^2 (106.9 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	10,000.00	8.69 (93.54)
Bidder 2	20,000.00	17.38 (187.08)
Bidder 3	55,000.00	47.79 (514.41)
Bidder 4	15,000.00	13.03 (140.25)

Bridge with Grade, Drain & Surface Wilson Creek Bridge (KY 945)
Date Let: 09-27-13 Call: 101 County: Graves District: 01
NBI Structure Number: 042B00187N Bridge Area: 2,503 ft^2 (232.5 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	48,203.50	19.26 (207.31)
Bidder 2	30,000.00	11.99 (129.06)
Bidder 3	100,000.00	39.96 (430.12)
Bidder 4	95,000.00	37.96 (408.60)

Bridge with Grade, Drain & Surface KY 476
Date Let: 09-27-13 Call: 105 County: Perry District: 10
NBI Structure Number: 097B00008N Bridge Area: 3,446 ft^2 (320.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	35,000.00	10.16 (109.36)
Bidder 2	90,000.00	26.12 (281.15)
Bidder 3	89,000.00	25.83 (278.03)
Bidder 4	50,000.00	14.51 (156.18)
Bidder 5	130,000.00	37.73 (406.12)

Bridge Replacement Anthoston-Niagara Road (KY-136)
Date Let: 10-25-13 Call: 109 County: Henderson District: 02
NBI Structure Number: 051B00024N Bridge Area: 556 ft^2 (51.7 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	29,500.00	53.05 (571.02)
Bidder 2	38,000.00	68.34 (735.60)
Bidder 3	20,000.00	35.97 (387.18)
Bidder 4	42,500.00	76.43 (822.68)
Bidder 5	33,000.00	59.35 (638.84)

Bridge Replacement Stanton-Slade Road (KY 11)
Date Let: 11-22-13 Call: 104 County: Powell District: 10
NBI Structure Number: 099B00039N Bridge Area: 1,385 ft^2 (128.7 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	15,000.00	10.83 (116.57)
Bidder 2	9,400.00	6.79 (73.09)
Bidder 3	43,000.00	31.04 (334.11)
Bidder 4	35,000.00	25.27 (272.00)

Bridge with Grade, Drain & Surface Beaver Dam - Leitchfield Road (US 62)
Date Let: 11-22-13 Call: 106 County: Ohio District: 02
NBI Structure Number: 092B00034N Bridge Area: 2,575 ft^2 (239.2 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	39,500.00	15.34 (165.12)
Bidder 2	66,000.00	25.63 (275.88)
Bidder 3	60,000.00	23.30 (250.80)
Bidder 4	15,000.00	5.83 (62.75)
Bidder 5	40,000.00	15.54 (167.27)

Bridge with Grade, Drain & Surface Sedalia to Mayfield Road (KY 79)
Date Let: 11-22-13 Call: 107 County: Graves District: 01
NBI Structure Number: 042B00046N Bridge Area: 1,612 ft^2 (149.8 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	33,000.00	20.47 (220.34)
Bidder 2	49,010.82	30.40 (327.22)
Bidder 3	40,000.00	24.81 (267.05)

Grade, Drain & Surface with Bridge Gratz-Moxley Road (KY-355)
Date Let: 12-13-13 Call: 106 County: Owen District: 06
NBI Structure Number: 094B00009N Bridge Area: 4,924 ft^2 (457.5 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	100,000.00	20.31 (218.61)
Bidder 2	55,087.89	11.19 (120.45)
Bidder 3	50,000.00	10.16 (109.36)
Bidder 4	163,860.00	33.28 (358.22)
Bidder 5	143,000.00	29.04 (312.58)
Bidder 6	140,500.00	28.54 (307.20)
Bidder 7	200,000.00	40.62 (437.23)
Bidder 8	133,000.00	27.01 (290.73)
Bidder 9	155,000.00	31.48 (338.85)

Grade, Drain & Surface with Bridge Morgantown Road (KY 79)
Date Let: 01-24-14 Call: 313 County: Logan District: 03
NBI Structure Number: 071B00009N Bridge Area: 2,049 ft^2 (190.4 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	22,000.00	10.74 (115.60)
Bidder 2	20,000.00	9.76 (105.06)
Bidder 3	32,000.00	15.62 (168.13)

Bridge Replacement Bloomfield Road (US 62)
Date Let: 04-25-14 Call: 105 County: Nelson District: 04
NBI Structure Number: 090B00023N Bridge Area: 1,072 ft^2 (99.6 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	25,000.00	23.33 (251.12)
Bidder 2	34,000.00	31.73 (341.54)
Bidder 3	24,000.00	22.40 (241.11)
Bidder 4	34,000.00	31.73 (341.54)

Bridge with Grade, Drain & Surface Frenchburg to Owingsville Road (KY 36)
Date Let: 06-27-14 Call: 109 County: Menifee District: 10
NBI Structure Number: 083B00001N Bridge Area: 2,795 ft^2 (259.7 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	50,000.00	17.89 (192.57)
Bidder 2	100,000.00	35.77 (385.02)
Bidder 3	180,000.00	64.39 (693.09)
Bidder 4	90,000.00	32.20 (346.60)
Bidder 5	125,000.00	44.72 (481.36)
Bidder 6	122,000.00	43.64 (469.74)
Bidder 7	39,100.00	13.99 (150.59)

Bridge with Grade, Drain & Surface KY 32 over Seas Branch
Date Let: 06-27-14 Call: 110 County: Rowan District: 09
NBI Structure Number: 103B00013N Bridge Area: 739 ft^2 (68.7 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	19,000.00	25.72 (276.85)
Bidder 2	4,600.00	6.23 (67.06)
Bidder 3	10,000.00	13.53 (145.64)
Bidder 4	10,000.00	13.53 (145.64)
Bidder 5	63,000.00	85.27 (917.84) *
Bidder 6	27,500.00	37.22 (400.63)
Bidder 7	32,500.00	43.99 (473.50)
Bidder 8	25,000.00	33.84 (364.25)

Bridge with Grade, Drain & Surface Morehead-Grayson Road (US-60)
Date Let: 08-22-14 Call: 106 County: Rowan District: 09
NBI Structure Number: 103B00006N
Bridge Area: 851 ft^2 (79.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	55,000.00	64.60 (695.35)
Bidder 2	25,000.00	29.36 (316.03)
Bidder 3	25,000.00	29.36 (316.03)
Bidder 4	29,500.00	34.65 (372.97)

Continuous Concrete Tee Beam Bridges (NBI Item 43=204)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
NBI Structure Number: 050B00006N Bridge Area: 8,447 ft^2 (784.8 m^2)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	100,000.00	11.84 (127.44)
Bidder 2	160,000.00	18.94 (203.87)
Bidder 3	200,000.00	23.68 (254.89)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
NBI Structure Number: 050B00027L Bridge Area: 5,620 ft^2 (522.1 m^2)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	62,500.00	11.12 (119.69)
Bidder 2	95,000.00	16.90 (181.91)
Bidder 3	110,837.70	19.72 (212.26)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
NBI Structure Number: 050B00027R Bridge Area: 5,620 ft^2 (522.1 m^2)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	62,500.00	11.12 (119.69)
Bidder 2	95,000.00	16.90 (181.91)
Bidder 3	110,837.70	19.72 (212.26)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
NBI Structure Number: 062B00016N Bridge Area: 7,400 ft^2 (687.5 m^2)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	120,000.00	16.22 (174.59)
Bidder 2	80,000.00	10.81 (116.36)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
NBI Structure Number: 050B00030L Bridge Area: 7,225 ft^2 (671.2 m^2)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	82,500.00	11.42 (122.92)
Bidder 2	100,000.00	13.84 (148.97)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
NBI Structure Number: 050B00030R Bridge Area: 7,225 ft^2 (671.2 m^2)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	82,500.00	11.42 (122.92)
Bidder 2	100,000.00	13.84 (148.97)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
NBI Structure Number: 050B00008N Bridge Area: 9,612 ft^2 (874.6 m^2)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	120,000.00	12.48 (134.33)
Bidder 2	100,000.00	10.40 (111.94)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
NBI Structure Number: 047B00042N Bridge Area: 9,414 ft^2 (874.6 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	140,000.00	14.87 (160.06)
Bidder 2	100,000.00	10.62 (114.31)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
NBI Structure Number: 047B00064N Bridge Area: 7,332 ft^2 (681.2 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	140,000.00	19.10 (205.59)
Bidder 2	80,000.00	10.91 (117.43)

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04
NBI Structure Number: 047B00029N Bridge Area: 12,563 ft^2 (1,167.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	140,000.00	11.14 (119.91)
Bidder 2	100,000.00	7.96 (85.68)

Concrete Culvert (NBI Item 43=119)

Bridge with Grade, Drain & Surface Low Water Drive (CR 1336)
Date Let: 05-24-13 Call: 352 County: Harlan District: 11
NBI Structure Number: 048B00135N Bridge Area: 2,640 ft^2 (245.3 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	25,000.00	9.47 (101.93)
Bidder 2	20,000.00	7.58 (81.59)
Bidder 3	15,000.00	5.68 (61.14)
Bidder 4	52,500.00	19.89 (214.09)

Concrete Channel Beam Bridges (NBI Item 43=122)

Bridge with Grade, Drain & Surface Outland School Road (KY-1536)
Date Let: 05-30-14 Call: 103 County: Calloway District: 01
NBI Structure Number: 018B00108N Bridge Area: 1,314 ft^2 (122.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	34,600.00	26.33 (283.41)
Bidder 2	18,500.00	14.08 (151.56)
Bidder 3	40,000.00	30.44 (327.65)

Grade, Drain & Surface with Bridge Kenneth Barrett Road (KY 30)
Date Let: 09-26-14 Call: 112 County: Owsley District: 10
NBI Structure Number: 095B00013N Bridge Area: 1,556 ft^2 (144.6 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	11,000.00	7.07 (76.10)
Bidder 2	15,000.00	9.64 (103.76)
Bidder 3	12,000.00	7.71 (82.99)
Bidder 4	30,000.00	19.28 (207.53
Bidder 5	15,000.00	9.64 (103.76)

Grade & Drain with Bridge KY 343
Date Let: 09-26-14 Call: 119 County: Letcher District: 12
NBI Structure Number: 067B00015N Bridge Area: 656 ft^2 (60.9 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	32,500.00	49.52 (533.03)
Bidder 2	20,000.00	30.48 (328.08)
Bidder 3	20,000.00	30.48 (328.08)

Bridge Replacement Pryorsburg to Dublin Road (KY 1748)
Date Let: 10-24-14 Call: 108 County: Graves District: 01
NBI Structure Number: 042B00236N Bridge Area: 1,300 ft^2 (120.8 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	27,000.00	20.77 (223.57)
Bidder 2	17,500.00	13.46 (144.88)
Bidder 3	45,318.00	34.86 (375.23)
Bidder 4	38,000.00	29.23 (314.63)

Steel Stringer/multi-beam or Girder Bridges (NBI Item 43=302)

Bridge with Grade, Drain & Surface Dahl Road (KY 1677)
Date Let: 08-16-13 Call: 106 County: Pulaski District: 08
NBI Structure Number: 100B00023N Bridge Area: 1,168 ft^2 (108.5 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	20,000.00	17.12 (184.28)
Bidder 2	7,500.00	6.42 (69.10)
Bidder 3	20,000.00	17.12 (184.28)
Bidder 4	25,000.00	21.41 (230.45)
Bidder 5	25,000.00	21.41 (230.45)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
NBI Structure Number: 050B00029L Bridge Area: 4,698 ft^2 (436.5 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	75,000.00	15.96 (171.79)
Bidder 2	112,500.00	23.95 (257.79)
Bidder 3	150,901.11	32.12 (345.74)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
NBI Structure Number: 050B00029R Bridge Area: 4,698 ft^2 (436.5 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	75,000.00	15.96 (171.79)
Bidder 2	112,500.00	23.95 (257.79)
Bidder 3	150,901.11	32.12 (345.74)

Bridge with Grade, Drain & Surface Buffalo Branch Road (CR-1327)
Date Let: 11-22-13 Call: 111 County: Bell District: 11
NBI Structure Number: 007C00048N Bridge Area: 681 ft^2 (63.3 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	10,000.00	14.68 (158.01)
Bidder 2	6,000.00	8.81 (94.83)
Bidder 3	10,000.00	14.68 (158.01)
Bidder 4	47,500.00	69.75 (750.78) *

Bridge Replacement Pacies Branch Road (CR 1245)
Date Let: 03-28-14 Call: 112 County: Letcher District: 12
NBI Structure Number: 067C00027N Bridge Area: 332 ft^2 (30.8 m^2)

	Total Removal Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	30,000.00	90.49 (974.02) *
Bidder 2	7,700.00	23.23 (250.04)

Bridge Replacement Hacker Branch Road (CR-1136)
Date Let: 07-11-14 Call: 107 County: Owsley District: 10
NBI Structure Number: 095C00007N Bridge Area: 1,565 ft^2 (145.4 m^2)

	Total Removal Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	10,000.00	6.39 (68.78)
Bidder 2	25,000.00	15.97 (171.90)
Bidder 3	27,000.00	17.25 (185.68)

Bridge Replacement Rye Branch Road (CR 1756)
Date Let: 07-11-14 Call: 108 County: Magoffin District: 10
NBI Structure Number: 077C00048N Bridge Area: 638 ft^2 (59.3 m^2)

	Total Removal Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	9,500.00	14.89 (160.27)
Bidder 2	5,000.00	7.84 (84.39)
Bidder 3	22,500.00	35.26 (379.53)

Bridge with Grade & Drain Stinson Road (CR-1700)
Date Let: 07-11-14 Call: 115 County: Wayne District: 08
NBI Structure Number: 116C00040N Bridge Area: 609 ft^2 (56.6 m^2)

	Total Removal Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	11,100.00	18.21 (196.01)
Bidder 2	77,000.00	126.34 (1,359.91) *
Bidder 3	50,000.00	82.04 (883.07) *

Bridge with Grade & Drain Curtis Road (CR 1226)
Date Let: 08-22-14 Call: 111 County: Boyle District: 07
NBI Structure Number: 011C00042N Bridge Area: 860 ft^2 (79.9 m^2)

	Total Removal Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	15,000.00	17.44 (187.72)
Bidder 2	30,000.00	34.87 (375.34)

Bridge with Grade, Drain & Surface Oscar Bowling Road (CR 1113A)
Date Let: 09-26-14 Call: 104 County: Clay District: 11
NBI Structure Number: 026C00063N Bridge Area: 1,373 ft^2 (127.6 m^2)

	Total Removal Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	30,000.00	21.84 (235.08)
Bidder 2	20,000.00	14.56 (156.72)

Bridge Replacement Hade Bell Road (CR 1167)
Date Let: 09-26-14 Call: 116 County: Allen District: 03
NBI Structure Number: 002C00012N Bridge Area: 506 ft^2 (47.0 m^2)

	Total Removal Items, $	Unit Cost, \$/ft^2 (\$/m^2)
Bidder 1	20,000.00	39.50 (425.17)
Bidder 2	19,000.00	37.52 (403.86)

Bridge Replacement Hemp Patch Branch Road (CR-1002)
Date Let: 10-24-14 Call: 302 County: Knott District: 12
NBI Structure Number: 060C00001N Bridge Area: 1,004 ft^2 (93.3 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	10,000.00	9.96 (107.21)
Bidder 2	5,000.00	4.98 (53.60)
Bidder 3	14,500.00	14.45 (155.54)
Bidder 4	22,500.00	22.42 (241.33)

Continuous Steel Stringer/multi-beam or Girder Bridges (NBI Item 43=402)

Bridge Replacement Elk Lick Creek Road (CR 1224)
Date Let: 05-30-14 Call: 110 County: Lee District: 10
NBI Structure Number: 065C00023N Bridge Area: 495 ft^2 (46.0 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	2,000.00	4.04 (43.49)
Bidder 2	16,300.00	32.91 (354.24)
Bidder 3	7,500.00	15.14 (162.96)
Bidder 4	24,000.00	48.46 (521.62)

Bridge Replacement Mobley Mill Road (CR 1327)
Date Let: 08-22-14 Call: 108 County: Nelson District: 04
NBI Structure Number: 090C00039N Bridge Area: 1,742 ft^2 (161.8 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	10,000.00	5.74 (61.78)
Bidder 2	31,000.00	17.80 (191.60)
Bidder 3	11,000.00	6.31 (67.92)
Bidder 4	25,000.00	14.35 (154.46)

Bridge with Grade, Drain & Surface KG Estates Road (CR 1162)
Date Let: 09-26-14 Call: 118 County: Lawrence District: 12
NBI Structure Number: 064C00078N Bridge Area: 996 ft^2 (92.5 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	48,500.00	48.71 (524.31)
Bidder 2	40,000.00	40.17 (432.38)

Continuous Steel Girder and Floorbeam System Bridges (NBI Item 43=403)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
NBI Structure Number: 050B00031L Bridge Area: 24,158 ft^2 (2,244.4 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	400,000.00	16.56 (178.25)
Bidder 2	625,000.00	25.87 (278.46)
Bidder 3	815,000.00	33.74 (363.17)

Bridge with Grade, Drain & Surface Tennessee State Line to E-Town Road (I-65)
Date Let: 11-22-13 Call: 109 County: Hart District: 04
NBI Structure Number: 050B00031R Bridge Area: 24,158 ft^2 (2,244.4 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	400,000.00	16.56 (178.25)
Bidder 2	625,000.00	25.87 (278.46)
Bidder 3	815,000.00	33.74 (363.17)

Bridge with Grade, Drain & Surface Patty Loveless Drive (KY 80)
Date Let: 12-13-13 Call: 105 County: Pike District: 12
NBI Structure Number: 098B00137N Bridge Area: 28,356 ft^2 (2,634.4 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	45,000.00	1.59 (17.11) *
Bidder 2	1,000.00	0.04 (0.43) *

Steel Thru Truss Bridges (NBI Item 43=310)

Bridge with Grade, Drain & Surface Ray Road (CR 1060)
Date Let: 07-12-13 Call: 200 County: Daviess District: 02
NBI Structure Number: 030C00018N Bridge Area: 1,296 ft^2 (120.4 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	20,000.00	15.43 (166.09)
Bidder 2	8,000.00	6.17 (66.41)
Bidder 3	23,000.00	17.75 (191.06)
Bidder 4	35,000.00	27.01 (290.73)
Bidder 5	25,000.00	19.29 (207.64)

Bridge with Grade, Drain & Surface Glomawr to Hazard Road (KY 451)
Date Let: 11-22-13 Call: 108 County: Perry District: 10
NBI Structure Number: 097B00016N Bridge Area: 8,247 ft^2 (766.2 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	109,426.97	13.27 (142.84)
Bidder 2	120,000.00	14.55 (156.61)
Bidder 3	209,000.00	25.34 (272.76)
Bidder 4	265,000.00	32.13 (345.84)

Bridge with Grade, Drain & Surface Hazard-Hyden Road (KY-80)
Date Let: 07-11-14 Call: 113 County: Perry District: 10
NBI Structure Number: 097B00029N Bridge Area: 9,576 ft^2 (889.6 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	180,000.00	18.80 (202.36)
Bidder 2	165,000.00	17.23 (185.46)
Bidder 3	185,365.00	19.36 (208.39)
Bidder 4	1,050,000.00	109.65 (1,180.26) *

Bridge Replacement Glasgow Street (CS 1053)
Date Let: 08-22-14 Call: 107 County: Metcalfe District: 03
NBI Structure Number: 085C00007N Bridge Area: 1,255 ft^2 (116.6 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	24,000.00	19.12 (205.81)
Bidder 2	15,000.00	11.95 (128.63)
Bidder 3	30,000.00	23.90 (257.26)
Bidder 4	25,000.00	19.92 (214.42)

Bridge with Grade, Drain & Surface Booneville-Jackson Road (KY 30)
Date Let: 09-26-14 Call: 113 County: Breathitt District: 10
NBI Structure Number: 013B00017N Bridge Area: 6,951 ft^2 (645.8 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	150,000.00	21.58 (232.28)
Bidder 2	115,000.00	16.54 (178.03)
Bidder 3	335,000.00	48.20 (518.82)
Bidder 4	485,000.00	69.78 (751.10) *

Prestressed Concrete Box Beam or Girders – Multiple Bridges (NBI Item 43=505)

Bridge Replacement Bridge over Little Goose Creek
Date Let: 05-24-13 Call: 368 County: Clay District: 11
NBI Structure Number: 026B00041N Bridge Area: 1,320 ft^2 (122.6 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	13,000.00	9.85 (106.02)
Bidder 2	22,000.00	16.67 (179.43)
Bidder 3	13,500.00	10.23 (110.11)

Bridge with Grade, Drain & Surface Woodbine-Barbourville Road (KY 6)
Date Let: 08-16-13 Call: 202 County: Knox District: 11
NBI Structure Number: 061B00042N Bridge Area: 1,430 ft^2 (132.9 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	20,000.00	13.99 (150.59)
Bidder 2	200,000.00	139.87 (1,505.54) *

Bridge with Grade, Drain & Surface Woodbine-Barbourville Road (KY 6)
Date Let: 08-16-13 Call: 202 County: Knox District: 11
NBI Structure Number: 061B00043N Bridge Area: 1,183 ft^2 (109.9 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	20,000.00	16.91 (182.02)
Bidder 2	200,000.00	169.10 (1,820.17) *

Bridge Replacement KY-502
Date Let: 09-27-13 Call: 111 County: Hopkins District: 02
NBI Structure Number: 054B00125N Bridge Area: 3,887 ft^2 (361.1 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	200,000.00	51.45 (553.80)
Bidder 2	405,000.00	104.19 (1,121.49) *
Bidder 3	250,000.00	64.32 (692.33)

Bridge with Grade, Drain & Surface Gray-Indian Creek Road (KY 3437)
Date Let: 11-22-13 Call: 105 County: Knox District: 11
NBI Structure Number: 061B00086N Bridge Area: 503 ft^2 (46.7 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	7,000.00	13.92 (149.83)
Bidder 2	10,000.00	19.89 (214.09)
Bidder 3	10,000.00	19.89 (214.09)

Bridge with Grade, Drain & Surface Lower Johns Creek Road (KY-194)
Date Let: 06-27-14 Call: 207 County: Floyd District: 12
NBI Structure Number: 036B00065N Bridge Area: 946 ft^2 (87.9 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	10,000.00	10.58 (113.88)

Bridge with Grade, Drain & Surface KY-49
Date Let: 08-22-14 Call: 313 County: Marion District: 04
NBI Structure Number: 078B00066N Bridge Area: 1,509 ft^2 (140.2 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	18,000.00	11.93 (128.41)
Bidder 2	29,950.00	19.85 (213.66)
Bidder 3	18,000.00	11.93 (128.41)

Bridge with Grade, Drain & Surface Upper Wolf Creek Road (CR 1134)
Date Let: 10-24-14 Call: 110 County: Owsley District: 10
NBI Structure Number: 095C00018N Bridge Area: 2,174 ft^2 (202.0 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	15,000.00	6.90 (74.27)
Bidder 2	62,000.00	28.52 (306.99)
Bidder 3	75,000.00	34.50 (371.35)
Bidder 4	72,000.00	33.12 (356.50)
Bidder 5	155,000.00	71.31 (767.57)

Timber Stringer/multi-beam or Girder Bridge (NBI Item 43=702)

Bridge with Grade, Drain & Surface Brown Badgett Loop (CR 1092)
Date Let: 01-25-13 Call: 103 County: Hopkins District: 02
NBI Structure Number: 054C00004N Bridge Area: 1,681 ft^2 (156.2 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	53,000.00	31.53 (339.38)
Bidder 2	60,500.00	35.99 (387.39)
Bidder 3	50,000.00	29.75 (320.23)
Bidder 4	60,000.00	35.70 (384.27)
Bidder 5	29,000.00	17.25 (185.68)
Bidder 6	15,000.00	8.92 (96.01)

Although the following project only called for the removal of the existing superstructure and abutment, the existing bridge was a single span steel thru truss.

Bridge Replacement Tebb's Bend (CR-1236)
Date Let: 09-26-14 Call: 103 County: Taylor District: 04
NBI Structure Number: 109C00015N Bridge Area: 2,669 ft^2 (248.0 m^2)

	Total Removal Items, $	Unit Cost, $/$ft^2$ ($/$m^2$)
Bidder 1	50,000.00	18.73 (201.61)
Bidder 2	150,000.00	56.20 (604.93)
Bidder 3	135,561.56	50.79 (546.70)
Bidder 4	100,000.00	37.47 (403.32)

Bridge Deck Removals

The cost analysis for deck removal included the following bid item:

- Remove existing deck

The calculated unit costs are summarized in Table C.5.

Table C.5-Bridge deck removal costs summary

Structure Type	n	Unit Costs, $/ft² ($/m²)	
		Mean	Standard Deviation
402	3	4.87 (52.42)	2.61 (28.09)
505	7	12.69 (136.59)	5.77 (62.11)

The following is a summary of unit costs for the project used in the analysis.

Asphalt Rehab with Bridge (s) Martha Layne Collins Parkway (BG 9002)
Date Let: 04-19-13 Call: 425 County: Various District: 04
NBI Structure Number: 115B00041L and 115B00041R
Existing structure type-main: continuous steel stringer/multi-beam or girder (NBI Item 43=402)
Area each bridge: 18,123 ft² (1,683.7 m²)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	250,000.00	6.90 (74.27)
Bidder 2	210,000.00	5.79 (62.32)
Bidder 3	70,000.00	1.93 (20.77)

The following project was not used in the cost analysis for deck removal because the structure type is adjacent prestressed concrete box beams. The different structural configuration results in removal conditions that are different than a slab on beam structure. Therefore these costs were not considered to be appropriate for this study.

Bridge Deck Restoration & Waterproofing Robertson County KY 165 and KY 616
Date Let: 08-16-13 Call: 410 County: Robertson District: 06
NBI Structure Number: 101B00018N
Existing structure type-main: prestressed concrete box beam or girders - multiple (NBI Item 43=505)
Area: 5,910 ft² (549.1 m²)

	Total Removal Items, $	Unit Cost, $/ft² ($/m²)
Bidder 1	20,000.00	3.38 (36.36)
Bidder 2	55,000.00	9.31 (100.21)
Bidder 3	50,000.00	8.46 (91.06)
Bidder 4	86,000.00	14.55 (156.61)
Bidder 5	100,000.00	16.92 (182.12)
Bidder 6	115,000.00	19.46 (209.46)
Bidder 7	99,168.81	16.78 (177.39)

Bridge Rail Retrofits

The cost analysis for bridge rail retrofit with thrie beam included the following bid items:

- Guardrail Thrie Beam
- Thrie Beam to W Beam Connector

The calculated unit costs are summarized in Table C.6.

Table C.6-Thrie beam retrofit costs summary

Cost Analysis Case	n	Unit Costs, $/ft ($/m)	
		Mean	Standard Deviation
Excluding $180.00/ft ($590.55/m) unit cost	5	76.99 (252.59)	14.52 (47.64)
All costs included	6	94.16 (308.92)	44.01 (144.39)

The following are summaries of unit costs for the projects used in the analysis.

Guardrail Russell - Greenup (US 23)
Date Let: 06-14-13 Call: 202 County: Greenup District: 09

Unit Cost-Thrie Beam Retrofit		
Item	Bidder 1	Bidder 2
Guardrail Thrie Beam, $/ft ($/m)	28.75 (94.32)	100.00 (328.08)
Thrie Beam to W Beam Connector, $/each	400.00	500.00

Divide the cost of one connector by its length, 6.25 feet (1.91 m) to get an equivalent cost per length and add to the thrie beam cost. These costs were used in the analysis.

Unit Cost-Thrie Beam Retrofit, $/ft ($/m)	
Bidder 1	Bidder 2
100.75 (330.54)	180.00 (590.55)

Asphalt Rehab with Bridge(s) Louisville-Cincinnati Road (1-71)
Date Let: 09-27-13 Call: 200 County: Henry District: 05

Unit Cost-Thrie Beam Retrofit, $/ft ($/m)*			
Bidder 1	Bidder 2	Bidder 3	Bidder 4
65.00 (213.25)	80.71 (264.80)	70.00 (229.66)	68.50 (224.74)

*Includes connectors to W beam rail

APPENDIX D: MAINTENANCE OF TRAFFIC COSTS

Appendix D contains summaries of bid items and costs for maintenance of traffic (MOT) during the following:

- Bridge construction
- Bridge deck restoration

Maintenance of Traffic-Bridge Construction

The analysis of maintenance of traffic (MOT) costs calculated the percentage of the total contract amount that was bid for MOT items. The analysis included the following MOT bid items:

- Arrow Panel
- Barricade-Type III
- Concrete Median Barrier Type 9C2
- Concrete Barrier Wall Type 9T
- Crash Cushion TY VI Class B TL2
- Crash Cushion TY VI Class B TL3
- Crash Cushion TY VI Class BT TL2
- Crash Cushion TY VI Class BT TL3
- Crash Cushion Type IX-A
- Creek Crossing
- Diversions (By-Pass Detours)
- Install Temp Concrete Med Barrier
- Lane Closure
- Law Enforcement Officer
- Maintain & Control Traffic
- Pave Mark Temp Paint Stop Bar-24 in
- Pave Striping-Temp Paint-12 in
- Pave Striping-Temp Paint-4 in
- Pave Striping-Temp Paint-6 in
- Pave Striping-Temp Rem Tape-B
- Pave Striping-Temp Rem Tape-W
- Pave Striping-Temp Rem Tape-Y
- Pavement Marker Type IVA-BY Temp
- Pavement Marker Type IVA-MY Temp
- Portable Changeable Message Sign
- Relocate Concrete Barrier Wall
- Relocate Crash Cushion
- Relocate Temp Concrete Barrier
- Signs
- Temp Concrete Med Barrier
- Temp Crash Cushion
- Temp Guardrail
- Temp Median Crossover
- Temp Signal
- Temp Signal 2 Phase
- Temporary Signs
- Tubular Markers

Not all items were used on every project. The results of the analysis are summarized in Table D1.

Table D1-Maintenance of traffic analysis summary bridge replacement

Analysis Case	n	Mean	Standard Deviation
Precast PC I beams	114	3.41%	2.77%
Precast PC box beams	133	3.12%	3.55%
RC culvert	3	16.27%	2.23%
All types	250	3.41%	3.50%

The following are summaries of MOT percentages for each project used in the analysis.

Bridge with Grade, Drain & Surface Brown Badgett Loop (CR 1092)
Date Let: 01-25-13 Call: 103 County: Hopkins District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	9,543.62	1,805,945.22	0.53
Bidder 2	7,601.00	1,899,850.23	0.40
Bidder 3	12,684.00	1,944,512.77	0.65
Bidder 4	12,453.00	1,988,759.09	0.63
Bidder 5	12,684.00	2,146,221.90	0.59
Bidder 6	111,060.00	2,656,235.33	4.18

Grade, Drain & Surface with Bridge Georgetown Northwest Bypass
Date Let: 04-19-13 Call: 101 County: Scott District: 07

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	153,547.81	12,989,572.70	1.18
Bidder 2	221,160.49	13,527,266.37	1.63
Bidder 3	177,774.40	13,566,463.38	1.31
Bidder 4	186,733.20	13,665,008.63	1.37
Bidder 5	177,984.10	13,782,220.09	1.29
Bidder 6	133,770.00	14,225,780.57	0.94

Grade, Drain & Surface with Bridge Hooker Branch Road (CR 1276)
Date Let: 07-12-13 Call: 366 County: Clay District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	32,661.60	1,905,366.71	1.71
Bidder 2	26,871.20	2,021,640.81	1.33
Bidder 3	20,575.20	2,068,642.54	0.99
Bidder 4	40,527.20	2,238,985.14	1.81
Bidder 5	80,670.00	2,822,095.55	2.86

Bridge with Grade, Drain & Surface Dahl Road (KY 1677)
Date Let: 08-16-13 Call: 106 County: Pulaski District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	9,044.00	796,767.60	1.14
Bidder 2	9,908.00	839,199.35	1.18
Bidder 3	38,568.00	875,900.00	4.40
Bidder 4	12,552.00	909,134.52	1.38
Bidder 5	6,650.00	932,078.86	0.71

Bridge with Grade, Drain & Surface KY 476

Date Let: 09-27-13 Call: 105 County: Perry District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	100,277.50	1,422,535.50	7.05
Bidder 2	53,736.50	1,575,056.78	3.41
Bidder 3	173,204.50	1,854,347.34	9.34
Bidder 4	149,230.50	1,915,908.17	7.79
Bidder 5	189,861.71	1,952,550.75	9.72

Grade, Drain & Surface with Bridge Kuttawa-Princeton Road (US 62)

Date Let: 09-27-13 Call: 317 County: Lyon District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	301,754.84	14,869,588.01	2.03
Bidder 2	389,724.40	17,448,243.17	2.23

Bridge Replacement Stanton-Slade Road (KY 11)

Date Let: 11-22-13 Call: 104 County: Powell District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	75,300.80	895,095.49	8.41
Bidder 2	72,917.00	982,594.15	7.42
Bidder 3	92,366.80	997,701.81	9.26
Bidder 4	188,700.80	1,332,867.48	14.16

Bridge with Grade, Drain & Surface Beaver Dam - Leitchfield Road (US 62)

Date Let: 11-22-13 Call: 106 County: Ohio District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	2,724.00	849,506.11	0.32
Bidder 2	4,724.00	979,852.08	0.48
Bidder 3	2,116.00	986,670.88	0.21
Bidder 4	2,944.00	998,489.59	0.29
Bidder 5	10,344.00	1,071,853.80	0.97

Bridge with Grade, Drain & Surface Glomawr to Hazard Road (KY 451)

Date Let: 11-22-13 Call: 108 County: Perry District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	23,360.62	2,535,118.11	0.92
Bidder 2	23,142.70	2,670,259.63	0.87
Bidder 3	28,673.50	3,005,043.64	0.95
Bidder 4	50,820.70	3,775,000.00	1.35

Bridge with Grade, Drain & Surface Buffalo Branch Road (CR-1327)

Date Let: 11-22-13 Call: 111 County: Bell District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	15,100.00	475,850.00	3.17
Bidder 2	8,500.00	504,497.78	1.68
Bidder 3	7,600.00	534,380.10	1.42
Bidder 4	33,300.00	613,600.97	5.43

Grade, Drain & Surface with Bridge Gratz-Moxley Road (KY-355)
Date Let: 12-13-13 Call: 106 County: Owen District: 06

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	89,514.50	1,546,652.16	5.79
Bidder 2	94,190.50	1,623,700.00	5.80
Bidder 3	87,014.50	1,625,648.35	5.35
Bidder 4	111,085.50	1,750,662.02	6.35
Bidder 5	154,514.50	1,769,334.22	8.73
Bidder 6	120,926.50	1,839,724.00	6.57
Bidder 7	110,006.56	1,860,657.00	5.91
Bidder 8	189,014.50	1,870,341.94	10.11
Bidder 9	185,400.00	2,045,723.25	9.06

Grade & Drain with Bridge Partridge to Oven Fork Road (US 119, Section 3B)
Date Let: 12-13-13 Call: 113 County: Letcher District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	4,420.00	7,578,221.53	0.06
Bidder 2	3,294.00	7,754,235.24	0.04
Bidder 3	9,548.96	7,880,422.72	0.12
Bidder 4	12,780.00	9,192,686.00	0.14

Grade, Drain & Surface with Bridge US-68 and Louie B. Nunn Parkway
Date Let: 12-13-13 Call: 306 County: Metcalfe District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	391,503.25	9,682,936.69	4.04
Bidder 2	358,121.89	10,053,930.28	3.56
Bidder 3	614,784.71	10,074,064.58	6.10

Grade, Drain & Surface with Bridge New Moody Lane-Commerce Parkway (New Route)
Date Let: 12-13-13 Call: 307 County: Oldham District: 05

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	62,870.56	9,129,000.00	0.69
Bidder 2	142,196.00	9,484,979.49	1.50
Bidder 3	191,239.56	9,500,000.00	2.01
Bidder 4	152,561.80	9,550,564.42	1.60
Bidder 5	135,333.60	9,569,595.94	1.41
Bidder 6	120,497.35	9,916,269.92	1.22
Bidder 7	198,691.03	10,272,238.97	1.93
Bidder 8	188,126.78	10,838,290.31	1.74

Grade, Drain & Surface with Bridge Morgantown Road (KY 79)
Date Let: 01-24-14 Call: 313 County: Logan District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	226,205.00	3,698,030.22	6.12
Bidder 2	242,151.00	4,129,147.14	5.86
Bidder 3	251,134.56	4,184,763.00	6.00

Bridge with Grade, Drain & Surface Frenchburg to Owingsville Road (KY 36)
Date Let: 06-27-14 Call: 109 County: Menifee District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	37,210.00	1,030,975.29	3.61
Bidder 2	54,188.00	1,135,135.26	4.77
Bidder 3	38,613.00	1,252,303.33	3.08
Bidder 4	78,624.14	1,261,739.43	6.23
Bidder 5	49,520.00	1,269,226.50	3.90
Bidder 6	122,342.00	1,296,794.87	9.43
Bidder 7	70,970.00	1,556,668.07	4.56

Bridge Replacement Rye Branch Road (CR 1756)
Date Let: 07-11-14 Call: 108 County: Magoffin District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	11,960.00	353,862.26	3.38
Bidder 2	13,424.00	360,631.06	3.72
Bidder 3	13,080.00	401,434.99	3.26

Bridge with Grade, Drain & Surface Hazard-Hyden Road (KY-80)
Date Let: 07-11-14 Call: 113 County: Perry District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	135,085.80	4,277,564.72	3.16
Bidder 2	219,865.80	4,863,809.42	4.52
Bidder 3	134,235.80	5,457,242.25	2.46
Bidder 4	188,169.80	5,509,665.31	3.42

Bridge with Grade, Drain & Surface Tennessee State Line-Elizabethtown Road (I-65)
Date Let: 08-22-14 Call: 200 County: Hart District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	5,022,849.79	138,485,749.39	3.63
Bidder 2	7,612,965.54	144,700,000.00	5.26

Bridge with Grade, Drain & Surface KY-49
Date Let: 08-22-14 Call: 313 County: Marion District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	253,032.00	6,563,341.37	3.86
Bidder 2	227,647.00	7,142,390.72	3.19
Bidder 3	227,212.00	7,625,000.00	2.98

The following prestressed I-beam projects were included in the analysis of MOT costs but not in the analysis of replacement costs because bridge area data was not available.

Grade, Drain & Surface with Bridge Morgantown Road (KY 79)
Date Let: 12-13-13 Call: 300 County: Logan District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	272,151.00	4,198,460.80	6.48
Bidder 2	303,197.00	4,240,001.19	7.15

Bridge with Grade, Drain & Surface Oscar Bowling Road (CR 1113A)
Date Let: 09-26-14 Call: 104 County: Clay District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	90,225.00	1,345,000.00	6.71
Bidder 2	90,534.86	1,429,391.95	6.33

Grade, Drain & Surface with Bridge Kenneth Barrett Road (KY 30)
Date Let: 09-26-14 Call: 112 County: Owsley District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	70,995.84	3,916,594.89	1.81
Bidder 2	51,745.84	4,103,166.10	1.26
Bidder 3	112,645.84	4,359,000.00	2.58
Bidder 4	67,090.12	4,363,986.66	1.54
Bidder 5	108,455.74	4,553,738.21	2.38

Bridge with Grade, Drain & Surface Booneville-Jackson Road (KY 30)
Date Let: 09-26-14 Call: 113 County: Breathitt District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	100,055.30	3,141,110.54	3.19
Bidder 2	117,229.20	3,898,353.71	3.01
Bidder 3	182,311.30	4,373,538.22	4.17
Bidder 4	257,401.30	5,045,000.00	5.10

Grade & Drain with Bridge Simpsonville - Buck Creek Road (KY 1848)
Date Let: 10-24-14 Call: 118 County: Shelby District: 05

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	145,595.72	7,964,000.00	1.83
Bidder 2	135,013.72	8,193,500.00	1.65
Bidder 3	203,235.72	8,400,000.00	2.42
Bidder 4	90,504.82	8,443,035.77	1.07
Bidder 5	159,505.72	8,982,600.00	1.78

Bridge Replacement Hemp Patch Branch Road (CR-1002)
Date Let: 10-24-14 Call: 302 County: Knott District: 12
Proposal Description: FD04 SPP 060 1002 000-001

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	13,876.00	578,922.34	2.40
Bidder 2	19,232.50	582,948.64	3.30
Bidder 3	19,311.00	652,000.00	2.96
Bidder 4	13,826.00	687,400.70	2.01

The following projects were included in the analysis of MOT costs but not in the analysis of replacement costs because the bridge type was prestressed concrete box beam.

Bridge with Grade, Drain & Surface Fulton-Fulgham Road (KY 307)
Date Let: 03-22-13 Call: 104 County: Hickman District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	180,652.00	4,785,770.00	3.77
Bidder 2	675,325.10	7,999,354.11	8.44

Asphalt Rehab with Bridge(s) Martha Layne Collins Parkway (BG 9002)
Date Let: 04-19-13 Call: 425 County: Various District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	1,052,014.43	15,274,318.78	6.89
Bidder 2	870,315.75	16,440,000.00	5.29
Bidder 3	562,969.98	16,645,000.00	3.38

Bridge with Grade, Drain & Surface Low Water Drive (CR 1336)
Date Let: 05-24-13 Call: 352 County: Harlan District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	23,529.00	1,099,520.97	2.14
Bidder 2	25,453.00	1,115,808.16	2.28
Bidder 3	26,786.00	1,303,490.78	2.05
Bidder 4	37,464.00	1,393,334.07	2.69

Bridge with Grade, Drain & Surface Ray Road (CR 1060)
Date Let: 07-12-13 Call: 200 County: Daviess District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	4,332.00	506,417.49	0.86
Bidder 2	7,232.00	510,474.97	1.42
Bidder 3	9,199.20	585,581.00	1.57
Bidder 4	13,322.50	651,335.09	2.05
Bidder 5	14,732.00	679,247.20	2.17

Bridge with Grade, Drain & Surface Huddy-Mcveigh Road (KY 199)
Date Let: 08-16-13 Call: 103 County: Pike District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	4,063.00	921,425.55	0.44
Bidder 2	17,963.00	1,071,105.92	1.68
Bidder 3	37,467.80	1,197,516.40	3.13
Bidder 4	34,954.50	1,302,471.50	2.68

Bridge with Grade & Drain Bridge Connector
Date Let: 08-16-13 Call: 344 County: Martin District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	3,228.00	803,709.59	0.40
Bidder 2	10,535.00	881,765.54	1.19
Bidder 3	7,785.00	892,137.20	0.87

Bridge with Grade, Drain & Surface Wilson Creek Bridge (KY 945)
Date Let: 09-27-13 Call: 101 County: Graves District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	13,966.72	1,061,739.37	1.32
Bidder 2	12,320.00	1,181,273.31	1.04
Bidder 3	10,648.80	1,283,145.52	0.83
Bidder 4	9,049.00	1,298,504.00	0.70

Bridge Replacement East Union-Carlisle Road (KY-1285)
Date Let: 09-27-13 Call: 102 County: Nicholas District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	10,160.00	844,352.00	1.20
Bidder 2	10,236.00	851,117.74	1.20
Bidder 3	12,993.00	908,062.62	1.43
Bidder 4	15,532.00	982,293.27	1.58
Bidder 5	13,312.80	999,561.89	1.33
Bidder 6	13,936.00	1,027,542.18	1.36

Bridge Replacement KY-502
Date Let: 09-27-13 Call: 111 County: Hopkins District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	37,617.53	1,496,471.40	2.51
Bidder 2	4,252.00	1,534,048.98	0.28
Bidder 3	8,352.00	1,819,794.55	0.46

Bridge Replacement Anthoston-Niagara Road (KY-136)
Date Let: 10-25-13 Call: 109 County: Henderson District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	3,120.00	644,680.18	0.48
Bidder 2	2,920.00	695,836.16	0.42
Bidder 3	4,480.00	705,464.54	0.64
Bidder 4	7,100.00	713,383.91	1.00
Bidder 5	12,220.00	835,597.95	1.46

Bridge with Grade, Drain & Surface Gray-Indian Creek Road (KY 3437)
Date Let: 11-22-13 Call: 105 County: Knox District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	5,600.00	629,053.34	0.89
Bidder 2	7,790.00	630,903.09	1.23
Bidder 3	21,850.00	729,500.00	3.00

Bridge with Grade, Drain & Surface Sedalia to Mayfield Road (KY 79)
Date Let: 11-22-13 Call: 107 County: Graves District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	4,015.25	903,300.00	0.44
Bidder 2	12,027.85	906,572.53	1.33
Bidder 3	12,442.75	958,903.34	1.30

Bridge with Grade, Drain & Surface Baizetown-Windy Hill Road (KY 505 over Western KY Parkway)
Date Let: 12-13-13 Call: 402 County: Ohio District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	37,696.40	1,297,816.47	2.90
Bidder 2	25,000.40	1,326,690.97	1.88
Bidder 3	45,856.40	1,374,382.90	3.34
Bidder 4	166,762.40	1,758,287.84	9.48

Bridge with Grade, Drain & Surface KY 1505
Date Let: 01-24-14 Call: 101 County: Rockcastle District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	31,500.00	540,750.00	5.83
Bidder 2	36,125.00	555,019.67	6.51
Bidder 3	52,500.00	598,439.48	8.77
Bidder 4	24,332.50	620,293.57	3.92
Bidder 5	38,967.37	630,366.97	6.18
Bidder 6	41,958.33	741,746.41	5.66

Bridge Replacement Daniel Boone Drive (KY-11)
Date Let: 01-24-14 Call: 301 County: Knox District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	35,173.00	2,649,044.01	1.33
Bidder 2	31,068.00	2,658,452.65	1.17
Bidder 3	68,001.50	3,412,908.31	1.99

Bridge Replacement Pacies Branch Road (CR 1245)
Date Let: 03-28-14 Call: 112 County: Letcher District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	8,484.00	437,088.88	1.94
Bidder 2	5,304.52	530,009.43	1.00

Bridge Replacement Bloomfield Road (US 62)
Date Let: 04-25-14 Call: 105 County: Nelson District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	8,039.98	410,219.97	1.96
Bidder 2	10,170.00	473,997.78	2.15
Bidder 3	5,066.00	499,559.32	1.01
Bidder 4	8,866.00	558,843.58	1.59

Bridge with Grade, Drain & Surface Outland School Road (KY-1536)
Date Let: 05-30-14 Call: 103 County: Calloway District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	7,933.05	564,752.04	1.40
Bidder 2	2,292.00	589,089.00	0.39
Bidder 3	8,728.00	704,451.63	1.24

Bridge Replacement Tousey Road (CR 1872) over Spring Fork
Date Let: 05-30-14 Call: 108 County: Grayson District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	1,500.00	247,414.14	0.61
Bidder 2	2,500.00	259,974.76	0.96
Bidder 3	6,000.00	395,717.51	1.52

Bridge with Grade & Drain Stinson Road (CR-1700)
Date Let: 05-30-14 Call: 109 County: Wayne District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	52,220.00	584,268.40	8.94

Bridge Replacement Elk Lick Creek Road (CR 1224)
Date Let: 05-30-14 Call: 110 County: Lee District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	8,200.00	189,220.42	4.33
Bidder 2	41,500.00	224,848.10	18.46
Bidder 3	43,500.00	227,910.54	19.09
Bidder 4	1,000.00	243,728.50	0.41

Bridge with Grade, Drain & Surface KY 32 over Seas Branch
Date Let: 06-27-14 Call: 110 County: Rowan District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	53,455.00	907,243.52	5.89
Bidder 2	75,786.00	996,876.68	7.60
Bidder 3	82,792.00	1,112,225.48	7.44
Bidder 4	78,021.83	1,168,146.31	6.68
Bidder 5	173,902.00	1,218,490.41	14.27
Bidder 6	115,602.00	1,219,772.95	9.48
Bidder 7	191,902.75	1,222,250.96	15.70
Bidder 8	237,593.00	1,379,104.73	17.23

Bridge with Grade, Drain & Surface Lower Johns Creek Road (KY-194)
Date Let: 06-27-14 Call: 207 County: Floyd District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	22,350.00	798,175.52	2.80

Bridge Replacement Hacker Branch Road (CR-1136)
Date Let: 07-11-14 Call: 107 County: Owsley District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	10,000.00	908,735.60	1.10
Bidder 2	1,000.00	931,183.89	0.11
Bidder 3	32,500.00	1,104,653.07	2.94

Bridge with Grade, Drain & Surface Kg Estates Road (CR 1162)
Date Let: 07-11-14 Call: 109 County: Lawrence District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	28,145.00	697,491.87	4.04
Bidder 2	16,430.00	720,475.28	2.28

Bridge with Grade & Drain Stinson Road (CR-1700)
Date Let: 07-11-14 Call: 115 County: Wayne District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	28,915.00	366,965.44	7.88
Bidder 2	25,636.00	381,161.00	6.73
Bidder 3	22,020.00	498,981.95	4.41

Bridge with Grade, Drain & Surface Morehead-Grayson Road (US-60)
Date Let: 08-22-14 Call: 106 County: Rowan District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	82,033.96	1,777,455.92	4.62
Bidder 2	104,643.84	1,958,099.72	5.34
Bidder 3	100,088.80	2,040,112.57	4.91
Bidder 4	170,591.96	2,054,367.03	8.30

Bridge Replacement Glasgow Street (CS 1053)
Date Let: 08-22-14 Call: 107 County: Metcalfe District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	1,975.00	889,251.56	0.22
Bidder 2	1,735.00	935,417.89	0.19
Bidder 3	22,995.00	1,046,509.65	2.20
Bidder 4	6,626.57	1,162,102.31	0.57

Bridge Replacement Mobley Mill Road (CR 1327)
Date Let: 08-22-14 Call: 108 County: Nelson District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	3,422.00	326,336.65	1.05
Bidder 2	1,684.00	379,489.78	0.44
Bidder 3	3,186.00	385,347.04	0.83
Bidder 4	3,642.74	401,845.35	0.91

Bridge with Grade, Drain & Surface Upper Wolf Creek Road (CR 1134)
Date Let: 08-22-14 Call: 109 County: Owsley District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	6,172.50	688,250.58	0.90
Bidder 2	8,030.00	727,788.73	1.10
Bidder 3	9,222.50	746,698.10	1.24

Bridge with Grade & Drain Curtis Road (CR 1226)
Date Let: 08-22-14 Call: 111 County: Boyle District: 07

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	4,286.00	503,216.38	0.85
Bidder 2	5,522.12	592,950.97	0.93

Bridge Replacement Hade Bell Road (CR 1167)
Date Let: 09-26-14 Call: 116 County: Allen District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	2,270.00	356,355.71	0.64
Bidder 2	2,988.50	385,855.52	0.77

Bridge with Grade, Drain & Surface Wildie Road (CR-1071)
Date Let: 09-26-14 Call: 117 County: Rockcastle District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	17,750.00	543,590.31	3.27
Bidder 2	14,308.75	556,335.00	2.57
Bidder 3	9,985.89	567,949.77	1.76

Bridge with Grade, Drain & Surface Kg Estates Road (CR 1162)
Date Let: 09-26-14 Call: 118 County: Lawrence District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	35,262.00	718,909.19	4.90
Bidder 2	16,430.00	720,817.89	2.28

Bridge with Grade, Drain & Surface 10th Street (KY-2386)
Date Let: 09-26-14 Call: 306 County: Whitley District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	60,899.00	2,568,000.00	2.37
Bidder 2	21,053.00	2,717,624.63	0.77

Bridge Replacement Pryorsburg to Dublin Road (KY 1748)
Date Let: 10-24-14 Call: 108 County: Graves District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	3,960.00	499,248.06	0.79
Bidder 2	3,748.00	593,808.00	0.63
Bidder 3	14,916.00	628,858.68	2.37
Bidder 4	12,912.00	774,376.54	1.67

Bridge with Grade, Drain & Surface Upper Wolf Creek Road (CR 1134)
Date Let: 10-24-14 Call: 110 County: Owsley District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	17,822.50	560,100.00	3.18
Bidder 2	16,172.50	688,781.91	2.35
Bidder 3	17,522.50	696,905.94	2.51
Bidder 4	20,130.00	721,464.81	2.79
Bidder 5	25,964.00	909,200.91	2.86

Bridge Replacement Wildie Road (CR 1071)
Date Let: 10-24-14 Call: 111 County: Rockcastle District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	12,697.50	472,350.00	2.69
Bidder 2	12,457.00	500,851.70	2.49
Bidder 3	17,047.50	504,868.57	3.38
Bidder 4	9,097.50	543,018.80	1.68
Bidder 5	15,956.97	577,334.24	2.76

Grade & Drain with Asphalt Surface Chalybeate School Road (KY 743)
Date Let: 10-24-14 Call: 304 County: Edmonson District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	96,199.09	3,297,310.97	2.92

The following project was included in the analysis of MOT costs but not in the analysis of replacement costs because the bridge type was reinforced concrete box culvert.

Grade & Drain with Bridge KY 343
Date Let: 09-26-14 Call: 119 County: Letcher District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	70,714.00	504,849.77	14.01
Bidder 2	85,769.00	524,724.15	16.35
Bidder 3	110,456.00	598,309.85	18.46

Maintenance of Traffic-Bridge Deck Restoration

The analysis of maintenance of traffic (MOT) costs calculated the percentage of the total contract amount that was bid for MOT items. The analysis included the following MOT bid items:

- Arrow Panel
- Barricade-Type III
- Concrete Barrier Wall Type 9T
- Crash Cushion Type VI Class B TL2
- Crash Cushion Type VI Class B TL3
- Crash Cushion Type VI Class BT TL3
- Install Temp Crash Cushion
- Lane Closure
- Law Enforcement Officer
- Maintain & Control Traffic
- Pave Striping-Temp Paint-4 in
- Pave Striping-Temp Paint -6 in
- Pave Striping-Temp Rem Tape -B
- Pave Striping-Temp Rem Tape -W
- Pave Striping-Temp Rem Tape-Y
- Pavement Marker Type IVA-MW Temp
- Pavement Marker Type IVA-MY Temp
- Pavement Marker Type V-B W/R
- Police Officer with Vehicle
- Portable Changeable Message Sign
- Relocate Crash Cushion
- Relocate Temp Concrete Barrier
- Relocate Water-Filled Barriers
- Remove Pavement Marker Type V
- Signs
- Temp Concrete Median Barrier
- Temp Crash Cushion
- Temp Signal 2 Phase
- Temp Signal Multi Phase
- Temporary Signs
- Truck Mounted Attenuator
- Water-Filled Barriers

Not all items were used on every project. The results of the analysis are summarized in Table D2.

Table D2-Maintenance of traffic analysis summary bridge deck restoration

Analysis Case	n	Mean	Standard Deviation
MOT < 30%	270	14.19%	6.10%
MOT < 35%	276	14.46%	6.46%
MOT < 40%	280	14.75%	6.87%
All	283	15.12%	7.73%

The following are summaries of MOT percentages for each project used in the analysis.

Bridge Deck Overlay Butler County (WN 9007)
Date Let: 01-25-13 Call: 317 County: Butler District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	64,760.00	342,714.00	18.90
Bidder 2	68,945.00	352,658.20	19.55
Bidder 3	61,800.00	359,799.24	17.18
Bidder 4	81,200.00	370,450.00	21.92
Bidder 5	55,700.00	394,259.03	14.13
Bidder 6	77,150.00	417,997.30	18.46
Bidder 7	73,900.00	497,065.00	14.87

Bridge Deck Restoration & Waterproofing Interstate 64
Date Let: 02-22-13 Call: 100 County: Jefferson District: 05

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	71,995.00	326,889.00	22.02
Bidder 2	101,995.00	348,000.00	29.31
Bidder 3	78,797.00	348,000.00	22.64
Bidder 4	99,245.00	372,488.52	26.64
Bidder 5	85,095.00	390,520.70	21.79
Bidder 6	127,682.00	411,888.53	31.00

Bridge Deck Restoration & Waterproofing Campbell County (KY 9)
Date Let: 02-22-13 Call: 311 County: Campbell District: 06

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	59,300.00	584,185.49	10.15
Bidder 2	62,050.00	608,000.00	10.21
Bidder 3	101,010.00	688,574.00	14.67
Bidder 4	56,800.00	693,950.26	8.19
Bidder 5	65,700.00	718,203.86	9.15
Bidder 6	108,950.00	749,910.42	14.53

Bridge Deck Restoration & Waterproofing Bridge over North Fork of Triplett Creek
Date Let: 03-22-13 Call: 332 County: Rowan District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	29,343.00	179,566.50	16.34
Bidder 2	21,746.00	195,140.54	11.14
Bidder 3	70,192.00	205,016.10	34.24
Bidder 4	53,540.00	246,550.62	21.72
Bidder 5	22,895.00	273,178.03	8.38

Bridge Deck Restoration & Waterproofing Wayne & McCreary Cos. Bridge Overlays and Joint Replacements

Date Let: 03-22-13 Call: 434 County: Various District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	60,990.00	384,878.62	15.85
Bidder 2	105,360.00	422,043.30	24.96
Bidder 3	134,060.00	465,063.70	28.83
Bidder 4	80,560.00	480,000.00	16.78
Bidder 5	106,020.00	504,400.09	21.02
Bidder 6	49,380.00	549,869.87	8.98

Bridge Deck Overlay Hancock County

Date Let: 04-19-13 Call: 406 County: Hancock District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	49,725.00	366,602.53	13.56
Bidder 2	49,607.50	373,503.52	13.28
Bidder 3	27,040.00	407,319.32	6.64
Bidder 4	82,140.00	444,000.00	18.50
Bidder 5	43,840.00	447,250.00	9.80

Bridge Deck Restoration & Waterproofing New Circle Road Bridges

Date Let: 04-19-13 Call: 426 County: Fayette District: 07

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	269,204.00	1,757,032.16	15.32
Bidder 2	245,660.00	1,893,755.14	12.97
Bidder 3	248,284.00	1,984,735.50	12.51
Bidder 4	261,120.00	2,124,203.61	12.29

Bridge Deck Restoration & Waterproofing Bridge over Levisa Fork of Big Sandy

Date Let: 05-24-13 Call: 369 County: Floyd District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	50,434.00	493,286.00	10.22
Bidder 2	95,450.00	526,038.00	18.15
Bidder 3	101,238.00	649,803.01	15.58
Bidder 4	87,280.00	669,866.57	13.03
Bidder 5	107,490.00	740,600.00	14.51
Bidder 6	97,990.00	757,058.15	12.94

Bridge Deck Overlay KY 838 Crittenden and Livingston Countys

Date Let: 05-24-13 Call: 406 County: Various District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	4,200.00	362,587.65	1.16
Bidder 2	50,400.00	390,826.36	12.90
Bidder 3	6,900.00	393,250.60	1.75
Bidder 4	10,500.00	398,000.00	2.64
Bidder 5	32,500.00	511,946.72	6.35

Bridge Deck Restoration & Waterproofing KY 80 over KY 9006
Date Let: 05-24-13 Call: 420 County: Clay District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	82,197.00	514,214.72	15.98
Bidder 2	108,944.00	597,925.53	18.22
Bidder 3	125,890.00	648,249.05	19.42
Bidder 4	130,410.00	718,400.00	18.15
Bidder 5	129,874.00	730,391.97	17.78
Bidder 6	160,660.00	739,593.00	21.72
Bidder 7	114,580.00	755,823.40	15.16

Bridge Deck Restoration & Waterproofing Bridges over I-64
Date Let: 06-14-13 Call: 201 County: Bath District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	58,310.00	478,001.00	12.20
Bidder 2	66,785.00	499,871.77	13.36
Bidder 3	57,609.50	594,395.18	9.69
Bidder 4	213,729.00	618,439.40	34.56
Bidder 5	59,629.00	621,015.58	9.60
Bidder 6	106,335.00	750,000.00	14.18
Bidder 7	82,599.50	767,220.22	10.77
Bidder 8	96,432.00	776,643.30	12.42
Bidder 9	58,029.00	808,691.81	7.18

Bridge Deck Restoration & Waterproofing I-64 Bridges
Date Let: 08-16-13 Call: 201 County: Franklin District: 05

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	75,589.50	1,006,341.07	7.51
Bidder 2	283,090.00	1,186,067.80	23.87
Bidder 3	198,945.00	1,194,260.00	16.66
Bidder 4	323,727.00	1,279,942.42	25.29
Bidder 5	761,285.00	1,394,080.95	54.61

Bridge Deck Restoration & Waterproofing Robertson County KY 165 and KY 616
Date Let: 08-16-13 Call: 410 County: Robertson District: 06

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	31,468.00	380,405.20	8.27
Bidder 2	22,900.80	397,488.53	5.76
Bidder 3	28,600.80	409,257.75	6.99
Bidder 4	62,867.20	435,829.24	14.42
Bidder 5	69,500.80	458,514.14	15.16
Bidder 6	17,584.20	529,140.17	3.32
Bidder 7	45,059.50	565,000.00	7.98

Bridge Deck Overlay Boone County KY 8 and KY 536--Gallatin County KY 35
Date Let: 08-16-13 Call: 430 County: Various District: 06

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	78,670.00	593,151.55	13.26
Bidder 2	87,635.00	597,553.40	14.67
Bidder 3	91,634.65	625,952.80	14.64
Bidder 4	75,882.00	697,251.99	10.88
Bidder 5	46,226.24	700,000.00	6.60
Bidder 6	36,549.50	808,905.05	4.52

Bridge Deck Overlay Outerloop (KY 1065)
Date Let: 09-27-13 Call: 311 County: Jefferson District: 05

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	81,790.00	679,109.50	12.04
Bidder 2	50,975.00	680,392.00	7.49
Bidder 3	68,590.00	717,403.00	9.56
Bidder 4	44,439.20	731,310.25	6.08
Bidder 5	37,789.75	743,211.00	5.08
Bidder 6	36,784.00	760,025.37	4.84
Bidder 7	68,516.00	775,242.80	8.84
Bidder 8	51,120.00	849,250.00	6.02

Bridge Deck Restoration & Waterproofing KY 1773 Bridge over Grassy Creek
Date Let: 09-27-13 Call: 320 County: Carter District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	8,891.00	242,283.77	3.67
Bidder 2	9,895.00	257,092.50	3.85
Bidder 3	29,235.00	344,865.61	8.48

Bridge Deck Restoration & Waterproofing KY 386 Bridge over McBride Creek
Date Let: 09-27-13 Call: 322 County: Nicholas District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	14,344.00	137,579.93	10.43
Bidder 2	27,493.00	224,740.15	12.23

Bridge Deck Restoration & Waterproofing KY 699 Bridge over Leatherwood Creek
Date Let: 09-27-13 Call: 323 County: Perry District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	19,437.00	243,985.70	7.97
Bidder 2	21,043.00	262,310.69	8.02
Bidder 3	100,960.00	350,782.80	28.78
Bidder 4	115,788.00	364,534.00	31.76

Bridge Deck Restoration & Waterproofing Henderson County KY 285
Date Let: 10-25-13 Call: 301 County: Henderson District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	23,682.00	170,577.14	13.88
Bidder 2	27,777.00	186,466.30	14.90
Bidder 3	17,358.80	197,666.79	8.78
Bidder 4	24,832.00	197,848.32	12.55
Bidder 5	44,338.80	213,857.79	20.73
Bidder 6	24,568.60	234,403.75	10.48

Bridge Deck Restoration & Waterproofing Ohio County KY 1245
Date Let: 10-25-13 Call: 304 County: Ohio District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	22,340.00	149,869.30	14.91
Bidder 2	31,060.00	193,124.60	16.08
Bidder 3	23,720.00	198,321.67	11.96
Bidder 4	27,740.00	209,830.30	13.22
Bidder 5	57,340.00	233,742.30	24.53
Bidder 6	38,480.00	256,924.17	14.98

Bridge Deck Restoration & Waterproofing Union County KY 359
Date Let: 10-25-13 Call: 321 County: Union District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	28,250.00	223,910.80	12.62
Bidder 2	25,885.00	235,092.39	11.01
Bidder 3	45,500.00	278,758.57	16.32
Bidder 4	20,445.00	297,790.24	6.87

Bridge Deck Restoration & Waterproofing Davies County KY 3143, KY 554 and US 431
Date Let: 10-25-13 Call: 400 County: Daviess District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	85,140.00	434,403.28	19.60
Bidder 2	71,228.00	442,867.10	16.08
Bidder 3	56,175.00	465,583.78	12.07
Bidder 4	94,740.00	528,500.61	17.93
Bidder 5	63,940.00	567,292.35	11.27
Bidder 6	93,000.00	593,835.42	15.66
Bidder 7	61,800.00	596,820.69	10.35
Bidder 8	81,580.00	598,420.52	13.63

Bridge Deck Restoration & Waterproofing Bridge Overlays in Powell County
Date Let: 10-25-13 Call: 404 County: Powell District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	56,525.00	375,316.50	15.06
Bidder 2	64,282.00	469,842.80	13.68
Bidder 3	87,476.00	524,175.97	16.69
Bidder 4	120,205.00	593,953.05	20.24
Bidder 5	107,470.00	594,711.55	18.07
Bidder 6	132,576.00	598,866.80	22.14
Bidder 7	103,326.00	659,431.33	15.67
Bidder 8	95,832.00	677,677.00	14.14

Bridge Deck Restoration & Waterproofing District 9 Bridge Overlays
Date Let: 10-25-13 Call: 406 County: Various District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	79,576.00	696,209.67	11.43
Bidder 2	89,866.00	758,915.86	11.84
Bidder 3	182,368.00	779,724.30	23.39
Bidder 4	72,168.00	788,291.30	9.15
Bidder 5	77,676.00	799,161.05	9.72
Bidder 6	145,960.00	864,007.03	16.89
Bidder 7	133,952.00	936,928.70	14.30

Bridge Deck Restoration & Waterproofing Bluegrass Parkway
Date Let: 11-22-13 Call: 304 County: Nelson District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	64,484.00	426,172.22	15.13
Bidder 2	109,692.00	436,411.00	25.14
Bidder 3	83,490.00	446,551.00	18.70
Bidder 4	73,088.00	447,446.00	16.33
Bidder 5	134,450.00	449,101.00	29.94
Bidder 6	72,185.00	468,019.56	15.42
Bidder 7	67,788.00	472,379.21	14.35
Bidder 8	54,980.00	488,396.69	11.26

Bridge Deck Restoration & Waterproofing District 10 Bridge Overlays
Date Let: 11-22-13 Call: 406 County: Various District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	74,460.00	541,924.72	13.74
Bidder 2	152,066.00	570,456.15	26.66
Bidder 3	86,976.00	581,077.16	14.97
Bidder 4	108,580.00	604,617.60	17.96
Bidder 5	76,664.00	645,743.80	11.87
Bidder 6	138,440.00	706,281.46	19.60

Bridge Deck Restoration & Waterproofing Warren County KY 185
Date Let: 12-13-13 Call: 303 County: Warren District: 03

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	79,650.00	669,947.00	11.89
Bidder 2	44,330.00	692,135.65	6.40
Bidder 3	36,300.00	763,848.41	4.75
Bidder 4	74,720.00	767,673.75	9.73
Bidder 5	33,363.00	849,415.39	3.93
Bidder 6	45,320.00	912,467.95	4.97
Bidder 7	44,794.00	1,000,000.00	4.48

Bridge Deck Restoration & Waterproofing District 4 Bridge Overlays
Date Let: 12-13-13 Call: 401 County: Various District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	59,235.00	368,839.00	16.06
Bidder 2	60,735.00	396,670.00	15.31
Bidder 3	62,682.00	399,302.03	15.70
Bidder 4	53,616.00	417,662.60	12.84
Bidder 5	208,425.00	430,319.00	48.43
Bidder 6	50,382.00	446,680.50	11.28
Bidder 7	63,129.00	449,898.19	14.03

Bridge Deck Restoration & Waterproofing Bridge Over Culp Creek Rd
Date Let: 04-25-14 Call: 328 County: Greenup District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	16,422.00	230,410.08	7.13
Bidder 2	17,070.00	233,366.27	7.31
Bidder 3	46,843.00	262,803.00	17.82
Bidder 4	29,480.00	283,913.27	10.38
Bidder 5	17,073.00	296,224.92	5.76

Bridge Deck Restoration & Waterproofing US 31E
Date Let: 04-25-14 Call: 329 County: Nelson District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	21,189.00	261,859.11	8.09
Bidder 2	30,569.00	284,864.23	10.73
Bidder 3	43,019.00	329,124.88	13.07
Bidder 4	27,945.00	333,770.40	8.37

Bridge Deck Restoration & Waterproofing Fleming County Bridge Overlays

Date Let: 04-25-14 Call: 403 County: Fleming District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	35,280.00	240,321.15	14.68
Bidder 2	37,480.00	247,784.25	15.13
Bidder 3	40,638.00	299,849.38	13.55
Bidder 4	36,890.00	356,713.01	10.34
Bidder 5	81,686.00	364,499.00	22.41

Bridge Deck Restoration & Waterproofing Davies County

Date Let: 05-30-14 Call: 352 County: Daviess District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	57,672.50	221,318.20	26.06
Bidder 2	48,150.00	270,483.50	17.80
Bidder 3	84,065.00	289,540.92	29.03
Bidder 4	48,490.00	292,049.93	16.60
Bidder 5	64,900.00	299,695.80	21.66
Bidder 6	73,812.50	301,141.90	24.51

Bridge Deck Restoration & Waterproofing Hopkins

Date Let: 05-30-14 Call: 353 County: Hopkins District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	162,360.00	452,638.55	35.87
Bidder 2	84,650.00	515,926.54	16.41
Bidder 3	98,848.00	523,038.38	18.90
Bidder 4	147,650.00	572,290.30	25.80
Bidder 5	95,400.00	593,655.34	16.07
Bidder 6	122,100.00	606,092.10	20.15

Bridge Deck Restoration & Waterproofing Bridge over Licking River

Date Let: 05-30-14 Call: 354 County: Morgan District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	23,337.00	254,117.63	9.18
Bidder 2	44,969.00	292,315.20	15.38
Bidder 3	19,945.00	310,682.38	6.42
Bidder 4	50,245.00	342,734.60	14.66
Bidder 5	15,245.00	347,619.36	4.39
Bidder 6	86,380.00	366,294.00	23.58

Bridge Deck Restoration & Waterproofing Bridge over Middle Fork of Red River

Date Let: 05-30-14 Call: 355 County: Powell District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	32,817.00	170,621.97	19.23
Bidder 2	38,215.00	190,517.70	20.06
Bidder 3	52,114.00	206,032.16	25.29
Bidder 4	74,470.00	207,388.30	35.91
Bidder 5	36,805.00	258,413.77	14.24

Bridge Deck Restoration & Waterproofing KY 114 Overlays
Date Let: 05-30-14 Call: 440 County: Floyd District: 12

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	55,658.50	366,242.27	15.20
Bidder 2	56,788.00	379,004.56	14.98
Bidder 3	85,488.00	384,729.20	22.22
Bidder 4	61,980.00	391,227.10	15.84
Bidder 5	59,788.00	392,574.19	15.23

Bridge Deck Restoration & Waterproofing Davies County US 231
Date Let: 05-30-14 Call: 444 County: Daviess District: 02

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	93,769.00	460,777.00	20.35
Bidder 2	40,818.00	489,121.41	8.35
Bidder 3	76,760.00	513,202.00	14.96
Bidder 4	115,185.00	529,931.75	21.74
Bidder 5	44,685.00	537,515.98	8.31
Bidder 6	76,276.50	560,926.31	13.60
Bidder 7	97,185.00	583,290.00	16.66

Bridge Deck Restoration & Waterproofing Ballard County
Date Let: 05-30-14 Call: 445 County: Ballard District: 01

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	69,238.00	432,024.60	16.03
Bidder 2	71,605.00	461,404.92	15.52
Bidder 3	81,715.00	493,644.71	16.55
Bidder 4	41,985.00	562,607.51	7.46
Bidder 5	85,747.00	640,602.31	13.39

Bridge Deck Restoration & Waterproofing Bridges over Mountain Parkway
Date Let: 05-30-14 Call: 446 County: Powell District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	55,776.00	487,248.51	11.45
Bidder 2	72,938.00	495,021.80	14.73
Bidder 3	38,138.00	498,217.18	7.65
Bidder 4	43,988.00	522,500.60	8.42
Bidder 5	85,790.00	528,787.40	16.22

Bridge Deck Restoration & Waterproofing Bridge over Wilson Creek
Date Let: 06-27-14 Call: 316 County: Nelson District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	16,925.00	117,467.50	14.41
Bidder 2	20,269.50	163,710.07	12.38
Bidder 3	30,995.00	174,611.50	17.75
Bidder 4	22,490.00	179,482.50	12.53
Bidder 5	19,245.00	209,588.91	9.18

Bridge Deck Restoration & Waterproofing Interstate 64
Date Let: 07-11-14 Call: 100 County: Franklin District: 05

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	189,066.00	787,836.00	24.00
Bidder 2	74,340.00	835,469.00	8.90
Bidder 3	39,533.60	890,676.31	4.44
Bidder 4	77,200.00	923,620.82	8.36
Bidder 5	133,080.00	1,082,629.46	12.29

Bridge Deck Restoration & Waterproofing Bridge Overlays in Harlan County
Date Let: 08-22-14 Call: 435 County: Harlan District: 11

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	85,176.00	791,855.41	10.76
Bidder 2	182,235.00	851,170.40	21.41
Bidder 3	95,826.00	857,545.16	11.17
Bidder 4	281,604.00	950,600.40	29.62

Bridge Deck Restoration & Waterproofing Bridge Overlays in Perry County
Date Let: 08-22-14 Call: 445 County: Perry District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	101,276.00	748,644.42	13.53
Bidder 2	69,788.00	751,375.08	9.29
Bidder 3	87,936.00	822,514.71	10.69
Bidder 4	161,986.00	891,011.70	18.18
Bidder 5	240,890.00	899,935.70	26.77

Bridge Deck Restoration & Waterproofing Bridge over Ohio River
Date Let: 09-26-14 Call: 100 County: Boone District: 06

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	1,059,290.00	6,725,000.00	15.75
Bidder 2	1,550,465.00	8,153,368.39	19.02
Bidder 3	1,059,298.00	8,772,892.82	12.07
Bidder 4	1,419,050.00	8,871,092.00	16.00
Bidder 5	1,770,505.00	9,596,222.00	18.45

Bridge Deck Restoration & Waterproofing Western Kentucky Parkway Bridge Overlays
Date Let: 09-26-14 Call: 404 County: Hardin District: 04

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	156,748.00	735,209.66	21.32
Bidder 2	238,900.00	751,373.00	31.80
Bidder 3	245,226.04	758,000.00	32.35
Bidder 4	151,380.00	795,459.68	19.03
Bidder 5	209,580.00	849,857.00	24.66
Bidder 6	159,584.00	851,503.81	18.74

Bridge Deck Restoration & Waterproofing Bridge over Tygarts Creek
Date Let: 10-24-14 Call: 319 County: Carter District: 09

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	47,300.00	459,533.45	10.29
Bidder 2	38,800.00	497,414.50	7.80
Bidder 3	1,200.00	509,889.52	0.24
Bidder 4	51,300.00	512,384.40	10.01
Bidder 5	4,000.00	562,184.75	0.71
Bidder 6	15,050.00	609,471.66	2.47
Bidder 7	8,300.00	662,378.40	1.25

Bridge Deck Restoration & Waterproofing Bridge Overlays in Wayne County
Date Let: 10-24-14 Call: 403 County: Wayne District: 08

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	87,705.00	389,939.80	22.49
Bidder 2	76,182.00	404,524.40	18.83
Bidder 3	96,049.95	505,884.71	18.99
Bidder 4	62,829.00	514,635.59	12.21
Bidder 5	108,435.00	533,264.15	20.33

The following projects were included in the analysis of MOT costs but not in the analysis of overlay costs because they did not include a latex-modified concrete overlay.

Bridge Deck Restoration & Waterproofing Bridges over Mountain Parkway
Date Let: 06-14-13 Call: 405 County: Wolfe District: 10

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	38,243.00	181,435.80	21.08
Bidder 2	12,245.00	188,366.34	6.50
Bidder 3	49,745.00	240,826.30	20.66
Bidder 4	21,543.00	253,716.31	8.49
Bidder 5	30,170.00	264,780.20	11.39
Bidder 6	32,537.00	313,454.13	10.38
Bidder 7	82,840.00	408,254.16	20.29

Bridge Deck Restoration & Waterproofing Bridge over Harrods Creek
Date Let: 03-28-14 Call: 300 County: Oldham District: 05

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	4,248.00	57,753.20	7.36
Bidder 2	7,246.80	62,622.76	11.57
Bidder 3	10,947.20	83,917.12	13.05

Bridge Deck Restoration & Waterproofing Anderson County US 62 Tyron Bridge
Date Let: 08-22-14 Call: 319 County: Anderson District: 07

	MOT Items ($)	Total Bid, $	MOT Percent
Bidder 1	19,500.00	42,500.00	45.88
Bidder 2	13,500.00	44,500.00	30.34
Bidder 3	9,950.00	53,755.00	18.51
Bidder 4	25,000.00	99,472.18	25.13

APPENDIX E: PROBABILISTIC ANALYSIS

Appendix E contains the risk profile statistics and ascending cumulative probability plots for the following probabilistic analyses:

- Bridge over highway
- Bridge over highway with modified bridge construction time and cost
- Bridge over highway with limited variables
- Bridge over waterway
- Bridge over waterway with modified bridge construction time and cost

Bridge over Highway

Table E.1-Risk profile statistics for highway bridge ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	97,438	1,045,382	794,935	341,131	1,340,918
Maximum	1,900,008	8,127,154	9,416,041	2,117,072	6,808,270	8,115,999
Mean	1,203,146	2,487,246	3,690,392	1,250,889	2,190,694	3,441,584
Std Dev	156,583	1,170,485	1,180,960	175,993	906,419	929,941
Percentile						
1%	872,316	432,429	1,593,222	918,427	612,292	1,782,069
5%	945,174	793,004	1,982,405	989,862	885,351	2,096,983
10%	998,059	1,064,676	2,256,335	1,035,656	1,093,040	2,316,965
15%	1,036,328	1,271,769	2,466,409	1,068,262	1,255,455	2,483,991
20%	1,067,022	1,454,059	2,649,745	1,095,750	1,390,624	2,623,876
25%	1,093,240	1,618,878	2,815,350	1,121,263	1,516,133	2,753,954
30%	1,117,539	1,770,534	2,970,703	1,145,099	1,635,395	2,878,401
35%	1,139,266	1,916,931	3,117,045	1,167,704	1,751,407	2,996,011
40%	1,160,427	2,061,895	3,262,952	1,190,012	1,863,082	3,111,579
45%	1,180,850	2,207,432	3,410,607	1,211,954	1,975,540	3,225,424
50%	1,201,069	2,356,742	3,560,778	1,235,173	2,088,005	3,340,833
55%	1,220,708	2,508,172	3,714,483	1,258,333	2,204,872	3,460,045
60%	1,241,683	2,664,206	3,871,521	1,282,448	2,326,519	3,580,577
65%	1,263,431	2,835,780	4,041,007	1,307,817	2,454,685	3,713,426
70%	1,285,744	3,017,088	4,228,912	1,335,014	2,597,707	3,861,338
75%	1,309,538	3,217,436	4,431,141	1,364,839	2,755,398	4,018,037
80%	1,336,254	3,450,674	4,663,438	1,398,495	2,931,534	4,199,411
85%	1,367,361	3,729,281	4,943,681	1,438,184	3,146,207	4,423,492
90%	1,407,025	4,091,371	5,302,833	1,489,869	3,426,181	4,708,994
95%	1,464,162	4,630,264	5,855,001	1,564,673	3,851,427	5,135,324
99%	1,576,306	5,649,521	6,853,068	1,708,231	4,638,987	5,959,375

Table E.2-Risk profile statistics for highway bridge ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	128,948	1,136,745	794,935	627,597	1,664,219
Maximum	1,900,008	15,913,872	17,202,760	2,117,072	13,417,366	14,725,095
Mean	1,203,146	4,805,013	6,008,159	1,250,889	4,265,064	5,515,954
Std Dev	156,583	2,320,482	2,325,747	175,993	1,798,822	1,813,805
Percentile						
1%	872,316	717,568	1,901,047	918,427	1,125,222	2,332,708
5%	945,174	1,443,603	2,642,581	989,862	1,671,524	2,898,109
10%	998,059	1,983,136	3,180,393	1,035,656	2,084,829	3,321,224
15%	1,036,328	2,396,570	3,596,632	1,068,262	2,406,865	3,643,361
20%	1,067,022	2,758,475	3,954,421	1,095,750	2,681,582	3,919,214
25%	1,093,240	3,084,803	4,282,127	1,121,263	2,926,514	4,168,648
30%	1,117,539	3,387,221	4,588,013	1,145,099	3,163,495	4,409,121
35%	1,139,266	3,676,889	4,879,458	1,167,704	3,393,788	4,639,750
40%	1,160,427	3,962,949	5,165,387	1,190,012	3,617,512	4,864,784
45%	1,180,850	4,251,826	5,453,012	1,211,954	3,838,843	5,088,789
50%	1,201,069	4,548,437	5,748,648	1,235,173	4,062,532	5,315,901
55%	1,220,708	4,846,878	6,052,732	1,258,333	4,294,361	5,541,791
60%	1,241,683	5,156,019	6,361,843	1,282,448	4,533,615	5,783,157
65%	1,263,431	5,495,789	6,697,248	1,307,817	4,789,563	6,041,907
70%	1,285,744	5,854,924	7,063,779	1,335,014	5,073,127	6,329,824
75%	1,309,538	6,249,841	7,462,974	1,364,839	5,385,349	6,640,381
80%	1,336,254	6,711,539	7,923,100	1,398,495	5,734,930	6,995,903
85%	1,367,361	7,267,546	8,474,759	1,438,184	6,161,103	7,429,282
90%	1,407,025	7,981,769	9,191,668	1,489,869	6,718,945	7,990,383
95%	1,464,162	9,050,651	10,266,998	1,564,673	7,559,273	8,831,245
99%	1,576,306	11,077,926	12,262,742	1,708,231	9,125,888	10,418,898

Table E.3-Risk profile statistics for highway bridge ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	206,437	1,270,059	794,935	1,439,719	2,535,401
Maximum	1,900,008	39,277,797	40,562,914	2,117,072	33,244,654	34,552,383
Mean	1,203,146	11,758,315	12,961,461	1,250,889	10,488,175	11,739,065
Std Dev	156,583	5,771,415	5,773,489	175,993	4,476,565	4,486,264
Percentile						
1%	872,316	1,585,982	2,783,652	918,427	2,666,615	3,888,973
5%	945,174	3,388,038	4,596,383	989,862	4,028,280	5,265,337
10%	998,059	4,738,215	5,943,565	1,035,656	5,062,315	6,312,043
15%	1,036,328	5,764,651	6,972,496	1,068,262	5,861,357	7,103,400
20%	1,067,022	6,673,058	7,878,844	1,095,750	6,550,163	7,791,140
25%	1,093,240	7,486,983	8,680,707	1,121,263	7,160,756	8,400,892
30%	1,117,539	8,239,355	9,437,390	1,145,099	7,749,965	9,001,345
35%	1,139,266	8,958,709	10,156,542	1,167,704	8,321,916	9,568,357
40%	1,160,427	9,664,707	10,869,362	1,190,012	8,876,822	10,121,179
45%	1,180,850	10,383,858	11,589,573	1,211,954	9,429,836	10,679,482
50%	1,201,069	11,119,865	12,320,279	1,235,173	9,985,899	11,237,070
55%	1,220,708	11,863,936	13,067,967	1,258,333	10,562,750	11,808,288
60%	1,241,683	12,631,063	13,832,748	1,282,448	11,155,603	12,406,793
65%	1,263,431	13,470,428	14,672,003	1,307,817	11,793,266	13,040,609
70%	1,285,744	14,373,610	15,569,892	1,335,014	12,496,336	13,756,259
75%	1,309,538	15,351,251	16,561,290	1,364,839	13,276,944	14,523,221
80%	1,336,254	16,498,176	17,708,920	1,398,495	14,145,345	15,395,228
85%	1,367,361	17,884,613	19,086,306	1,438,184	15,206,662	16,465,633
90%	1,407,025	19,656,498	20,859,854	1,489,869	16,592,100	17,853,154
95%	1,464,162	22,317,651	23,537,864	1,564,673	18,687,465	19,951,555
99%	1,576,306	27,340,546	28,539,746	1,708,231	22,573,882	23,859,671

Table E.4-Risk profile statistics for highway bridge ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	690,790	1,806,946	794,935	752,672	1,843,415
Maximum	1,900,008	11,191,076	12,479,963	2,117,072	8,600,840	9,908,569
Mean	1,203,146	4,012,556	5,215,702	1,250,889	3,237,609	4,488,499
Std Dev	156,583	1,410,766	1,420,371	175,993	1,065,127	1,090,539
Percentile						
1%	872,316	1,473,263	2,642,809	918,427	1,348,978	2,519,661
5%	945,174	1,963,911	3,147,135	989,862	1,705,022	2,910,677
10%	998,059	2,295,765	3,486,805	1,035,656	1,948,617	3,168,273
15%	1,036,328	2,543,648	3,744,644	1,068,262	2,136,639	3,365,706
20%	1,067,022	2,762,035	3,959,026	1,095,750	2,300,995	3,531,210
25%	1,093,240	2,963,393	4,161,854	1,121,263	2,444,304	3,682,957
30%	1,117,539	3,149,028	4,349,547	1,145,099	2,582,765	3,827,301
35%	1,139,266	3,332,802	4,529,285	1,167,704	2,720,820	3,964,214
40%	1,160,427	3,508,662	4,707,391	1,190,012	2,853,351	4,102,558
45%	1,180,850	3,683,235	4,886,617	1,211,954	2,986,072	4,236,305
50%	1,201,069	3,865,747	5,071,344	1,235,173	3,120,120	4,372,410
55%	1,220,708	4,052,585	5,257,421	1,258,333	3,257,939	4,511,289
60%	1,241,683	4,245,816	5,451,197	1,282,448	3,403,322	4,659,087
65%	1,263,431	4,447,270	5,651,355	1,307,817	3,556,245	4,817,323
70%	1,285,744	4,662,528	5,875,186	1,335,014	3,723,358	4,984,699
75%	1,309,538	4,904,348	6,116,437	1,364,839	3,902,246	5,170,453
80%	1,336,254	5,179,627	6,395,274	1,398,495	4,110,965	5,380,937
85%	1,367,361	5,512,845	6,723,508	1,438,184	4,363,050	5,639,359
90%	1,407,025	5,933,560	7,150,655	1,489,869	4,688,068	5,972,862
95%	1,464,162	6,573,928	7,787,315	1,564,673	5,177,528	6,461,485
99%	1,576,306	7,770,867	8,992,684	1,708,231	6,110,561	7,415,750

Table E.5-Risk profile statistics for highway bridge ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	722,300	1,930,294	794,935	1,063,635	2,256,461
Maximum	1,900,008	18,977,794	20,266,682	2,117,072	15,209,936	16,517,665
Mean	1,203,146	6,330,323	7,533,469	1,250,889	5,311,980	6,562,869
Std Dev	156,583	2,530,719	2,536,052	175,993	1,939,853	1,956,718
Percentile						
1%	872,316	1,868,151	3,054,626	918,427	1,938,273	3,133,485
5%	945,174	2,684,329	3,883,606	989,862	2,532,482	3,754,640
10%	998,059	3,258,857	4,453,017	1,035,656	2,967,113	4,199,130
15%	1,036,328	3,702,118	4,904,151	1,068,262	3,306,553	4,543,798
20%	1,067,022	4,086,513	5,283,927	1,095,750	3,598,788	4,838,617
25%	1,093,240	4,442,203	5,643,559	1,121,263	3,862,853	5,104,769
30%	1,117,539	4,768,723	5,972,237	1,145,099	4,112,247	5,362,583
35%	1,139,266	5,091,612	6,292,662	1,167,704	4,367,917	5,613,147
40%	1,160,427	5,412,614	6,608,427	1,190,012	4,611,938	5,857,963
45%	1,180,850	5,724,548	6,927,899	1,211,954	4,848,313	6,100,857
50%	1,201,069	6,043,843	7,250,388	1,235,173	5,085,968	6,339,431
55%	1,220,708	6,380,034	7,584,815	1,258,333	5,338,865	6,593,957
60%	1,241,683	6,728,621	7,927,645	1,282,448	5,604,887	6,857,818
65%	1,263,431	7,088,269	8,295,244	1,307,817	5,882,195	7,142,829
70%	1,285,744	7,481,278	8,688,812	1,335,014	6,186,605	7,442,035
75%	1,309,538	7,918,934	9,127,494	1,364,839	6,519,861	7,781,507
80%	1,336,254	8,419,858	9,634,028	1,398,495	6,900,388	8,157,432
85%	1,367,361	9,019,055	10,232,593	1,438,184	7,362,019	8,631,906
90%	1,407,025	9,793,609	11,007,341	1,489,869	7,962,515	9,233,089
95%	1,464,162	10,952,717	12,167,788	1,564,673	8,853,724	10,127,765
99%	1,576,306	13,126,231	14,352,181	1,708,231	10,550,036	11,853,870

Table E.6-Risk profile statistics for highway bridge ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	816,830	2,022,003	794,935	1,978,980	3,144,649
Maximum	1,900,008	42,337,949	43,626,836	2,117,072	35,037,224	36,344,953
Mean	1,203,146	13,283,624	14,486,770	1,250,889	11,535,090	12,785,980
Std Dev	156,583	5,960,550	5,962,774	175,993	4,605,433	4,616,116
Percentile						
1%	872,316	2,844,264	4,031,257	918,427	3,536,571	4,768,463
5%	945,174	4,673,734	5,882,916	989,862	4,924,719	6,153,751
10%	998,059	6,044,544	7,246,086	1,035,656	5,956,079	7,205,100
15%	1,036,328	7,094,535	8,292,717	1,068,262	6,778,933	8,021,078
20%	1,067,022	8,012,264	9,213,564	1,095,750	7,459,721	8,709,063
25%	1,093,240	8,848,828	10,049,529	1,121,263	8,103,906	9,346,338
30%	1,117,539	9,620,709	10,828,172	1,145,099	8,700,974	9,956,863
35%	1,139,266	10,371,884	11,575,932	1,167,704	9,298,056	10,547,840
40%	1,160,427	11,113,571	12,308,718	1,190,012	9,871,473	11,121,189
45%	1,180,850	11,848,500	13,054,503	1,211,954	10,431,269	11,684,579
50%	1,201,069	12,609,807	13,817,945	1,235,173	11,002,411	12,255,098
55%	1,220,708	13,384,215	14,592,372	1,258,333	11,602,847	12,850,894
60%	1,241,683	14,203,659	15,399,410	1,282,448	12,221,115	13,466,766
65%	1,263,431	15,058,098	16,257,046	1,307,817	12,883,263	14,124,088
70%	1,285,744	15,977,979	17,181,878	1,335,014	13,607,587	14,859,684
75%	1,309,538	17,019,257	18,217,440	1,364,839	14,403,007	15,654,613
80%	1,336,254	18,186,446	19,402,790	1,398,495	15,295,393	16,555,744
85%	1,367,361	19,609,346	20,818,148	1,438,184	16,398,183	17,660,386
90%	1,407,025	21,461,131	22,660,891	1,489,869	17,817,470	19,087,773
95%	1,464,162	24,201,168	25,398,514	1,564,673	19,980,314	21,243,462
99%	1,576,306	29,395,091	30,608,721	1,708,231	23,970,207	25,252,243

Table E.7-Risk profile statistics for highway bridge ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	3,103,685	4,187,213	794,935	2,519,511	3,688,107
Maximum	1,900,008	26,190,632	27,554,763	2,117,072	19,710,031	20,858,993
Mean	1,203,146	10,791,710	11,994,856	1,250,889	7,890,566	9,141,455
Std Dev	156,583	3,018,819	3,025,201	175,993	2,115,615	2,140,584
Percentile						
1%	872,316	5,027,835	6,221,604	918,427	3,897,325	5,091,288
5%	945,174	6,201,260	7,399,223	989,862	4,730,081	5,940,267
10%	998,059	7,013,774	8,214,189	1,035,656	5,282,830	6,499,107
15%	1,036,328	7,612,451	8,818,029	1,068,262	5,696,640	6,927,315
20%	1,067,022	8,134,123	9,330,228	1,095,750	6,049,030	7,277,027
25%	1,093,240	8,595,871	9,795,708	1,121,263	6,354,480	7,589,744
30%	1,117,539	9,018,702	10,218,745	1,145,099	6,634,018	7,876,496
35%	1,139,266	9,424,442	10,623,052	1,167,704	6,904,079	8,143,975
40%	1,160,427	9,815,643	11,020,702	1,190,012	7,173,156	8,413,454
45%	1,180,850	10,191,980	11,393,374	1,211,954	7,450,134	8,691,982
50%	1,201,069	10,575,930	11,778,008	1,235,173	7,713,306	8,963,475
55%	1,220,708	10,963,323	12,170,565	1,258,333	7,981,474	9,238,719
60%	1,241,683	11,368,995	12,569,962	1,282,448	8,262,548	9,524,291
65%	1,263,431	11,800,112	13,004,798	1,307,817	8,565,452	9,824,245
70%	1,285,744	12,244,283	13,450,291	1,335,014	8,891,201	10,152,254
75%	1,309,538	12,731,325	13,937,650	1,364,839	9,236,565	10,500,609
80%	1,336,254	13,303,645	14,510,059	1,398,495	9,636,490	10,906,040
85%	1,367,361	13,964,300	15,175,338	1,438,184	10,112,248	11,387,842
90%	1,407,025	14,827,998	16,043,020	1,489,869	10,727,542	12,001,726
95%	1,464,162	16,123,374	17,337,248	1,564,673	11,644,613	12,944,882
99%	1,576,306	18,613,419	19,834,669	1,708,231	13,479,517	14,810,886

Table E.8-Risk profile statistics for highway bridge ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	3,232,036	4,315,564	794,935	2,830,474	4,023,300
Maximum	1,900,008	32,595,226	33,884,113	2,117,072	24,381,753	25,792,195
Mean	1,203,146	13,109,477	14,312,623	1,250,889	9,964,936	11,215,825
Std Dev	156,583	3,912,018	3,916,923	175,993	2,838,506	2,859,078
Percentile						
1%	872,316	5,765,631	6,944,840	918,427	4,719,163	5,914,247
5%	945,174	7,261,582	8,451,320	989,862	5,785,638	7,010,177
10%	998,059	8,258,649	9,456,711	1,035,656	6,487,893	7,715,102
15%	1,036,328	9,010,194	10,214,434	1,068,262	7,027,472	8,261,945
20%	1,067,022	9,659,422	10,855,600	1,095,750	7,475,790	8,711,570
25%	1,093,240	10,235,657	11,434,677	1,121,263	7,877,929	9,116,576
30%	1,117,539	10,773,734	11,976,009	1,145,099	8,259,585	9,498,858
35%	1,139,266	11,293,176	12,494,324	1,167,704	8,620,164	9,868,757
40%	1,160,427	11,790,615	12,991,105	1,190,012	8,983,124	10,231,507
45%	1,180,850	12,299,784	13,497,592	1,211,954	9,338,929	10,585,944
50%	1,201,069	12,798,769	14,002,997	1,235,173	9,697,881	10,945,213
55%	1,220,708	13,300,534	14,508,335	1,258,333	10,071,011	11,320,860
60%	1,241,683	13,828,191	15,033,865	1,282,448	10,455,931	11,713,893
65%	1,263,431	14,378,431	15,585,063	1,307,817	10,855,367	12,113,554
70%	1,285,744	14,976,863	16,183,398	1,335,014	11,279,906	12,542,013
75%	1,309,538	15,636,306	16,846,852	1,364,839	11,755,003	13,021,092
80%	1,336,254	16,362,041	17,574,146	1,398,495	12,304,093	13,567,844
85%	1,367,361	17,238,853	18,458,417	1,438,184	12,952,737	14,228,861
90%	1,407,025	18,369,728	19,580,654	1,489,869	13,796,960	15,074,705
95%	1,464,162	20,083,625	21,300,864	1,564,673	15,041,135	16,315,401
99%	1,576,306	23,291,785	24,504,388	1,708,231	17,536,966	18,840,269

Table E.9-Risk profile statistics for highway bridge ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	3,453,948	4,700,618	794,935	3,763,362	4,956,188
Maximum	1,900,008	55,955,380	57,244,268	2,117,072	43,004,201	44,311,930
Mean	1,203,146	20,062,778	21,265,924	1,250,889	16,188,047	17,438,936
Std Dev	156,583	7,053,829	7,056,515	175,993	5,325,634	5,339,699
Percentile						
1%	872,316	7,366,316	8,549,296	918,427	6,744,891	7,957,381
5%	945,174	9,819,553	11,016,051	989,862	8,525,108	9,759,652
10%	998,059	11,478,824	12,678,868	1,035,656	9,743,086	10,982,568
15%	1,036,328	12,718,239	13,924,777	1,068,262	10,683,195	11,924,305
20%	1,067,022	13,810,174	15,004,406	1,095,750	11,504,973	12,742,123
25%	1,093,240	14,816,966	16,017,933	1,121,263	12,221,519	13,465,542
30%	1,117,539	15,745,138	16,944,935	1,145,099	12,913,827	14,161,331
35%	1,139,266	16,664,011	17,858,390	1,167,704	13,604,101	14,853,101
40%	1,160,427	17,543,312	18,740,592	1,190,012	14,266,757	15,519,694
45%	1,180,850	18,416,174	19,624,725	1,211,954	14,930,360	16,186,149
50%	1,201,069	19,328,734	20,532,299	1,235,173	15,600,600	16,847,351
55%	1,220,708	20,262,925	21,467,226	1,258,333	16,289,696	17,541,123
60%	1,241,683	21,229,080	22,433,723	1,282,448	17,016,609	18,272,260
65%	1,263,431	22,236,350	23,439,542	1,307,817	17,781,227	19,029,834
70%	1,285,744	23,312,638	24,518,997	1,335,014	18,616,790	19,874,615
75%	1,309,538	24,521,739	25,730,166	1,364,839	19,511,231	20,769,732
80%	1,336,254	25,898,133	27,101,973	1,398,495	20,554,824	21,821,332
85%	1,367,361	27,564,227	28,773,031	1,438,184	21,815,248	23,077,053
90%	1,407,025	29,667,802	30,866,754	1,489,869	23,440,341	24,708,865
95%	1,464,162	32,869,642	34,066,445	1,564,673	25,887,641	27,141,899
99%	1,576,306	38,854,335	40,071,905	1,708,231	30,552,805	31,812,369

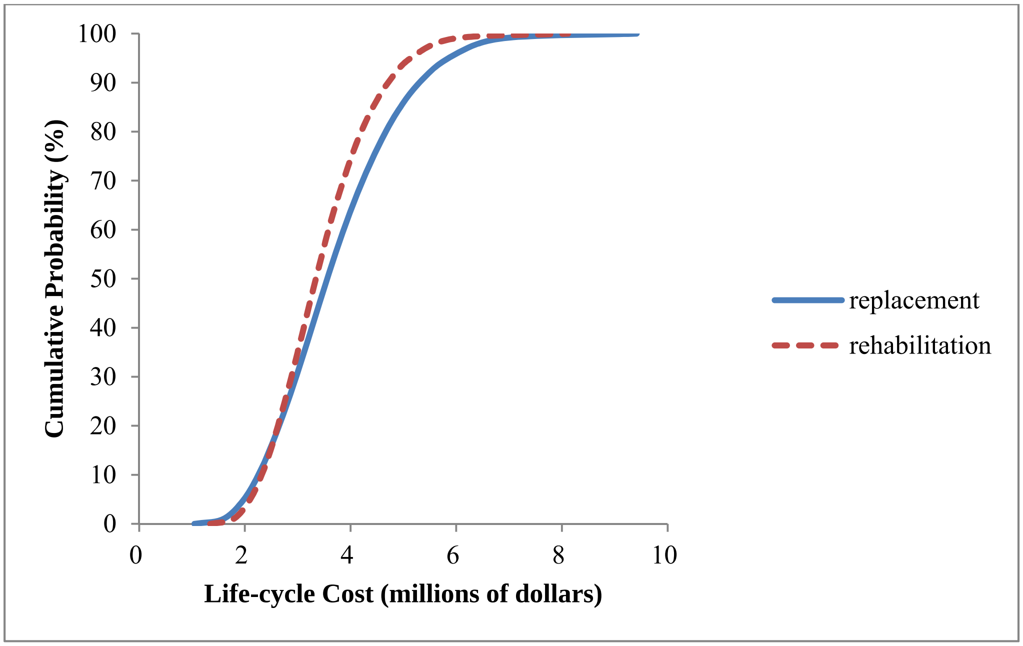


Figure E.1-Ascending cumulative probability distributions for highway bridge ADT case 1 (Table 3.6)

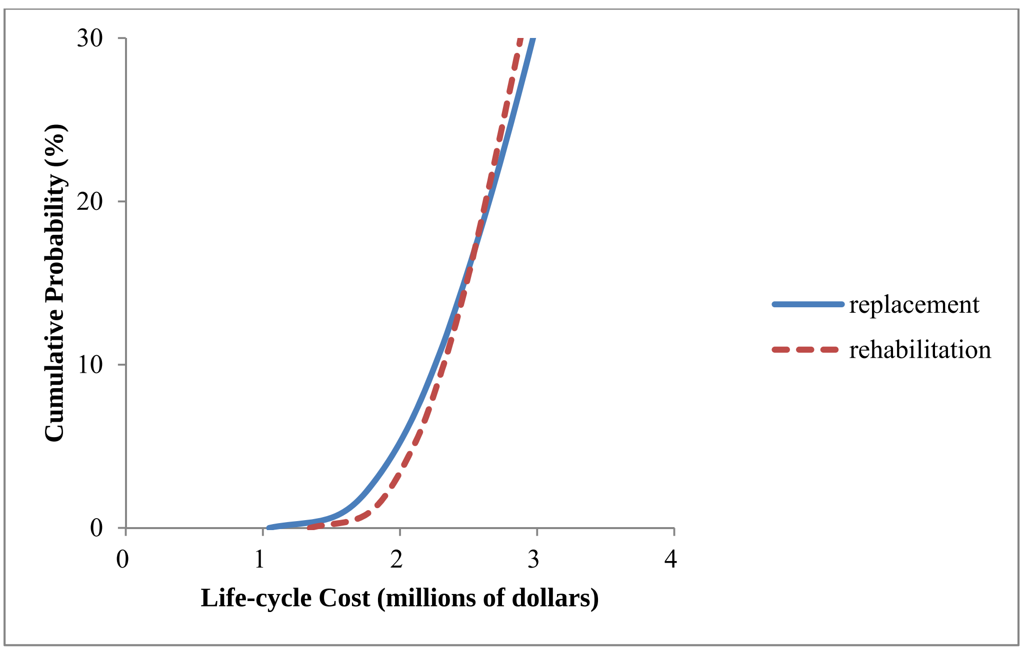


Figure E.2-Ascending cumulative probability distributions for highway bridge ADT case 1 (Table 3.6)

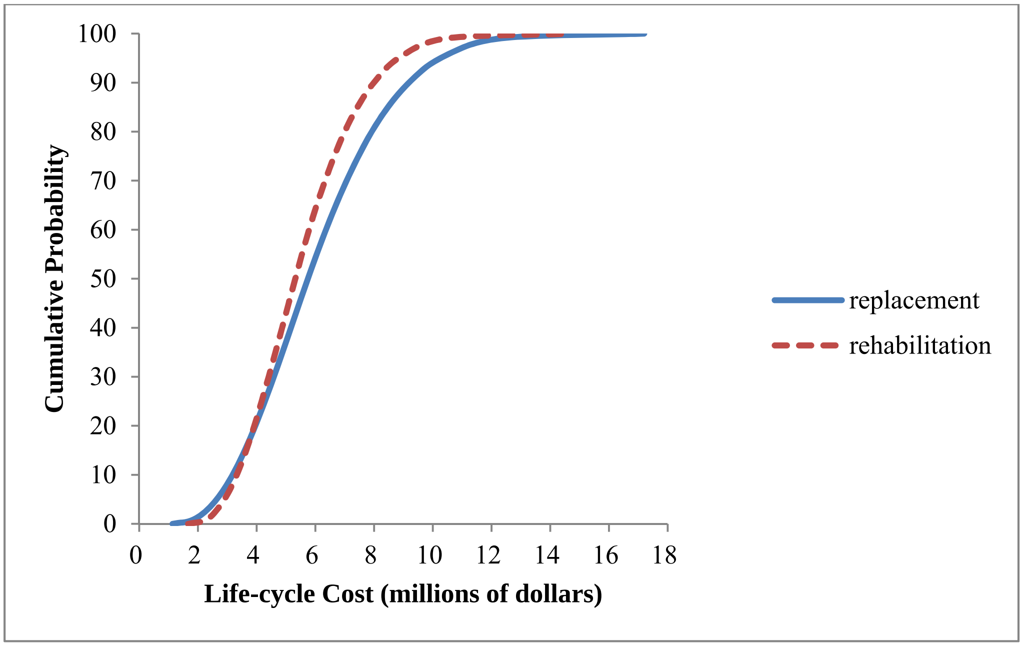


Figure E.3-Ascending cumulative probability distributions for highway bridge ADT case 2 (Table 3.6)

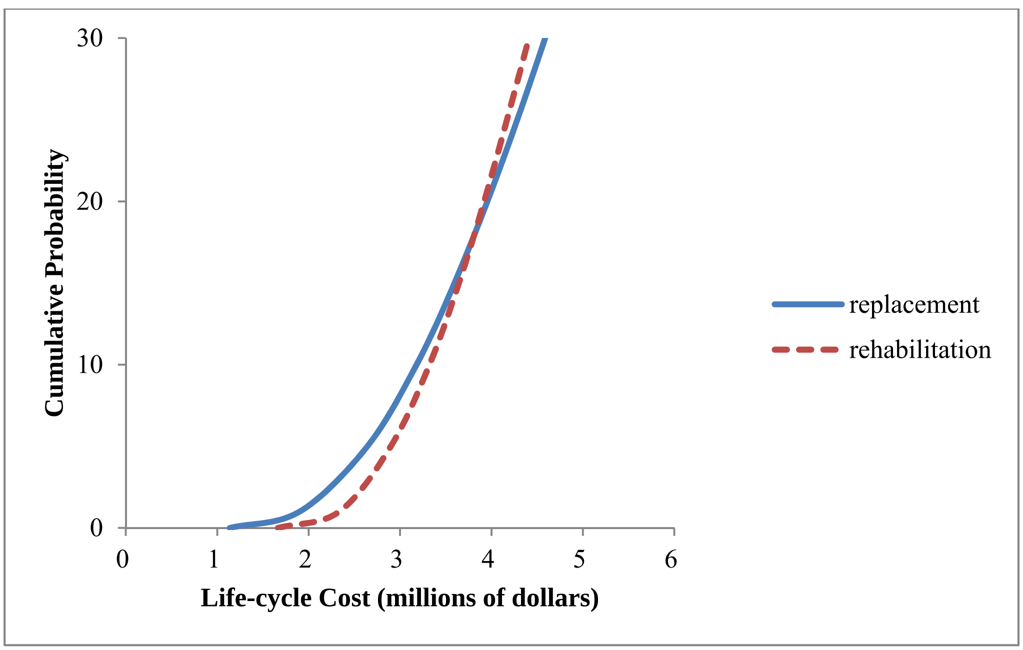


Figure E.4-Ascending cumulative probability distributions for highway bridge ADT case 2 (Table 3.6)

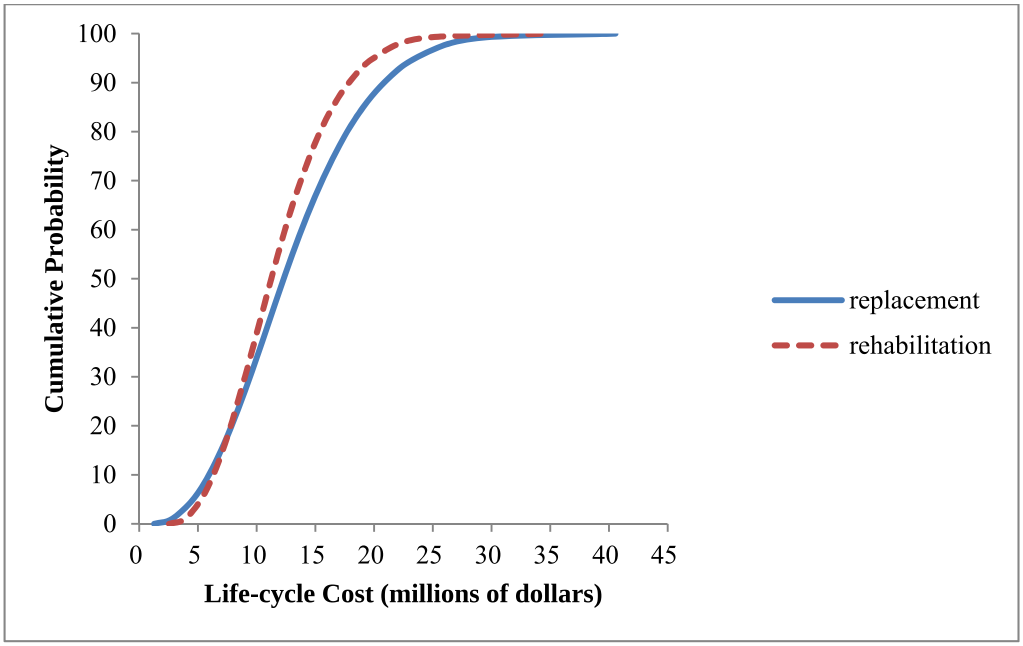


Figure E.5-Ascending cumulative probability distributions for highway bridge ADT case 3 (Table 3.6)

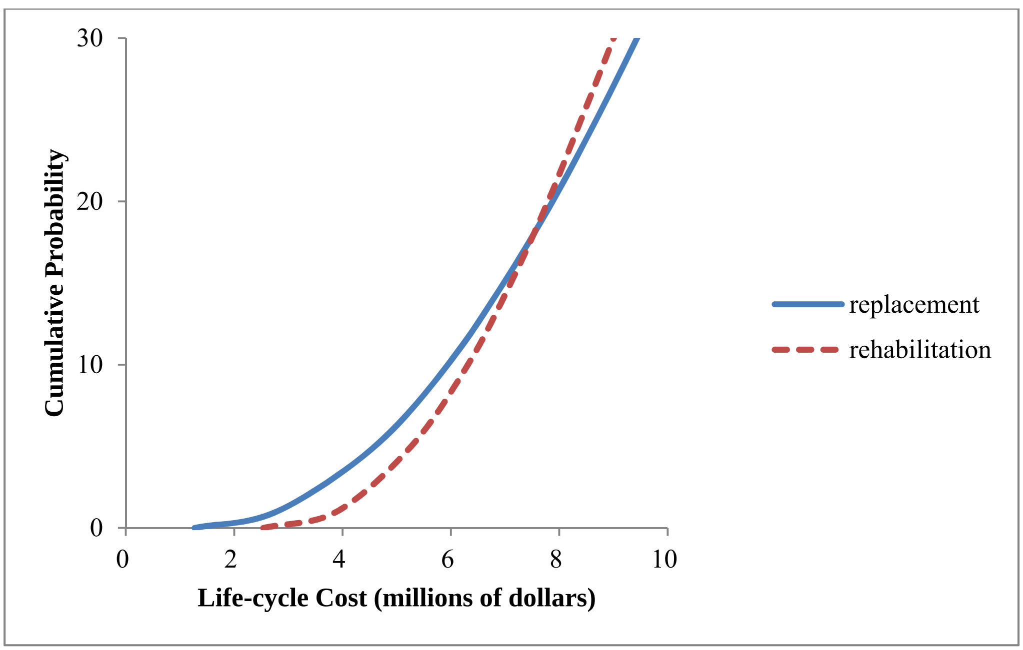


Figure E.6-Ascending cumulative probability distributions for highway bridge ADT case 3 (Table 3.6)

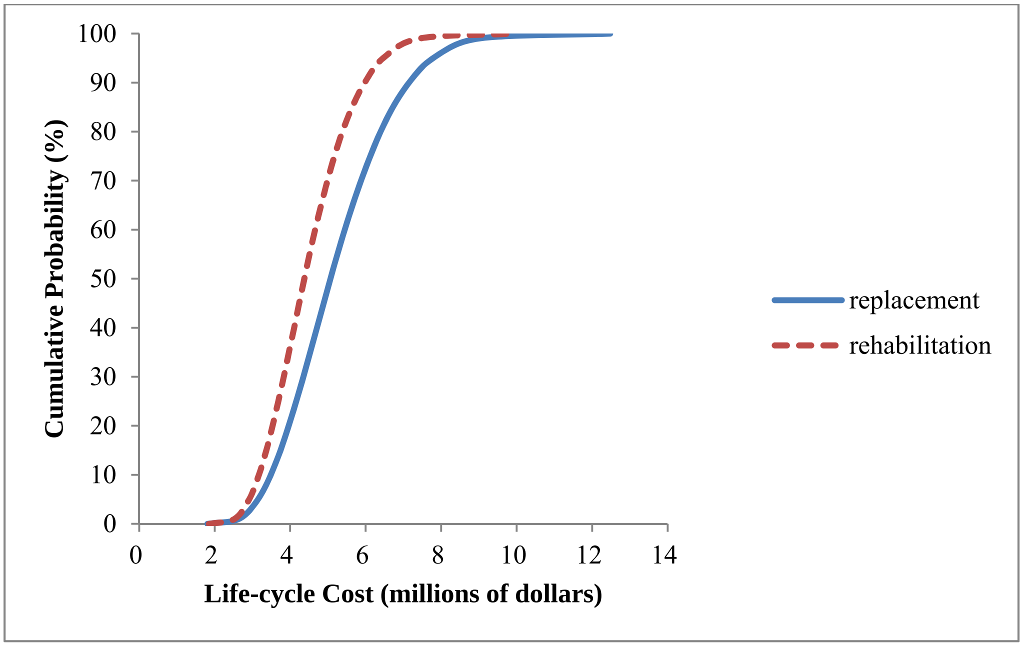


Figure E.7-Ascending cumulative probability distributions for highway bridge ADT case 4 (Table 3.6)

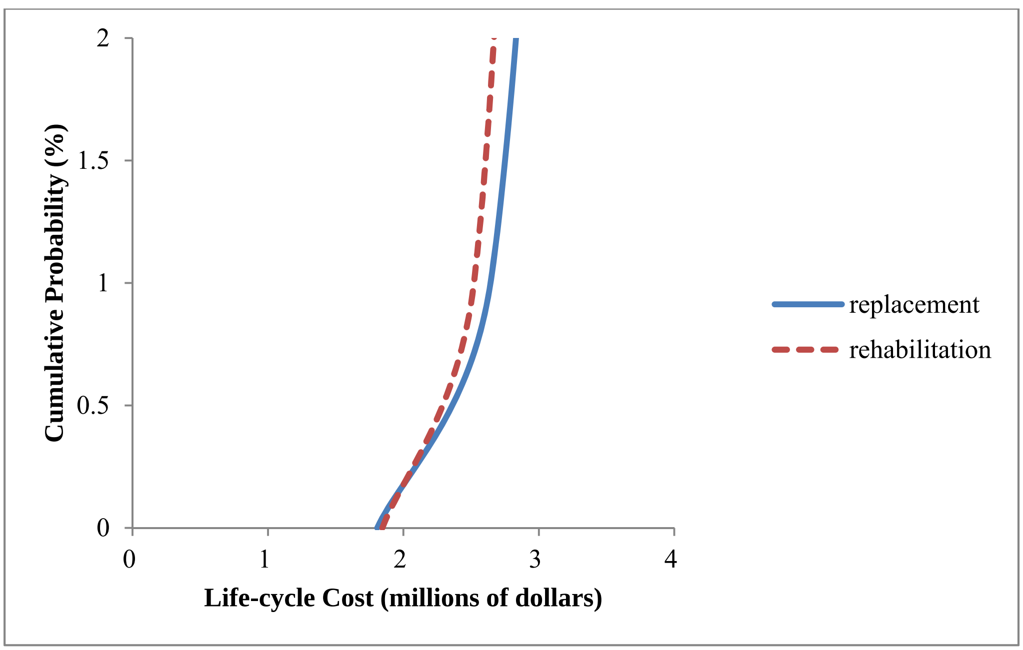


Figure E.8-Ascending cumulative probability distributions for highway bridge ADT case 4 (Table 3.6)

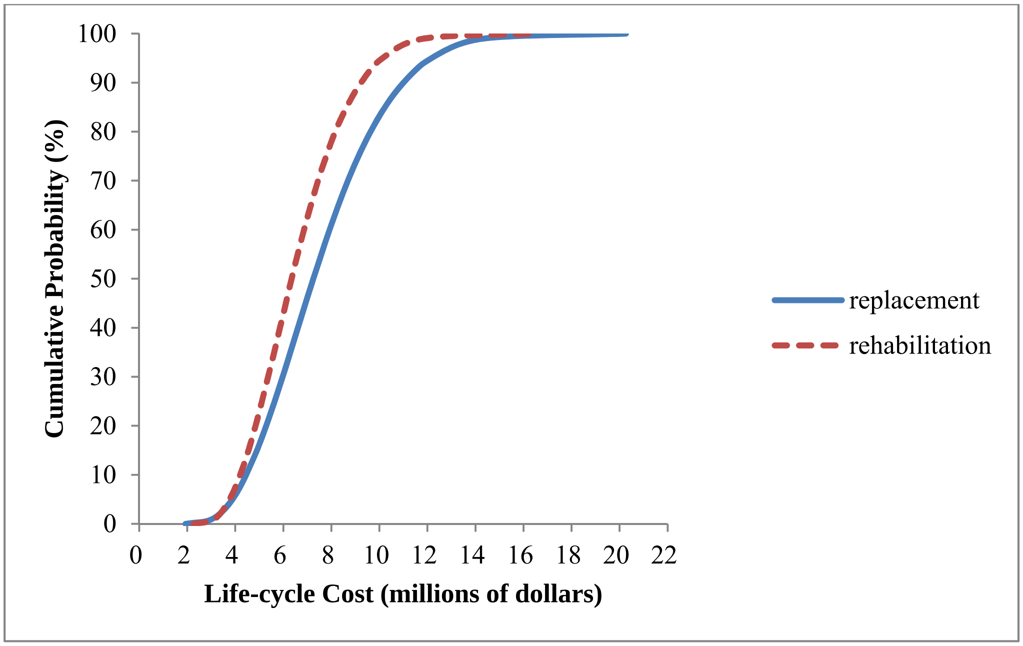


Figure E.9-Ascending cumulative probability distributions for highway bridge ADT case 5 (Table 3.6)

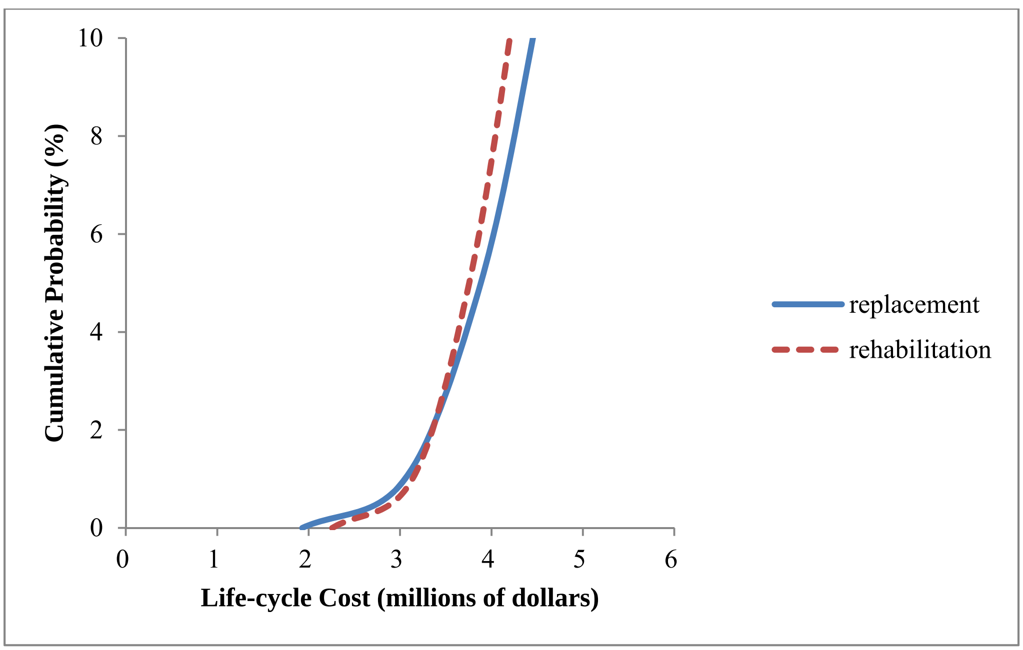


Figure E.10-Ascending cumulative probability distributions for highway bridge ADT case 5 (Table 3.6)

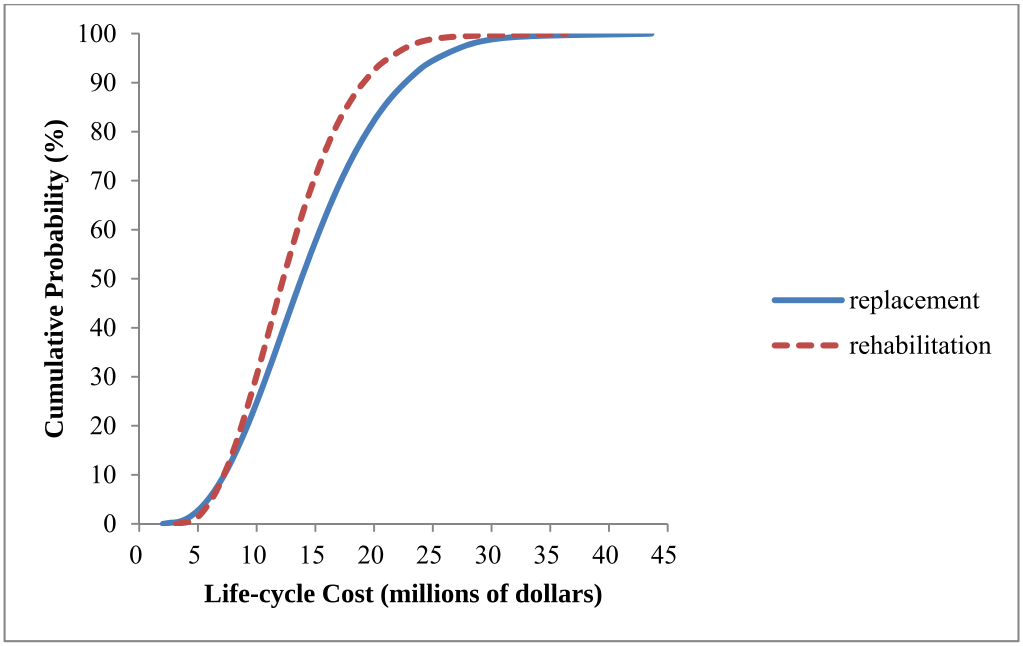


Figure E.11-Ascending cumulative probability distributions for highway bridge ADT case 6 (Table 3.6)

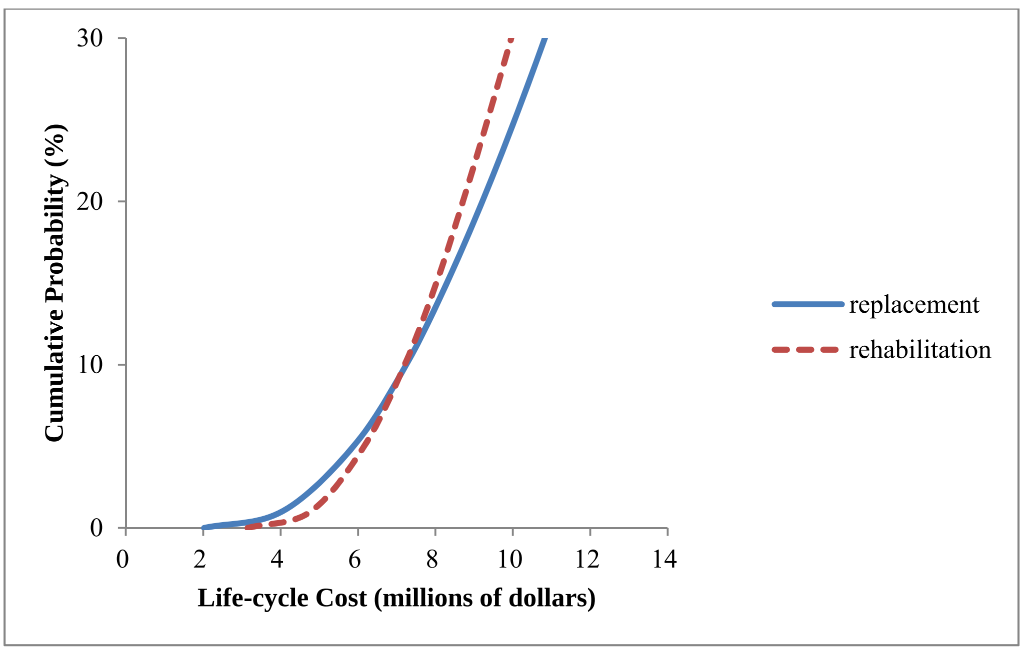


Figure E.12-Ascending cumulative probability distributions for highway bridge ADT case 6 (Table 3.6)

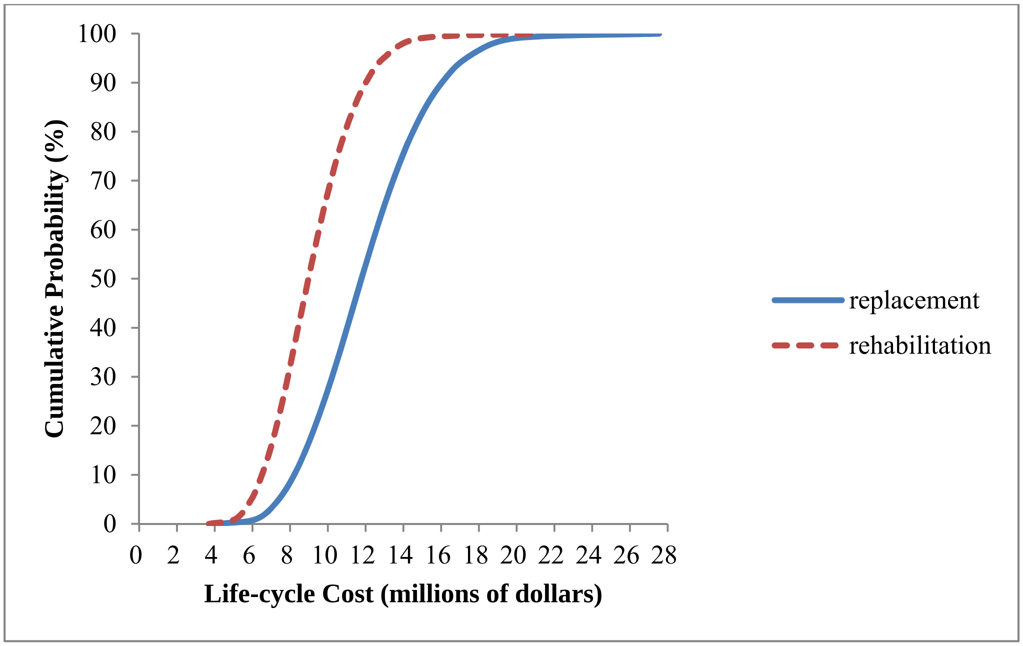


Figure E.13-Ascending cumulative probability distributions for highway bridge ADT case 7 (Table 3.6)

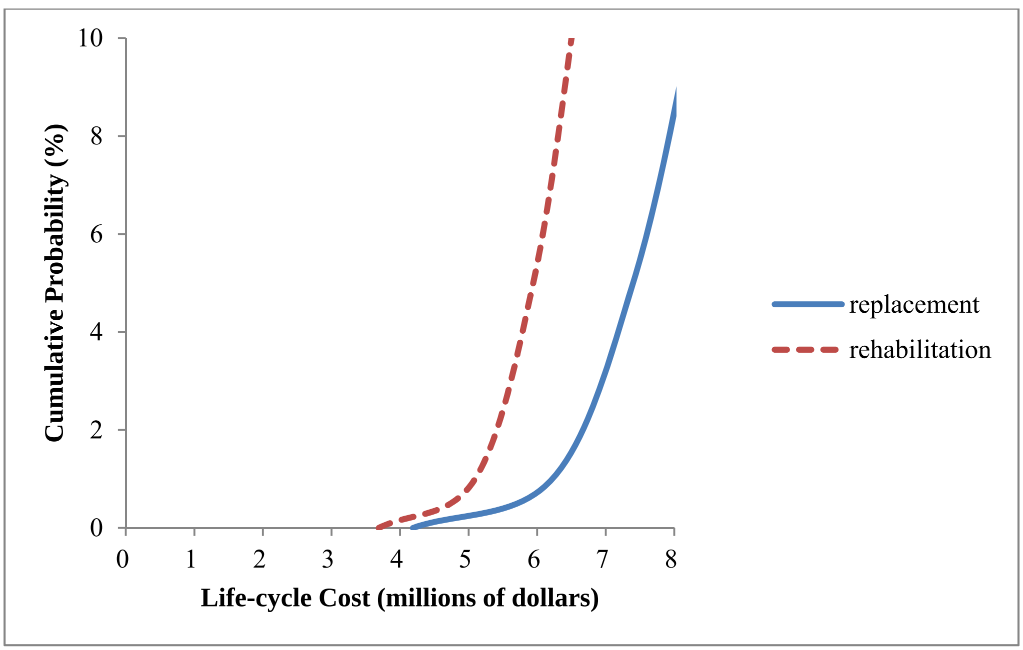


Figure E.14-Ascending cumulative probability distributions for highway bridge ADT case 7 (Table 3.6)

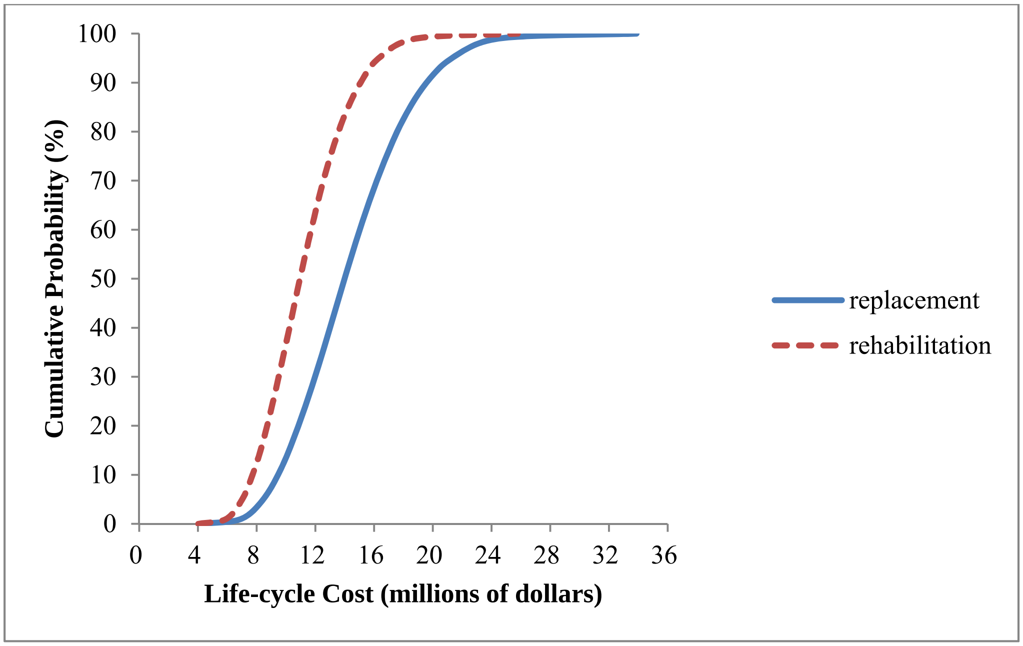


Figure E.15-Ascending cumulative probability distributions for highway bridge ADT case 8 (Table 3.6)

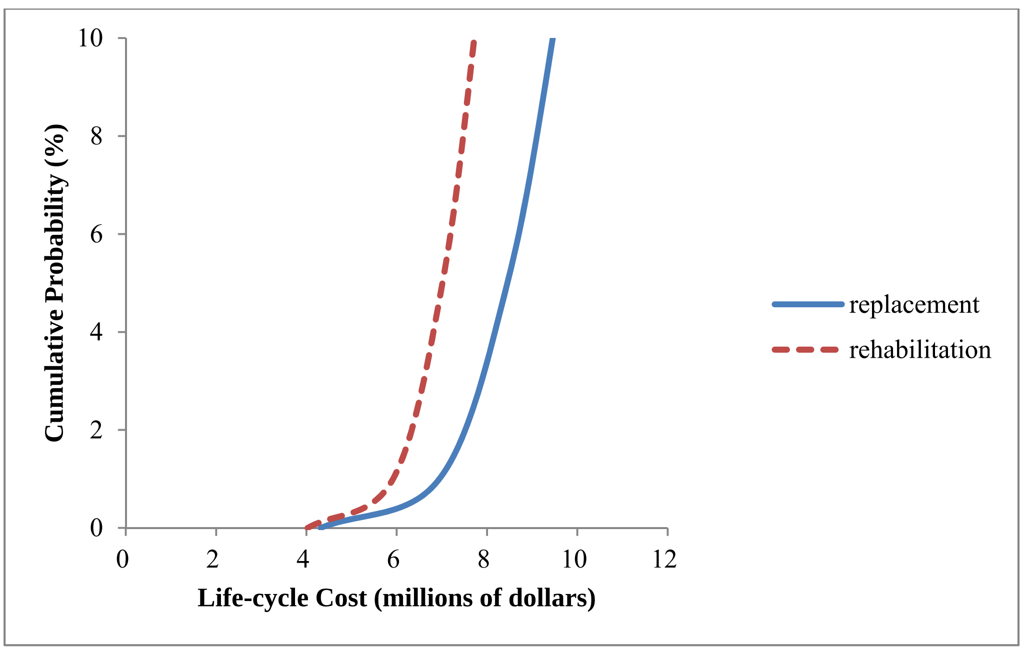


Figure E.16-Ascending cumulative probability distributions for highway bridge ADT case 8 (Table 3.6)

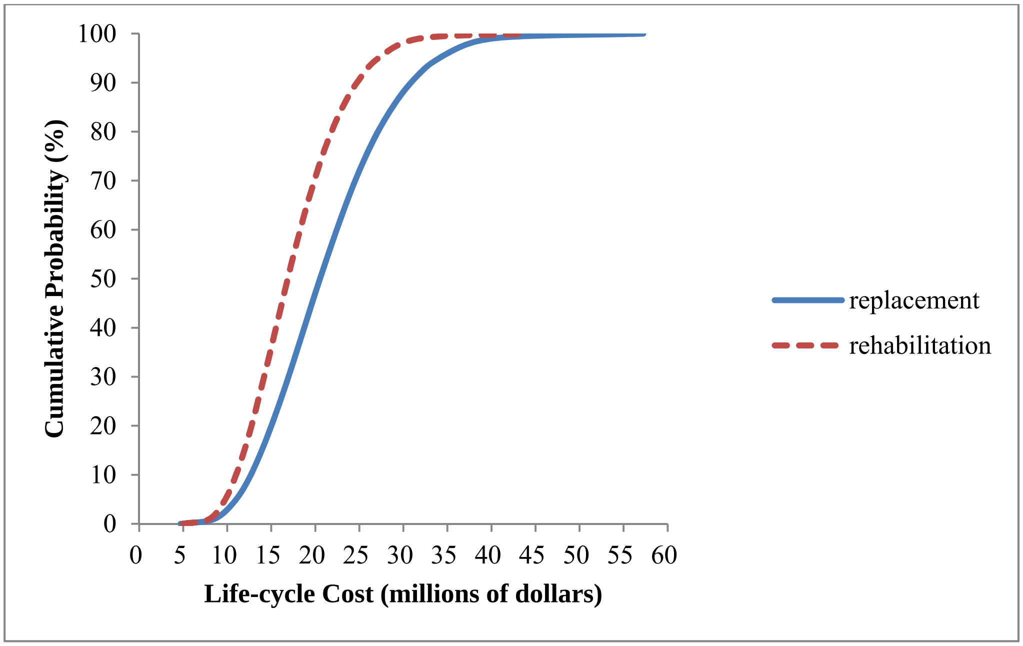


Figure E.17-Ascending cumulative probability distributions for highway bridge ADT case 9 (Table 3.6)

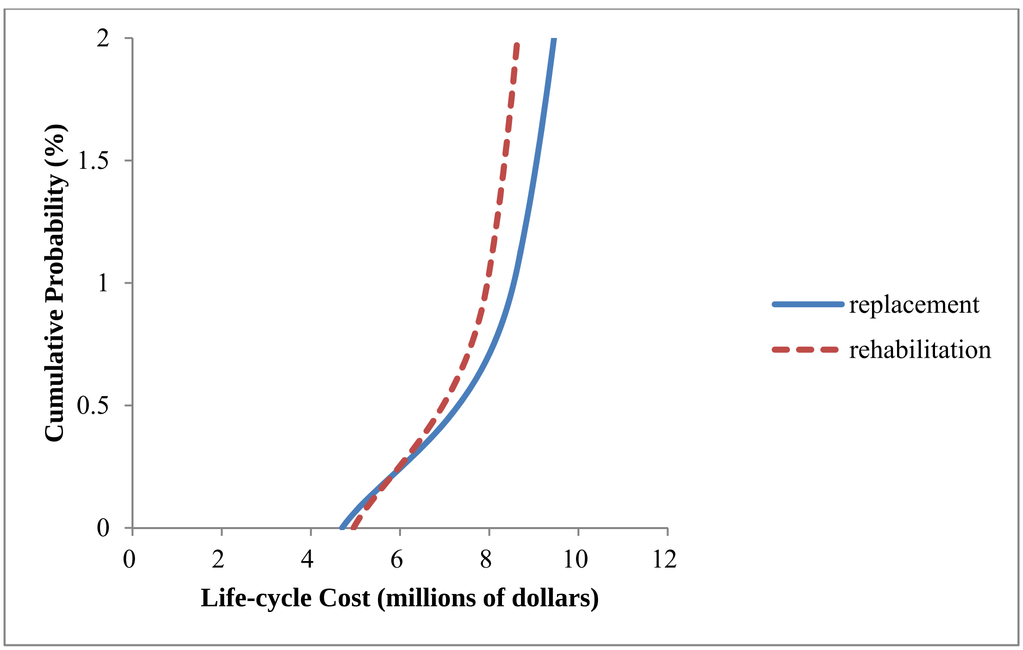


Figure E.18-Ascending cumulative probability distributions for highway bridge ADT case 9 (Table 3.6)

Bridge over Highway with Limited Variables

Table E.10-Risk profile statistics for highway bridge with limited variables limited ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	102,185	1,293,699	1,172,788	331,508	1,504,296
Maximum	1,191,515	8,278,948	9,470,463	1,172,788	6,519,239	7,692,027
Mean	1,191,515	2,468,495	3,660,009	1,172,788	2,129,102	3,301,889
Std Dev	0	1,175,057	1,175,057	0	876,721	876,721
Percentile						
1%	1,191,515	411,795	1,603,309	1,172,788	597,000	1,769,788
5%	1,191,515	771,918	1,963,433	1,172,788	860,283	2,033,071
10%	1,191,515	1,039,411	2,230,926	1,172,788	1,064,298	2,237,086
15%	1,191,515	1,248,972	2,440,487	1,172,788	1,219,474	2,392,262
20%	1,191,515	1,427,619	2,619,134	1,172,788	1,352,763	2,525,551
25%	1,191,515	1,592,421	2,783,936	1,172,788	1,474,569	2,647,357
30%	1,191,515	1,748,940	2,940,455	1,172,788	1,591,160	2,763,948
35%	1,191,515	1,896,125	3,087,640	1,172,788	1,702,694	2,875,482
40%	1,191,515	2,046,552	3,238,067	1,172,788	1,811,710	2,984,498
45%	1,191,515	2,189,612	3,381,126	1,172,788	1,921,860	3,094,648
50%	1,191,515	2,337,238	3,528,753	1,172,788	2,034,332	3,207,120
55%	1,191,515	2,491,621	3,683,135	1,172,788	2,148,200	3,320,987
60%	1,191,515	2,652,264	3,843,779	1,172,788	2,267,214	3,440,002
65%	1,191,515	2,817,281	4,008,796	1,172,788	2,391,910	3,564,697
70%	1,191,515	3,001,447	4,192,961	1,172,788	2,527,825	3,700,612
75%	1,191,515	3,203,006	4,394,521	1,172,788	2,677,812	3,850,600
80%	1,191,515	3,431,298	4,622,813	1,172,788	2,851,324	4,024,112
85%	1,191,515	3,711,538	4,903,053	1,172,788	3,056,992	4,229,780
90%	1,191,515	4,076,121	5,267,635	1,172,788	3,318,860	4,491,648
95%	1,191,515	4,605,957	5,797,472	1,172,788	3,727,382	4,900,170
99%	1,191,515	5,644,347	6,835,861	1,172,788	4,508,790	5,681,578

Table E.11-Risk profile statistics for highway bridge with limited variables limited ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	123,784	1,315,299	1,172,788	587,671	1,760,459
Maximum	1,191,515	16,327,092	17,518,607	1,172,788	12,886,251	14,059,039
Mean	1,191,515	4,790,065	5,981,580	1,172,788	4,158,914	5,331,702
Std Dev	0	2,332,461	2,332,461	0	1,742,661	1,742,661
Percentile						
1%	1,191,515	699,344	1,890,859	1,172,788	1,105,370	2,278,158
5%	1,191,515	1,416,765	2,608,279	1,172,788	1,633,029	2,805,817
10%	1,191,515	1,951,161	3,142,675	1,172,788	2,042,178	3,214,966
15%	1,191,515	2,371,272	3,562,787	1,172,788	2,353,193	3,525,981
20%	1,191,515	2,725,045	3,916,560	1,172,788	2,617,119	3,789,907
25%	1,191,515	3,055,272	4,246,787	1,172,788	2,860,320	4,033,107
30%	1,191,515	3,365,017	4,556,531	1,172,788	3,091,169	4,263,956
35%	1,191,515	3,656,520	4,848,034	1,172,788	3,311,994	4,484,782
40%	1,191,515	3,952,722	5,144,236	1,172,788	3,529,821	4,702,609
45%	1,191,515	4,237,852	5,429,367	1,172,788	3,749,267	4,922,054
50%	1,191,515	4,529,065	5,720,580	1,172,788	3,971,580	5,144,368
55%	1,191,515	4,836,252	6,027,767	1,172,788	4,196,943	5,369,730
60%	1,191,515	5,154,928	6,346,442	1,172,788	4,433,437	5,606,225
65%	1,191,515	5,482,301	6,673,816	1,172,788	4,682,179	5,854,967
70%	1,191,515	5,846,515	7,038,030	1,172,788	4,950,081	6,122,869
75%	1,191,515	6,247,103	7,438,618	1,172,788	5,248,507	6,421,295
80%	1,191,515	6,702,656	7,894,171	1,172,788	5,593,621	6,766,409
85%	1,191,515	7,253,934	8,445,449	1,172,788	6,003,695	7,176,483
90%	1,191,515	7,982,758	9,174,273	1,172,788	6,523,102	7,695,890
95%	1,191,515	9,030,446	10,221,961	1,172,788	7,337,277	8,510,065
99%	1,191,515	11,086,970	12,278,485	1,172,788	8,891,219	10,064,006

Table E.12-Risk profile statistics for highway bridge with limited variables limited ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	175,055	1,366,570	1,172,788	1,356,159	2,528,947
Maximum	1,191,515	40,471,525	41,663,039	1,172,788	31,987,287	33,160,075
Mean	1,191,515	11,754,776	12,946,291	1,172,788	10,248,350	11,421,138
Std Dev	0	5,805,077	5,805,077	0	4,340,689	4,340,689
Percentile						
1%	1,191,515	1,561,066	2,752,580	1,172,788	2,630,928	3,803,716
5%	1,191,515	3,351,052	4,542,567	1,172,788	3,957,354	5,130,142
10%	1,191,515	4,692,040	5,883,555	1,172,788	4,977,191	6,149,978
15%	1,191,515	5,738,923	6,930,437	1,172,788	5,747,438	6,920,226
20%	1,191,515	6,619,931	7,811,445	1,172,788	6,409,518	7,582,306
25%	1,191,515	7,439,862	8,631,377	1,172,788	7,015,978	8,188,766
30%	1,191,515	8,211,125	9,402,639	1,172,788	7,593,160	8,765,947
35%	1,191,515	8,937,950	10,129,465	1,172,788	8,141,740	9,314,528
40%	1,191,515	9,668,102	10,859,617	1,172,788	8,683,334	9,856,122
45%	1,191,515	10,387,479	11,578,994	1,172,788	9,228,952	10,401,740
50%	1,191,515	11,105,824	12,297,338	1,172,788	9,781,240	10,954,028
55%	1,191,515	11,869,891	13,061,405	1,172,788	10,344,170	11,516,958
60%	1,191,515	12,663,127	13,854,641	1,172,788	10,930,109	12,102,897
65%	1,191,515	13,476,119	14,667,634	1,172,788	11,551,618	12,724,406
70%	1,191,515	14,379,985	15,571,500	1,172,788	12,217,994	13,390,782
75%	1,191,515	15,382,029	16,573,544	1,172,788	12,958,380	14,131,168
80%	1,191,515	16,511,068	17,702,583	1,172,788	13,822,822	14,995,610
85%	1,191,515	17,887,238	19,078,753	1,172,788	14,840,953	16,013,741
90%	1,191,515	19,696,462	20,887,977	1,172,788	16,131,048	17,303,836
95%	1,191,515	22,311,022	23,502,537	1,172,788	18,165,398	19,338,186
99%	1,191,515	27,429,629	28,621,144	1,172,788	22,036,760	23,209,548

Table E.13-Risk profile statistics for highway bridge with limited variables limited ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	726,164	1,917,679	1,172,788	812,589	1,985,377
Maximum	1,191,515	10,356,181	11,547,696	1,172,788	7,889,286	9,062,074
Mean	1,191,515	3,790,812	4,982,327	1,172,788	3,022,707	4,195,495
Std Dev	0	1,358,784	1,358,784	0	986,888	986,888
Percentile						
1%	1,191,515	1,358,085	2,549,600	1,172,788	1,283,434	2,456,222
5%	1,191,515	1,821,355	3,012,870	1,172,788	1,600,765	2,773,553
10%	1,191,515	2,138,005	3,329,520	1,172,788	1,823,645	2,996,432
15%	1,191,515	2,380,754	3,572,269	1,172,788	1,994,474	3,167,262
20%	1,191,515	2,585,736	3,777,251	1,172,788	2,143,878	3,316,666
25%	1,191,515	2,771,363	3,962,877	1,172,788	2,282,683	3,455,471
30%	1,191,515	2,954,989	4,146,504	1,172,788	2,413,357	3,586,145
35%	1,191,515	3,130,625	4,322,140	1,172,788	2,538,264	3,711,052
40%	1,191,515	3,303,225	4,494,739	1,172,788	2,665,977	3,838,765
45%	1,191,515	3,477,625	4,669,140	1,172,788	2,790,166	3,962,954
50%	1,191,515	3,648,470	4,839,985	1,172,788	2,914,969	4,087,757
55%	1,191,515	3,827,485	5,019,000	1,172,788	3,045,740	4,218,528
60%	1,191,515	4,012,908	5,204,423	1,172,788	3,184,460	4,357,248
65%	1,191,515	4,208,457	5,399,972	1,172,788	3,328,913	4,501,701
70%	1,191,515	4,417,437	5,608,952	1,172,788	3,480,055	4,652,843
75%	1,191,515	4,652,335	5,843,850	1,172,788	3,650,269	4,823,056
80%	1,191,515	4,915,272	6,106,787	1,172,788	3,839,951	5,012,739
85%	1,191,515	5,231,492	6,423,007	1,172,788	4,067,409	5,240,196
90%	1,191,515	5,643,025	6,834,540	1,172,788	4,362,092	5,534,880
95%	1,191,515	6,252,406	7,443,920	1,172,788	4,812,734	5,985,522
99%	1,191,515	7,427,124	8,618,638	1,172,788	5,673,693	6,846,481

Table E.14-Risk profile statistics for highway bridge with limited variables limited ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	773,470	1,964,985	1,172,788	1,126,410	2,299,198
Maximum	1,191,515	18,404,325	19,595,840	1,172,788	14,256,298	15,429,086
Mean	1,191,515	6,112,382	7,303,897	1,172,788	5,052,519	6,225,307
Std Dev	0	2,502,624	2,502,624	0	1,845,573	1,845,573
Percentile						
1%	1,191,515	1,726,387	2,917,902	1,172,788	1,838,739	3,011,527
5%	1,191,515	2,511,094	3,702,609	1,172,788	2,391,797	3,564,584
10%	1,191,515	3,084,061	4,275,576	1,172,788	2,812,891	3,985,679
15%	1,191,515	3,509,859	4,701,374	1,172,788	3,131,071	4,303,859
20%	1,191,515	3,891,312	5,082,827	1,172,788	3,409,240	4,582,028
25%	1,191,515	4,233,857	5,425,372	1,172,788	3,669,116	4,841,904
30%	1,191,515	4,564,802	5,756,317	1,172,788	3,912,545	5,085,333
35%	1,191,515	4,891,326	6,082,841	1,172,788	4,145,316	5,318,103
40%	1,191,515	5,203,239	6,394,754	1,172,788	4,379,830	5,552,618
45%	1,191,515	5,515,812	6,707,327	1,172,788	4,613,353	5,786,141
50%	1,191,515	5,838,469	7,029,984	1,172,788	4,847,678	6,020,466
55%	1,191,515	6,162,360	7,353,874	1,172,788	5,092,138	6,264,926
60%	1,191,515	6,506,199	7,697,714	1,172,788	5,347,394	6,520,182
65%	1,191,515	6,863,217	8,054,732	1,172,788	5,609,658	6,782,446
70%	1,191,515	7,254,455	8,445,970	1,172,788	5,896,505	7,069,293
75%	1,191,515	7,685,217	8,876,732	1,172,788	6,217,986	7,390,774
80%	1,191,515	8,172,800	9,364,315	1,172,788	6,575,100	7,747,888
85%	1,191,515	8,765,507	9,957,022	1,172,788	7,008,203	8,180,991
90%	1,191,515	9,538,859	10,730,374	1,172,788	7,559,492	8,732,279
95%	1,191,515	10,656,167	11,847,682	1,172,788	8,410,348	9,583,136
99%	1,191,515	12,857,536	14,049,050	1,172,788	10,046,797	11,219,585

Table E.15-Risk profile statistics for highway bridge with limited variables limited ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	868,788	2,060,302	1,172,788	2,034,268	3,207,056
Maximum	1,191,515	42,548,758	43,740,272	1,172,788	33,357,333	34,530,121
Mean	1,191,515	13,077,093	14,268,608	1,172,788	11,141,955	12,314,743
Std Dev	0	5,966,015	5,966,015	0	4,438,778	4,438,778
Percentile						
1%	1,191,515	2,670,125	3,861,640	1,172,788	3,417,695	4,590,483
5%	1,191,515	4,475,235	5,666,750	1,172,788	4,726,569	5,899,357
10%	1,191,515	5,842,020	7,033,535	1,172,788	5,755,841	6,928,629
15%	1,191,515	6,878,046	8,069,561	1,172,788	6,528,011	7,700,799
20%	1,191,515	7,795,964	8,987,479	1,172,788	7,209,116	8,381,903
25%	1,191,515	8,613,794	9,805,308	1,172,788	7,821,386	8,994,174
30%	1,191,515	9,411,155	10,602,670	1,172,788	8,406,472	9,579,260
35%	1,191,515	10,168,164	11,359,679	1,172,788	8,976,957	10,149,744
40%	1,191,515	10,920,454	12,111,969	1,172,788	9,530,456	10,703,244
45%	1,191,515	11,653,470	12,844,985	1,172,788	10,090,824	11,263,612
50%	1,191,515	12,415,774	13,607,289	1,172,788	10,657,966	11,830,754
55%	1,191,515	13,190,705	14,382,220	1,172,788	11,238,229	12,411,017
60%	1,191,515	14,008,282	15,199,797	1,172,788	11,839,889	13,012,677
65%	1,191,515	14,848,134	16,039,649	1,172,788	12,476,761	13,649,549
70%	1,191,515	15,782,649	16,974,163	1,172,788	13,160,193	14,332,981
75%	1,191,515	16,807,591	17,999,106	1,172,788	13,924,297	15,097,085
80%	1,191,515	17,970,435	19,161,949	1,172,788	14,797,740	15,970,528
85%	1,191,515	19,387,940	20,579,455	1,172,788	15,836,817	17,009,604
90%	1,191,515	21,241,235	22,432,750	1,172,788	17,175,942	18,348,730
95%	1,191,515	23,929,326	25,120,841	1,172,788	19,236,486	20,409,274
99%	1,191,515	29,189,550	30,381,065	1,172,788	23,180,495	24,353,283

Table E.16-Risk profile statistics for highway bridge with limited variables limited ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	3,373,496	4,565,011	1,172,788	2,694,755	3,867,543
Maximum	1,191,515	19,588,328	20,779,843	1,172,788	13,978,382	15,151,170
Mean	1,191,515	9,667,779	10,859,294	1,172,788	6,994,286	8,167,074
Std Dev	0	2,461,665	2,461,665	0	1,644,666	1,644,666
Percentile						
1%	1,191,515	4,731,149	5,922,664	1,172,788	3,733,878	4,906,665
5%	1,191,515	5,733,299	6,924,814	1,172,788	4,413,269	5,586,057
10%	1,191,515	6,467,978	7,659,493	1,172,788	4,879,545	6,052,333
15%	1,191,515	7,015,998	8,207,513	1,172,788	5,239,891	6,412,678
20%	1,191,515	7,487,756	8,679,271	1,172,788	5,535,574	6,708,362
25%	1,191,515	7,896,591	9,088,105	1,172,788	5,796,275	6,969,063
30%	1,191,515	8,271,917	9,463,431	1,172,788	6,046,476	7,219,263
35%	1,191,515	8,618,133	9,809,647	1,172,788	6,270,223	7,443,011
40%	1,191,515	8,948,275	10,139,790	1,172,788	6,491,342	7,664,130
45%	1,191,515	9,269,422	10,460,937	1,172,788	6,707,213	7,880,000
50%	1,191,515	9,589,226	10,780,740	1,172,788	6,919,394	8,092,182
55%	1,191,515	9,902,402	11,093,916	1,172,788	7,134,320	8,307,108
60%	1,191,515	10,228,812	11,420,326	1,172,788	7,354,171	8,526,958
65%	1,191,515	10,557,640	11,749,154	1,172,788	7,583,200	8,755,988
70%	1,191,515	10,923,833	12,115,348	1,172,788	7,826,016	8,998,804
75%	1,191,515	11,324,993	12,516,508	1,172,788	8,091,285	9,264,073
80%	1,191,515	11,770,499	12,962,013	1,172,788	8,393,265	9,566,052
85%	1,191,515	12,288,647	13,480,162	1,172,788	8,738,895	9,911,682
90%	1,191,515	12,935,064	14,126,579	1,172,788	9,181,902	10,354,690
95%	1,191,515	13,905,755	15,097,269	1,172,788	9,845,735	11,018,522
99%	1,191,515	15,636,758	16,828,273	1,172,788	11,049,437	12,222,225

Table E.17-Risk profile statistics for highway bridge with limited variables limited ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	3,488,900	4,680,415	1,172,788	3,060,108	4,232,895
Maximum	1,191,515	27,636,472	28,827,987	1,172,788	20,345,394	21,518,181
Mean	1,191,515	11,989,349	13,180,864	1,172,788	9,024,098	10,196,886
Std Dev	0	3,473,365	3,473,365	0	2,421,953	2,421,953
Percentile						
1%	1,191,515	5,384,054	6,575,569	1,172,788	4,486,421	5,659,209
5%	1,191,515	6,706,593	7,898,108	1,172,788	5,406,352	6,579,140
10%	1,191,515	7,652,641	8,844,155	1,172,788	6,025,962	7,198,750
15%	1,191,515	8,338,803	9,530,318	1,172,788	6,478,906	7,651,694
20%	1,191,515	8,919,687	10,111,202	1,172,788	6,881,858	8,054,646
25%	1,191,515	9,448,204	10,639,718	1,172,788	7,238,945	8,411,733
30%	1,191,515	9,931,268	11,122,783	1,172,788	7,562,605	8,735,393
35%	1,191,515	10,398,922	11,590,436	1,172,788	7,887,019	9,059,807
40%	1,191,515	10,855,889	12,047,404	1,172,788	8,206,671	9,379,459
45%	1,191,515	11,297,276	12,488,790	1,172,788	8,511,519	9,684,307
50%	1,191,515	11,740,662	12,932,177	1,172,788	8,816,965	9,989,753
55%	1,191,515	12,189,214	13,380,729	1,172,788	9,138,664	10,311,452
60%	1,191,515	12,646,677	13,838,192	1,172,788	9,468,412	10,641,200
65%	1,191,515	13,134,232	14,325,747	1,172,788	9,820,868	10,993,656
70%	1,191,515	13,654,760	14,846,275	1,172,788	10,194,262	11,367,050
75%	1,191,515	14,237,127	15,428,642	1,172,788	10,596,077	11,768,865
80%	1,191,515	14,908,121	16,099,636	1,172,788	11,053,464	12,226,252
85%	1,191,515	15,680,733	16,872,248	1,172,788	11,587,226	12,760,014
90%	1,191,515	16,644,790	17,836,305	1,172,788	12,281,173	13,453,961
95%	1,191,515	18,141,488	19,333,002	1,172,788	13,342,370	14,515,158
99%	1,191,515	20,905,082	22,096,597	1,172,788	15,310,909	16,483,697

Table E.18-Risk profile statistics for highway bridge with limited variables limited ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	1,191,515	3,630,819	4,822,334	1,172,788	4,062,945	5,235,732
Maximum	1,191,515	51,780,905	52,972,419	1,172,788	39,446,429	40,619,217
Mean	1,191,515	18,954,060	20,145,575	1,172,788	15,113,535	16,286,323
Std Dev	0	6,793,922	6,793,922	0	4,934,438	4,934,438
Percentile						
1%	1,191,515	6,790,427	7,981,942	1,172,788	6,417,171	7,589,959
5%	1,191,515	9,106,776	10,298,290	1,172,788	8,003,825	9,176,613
10%	1,191,515	10,690,025	11,881,540	1,172,788	9,118,223	10,291,010
15%	1,191,515	11,903,771	13,095,285	1,172,788	9,972,371	11,145,159
20%	1,191,515	12,928,679	14,120,193	1,172,788	10,719,392	11,892,180
25%	1,191,515	13,856,813	15,048,328	1,172,788	11,413,417	12,586,205
30%	1,191,515	14,774,944	15,966,459	1,172,788	12,066,786	13,239,573
35%	1,191,515	15,653,127	16,844,642	1,172,788	12,691,319	13,864,107
40%	1,191,515	16,516,123	17,707,637	1,172,788	13,329,887	14,502,675
45%	1,191,515	17,388,127	18,579,642	1,172,788	13,950,831	15,123,619
50%	1,191,515	18,242,351	19,433,866	1,172,788	14,574,847	15,747,635
55%	1,191,515	19,137,425	20,328,940	1,172,788	15,228,700	16,401,488
60%	1,191,515	20,064,542	21,256,057	1,172,788	15,922,301	17,095,089
65%	1,191,515	21,042,285	22,233,800	1,172,788	16,644,567	17,817,354
70%	1,191,515	22,087,186	23,278,701	1,172,788	17,400,277	18,573,064
75%	1,191,515	23,261,676	24,453,191	1,172,788	18,251,343	19,424,131
80%	1,191,515	24,576,359	25,767,874	1,172,788	19,199,757	20,372,545
85%	1,191,515	26,157,461	27,348,976	1,172,788	20,337,043	21,509,831
90%	1,191,515	28,215,126	29,406,641	1,172,788	21,810,461	22,983,249
95%	1,191,515	31,262,028	32,453,542	1,172,788	24,063,670	25,236,457
99%	1,191,515	37,135,618	38,327,133	1,172,788	28,368,467	29,541,255

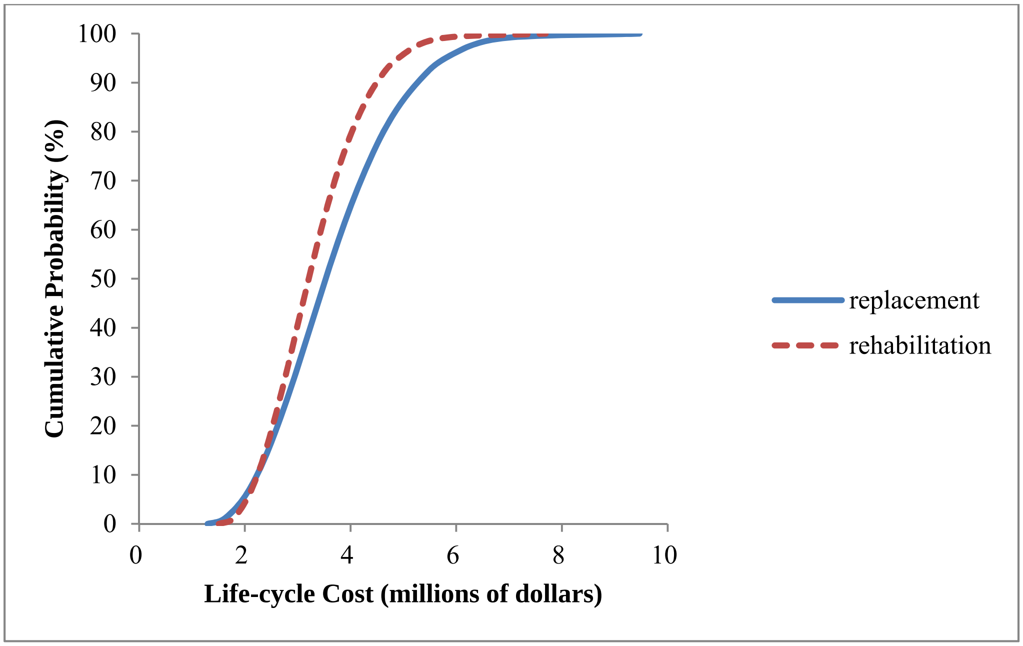


Figure E.19-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 1 (Table 3.6)

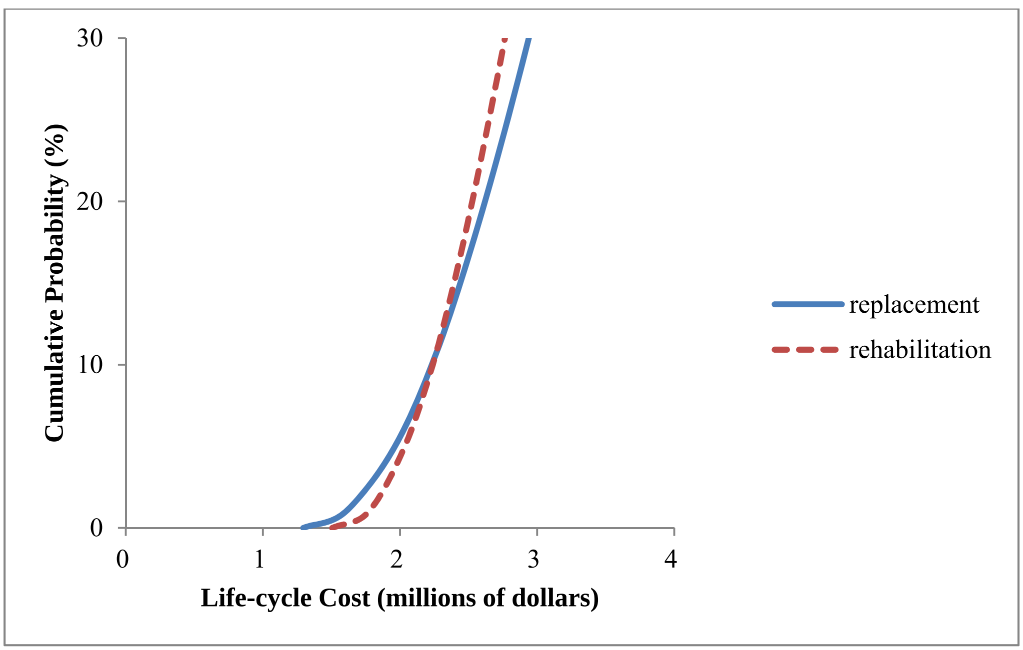


Figure E.20-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 1 (Table 3.6)

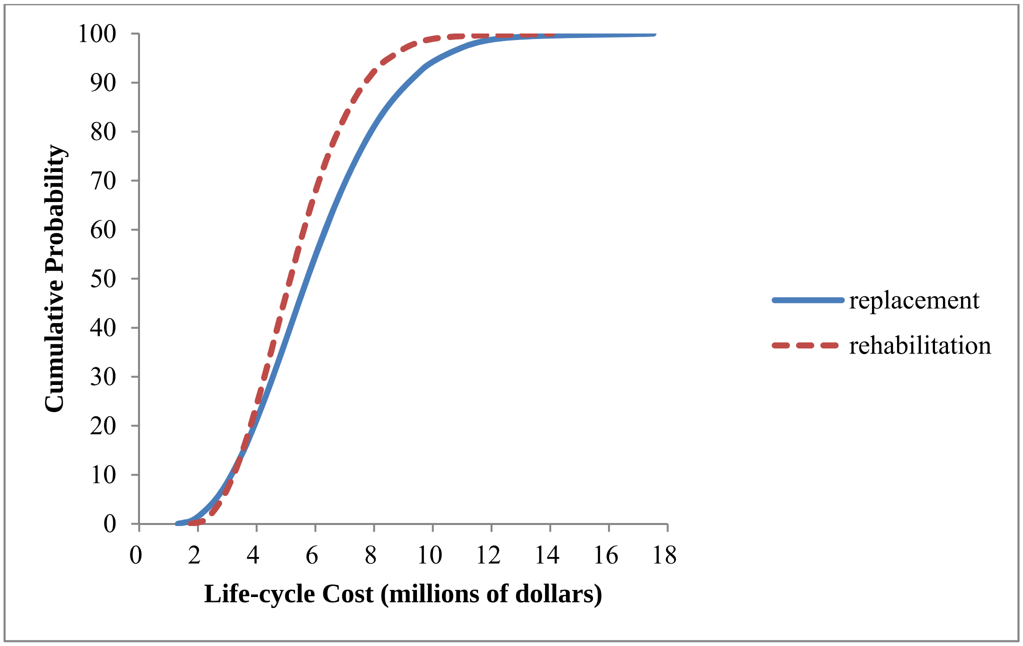


Figure E.21-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 2 (Table 3.6)

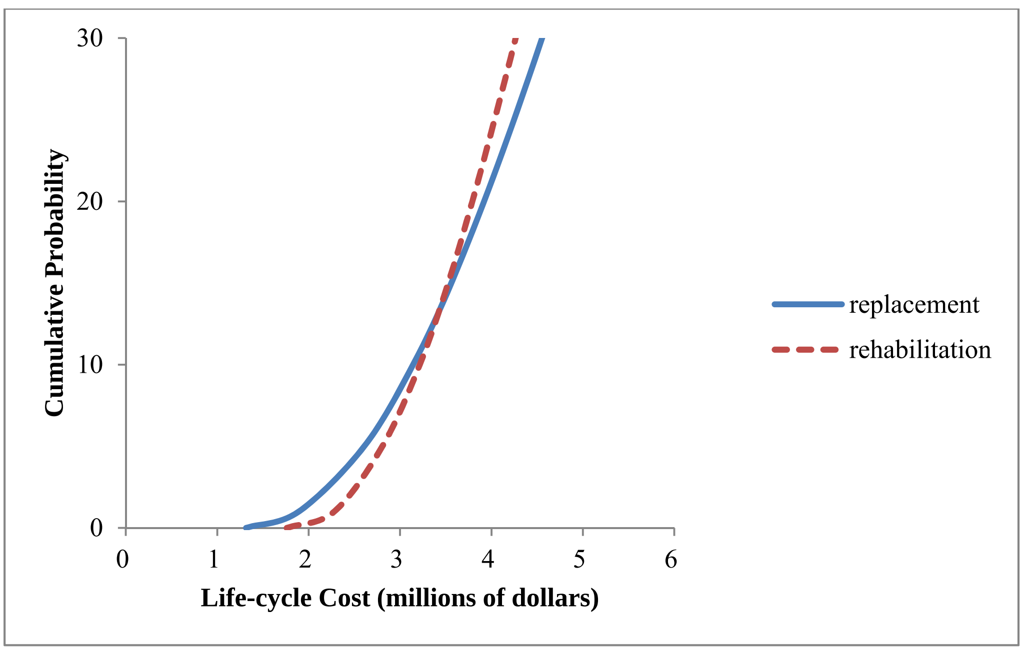


Figure E.22-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 2 (Table 3.6)

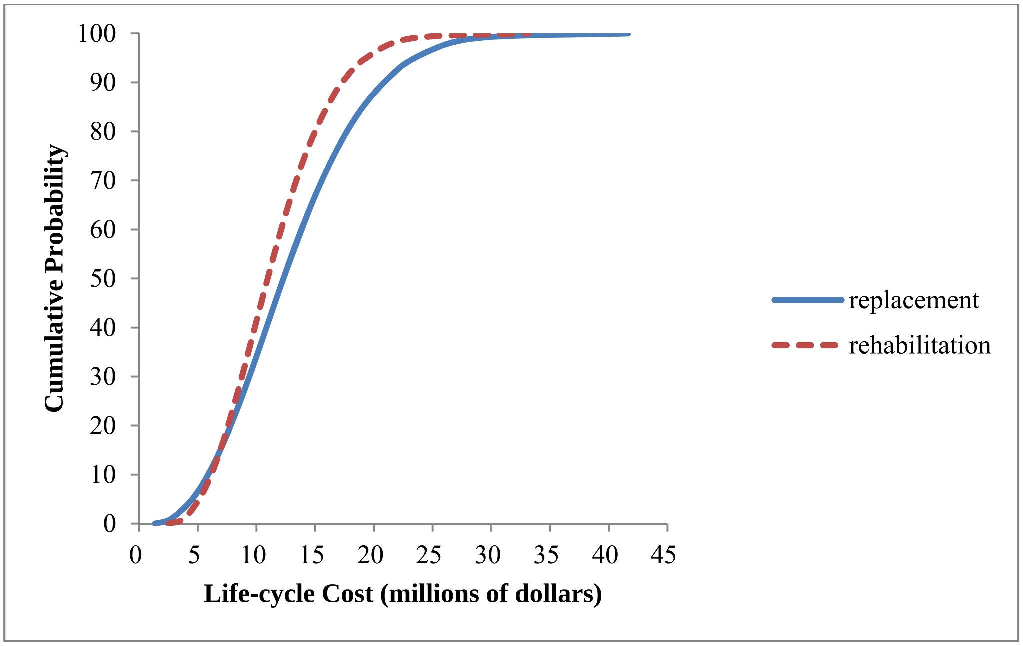


Figure E.23-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 3 (Table 3.6)

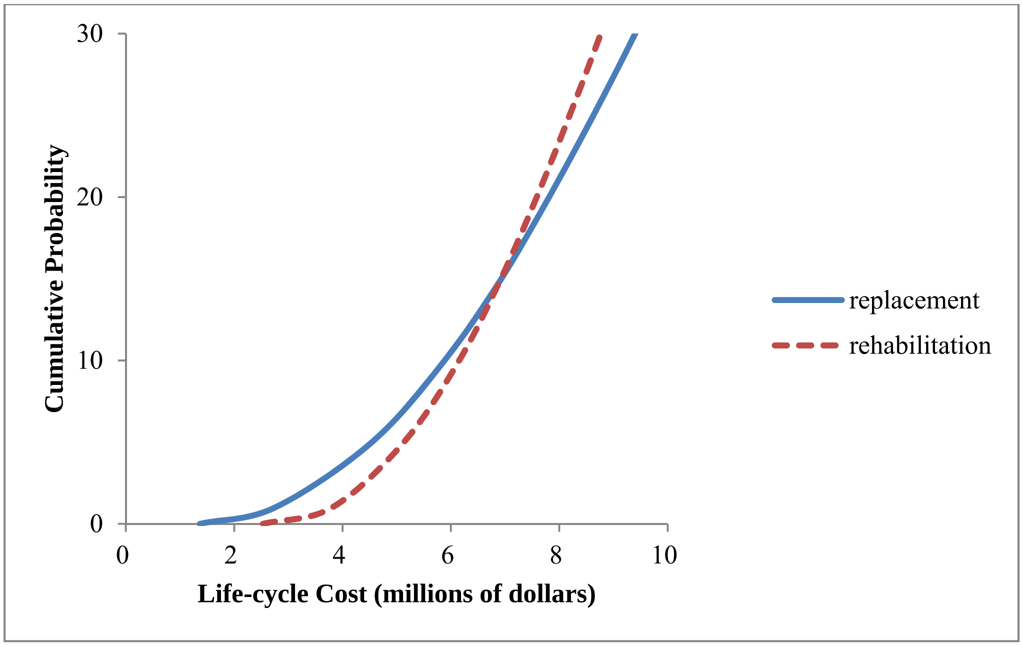


Figure E.24-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 3 (Table 3.6)

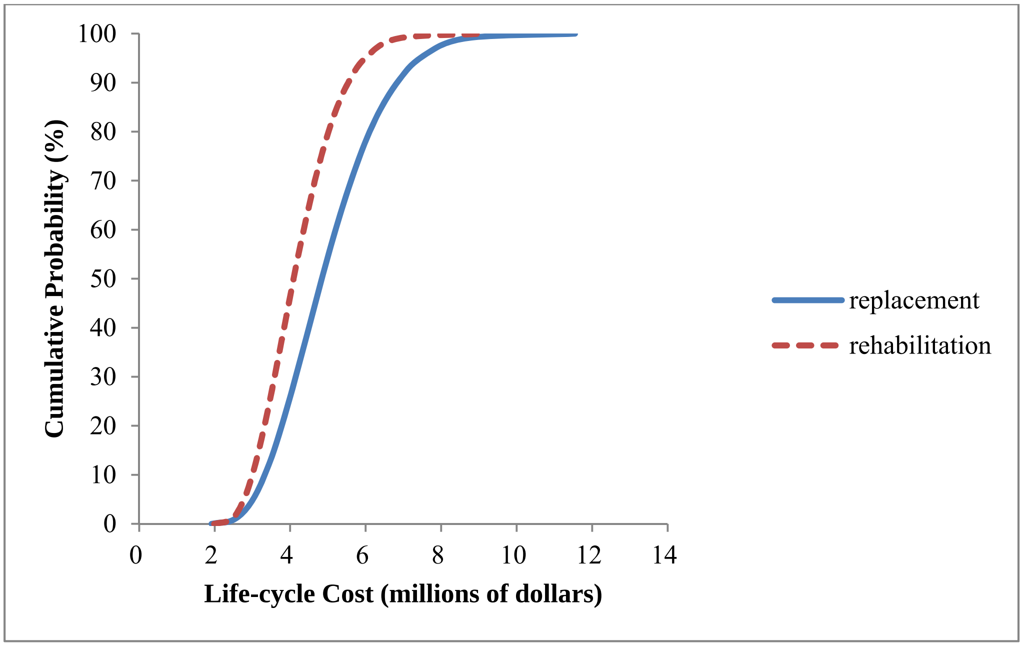


Figure E.25-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 4 (Table 3.6)

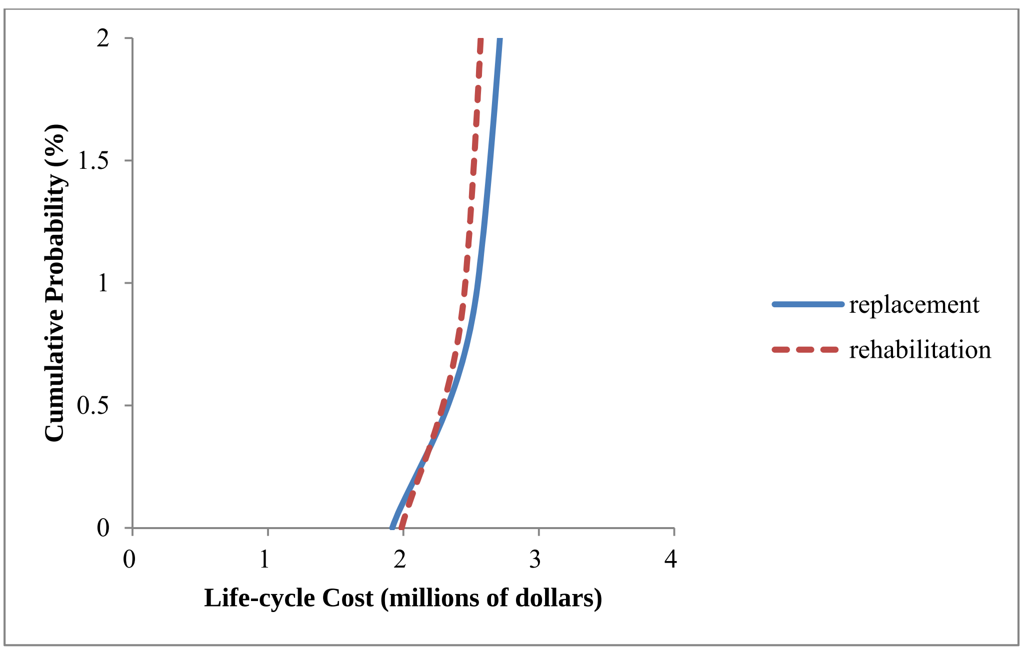


Figure E.26-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 4 (Table 3.6)

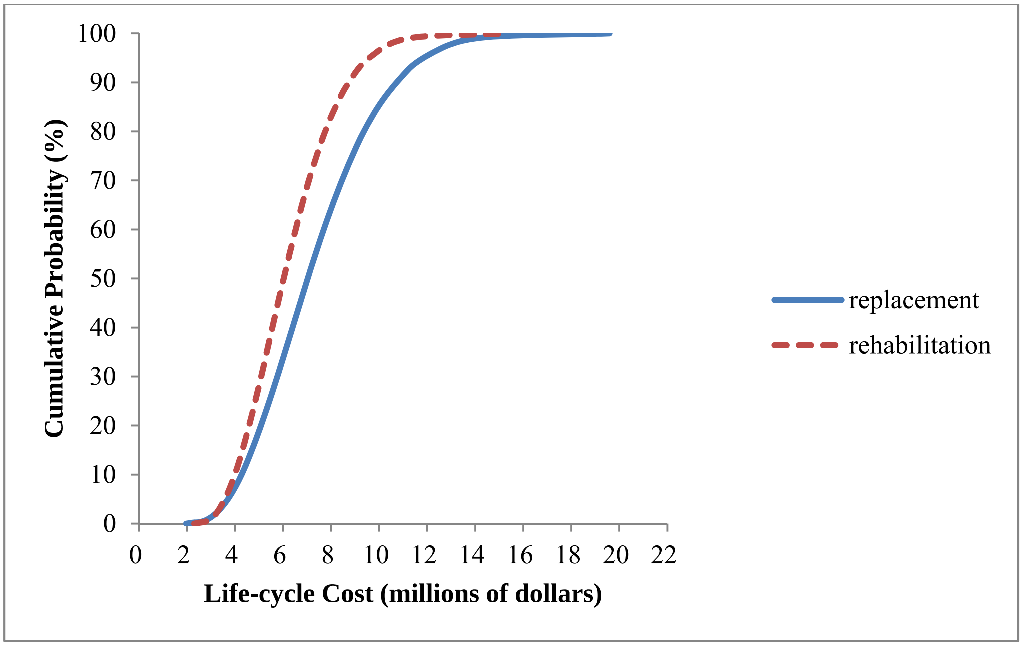


Figure E.27-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 5 (Table 3.6)

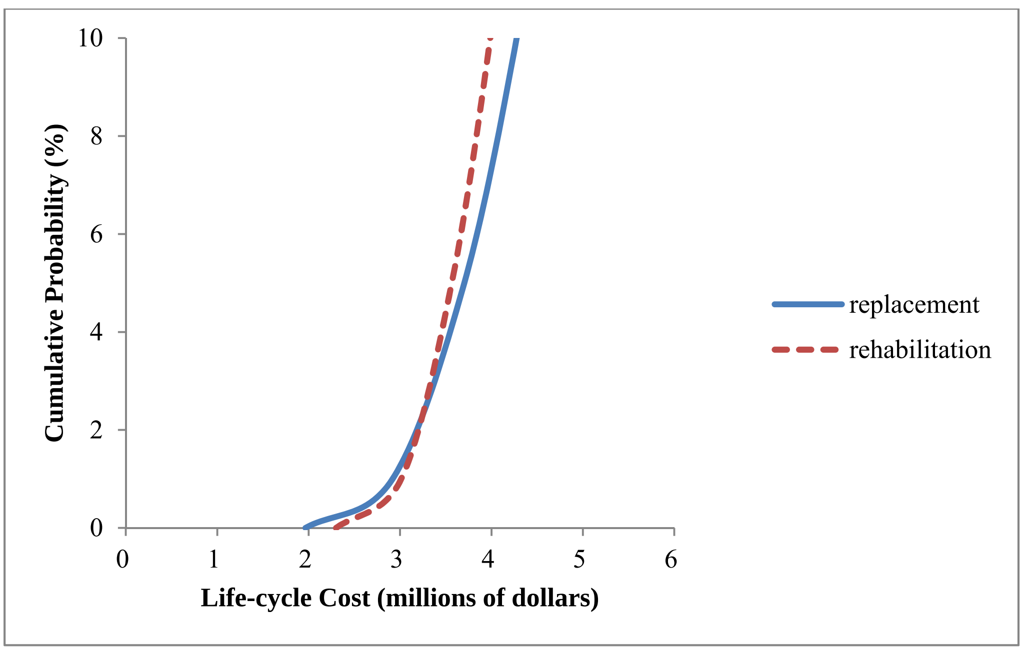


Figure E.28-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 5 (Table 3.6)

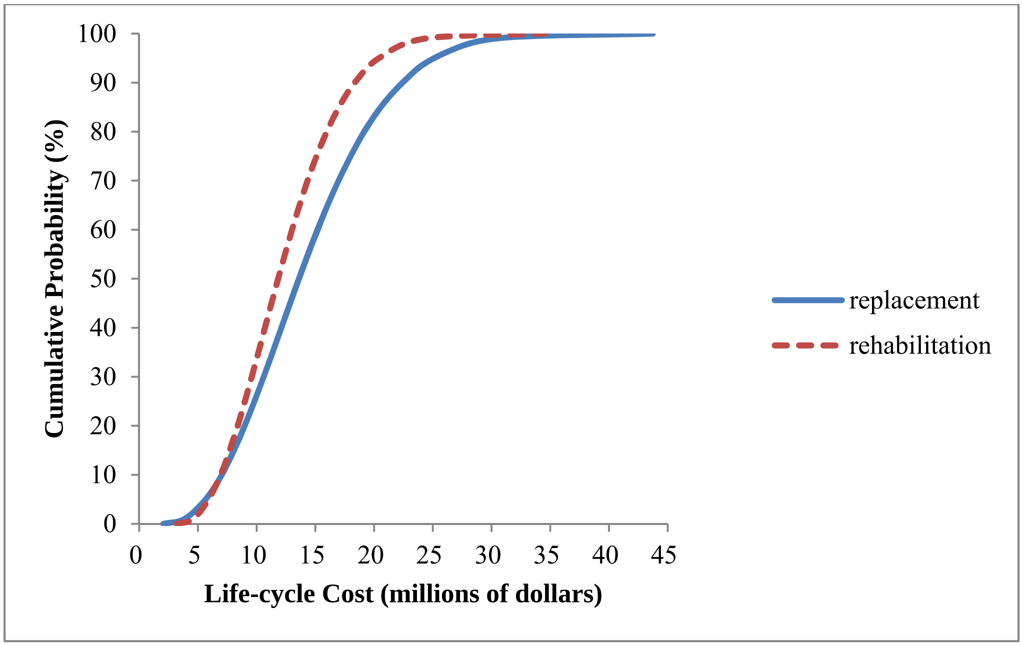


Figure E.29-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 6 (Table 3.6)

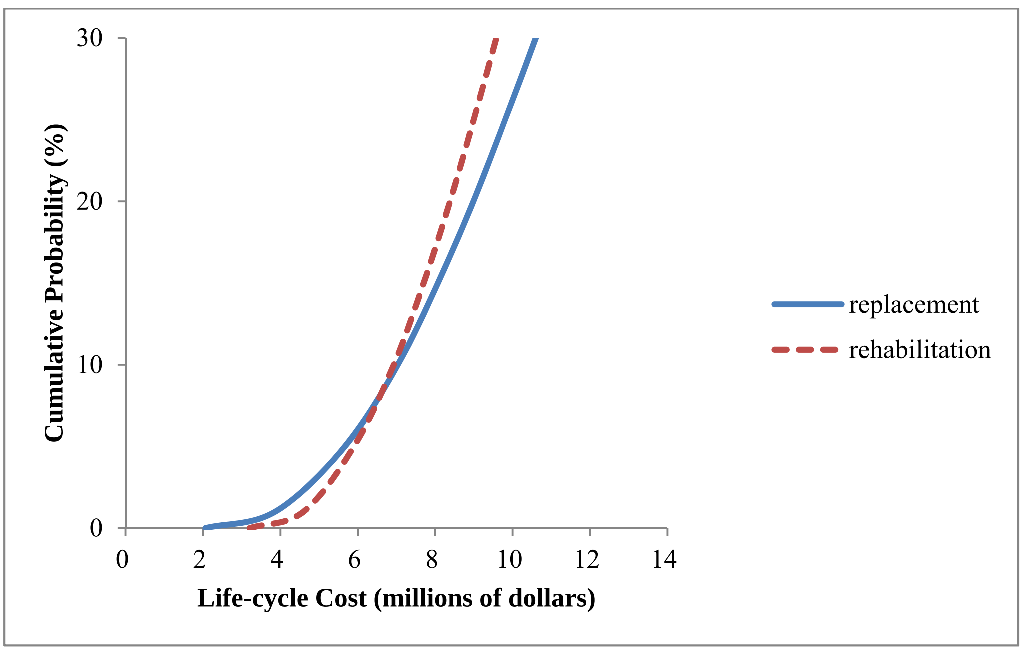


Figure E.30-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 6 (Table 3.6)

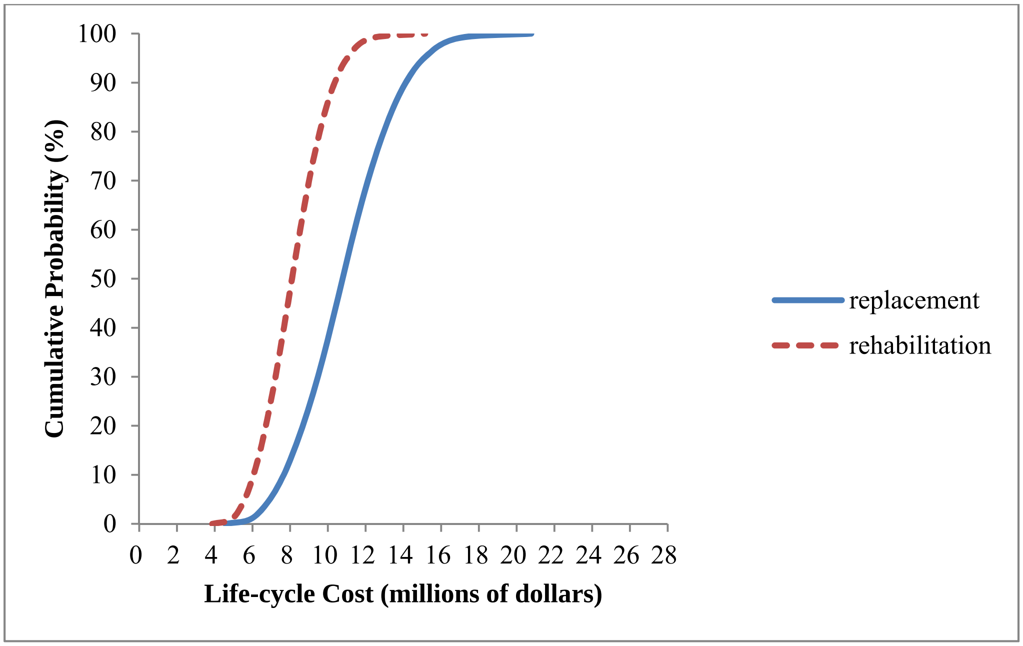


Figure E.31-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 7 (Table 3.6)

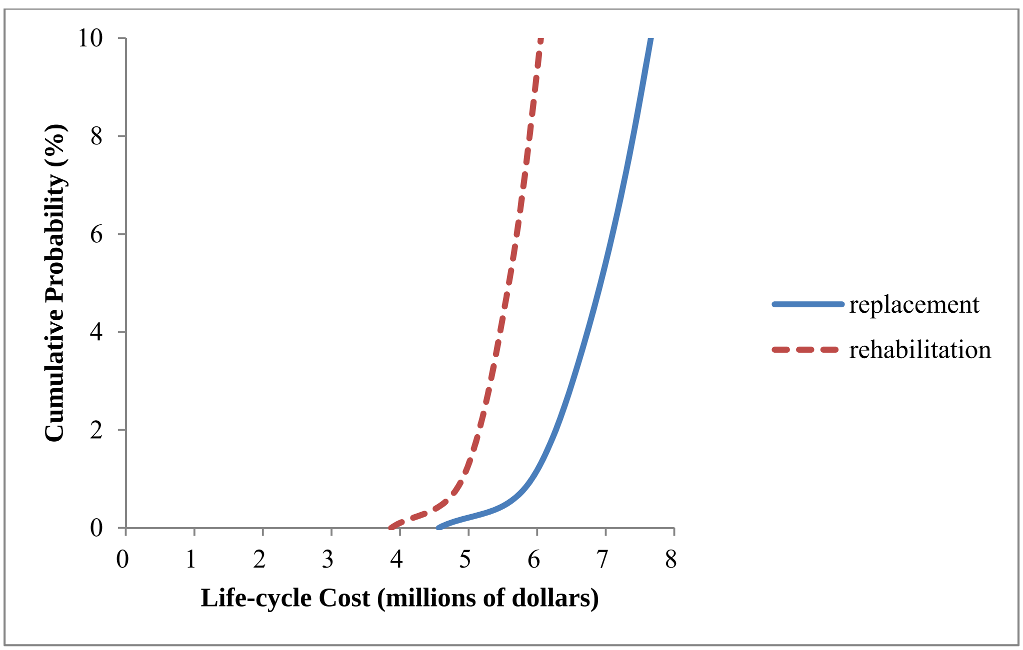


Figure E.32-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 7 (Table 3.6)

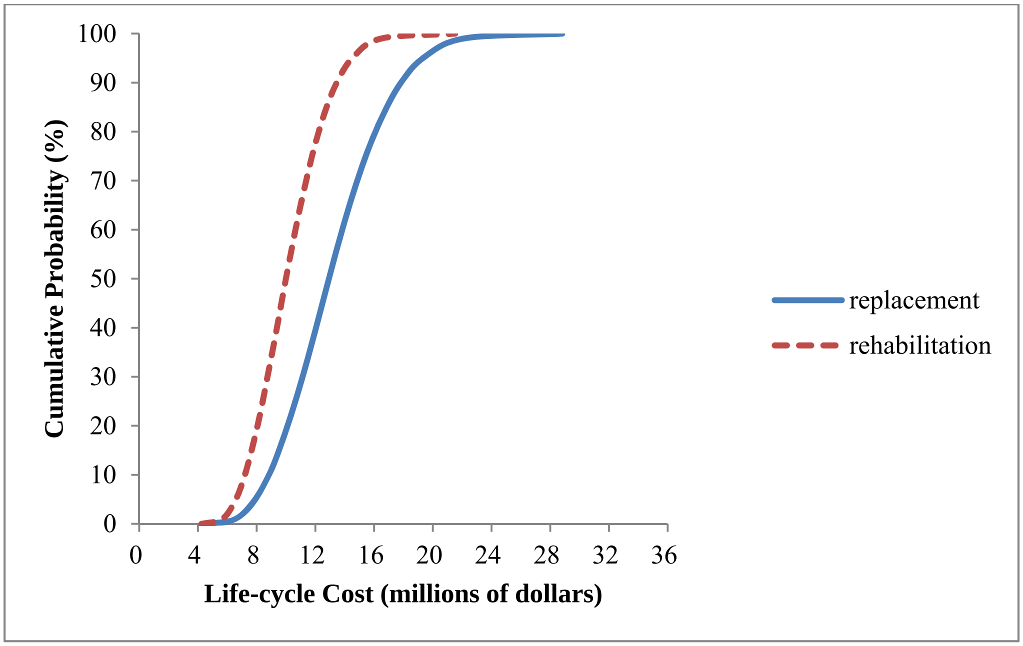


Figure E.33-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 8 (Table 3.6)

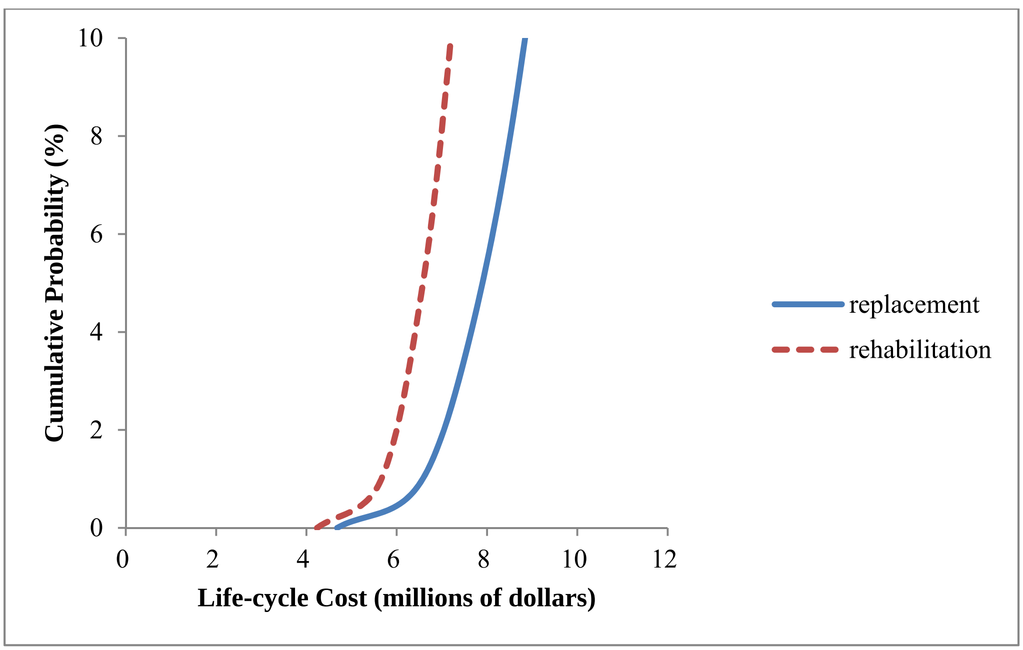


Figure E.34-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 8 (Table 3.6)

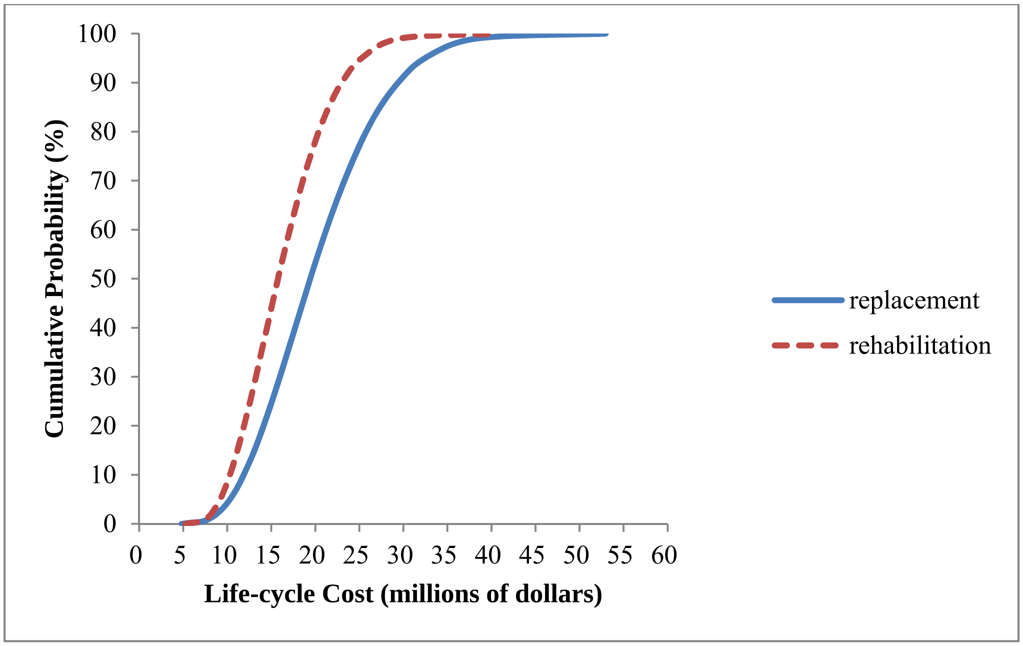


Figure E.35-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 9 (Table 3.6)

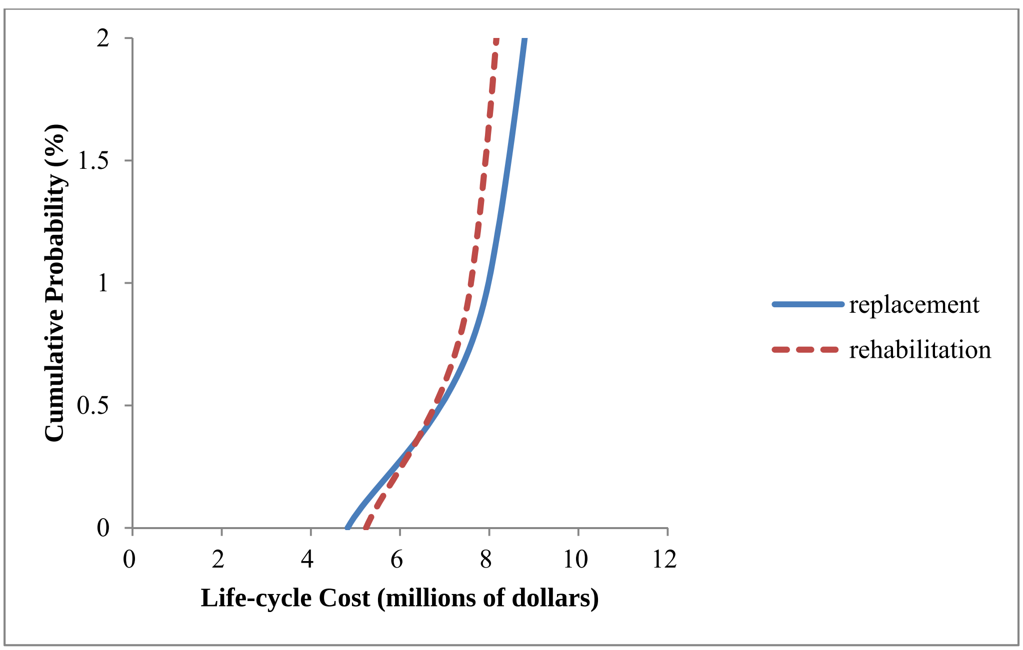


Figure E.36-Ascending cumulative probability distributions for highway bridge with limited variables limited ADT case 9 (Table 3.6)

Bridge over Highway with Modified Bridge Construction Time and Cost

Table E.19-Risk profile statistics for highway bridge with modification 1a ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	90,021	997,558	794,935	325,137	1,309,070
Maximum	1,900,008	6,169,989	7,458,877	2,117,072	5,257,288	6,584,774
Mean	1,203,146	1,940,574	3,143,720	1,250,889	1,775,886	3,026,776
Std Dev	156,583	882,656	896,516	175,993	685,605	714,611
Percentile						
1%	872,316	350,983	1,498,369	918,427	552,626	1,704,352
5%	945,174	641,569	1,824,990	989,862	772,733	1,976,453
10%	998,059	858,168	2,045,021	1,035,656	938,675	2,155,608
15%	1,036,328	1,022,892	2,212,653	1,068,262	1,065,372	2,289,334
20%	1,067,022	1,165,884	2,358,998	1,095,750	1,173,812	2,401,838
25%	1,093,240	1,293,179	2,487,584	1,121,263	1,270,432	2,504,710
30%	1,117,539	1,409,749	2,607,132	1,145,099	1,362,892	2,601,538
35%	1,139,266	1,520,568	2,719,292	1,167,704	1,451,651	2,691,652
40%	1,160,427	1,631,253	2,831,197	1,190,012	1,534,851	2,783,202
45%	1,180,850	1,738,344	2,942,311	1,211,954	1,619,499	2,870,397
50%	1,201,069	1,851,573	3,056,106	1,235,173	1,705,154	2,958,214
55%	1,220,708	1,964,694	3,171,178	1,258,333	1,793,216	3,048,399
60%	1,241,683	2,082,071	3,288,857	1,282,448	1,883,209	3,140,512
65%	1,263,431	2,205,917	3,418,629	1,307,817	1,979,547	3,241,550
70%	1,285,744	2,342,544	3,555,567	1,335,014	2,086,393	3,353,330
75%	1,309,538	2,492,286	3,707,100	1,364,839	2,201,981	3,474,252
80%	1,336,254	2,666,429	3,881,803	1,398,495	2,335,023	3,610,000
85%	1,367,361	2,874,579	4,089,979	1,438,184	2,496,929	3,775,584
90%	1,407,025	3,142,691	4,360,836	1,489,869	2,705,669	3,993,572
95%	1,464,162	3,547,200	4,774,802	1,564,673	3,024,648	4,314,100
99%	1,576,306	4,309,443	5,522,246	1,708,231	3,614,423	4,948,396

Table E.20-Risk profile statistics for highway bridge with modification 1a ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	118,709	1,068,418	794,935	601,470	1,629,127
Maximum	1,900,008	12,077,864	13,366,752	2,117,072	10,358,029	11,665,758
Mean	1,203,146	3,745,172	4,948,318	1,250,889	3,456,912	4,707,801
Std Dev	156,583	1,751,880	1,758,866	175,993	1,361,823	1,379,772
Percentile						
1%	872,316	583,335	1,756,457	918,427	1,019,224	2,218,221
5%	945,174	1,161,993	2,358,478	989,862	1,462,135	2,684,842
10%	998,059	1,594,067	2,791,767	1,035,656	1,793,448	3,024,261
15%	1,036,328	1,922,247	3,121,867	1,068,262	2,043,752	3,279,425
20%	1,067,022	2,209,515	3,407,940	1,095,750	2,262,721	3,497,627
25%	1,093,240	2,462,157	3,657,462	1,121,263	2,454,289	3,693,355
30%	1,117,539	2,692,754	3,893,805	1,145,099	2,637,004	3,879,868
35%	1,139,266	2,913,494	4,114,834	1,167,704	2,813,109	4,057,590
40%	1,160,427	3,133,371	4,333,057	1,190,012	2,979,504	4,228,166
45%	1,180,850	3,346,793	4,553,143	1,211,954	3,147,257	4,399,607
50%	1,201,069	3,568,150	4,772,998	1,235,173	3,317,459	4,570,583
55%	1,220,708	3,795,731	5,001,939	1,258,333	3,492,652	4,743,925
60%	1,241,683	4,025,948	5,231,032	1,282,448	3,671,218	4,922,869
65%	1,263,431	4,271,779	5,480,888	1,307,817	3,862,799	5,118,084
70%	1,285,744	4,543,830	5,753,868	1,335,014	4,074,350	5,334,255
75%	1,309,538	4,842,393	6,049,714	1,364,839	4,304,160	5,567,692
80%	1,336,254	5,185,603	6,396,850	1,398,495	4,566,549	5,830,948
85%	1,367,361	5,599,326	6,805,875	1,438,184	4,887,850	6,160,430
90%	1,407,025	6,131,129	7,336,113	1,489,869	5,303,333	6,575,655
95%	1,464,162	6,929,193	8,149,573	1,564,673	5,932,972	7,211,992
99%	1,576,306	8,448,706	9,629,246	1,708,231	7,112,082	8,424,459

Table E.21-Risk profile statistics for highway bridge with modification 1a ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	168,106	1,191,470	794,935	1,406,645	2,510,383
Maximum	1,900,008	29,801,489	31,090,376	2,117,072	25,660,251	26,967,980
Mean	1,203,146	9,158,966	10,362,112	1,250,889	8,499,989	9,750,878
Std Dev	156,583	4,360,248	4,363,015	175,993	3,390,877	3,401,917
Percentile						
1%	872,316	1,277,851	2,468,095	918,427	2,425,776	3,652,798
5%	945,174	2,722,589	3,929,628	989,862	3,526,149	4,758,878
10%	998,059	3,801,069	5,001,271	1,035,656	4,356,068	5,598,399
15%	1,036,328	4,622,680	5,827,959	1,068,262	4,983,611	6,223,611
20%	1,067,022	5,336,871	6,533,341	1,095,750	5,527,492	6,767,014
25%	1,093,240	5,971,690	7,170,912	1,121,263	6,004,540	7,247,829
30%	1,117,539	6,542,224	7,746,759	1,145,099	6,458,996	7,706,494
35%	1,139,266	7,092,901	8,293,575	1,167,704	6,896,524	8,142,161
40%	1,160,427	7,640,337	8,837,343	1,190,012	7,313,531	8,566,048
45%	1,180,850	8,175,023	9,375,704	1,211,954	7,733,883	8,982,544
50%	1,201,069	8,722,896	9,930,136	1,235,173	8,154,275	9,408,297
55%	1,220,708	9,286,985	10,491,821	1,258,333	8,592,671	9,839,576
60%	1,241,683	9,856,682	11,063,874	1,282,448	9,036,346	10,287,804
65%	1,263,431	10,468,818	11,677,675	1,307,817	9,510,853	10,755,360
70%	1,285,744	11,145,870	12,358,697	1,335,014	10,036,815	11,291,875
75%	1,309,538	11,891,578	13,095,909	1,364,839	10,610,228	11,870,950
80%	1,336,254	12,744,660	13,949,661	1,398,495	11,262,566	12,518,538
85%	1,367,361	13,772,002	14,973,482	1,438,184	12,065,175	13,328,162
90%	1,407,025	15,092,570	16,295,835	1,489,869	13,096,259	14,360,132
95%	1,464,162	17,076,288	18,286,772	1,564,673	14,665,803	15,925,793
99%	1,576,306	20,850,612	22,031,936	1,708,231	17,599,181	18,868,732

Table E.22-Risk profile statistics for highway bridge with modification 1a ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	642,010	1,771,192	794,935	717,009	1,775,760
Maximum	1,900,008	8,529,020	9,817,908	2,117,072	6,666,214	8,073,471
Mean	1,203,146	3,164,359	4,367,505	1,250,889	2,629,633	3,880,523
Std Dev	156,583	1,045,795	1,058,676	175,993	794,843	825,713
Percentile						
1%	872,316	1,258,634	2,419,910	918,427	1,205,917	2,358,550
5%	945,174	1,640,809	2,819,098	989,862	1,478,195	2,675,969
10%	998,059	1,895,584	3,081,438	1,035,656	1,666,617	2,879,974
15%	1,036,328	2,083,236	3,275,555	1,068,262	1,812,154	3,033,052
20%	1,067,022	2,244,368	3,442,253	1,095,750	1,933,629	3,159,281
25%	1,093,240	2,391,810	3,589,094	1,121,263	2,043,447	3,278,524
30%	1,117,539	2,529,702	3,726,621	1,145,099	2,145,312	3,387,241
35%	1,139,266	2,662,735	3,862,247	1,167,704	2,249,019	3,491,116
40%	1,160,427	2,794,292	3,993,504	1,190,012	2,347,291	3,592,615
45%	1,180,850	2,921,849	4,123,998	1,211,954	2,446,127	3,696,558
50%	1,201,069	3,052,076	4,259,276	1,235,173	2,543,022	3,794,775
55%	1,220,708	3,193,318	4,398,662	1,258,333	2,644,258	3,901,123
60%	1,241,683	3,333,619	4,537,359	1,282,448	2,752,254	4,013,061
65%	1,263,431	3,481,404	4,690,594	1,307,817	2,866,938	4,129,807
70%	1,285,744	3,644,032	4,856,531	1,335,014	2,988,436	4,255,846
75%	1,309,538	3,819,026	5,037,071	1,364,839	3,123,061	4,395,470
80%	1,336,254	4,024,042	5,242,987	1,398,495	3,278,814	4,552,408
85%	1,367,361	4,274,788	5,487,659	1,438,184	3,465,580	4,748,451
90%	1,407,025	4,585,916	5,806,514	1,489,869	3,708,530	4,998,910
95%	1,464,162	5,066,175	6,283,098	1,564,673	4,074,613	5,367,879
99%	1,576,306	5,959,638	7,192,815	1,708,231	4,778,293	6,107,046

Table E.23-Risk profile statistics for highway bridge with modification 1a ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	670,698	1,801,763	794,935	1,020,890	2,169,823
Maximum	1,900,008	14,436,895	15,725,783	2,117,072	11,766,955	13,074,684
Mean	1,203,146	4,968,957	6,172,103	1,250,889	4,310,659	5,561,548
Std Dev	156,583	1,892,132	1,899,248	175,993	1,457,543	1,477,515
Percentile						
1%	872,316	1,575,032	2,743,552	918,427	1,724,391	2,913,798
5%	945,174	2,215,293	3,408,017	989,862	2,196,267	3,413,297
10%	998,059	2,661,202	3,856,579	1,035,656	2,542,371	3,771,732
15%	1,036,328	3,009,494	4,204,284	1,068,262	2,803,700	4,039,200
20%	1,067,022	3,304,766	4,501,954	1,095,750	3,027,948	4,263,684
25%	1,093,240	3,570,901	4,768,206	1,121,263	3,232,435	4,472,647
30%	1,117,539	3,819,268	5,018,345	1,145,099	3,424,641	4,668,350
35%	1,139,266	4,058,087	5,259,468	1,167,704	3,611,496	4,856,750
40%	1,160,427	4,299,558	5,496,743	1,190,012	3,796,244	5,042,664
45%	1,180,850	4,529,320	5,730,417	1,211,954	3,972,270	5,224,136
50%	1,201,069	4,766,424	5,972,543	1,235,173	4,152,253	5,404,507
55%	1,220,708	5,013,043	6,221,386	1,258,333	4,341,019	5,594,613
60%	1,241,683	5,268,833	6,470,136	1,282,448	4,533,513	5,789,633
65%	1,263,431	5,538,018	6,745,132	1,307,817	4,743,805	5,999,135
70%	1,285,744	5,829,558	7,039,733	1,335,014	4,968,614	6,227,590
75%	1,309,538	6,153,921	7,365,776	1,364,839	5,216,906	6,478,907
80%	1,336,254	6,526,298	7,736,039	1,398,495	5,498,219	6,762,812
85%	1,367,361	6,973,195	8,186,452	1,438,184	5,847,661	7,115,695
90%	1,407,025	7,554,707	8,760,929	1,489,869	6,292,134	7,567,834
95%	1,464,162	8,415,690	9,632,605	1,564,673	6,966,491	8,241,989
99%	1,576,306	10,042,927	11,272,776	1,708,231	8,237,043	9,545,733

Table E.24-Risk profile statistics for highway bridge with modification 1a ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	756,764	1,878,062	794,935	1,869,712	3,094,899
Maximum	1,900,008	32,160,520	33,449,407	2,117,072	27,069,177	28,376,906
Mean	1,203,146	10,382,751	11,585,897	1,250,889	9,353,736	10,604,625
Std Dev	156,583	4,484,671	4,487,634	175,993	3,477,407	3,489,522
Percentile						
1%	872,316	2,332,655	3,532,769	918,427	3,170,503	4,388,169
5%	945,174	3,809,736	5,004,451	989,862	4,279,339	5,519,735
10%	998,059	4,890,918	6,096,907	1,035,656	5,117,681	6,355,594
15%	1,036,328	5,718,814	6,919,969	1,068,262	5,756,658	6,993,299
20%	1,067,022	6,441,654	7,647,795	1,095,750	6,298,123	7,535,326
25%	1,093,240	7,088,499	8,282,768	1,121,263	6,788,551	8,027,523
30%	1,117,539	7,672,997	8,876,055	1,145,099	7,255,803	8,498,880
35%	1,139,266	8,238,469	9,441,882	1,167,704	7,696,878	8,946,118
40%	1,160,427	8,801,078	10,000,055	1,190,012	8,128,977	9,378,029
45%	1,180,850	9,347,148	10,553,182	1,211,954	8,556,178	9,806,382
50%	1,201,069	9,924,011	11,129,998	1,235,173	8,986,386	10,241,860
55%	1,220,708	10,503,668	11,709,480	1,258,333	9,435,293	10,684,449
60%	1,241,683	11,098,011	12,300,194	1,282,448	9,891,651	11,145,651
65%	1,263,431	11,732,557	12,934,898	1,307,817	10,387,019	11,630,014
70%	1,285,744	12,419,411	13,631,429	1,335,014	10,928,777	12,183,379
75%	1,309,538	13,193,320	14,395,870	1,364,839	11,515,149	12,772,000
80%	1,336,254	14,072,070	15,279,160	1,398,495	12,189,775	13,451,938
85%	1,367,361	15,127,400	16,338,058	1,438,184	13,008,667	14,271,654
90%	1,407,025	16,492,394	17,692,526	1,489,869	14,073,898	15,344,131
95%	1,464,162	18,549,604	19,762,810	1,564,673	15,693,767	16,957,775
99%	1,576,306	22,423,928	23,645,323	1,708,231	18,693,984	19,981,028

Table E.25-Risk profile statistics for highway bridge with modification 1a ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	2,956,087	4,012,547	794,935	2,369,518	3,443,181
Maximum	1,900,008	20,074,314	21,438,445	2,117,072	15,347,922	16,496,884
Mean	1,203,146	8,603,403	9,806,549	1,250,889	6,424,063	7,674,953
Std Dev	156,583	2,197,875	2,206,502	175,993	1,552,791	1,582,094
Percentile						
1%	872,316	4,465,754	5,644,656	918,427	3,528,004	4,696,844
5%	945,174	5,325,220	6,517,269	989,862	4,141,612	5,341,159
10%	998,059	5,903,678	7,089,596	1,035,656	4,532,428	5,755,112
15%	1,036,328	6,320,163	7,519,347	1,068,262	4,833,873	6,056,036
20%	1,067,022	6,674,350	7,873,262	1,095,750	5,077,816	6,303,979
25%	1,093,240	7,000,415	8,198,952	1,121,263	5,297,420	6,527,704
30%	1,117,539	7,301,874	8,500,382	1,145,099	5,495,509	6,734,208
35%	1,139,266	7,583,302	8,783,267	1,167,704	5,689,813	6,931,764
40%	1,160,427	7,860,236	9,062,461	1,190,012	5,886,554	7,124,974
45%	1,180,850	8,141,292	9,344,022	1,211,954	6,083,077	7,325,691
50%	1,201,069	8,414,048	9,617,236	1,235,173	6,276,841	7,527,360
55%	1,220,708	8,692,930	9,900,772	1,258,333	6,472,007	7,730,012
60%	1,241,683	8,990,510	10,193,211	1,282,448	6,678,784	7,940,918
65%	1,263,431	9,306,283	10,508,589	1,307,817	6,901,675	8,161,561
70%	1,285,744	9,636,301	10,849,126	1,335,014	7,138,812	8,403,624
75%	1,309,538	10,001,446	11,207,134	1,364,839	7,398,173	8,668,785
80%	1,336,254	10,420,380	11,630,980	1,398,495	7,693,722	8,967,514
85%	1,367,361	10,914,810	12,128,048	1,438,184	8,054,170	9,331,975
90%	1,407,025	11,557,559	12,770,846	1,489,869	8,514,851	9,795,780
95%	1,464,162	12,528,913	13,744,229	1,564,673	9,203,966	10,509,761
99%	1,576,306	14,400,405	15,625,073	1,708,231	10,595,308	11,928,909

Table E.26-Risk profile statistics for highway bridge with modification 1a ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	3,076,646	4,160,174	794,935	2,673,399	3,841,428
Maximum	1,900,008	24,921,478	26,210,365	2,117,072	18,878,028	20,288,470
Mean	1,203,146	10,408,001	11,611,147	1,250,889	8,105,089	9,355,978
Std Dev	156,583	2,861,880	2,868,488	175,993	2,093,914	2,117,765
Percentile						
1%	872,316	5,066,257	6,242,360	918,427	4,243,157	5,422,548
5%	945,174	6,182,493	7,372,902	989,862	5,044,770	6,258,382
10%	998,059	6,901,578	8,099,713	1,035,656	5,569,733	6,793,244
15%	1,036,328	7,444,228	8,645,607	1,068,262	5,950,411	7,176,311
20%	1,067,022	7,897,230	9,093,226	1,095,750	6,276,663	7,507,743
25%	1,093,240	8,309,691	9,510,777	1,121,263	6,569,581	7,806,266
30%	1,117,539	8,695,026	9,892,703	1,145,099	6,848,010	8,087,304
35%	1,139,266	9,063,264	10,265,840	1,167,704	7,113,727	8,356,416
40%	1,160,427	9,419,228	10,618,942	1,190,012	7,372,759	8,619,827
45%	1,180,850	9,784,031	10,988,206	1,211,954	7,630,150	8,879,099
50%	1,201,069	10,148,137	11,350,609	1,235,173	7,897,302	9,141,470
55%	1,220,708	10,518,290	11,720,536	1,258,333	8,167,842	9,422,124
60%	1,241,683	10,902,672	12,102,207	1,282,448	8,448,227	9,704,457
65%	1,263,431	11,308,308	12,513,996	1,307,817	8,741,642	10,002,771
70%	1,285,744	11,749,359	12,955,900	1,335,014	9,058,735	10,319,762
75%	1,309,538	12,233,301	13,441,958	1,364,839	9,413,700	10,676,581
80%	1,336,254	12,772,219	13,985,034	1,398,495	9,819,331	11,085,661
85%	1,367,361	13,427,567	14,638,717	1,438,184	10,306,708	11,580,532
90%	1,407,025	14,262,808	15,474,093	1,489,869	10,935,629	12,214,854
95%	1,464,162	15,543,452	16,760,078	1,564,673	11,871,299	13,148,019
99%	1,576,306	17,958,254	19,165,358	1,708,231	13,746,767	15,059,833

Table E.27-Risk profile statistics for highway bridge with modification 1a ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	3,210,049	4,463,100	794,935	3,585,043	4,777,869
Maximum	1,900,008	42,645,102	43,933,990	2,117,072	33,331,071	34,638,800
Mean	1,203,146	15,821,795	17,024,941	1,250,889	13,148,166	14,399,055
Std Dev	156,583	5,228,973	5,232,555	175,993	3,974,215	3,990,066
Percentile						
1%	872,316	6,293,168	7,507,595	918,427	6,029,587	7,234,775
5%	945,174	8,204,045	9,401,734	989,862	7,390,977	8,616,700
10%	998,059	9,477,921	10,674,422	1,035,656	8,333,083	9,570,171
15%	1,036,328	10,416,179	11,621,841	1,068,262	9,060,772	10,297,799
20%	1,067,022	11,221,838	12,429,409	1,095,750	9,668,144	10,908,457
25%	1,093,240	11,959,051	13,161,047	1,121,263	10,217,237	11,449,992
30%	1,117,539	12,648,508	13,842,045	1,145,099	10,726,561	11,971,849
35%	1,139,266	13,313,676	14,518,855	1,167,704	11,245,093	12,493,007
40%	1,160,427	13,971,462	15,174,979	1,190,012	11,736,454	12,984,129
45%	1,180,850	14,609,245	15,814,882	1,211,954	12,230,633	13,480,860
50%	1,201,069	15,260,379	16,474,302	1,235,173	12,715,112	13,964,203
55%	1,220,708	15,966,588	17,161,367	1,258,333	13,221,292	14,475,638
60%	1,241,683	16,668,096	17,863,934	1,282,448	13,761,268	15,015,849
65%	1,263,431	17,407,021	18,613,495	1,307,817	14,334,688	15,588,001
70%	1,285,744	18,220,159	19,429,094	1,335,014	14,942,179	16,199,912
75%	1,309,538	19,095,131	20,315,728	1,364,839	15,615,304	16,874,316
80%	1,336,254	20,120,211	21,326,163	1,398,495	16,394,069	17,650,827
85%	1,367,361	21,373,942	22,579,698	1,438,184	17,327,900	18,603,276
90%	1,407,025	22,929,578	24,132,666	1,489,869	18,542,650	19,809,358
95%	1,464,162	25,330,877	26,527,996	1,564,673	20,373,063	21,643,298
99%	1,576,306	29,798,190	31,028,078	1,708,231	23,891,464	25,162,864

Table E.28-Risk profile statistics for highway bridge with modification 1b ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	90,021	1,027,298	808,309	325,137	1,327,996
Maximum	1,944,452	6,169,989	7,503,321	2,146,195	5,257,288	6,611,554
Mean	1,247,249	1,940,574	3,187,823	1,272,986	1,775,886	3,048,873
Std Dev	157,243	882,656	896,632	177,405	685,605	715,229
Percentile						
1%	909,437	350,983	1,542,613	936,836	552,626	1,724,515
5%	987,669	641,569	1,868,950	1,009,296	772,733	1,998,067
10%	1,042,125	858,168	2,089,047	1,055,715	938,675	2,176,296
15%	1,080,624	1,022,892	2,256,740	1,089,072	1,065,372	2,310,547
20%	1,111,453	1,165,884	2,402,901	1,116,431	1,173,812	2,423,929
25%	1,137,683	1,293,179	2,531,709	1,142,526	1,270,432	2,526,670
30%	1,161,984	1,409,749	2,651,148	1,166,589	1,362,892	2,623,376
35%	1,183,711	1,520,568	2,763,153	1,189,459	1,451,651	2,713,262
40%	1,204,872	1,631,253	2,875,041	1,211,881	1,534,851	2,805,375
45%	1,225,295	1,738,344	2,986,307	1,234,111	1,619,499	2,892,470
50%	1,245,513	1,851,573	3,100,183	1,257,297	1,705,154	2,980,107
55%	1,265,153	1,964,694	3,215,442	1,280,642	1,793,216	3,070,626
60%	1,286,127	2,082,071	3,333,154	1,304,810	1,883,209	3,162,718
65%	1,307,875	2,205,917	3,462,756	1,330,303	1,979,547	3,263,939
70%	1,330,189	2,342,544	3,599,787	1,357,949	2,086,393	3,375,736
75%	1,353,983	2,492,286	3,751,284	1,387,921	2,201,981	3,496,441
80%	1,380,699	2,666,429	3,926,162	1,421,829	2,335,023	3,632,643
85%	1,411,806	2,874,579	4,134,195	1,461,708	2,496,929	3,798,429
90%	1,451,469	3,142,691	4,404,918	1,513,580	2,705,669	4,016,266
95%	1,508,607	3,547,200	4,819,204	1,589,424	3,024,648	4,337,728
99%	1,620,750	4,309,443	5,566,691	1,733,931	3,614,423	4,973,817

Table E.29-Risk profile statistics for highway bridge with modification 1b ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	118,709	1,098,158	808,309	601,470	1,647,654
Maximum	1,944,452	12,077,864	13,411,196	2,146,195	10,358,029	11,695,896
Mean	1,247,249	3,745,172	4,992,421	1,272,986	3,456,912	4,729,898
Std Dev	157,243	1,751,880	1,758,926	177,405	1,361,823	1,380,218
Percentile						
1%	909,437	583,335	1,800,325	936,836	1,019,224	2,239,490
5%	987,669	1,161,993	2,402,316	1,009,296	1,462,135	2,706,265
10%	1,042,125	1,594,067	2,835,769	1,055,715	1,793,448	3,045,345
15%	1,080,624	1,922,247	3,166,062	1,089,072	2,043,752	3,300,793
20%	1,111,453	2,209,515	3,452,184	1,116,431	2,262,721	3,520,034
25%	1,137,683	2,462,157	3,701,251	1,142,526	2,454,289	3,715,374
30%	1,161,984	2,692,754	3,938,109	1,166,589	2,637,004	3,901,400
35%	1,183,711	2,913,494	4,158,958	1,189,459	2,813,109	4,079,700
40%	1,204,872	3,133,371	4,376,839	1,211,881	2,979,504	4,250,507
45%	1,225,295	3,346,793	4,597,366	1,234,111	3,147,257	4,421,319
50%	1,245,513	3,568,150	4,816,827	1,257,297	3,317,459	4,592,720
55%	1,265,153	3,795,731	5,046,169	1,280,642	3,492,652	4,766,220
60%	1,286,127	4,025,948	5,274,931	1,304,810	3,671,218	4,945,272
65%	1,307,875	4,271,779	5,524,808	1,330,303	3,862,799	5,140,729
70%	1,330,189	4,543,830	5,798,034	1,357,949	4,074,350	5,356,842
75%	1,353,983	4,842,393	6,093,998	1,387,921	4,304,160	5,589,340
80%	1,380,699	5,185,603	6,441,133	1,421,829	4,566,549	5,853,548
85%	1,411,806	5,599,326	6,850,029	1,461,708	4,887,850	6,183,198
90%	1,451,469	6,131,129	7,380,430	1,513,580	5,303,333	6,598,026
95%	1,508,607	6,929,193	8,193,805	1,589,424	5,932,972	7,235,192
99%	1,620,750	8,448,706	9,672,596	1,733,931	7,112,082	8,447,405

Table E.30-Risk profile statistics for highway bridge with modification 1b ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	168,106	1,235,915	808,309	1,406,645	2,531,366
Maximum	1,944,452	29,801,489	31,134,821	2,146,195	25,660,251	26,998,118
Mean	1,247,249	9,158,966	10,406,214	1,272,986	8,499,989	9,772,975
Std Dev	157,243	4,360,248	4,363,039	177,405	3,390,877	3,402,251
Percentile						
1%	909,437	1,277,851	2,512,540	936,836	2,425,776	3,673,196
5%	987,669	2,722,589	3,973,555	1,009,296	3,526,149	4,780,419
10%	1,042,125	3,801,069	5,045,716	1,055,715	4,356,068	5,619,889
15%	1,080,624	4,622,680	5,872,142	1,089,072	4,983,611	6,244,742
20%	1,111,453	5,336,871	6,577,596	1,116,431	5,527,492	6,789,275
25%	1,137,683	5,971,690	7,215,241	1,142,526	6,004,540	7,269,772
30%	1,161,984	6,542,224	7,789,990	1,166,589	6,458,996	7,727,454
35%	1,183,711	7,092,901	8,337,722	1,189,459	6,896,524	8,163,191
40%	1,204,872	7,640,337	8,881,592	1,211,881	7,313,531	8,586,967
45%	1,225,295	8,175,023	9,419,962	1,234,111	7,733,883	9,004,201
50%	1,245,513	8,722,896	9,974,581	1,257,297	8,154,275	9,429,955
55%	1,265,153	9,286,985	10,536,100	1,280,642	8,592,671	9,861,931
60%	1,286,127	9,856,682	11,108,088	1,304,810	9,036,346	10,309,819
65%	1,307,875	10,468,818	11,721,793	1,330,303	9,510,853	10,778,112
70%	1,330,189	11,145,870	12,402,487	1,357,949	10,036,815	11,314,651
75%	1,353,983	11,891,578	13,140,354	1,387,921	10,610,228	11,892,448
80%	1,380,699	12,744,660	13,994,106	1,421,829	11,262,566	12,540,607
85%	1,411,806	13,772,002	15,017,927	1,461,708	12,065,175	13,350,542
90%	1,451,469	15,092,570	16,339,853	1,513,580	13,096,259	14,383,696
95%	1,508,607	17,076,288	18,329,580	1,589,424	14,665,803	15,952,314
99%	1,620,750	20,850,612	22,076,381	1,733,931	17,599,181	18,894,407

Table E.31-Risk profile statistics for highway bridge with modification 1b ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	642,010	1,815,637	808,309	717,009	1,789,808
Maximum	1,944,452	8,529,020	9,862,352	2,146,195	6,666,214	8,100,251
Mean	1,247,249	3,164,359	4,411,608	1,272,986	2,629,633	3,902,619
Std Dev	157,243	1,045,795	1,058,776	177,405	794,843	826,455
Percentile						
1%	909,437	1,258,634	2,463,450	936,836	1,205,917	2,377,572
5%	987,669	1,640,809	2,863,018	1,009,296	1,478,195	2,696,613
10%	1,042,125	1,895,584	3,125,760	1,055,715	1,666,617	2,901,171
15%	1,080,624	2,083,236	3,319,584	1,089,072	1,812,154	3,054,425
20%	1,111,453	2,244,368	3,486,222	1,116,431	1,933,629	3,180,512
25%	1,137,683	2,391,810	3,633,105	1,142,526	2,043,447	3,300,842
30%	1,161,984	2,529,702	3,770,395	1,166,589	2,145,312	3,409,131
35%	1,183,711	2,662,735	3,906,336	1,189,459	2,249,019	3,513,336
40%	1,204,872	2,794,292	4,037,721	1,211,881	2,347,291	3,614,703
45%	1,225,295	2,921,849	4,168,336	1,234,111	2,446,127	3,718,450
50%	1,245,513	3,052,076	4,303,478	1,257,297	2,543,022	3,817,188
55%	1,265,153	3,193,318	4,442,638	1,280,642	2,644,258	3,923,034
60%	1,286,127	3,333,619	4,581,448	1,304,810	2,752,254	4,035,454
65%	1,307,875	3,481,404	4,734,713	1,330,303	2,866,938	4,152,032
70%	1,330,189	3,644,032	4,900,877	1,357,949	2,988,436	4,277,958
75%	1,353,983	3,819,026	5,081,215	1,387,921	3,123,061	4,418,273
80%	1,380,699	4,024,042	5,286,941	1,421,829	3,278,814	4,574,997
85%	1,411,806	4,274,788	5,531,505	1,461,708	3,465,580	4,770,915
90%	1,451,469	4,585,916	5,850,747	1,513,580	3,708,530	5,022,203
95%	1,508,607	5,066,175	6,327,521	1,589,424	4,074,613	5,391,735
99%	1,620,750	5,959,638	7,237,259	1,733,931	4,778,293	6,130,148

Table E.32-Risk profile statistics for highway bridge with modification 1b ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	670,698	1,846,207	808,309	1,020,890	2,188,054
Maximum	1,944,452	14,436,895	15,770,227	2,146,195	11,766,955	13,104,822
Mean	1,247,249	4,968,957	6,216,206	1,272,986	4,310,659	5,583,645
Std Dev	157,243	1,892,132	1,899,304	177,405	1,457,543	1,478,048
Percentile						
1%	909,437	1,575,032	2,787,996	936,836	1,724,391	2,934,139
5%	987,669	2,215,293	3,452,060	1,009,296	2,196,267	3,434,892
10%	1,042,125	2,661,202	3,900,457	1,055,715	2,542,371	3,793,302
15%	1,080,624	3,009,494	4,248,094	1,089,072	2,803,700	4,060,825
20%	1,111,453	3,304,766	4,546,198	1,116,431	3,027,948	4,285,685
25%	1,137,683	3,570,901	4,812,392	1,142,526	3,232,435	4,494,366
30%	1,161,984	3,819,268	5,062,552	1,166,589	3,424,641	4,689,853
35%	1,183,711	4,058,087	5,303,625	1,189,459	3,611,496	4,878,929
40%	1,204,872	4,299,558	5,540,877	1,211,881	3,796,244	5,064,965
45%	1,225,295	4,529,320	5,774,559	1,234,111	3,972,270	5,245,814
50%	1,245,513	4,766,424	6,016,546	1,257,297	4,152,253	5,426,838
55%	1,265,153	5,013,043	6,265,475	1,280,642	4,341,019	5,616,453
60%	1,286,127	5,268,833	6,514,365	1,304,810	4,533,513	5,811,249
65%	1,307,875	5,538,018	6,789,417	1,330,303	4,743,805	6,021,282
70%	1,330,189	5,829,558	7,083,921	1,357,949	4,968,614	6,249,763
75%	1,353,983	6,153,921	7,409,864	1,387,921	5,216,906	6,501,222
80%	1,380,699	6,526,298	7,780,179	1,421,829	5,498,219	6,784,903
85%	1,411,806	6,973,195	8,230,571	1,461,708	5,847,661	7,138,972
90%	1,451,469	7,554,707	8,805,369	1,513,580	6,292,134	7,590,386
95%	1,508,607	8,415,690	9,677,050	1,589,424	6,966,491	8,263,839
99%	1,620,750	10,042,927	11,317,221	1,733,931	8,237,043	9,568,238

Table E.33-Risk profile statistics for highway bridge with modification 1b ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	756,764	1,922,507	808,309	1,869,712	3,120,798
Maximum	1,944,452	32,160,520	33,493,852	2,146,195	27,069,177	28,407,044
Mean	1,247,249	10,382,751	11,629,999	1,272,986	9,353,736	10,626,722
Std Dev	157,243	4,484,671	4,487,658	177,405	3,477,407	3,489,897
Percentile						
1%	909,437	2,332,655	3,576,925	936,836	3,170,503	4,409,842
5%	987,669	3,809,736	5,047,962	1,009,296	4,279,339	5,542,346
10%	1,042,125	4,890,918	6,141,088	1,055,715	5,117,681	6,377,337
15%	1,080,624	5,718,814	6,963,648	1,089,072	5,756,658	7,015,326
20%	1,111,453	6,441,654	7,691,619	1,116,431	6,298,123	7,556,706
25%	1,137,683	7,088,499	8,327,125	1,142,526	6,788,551	8,049,385
30%	1,161,984	7,672,997	8,920,399	1,166,589	7,255,803	8,520,795
35%	1,183,711	8,238,469	9,485,868	1,189,459	7,696,878	8,968,457
40%	1,204,872	8,801,078	10,044,357	1,211,881	8,128,977	9,399,801
45%	1,225,295	9,347,148	10,597,140	1,234,111	8,556,178	9,828,770
50%	1,245,513	9,924,011	11,173,945	1,257,297	8,986,386	10,264,287
55%	1,265,153	10,503,668	11,753,239	1,280,642	9,435,293	10,706,111
60%	1,286,127	11,098,011	12,344,287	1,304,810	9,891,651	11,167,673
65%	1,307,875	11,732,557	12,978,326	1,330,303	10,387,019	11,651,786
70%	1,330,189	12,419,411	13,675,633	1,357,949	10,928,777	12,206,215
75%	1,353,983	13,193,320	14,440,189	1,387,921	11,515,149	12,795,270
80%	1,380,699	14,072,070	15,322,313	1,421,829	12,189,775	13,475,177
85%	1,411,806	15,127,400	16,382,341	1,461,708	13,008,667	14,294,526
90%	1,451,469	16,492,394	17,736,971	1,513,580	14,073,898	15,366,126
95%	1,508,607	18,549,604	19,807,254	1,589,424	15,693,767	16,981,518
99%	1,620,750	22,423,928	23,689,441	1,733,931	18,693,984	20,004,580

Table E.34-Risk profile statistics for highway bridge with modification 1b ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	2,956,087	4,056,992	808,309	2,369,518	3,457,229
Maximum	1,944,452	20,074,314	21,482,889	2,146,195	15,347,922	16,522,568
Mean	1,247,249	8,603,403	9,850,652	1,272,986	6,424,063	7,697,050
Std Dev	157,243	2,197,875	2,206,554	177,405	1,552,791	1,582,961
Percentile						
1%	909,437	4,465,754	5,688,280	936,836	3,528,004	4,718,047
5%	987,669	5,325,220	6,561,403	1,009,296	4,141,612	5,361,785
10%	1,042,125	5,903,678	7,133,710	1,055,715	4,532,428	5,775,661
15%	1,080,624	6,320,163	7,562,988	1,089,072	4,833,873	6,077,302
20%	1,111,453	6,674,350	7,917,585	1,116,431	5,077,816	6,325,406
25%	1,137,683	7,000,415	8,243,200	1,142,526	5,297,420	6,549,117
30%	1,161,984	7,301,874	8,544,355	1,166,589	5,495,509	6,755,573
35%	1,183,711	7,583,302	8,827,404	1,189,459	5,689,813	6,953,574
40%	1,204,872	7,860,236	9,106,642	1,211,881	5,886,554	7,147,287
45%	1,225,295	8,141,292	9,388,161	1,234,111	6,083,077	7,347,974
50%	1,245,513	8,414,048	9,661,366	1,257,297	6,276,841	7,548,467
55%	1,265,153	8,692,930	9,944,880	1,280,642	6,472,007	7,752,317
60%	1,286,127	8,990,510	10,237,146	1,304,810	6,678,784	7,962,711
65%	1,307,875	9,306,283	10,552,908	1,330,303	6,901,675	8,183,808
70%	1,330,189	9,636,301	10,893,225	1,357,949	7,138,812	8,426,128
75%	1,353,983	10,001,446	11,251,306	1,387,921	7,398,173	8,691,476
80%	1,380,699	10,420,380	11,675,233	1,421,829	7,693,722	8,990,889
85%	1,411,806	10,914,810	12,171,993	1,461,708	8,054,170	9,355,328
90%	1,451,469	11,557,559	12,815,032	1,513,580	8,514,851	9,817,797
95%	1,508,607	12,528,913	13,788,656	1,589,424	9,203,966	10,533,982
99%	1,620,750	14,400,405	15,669,517	1,733,931	10,595,308	11,953,431

Table E.35-Risk profile statistics for highway bridge with modification 1b ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	3,076,646	4,204,618	808,309	2,673,399	3,855,475
Maximum	1,944,452	24,921,478	26,254,810	2,146,195	18,878,028	20,315,155
Mean	1,247,249	10,408,001	11,655,250	1,272,986	8,105,089	9,378,075
Std Dev	157,243	2,861,880	2,868,528	177,405	2,093,914	2,118,495
Percentile						
1%	909,437	5,066,257	6,286,805	936,836	4,243,157	5,442,619
5%	987,669	6,182,493	7,417,120	1,009,296	5,044,770	6,279,707
10%	1,042,125	6,901,578	8,144,157	1,055,715	5,569,733	6,814,998
15%	1,080,624	7,444,228	8,690,011	1,089,072	5,950,411	7,197,490
20%	1,111,453	7,897,230	9,137,170	1,116,431	6,276,663	7,529,030
25%	1,137,683	8,309,691	9,554,974	1,142,526	6,569,581	7,828,390
30%	1,161,984	8,695,026	9,936,792	1,166,589	6,848,010	8,109,006
35%	1,183,711	9,063,264	10,309,881	1,189,459	7,113,727	8,378,178
40%	1,204,872	9,419,228	10,663,242	1,211,881	7,372,759	8,641,049
45%	1,225,295	9,784,031	11,031,918	1,234,111	7,630,150	8,901,114
50%	1,245,513	10,148,137	11,394,754	1,257,297	7,897,302	9,163,765
55%	1,265,153	10,518,290	11,764,884	1,280,642	8,167,842	9,443,952
60%	1,286,127	10,902,672	12,145,930	1,304,810	8,448,227	9,726,794
65%	1,307,875	11,308,308	12,558,050	1,330,303	8,741,642	10,025,717
70%	1,330,189	11,749,359	13,000,320	1,357,949	9,058,735	10,342,546
75%	1,353,983	12,233,301	13,486,198	1,387,921	9,413,700	10,699,374
80%	1,380,699	12,772,219	14,029,134	1,421,829	9,819,331	11,108,128
85%	1,411,806	13,427,567	14,682,771	1,461,708	10,306,708	11,602,551
90%	1,451,469	14,262,808	15,518,198	1,513,580	10,935,629	12,238,260
95%	1,508,607	15,543,452	16,804,522	1,589,424	11,871,299	13,172,074
99%	1,620,750	17,958,254	19,205,114	1,733,931	13,746,767	15,085,145

Table E.36-Risk profile statistics for highway bridge with modification 1b ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	792,740	3,210,049	4,507,544	808,309	3,585,043	4,802,214
Maximum	1,944,452	42,645,102	43,978,434	2,146,195	33,331,071	34,668,938
Mean	1,247,249	15,821,795	17,069,044	1,272,986	13,148,166	14,421,152
Std Dev	157,243	5,228,973	5,232,577	177,405	3,974,215	3,990,584
Percentile						
1%	909,437	6,293,168	7,552,040	936,836	6,029,587	7,255,645
5%	987,669	8,204,045	9,446,080	1,009,296	7,390,977	8,638,237
10%	1,042,125	9,477,921	10,718,004	1,055,715	8,333,083	9,592,514
15%	1,080,624	10,416,179	11,665,935	1,089,072	9,060,772	10,319,403
20%	1,111,453	11,221,838	12,473,484	1,116,431	9,668,144	10,929,665
25%	1,137,683	11,959,051	13,204,602	1,142,526	10,217,237	11,471,954
30%	1,161,984	12,648,508	13,886,443	1,166,589	10,726,561	11,993,732
35%	1,183,711	13,313,676	14,563,274	1,189,459	11,245,093	12,514,817
40%	1,204,872	13,971,462	15,219,325	1,211,881	11,736,454	13,005,845
45%	1,225,295	14,609,245	15,858,556	1,234,111	12,230,633	13,503,464
50%	1,245,513	15,260,379	16,518,588	1,257,297	12,715,112	13,986,044
55%	1,265,153	15,966,588	17,205,375	1,280,642	13,221,292	14,498,797
60%	1,286,127	16,668,096	17,907,900	1,304,810	13,761,268	15,038,077
65%	1,307,875	17,407,021	18,657,745	1,330,303	14,334,688	15,610,458
70%	1,330,189	18,220,159	19,472,739	1,357,949	14,942,179	16,221,982
75%	1,353,983	19,095,131	20,360,172	1,387,921	15,615,304	16,896,433
80%	1,380,699	20,120,211	21,370,567	1,421,829	16,394,069	17,673,878
85%	1,411,806	21,373,942	22,624,142	1,461,708	17,327,900	18,625,620
90%	1,451,469	22,929,578	24,176,660	1,513,580	18,542,650	19,832,542
95%	1,508,607	25,330,877	26,572,121	1,589,424	20,373,063	21,663,393
99%	1,620,750	29,798,190	31,072,523	1,733,931	23,891,464	25,186,747

Table E.37-Risk profile statistics for highway bridge with modification 1c ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	90,021	1,057,038	820,832	325,137	1,346,887
Maximum	1,988,814	6,169,989	7,547,683	2,175,264	5,257,288	6,638,284
Mean	1,291,342	1,940,574	3,231,916	1,295,078	1,775,886	3,070,965
Std Dev	157,783	882,656	896,727	178,823	685,605	715,852
Percentile						
1%	946,742	350,983	1,585,684	954,917	552,626	1,745,801
5%	1,030,871	641,569	1,912,979	1,029,034	772,733	2,018,866
10%	1,086,197	858,168	2,132,721	1,075,676	938,675	2,197,421
15%	1,124,870	1,022,892	2,300,815	1,109,911	1,065,372	2,332,322
20%	1,155,805	1,165,884	2,447,112	1,137,403	1,173,812	2,445,790
25%	1,182,038	1,293,179	2,575,751	1,163,647	1,270,432	2,548,447
30%	1,206,346	1,409,749	2,695,035	1,188,233	1,362,892	2,645,096
35%	1,228,071	1,520,568	2,807,344	1,211,133	1,451,651	2,734,997
40%	1,249,234	1,631,253	2,919,021	1,233,824	1,534,851	2,827,337
45%	1,269,657	1,738,344	3,030,411	1,256,285	1,619,499	2,914,519
50%	1,289,875	1,851,573	3,144,289	1,279,594	1,705,154	3,002,168
55%	1,309,515	1,964,694	3,259,534	1,302,895	1,793,216	3,092,654
60%	1,330,489	2,082,071	3,377,163	1,327,225	1,883,209	3,184,976
65%	1,352,237	2,205,917	3,506,818	1,352,962	1,979,547	3,286,203
70%	1,374,551	2,342,544	3,644,110	1,380,727	2,086,393	3,398,030
75%	1,398,345	2,492,286	3,795,477	1,410,791	2,201,981	3,518,405
80%	1,425,061	2,666,429	3,970,430	1,445,178	2,335,023	3,655,060
85%	1,456,167	2,874,579	4,178,526	1,485,037	2,496,929	3,821,233
90%	1,495,831	3,142,691	4,449,280	1,537,367	2,705,669	4,039,021
95%	1,552,969	3,547,200	4,863,566	1,613,720	3,024,648	4,360,704
99%	1,665,112	4,309,443	5,610,983	1,759,239	3,614,423	4,996,673

Table E.38-Risk profile statistics for highway bridge with modification 1c ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	118,709	1,127,898	820,832	601,470	1,666,146
Maximum	1,988,814	12,077,864	13,455,558	2,175,264	10,358,029	11,725,978
Mean	1,291,342	3,745,172	5,036,514	1,295,078	3,456,912	4,751,990
Std Dev	157,783	1,751,880	1,758,975	178,823	1,361,823	1,380,667
Percentile						
1%	946,742	583,335	1,844,264	954,917	1,019,224	2,260,567
5%	1,030,871	1,161,993	2,446,458	1,029,034	1,462,135	2,727,541
10%	1,086,197	1,594,067	2,879,857	1,075,676	1,793,448	3,067,002
15%	1,124,870	1,922,247	3,210,124	1,109,911	2,043,752	3,322,516
20%	1,155,805	2,209,515	3,496,253	1,137,403	2,262,721	3,541,623
25%	1,182,038	2,462,157	3,745,203	1,163,647	2,454,289	3,737,500
30%	1,206,346	2,692,754	3,982,303	1,188,233	2,637,004	3,923,405
35%	1,228,071	2,913,494	4,202,924	1,211,133	2,813,109	4,101,526
40%	1,249,234	3,133,371	4,421,071	1,233,824	2,979,504	4,272,305
45%	1,269,657	3,346,793	4,641,179	1,256,285	3,147,257	4,443,327
50%	1,289,875	3,568,150	4,860,869	1,279,594	3,317,459	4,614,960
55%	1,309,515	3,795,731	5,090,302	1,302,895	3,492,652	4,788,367
60%	1,330,489	4,025,948	5,318,799	1,327,225	3,671,218	4,967,648
65%	1,352,237	4,271,779	5,568,928	1,352,962	3,862,799	5,162,386
70%	1,374,551	4,543,830	5,842,269	1,380,727	4,074,350	5,379,720
75%	1,398,345	4,842,393	6,138,209	1,410,791	4,304,160	5,612,465
80%	1,425,061	5,185,603	6,485,439	1,445,178	4,566,549	5,875,496
85%	1,456,167	5,599,326	6,894,365	1,485,037	4,887,850	6,205,620
90%	1,495,831	6,131,129	7,423,839	1,537,367	5,303,333	6,621,603
95%	1,552,969	6,929,193	8,238,167	1,613,720	5,932,972	7,258,412
99%	1,665,112	8,448,706	9,716,957	1,759,239	7,112,082	8,469,506

Table E.39-Risk profile statistics for highway bridge with modification 1c ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	168,106	1,280,277	820,832	1,406,645	2,551,759
Maximum	1,988,814	29,801,489	31,179,182	2,175,264	25,660,251	27,028,200
Mean	1,291,342	9,158,966	10,450,307	1,295,078	8,499,989	9,795,067
Std Dev	157,783	4,360,248	4,363,059	178,823	3,390,877	3,402,587
Percentile						
1%	946,742	1,277,851	2,556,902	954,917	2,425,776	3,692,704
5%	1,030,871	2,722,589	4,017,917	1,029,034	3,526,149	4,803,446
10%	1,086,197	3,801,069	5,089,534	1,075,676	4,356,068	5,641,623
15%	1,124,870	4,622,680	5,916,341	1,109,911	4,983,611	6,266,690
20%	1,155,805	5,336,871	6,621,733	1,137,403	5,527,492	6,810,291
25%	1,182,038	5,971,690	7,259,569	1,163,647	6,004,540	7,292,072
30%	1,206,346	6,542,224	7,833,543	1,188,233	6,458,996	7,749,927
35%	1,228,071	7,092,901	8,381,338	1,211,133	6,896,524	8,184,663
40%	1,249,234	7,640,337	8,925,499	1,233,824	7,313,531	8,609,767
45%	1,269,657	8,175,023	9,463,882	1,256,285	7,733,883	9,026,088
50%	1,289,875	8,722,896	10,018,926	1,279,594	8,154,275	9,451,970
55%	1,309,515	9,286,985	10,579,824	1,302,895	8,592,671	9,883,424
60%	1,330,489	9,856,682	11,152,287	1,327,225	9,036,346	10,331,755
65%	1,352,237	10,468,818	11,765,907	1,352,962	9,510,853	10,800,847
70%	1,374,551	11,145,870	12,446,830	1,380,727	10,036,815	11,337,430
75%	1,398,345	11,891,578	13,184,488	1,410,791	10,610,228	11,915,070
80%	1,425,061	12,744,660	14,038,468	1,445,178	11,262,566	12,562,123
85%	1,456,167	13,772,002	15,062,112	1,485,037	12,065,175	13,372,390
90%	1,495,831	15,092,570	16,384,215	1,537,367	13,096,259	14,406,561
95%	1,552,969	17,076,288	18,373,942	1,613,720	14,665,803	15,976,713
99%	1,665,112	20,850,612	22,120,743	1,759,239	17,599,181	18,917,288

Table E.40-Risk profile statistics for highway bridge with modification 1c ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	642,010	1,859,999	820,832	717,009	1,803,855
Maximum	1,988,814	8,529,020	9,906,714	2,175,264	6,666,214	8,126,982
Mean	1,291,342	3,164,359	4,455,701	1,295,078	2,629,633	3,924,711
Std Dev	157,783	1,045,795	1,058,860	178,823	794,843	827,201
Percentile						
1%	946,742	1,258,634	2,507,562	954,917	1,205,917	2,398,216
5%	1,030,871	1,640,809	2,907,369	1,029,034	1,478,195	2,716,902
10%	1,086,197	1,895,584	3,169,983	1,075,676	1,666,617	2,923,058
15%	1,124,870	2,083,236	3,363,757	1,109,911	1,812,154	3,075,791
20%	1,155,805	2,244,368	3,530,098	1,137,403	1,933,629	3,201,837
25%	1,182,038	2,391,810	3,677,419	1,163,647	2,043,447	3,322,534
30%	1,206,346	2,529,702	3,814,634	1,188,233	2,145,312	3,430,741
35%	1,228,071	2,662,735	3,950,409	1,211,133	2,249,019	3,534,794
40%	1,249,234	2,794,292	4,081,824	1,233,824	2,347,291	3,636,882
45%	1,269,657	2,921,849	4,212,503	1,256,285	2,446,127	3,740,225
50%	1,289,875	3,052,076	4,347,345	1,279,594	2,543,022	3,839,435
55%	1,309,515	3,193,318	4,486,837	1,302,895	2,644,258	3,944,798
60%	1,330,489	3,333,619	4,625,464	1,327,225	2,752,254	4,057,328
65%	1,352,237	3,481,404	4,778,885	1,352,962	2,866,938	4,174,030
70%	1,374,551	3,644,032	4,944,769	1,380,727	2,988,436	4,300,239
75%	1,398,345	3,819,026	5,125,306	1,410,791	3,123,061	4,440,633
80%	1,425,061	4,024,042	5,331,266	1,445,178	3,278,814	4,597,684
85%	1,456,167	4,274,788	5,575,650	1,485,037	3,465,580	4,793,863
90%	1,495,831	4,585,916	5,894,908	1,537,367	3,708,530	5,044,774
95%	1,552,969	5,066,175	6,371,813	1,613,720	4,074,613	5,413,902
99%	1,665,112	5,959,638	7,281,621	1,759,239	4,778,293	6,151,815

Table E.41-Risk profile statistics for highway bridge with modification 1c ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	670,698	1,890,569	820,832	1,020,890	2,202,102
Maximum	1,988,814	14,436,895	15,814,589	2,175,264	11,766,955	13,134,904
Mean	1,291,342	4,968,957	6,260,299	1,295,078	4,310,659	5,605,737
Std Dev	157,783	1,892,132	1,899,350	178,823	1,457,543	1,478,583
Percentile						
1%	946,742	1,575,032	2,831,220	954,917	1,724,391	2,954,293
5%	1,030,871	2,215,293	3,496,239	1,029,034	2,196,267	3,456,757
10%	1,086,197	2,661,202	3,944,335	1,075,676	2,542,371	3,814,910
15%	1,124,870	3,009,494	4,292,279	1,109,911	2,803,700	4,082,602
20%	1,155,805	3,304,766	4,590,224	1,137,403	3,027,948	4,308,008
25%	1,182,038	3,570,901	4,856,534	1,163,647	3,232,435	4,515,833
30%	1,206,346	3,819,268	5,106,629	1,188,233	3,424,641	4,711,487
35%	1,228,071	4,058,087	5,347,666	1,211,133	3,611,496	4,901,307
40%	1,249,234	4,299,558	5,585,050	1,233,824	3,796,244	5,086,737
45%	1,269,657	4,529,320	5,818,309	1,256,285	3,972,270	5,267,416
50%	1,289,875	4,766,424	6,060,767	1,279,594	4,152,253	5,448,911
55%	1,309,515	5,013,043	6,309,406	1,302,895	4,341,019	5,638,243
60%	1,330,489	5,268,833	6,558,167	1,327,225	4,533,513	5,833,585
65%	1,352,237	5,538,018	6,833,638	1,352,962	4,743,805	6,042,890
70%	1,374,551	5,829,558	7,128,046	1,380,727	4,968,614	6,272,104
75%	1,398,345	6,153,921	7,454,203	1,410,791	5,216,906	6,523,581
80%	1,425,061	6,526,298	7,824,306	1,445,178	5,498,219	6,807,238
85%	1,456,167	6,973,195	8,274,240	1,485,037	5,847,661	7,162,081
90%	1,495,831	7,554,707	8,849,665	1,537,367	6,292,134	7,613,500
95%	1,552,969	8,415,690	9,721,412	1,613,720	6,966,491	8,286,659
99%	1,665,112	10,042,927	11,361,583	1,759,239	8,237,043	9,593,199

Table E.42-Risk profile statistics for highway bridge with modification 1c ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	756,764	1,966,869	820,832	1,869,712	3,146,649
Maximum	1,988,814	32,160,520	33,538,214	2,175,264	27,069,177	28,437,126
Mean	1,291,342	10,382,751	11,674,092	1,295,078	9,353,736	10,648,814
Std Dev	157,783	4,484,671	4,487,678	178,823	3,477,407	3,490,273
Percentile						
1%	946,742	2,332,655	3,621,285	954,917	3,170,503	4,430,248
5%	1,030,871	3,809,736	5,092,324	1,029,034	4,279,339	5,563,711
10%	1,086,197	4,890,918	6,184,438	1,075,676	5,117,681	6,399,857
15%	1,124,870	5,718,814	7,007,855	1,109,911	5,756,658	7,037,210
20%	1,155,805	6,441,654	7,735,778	1,137,403	6,298,123	7,578,745
25%	1,182,038	7,088,499	8,371,487	1,163,647	6,788,551	8,071,874
30%	1,206,346	7,672,997	8,963,807	1,188,233	7,255,803	8,542,870
35%	1,228,071	8,238,469	9,530,010	1,211,133	7,696,878	8,990,566
40%	1,249,234	8,801,078	10,088,478	1,233,824	8,128,977	9,421,400
45%	1,269,657	9,347,148	10,641,280	1,256,285	8,556,178	9,850,512
50%	1,289,875	9,924,011	11,217,999	1,279,594	8,986,386	10,286,124
55%	1,309,515	10,503,668	11,797,323	1,302,895	9,435,293	10,727,480
60%	1,330,489	11,098,011	12,388,287	1,327,225	9,891,651	11,189,932
65%	1,352,237	11,732,557	13,022,281	1,352,962	10,387,019	11,674,745
70%	1,374,551	12,419,411	13,719,943	1,380,727	10,928,777	12,227,600
75%	1,398,345	13,193,320	14,484,309	1,410,791	11,515,149	12,818,244
80%	1,425,061	14,072,070	15,366,352	1,445,178	12,189,775	13,498,272
85%	1,456,167	15,127,400	16,426,703	1,485,037	13,008,667	14,316,935
90%	1,495,831	16,492,394	17,781,333	1,537,367	14,073,898	15,389,437
95%	1,552,969	18,549,604	19,850,531	1,613,720	15,693,767	17,004,943
99%	1,665,112	22,423,928	23,733,803	1,759,239	18,693,984	20,028,870

Table E.43-Risk profile statistics for highway bridge with modification 1c ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	2,956,087	4,101,354	820,832	2,369,518	3,471,277
Maximum	1,988,814	20,074,314	21,527,251	2,175,264	15,347,922	16,548,204
Mean	1,291,342	8,603,403	9,894,745	1,295,078	6,424,063	7,719,142
Std Dev	157,783	2,197,875	2,206,598	178,823	1,552,791	1,583,830
Percentile						
1%	946,742	4,465,754	5,732,012	954,917	3,528,004	4,737,391
5%	1,030,871	5,325,220	6,605,574	1,029,034	4,141,612	5,382,376
10%	1,086,197	5,903,678	7,178,037	1,075,676	4,532,428	5,796,507
15%	1,124,870	6,320,163	7,607,186	1,109,911	4,833,873	6,097,980
20%	1,155,805	6,674,350	7,961,542	1,137,403	5,077,816	6,347,469
25%	1,182,038	7,000,415	8,287,333	1,163,647	5,297,420	6,570,583
30%	1,206,346	7,301,874	8,588,303	1,188,233	5,495,509	6,777,137
35%	1,228,071	7,583,302	8,871,460	1,211,133	5,689,813	6,975,470
40%	1,249,234	7,860,236	9,150,814	1,233,824	5,886,554	7,168,897
45%	1,269,657	8,141,292	9,432,269	1,256,285	6,083,077	7,370,406
50%	1,289,875	8,414,048	9,705,333	1,279,594	6,276,841	7,570,280
55%	1,309,515	8,692,930	9,988,915	1,302,895	6,472,007	7,774,778
60%	1,330,489	8,990,510	10,281,413	1,327,225	6,678,784	7,985,217
65%	1,352,237	9,306,283	10,597,250	1,352,962	6,901,675	8,206,133
70%	1,374,551	9,636,301	10,937,451	1,380,727	7,138,812	8,448,637
75%	1,398,345	10,001,446	11,295,590	1,410,791	7,398,173	8,713,562
80%	1,425,061	10,420,380	11,719,341	1,445,178	7,693,722	9,014,007
85%	1,456,167	10,914,810	12,215,967	1,485,037	8,054,170	9,377,907
90%	1,495,831	11,557,559	12,859,332	1,537,367	8,514,851	9,840,899
95%	1,552,969	12,528,913	13,833,018	1,613,720	9,203,966	10,558,396
99%	1,665,112	14,400,405	15,713,879	1,759,239	10,595,308	11,976,158

Table E.44-Risk profile statistics for highway bridge with modification 1c ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	3,076,646	4,248,980	820,832	2,673,399	3,869,523
Maximum	1,988,814	24,921,478	26,299,172	2,175,264	18,878,028	20,341,791
Mean	1,291,342	10,408,001	11,699,343	1,295,078	8,105,089	9,400,167
Std Dev	157,783	2,861,880	2,868,563	178,823	2,093,914	2,119,227
Percentile						
1%	946,742	5,066,257	6,331,167	954,917	4,243,157	5,462,112
5%	1,030,871	6,182,493	7,461,353	1,029,034	5,044,770	6,301,477
10%	1,086,197	6,901,578	8,188,123	1,075,676	5,569,733	6,836,353
15%	1,124,870	7,444,228	8,734,291	1,109,911	5,950,411	7,218,665
20%	1,155,805	7,897,230	9,181,436	1,137,403	6,276,663	7,550,531
25%	1,182,038	8,309,691	9,599,241	1,163,647	6,569,581	7,849,555
30%	1,206,346	8,695,026	9,980,860	1,188,233	6,848,010	8,130,528
35%	1,228,071	9,063,264	10,353,981	1,211,133	7,113,727	8,400,270
40%	1,249,234	9,419,228	10,707,014	1,233,824	7,372,759	8,662,728
45%	1,269,657	9,784,031	11,076,060	1,256,285	7,630,150	8,922,738
50%	1,289,875	10,148,137	11,438,789	1,279,594	7,897,302	9,185,496
55%	1,309,515	10,518,290	11,808,915	1,302,895	8,167,842	9,466,429
60%	1,330,489	10,902,672	12,190,087	1,327,225	8,448,227	9,748,765
65%	1,352,237	11,308,308	12,602,174	1,352,962	8,741,642	10,048,131
70%	1,374,551	11,749,359	13,044,642	1,380,727	9,058,735	10,365,269
75%	1,398,345	12,233,301	13,530,347	1,410,791	9,413,700	10,721,869
80%	1,425,061	12,772,219	14,073,130	1,445,178	9,819,331	11,130,095
85%	1,456,167	13,427,567	14,726,770	1,485,037	10,306,708	11,625,800
90%	1,495,831	14,262,808	15,562,413	1,537,367	10,935,629	12,261,350
95%	1,552,969	15,543,452	16,848,884	1,613,720	11,871,299	13,196,738
99%	1,665,112	17,958,254	19,249,476	1,759,239	13,746,767	15,110,538

Table E.45-Risk profile statistics for highway bridge with modification 1c ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	3,210,049	4,551,906	820,832	3,585,043	4,826,513
Maximum	1,988,814	42,645,102	44,022,796	2,175,264	33,331,071	34,699,020
Mean	1,291,342	15,821,795	17,113,137	1,295,078	13,148,166	14,443,244
Std Dev	157,783	5,228,973	5,232,596	178,823	3,974,215	3,991,103
Percentile						
1%	946,742	6,293,168	7,596,402	954,917	6,029,587	7,275,770
5%	1,030,871	8,204,045	9,490,363	1,029,034	7,390,977	8,660,948
10%	1,086,197	9,477,921	10,761,943	1,075,676	8,333,083	9,614,395
15%	1,124,870	10,416,179	11,710,083	1,109,911	9,060,772	10,341,102
20%	1,155,805	11,221,838	12,517,810	1,137,403	9,668,144	10,951,397
25%	1,182,038	11,959,051	13,248,875	1,163,647	10,217,237	11,493,244
30%	1,206,346	12,648,508	13,930,734	1,188,233	10,726,561	12,016,120
35%	1,228,071	13,313,676	14,607,583	1,211,133	11,245,093	12,536,832
40%	1,249,234	13,971,462	15,263,454	1,233,824	11,736,454	13,028,016
45%	1,269,657	14,609,245	15,902,713	1,256,285	12,230,633	13,525,430
50%	1,289,875	15,260,379	16,562,773	1,279,594	12,715,112	14,008,419
55%	1,309,515	15,966,588	17,249,557	1,302,895	13,221,292	14,521,019
60%	1,330,489	16,668,096	17,952,135	1,327,225	13,761,268	15,060,416
65%	1,352,237	17,407,021	18,701,019	1,352,962	14,334,688	15,632,730
70%	1,374,551	18,220,159	19,516,179	1,380,727	14,942,179	16,244,051
75%	1,398,345	19,095,131	20,404,441	1,410,791	15,615,304	16,918,755
80%	1,425,061	20,120,211	21,414,903	1,445,178	16,394,069	17,696,684
85%	1,456,167	21,373,942	22,668,504	1,485,037	17,327,900	18,648,662
90%	1,495,831	22,929,578	24,221,022	1,537,367	18,542,650	19,855,043
95%	1,552,969	25,330,877	26,616,483	1,613,720	20,373,063	21,688,611
99%	1,665,112	29,798,190	31,116,885	1,759,239	23,891,464	25,211,166

Table E.46-Risk profile statistics for highway bridge with modification 2a ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	78,929	947,298	794,935	308,443	1,266,557
Maximum	1,900,008	4,013,285	5,302,172	2,117,072	3,548,792	5,036,640
Mean	1,203,146	1,358,661	2,561,807	1,250,889	1,334,318	2,585,208
Std Dev	156,583	577,938	598,904	175,993	452,048	492,168
Percentile						
1%	872,316	261,977	1,392,932	918,427	485,859	1,618,019
5%	945,174	472,674	1,645,864	989,862	648,989	1,837,408
10%	998,059	629,667	1,809,847	1,035,656	768,321	1,972,804
15%	1,036,328	748,818	1,932,876	1,068,262	860,266	2,073,249
20%	1,067,022	852,220	2,037,376	1,095,750	936,865	2,156,322
25%	1,093,240	941,210	2,131,090	1,121,263	1,005,739	2,231,343
30%	1,117,539	1,022,089	2,216,285	1,145,099	1,069,283	2,299,095
35%	1,139,266	1,098,332	2,293,653	1,167,704	1,128,227	2,364,896
40%	1,160,427	1,171,362	2,370,300	1,190,012	1,187,023	2,428,110
45%	1,180,850	1,244,661	2,446,054	1,211,954	1,243,136	2,489,544
50%	1,201,069	1,317,547	2,520,764	1,235,173	1,300,025	2,551,265
55%	1,220,708	1,392,337	2,598,577	1,258,333	1,357,844	2,612,884
60%	1,241,683	1,467,604	2,678,055	1,282,448	1,417,563	2,677,571
65%	1,263,431	1,548,091	2,763,264	1,307,817	1,479,832	2,745,756
70%	1,285,744	1,633,231	2,850,811	1,335,014	1,548,391	2,821,069
75%	1,309,538	1,729,559	2,948,178	1,364,839	1,622,169	2,901,393
80%	1,336,254	1,838,976	3,059,368	1,398,495	1,706,325	2,991,553
85%	1,367,361	1,970,768	3,191,833	1,438,184	1,808,990	3,101,294
90%	1,407,025	2,136,337	3,363,370	1,489,869	1,941,792	3,242,103
95%	1,464,162	2,384,873	3,622,426	1,564,673	2,138,970	3,454,572
99%	1,576,306	2,853,280	4,091,705	1,708,231	2,511,545	3,861,963

Table E.47-Risk profile statistics for highway bridge with modification 2a ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	93,699	996,612	794,935	574,198	1,580,217
Maximum	1,900,008	7,850,761	9,139,649	2,117,072	6,987,992	8,295,721
Mean	1,203,146	2,617,010	3,820,155	1,250,889	2,596,623	3,847,513
Std Dev	156,583	1,149,925	1,160,561	175,993	899,595	923,728
Percentile						
1%	872,316	428,422	1,595,336	918,427	904,490	2,083,492
5%	945,174	851,953	2,039,030	989,862	1,228,602	2,448,758
10%	998,059	1,165,065	2,356,813	1,035,656	1,469,091	2,694,551
15%	1,036,328	1,403,188	2,597,595	1,068,262	1,651,544	2,880,138
20%	1,067,022	1,608,701	2,802,715	1,095,750	1,806,441	3,037,396
25%	1,093,240	1,786,369	2,979,540	1,121,263	1,943,131	3,176,100
30%	1,117,539	1,947,864	3,145,646	1,145,099	2,070,158	3,306,736
35%	1,139,266	2,099,051	3,297,193	1,167,704	2,187,387	3,431,290
40%	1,160,427	2,245,376	3,446,931	1,190,012	2,304,252	3,549,244
45%	1,180,850	2,391,613	3,592,530	1,211,954	2,415,714	3,665,446
50%	1,201,069	2,535,767	3,742,340	1,235,173	2,529,916	3,780,947
55%	1,220,708	2,685,491	3,889,029	1,258,333	2,644,545	3,896,948
60%	1,241,683	2,834,506	4,041,828	1,282,448	2,763,770	4,016,765
65%	1,263,431	2,995,066	4,204,204	1,307,817	2,887,609	4,145,702
70%	1,285,744	3,164,060	4,377,165	1,335,014	3,023,509	4,286,017
75%	1,309,538	3,356,654	4,565,553	1,364,839	3,170,657	4,436,727
80%	1,336,254	3,573,650	4,785,636	1,398,495	3,338,024	4,610,565
85%	1,367,361	3,835,396	5,043,901	1,438,184	3,541,683	4,817,411
90%	1,407,025	4,164,547	5,377,835	1,489,869	3,804,843	5,084,132
95%	1,464,162	4,657,696	5,885,563	1,564,673	4,195,282	5,483,292
99%	1,576,306	5,588,238	6,797,995	1,708,231	4,937,064	6,257,491

Table E.48-Risk profile statistics for highway bridge with modification 2a ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	127,832	1,106,136	794,935	1,362,788	2,423,998
Maximum	1,900,008	19,363,191	20,652,078	2,117,072	17,305,593	18,613,322
Mean	1,203,146	6,392,055	7,595,201	1,250,889	6,383,538	7,634,428
Std Dev	156,583	2,866,321	2,870,551	175,993	2,242,491	2,256,353
Percentile						
1%	872,316	931,314	2,121,850	918,427	2,156,779	3,372,918
5%	945,174	1,987,056	3,183,571	989,862	2,970,341	4,209,945
10%	998,059	2,770,779	3,968,177	1,035,656	3,570,107	4,811,132
15%	1,036,328	3,364,531	4,561,987	1,068,262	4,026,508	5,261,986
20%	1,067,022	3,878,149	5,079,627	1,095,750	4,415,080	5,654,378
25%	1,093,240	4,322,657	5,521,978	1,121,263	4,755,257	5,995,492
30%	1,117,539	4,727,902	5,927,093	1,145,099	5,072,593	6,313,335
35%	1,139,266	5,102,957	6,305,448	1,167,704	5,365,653	6,612,681
40%	1,160,427	5,469,052	6,671,127	1,190,012	5,655,828	6,900,945
45%	1,180,850	5,831,555	7,029,583	1,211,954	5,932,879	7,185,343
50%	1,201,069	6,192,154	7,399,711	1,235,173	6,218,148	7,466,519
55%	1,220,708	6,562,405	7,767,329	1,258,333	6,503,052	7,756,319
60%	1,241,683	6,938,132	8,144,058	1,282,448	6,803,099	8,053,670
65%	1,263,431	7,336,844	8,542,293	1,307,817	7,109,635	8,361,248
70%	1,285,744	7,758,321	8,966,373	1,335,014	7,450,525	8,703,402
75%	1,309,538	8,234,989	9,440,388	1,364,839	7,817,292	9,075,595
80%	1,336,254	8,776,426	9,977,918	1,398,495	8,233,411	9,497,210
85%	1,367,361	9,427,539	10,631,162	1,438,184	8,742,049	10,009,568
90%	1,407,025	10,247,078	11,451,055	1,489,869	9,395,896	10,662,232
95%	1,464,162	11,474,267	12,686,019	1,564,673	10,368,572	11,645,882
99%	1,576,306	13,796,289	14,980,815	1,708,231	12,210,960	13,494,017

Table E.49-Risk profile statistics for highway bridge with modification 2a ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	591,932	1,645,830	794,935	680,311	1,691,693
Maximum	1,900,008	5,595,559	6,884,446	2,117,072	4,535,112	6,082,972
Mean	1,203,146	2,261,471	3,464,617	1,250,889	1,982,437	3,233,326
Std Dev	156,583	658,796	678,975	175,993	508,788	551,225
Percentile						
1%	872,316	1,011,792	2,145,779	918,427	1,031,280	2,160,910
5%	945,174	1,275,507	2,444,803	989,862	1,225,076	2,404,449
10%	998,059	1,449,534	2,626,876	1,035,656	1,356,587	2,555,311
15%	1,036,328	1,579,467	2,763,187	1,068,262	1,456,067	2,665,687
20%	1,067,022	1,685,442	2,874,459	1,095,750	1,538,574	2,756,919
25%	1,093,240	1,783,393	2,974,682	1,121,263	1,612,976	2,837,548
30%	1,117,539	1,872,561	3,067,339	1,145,099	1,682,479	2,912,694
35%	1,139,266	1,957,845	3,155,712	1,167,704	1,747,383	2,984,257
40%	1,160,427	2,040,489	3,240,682	1,190,012	1,810,594	3,053,171
45%	1,180,850	2,122,831	3,323,459	1,211,954	1,873,931	3,120,595
50%	1,201,069	2,205,228	3,407,754	1,235,173	1,937,428	3,189,360
55%	1,220,708	2,289,561	3,495,902	1,258,333	2,002,135	3,258,603
60%	1,241,683	2,376,193	3,587,877	1,282,448	2,069,687	3,332,473
65%	1,263,431	2,467,183	3,680,150	1,307,817	2,141,025	3,409,548
70%	1,285,744	2,568,752	3,782,320	1,335,014	2,217,962	3,491,612
75%	1,309,538	2,678,705	3,898,536	1,364,839	2,300,897	3,582,814
80%	1,336,254	2,803,672	4,026,034	1,398,495	2,398,717	3,685,089
85%	1,367,361	2,956,200	4,180,645	1,438,184	2,515,533	3,806,113
90%	1,407,025	3,150,282	4,375,524	1,489,869	2,665,896	3,970,574
95%	1,464,162	3,444,807	4,675,107	1,564,673	2,893,255	4,209,203
99%	1,576,306	3,997,146	5,230,090	1,708,231	3,336,851	4,690,465

Table E.50-Risk profile statistics for highway bridge with modification 2a ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	617,723	1,667,198	794,935	958,389	2,038,505
Maximum	1,900,008	9,433,035	10,721,923	2,117,072	7,974,312	9,282,041
Mean	1,203,146	3,519,820	4,722,966	1,250,889	3,244,742	4,495,631
Std Dev	156,583	1,215,739	1,226,750	175,993	947,355	973,953
Percentile						
1%	872,316	1,227,084	2,388,647	918,427	1,481,922	2,647,706
5%	945,174	1,681,946	2,869,886	989,862	1,822,530	3,032,949
10%	998,059	2,003,840	3,194,434	1,035,656	2,068,448	3,292,334
15%	1,036,328	2,247,618	3,440,470	1,068,262	2,257,300	3,483,757
20%	1,067,022	2,455,670	3,650,015	1,095,750	2,413,619	3,644,902
25%	1,093,240	2,638,628	3,833,175	1,121,263	2,554,964	3,788,890
30%	1,117,539	2,803,918	4,000,930	1,145,099	2,686,522	3,923,743
35%	1,139,266	2,966,042	4,164,299	1,167,704	2,810,571	4,051,062
40%	1,160,427	3,117,576	4,317,359	1,190,012	2,929,765	4,175,782
45%	1,180,850	3,269,144	4,471,299	1,211,954	3,046,115	4,296,112
50%	1,201,069	3,423,759	4,628,057	1,235,173	3,166,428	4,418,473
55%	1,220,708	3,580,718	4,785,604	1,258,333	3,285,900	4,540,559
60%	1,241,683	3,740,491	4,948,581	1,282,448	3,414,276	4,667,961
65%	1,263,431	3,905,221	5,114,652	1,307,817	3,545,498	4,801,995
70%	1,285,744	4,089,894	5,301,693	1,335,014	3,688,401	4,951,699
75%	1,309,538	4,293,857	5,504,046	1,364,839	3,845,388	5,112,124
80%	1,336,254	4,526,845	5,737,546	1,398,495	4,021,378	5,295,278
85%	1,367,361	4,806,389	6,016,458	1,438,184	4,238,889	5,515,474
90%	1,407,025	5,159,980	6,375,001	1,489,869	4,517,643	5,802,530
95%	1,464,162	5,691,958	6,917,776	1,564,673	4,937,199	6,225,451
99%	1,576,306	6,697,402	7,913,117	1,708,231	5,735,306	7,053,316

Table E.51-Risk profile statistics for highway bridge with modification 2a ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	689,015	1,727,365	794,935	1,755,654	2,914,370
Maximum	1,900,008	20,945,465	22,234,352	2,117,072	18,291,914	19,599,643
Mean	1,203,146	7,294,866	8,498,011	1,250,889	7,031,657	8,282,546
Std Dev	156,583	2,922,082	2,926,628	175,993	2,284,306	2,299,460
Percentile						
1%	872,316	1,774,381	2,960,301	918,427	2,760,500	3,975,836
5%	945,174	2,830,968	4,031,496	989,862	3,577,956	4,806,718
10%	998,059	3,616,066	4,814,580	1,035,656	4,176,818	5,419,030
15%	1,036,328	4,213,265	5,417,741	1,068,262	4,640,209	5,872,341
20%	1,067,022	4,733,439	5,933,829	1,095,750	5,023,088	6,264,472
25%	1,093,240	5,182,274	6,381,843	1,121,263	5,372,103	6,612,031
30%	1,117,539	5,589,822	6,787,648	1,145,099	5,691,357	6,934,756
35%	1,139,266	5,969,555	7,168,779	1,167,704	5,986,215	7,235,869
40%	1,160,427	6,340,356	7,542,375	1,190,012	6,281,710	7,530,557
45%	1,180,850	6,706,647	7,910,595	1,211,954	6,564,454	7,817,174
50%	1,201,069	7,080,610	8,285,787	1,235,173	6,850,362	8,103,062
55%	1,220,708	7,456,941	8,664,908	1,258,333	7,145,440	8,397,260
60%	1,241,683	7,840,403	9,044,836	1,282,448	7,448,397	8,700,039
65%	1,263,431	8,243,085	9,448,031	1,307,817	7,763,326	9,018,111
70%	1,285,744	8,675,817	9,886,925	1,335,014	8,107,913	9,365,331
75%	1,309,538	9,160,396	10,371,135	1,364,839	8,486,121	9,741,198
80%	1,336,254	9,722,103	10,927,413	1,398,495	8,912,855	10,176,400
85%	1,367,361	10,388,192	11,592,602	1,438,184	9,428,254	10,699,207
90%	1,407,025	11,227,889	12,433,323	1,489,869	10,097,358	11,364,721
95%	1,464,162	12,497,744	13,717,234	1,564,673	11,103,441	12,379,651
99%	1,576,306	14,883,292	16,084,446	1,708,231	12,997,375	14,289,184

Table E.52-Risk profile statistics for highway bridge with modification 2a ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	2,683,260	3,641,301	794,935	2,215,176	3,187,943
Maximum	1,900,008	13,297,485	14,661,615	2,117,072	10,527,202	11,676,164
Mean	1,203,146	6,273,960	7,477,106	1,250,889	4,862,963	6,113,852
Std Dev	156,583	1,325,011	1,339,015	175,993	955,762	995,000
Percentile						
1%	872,316	3,772,649	4,937,529	918,427	3,067,367	4,210,830
5%	945,174	4,325,386	5,503,095	989,862	3,468,170	4,651,042
10%	998,059	4,670,818	5,849,353	1,035,656	3,714,345	4,917,004
15%	1,036,328	4,914,601	6,106,747	1,068,262	3,888,640	5,104,559
20%	1,067,022	5,126,754	6,319,045	1,095,750	4,040,107	5,259,300
25%	1,093,240	5,312,452	6,509,507	1,121,263	4,171,958	5,395,225
30%	1,117,539	5,490,793	6,685,807	1,145,099	4,295,208	5,525,402
35%	1,139,266	5,655,838	6,853,213	1,167,704	4,415,210	5,651,208
40%	1,160,427	5,817,094	7,020,279	1,190,012	4,531,751	5,774,476
45%	1,180,850	5,981,392	7,182,528	1,211,954	4,648,460	5,895,958
50%	1,201,069	6,143,859	7,349,778	1,235,173	4,765,756	6,019,770
55%	1,220,708	6,313,024	7,521,566	1,258,333	4,888,622	6,143,513
60%	1,241,683	6,490,961	7,697,628	1,282,448	5,015,442	6,278,535
65%	1,263,431	6,676,561	7,885,659	1,307,817	5,146,277	6,416,444
70%	1,285,744	6,883,594	8,090,756	1,335,014	5,295,229	6,568,445
75%	1,309,538	7,106,324	8,319,817	1,364,839	5,455,335	6,731,643
80%	1,336,254	7,360,158	8,578,569	1,398,495	5,639,248	6,920,051
85%	1,367,361	7,660,263	8,877,871	1,438,184	5,854,938	7,147,491
90%	1,407,025	8,052,656	9,271,903	1,489,869	6,148,712	7,440,558
95%	1,464,162	8,654,708	9,887,205	1,564,673	6,580,837	7,899,457
99%	1,576,306	9,821,619	11,059,651	1,708,231	7,469,647	8,820,397

Table E.53-Risk profile statistics for highway bridge with modification 2a ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	2,882,282	3,981,174	794,935	2,511,771	3,561,870
Maximum	1,900,008	16,465,364	17,754,251	2,117,072	12,919,265	14,224,469
Mean	1,203,146	7,532,309	8,735,455	1,250,889	6,125,268	7,376,157
Std Dev	156,583	1,745,619	1,756,244	175,993	1,304,546	1,335,853
Percentile						
1%	872,316	4,211,796	5,376,057	918,427	3,661,849	4,826,061
5%	945,174	4,945,512	6,132,513	989,862	4,206,371	5,403,833
10%	998,059	5,410,309	6,598,361	1,035,656	4,543,188	5,755,155
15%	1,036,328	5,740,546	6,934,480	1,068,262	4,789,982	6,005,385
20%	1,067,022	6,018,517	7,216,084	1,095,750	4,996,143	6,224,894
25%	1,093,240	6,271,119	7,467,426	1,121,263	5,184,207	6,416,447
30%	1,117,539	6,500,630	7,700,067	1,145,099	5,356,898	6,591,748
35%	1,139,266	6,723,971	7,922,764	1,167,704	5,517,149	6,760,363
40%	1,160,427	6,941,171	8,140,033	1,190,012	5,679,853	6,925,475
45%	1,180,850	7,154,030	8,357,918	1,211,954	5,840,125	7,089,758
50%	1,201,069	7,368,758	8,571,434	1,235,173	6,003,326	7,253,950
55%	1,220,708	7,592,289	8,798,434	1,258,333	6,170,856	7,421,067
60%	1,241,683	7,825,854	9,029,353	1,282,448	6,337,773	7,599,175
65%	1,263,431	8,073,028	9,278,372	1,307,817	6,518,057	7,785,477
70%	1,285,744	8,340,592	9,553,873	1,335,014	6,715,764	7,986,207
75%	1,309,538	8,637,039	9,847,477	1,364,839	6,937,390	8,207,361
80%	1,336,254	8,963,984	10,175,960	1,398,495	7,186,157	8,459,705
85%	1,367,361	9,367,750	10,580,217	1,438,184	7,487,156	8,768,431
90%	1,407,025	9,871,275	11,091,890	1,489,869	7,877,563	9,165,014
95%	1,464,162	10,666,711	11,878,283	1,564,673	8,460,748	9,763,995
99%	1,576,306	12,156,586	13,384,190	1,708,231	9,639,339	10,967,749

Table E.54-Risk profile statistics for highway bridge with modification 2a ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	760,300	2,959,658	4,082,313	794,935	3,401,555	4,594,381
Maximum	1,900,008	27,977,793	29,266,681	2,117,072	22,675,560	23,983,289
Mean	1,203,146	11,307,355	12,510,501	1,250,889	9,912,183	11,163,072
Std Dev	156,583	3,293,978	3,299,575	175,993	2,543,942	2,563,720
Percentile						
1%	872,316	5,058,960	6,244,660	918,427	5,156,399	6,362,468
5%	945,174	6,377,537	7,572,868	989,862	6,125,381	7,345,824
10%	998,059	7,247,668	8,441,689	1,035,656	6,782,936	8,015,469
15%	1,036,328	7,897,333	9,097,458	1,068,262	7,280,337	8,519,744
20%	1,067,022	8,427,211	9,627,570	1,095,750	7,692,870	8,924,156
25%	1,093,240	8,916,963	10,114,409	1,121,263	8,064,880	9,301,287
30%	1,117,539	9,362,805	10,563,822	1,145,099	8,412,394	9,655,007
35%	1,139,266	9,789,223	10,989,508	1,167,704	8,736,917	9,983,418
40%	1,160,427	10,202,445	11,404,427	1,190,012	9,052,970	10,300,428
45%	1,180,850	10,614,153	11,812,708	1,211,954	9,369,656	10,621,712
50%	1,201,069	11,026,138	12,230,818	1,235,173	9,687,138	10,937,159
55%	1,220,708	11,447,806	12,649,734	1,258,333	10,010,676	11,261,102
60%	1,241,683	11,880,965	13,083,196	1,282,448	10,348,433	11,600,693
65%	1,263,431	12,335,916	13,546,206	1,307,817	10,705,127	11,962,501
70%	1,285,744	12,843,762	14,048,296	1,335,014	11,089,808	12,345,853
75%	1,309,538	13,393,523	14,602,078	1,364,839	11,504,486	12,766,224
80%	1,336,254	14,018,362	15,225,794	1,398,495	11,993,586	13,259,262
85%	1,367,361	14,780,998	15,992,097	1,438,184	12,577,667	13,852,193
90%	1,407,025	15,751,410	16,957,693	1,489,869	13,329,478	14,611,444
95%	1,464,162	17,224,035	18,431,115	1,564,673	14,466,273	15,750,409
99%	1,576,306	19,985,728	21,191,987	1,708,231	16,684,256	17,981,111

Table E.55-Risk profile statistics for highway bridge with modification 2b ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	78,929	1,006,778	820,832	308,443	1,304,375
Maximum	1,988,814	4,013,285	5,390,979	2,175,264	3,548,792	5,090,150
Mean	1,291,342	1,358,661	2,650,003	1,295,078	1,334,318	2,629,396
Std Dev	157,783	577,938	599,220	178,823	452,048	493,737
Percentile						
1%	946,742	261,977	1,480,251	954,917	485,859	1,659,104
5%	1,030,871	472,674	1,734,077	1,029,034	648,989	1,879,650
10%	1,086,197	629,667	1,897,259	1,075,676	768,321	2,014,829
15%	1,124,870	748,818	2,020,490	1,109,911	860,266	2,116,166
20%	1,155,805	852,220	2,124,864	1,137,403	936,865	2,199,096
25%	1,182,038	941,210	2,219,124	1,163,647	1,005,739	2,273,980
30%	1,206,346	1,022,089	2,304,308	1,188,233	1,069,283	2,342,785
35%	1,228,071	1,098,332	2,381,633	1,211,133	1,128,227	2,408,267
40%	1,249,234	1,171,362	2,458,678	1,233,824	1,187,023	2,472,232
45%	1,269,657	1,244,661	2,534,421	1,256,285	1,243,136	2,533,317
50%	1,289,875	1,317,547	2,609,038	1,279,594	1,300,025	2,595,083
55%	1,309,515	1,392,337	2,686,967	1,302,895	1,357,844	2,657,262
60%	1,330,489	1,467,604	2,766,416	1,327,225	1,417,563	2,722,263
65%	1,352,237	1,548,091	2,851,658	1,352,962	1,479,832	2,790,443
70%	1,374,551	1,633,231	2,939,208	1,380,727	1,548,391	2,866,231
75%	1,398,345	1,729,559	3,036,565	1,410,791	1,622,169	2,946,801
80%	1,425,061	1,838,976	3,147,852	1,445,178	1,706,325	3,037,319
85%	1,456,167	1,970,768	3,280,335	1,485,037	1,808,990	3,146,876
90%	1,495,831	2,136,337	3,451,735	1,537,367	1,941,792	3,288,024
95%	1,552,969	2,384,873	3,711,120	1,613,720	2,138,970	3,501,098
99%	1,665,112	2,853,280	4,180,110	1,759,239	2,511,545	3,910,086

Table E.56-Risk profile statistics for highway bridge with modification 2b ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	93,699	1,056,091	820,832	574,198	1,617,236
Maximum	1,988,814	7,850,761	9,228,455	2,175,264	6,987,992	8,355,941
Mean	1,291,342	2,617,010	3,908,351	1,295,078	2,596,623	3,891,702
Std Dev	157,783	1,149,925	1,160,724	178,823	899,595	924,828
Percentile						
1%	946,742	428,422	1,681,405	954,917	904,490	2,125,147
5%	1,030,871	851,953	2,126,640	1,029,034	1,228,602	2,491,943
10%	1,086,197	1,165,065	2,445,215	1,075,676	1,469,091	2,737,549
15%	1,124,870	1,403,188	2,685,287	1,109,911	1,651,544	2,923,093
20%	1,155,805	1,608,701	2,890,882	1,137,403	1,806,441	3,081,022
25%	1,182,038	1,786,369	3,067,803	1,163,647	1,943,131	3,220,307
30%	1,206,346	1,947,864	3,233,704	1,188,233	2,070,158	3,351,062
35%	1,228,071	2,099,051	3,385,547	1,211,133	2,187,387	3,474,832
40%	1,249,234	2,245,376	3,535,161	1,233,824	2,304,252	3,592,711
45%	1,269,657	2,391,613	3,680,879	1,256,285	2,415,714	3,709,249
50%	1,289,875	2,535,767	3,830,252	1,279,594	2,529,916	3,825,259
55%	1,309,515	2,685,491	3,977,124	1,302,895	2,644,545	3,941,045
60%	1,330,489	2,834,506	4,130,224	1,327,225	2,763,770	4,061,325
65%	1,352,237	2,995,066	4,292,303	1,352,962	2,887,609	4,190,360
70%	1,374,551	3,164,060	4,465,248	1,380,727	3,023,509	4,330,741
75%	1,398,345	3,356,654	4,654,010	1,410,791	3,170,657	4,482,067
80%	1,425,061	3,573,650	4,874,059	1,445,178	3,338,024	4,655,617
85%	1,456,167	3,835,396	5,132,442	1,485,037	3,541,683	4,862,468
90%	1,495,831	4,164,547	5,466,494	1,537,367	3,804,843	5,130,008
95%	1,552,969	4,657,696	5,973,421	1,613,720	4,195,282	5,528,634
99%	1,665,112	5,588,238	6,884,423	1,759,239	4,937,064	6,305,326

Table E.57-Risk profile statistics for highway bridge with modification 2b ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	127,832	1,194,942	820,832	1,362,788	2,461,017
Maximum	1,988,814	19,363,191	20,740,885	2,175,264	17,305,593	18,673,543
Mean	1,291,342	6,392,055	7,683,397	1,295,078	6,383,538	7,678,617
Std Dev	157,783	2,866,321	2,870,617	178,823	2,242,491	2,257,126
Percentile						
1%	946,742	931,314	2,209,903	954,917	2,156,779	3,415,726
5%	1,030,871	1,987,056	3,272,209	1,029,034	2,970,341	4,253,673
10%	1,086,197	2,770,779	4,055,480	1,075,676	3,570,107	4,853,269
15%	1,124,870	3,364,531	4,649,997	1,109,911	4,026,508	5,306,098
20%	1,155,805	3,878,149	5,167,240	1,137,403	4,415,080	5,698,154
25%	1,182,038	4,322,657	5,610,427	1,163,647	4,755,257	6,039,679
30%	1,206,346	4,727,902	6,015,291	1,188,233	5,072,593	6,356,686
35%	1,228,071	5,102,957	6,393,754	1,211,133	5,365,653	6,656,275
40%	1,249,234	5,469,052	6,758,760	1,233,824	5,655,828	6,944,466
45%	1,269,657	5,831,555	7,118,025	1,256,285	5,932,879	7,228,926
50%	1,289,875	6,192,154	7,488,168	1,279,594	6,218,148	7,509,824
55%	1,309,515	6,562,405	7,855,472	1,302,895	6,503,052	7,800,169
60%	1,330,489	6,938,132	8,232,242	1,327,225	6,803,099	8,098,011
65%	1,352,237	7,336,844	8,630,632	1,352,962	7,109,635	8,405,065
70%	1,374,551	7,758,321	9,054,950	1,380,727	7,450,525	8,747,693
75%	1,398,345	8,234,989	9,528,224	1,410,791	7,817,292	9,119,556
80%	1,425,061	8,776,426	10,066,209	1,445,178	8,233,411	9,541,882
85%	1,456,167	9,427,539	10,719,235	1,485,037	8,742,049	10,052,911
90%	1,495,831	10,247,078	11,539,095	1,537,367	9,395,896	10,706,288
95%	1,552,969	11,474,267	12,773,547	1,613,720	10,368,572	11,689,639
99%	1,665,112	13,796,289	15,069,164	1,759,239	12,210,960	13,538,619

Table E.58-Risk profile statistics for highway bridge with modification 2b ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	591,932	1,705,310	820,832	680,311	1,715,843
Maximum	1,988,814	5,595,559	6,973,253	2,175,264	4,535,112	6,136,483
Mean	1,291,342	2,261,471	3,552,813	1,295,078	1,982,437	3,277,515
Std Dev	157,783	658,796	679,258	178,823	508,788	553,082
Percentile						
1%	946,742	1,011,792	2,232,565	954,917	1,031,280	2,200,550
5%	1,030,871	1,275,507	2,532,461	1,029,034	1,225,076	2,445,697
10%	1,086,197	1,449,534	2,714,992	1,075,676	1,356,587	2,597,120
15%	1,124,870	1,579,467	2,851,579	1,109,911	1,456,067	2,707,821
20%	1,155,805	1,685,442	2,962,662	1,137,403	1,538,574	2,799,562
25%	1,182,038	1,783,393	3,062,537	1,163,647	1,612,976	2,880,766
30%	1,206,346	1,872,561	3,155,299	1,188,233	1,682,479	2,955,902
35%	1,228,071	1,957,845	3,243,944	1,211,133	1,747,383	3,027,658
40%	1,249,234	2,040,489	3,328,680	1,233,824	1,810,594	3,096,615
45%	1,269,657	2,122,831	3,411,978	1,256,285	1,873,931	3,165,003
50%	1,289,875	2,205,228	3,496,107	1,279,594	1,937,428	3,233,400
55%	1,309,515	2,289,561	3,584,255	1,302,895	2,002,135	3,303,160
60%	1,330,489	2,376,193	3,676,204	1,327,225	2,069,687	3,377,392
65%	1,352,237	2,467,183	3,768,314	1,352,962	2,141,025	3,454,224
70%	1,374,551	2,568,752	3,870,856	1,380,727	2,217,962	3,536,281
75%	1,398,345	2,678,705	3,986,669	1,410,791	2,300,897	3,627,606
80%	1,425,061	2,803,672	4,114,362	1,445,178	2,398,717	3,730,342
85%	1,456,167	2,956,200	4,269,222	1,485,037	2,515,533	3,851,765
90%	1,495,831	3,150,282	4,463,867	1,537,367	2,665,896	4,016,924
95%	1,552,969	3,444,807	4,763,607	1,613,720	2,893,255	4,256,401
99%	1,665,112	3,997,146	5,318,849	1,759,239	3,336,851	4,738,842

Table E.59-Risk profile statistics for highway bridge with modification 2b ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	617,723	1,754,624	820,832	958,389	2,077,641
Maximum	1,988,814	9,433,035	10,810,729	2,175,264	7,974,312	9,342,262
Mean	1,291,342	3,519,820	4,811,161	1,295,078	3,244,742	4,539,820
Std Dev	157,783	1,215,739	1,226,906	178,823	947,355	975,255
Percentile						
1%	946,742	1,227,084	2,475,973	954,917	1,481,922	2,689,300
5%	1,030,871	1,681,946	2,958,138	1,029,034	1,822,530	3,075,318
10%	1,086,197	2,003,840	3,282,582	1,075,676	2,068,448	3,334,707
15%	1,124,870	2,247,618	3,528,666	1,109,911	2,257,300	3,526,850
20%	1,155,805	2,455,670	3,738,055	1,137,403	2,413,619	3,688,879
25%	1,182,038	2,638,628	3,921,650	1,163,647	2,554,964	3,832,125
30%	1,206,346	2,803,918	4,089,002	1,188,233	2,686,522	3,966,959
35%	1,228,071	2,966,042	4,252,506	1,211,133	2,810,571	4,094,112
40%	1,249,234	3,117,576	4,405,747	1,233,824	2,929,765	4,219,364
45%	1,269,657	3,269,144	4,559,442	1,256,285	3,046,115	4,340,577
50%	1,289,875	3,423,759	4,716,088	1,279,594	3,166,428	4,462,768
55%	1,309,515	3,580,718	4,873,596	1,302,895	3,285,900	4,585,144
60%	1,330,489	3,740,491	5,036,896	1,327,225	3,414,276	4,711,977
65%	1,352,237	3,905,221	5,202,973	1,352,962	3,545,498	4,847,165
70%	1,374,551	4,089,894	5,390,014	1,380,727	3,688,401	4,996,736
75%	1,398,345	4,293,857	5,592,382	1,410,791	3,845,388	5,156,789
80%	1,425,061	4,526,845	5,825,779	1,445,178	4,021,378	5,340,934
85%	1,456,167	4,806,389	6,104,894	1,485,037	4,238,889	5,560,633
90%	1,495,831	5,159,980	6,463,373	1,537,367	4,517,643	5,848,849
95%	1,552,969	5,691,958	7,006,257	1,613,720	4,937,199	6,271,969
99%	1,665,112	6,697,402	8,001,047	1,759,239	5,735,306	7,100,787

Table E.60-Risk profile statistics for highway bridge with modification 2b ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	689,015	1,816,171	820,832	1,755,654	2,953,506
Maximum	1,988,814	20,945,465	22,323,159	2,175,264	18,291,914	19,659,863
Mean	1,291,342	7,294,866	8,586,207	1,295,078	7,031,657	8,326,735
Std Dev	157,783	2,922,082	2,926,694	178,823	2,284,306	2,300,328
Percentile						
1%	946,742	1,774,381	3,049,107	954,917	2,760,500	4,019,057
5%	1,030,871	2,830,968	4,120,302	1,029,034	3,577,956	4,849,066
10%	1,086,197	3,616,066	4,902,223	1,075,676	4,176,818	5,461,945
15%	1,124,870	4,213,265	5,505,687	1,109,911	4,640,209	5,915,652
20%	1,155,805	4,733,439	6,021,791	1,137,403	5,023,088	6,308,214
25%	1,182,038	5,182,274	6,470,270	1,163,647	5,372,103	6,655,986
30%	1,206,346	5,589,822	6,875,907	1,188,233	5,691,357	6,977,435
35%	1,228,071	5,969,555	7,256,547	1,211,133	5,986,215	7,278,868
40%	1,249,234	6,340,356	7,630,681	1,233,824	6,281,710	7,574,554
45%	1,269,657	6,706,647	7,998,797	1,256,285	6,564,454	7,861,027
50%	1,289,875	7,080,610	8,373,957	1,279,594	6,850,362	8,146,048
55%	1,309,515	7,456,941	8,753,208	1,302,895	7,145,440	8,441,070
60%	1,330,489	7,840,403	9,133,060	1,327,225	7,448,397	8,743,853
65%	1,352,237	8,243,085	9,535,960	1,352,962	7,763,326	9,063,648
70%	1,374,551	8,675,817	9,975,082	1,380,727	8,107,913	9,409,177
75%	1,398,345	9,160,396	10,459,148	1,410,791	8,486,121	9,786,503
80%	1,425,061	9,722,103	11,015,905	1,445,178	8,912,855	10,222,446
85%	1,456,167	10,388,192	11,680,998	1,485,037	9,428,254	10,744,816
90%	1,495,831	11,227,889	12,521,397	1,537,367	10,097,358	11,411,419
95%	1,552,969	12,497,744	13,806,040	1,613,720	11,103,441	12,425,060
99%	1,665,112	14,883,292	16,173,252	1,759,239	12,997,375	14,335,179

Table E.61-Risk profile statistics for highway bridge with modification 2b ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	2,683,260	3,730,108	820,832	2,215,176	3,216,038
Maximum	1,988,814	13,297,485	14,750,422	2,175,264	10,527,202	11,727,483
Mean	1,291,342	6,273,960	7,565,302	1,295,078	4,862,963	6,158,041
Std Dev	157,783	1,325,011	1,339,169	178,823	955,762	997,154
Percentile						
1%	946,742	3,772,649	5,025,300	954,917	3,067,367	4,251,380
5%	1,030,871	4,325,386	5,590,951	1,029,034	3,468,170	4,691,742
10%	1,086,197	4,670,818	5,936,722	1,075,676	3,714,345	4,958,175
15%	1,124,870	4,914,601	6,194,503	1,109,911	3,888,640	5,146,428
20%	1,155,805	5,126,754	6,407,529	1,137,403	4,040,107	5,301,646
25%	1,182,038	5,312,452	6,597,742	1,163,647	4,171,958	5,437,871
30%	1,206,346	5,490,793	6,773,904	1,188,233	4,295,208	5,568,206
35%	1,228,071	5,655,838	6,941,598	1,211,133	4,415,210	5,694,584
40%	1,249,234	5,817,094	7,108,251	1,233,824	4,531,751	5,818,052
45%	1,269,657	5,981,392	7,270,496	1,256,285	4,648,460	5,939,879
50%	1,289,875	6,143,859	7,438,243	1,279,594	4,765,756	6,063,655
55%	1,309,515	6,313,024	7,609,809	1,302,895	4,888,622	6,187,948
60%	1,330,489	6,490,961	7,786,275	1,327,225	5,015,442	6,323,275
65%	1,352,237	6,676,561	7,974,105	1,352,962	5,146,277	6,461,124
70%	1,374,551	6,883,594	8,179,147	1,380,727	5,295,229	6,613,383
75%	1,398,345	7,106,324	8,408,173	1,410,791	5,455,335	6,777,442
80%	1,425,061	7,360,158	8,666,901	1,445,178	5,639,248	6,965,378
85%	1,456,167	7,660,263	8,966,530	1,485,037	5,854,938	7,193,726
90%	1,495,831	8,052,656	9,360,407	1,537,367	6,148,712	7,487,592
95%	1,552,969	8,654,708	9,975,275	1,613,720	6,580,837	7,947,348
99%	1,665,112	9,821,619	11,146,639	1,759,239	7,469,647	8,866,926

Table E.62-Risk profile statistics for highway bridge with modification 2b ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	2,882,282	4,069,981	820,832	2,511,771	3,589,965
Maximum	1,988,814	16,465,364	17,843,058	2,175,264	12,919,265	14,280,074
Mean	1,291,342	7,532,309	8,823,651	1,295,078	6,125,268	7,420,346
Std Dev	157,783	1,745,619	1,756,361	178,823	1,304,546	1,337,640
Percentile						
1%	946,742	4,211,796	5,463,587	954,917	3,661,849	4,865,255
5%	1,030,871	4,945,512	6,220,629	1,029,034	4,206,371	5,445,611
10%	1,086,197	5,410,309	6,686,067	1,075,676	4,543,188	5,796,992
15%	1,124,870	5,740,546	7,022,927	1,109,911	4,789,982	6,046,867
20%	1,155,805	6,018,517	7,303,989	1,137,403	4,996,143	6,267,422
25%	1,182,038	6,271,119	7,555,739	1,163,647	5,184,207	6,458,999
30%	1,206,346	6,500,630	7,788,228	1,188,233	5,356,898	6,634,332
35%	1,228,071	6,723,971	8,011,173	1,211,133	5,517,149	6,803,598
40%	1,249,234	6,941,171	8,228,126	1,233,824	5,679,853	6,968,419
45%	1,269,657	7,154,030	8,446,259	1,256,285	5,840,125	7,133,376
50%	1,289,875	7,368,758	8,660,028	1,279,594	6,003,326	7,298,514
55%	1,309,515	7,592,289	8,886,490	1,302,895	6,170,856	7,464,808
60%	1,330,489	7,825,854	9,117,247	1,327,225	6,337,773	7,643,249
65%	1,352,237	8,073,028	9,366,996	1,352,962	6,518,057	7,830,464
70%	1,374,551	8,340,592	9,642,370	1,380,727	6,715,764	8,031,420
75%	1,398,345	8,637,039	9,935,690	1,410,791	6,937,390	8,252,516
80%	1,425,061	8,963,984	10,264,263	1,445,178	7,186,157	8,505,080
85%	1,456,167	9,367,750	10,668,087	1,485,037	7,487,156	8,815,168
90%	1,495,831	9,871,275	11,180,609	1,537,367	7,877,563	9,211,521
95%	1,552,969	10,666,711	11,967,089	1,613,720	8,460,748	9,811,332
99%	1,665,112	12,156,586	13,472,997	1,759,239	9,639,339	11,017,298

Table E.63-Risk profile statistics for highway bridge with modification 2b ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	836,262	2,959,658	4,171,120	820,832	3,401,555	4,643,025
Maximum	1,988,814	27,977,793	29,355,487	2,175,264	22,675,560	24,043,509
Mean	1,291,342	11,307,355	12,598,697	1,295,078	9,912,183	11,207,261
Std Dev	157,783	3,293,978	3,299,637	178,823	2,543,942	2,564,936
Percentile						
1%	946,742	5,058,960	6,332,306	954,917	5,156,399	6,405,547
5%	1,030,871	6,377,537	7,661,280	1,029,034	6,125,381	7,388,363
10%	1,086,197	7,247,668	8,529,494	1,075,676	6,782,936	8,057,794
15%	1,124,870	7,897,333	9,185,818	1,109,911	7,280,337	8,563,368
20%	1,155,805	8,427,211	9,715,638	1,137,403	7,692,870	8,966,782
25%	1,182,038	8,916,963	10,202,394	1,163,647	8,064,880	9,342,854
30%	1,206,346	9,362,805	10,651,819	1,188,233	8,412,394	9,698,071
35%	1,228,071	9,789,223	11,077,774	1,211,133	8,736,917	10,026,462
40%	1,249,234	10,202,445	11,493,052	1,233,824	9,052,970	10,344,584
45%	1,269,657	10,614,153	11,901,208	1,256,285	9,369,656	10,665,313
50%	1,289,875	11,026,138	12,319,100	1,279,594	9,687,138	10,981,325
55%	1,309,515	11,447,806	12,737,774	1,302,895	10,010,676	11,306,661
60%	1,330,489	11,880,965	13,171,043	1,327,225	10,348,433	11,644,756
65%	1,352,237	12,335,916	13,634,888	1,352,962	10,705,127	12,005,992
70%	1,374,551	12,843,762	14,135,978	1,380,727	11,089,808	12,389,436
75%	1,398,345	13,393,523	14,690,246	1,410,791	11,504,486	12,810,296
80%	1,425,061	14,018,362	15,313,696	1,445,178	11,993,586	13,302,778
85%	1,456,167	14,780,998	16,080,614	1,485,037	12,577,667	13,896,796
90%	1,495,831	15,751,410	17,045,823	1,537,367	13,329,478	14,656,238
95%	1,552,969	17,224,035	18,519,761	1,613,720	14,466,273	15,799,103
99%	1,665,112	19,985,728	21,280,793	1,759,239	16,684,256	18,034,818

Table E.64-Risk profile statistics for highway bridge with modification 2c ADT case 1 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	78,929	1,080,092	855,949	308,443	1,342,192
Maximum	2,077,621	4,013,285	5,479,785	2,233,456	3,548,792	5,143,661
Mean	1,379,772	1,358,661	2,738,433	1,339,385	1,334,318	2,673,703
Std Dev	158,586	577,938	599,438	181,707	452,048	495,337
Percentile						
1%	1,023,311	261,977	1,567,573	992,687	485,859	1,699,901
5%	1,118,700	472,674	1,822,511	1,068,506	648,989	1,921,664
10%	1,174,741	629,667	1,985,722	1,115,965	768,321	2,057,621
15%	1,213,633	748,818	2,108,777	1,151,129	860,266	2,159,103
20%	1,244,593	852,220	2,213,145	1,179,273	936,865	2,241,864
25%	1,270,845	941,210	2,307,615	1,206,152	1,005,739	2,317,231
30%	1,295,152	1,022,089	2,392,593	1,231,097	1,069,283	2,386,506
35%	1,316,877	1,098,332	2,470,179	1,254,380	1,128,227	2,452,106
40%	1,338,040	1,171,362	2,547,328	1,277,439	1,187,023	2,515,816
45%	1,358,464	1,244,661	2,622,842	1,300,664	1,243,136	2,577,400
50%	1,378,682	1,317,547	2,697,578	1,323,942	1,300,025	2,639,161
55%	1,398,321	1,392,337	2,775,570	1,347,627	1,357,844	2,701,889
60%	1,419,296	1,467,604	2,854,881	1,372,330	1,417,563	2,766,948
65%	1,441,044	1,548,091	2,940,220	1,398,661	1,479,832	2,835,238
70%	1,463,357	1,633,231	3,027,858	1,426,376	1,548,391	2,911,182
75%	1,487,151	1,729,559	3,125,261	1,456,844	1,622,169	2,992,285
80%	1,513,867	1,838,976	3,236,567	1,491,904	1,706,325	3,082,713
85%	1,544,974	1,970,768	3,369,003	1,532,274	1,808,990	3,192,462
90%	1,584,638	2,136,337	3,540,423	1,585,572	1,941,792	3,333,684
95%	1,641,775	2,384,873	3,799,920	1,662,394	2,138,970	3,547,917
99%	1,753,919	2,853,280	4,268,917	1,809,276	2,511,545	3,959,382

Table E.65-Risk profile statistics for highway bridge with modification 2c ADT case 2 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	93,699	1,129,405	855,949	574,198	1,654,255
Maximum	2,077,621	7,850,761	9,317,262	2,233,456	6,987,992	8,416,162
Mean	1,379,772	2,617,010	3,996,781	1,339,385	2,596,623	3,936,008
Std Dev	158,586	1,149,925	1,160,839	181,707	899,595	925,946
Percentile						
1%	1,023,311	428,422	1,769,944	992,687	904,490	2,166,398
5%	1,118,700	851,953	2,214,532	1,068,506	1,228,602	2,534,379
10%	1,174,741	1,165,065	2,533,514	1,115,965	1,469,091	2,780,187
15%	1,213,633	1,403,188	2,773,525	1,151,129	1,651,544	2,966,768
20%	1,244,593	1,608,701	2,979,154	1,179,273	1,806,441	3,124,475
25%	1,270,845	1,786,369	3,156,301	1,206,152	1,943,131	3,263,744
30%	1,295,152	1,947,864	3,321,682	1,231,097	2,070,158	3,394,790
35%	1,316,877	2,099,051	3,474,114	1,254,380	2,187,387	3,518,143
40%	1,338,040	2,245,376	3,623,276	1,277,439	2,304,252	3,636,933
45%	1,358,464	2,391,613	3,769,305	1,300,664	2,415,714	3,752,941
50%	1,378,682	2,535,767	3,918,606	1,323,942	2,529,916	3,869,703
55%	1,398,321	2,685,491	4,065,719	1,347,627	2,644,545	3,985,357
60%	1,419,296	2,834,506	4,218,763	1,372,330	2,763,770	4,105,598
65%	1,441,044	2,995,066	4,380,615	1,398,661	2,887,609	4,235,043
70%	1,463,357	3,164,060	4,553,722	1,426,376	3,023,509	4,375,718
75%	1,487,151	3,356,654	4,742,766	1,456,844	3,170,657	4,526,762
80%	1,513,867	3,573,650	4,962,622	1,491,904	3,338,024	4,700,323
85%	1,544,974	3,835,396	5,220,688	1,532,274	3,541,683	4,907,177
90%	1,584,638	4,164,547	5,555,234	1,585,572	3,804,843	5,176,126
95%	1,641,775	4,657,696	6,062,228	1,662,394	4,195,282	5,574,736
99%	1,753,919	5,588,238	6,973,230	1,809,276	4,937,064	6,353,627

Table E.66-Risk profile statistics for highway bridge with modification 2c ADT case 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	127,832	1,277,346	855,949	1,362,788	2,498,036
Maximum	2,077,621	19,363,191	20,829,691	2,233,456	17,305,593	18,733,763
Mean	1,379,772	6,392,055	7,771,827	1,339,385	6,383,538	7,722,923
Std Dev	158,586	2,866,321	2,870,667	181,707	2,242,491	2,257,909
Percentile						
1%	1,023,311	931,314	2,297,242	992,687	2,156,779	3,459,426
5%	1,118,700	1,987,056	3,360,980	1,068,506	2,970,341	4,297,195
10%	1,174,741	2,770,779	4,143,779	1,115,965	3,570,107	4,896,784
15%	1,213,633	3,364,531	4,738,612	1,151,129	4,026,508	5,350,388
20%	1,244,593	3,878,149	5,255,523	1,179,273	4,415,080	5,741,965
25%	1,270,845	4,322,657	5,699,004	1,206,152	4,755,257	6,083,655
30%	1,295,152	4,727,902	6,103,848	1,231,097	5,072,593	6,400,588
35%	1,316,877	5,102,957	6,482,032	1,254,380	5,365,653	6,700,349
40%	1,338,040	5,469,052	6,847,291	1,277,439	5,655,828	6,989,037
45%	1,358,464	5,831,555	7,206,586	1,300,664	5,932,879	7,273,022
50%	1,378,682	6,192,154	7,576,734	1,323,942	6,218,148	7,553,978
55%	1,398,321	6,562,405	7,943,812	1,347,627	6,503,052	7,844,089
60%	1,419,296	6,938,132	8,320,895	1,372,330	6,803,099	8,142,722
65%	1,441,044	7,336,844	8,719,007	1,398,661	7,109,635	8,450,057
70%	1,463,357	7,758,321	9,143,694	1,426,376	7,450,525	8,792,085
75%	1,487,151	8,234,989	9,616,937	1,456,844	7,817,292	9,163,162
80%	1,513,867	8,776,426	10,154,994	1,491,904	8,233,411	9,586,527
85%	1,544,974	9,427,539	10,807,296	1,532,274	8,742,049	10,097,793
90%	1,584,638	10,247,078	11,627,902	1,585,572	9,395,896	10,751,556
95%	1,641,775	11,474,267	12,862,026	1,662,394	10,368,572	11,735,758
99%	1,753,919	13,796,289	15,157,535	1,809,276	12,210,960	13,587,977

Table E.67-Risk profile statistics for highway bridge with modification 2c ADT case 4 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	591,932	1,778,624	855,949	680,311	1,751,672
Maximum	2,077,621	5,595,559	7,062,059	2,233,456	4,535,112	6,189,993
Mean	1,379,772	2,261,471	3,641,243	1,339,385	1,982,437	3,321,821
Std Dev	158,586	658,796	679,454	181,707	508,788	554,965
Percentile						
1%	1,023,311	1,011,792	2,319,289	992,687	1,031,280	2,239,312
5%	1,118,700	1,275,507	2,620,126	1,068,506	1,225,076	2,486,517
10%	1,174,741	1,449,534	2,803,198	1,115,965	1,356,587	2,639,101
15%	1,213,633	1,579,467	2,939,824	1,151,129	1,456,067	2,750,458
20%	1,244,593	1,685,442	3,050,903	1,179,273	1,538,574	2,842,154
25%	1,270,845	1,783,393	3,150,921	1,206,152	1,612,976	2,923,882
30%	1,295,152	1,872,561	3,243,527	1,231,097	1,682,479	2,999,557
35%	1,316,877	1,957,845	3,332,358	1,254,380	1,747,383	3,071,494
40%	1,338,040	2,040,489	3,417,119	1,277,439	1,810,594	3,140,087
45%	1,358,464	2,122,831	3,500,388	1,300,664	1,873,931	3,208,833
50%	1,378,682	2,205,228	3,584,486	1,323,942	1,937,428	3,277,453
55%	1,398,321	2,289,561	3,672,889	1,347,627	2,002,135	3,347,690
60%	1,419,296	2,376,193	3,764,825	1,372,330	2,069,687	3,421,667
65%	1,441,044	2,467,183	3,856,871	1,398,661	2,141,025	3,499,568
70%	1,463,357	2,568,752	3,959,343	1,426,376	2,217,962	3,581,600
75%	1,487,151	2,678,705	4,075,299	1,456,844	2,300,897	3,673,567
80%	1,513,867	2,803,672	4,203,020	1,491,904	2,398,717	3,776,515
85%	1,544,974	2,956,200	4,357,598	1,532,274	2,515,533	3,897,877
90%	1,584,638	3,150,282	4,552,408	1,585,572	2,665,896	4,064,043
95%	1,641,775	3,444,807	4,852,284	1,662,394	2,893,255	4,302,807
99%	1,753,919	3,997,146	5,407,656	1,809,276	3,336,851	4,786,479

Table E.68-Risk profile statistics for highway bridge with modification 2c ADT case 5 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	617,723	1,827,937	855,949	958,389	2,116,777
Maximum	2,077,621	9,433,035	10,899,536	2,233,456	7,974,312	9,402,482
Mean	1,379,772	3,519,820	4,899,591	1,339,385	3,244,742	4,584,126
Std Dev	158,586	1,215,739	1,227,018	181,707	947,355	976,573
Percentile						
1%	1,023,311	1,227,084	2,563,241	992,687	1,481,922	2,729,448
5%	1,118,700	1,681,946	3,045,848	1,068,506	1,822,530	3,117,297
10%	1,174,741	2,003,840	3,370,921	1,115,965	2,068,448	3,376,965
15%	1,213,633	2,247,618	3,616,965	1,151,129	2,257,300	3,569,922
20%	1,244,593	2,455,670	3,826,128	1,179,273	2,413,619	3,732,250
25%	1,270,845	2,638,628	4,010,006	1,206,152	2,554,964	3,875,710
30%	1,295,152	2,803,918	4,177,474	1,231,097	2,686,522	4,010,551
35%	1,316,877	2,966,042	4,340,965	1,254,380	2,810,571	4,137,713
40%	1,338,040	3,117,576	4,494,219	1,277,439	2,929,765	4,263,604
45%	1,358,464	3,269,144	4,647,826	1,300,664	3,046,115	4,384,463
50%	1,378,682	3,423,759	4,804,086	1,323,942	3,166,428	4,506,871
55%	1,398,321	3,580,718	4,962,272	1,347,627	3,285,900	4,629,571
60%	1,419,296	3,740,491	5,125,366	1,372,330	3,414,276	4,756,452
65%	1,441,044	3,905,221	5,291,464	1,398,661	3,545,498	4,892,329
70%	1,463,357	4,089,894	5,478,611	1,426,376	3,688,401	5,041,946
75%	1,487,151	4,293,857	5,680,688	1,456,844	3,845,388	5,202,736
80%	1,513,867	4,526,845	5,913,945	1,491,904	4,021,378	5,385,673
85%	1,544,974	4,806,389	6,193,591	1,532,274	4,238,889	5,605,509
90%	1,584,638	5,159,980	6,552,180	1,585,572	4,517,643	5,894,578
95%	1,641,775	5,691,958	7,095,031	1,662,394	4,937,199	6,318,316
99%	1,753,919	6,697,402	8,089,854	1,809,276	5,735,306	7,152,710

Table E.69-Risk profile statistics for highway bridge with modification 2c ADT case 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	689,015	1,904,978	855,949	1,755,654	2,992,641
Maximum	2,077,621	20,945,465	22,411,965	2,233,456	18,291,914	19,720,084
Mean	1,379,772	7,294,866	8,674,637	1,339,385	7,031,657	8,371,041
Std Dev	158,586	2,922,082	2,926,744	181,707	2,284,306	2,301,206
Percentile						
1%	1,023,311	1,774,381	3,137,629	992,687	2,760,500	4,061,092
5%	1,118,700	2,830,968	4,209,109	1,068,506	3,577,956	4,891,544
10%	1,174,741	3,616,066	4,990,940	1,115,965	4,176,818	5,504,513
15%	1,213,633	4,213,265	5,593,743	1,151,129	4,640,209	5,959,094
20%	1,244,593	4,733,439	6,109,981	1,179,273	5,023,088	6,351,295
25%	1,270,845	5,182,274	6,558,783	1,206,152	5,372,103	6,699,244
30%	1,295,152	5,589,822	6,964,244	1,231,097	5,691,357	7,021,158
35%	1,316,877	5,969,555	7,344,921	1,254,380	5,986,215	7,323,366
40%	1,338,040	6,340,356	7,718,575	1,277,439	6,281,710	7,617,950
45%	1,358,464	6,706,647	8,087,512	1,300,664	6,564,454	7,905,131
50%	1,378,682	7,080,610	8,462,276	1,323,942	6,850,362	8,190,231
55%	1,398,321	7,456,941	8,841,466	1,347,627	7,145,440	8,485,472
60%	1,419,296	7,840,403	9,221,419	1,372,330	7,448,397	8,788,062
65%	1,441,044	8,243,085	9,624,724	1,398,661	7,763,326	9,108,010
70%	1,463,357	8,675,817	10,063,825	1,426,376	8,107,913	9,453,836
75%	1,487,151	9,160,396	10,547,640	1,456,844	8,486,121	9,830,740
80%	1,513,867	9,722,103	11,104,712	1,491,904	8,912,855	10,267,352
85%	1,544,974	10,388,192	11,769,288	1,532,274	9,428,254	10,789,860
90%	1,584,638	11,227,889	12,609,980	1,585,572	10,097,358	11,456,284
95%	1,641,775	12,497,744	13,894,436	1,662,394	11,103,441	12,471,826
99%	1,753,919	14,883,292	16,261,375	1,809,276	12,997,375	14,381,003

Table E.70-Risk profile statistics for highway bridge with modification 2c ADT case 7 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	2,683,260	3,818,915	855,949	2,215,176	3,244,134
Maximum	2,077,621	13,297,485	14,839,228	2,233,456	10,527,202	11,778,803
Mean	1,379,772	6,273,960	7,653,732	1,339,385	4,862,963	6,202,347
Std Dev	158,586	1,325,011	1,339,279	181,707	955,762	999,321
Percentile						
1%	1,023,311	3,772,649	5,113,224	992,687	3,067,367	4,291,144
5%	1,118,700	4,325,386	5,679,221	1,068,506	3,468,170	4,732,429
10%	1,174,741	4,670,818	6,025,303	1,115,965	3,714,345	5,000,148
15%	1,213,633	4,914,601	6,282,928	1,151,129	3,888,640	5,188,634
20%	1,244,593	5,126,754	6,495,848	1,179,273	4,040,107	5,344,333
25%	1,270,845	5,312,452	6,685,770	1,206,152	4,171,958	5,480,212
30%	1,295,152	5,490,793	6,862,248	1,231,097	4,295,208	5,611,502
35%	1,316,877	5,655,838	7,030,055	1,254,380	4,415,210	5,737,998
40%	1,338,040	5,817,094	7,196,436	1,277,439	4,531,751	5,861,158
45%	1,358,464	5,981,392	7,358,774	1,300,664	4,648,460	5,983,983
50%	1,378,682	6,143,859	7,526,655	1,323,942	4,765,756	6,107,468
55%	1,398,321	6,313,024	7,697,791	1,347,627	4,888,622	6,233,391
60%	1,419,296	6,490,961	7,874,646	1,372,330	5,015,442	6,367,416
65%	1,441,044	6,676,561	8,062,641	1,398,661	5,146,277	6,505,801
70%	1,463,357	6,883,594	8,267,338	1,426,376	5,295,229	6,658,704
75%	1,487,151	7,106,324	8,496,964	1,456,844	5,455,335	6,823,481
80%	1,513,867	7,360,158	8,755,498	1,491,904	5,639,248	7,011,400
85%	1,544,974	7,660,263	9,054,870	1,532,274	5,854,938	7,241,000
90%	1,584,638	8,052,656	9,449,128	1,585,572	6,148,712	7,534,781
95%	1,641,775	8,654,708	10,064,082	1,662,394	6,580,837	7,995,078
99%	1,753,919	9,821,619	11,235,365	1,809,276	7,469,647	8,917,280

Table E.71-Risk profile statistics for highway bridge with modification 2c ADT case 8 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	2,882,282	4,158,787	855,949	2,511,771	3,618,061
Maximum	2,077,621	16,465,364	17,931,864	2,233,456	12,919,265	14,335,679
Mean	1,379,772	7,532,309	8,912,081	1,339,385	6,125,268	7,464,652
Std Dev	158,586	1,745,619	1,756,446	181,707	1,304,546	1,339,438
Percentile						
1%	1,023,311	4,211,796	5,552,393	992,687	3,661,849	4,904,530
5%	1,118,700	4,945,512	6,308,696	1,068,506	4,206,371	5,487,350
10%	1,174,741	5,410,309	6,774,595	1,115,965	4,543,188	5,839,207
15%	1,213,633	5,740,546	7,111,398	1,151,129	4,789,982	6,090,325
20%	1,244,593	6,018,517	7,392,066	1,179,273	4,996,143	6,310,122
25%	1,270,845	6,271,119	7,644,424	1,206,152	5,184,207	6,502,096
30%	1,295,152	6,500,630	7,876,899	1,231,097	5,356,898	6,677,466
35%	1,316,877	6,723,971	8,099,471	1,254,380	5,517,149	6,846,778
40%	1,338,040	6,941,171	8,316,601	1,277,439	5,679,853	7,012,529
45%	1,358,464	7,154,030	8,534,277	1,300,664	5,840,125	7,176,677
50%	1,378,682	7,368,758	8,748,168	1,323,942	6,003,326	7,342,681
55%	1,398,321	7,592,289	8,974,630	1,347,627	6,170,856	7,509,110
60%	1,419,296	7,825,854	9,205,895	1,372,330	6,337,773	7,688,200
65%	1,441,044	8,073,028	9,455,660	1,398,661	6,518,057	7,875,278
70%	1,463,357	8,340,592	9,731,040	1,426,376	6,715,764	8,076,536
75%	1,487,151	8,637,039	10,024,138	1,456,844	6,937,390	8,298,152
80%	1,513,867	8,963,984	10,352,808	1,491,904	7,186,157	8,550,853
85%	1,544,974	9,367,750	10,756,891	1,532,274	7,487,156	8,860,807
90%	1,584,638	9,871,275	11,269,059	1,585,572	7,877,563	9,258,328
95%	1,641,775	10,666,711	12,055,808	1,662,394	8,460,748	9,859,240
99%	1,753,919	12,156,586	13,561,803	1,809,276	9,639,339	11,063,571

Table E.72-Risk profile statistics for highway bridge with modification 2c ADT case 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	895,742	2,959,658	4,259,926	855,949	3,401,555	4,691,669
Maximum	2,077,621	27,977,793	29,444,294	2,233,456	22,675,560	24,103,729
Mean	1,379,772	11,307,355	12,687,126	1,339,385	9,912,183	11,251,568
Std Dev	158,586	3,293,978	3,299,686	181,707	2,543,942	2,566,159
Percentile						
1%	1,023,311	5,058,960	6,421,113	992,687	5,156,399	6,445,711
5%	1,118,700	6,377,537	7,749,826	1,068,506	6,125,381	7,429,803
10%	1,174,741	7,247,668	8,617,719	1,115,965	6,782,936	8,101,338
15%	1,213,633	7,897,333	9,274,560	1,151,129	7,280,337	8,606,258
20%	1,244,593	8,427,211	9,804,143	1,179,273	7,692,870	9,010,297
25%	1,270,845	8,916,963	10,290,962	1,206,152	8,064,880	9,386,136
30%	1,295,152	9,362,805	10,739,662	1,231,097	8,412,394	9,741,724
35%	1,316,877	9,789,223	11,166,094	1,254,380	8,736,917	10,069,469
40%	1,338,040	10,202,445	11,581,092	1,277,439	9,052,970	10,387,631
45%	1,358,464	10,614,153	11,989,700	1,300,664	9,369,656	10,708,942
50%	1,378,682	11,026,138	12,407,540	1,323,942	9,687,138	11,025,080
55%	1,398,321	11,447,806	12,826,322	1,347,627	10,010,676	11,350,987
60%	1,419,296	11,880,965	13,259,618	1,372,330	10,348,433	11,689,478
65%	1,441,044	12,335,916	13,723,167	1,398,661	10,705,127	12,050,249
70%	1,463,357	12,843,762	14,224,378	1,426,376	11,089,808	12,433,531
75%	1,487,151	13,393,523	14,778,832	1,456,844	11,504,486	12,854,300
80%	1,513,867	14,018,362	15,402,112	1,491,904	11,993,586	13,346,651
85%	1,544,974	14,780,998	16,169,200	1,532,274	12,577,667	13,941,327
90%	1,584,638	15,751,410	17,134,629	1,585,572	13,329,478	14,701,350
95%	1,641,775	17,224,035	18,608,398	1,662,394	14,466,273	15,845,304
99%	1,753,919	19,985,728	21,369,600	1,809,276	16,684,256	18,080,119

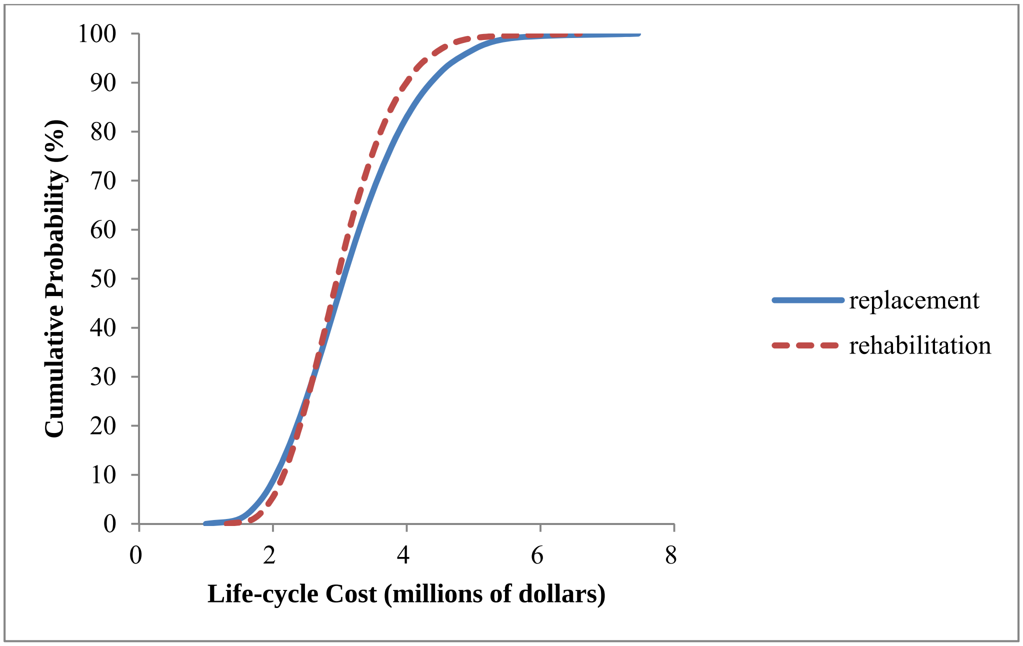


Figure E.37-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 1 (Table 3.6)

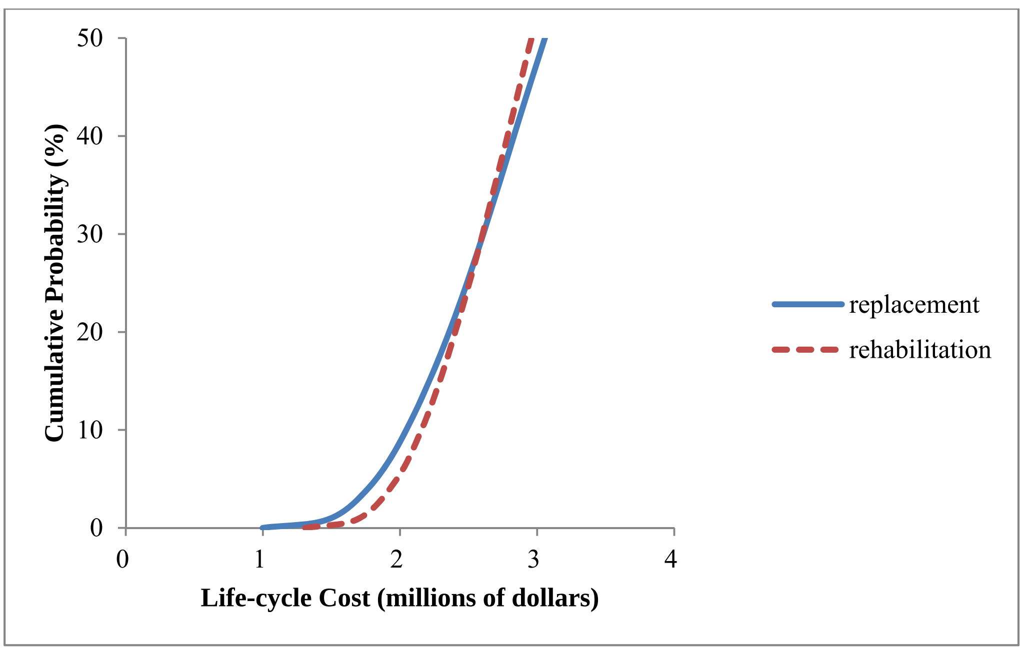


Figure E.38-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 1 (Table 3.6)

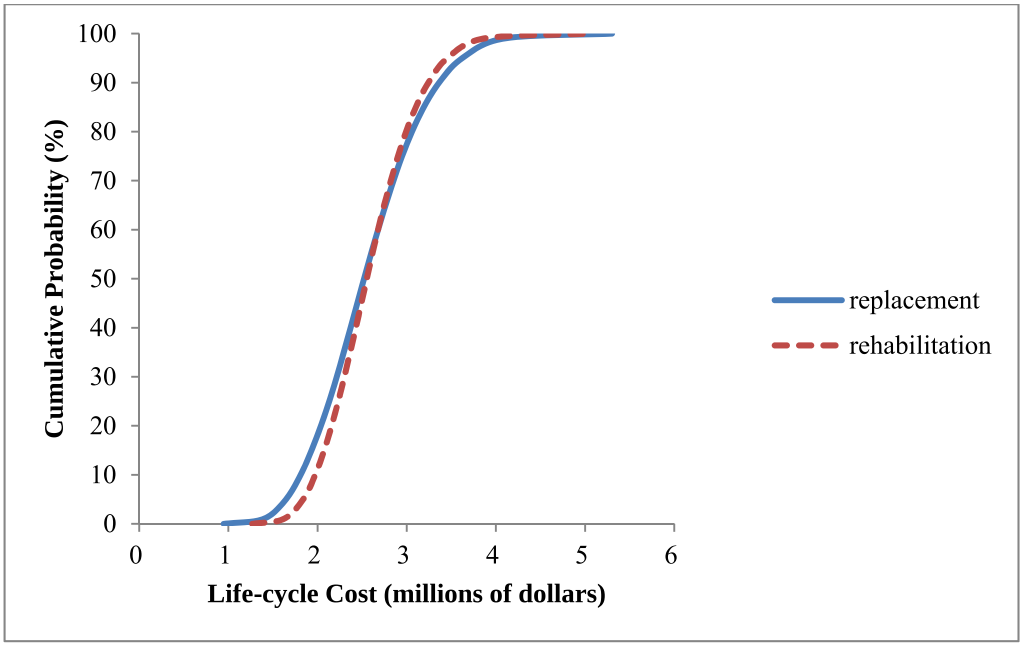


Figure E.39-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 1 (Table 3.6)

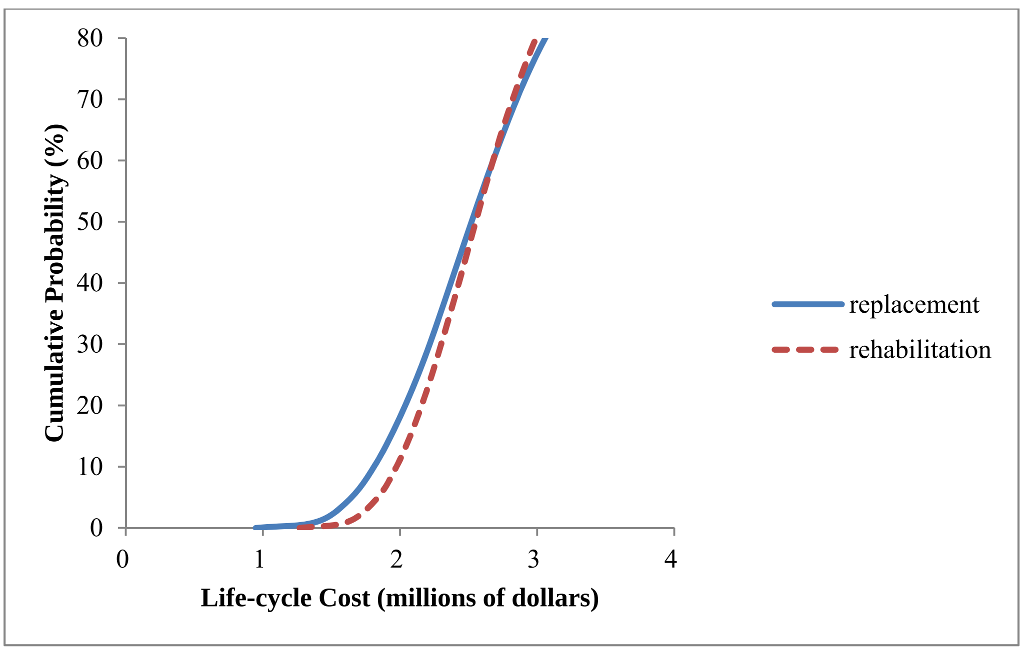


Figure E.40-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 1 (Table 3.6)

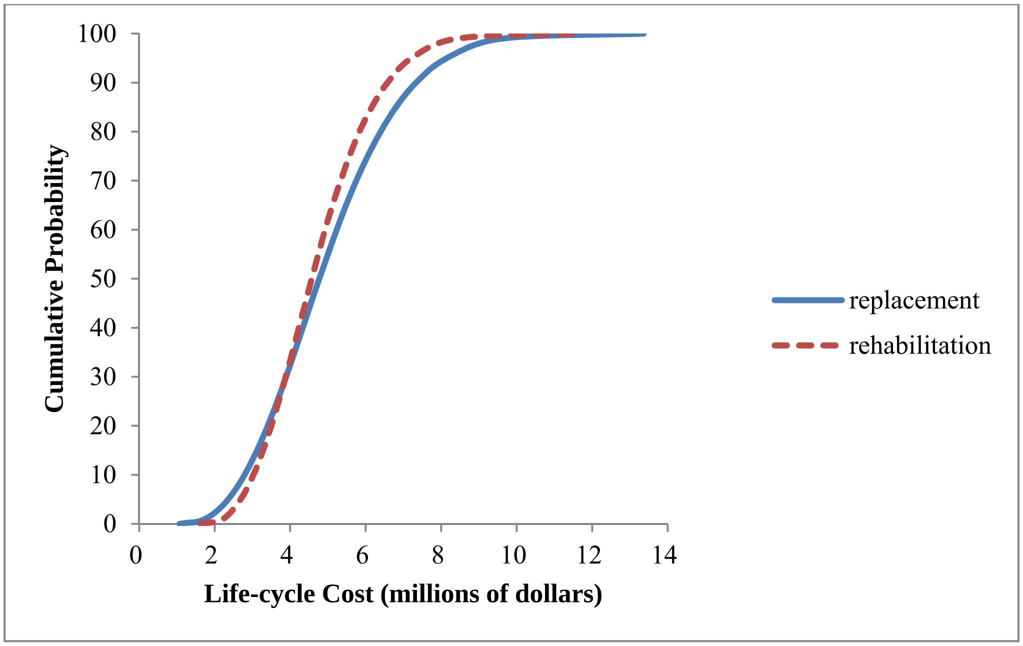


Figure E.41-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 2 (Table 3.6)

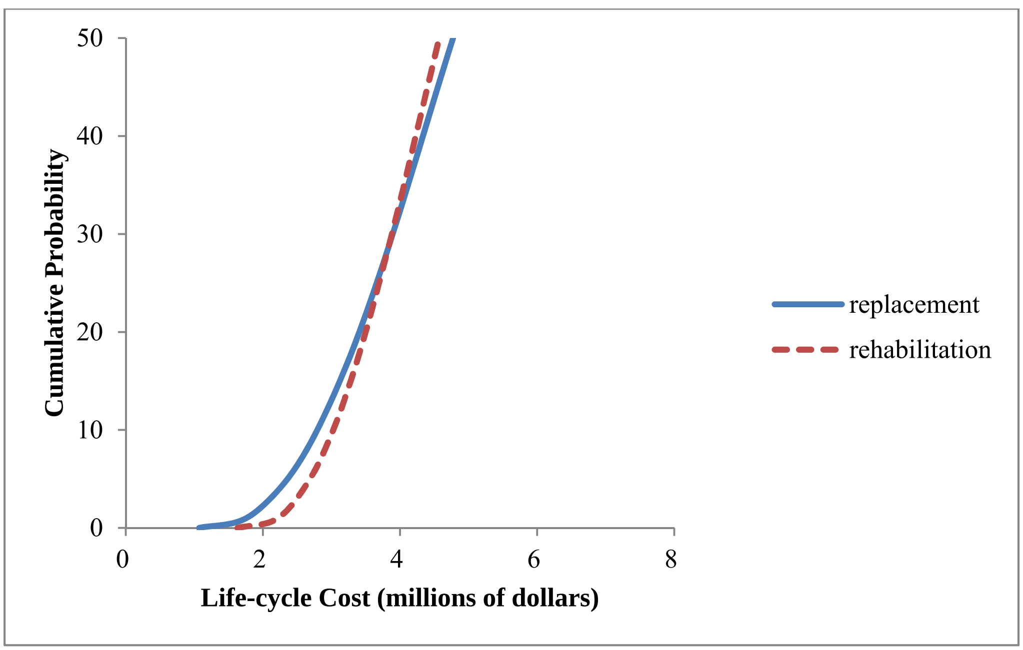


Figure E.42-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 2 (Table 3.6)

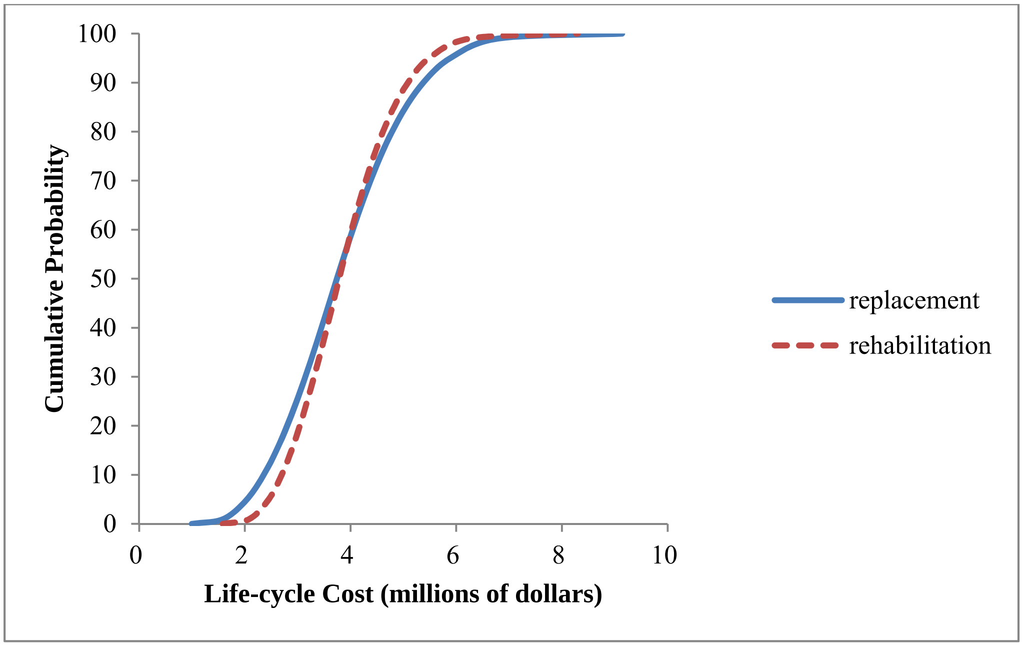


Figure E.43-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 2 (Table 3.6)

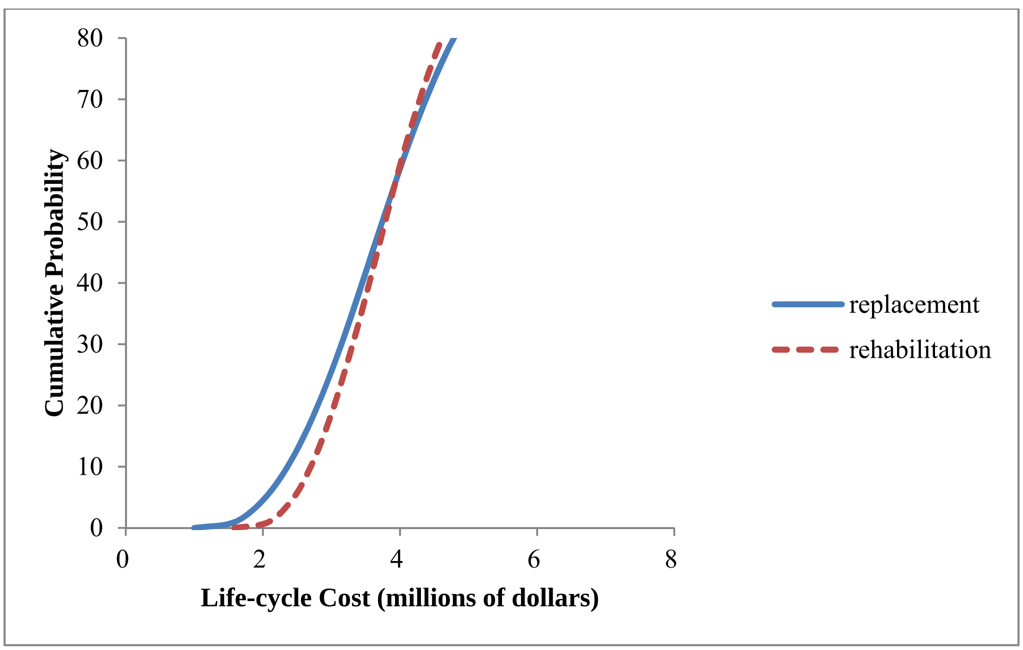


Figure E.44-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 2 (Table 3.6)

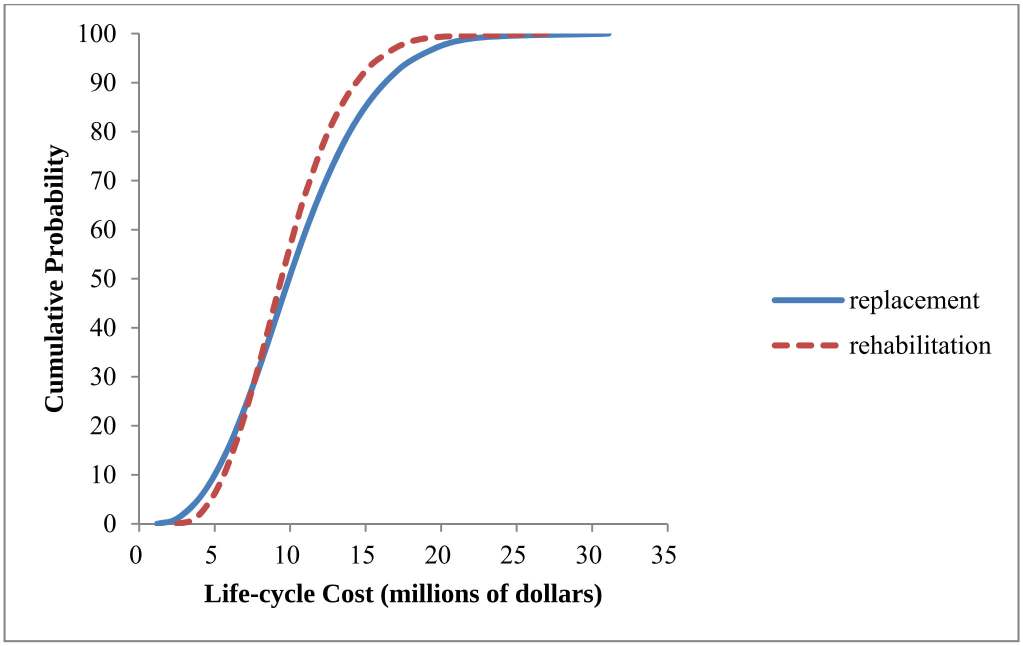


Figure E.45-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 3 (Table 3.6)

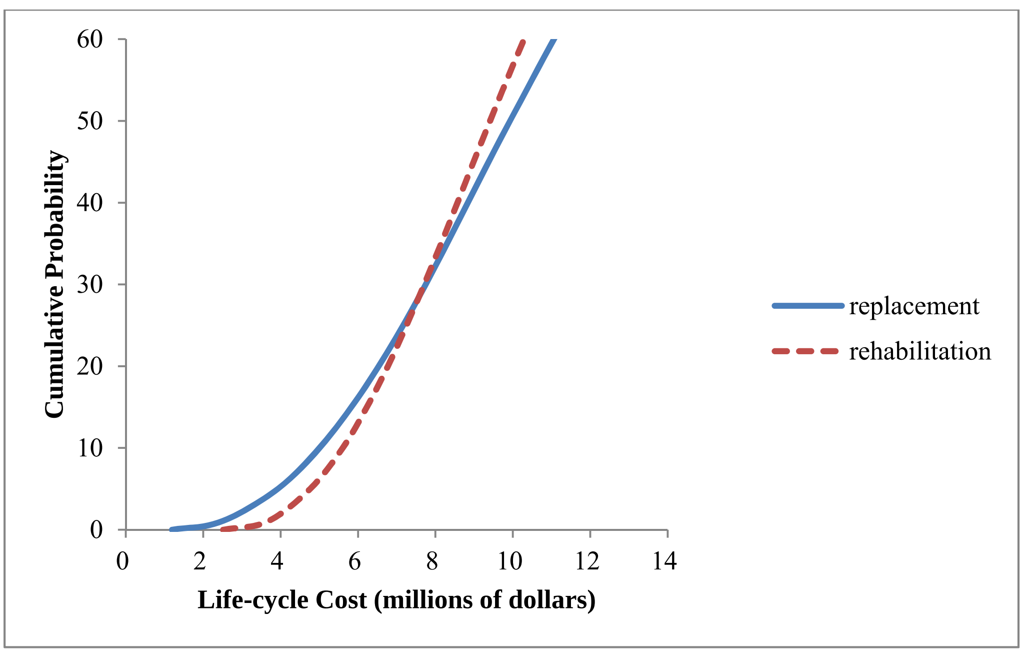


Figure E.46-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 3 (Table 3.6)

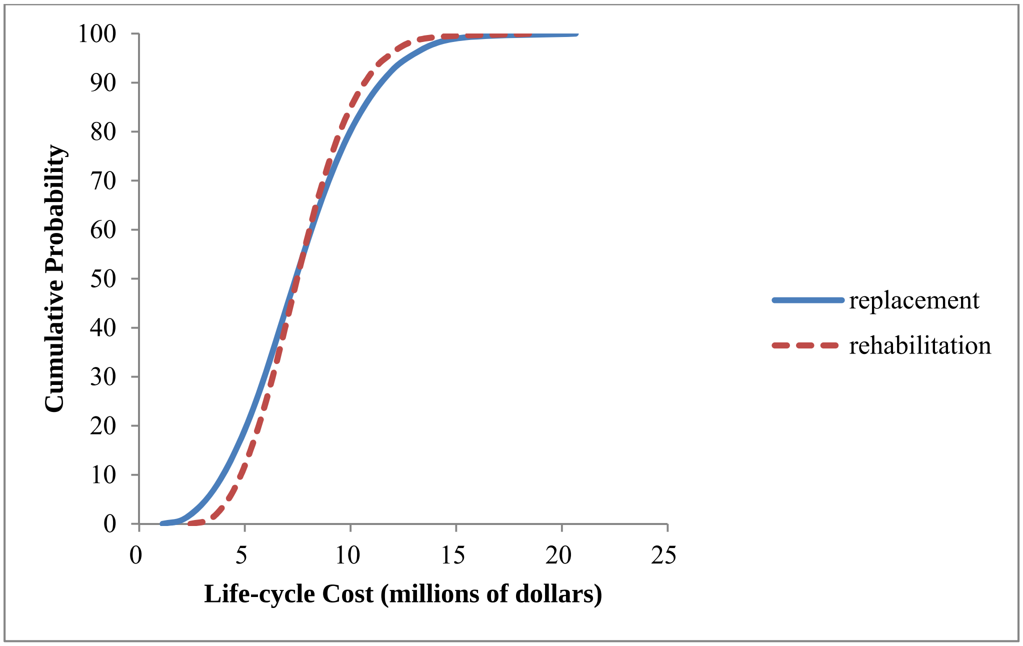


Figure E.47-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 3 (Table 3.6)

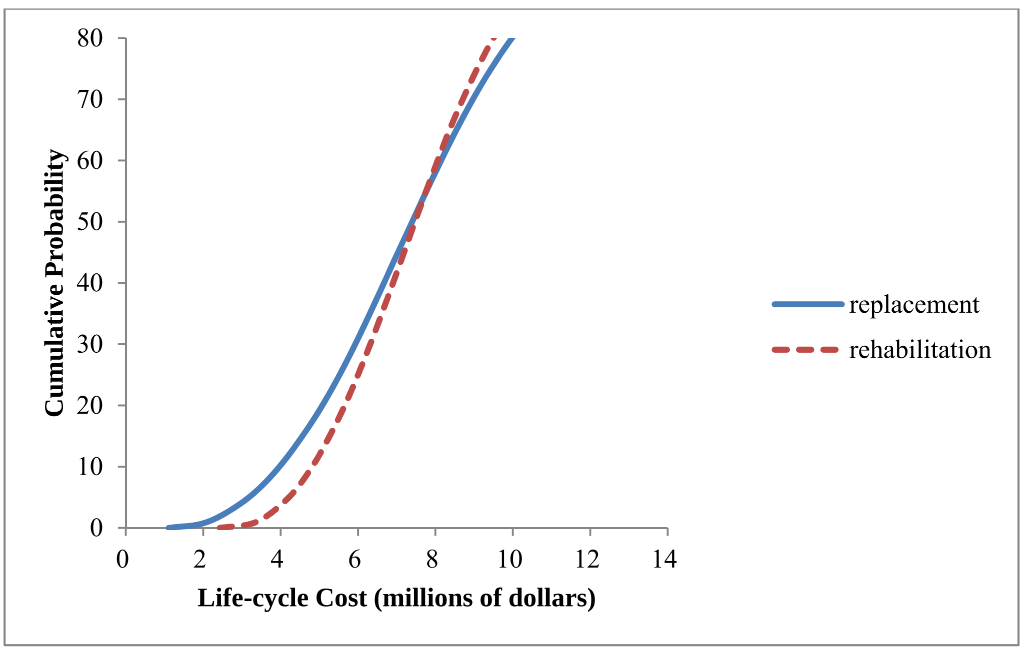


Figure E.48-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 3 (Table 3.6)

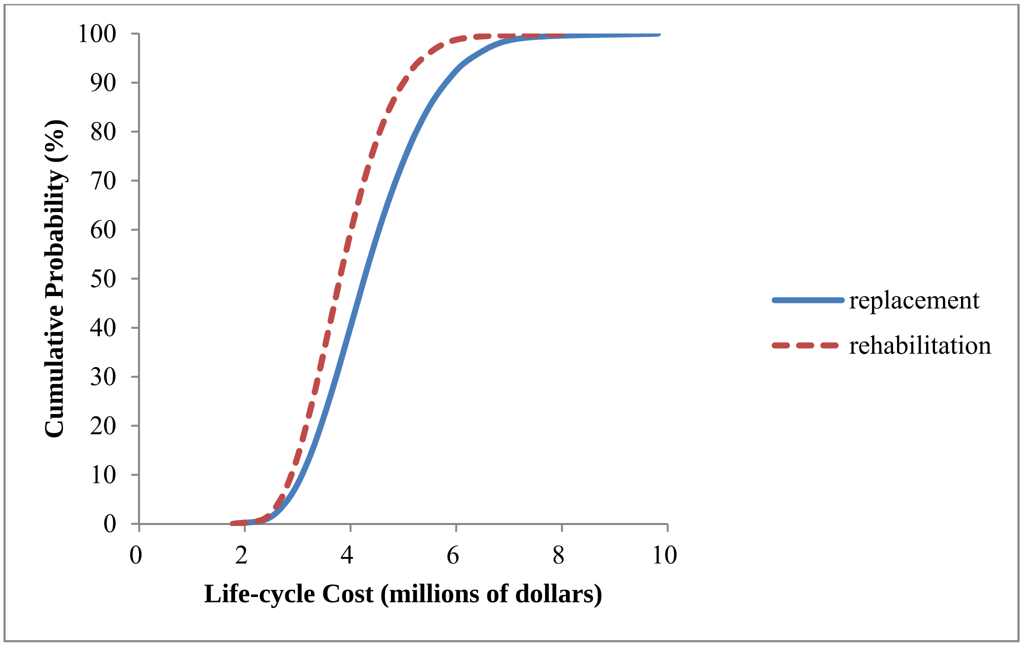


Figure E.49-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 4 (Table 3.6)

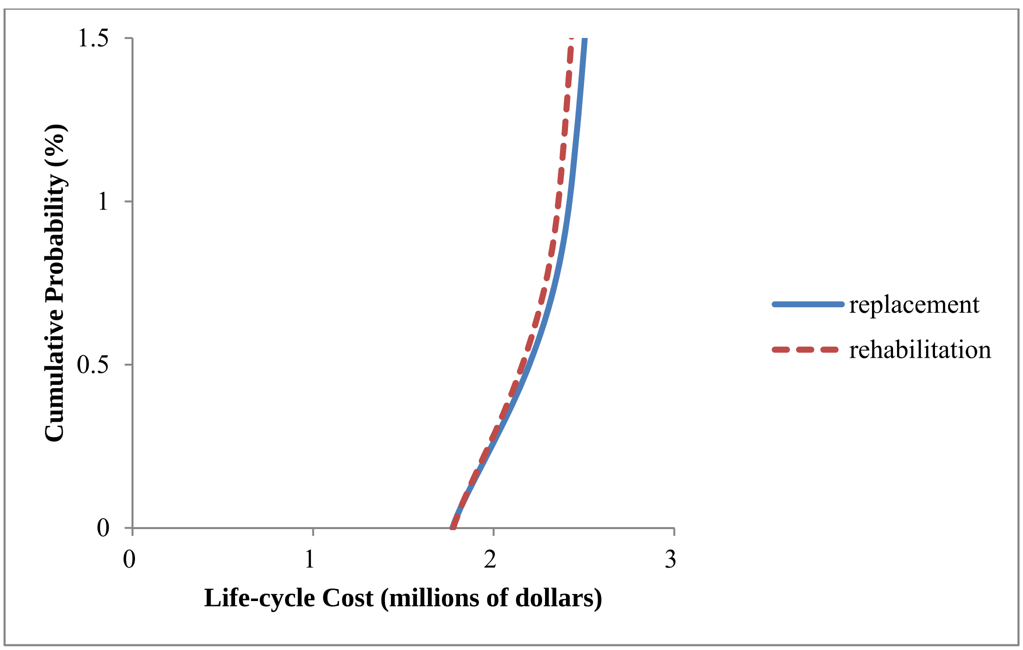


Figure E.50-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 4 (Table 3.6)

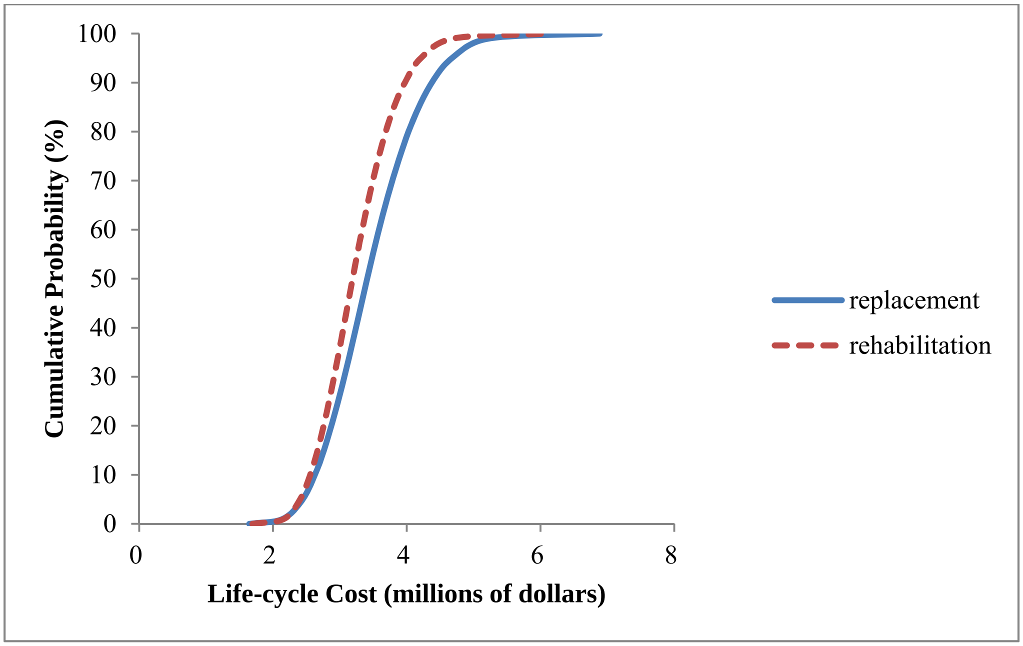


Figure E.51-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 4 (Table 3.6)

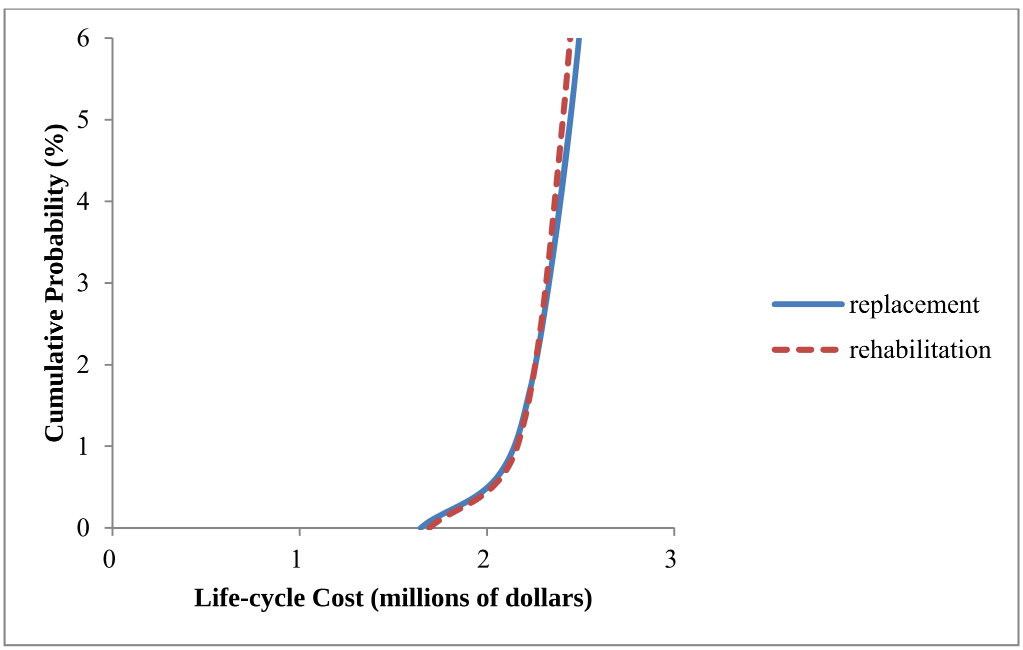


Figure E.52-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 4 (Table 3.6)

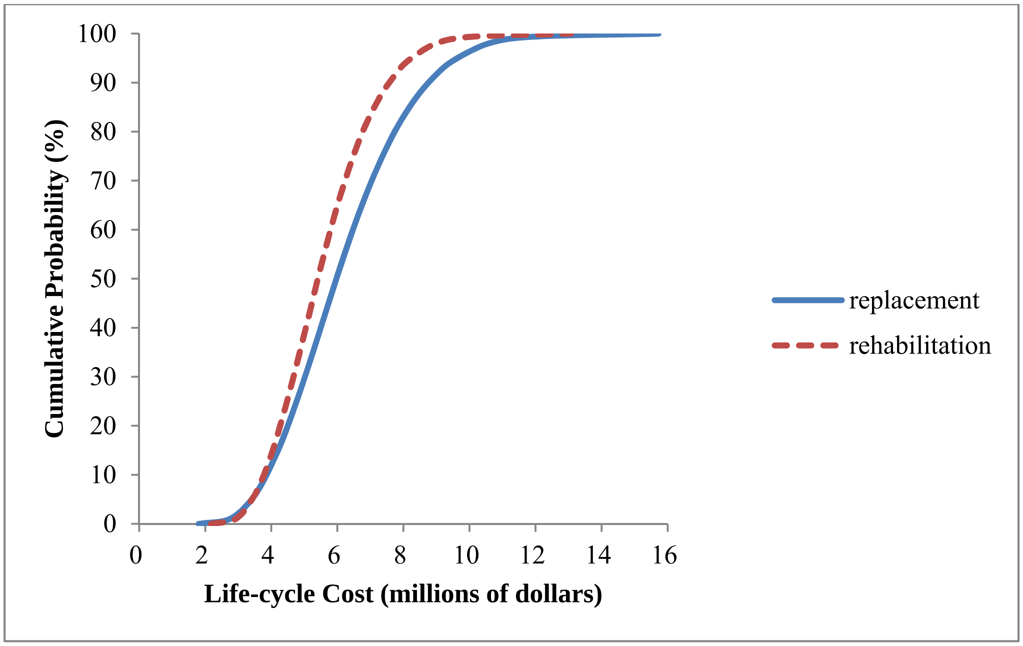


Figure E.53-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 5 (Table 3.6)

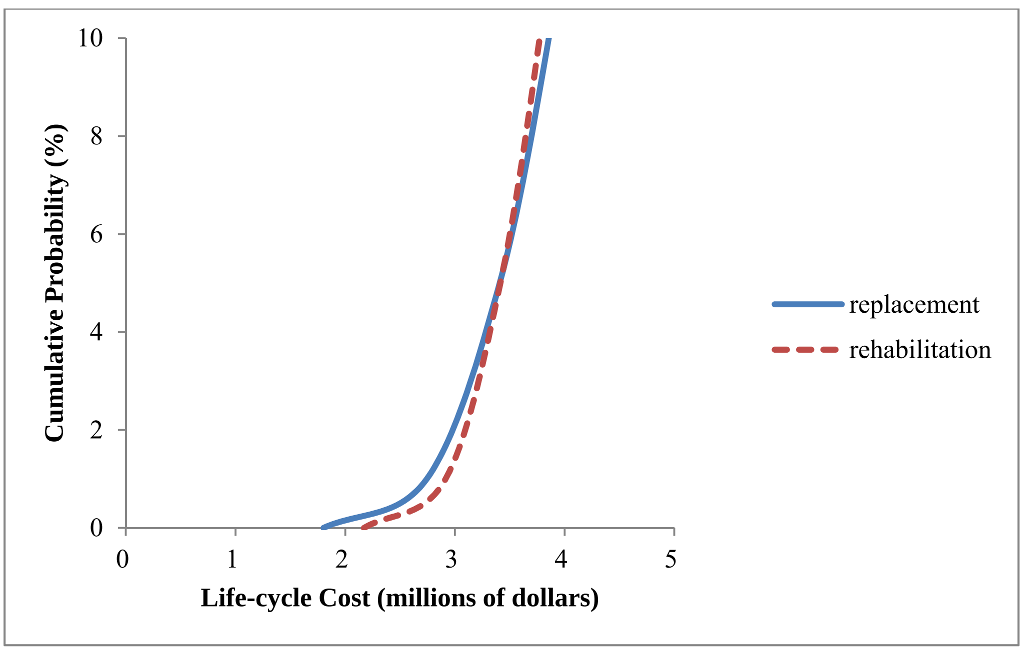


Figure E.54-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 5 (Table 3.6)

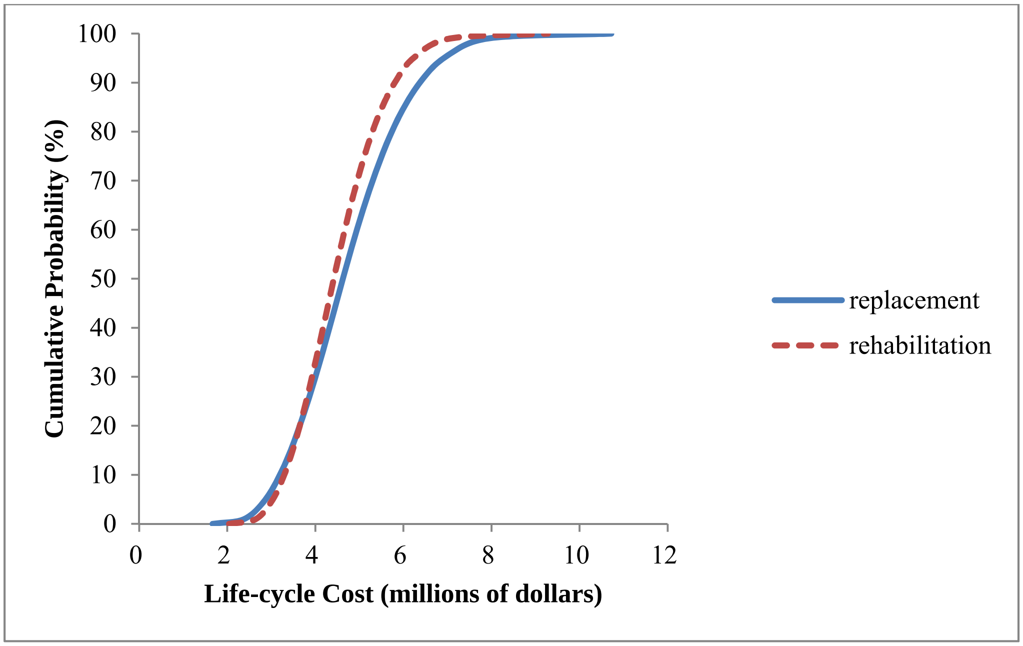


Figure E.55-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 5 (Table 3.6)

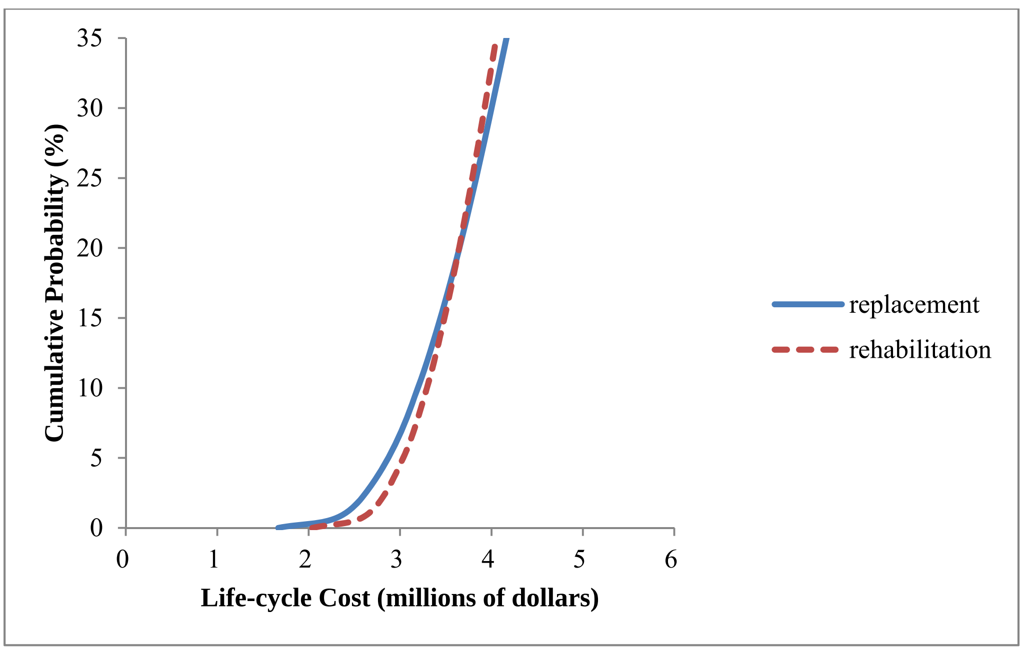


Figure E.56-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 5 (Table 3.6)

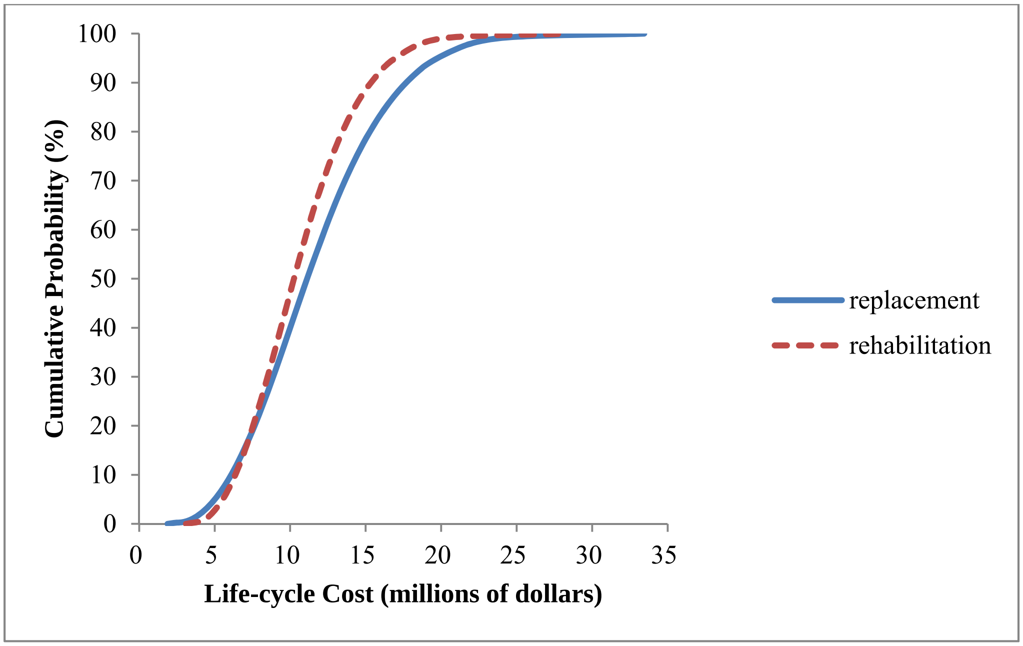


Figure E.57-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 6 (Table 3.6)

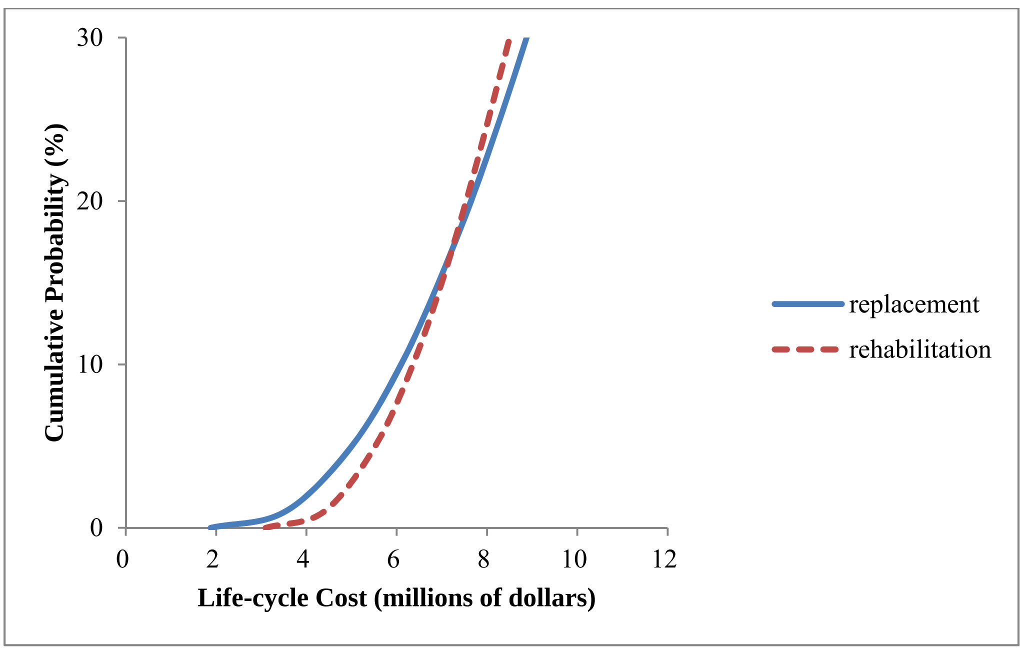


Figure E.58-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 6 (Table 3.6)

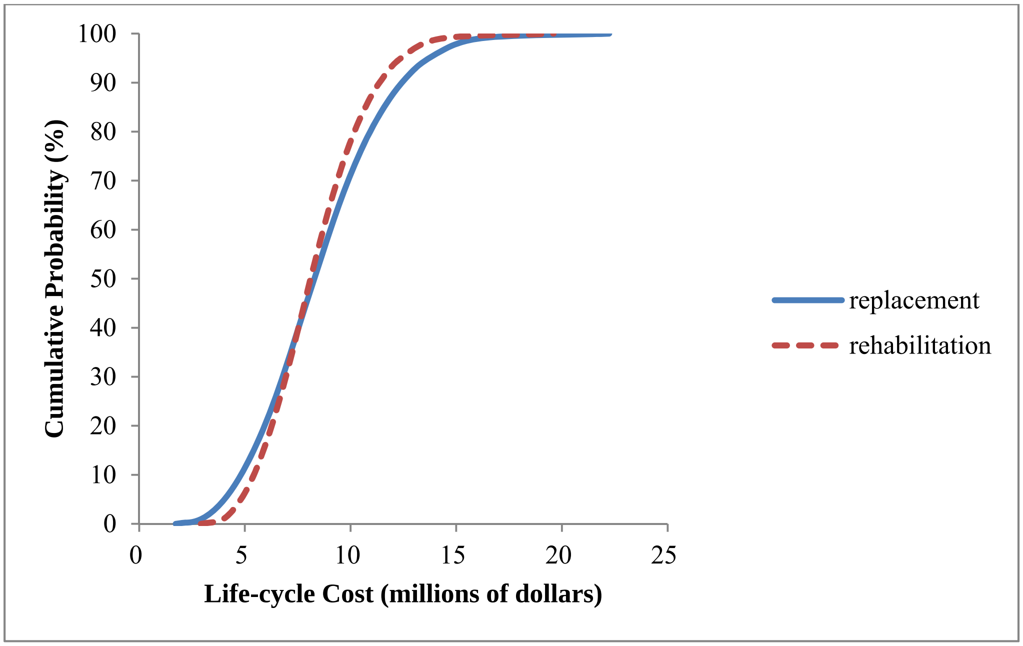


Figure E.59-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 6 (Table 3.6)

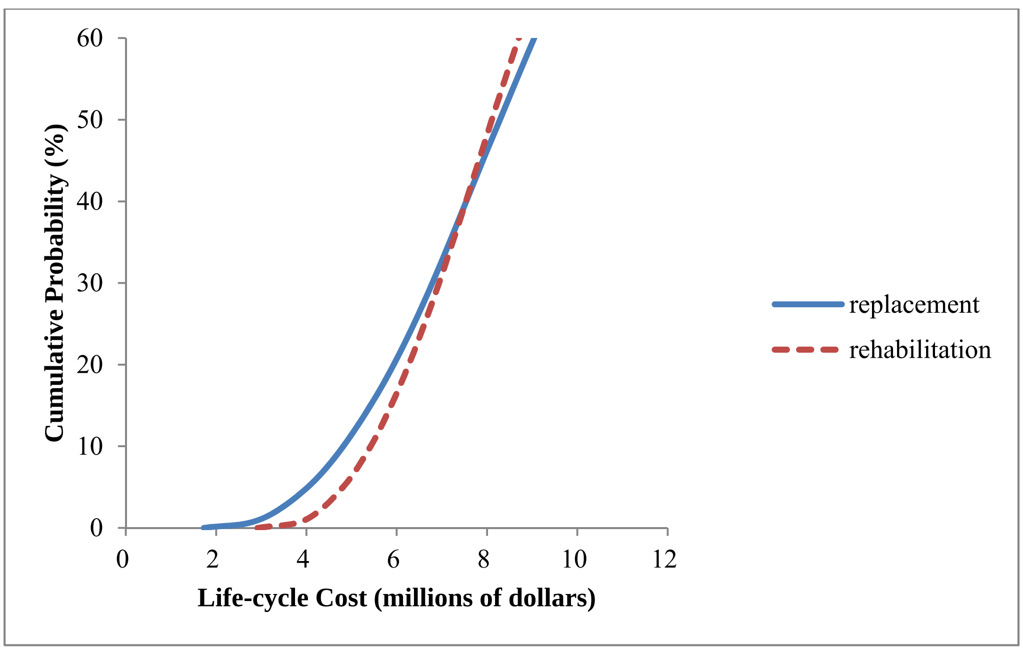


Figure E.60-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 6 (Table 3.6)

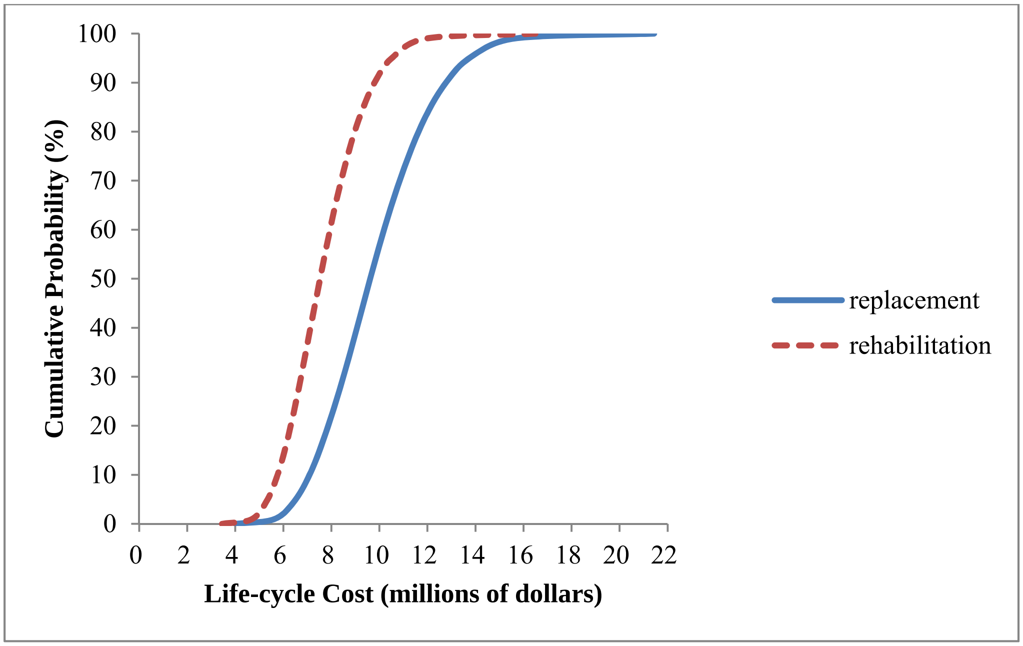


Figure E.61-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 7 (Table 3.6)

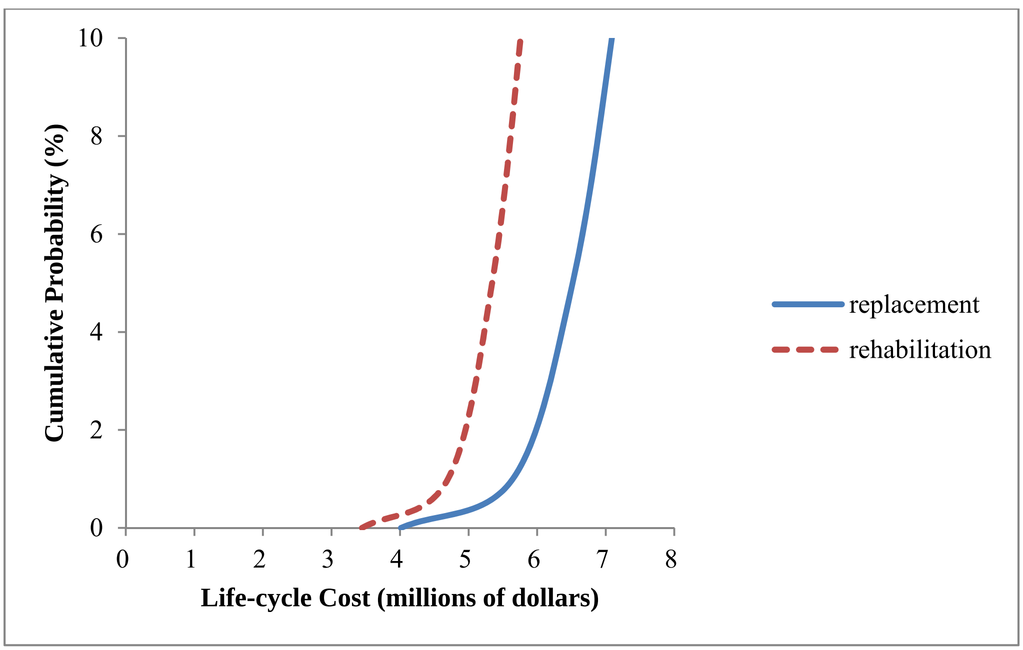


Figure E.62-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 7 (Table 3.6)

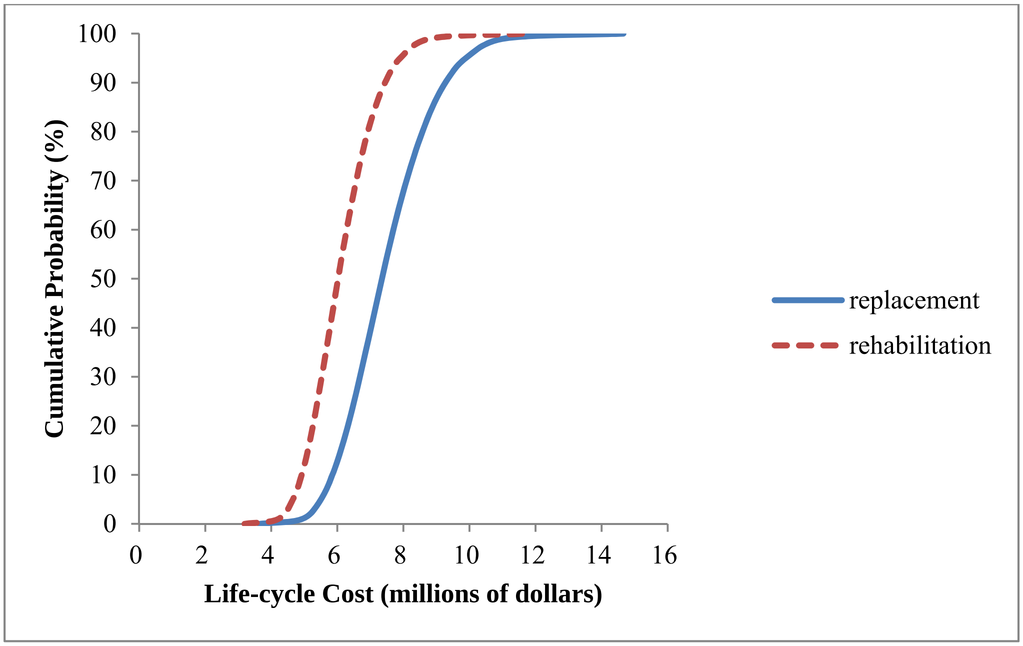


Figure E.63-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 7 (Table 3.6)

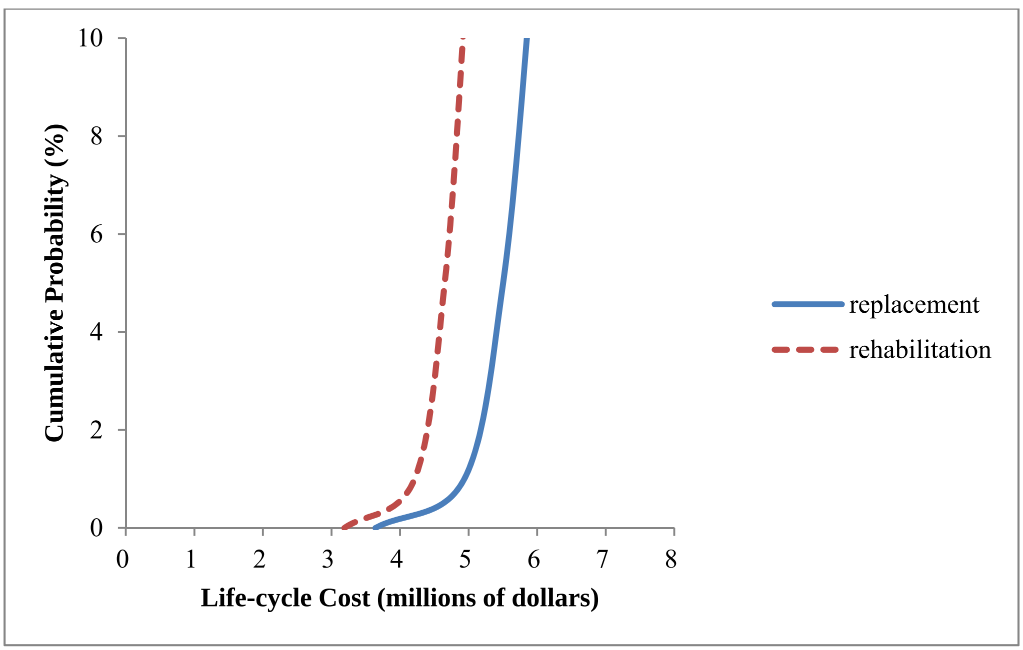


Figure E.64-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 7 (Table 3.6)

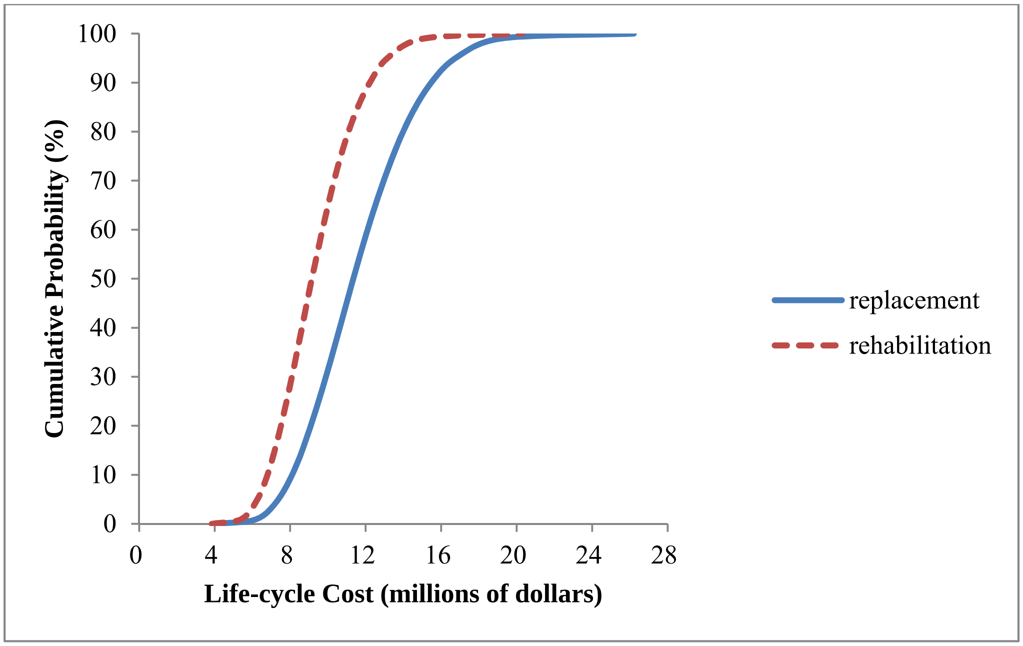


Figure E.65-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 8 (Table 3.6)

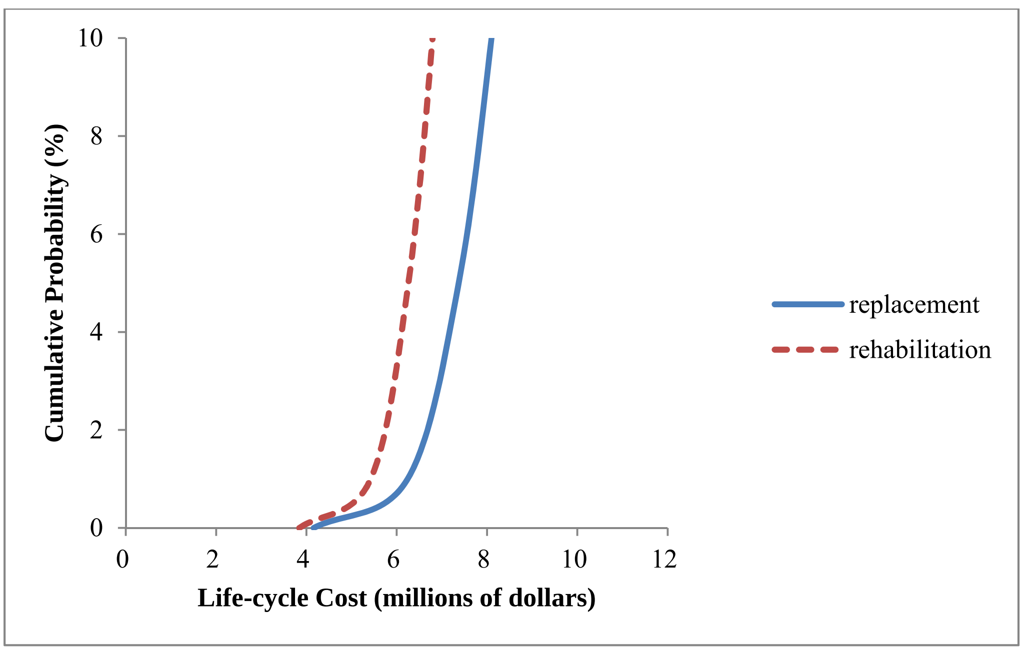


Figure E.66-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 8 (Table 3.6)

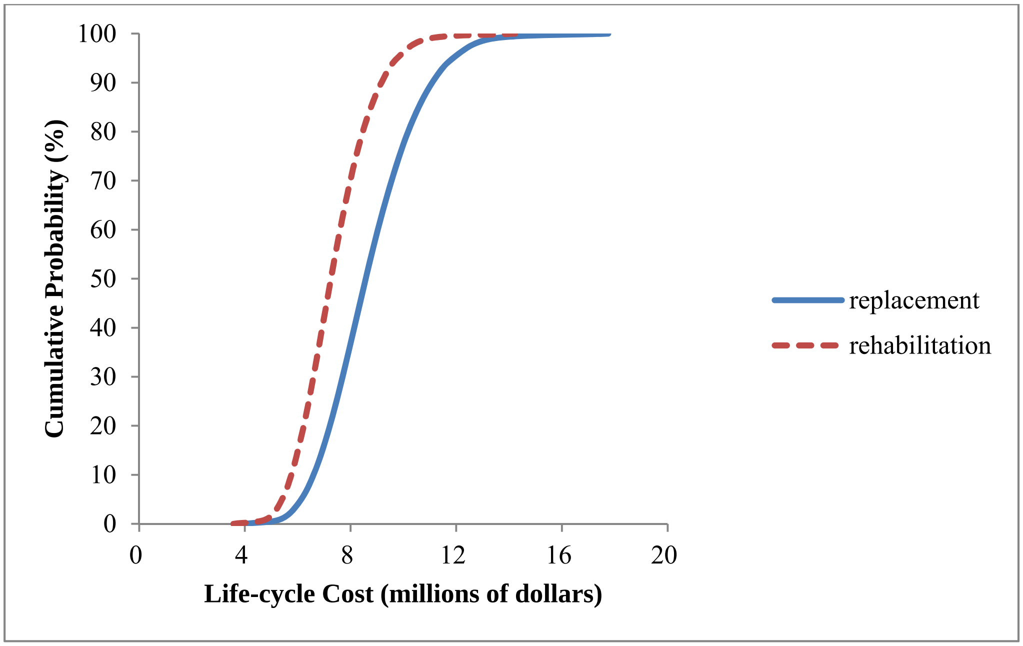


Figure E.67-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 8 (Table 3.6)

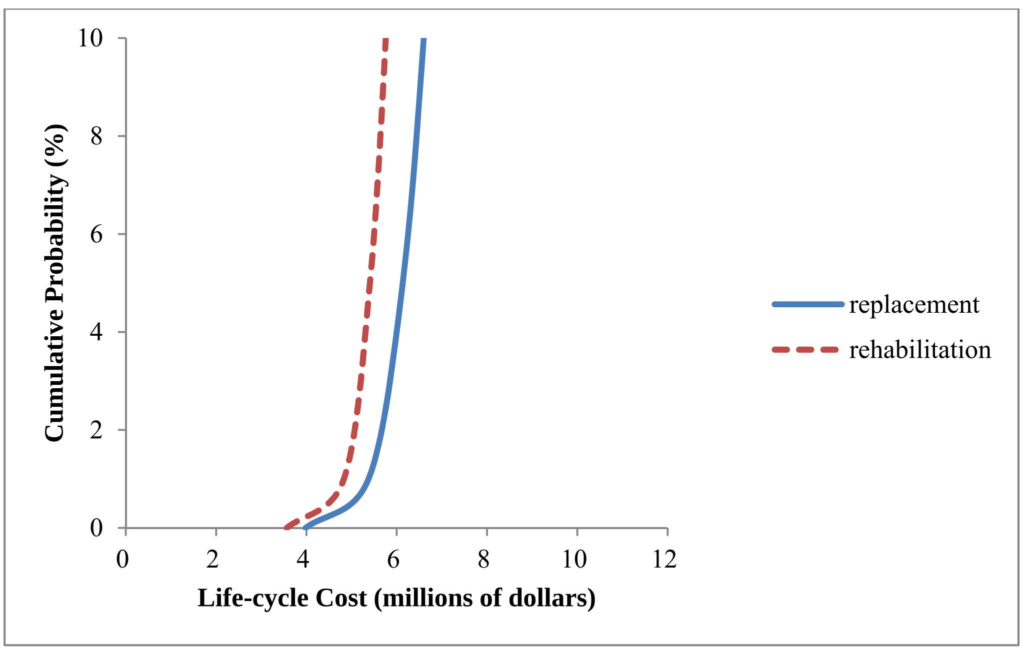


Figure E.68-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 8 (Table 3.6)

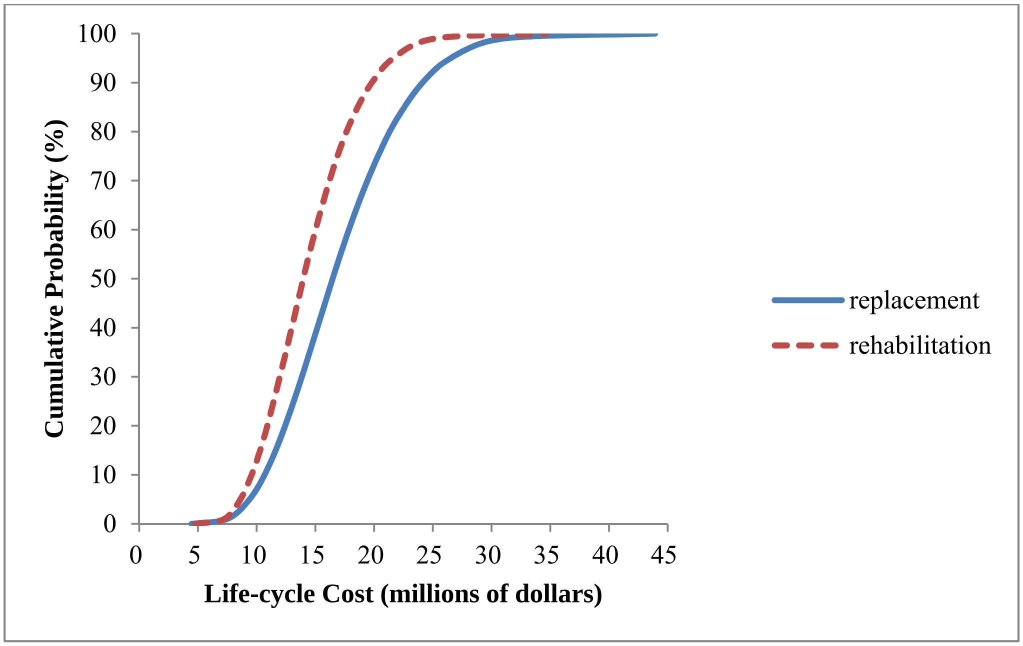


Figure E.69-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 9 (Table 3.6)

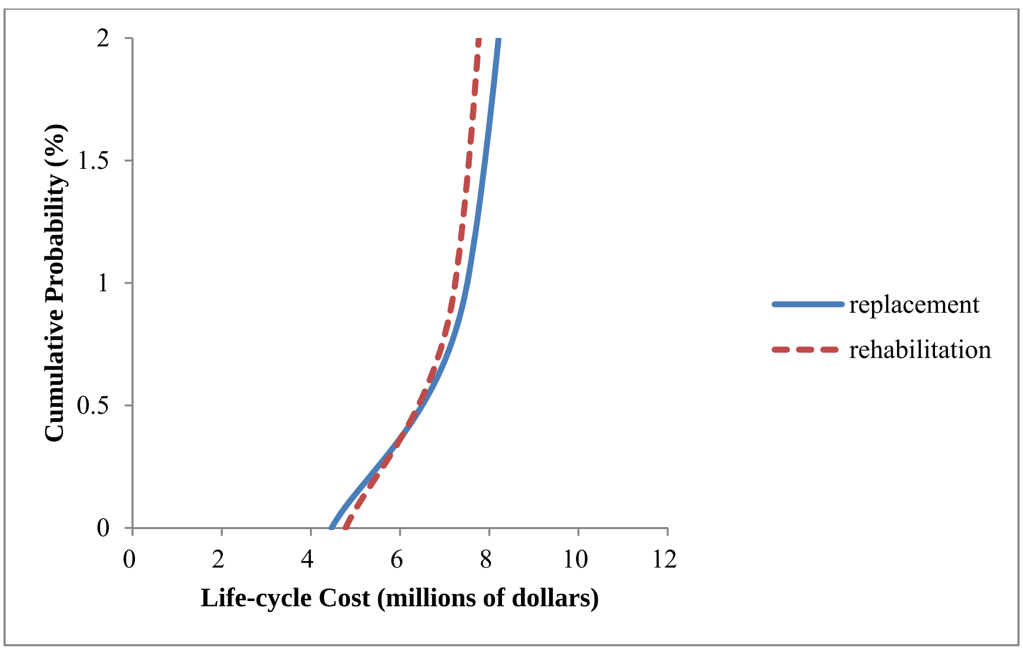


Figure E.70-Ascending cumulative probability distributions for highway bridge with modification 1a ADT case 9 (Table 3.6)

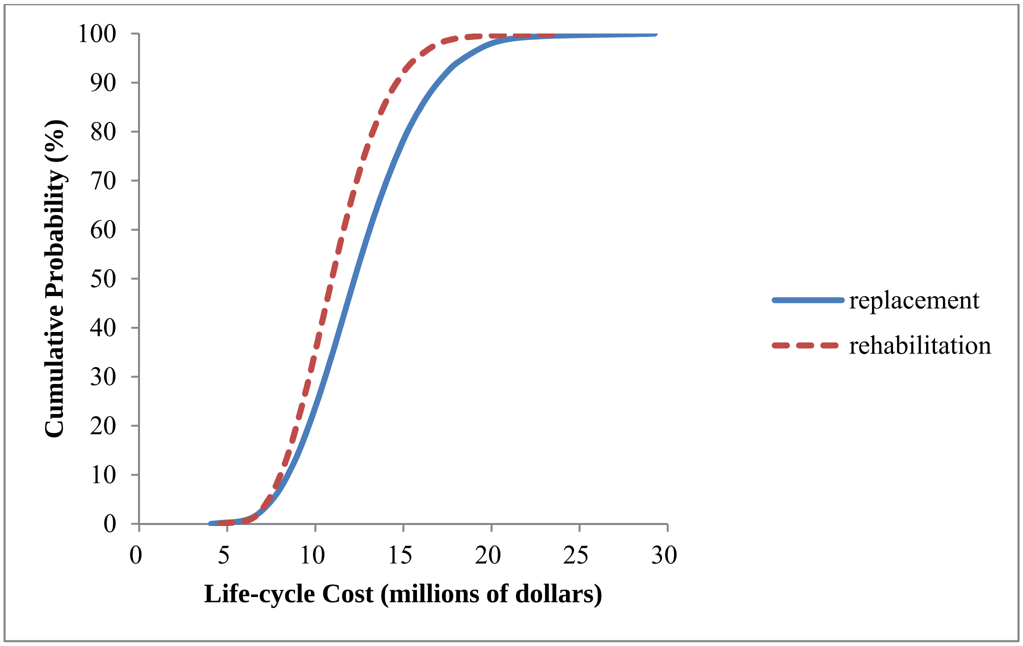


Figure E.71-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 9 (Table 3.6)

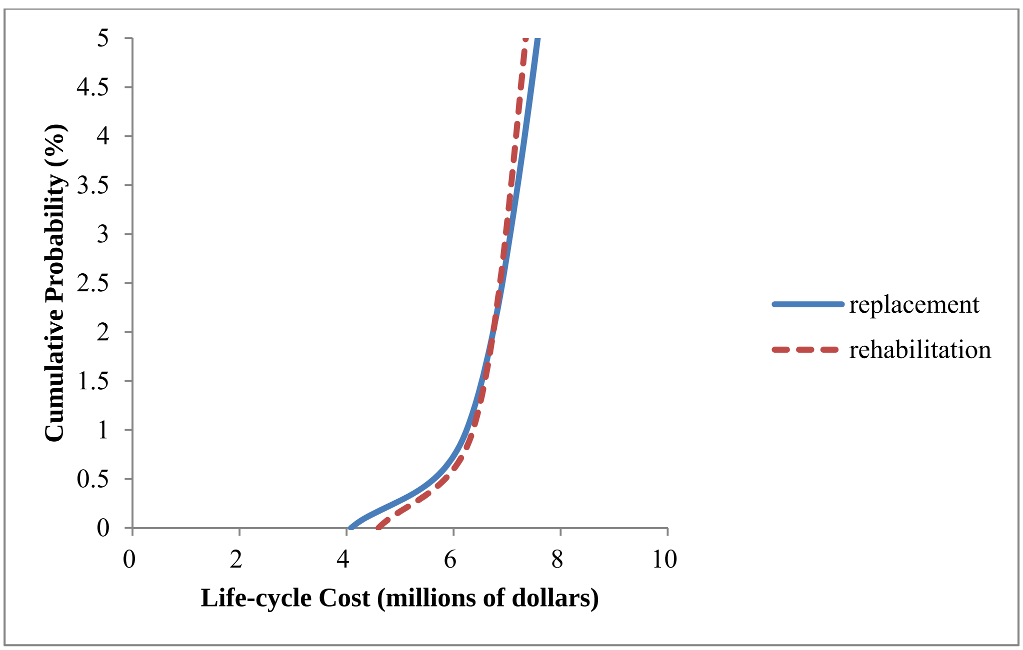


Figure E.72-Ascending cumulative probability distributions for highway bridge with modification 2a ADT case 9 (Table 3.6)

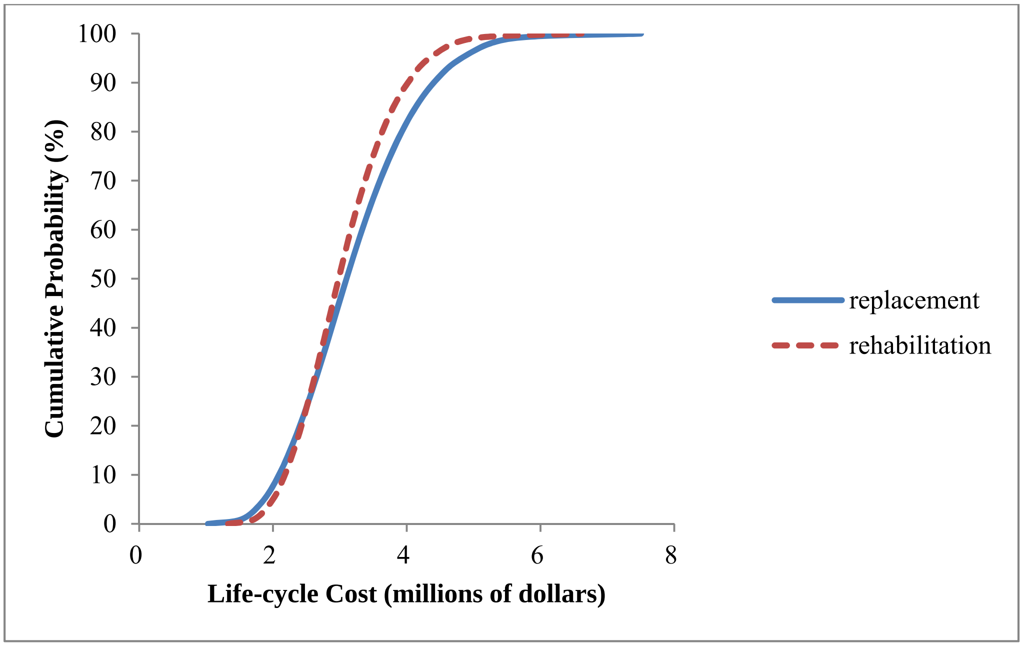


Figure E.73-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 1 (Table 3.6)

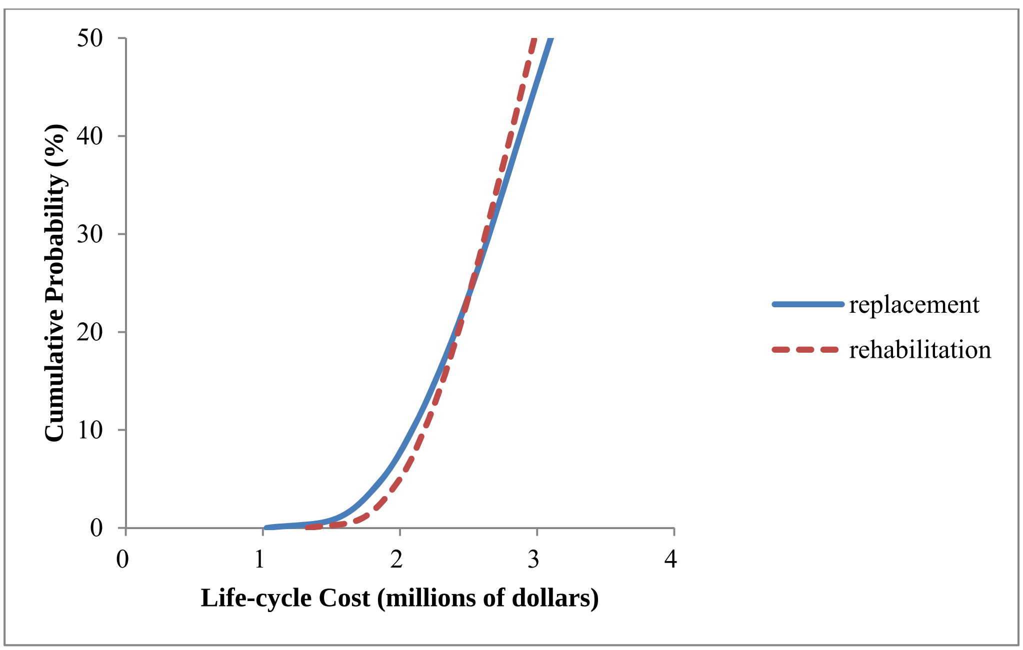


Figure E.74-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 1 (Table 3.6)

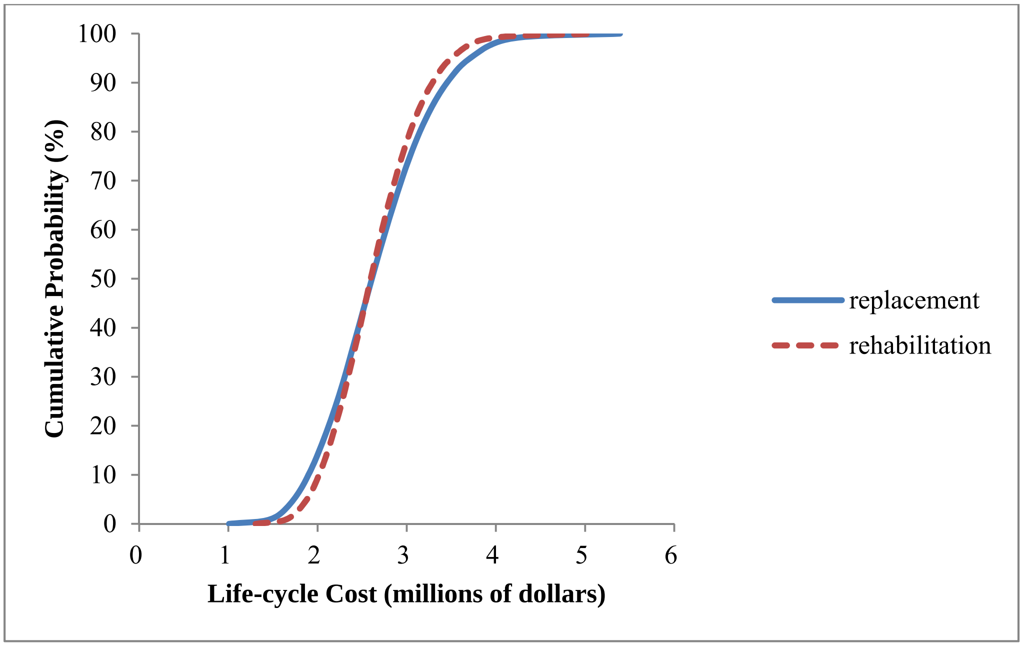


Figure E.75-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 1 (Table 3.6)

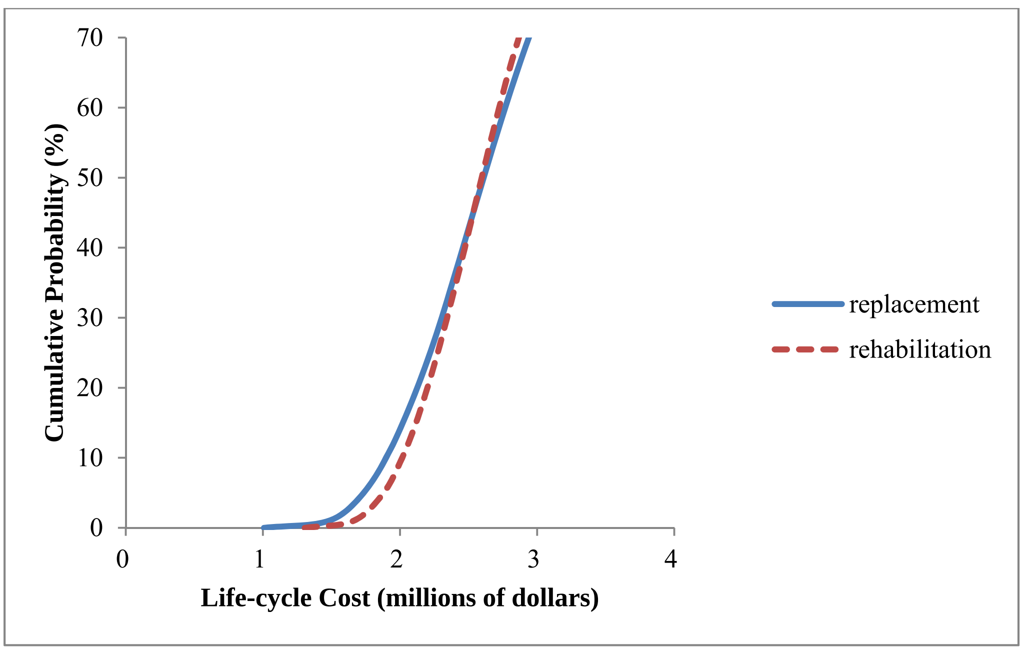


Figure E.76-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 1 (Table 3.6)

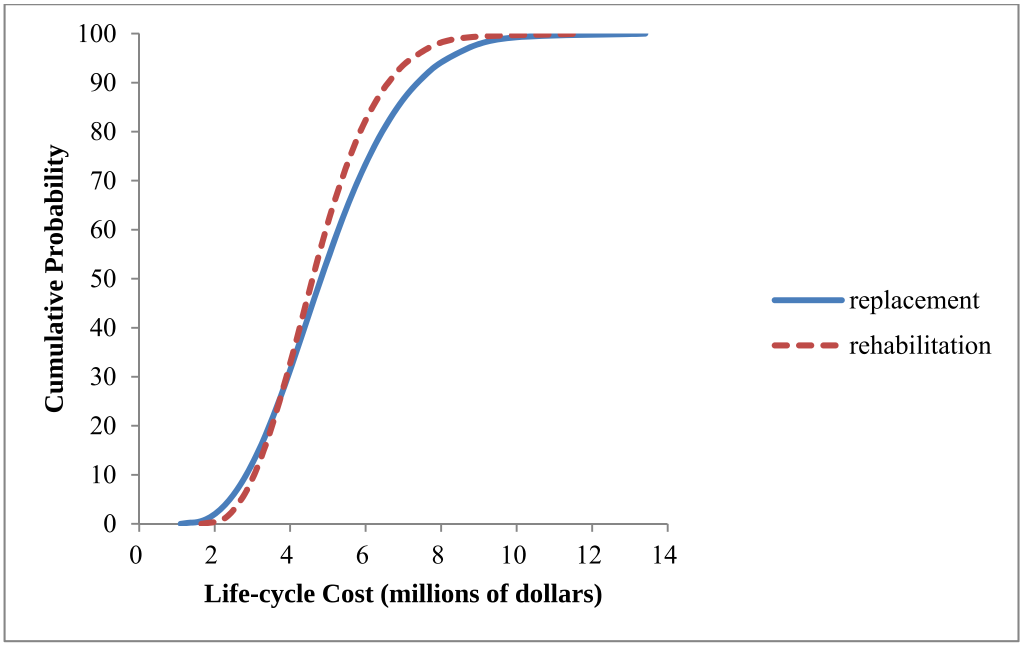


Figure E.77-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 2 (Table 3.6)

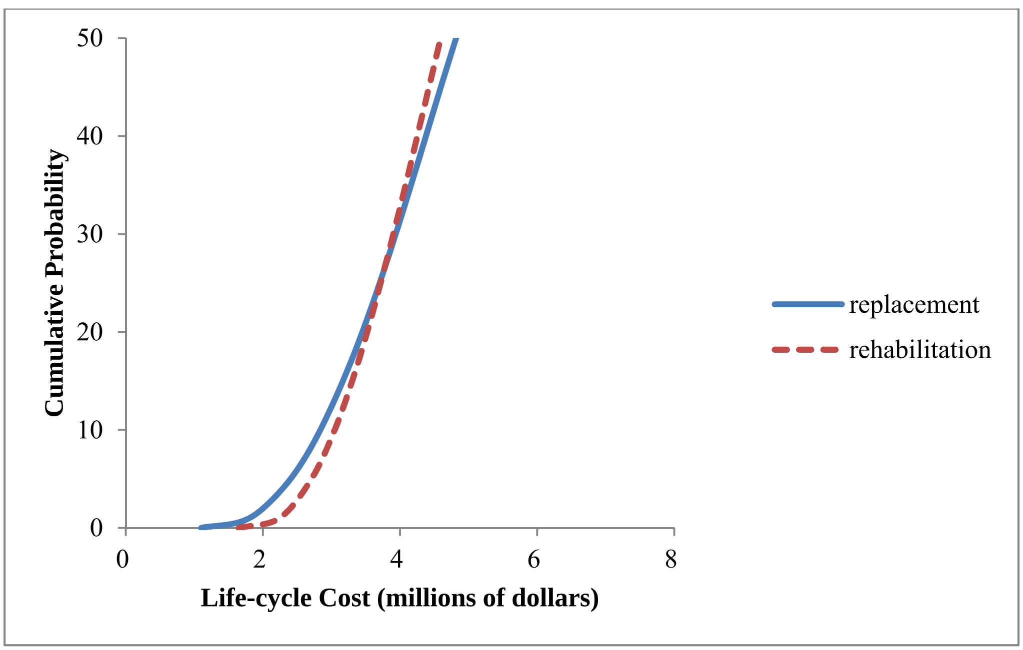


Figure E.78-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 2 (Table 3.6)

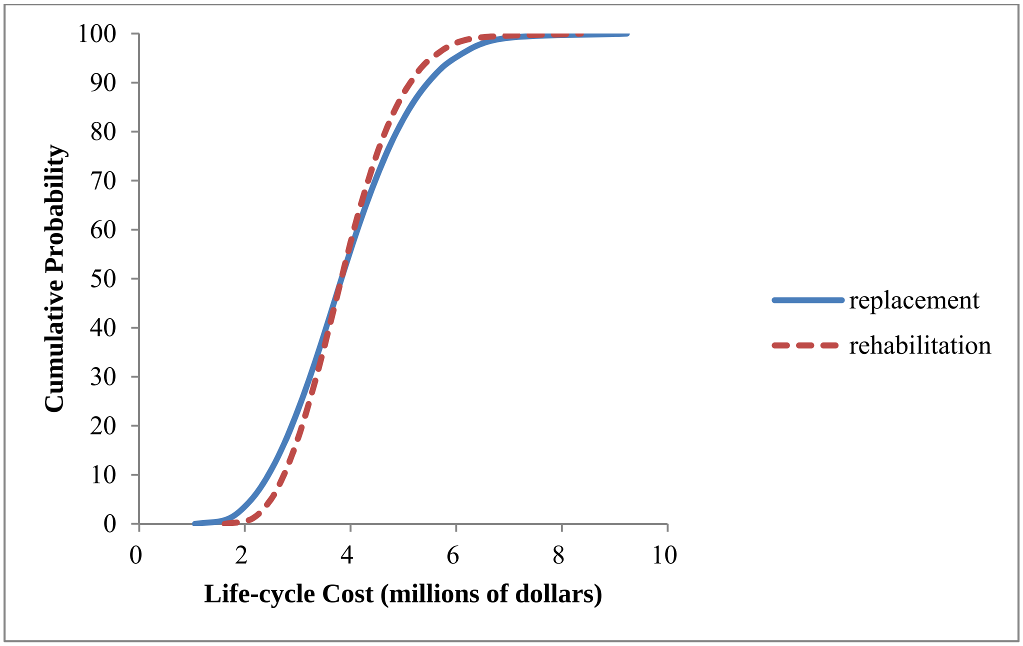


Figure E.79-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 2 (Table 3.6)

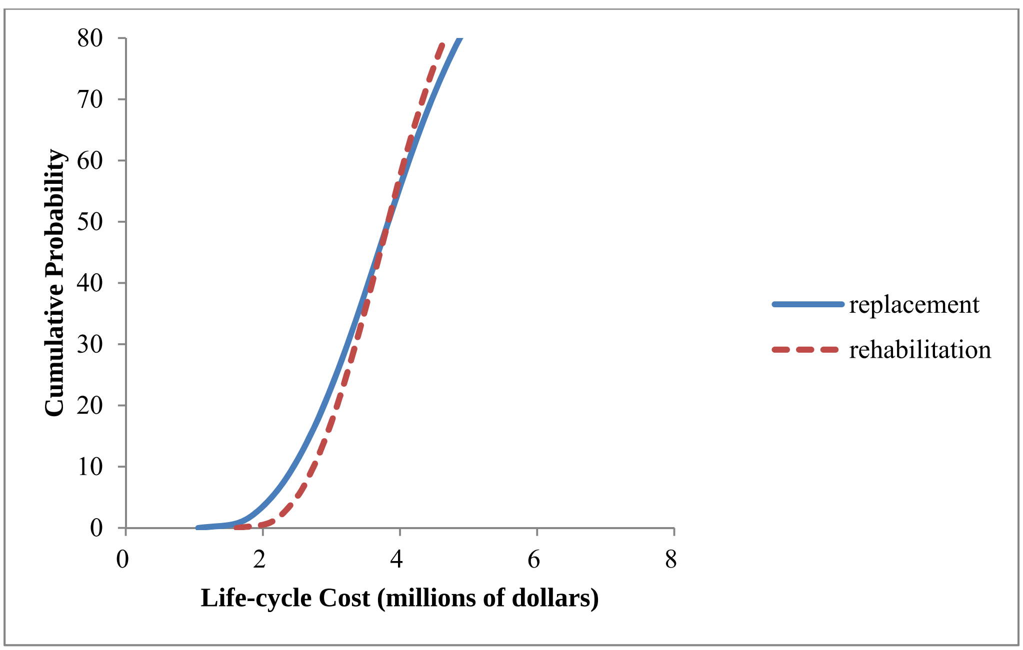


Figure E.80-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 2 (Table 3.6)

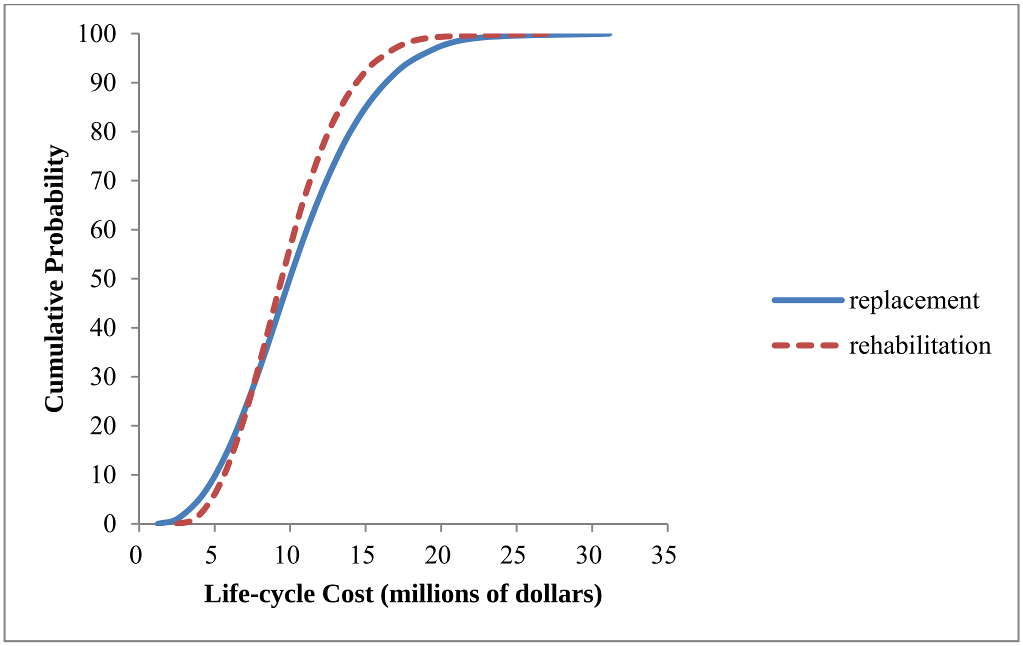


Figure E.81-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 3 (Table 3.6)

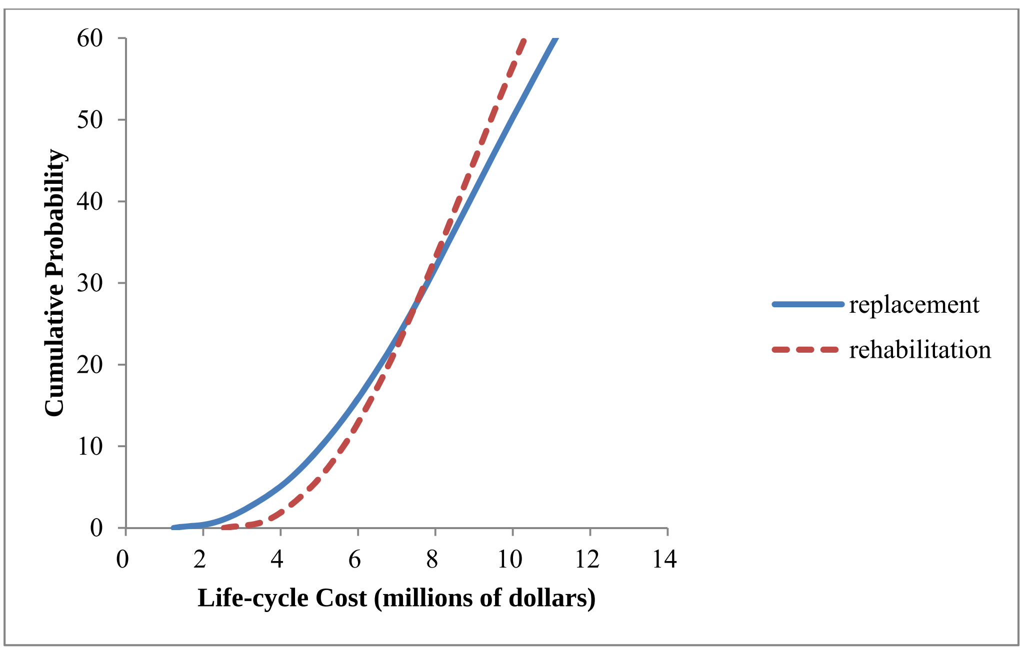


Figure E.82-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 3 (Table 3.6)

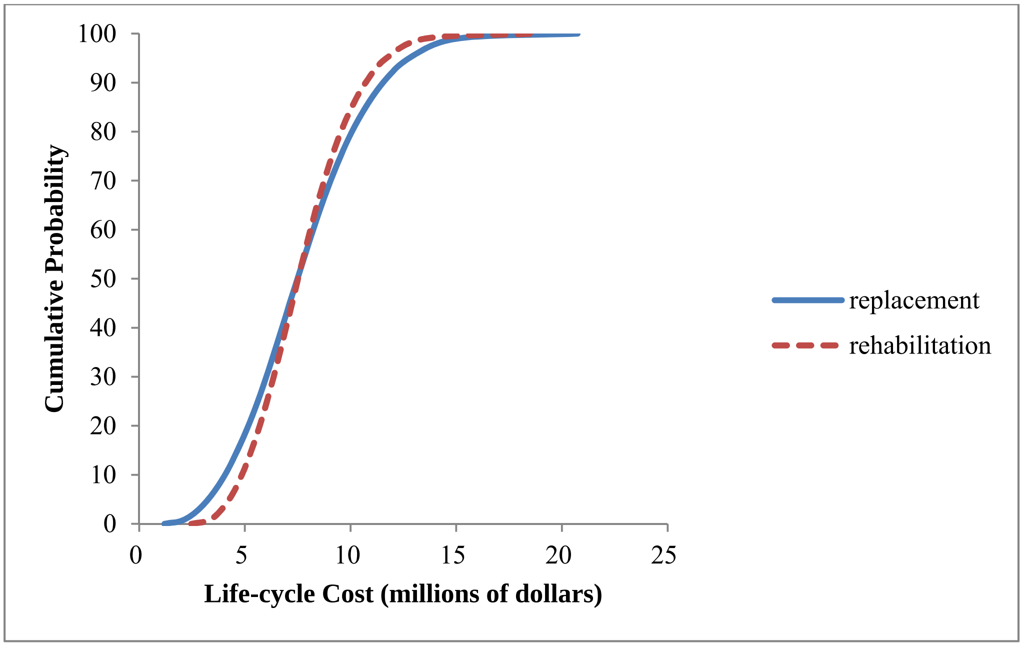


Figure E.83-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 3 (Table 3.6)

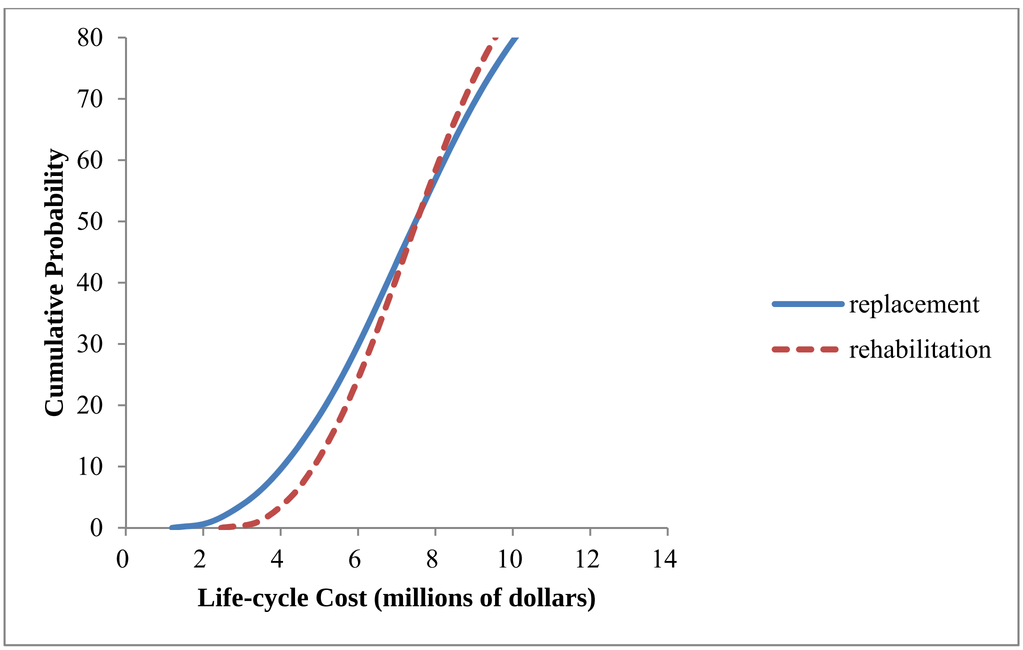


Figure E.84-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 3 (Table 3.6)

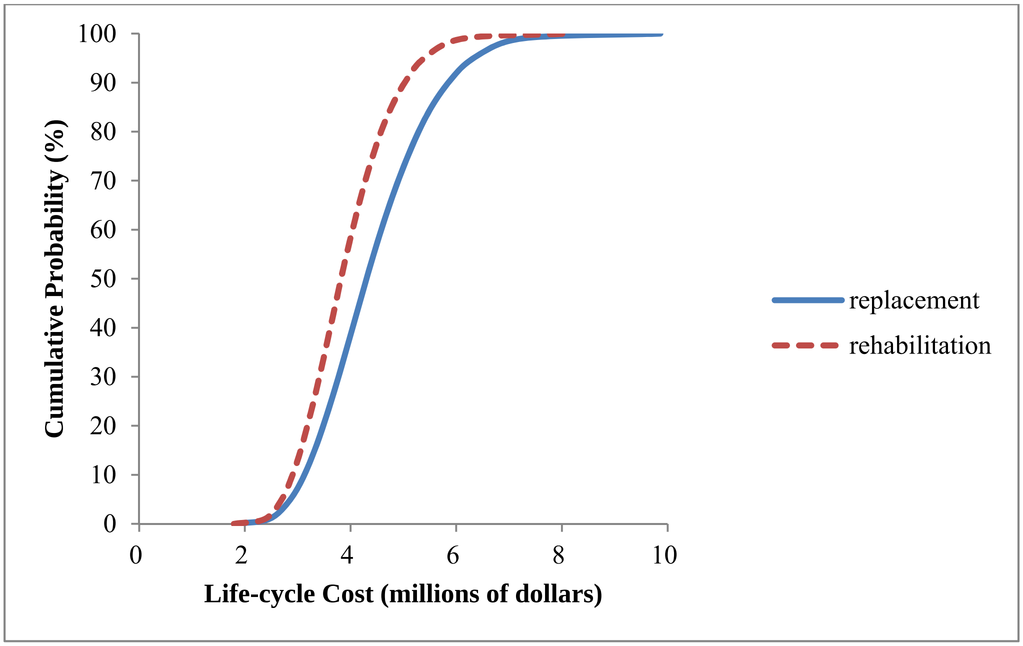


Figure E.85-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 4 (Table 3.6)

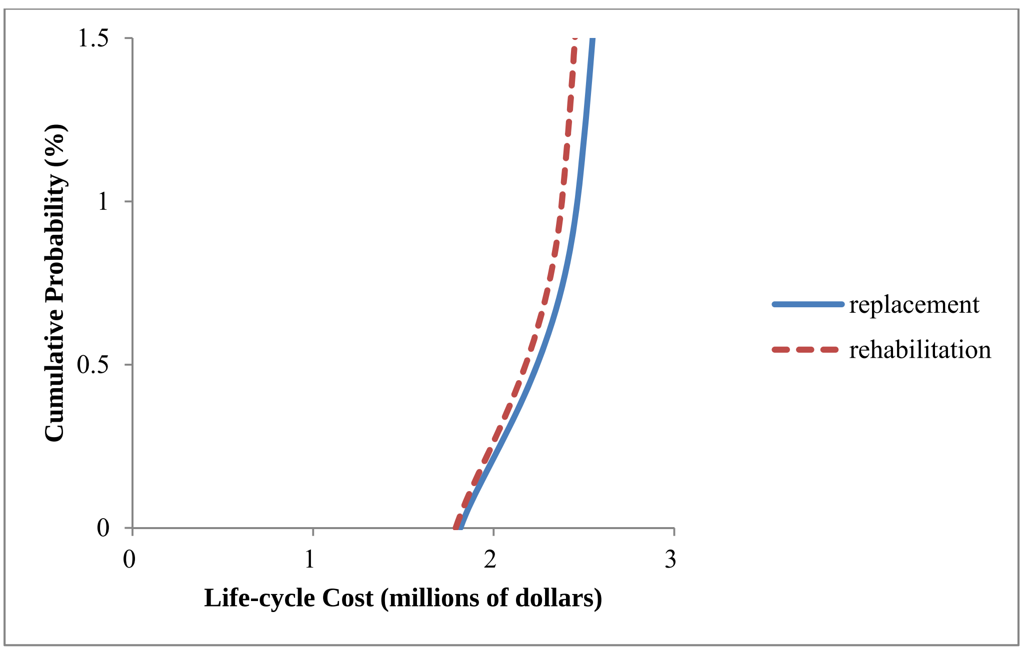


Figure E.86-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 4 (Table 3.6)

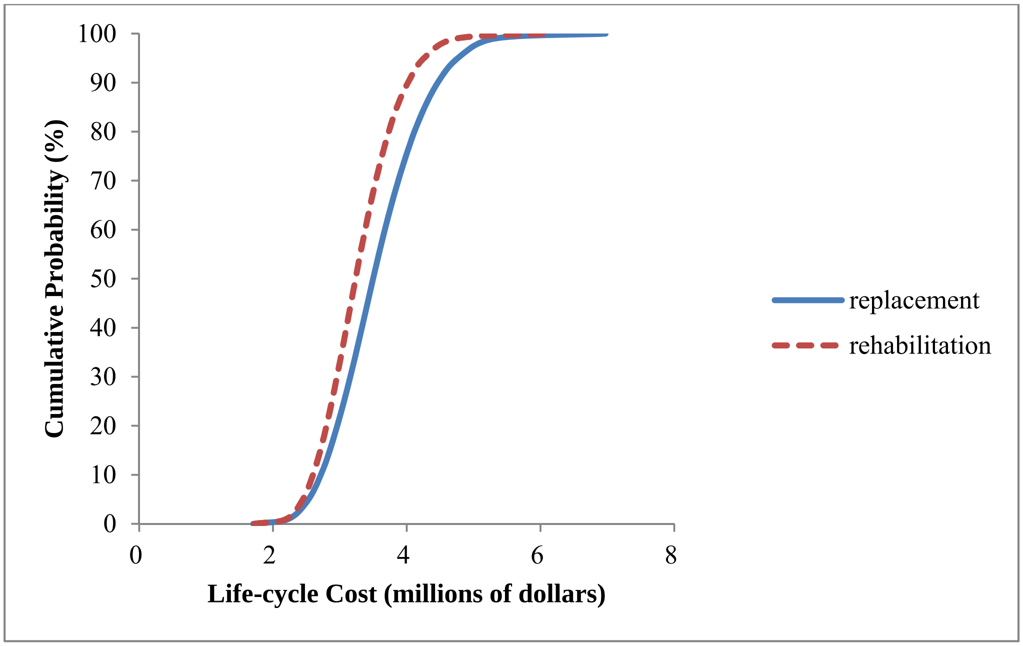


Figure E.87-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 4 (Table 3.6)

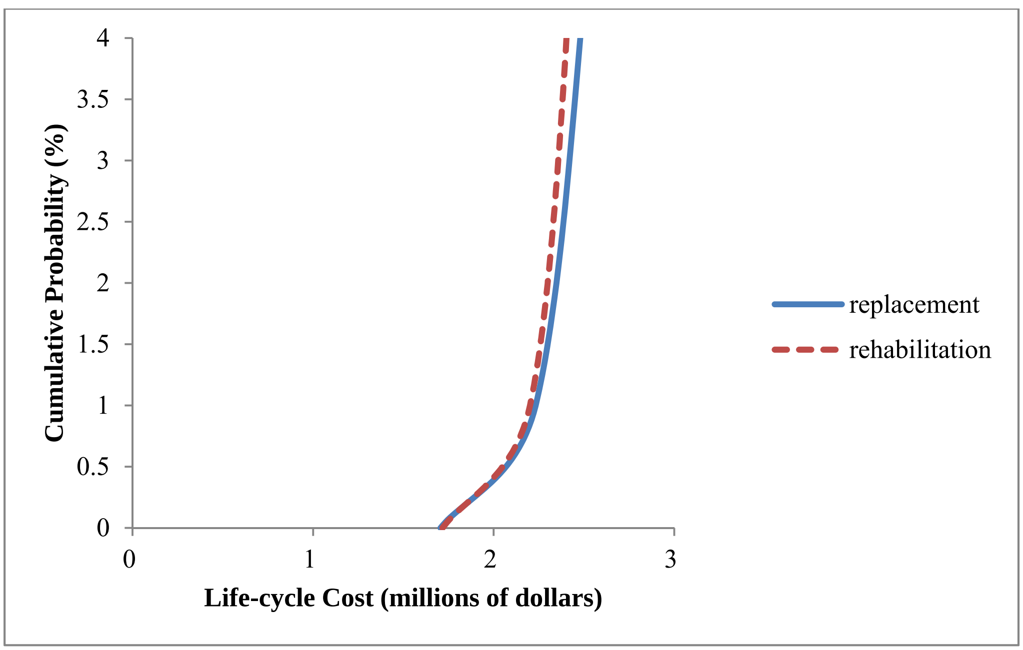


Figure E.88-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 4 (Table 3.6)

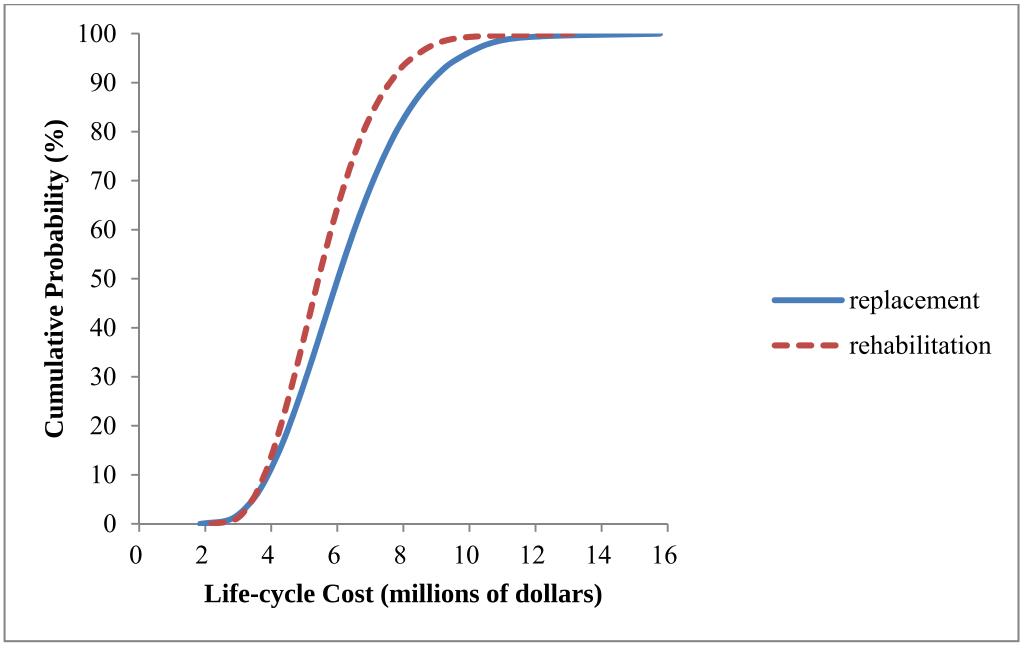


Figure E.89-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 5 (Table 3.6)

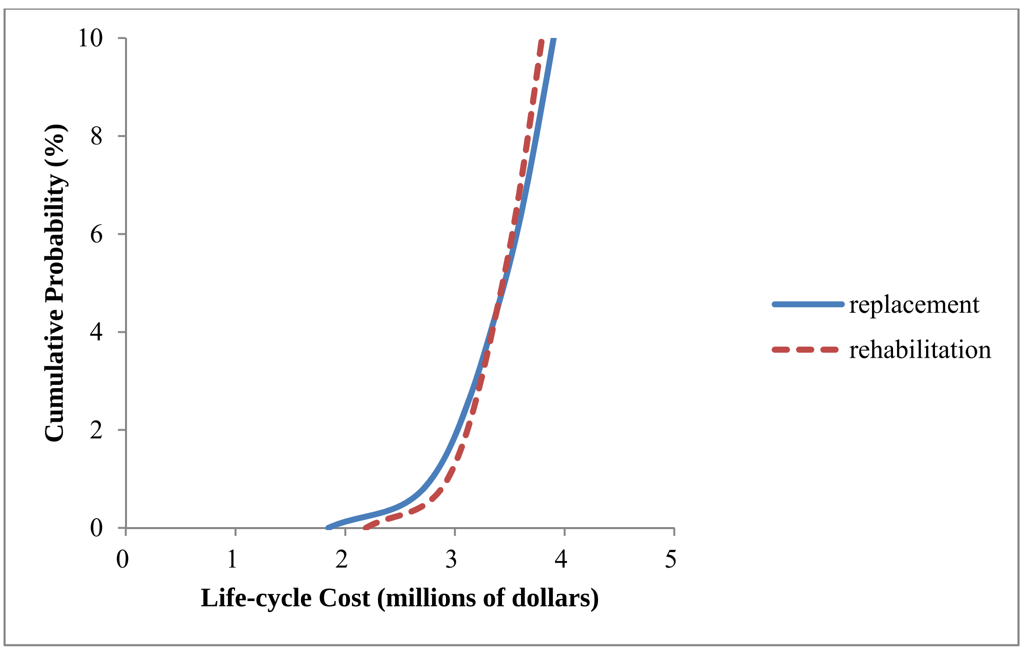


Figure E.90-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 5 (Table 3.6)

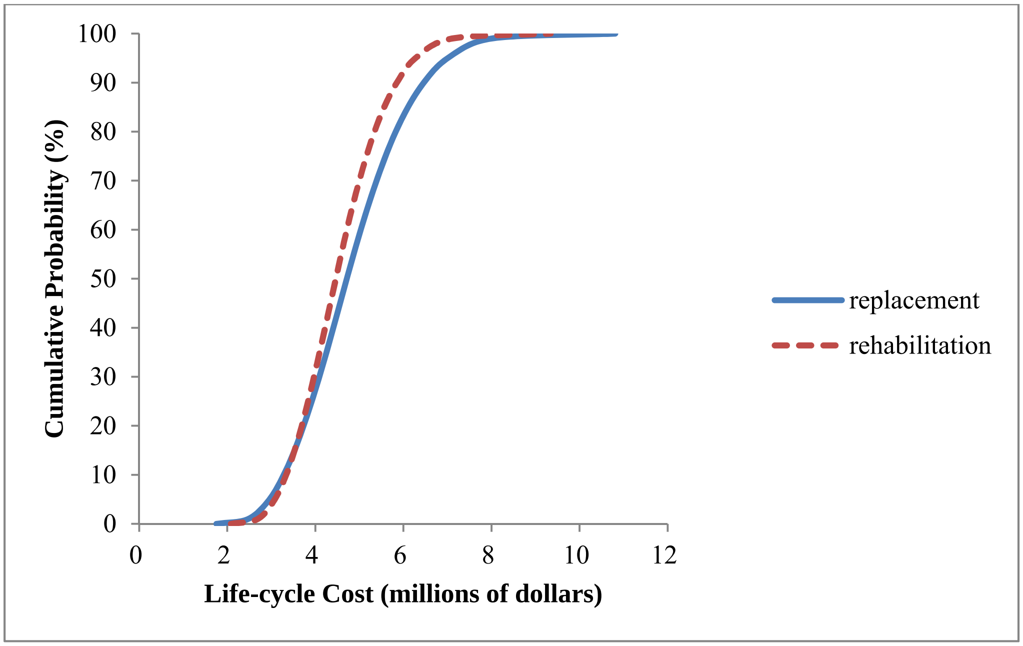


Figure E.91-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 5 (Table 3.6)

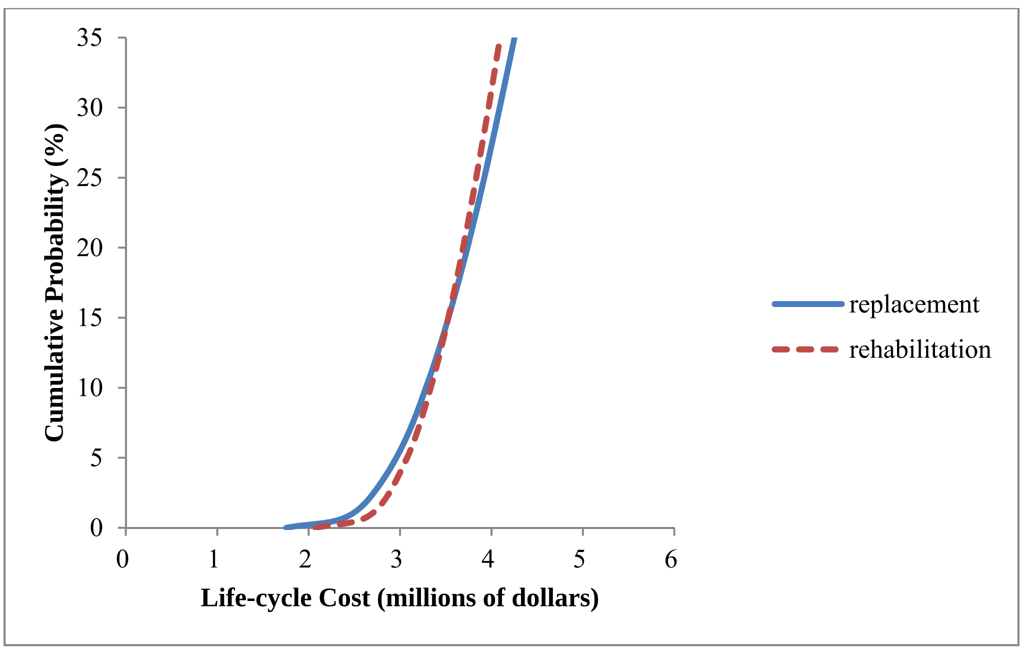


Figure E.92-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 5 (Table 3.6)

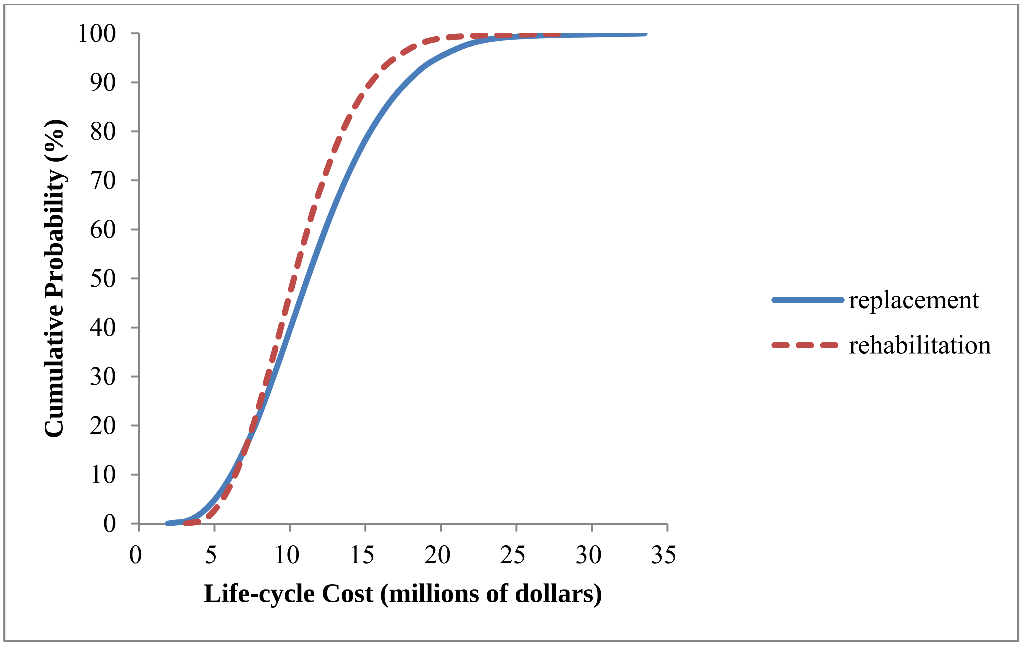


Figure E.93-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 6 (Table 3.6)

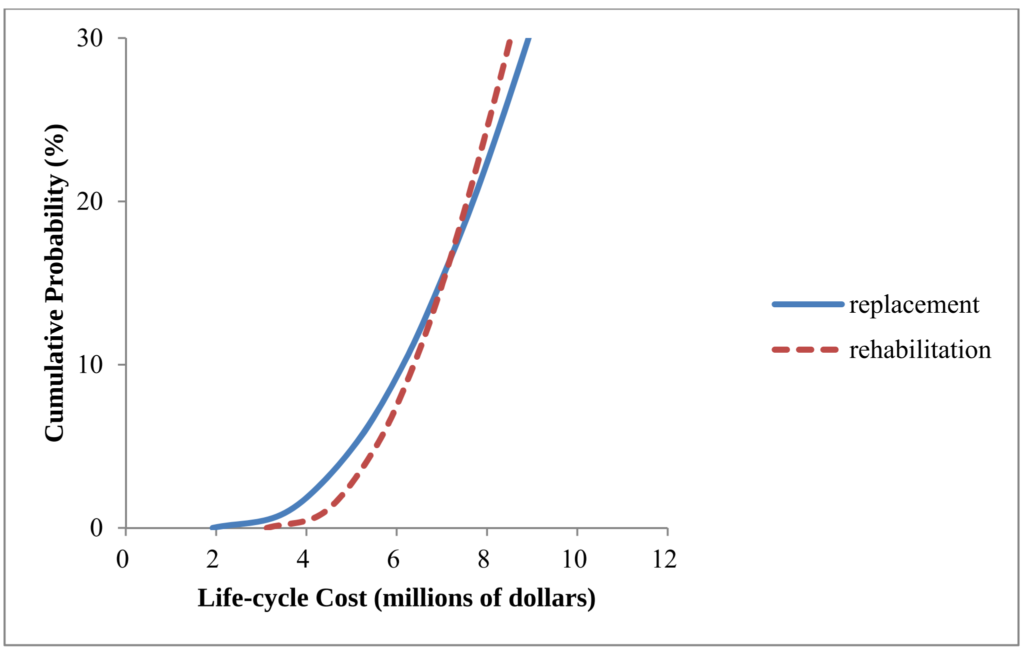


Figure E.94-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 6 (Table 3.6)

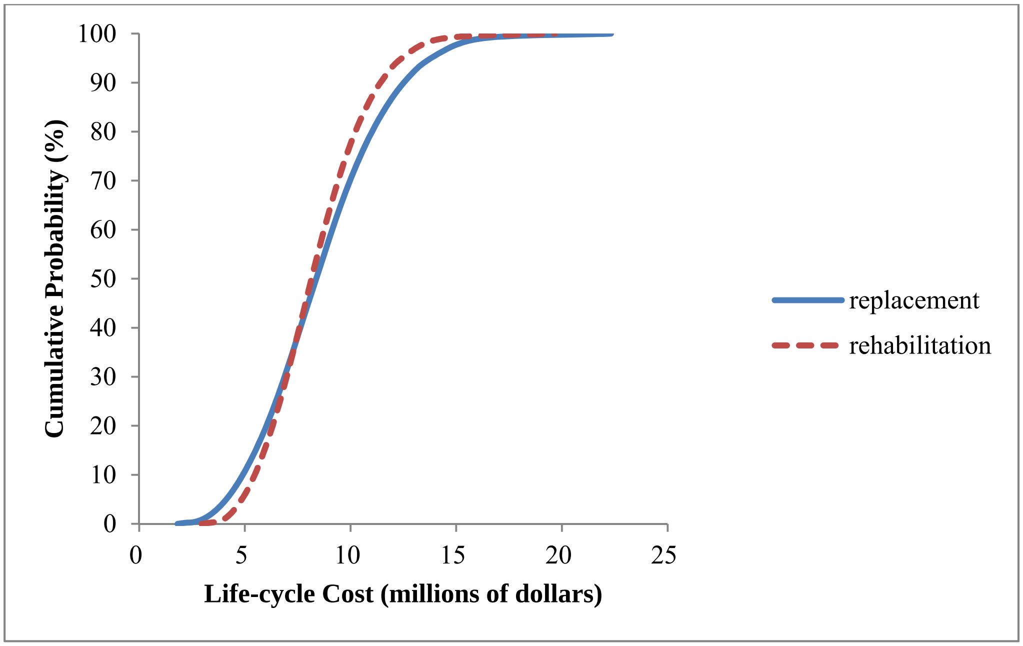


Figure E.95-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 6 (Table 3.6)

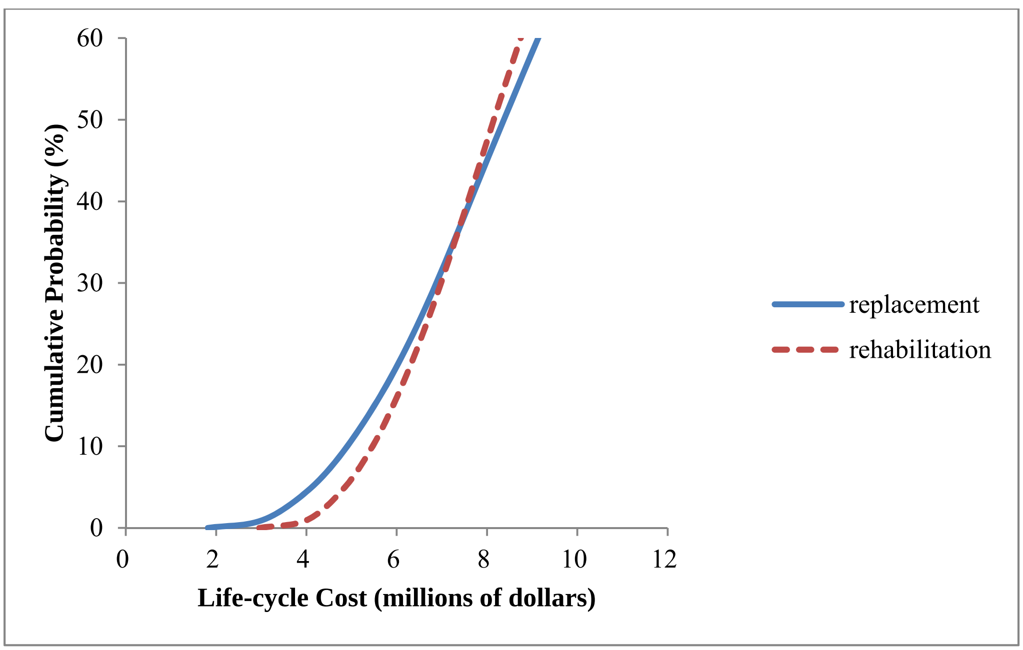


Figure E.96-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 6 (Table 3.6)

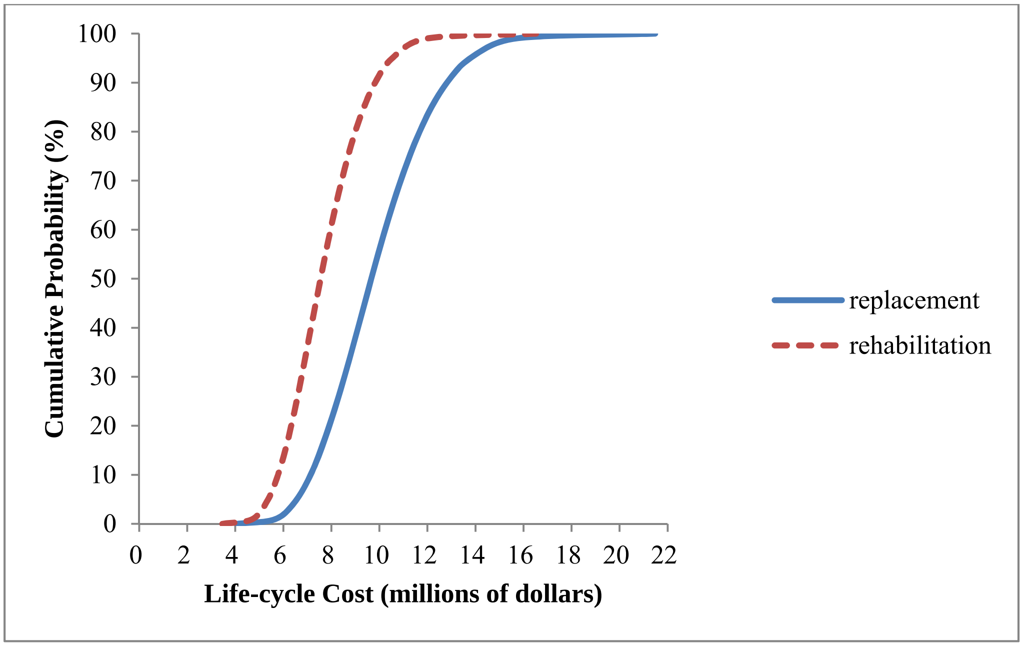


Figure E.97-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 7 (Table 3.6)

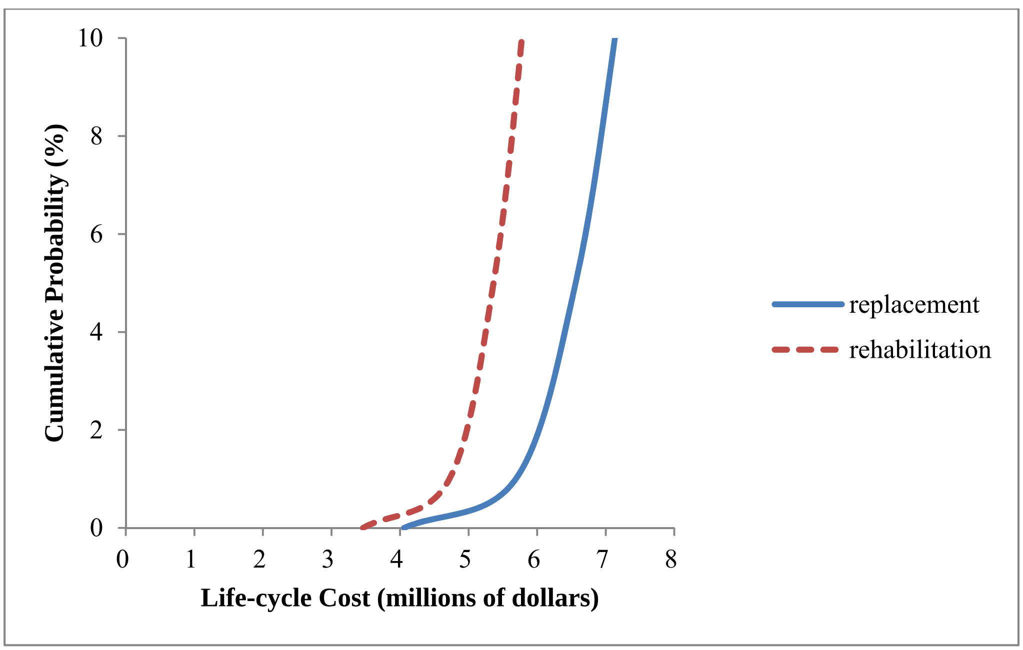


Figure E.98-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 7 (Table 3.6)

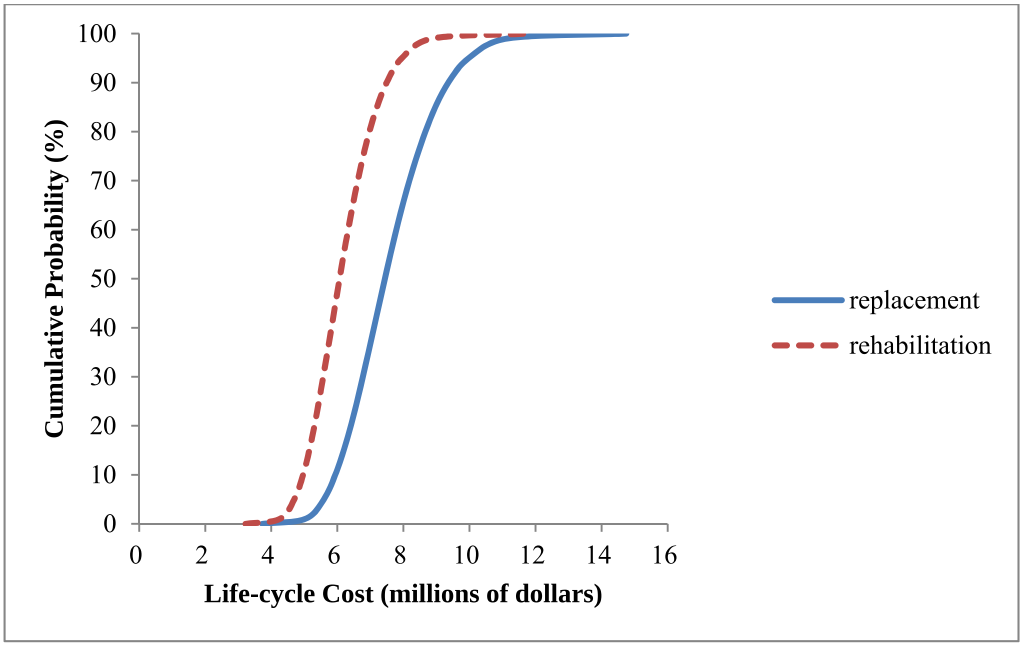


Figure E.99-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 7 (Table 3.6)

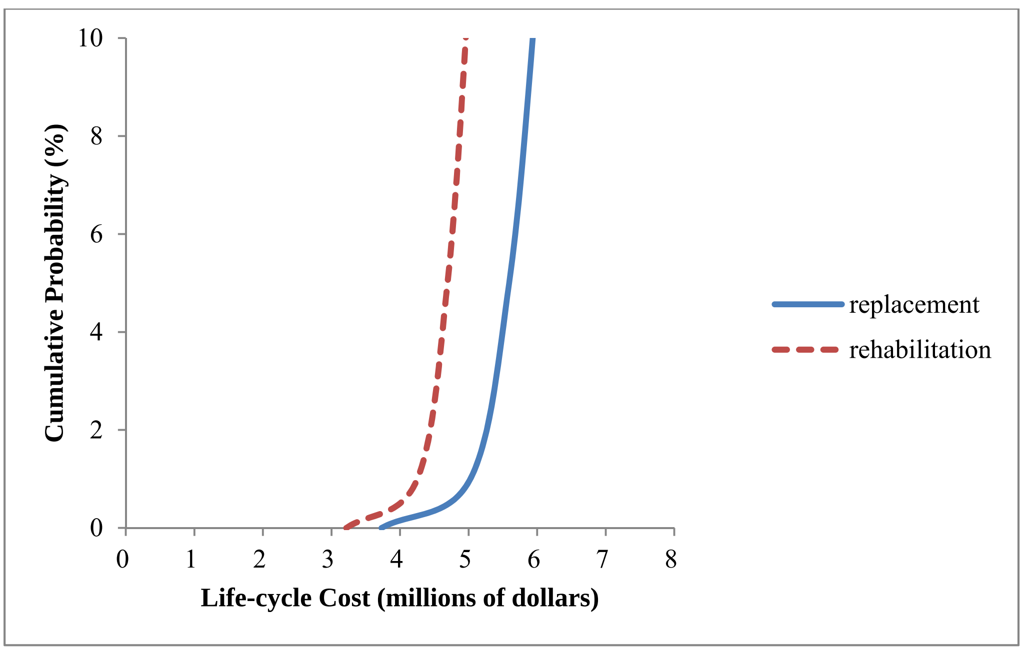


Figure E.100-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 7 (Table 3.6)

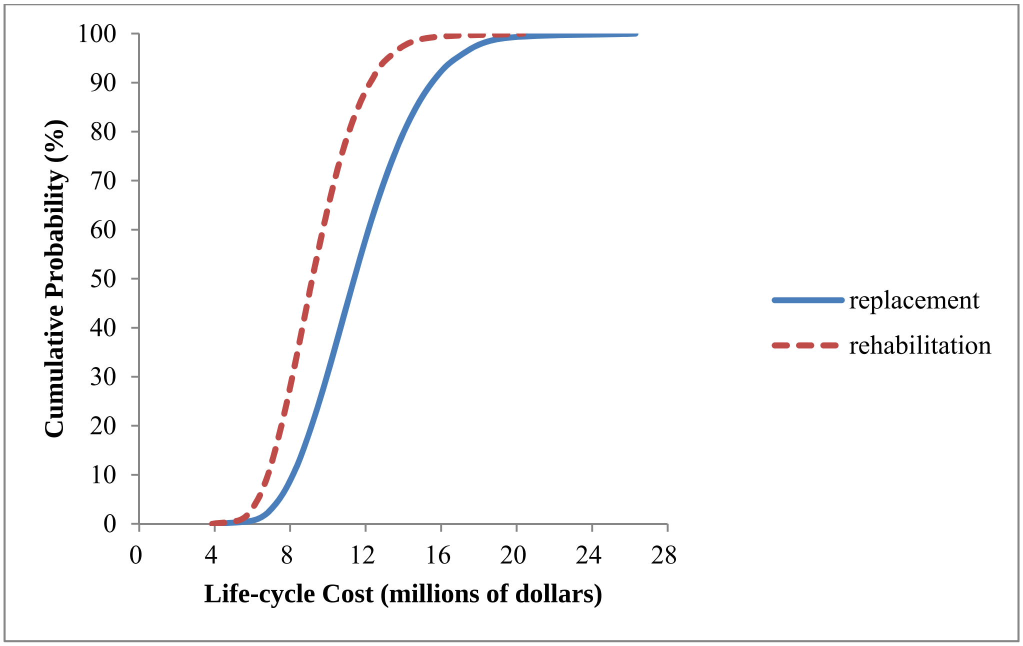


Figure E.101-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 8 (Table 3.6)

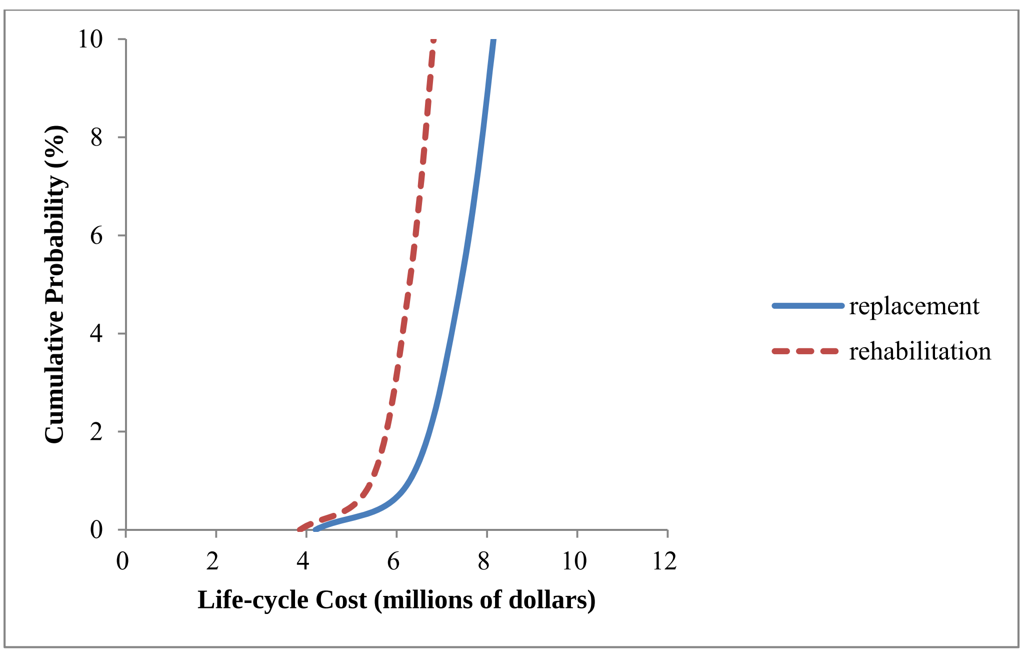


Figure E.102-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 8 (Table 3.6)

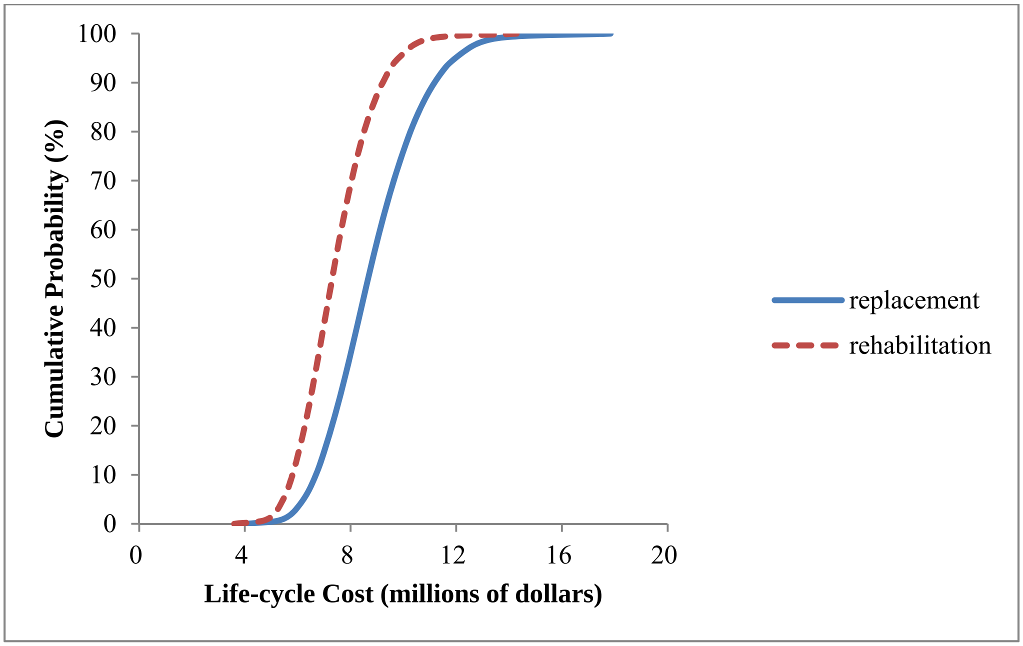


Figure E.103-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 8 (Table 3.6)

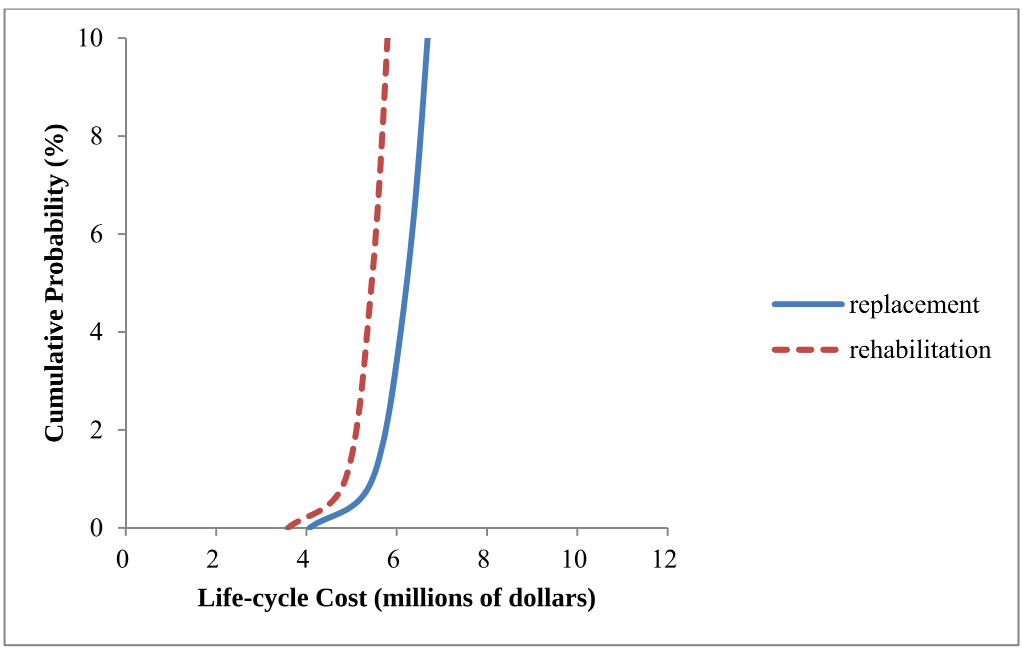


Figure E.104-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 8 (Table 3.6)

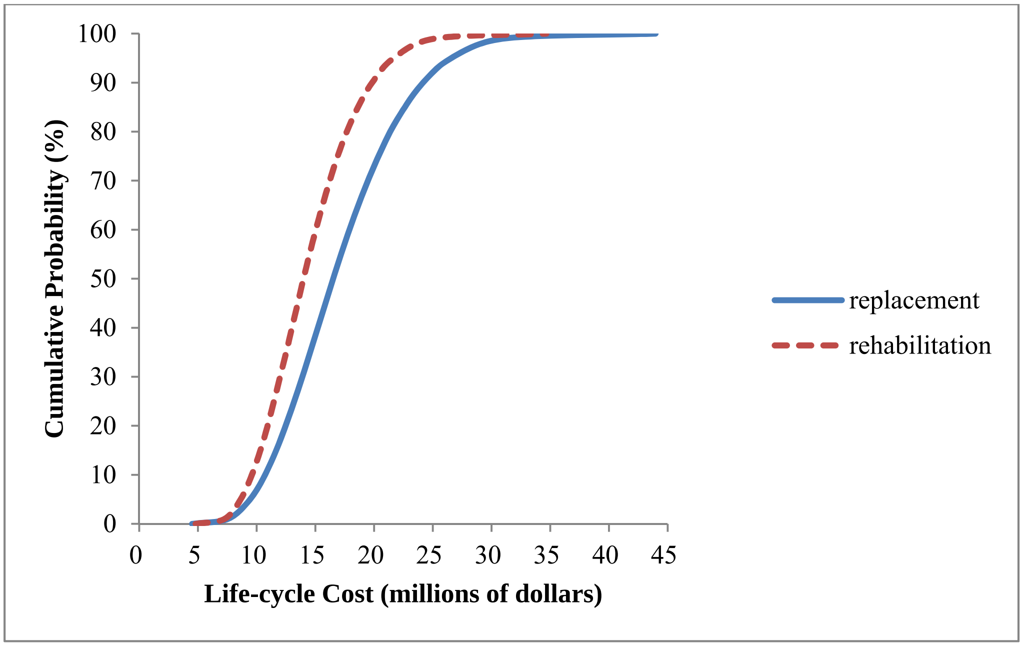


Figure E.105-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 9 (Table 3.6)

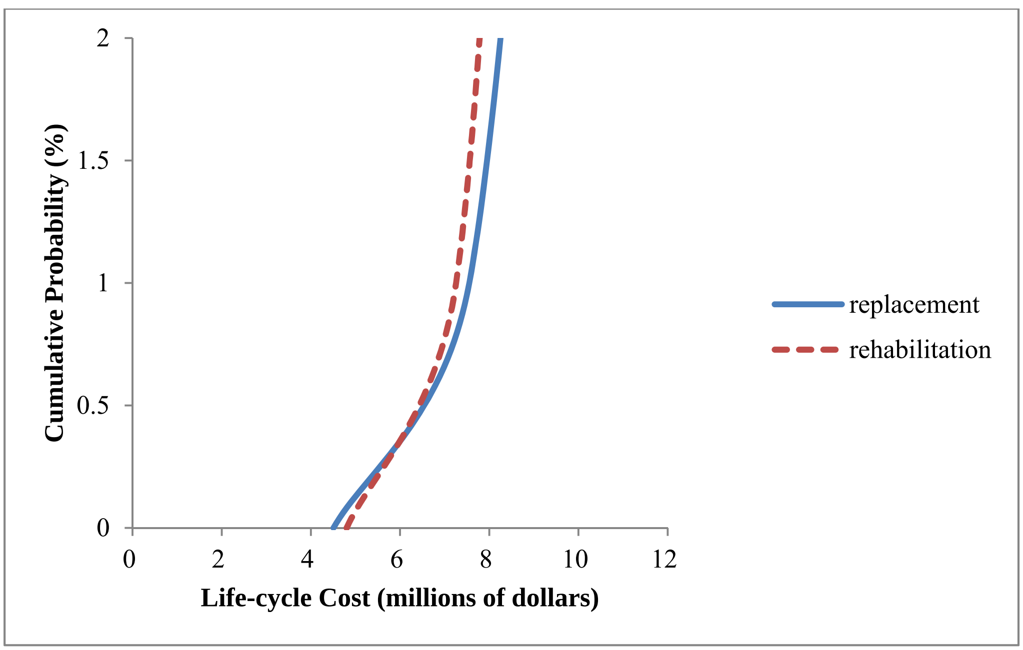


Figure E.106-Ascending cumulative probability distributions for highway bridge with modification 1b ADT case 9 (Table 3.6)

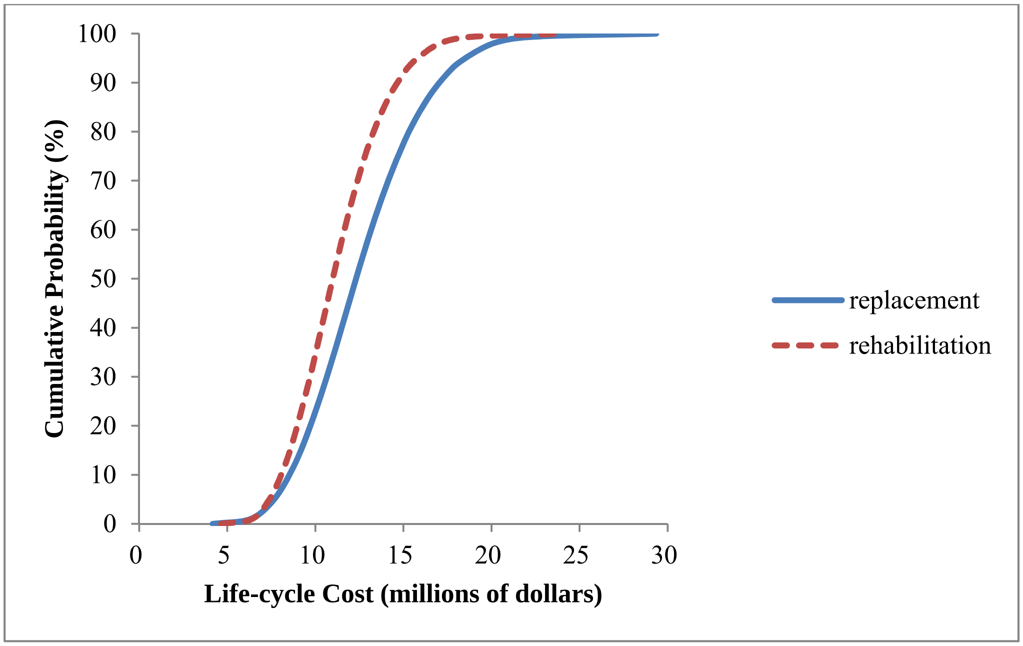


Figure E.107-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 9 (Table 3.6)

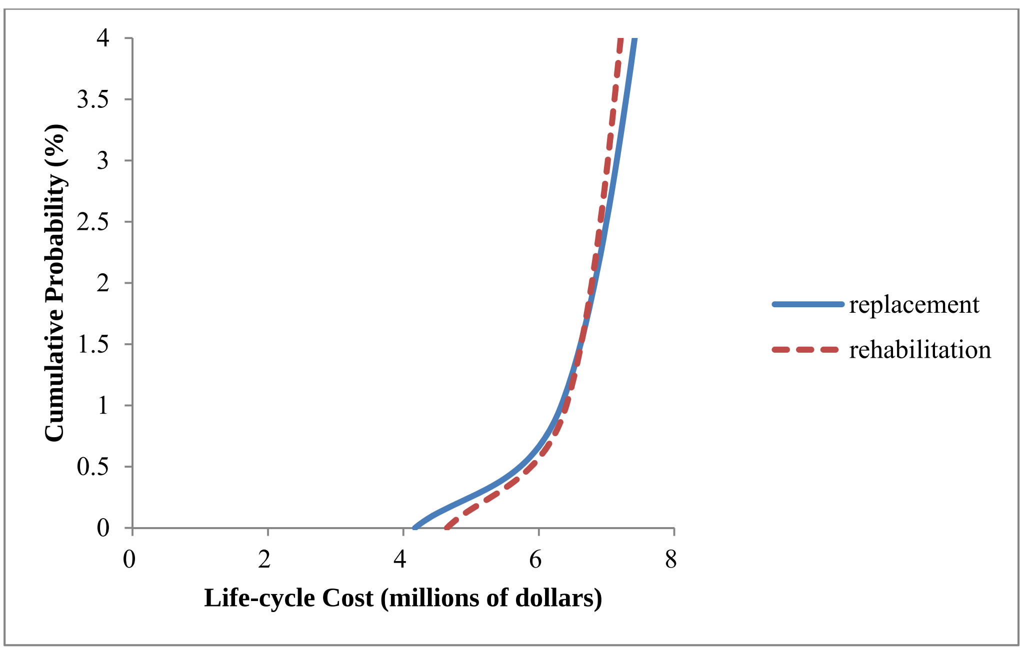


Figure E.108-Ascending cumulative probability distributions for highway bridge with modification 2b ADT case 9 (Table 3.6)

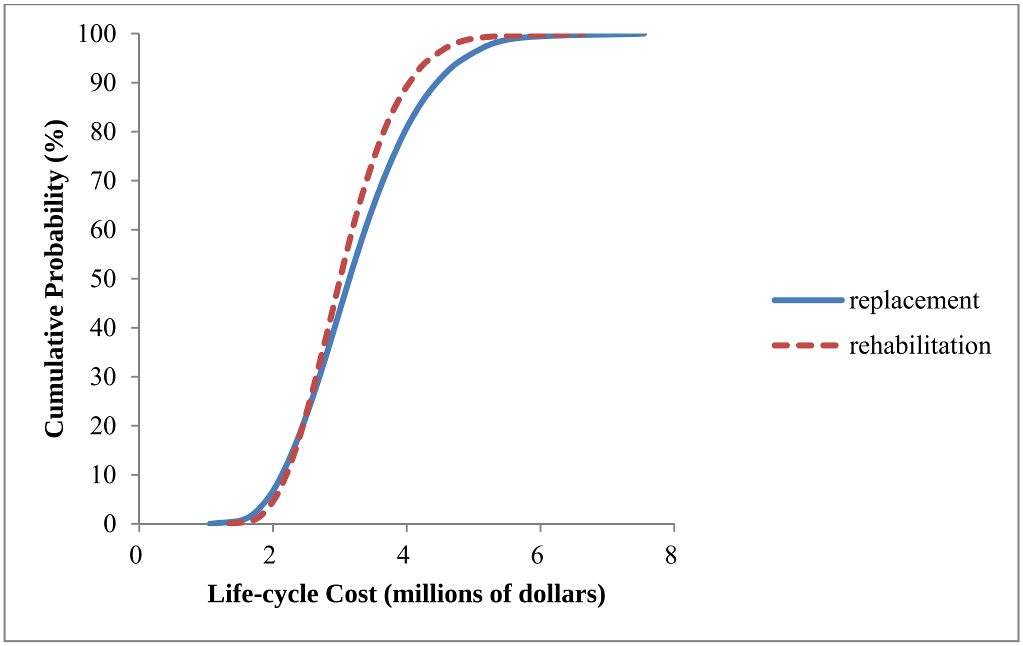


Figure E.109-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 1 (Table 3.6)

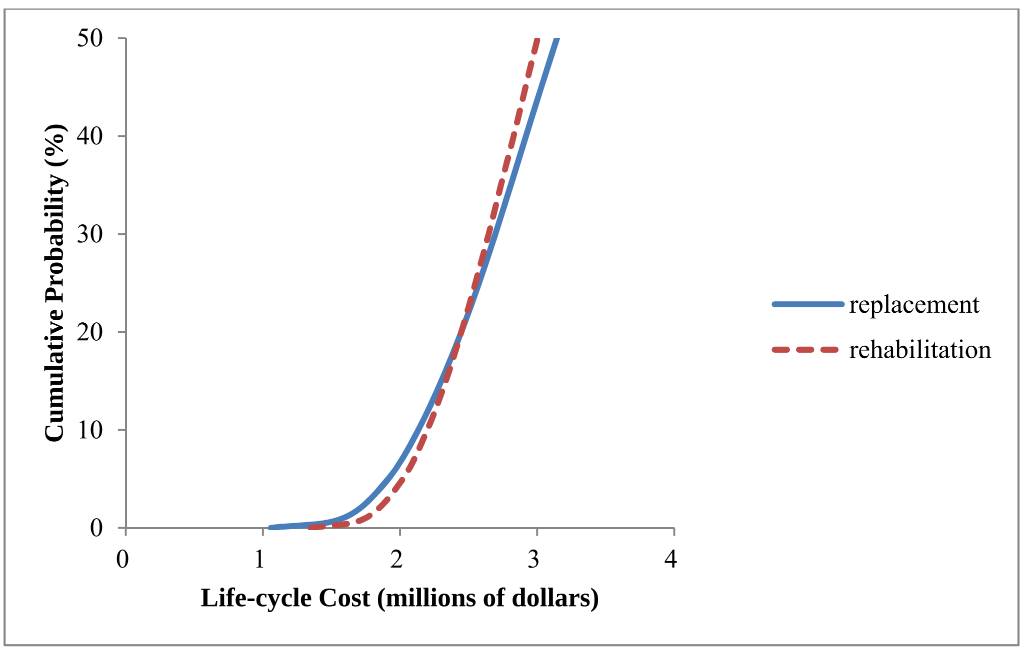


Figure E.110-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 1 (Table 3.6)

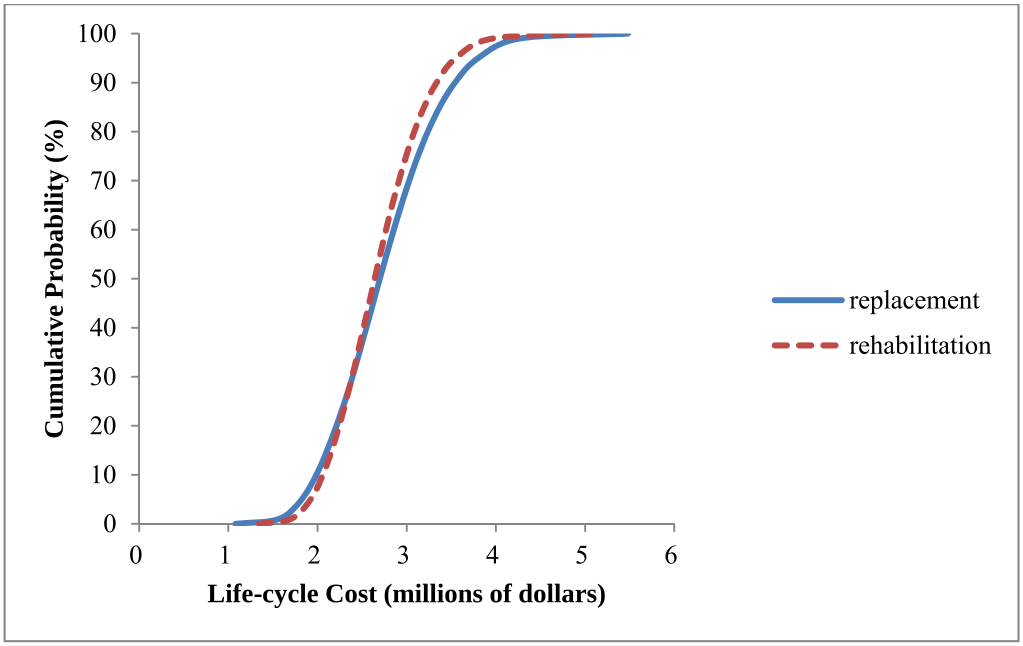


Figure E.111-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 1 (Table 3.6)

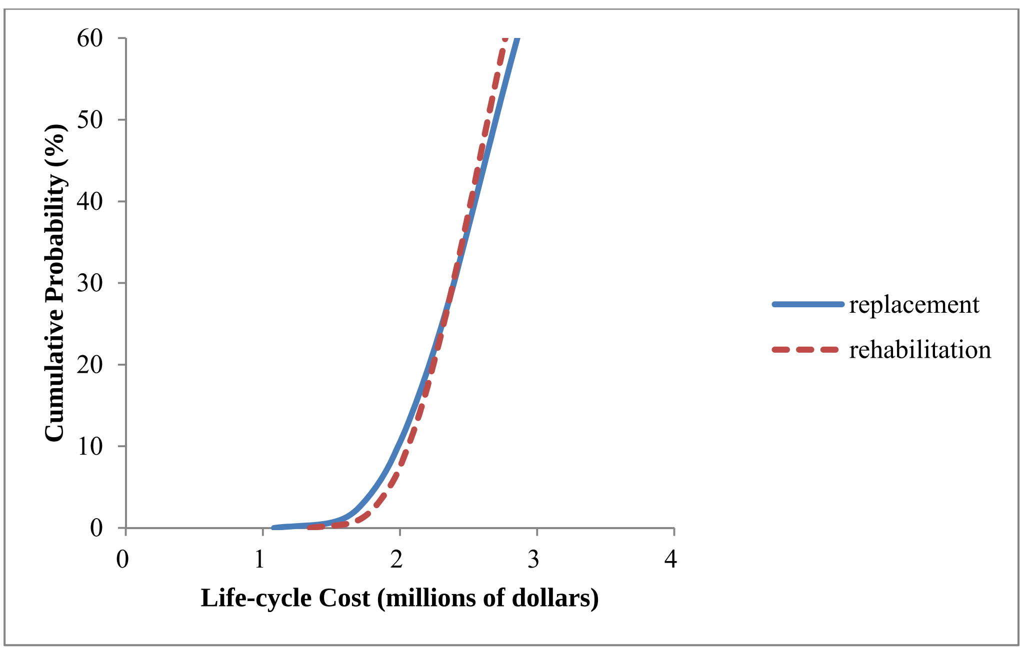


Figure E.112-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 1 (Table 3.6)

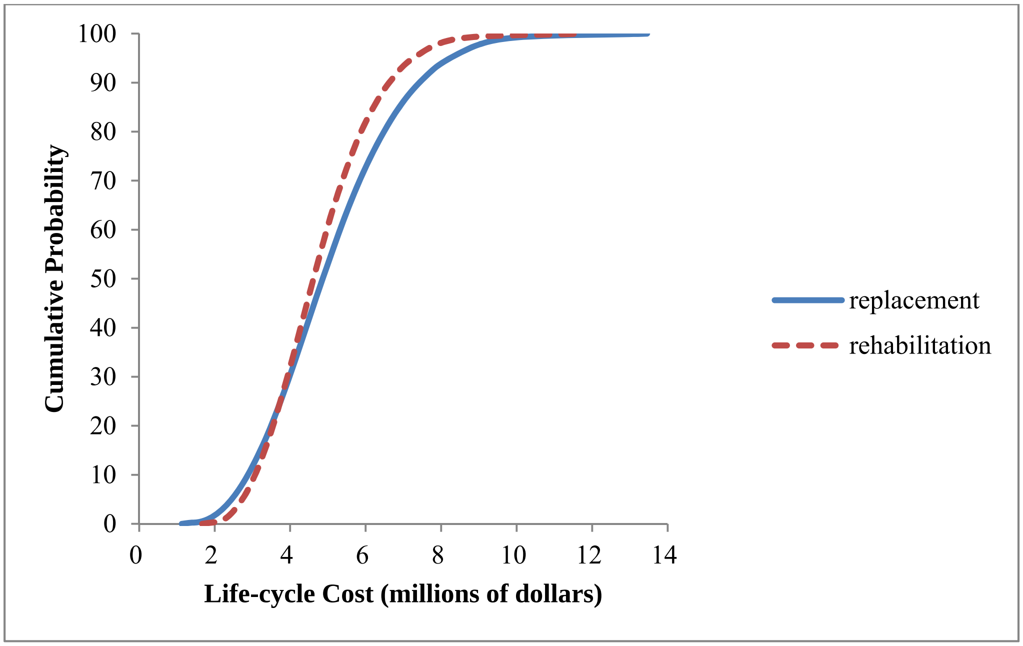


Figure E.113-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 2 (Table 3.6)

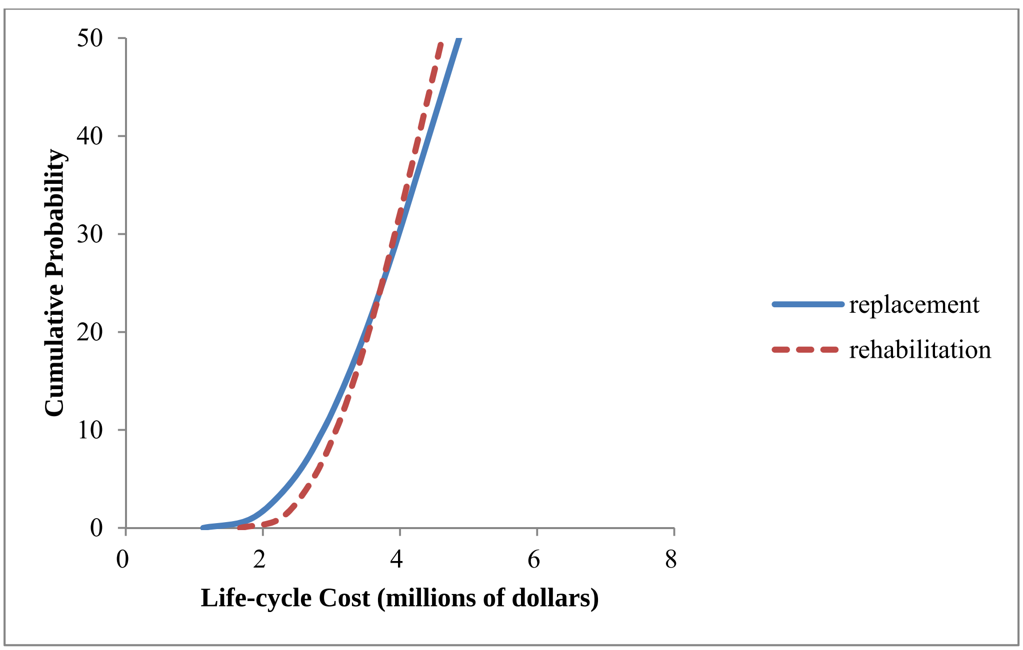


Figure E.114-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 2 (Table 3.6)

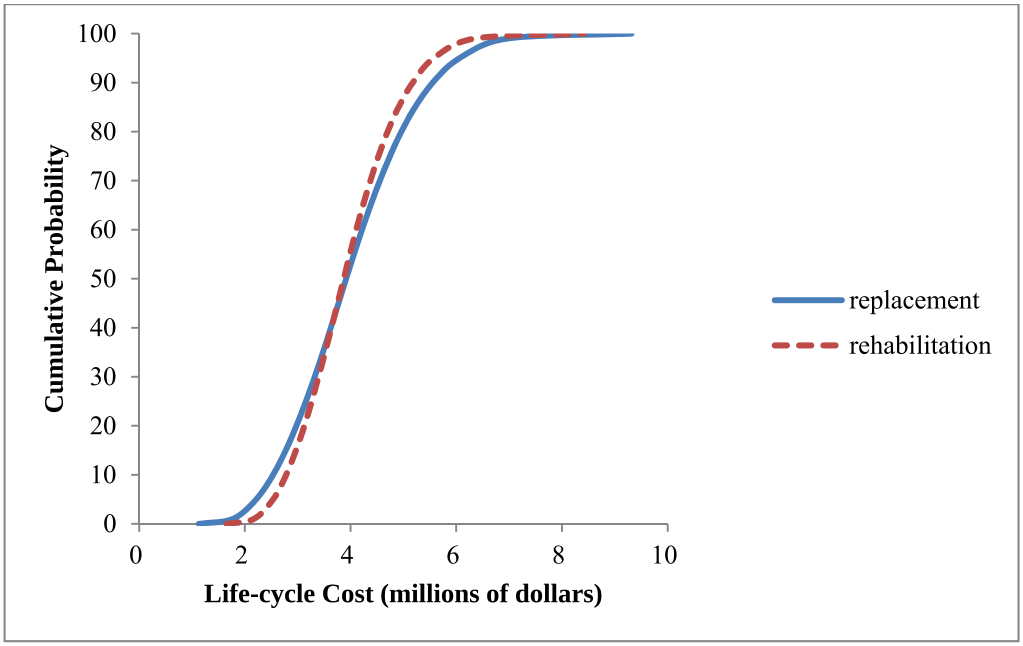


Figure E.115-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 2 (Table 3.6)

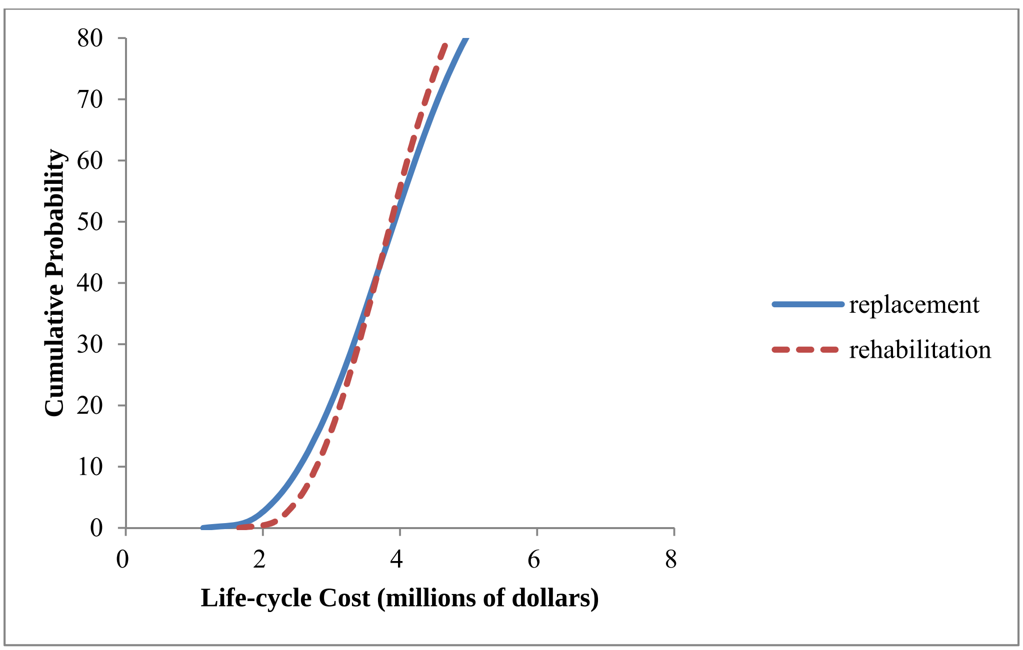


Figure E.116-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 2 (Table 3.6)

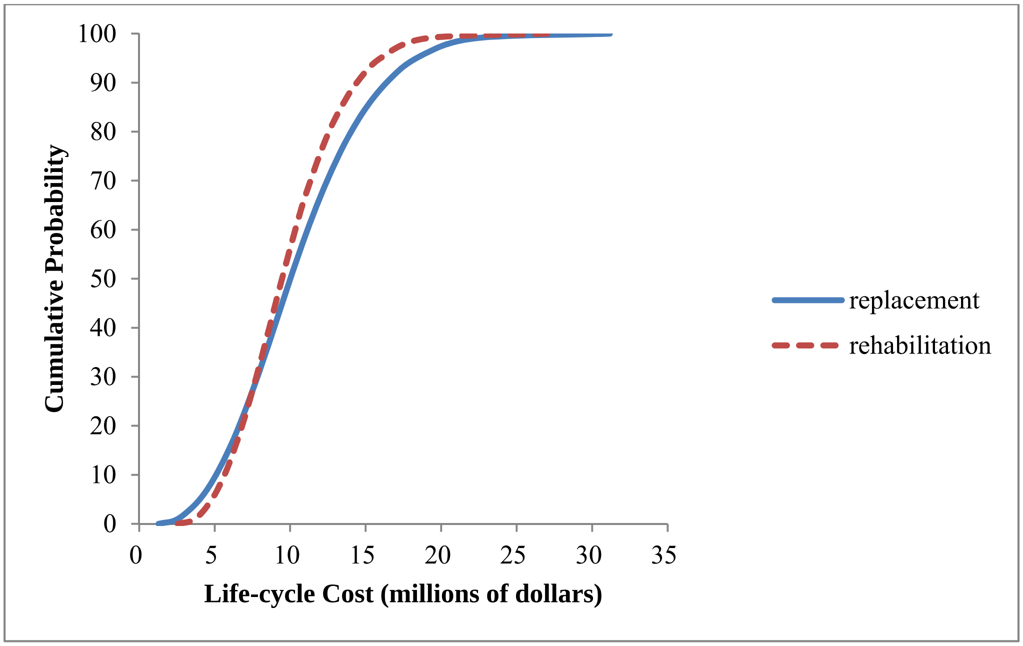


Figure E.117-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 3 (Table 3.6)

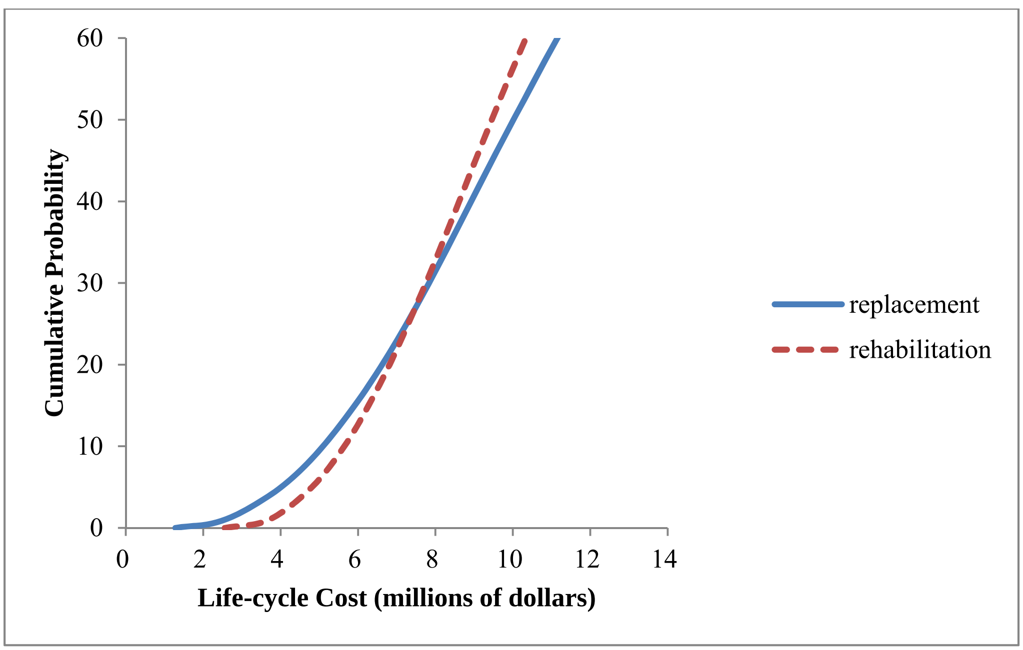


Figure E.118-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 3 (Table 3.6)

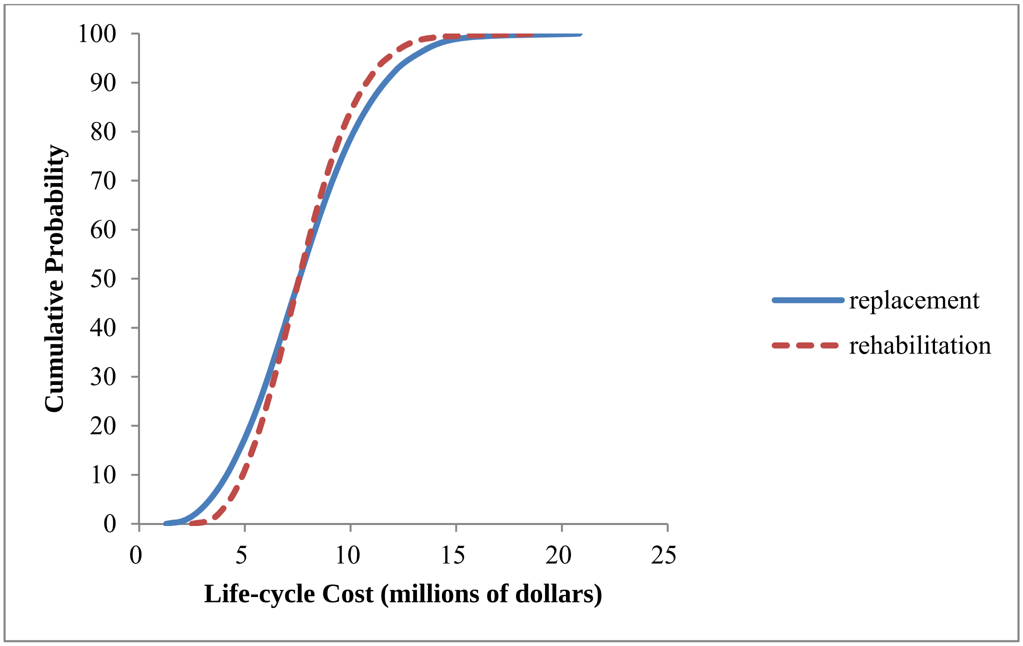


Figure E.119-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 3 (Table 3.6)

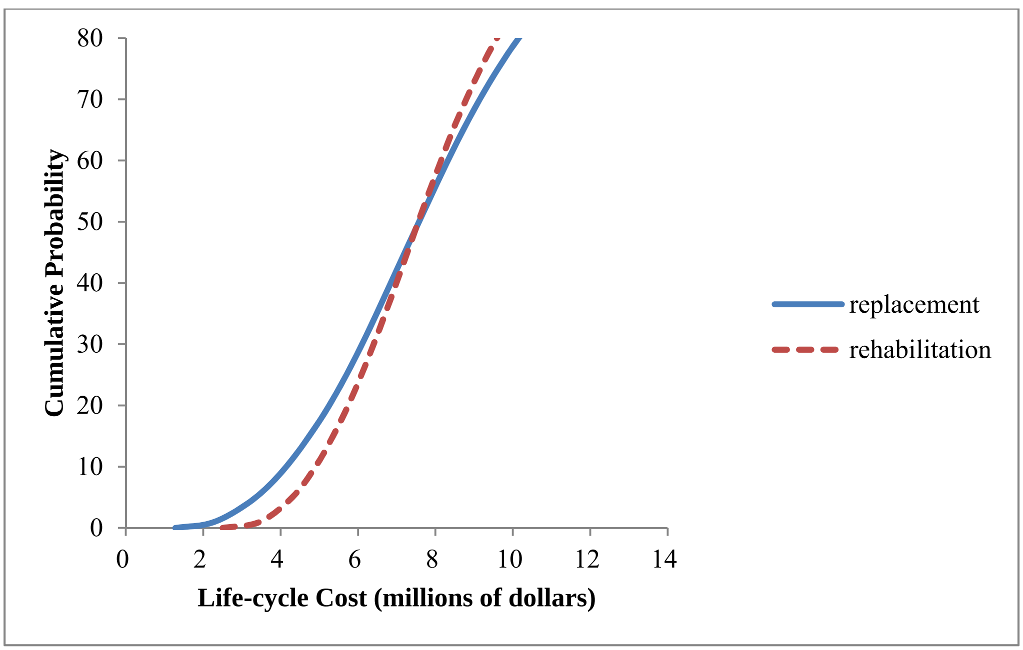


Figure E.120-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 3 (Table 3.6)

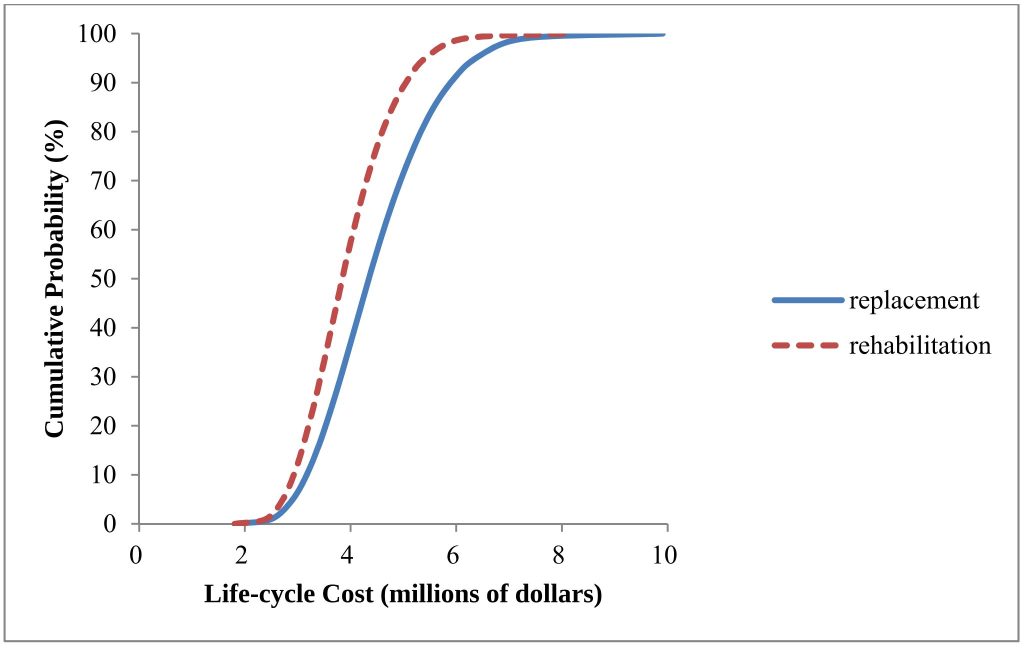


Figure E.121-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 4 (Table 3.6)

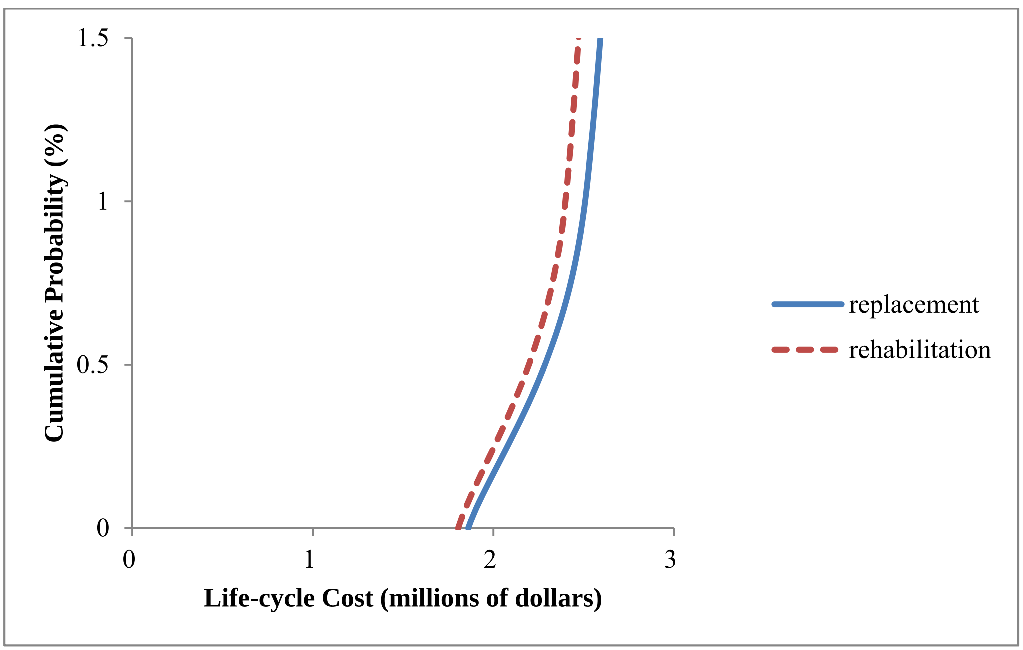


Figure E.122-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 4 (Table 3.6)

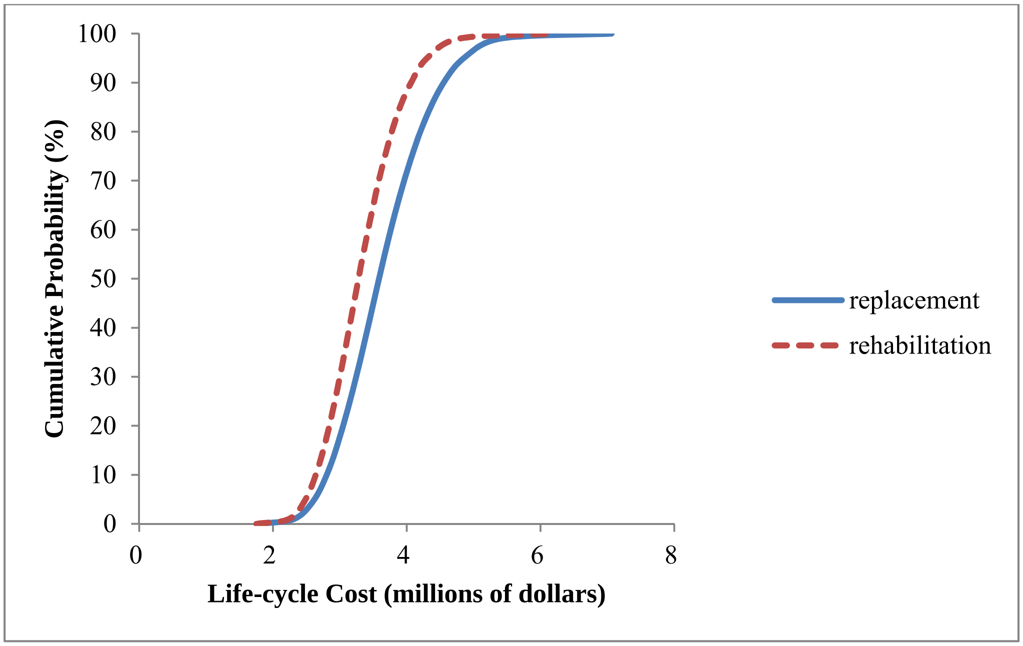


Figure E.123-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 4 (Table 3.6)

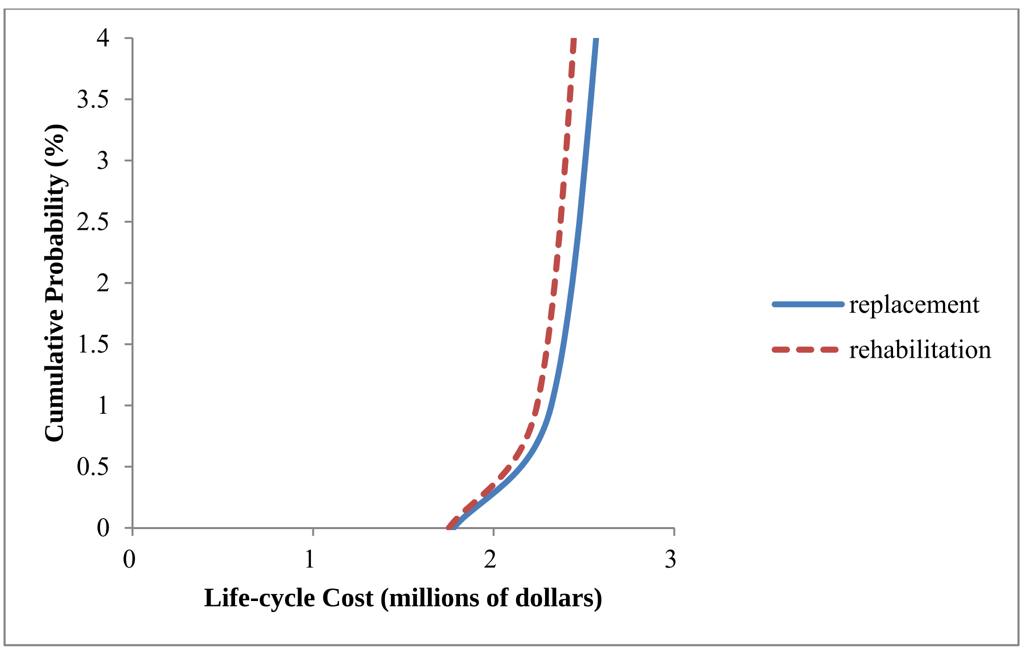


Figure E.124-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 4 (Table 3.6)

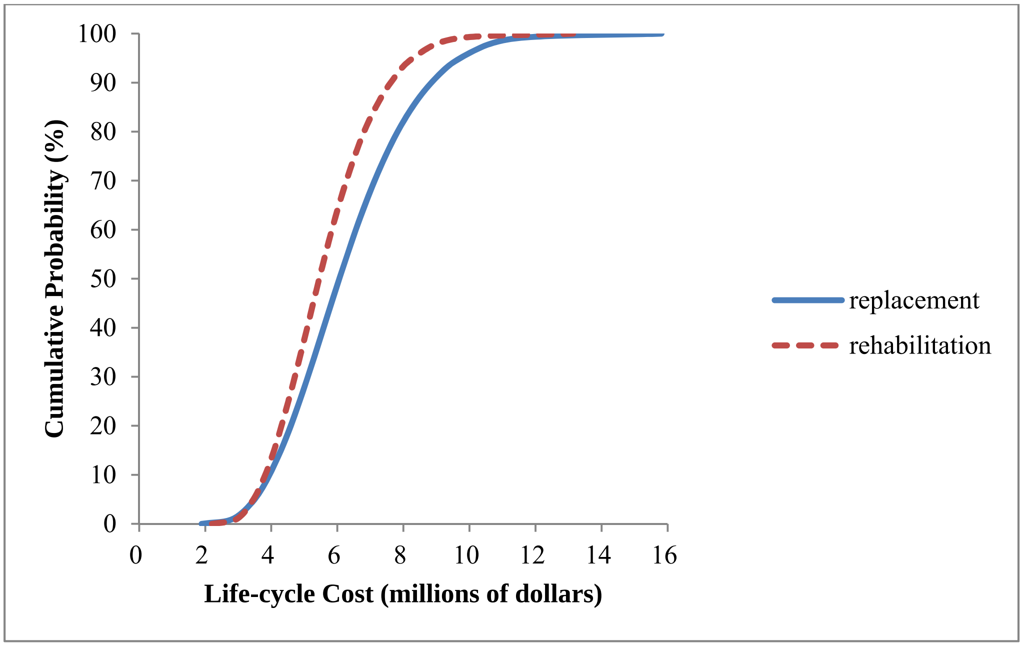


Figure E.125-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 5 (Table 3.6)

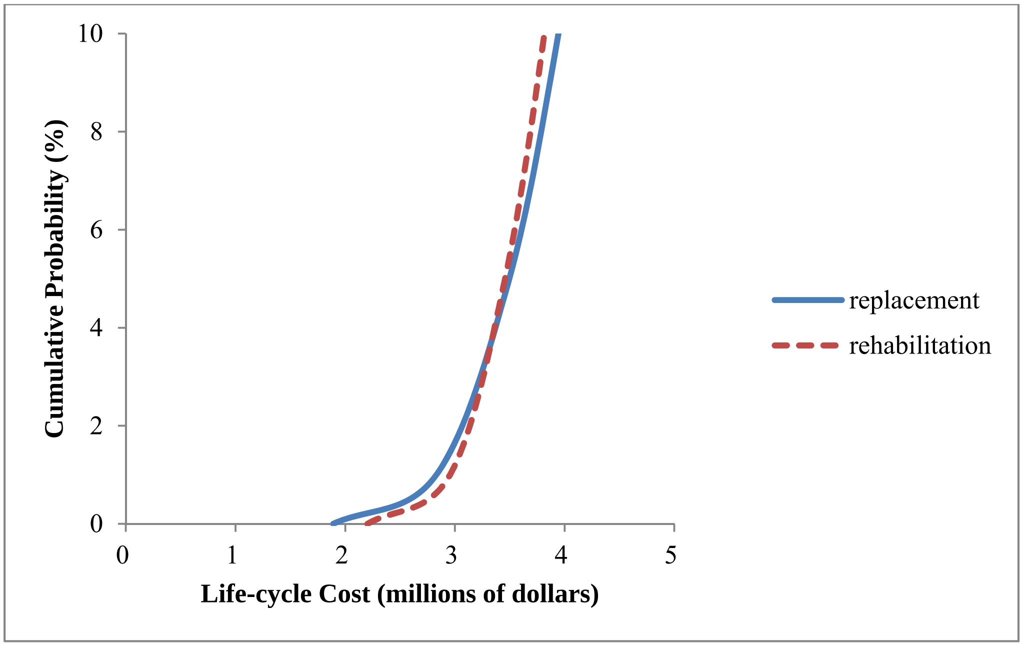


Figure E.126-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 5 (Table 3.6)

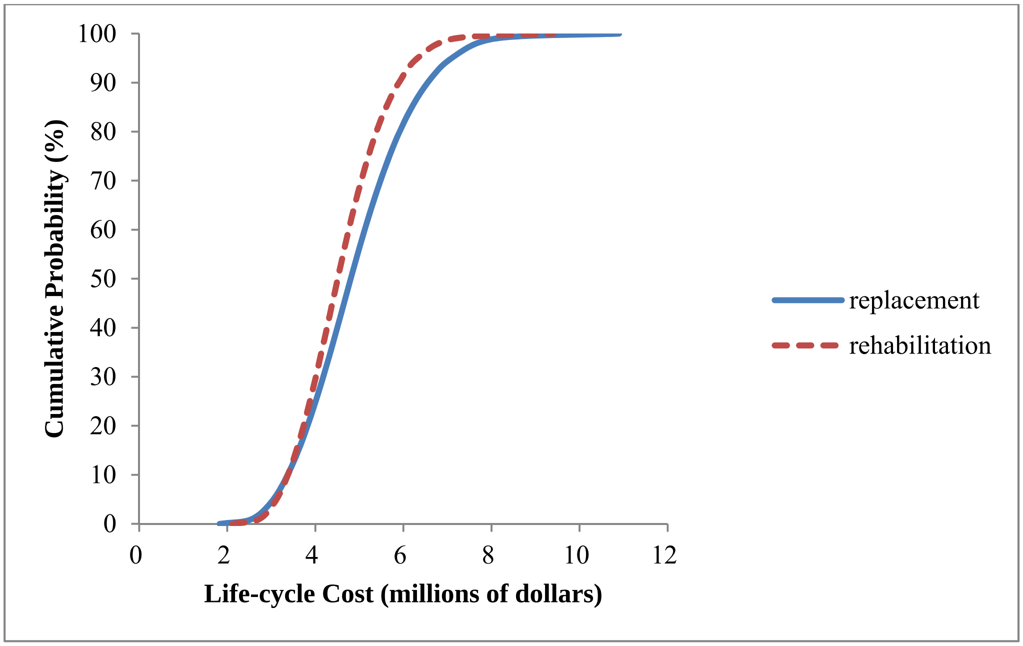


Figure E.127-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 5 (Table 3.6)

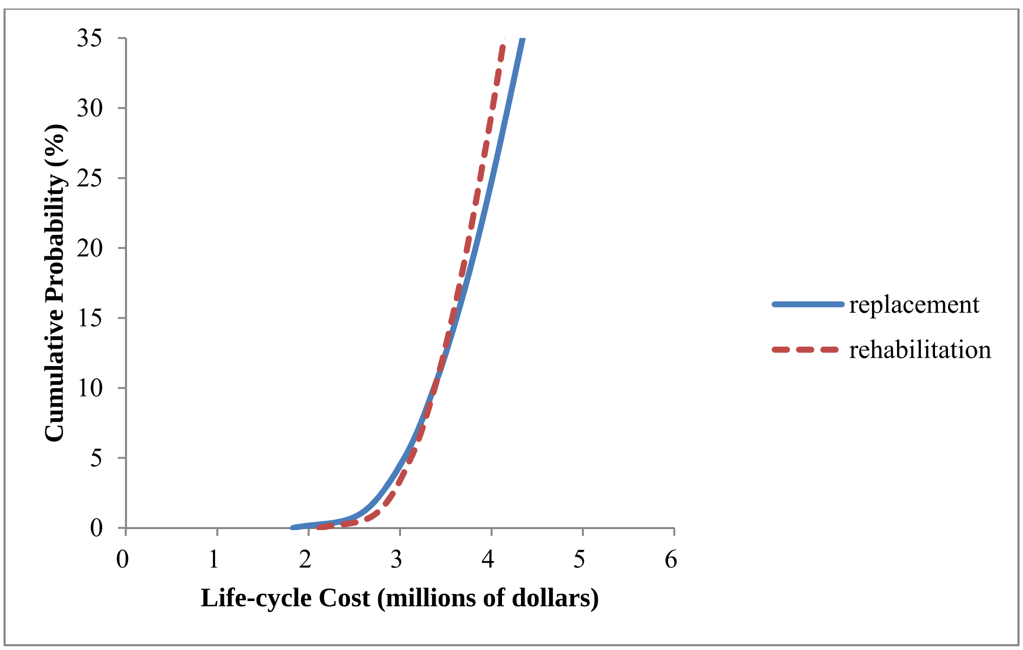


Figure E.128-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 5 (Table 3.6)

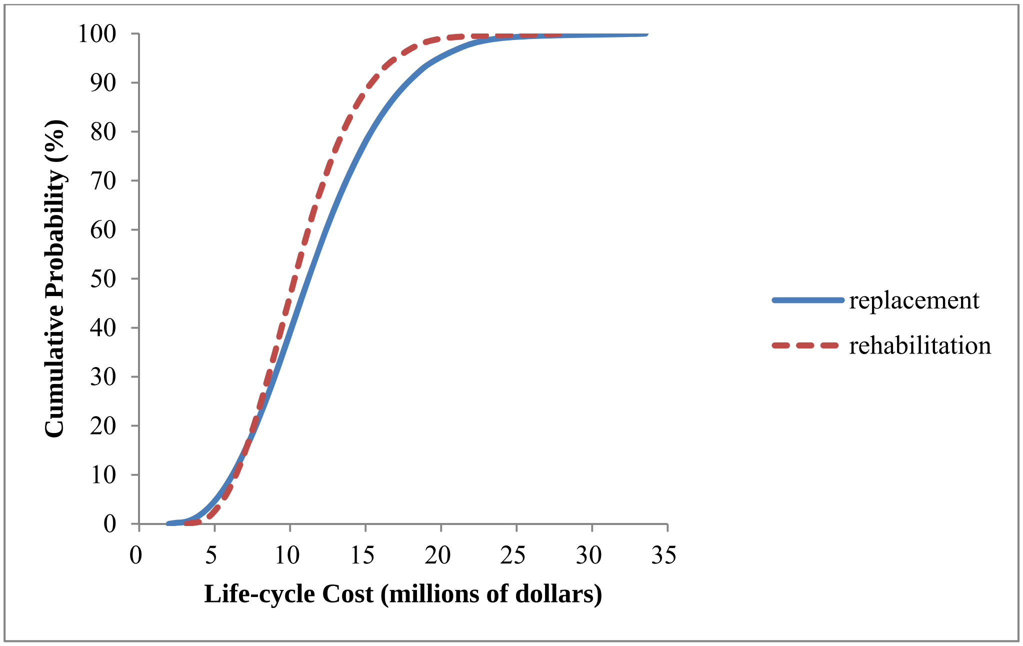


Figure E.129-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 6 (Table 3.6)

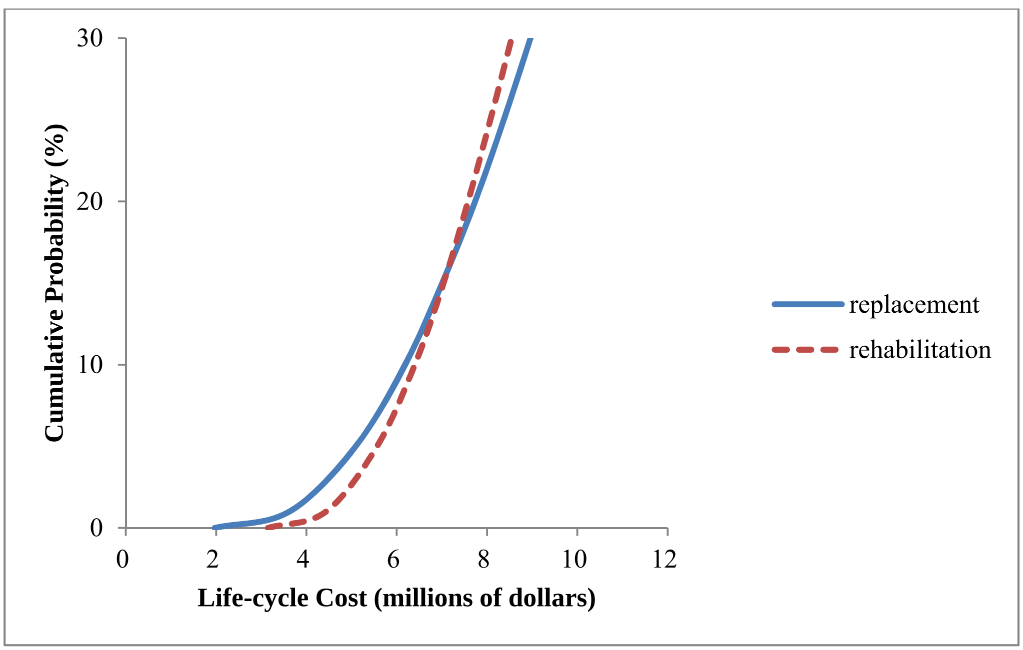


Figure E.130-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 6 (Table 3.6)

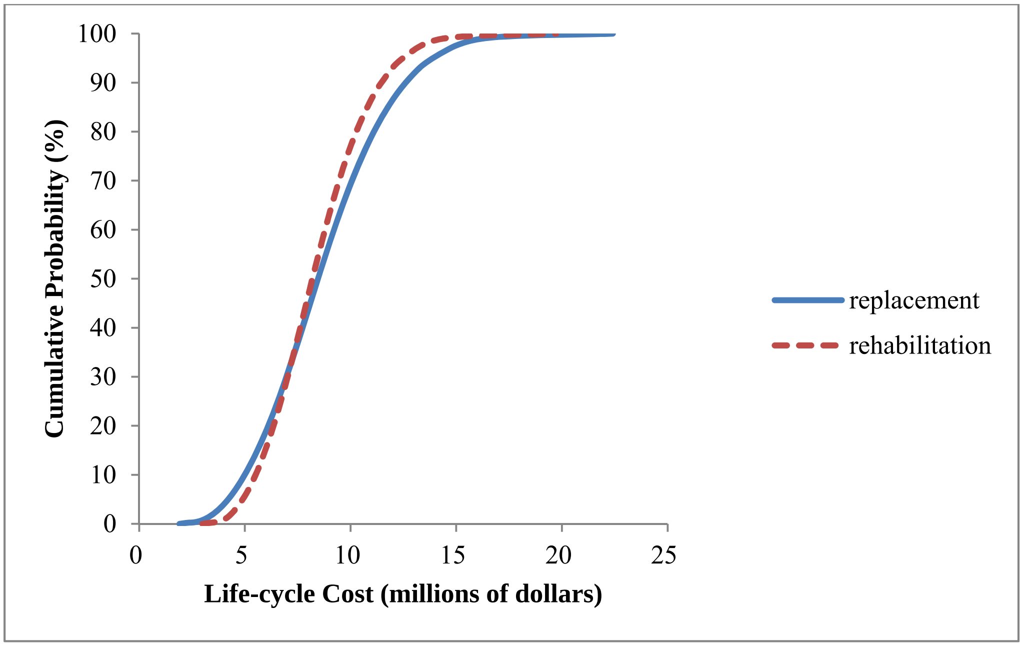


Figure E.131-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 6 (Table 3.6)

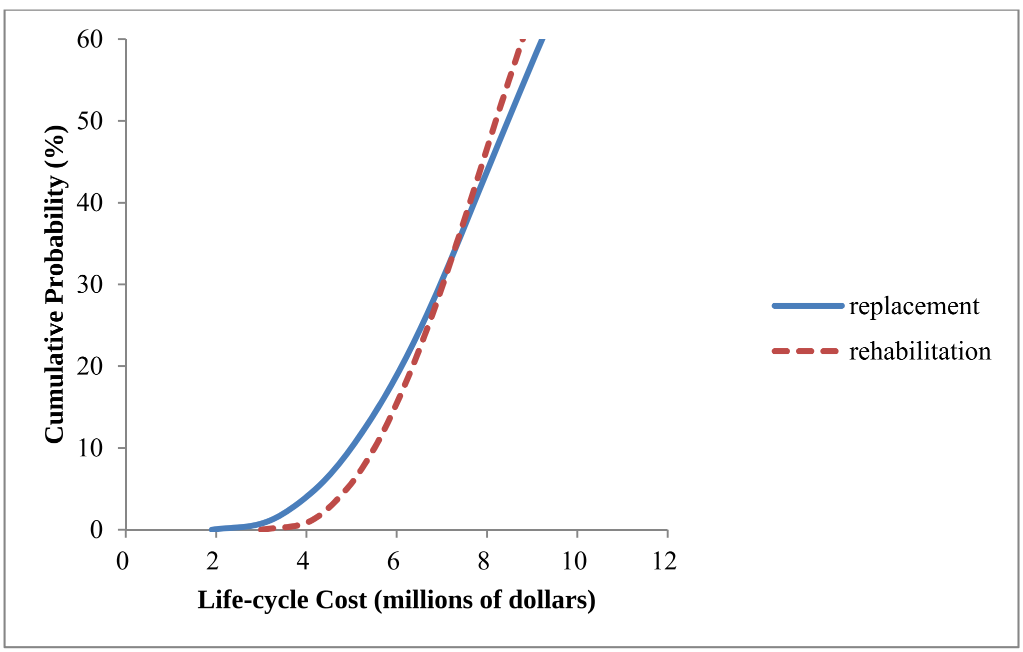


Figure E.132-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 6 (Table 3.6)

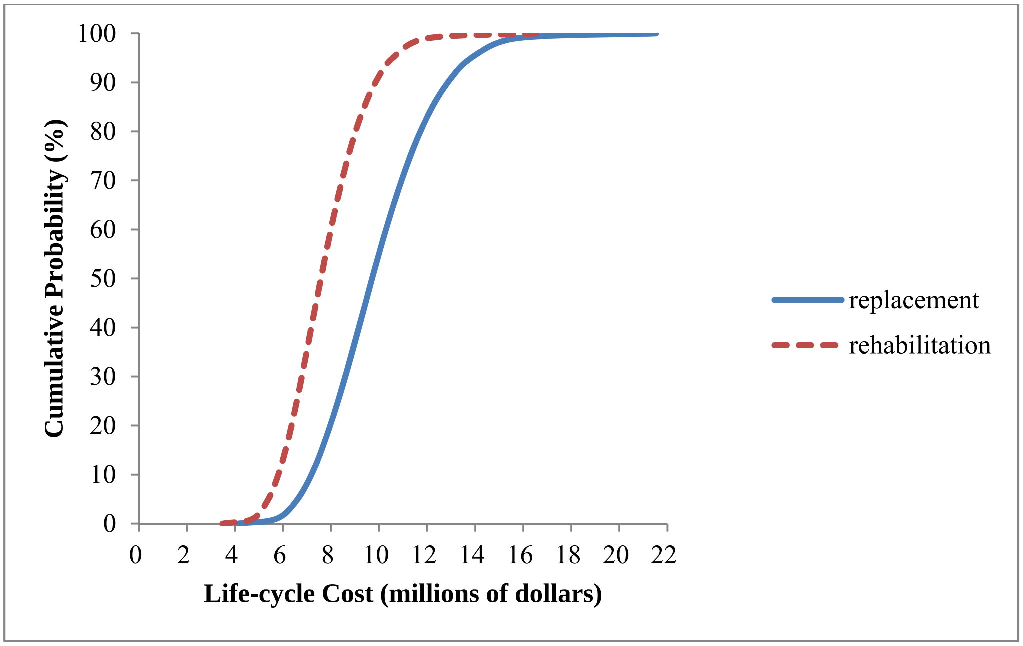


Figure E.133-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 7 (Table 3.6)

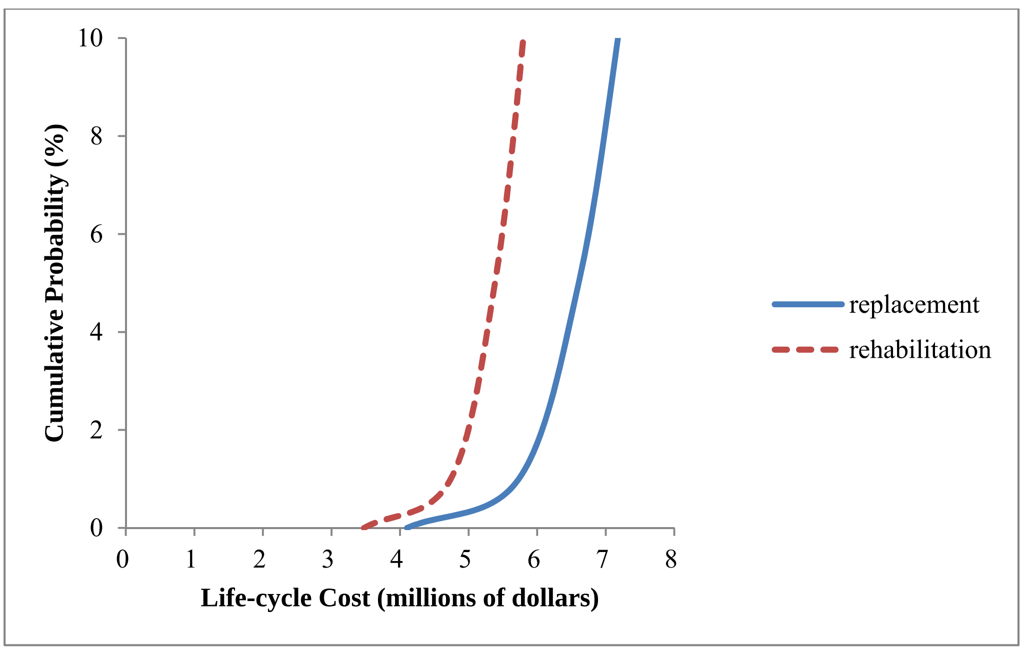


Figure E.134-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 7 (Table 3.6)

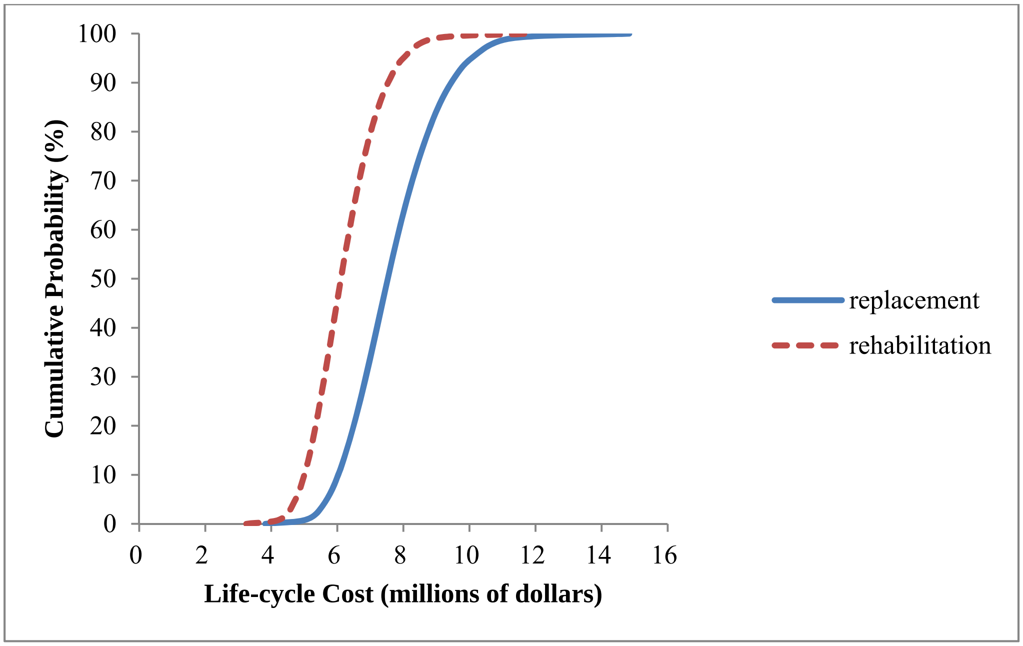


Figure E.135-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 7 (Table 3.6)

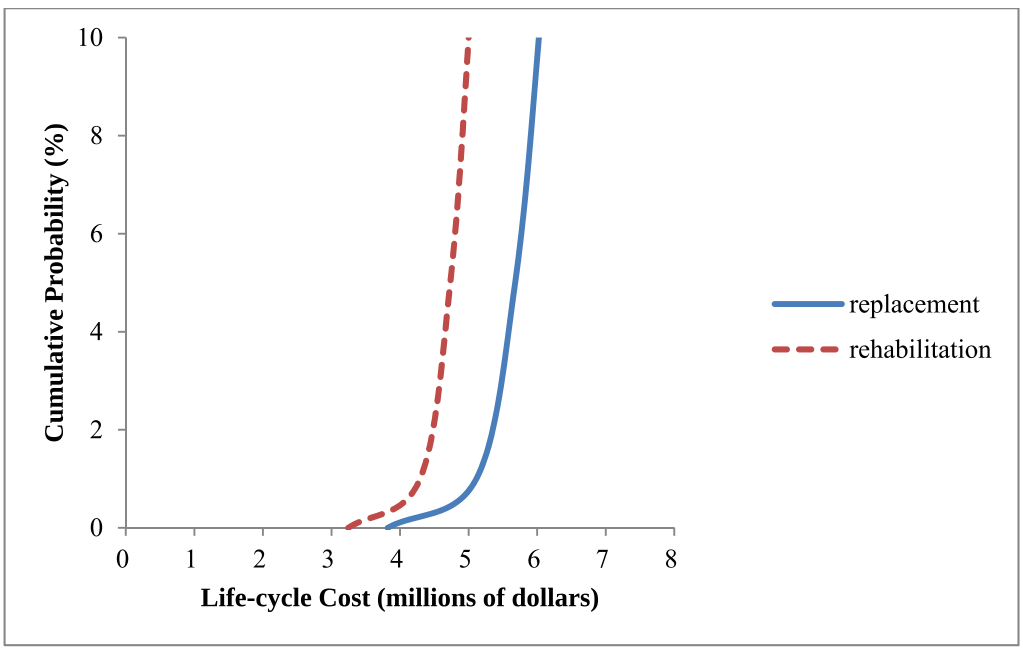


Figure E.136-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 7 (Table 3.6)

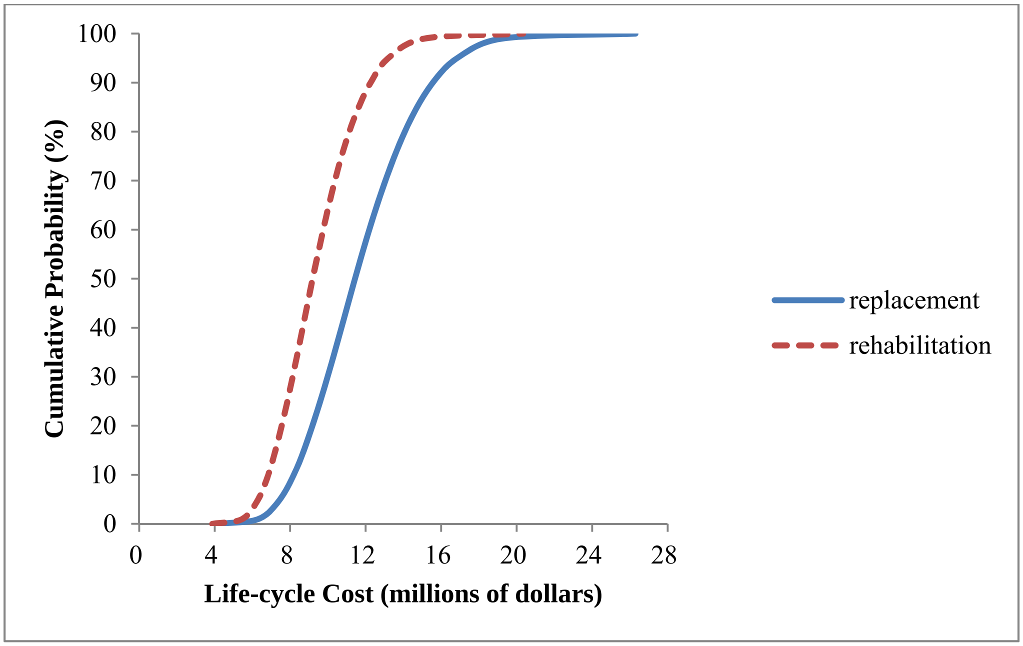


Figure E.137-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 8 (Table 3.6)

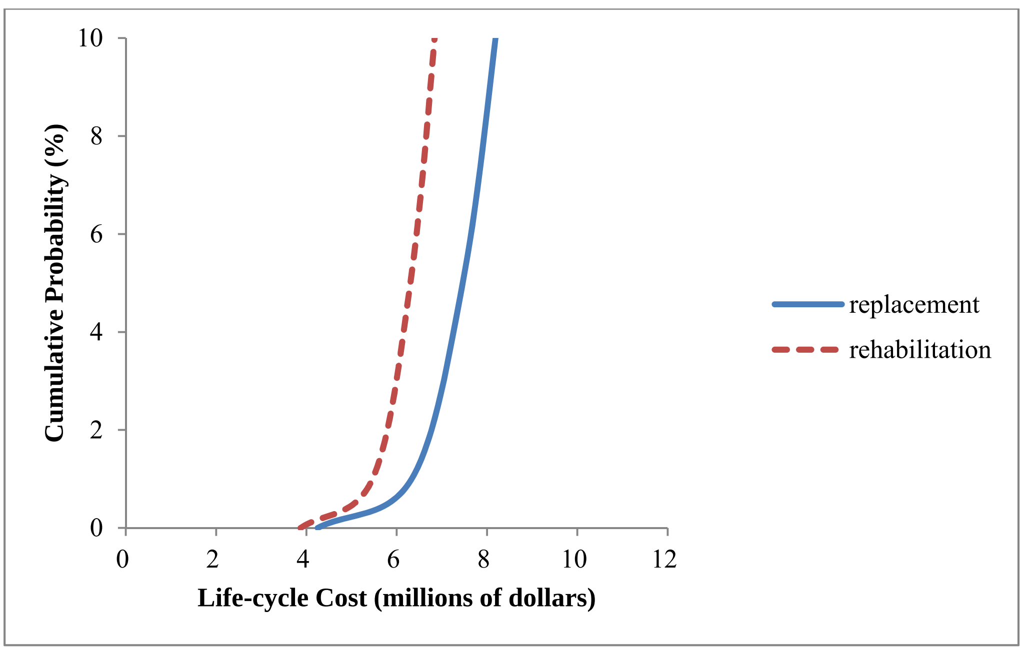


Figure E.138-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 8 (Table 3.6)

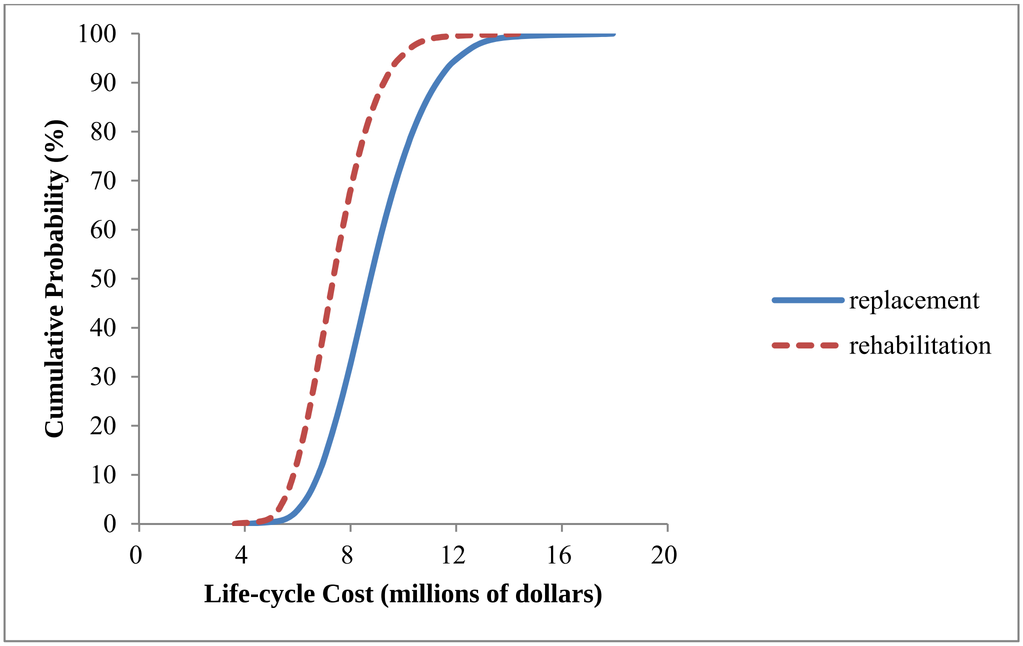


Figure E.139-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 8 (Table 3.6)

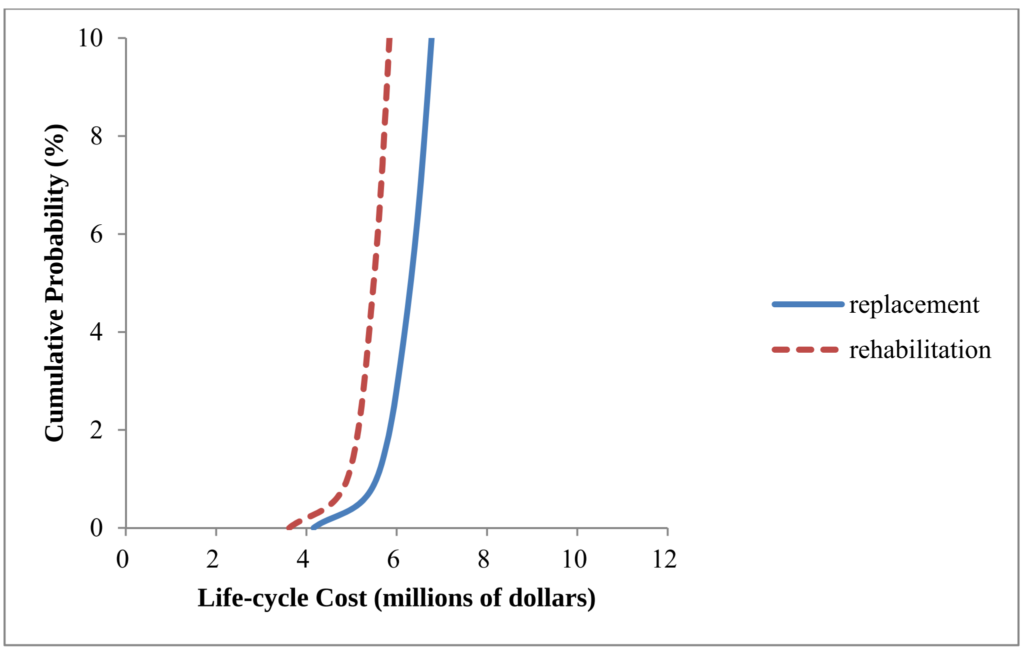


Figure E.140-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 8 (Table 3.6)

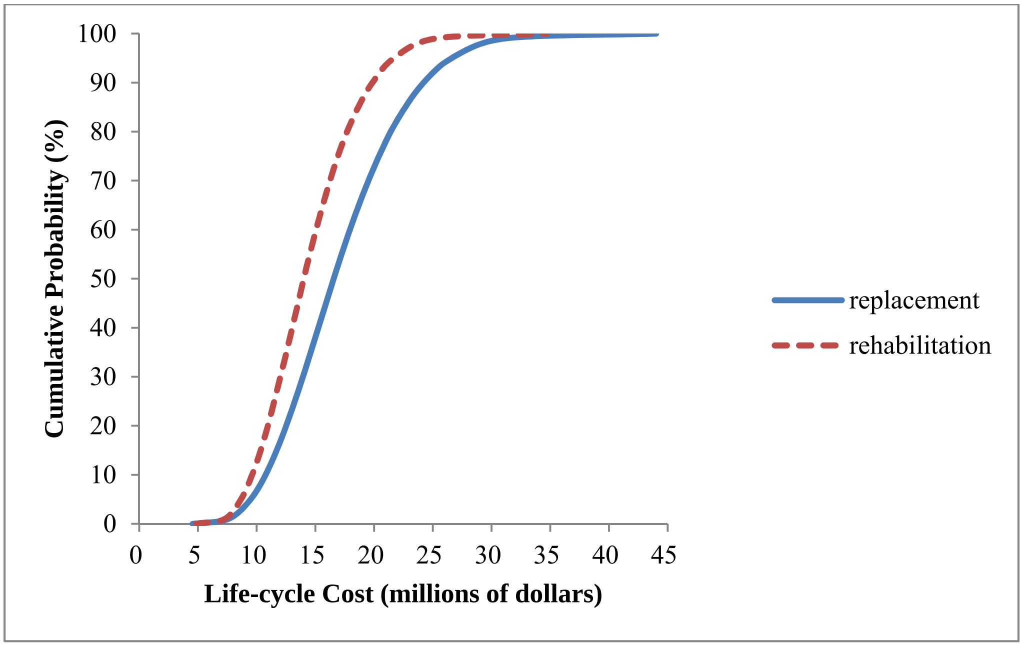


Figure E.141-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 9 (Table 3.6)

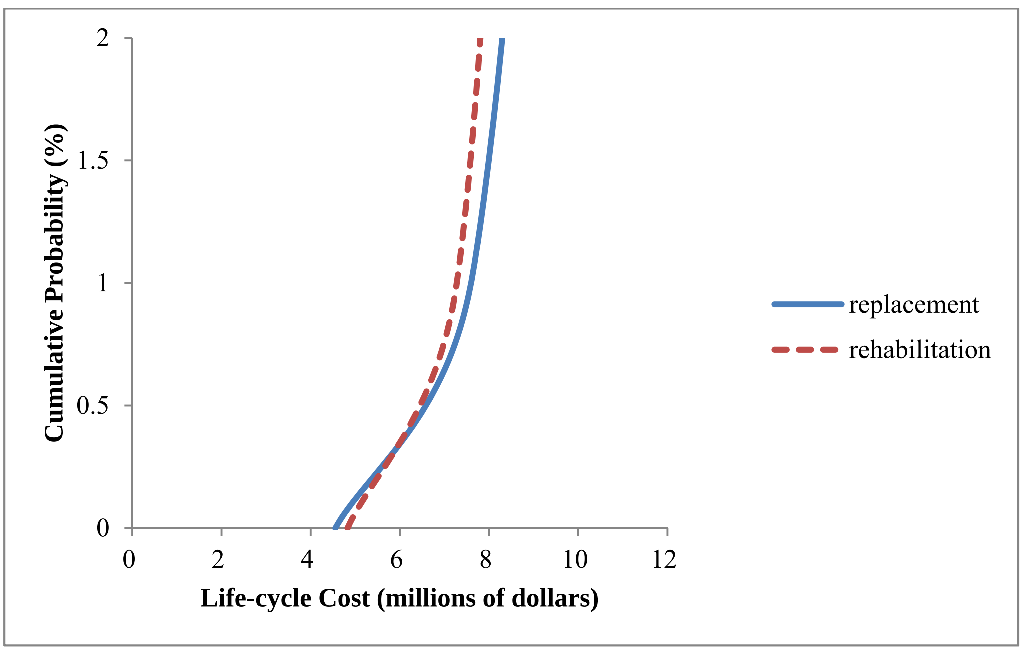


Figure E.142-Ascending cumulative probability distributions for highway bridge with modification 1c ADT case 9 (Table 3.6)

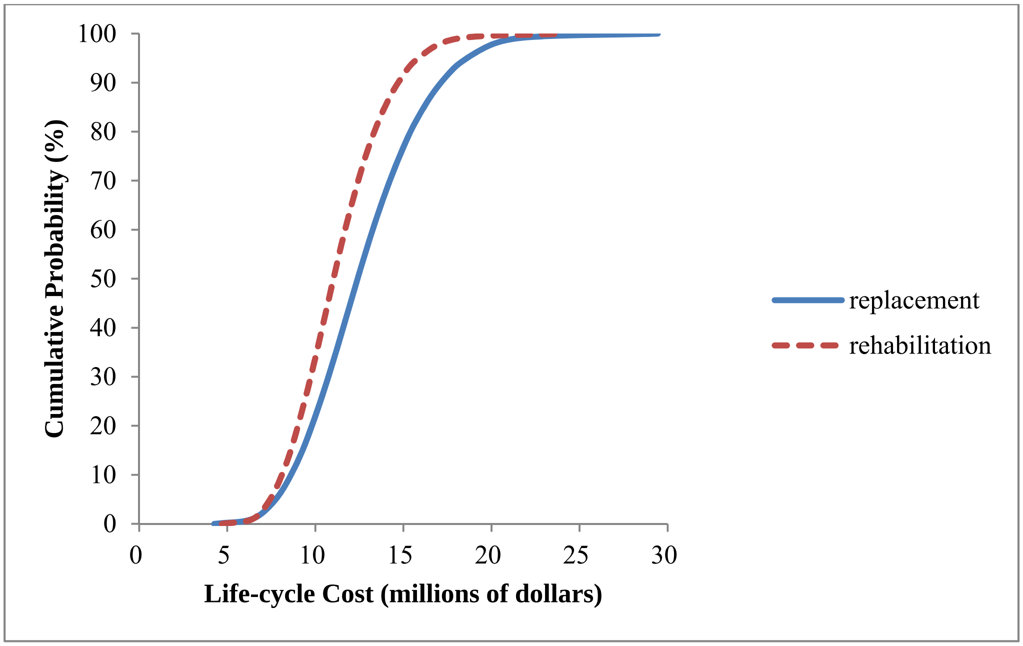


Figure E.143-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 9 (Table 3.6)

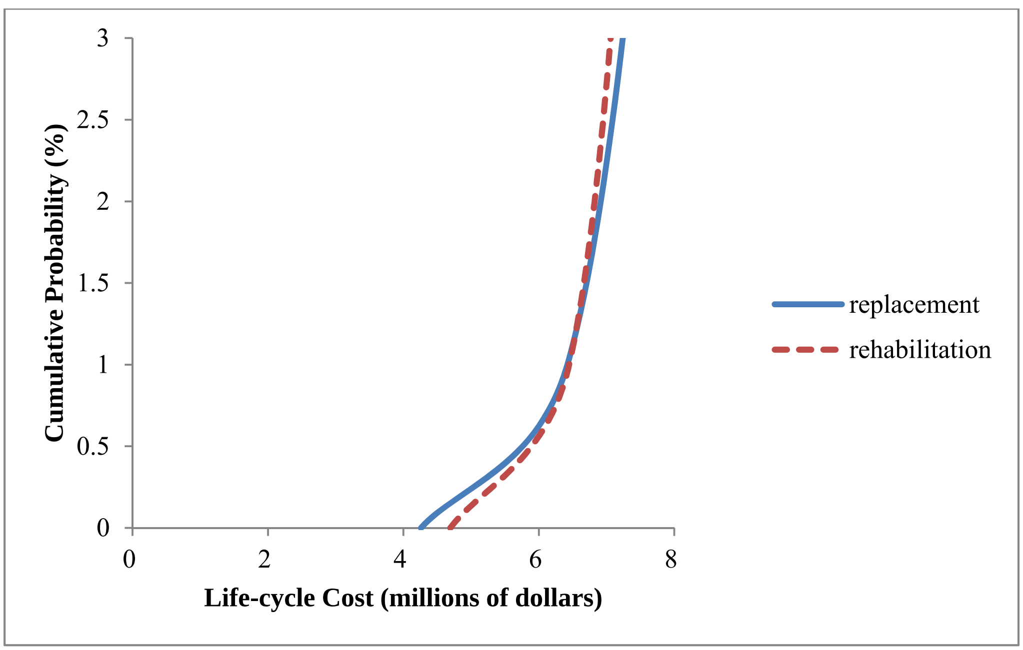


Figure E.144-Ascending cumulative probability distributions for highway bridge with modification 2c ADT case 9 (Table 3.6)

Bridge over Waterway

Table E.73-Risk profile statistics for waterway bridge ADT case 1, 2, 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	53,116	891,678	786,562	39,006	851,797
Maximum	1,886,683	411,419	2,099,277	2,215,473	286,894	2,349,832
Mean	1,203,246	169,450	1,372,696	1,250,895	116,344	1,367,239
Std Dev	156,504	47,126	164,297	176,045	31,651	182,463
Percentile						
1%	873,490	80,689	1,020,770	918,986	57,861	1,018,704
5%	944,947	99,017	1,103,899	989,239	69,982	1,094,742
10%	998,467	111,184	1,158,942	1,034,196	77,919	1,142,099
15%	1,036,577	120,374	1,198,613	1,067,266	83,794	1,176,580
20%	1,066,694	128,237	1,230,846	1,095,370	88,830	1,206,619
25%	1,093,671	135,326	1,258,182	1,120,827	93,338	1,233,103
30%	1,117,573	141,718	1,283,220	1,145,079	97,624	1,258,271
35%	1,139,495	148,013	1,305,744	1,168,546	101,627	1,282,617
40%	1,160,819	154,002	1,327,379	1,191,641	105,440	1,306,817
45%	1,180,699	159,803	1,348,664	1,213,326	109,287	1,329,282
50%	1,200,602	165,669	1,369,918	1,235,845	113,264	1,352,987
55%	1,221,005	171,626	1,391,100	1,259,393	117,276	1,376,516
60%	1,241,661	177,741	1,412,699	1,283,146	121,493	1,400,997
65%	1,263,269	184,205	1,434,692	1,308,004	125,914	1,426,921
70%	1,285,361	191,190	1,458,179	1,335,033	130,591	1,455,079
75%	1,309,835	199,092	1,483,741	1,364,473	135,889	1,484,959
80%	1,336,248	207,921	1,512,371	1,397,719	141,935	1,519,071
85%	1,367,322	218,579	1,546,293	1,436,754	149,250	1,560,225
90%	1,407,246	232,484	1,587,310	1,488,415	158,699	1,612,862
95%	1,465,450	253,748	1,647,150	1,563,780	173,397	1,690,663
99%	1,574,505	294,779	1,762,279	1,709,471	202,785	1,840,100

Table E.74-Risk profile statistics for waterway bridge ADT case 4, 5, 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	531,160	1,404,465	786,562	390,063	1,319,945
Maximum	1,886,683	4,114,194	5,397,530	2,215,473	2,868,944	4,402,624
Mean	1,203,246	1,694,502	2,897,748	1,250,895	1,163,436	2,414,331
Std Dev	156,504	471,264	499,374	176,045	316,507	379,687
Percentile						
1%	873,490	806,888	1,916,097	918,986	578,605	1,673,552
5%	944,947	990,171	2,138,400	989,239	699,821	1,844,358
10%	998,467	1,111,839	2,279,085	1,034,196	779,185	1,950,336
15%	1,036,577	1,203,738	2,380,220	1,067,266	837,935	2,026,018
20%	1,066,694	1,282,370	2,465,145	1,095,370	888,295	2,086,786
25%	1,093,671	1,353,263	2,539,292	1,120,827	933,381	2,141,249
30%	1,117,573	1,417,176	2,607,928	1,145,079	976,236	2,193,665
35%	1,139,495	1,480,126	2,673,755	1,168,546	1,016,274	2,242,670
40%	1,160,819	1,540,020	2,737,070	1,191,641	1,054,397	2,290,398
45%	1,180,699	1,598,028	2,801,269	1,213,326	1,092,866	2,336,830
50%	1,200,602	1,656,693	2,864,064	1,235,845	1,132,640	2,384,659
55%	1,221,005	1,716,256	2,927,224	1,259,393	1,172,760	2,431,600
60%	1,241,661	1,777,412	2,992,245	1,283,146	1,214,929	2,482,383
65%	1,263,269	1,842,052	3,061,717	1,308,004	1,259,139	2,534,923
70%	1,285,361	1,911,902	3,134,515	1,335,033	1,305,909	2,590,858
75%	1,309,835	1,990,920	3,215,510	1,364,473	1,358,891	2,655,160
80%	1,336,248	2,079,215	3,308,260	1,397,719	1,419,350	2,725,250
85%	1,367,322	2,185,789	3,418,098	1,436,754	1,492,501	2,808,542
90%	1,407,246	2,324,844	3,560,087	1,488,415	1,586,986	2,915,979
95%	1,465,450	2,537,476	3,781,195	1,563,780	1,733,969	3,088,225
99%	1,574,505	2,947,792	4,205,849	1,709,471	2,027,848	3,425,844

Table E.75-Risk profile statistics for waterway bridge ADT case 7, 8, 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	2,655,799	3,565,685	786,562	1,950,313	3,105,571
Maximum	1,886,683	20,570,971	21,854,307	2,215,473	14,344,720	15,829,508
Mean	1,203,246	8,472,510	9,675,756	1,250,895	5,817,179	7,068,074
Std Dev	156,504	2,356,318	2,364,463	176,045	1,582,536	1,612,570
Percentile						
1%	873,490	4,034,439	5,207,906	918,986	2,893,025	4,069,846
5%	944,947	4,950,856	6,132,518	989,239	3,499,104	4,703,621
10%	998,467	5,559,193	6,744,633	1,034,196	3,895,925	5,110,781
15%	1,036,577	6,018,690	7,220,006	1,067,266	4,189,675	5,413,799
20%	1,066,694	6,411,848	7,609,122	1,095,370	4,441,475	5,666,699
25%	1,093,671	6,766,314	7,962,096	1,120,827	4,666,907	5,898,997
30%	1,117,573	7,085,878	8,281,463	1,145,079	4,881,179	6,112,208
35%	1,139,495	7,400,629	8,603,959	1,168,546	5,081,368	6,319,369
40%	1,160,819	7,700,099	8,902,410	1,191,641	5,271,986	6,517,858
45%	1,180,699	7,990,138	9,192,793	1,213,326	5,464,328	6,708,379
50%	1,200,602	8,283,463	9,487,001	1,235,845	5,663,198	6,908,288
55%	1,221,005	8,581,282	9,788,007	1,259,393	5,863,799	7,118,068
60%	1,241,661	8,887,059	10,098,029	1,283,146	6,074,643	7,328,280
65%	1,263,269	9,210,260	10,418,757	1,308,004	6,295,693	7,553,893
70%	1,285,361	9,559,512	10,768,974	1,335,033	6,529,546	7,799,913
75%	1,309,835	9,954,600	11,164,774	1,364,473	6,794,455	8,067,118
80%	1,336,248	10,396,073	11,610,581	1,397,719	7,096,749	8,370,980
85%	1,367,322	10,928,945	12,136,716	1,436,754	7,462,507	8,743,362
90%	1,407,246	11,624,219	12,844,990	1,488,415	7,934,928	9,224,814
95%	1,465,450	12,687,378	13,901,461	1,563,780	8,669,846	9,968,150
99%	1,574,505	14,738,961	15,955,857	1,709,471	10,139,242	11,465,950

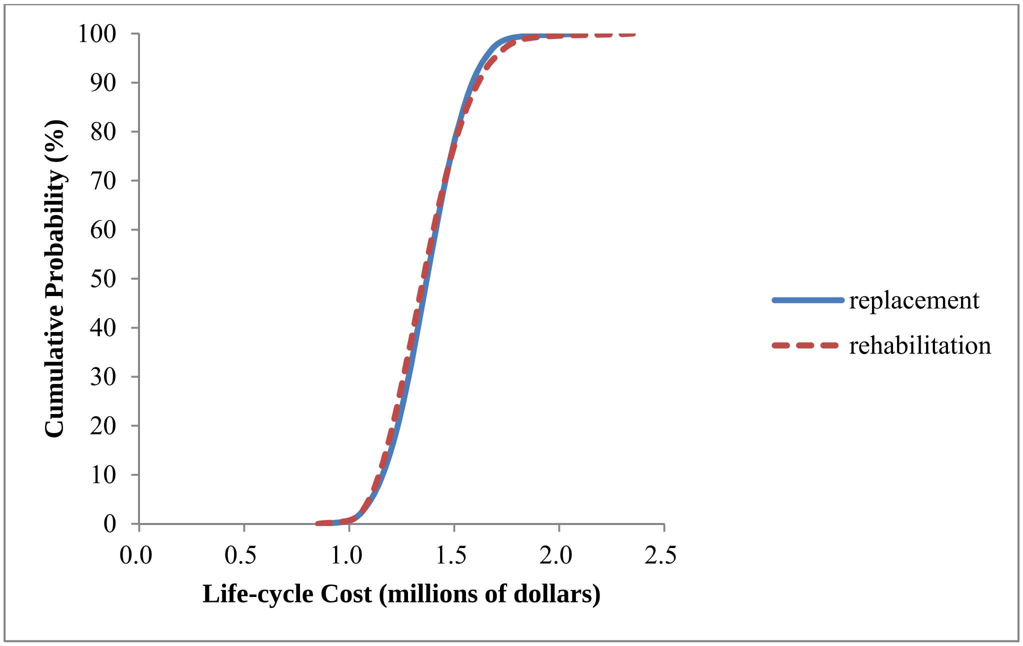


Figure E.145-Ascending cumulative probability distributions for waterway bridge ADT case 1, 2, 3 (Table 3.6)

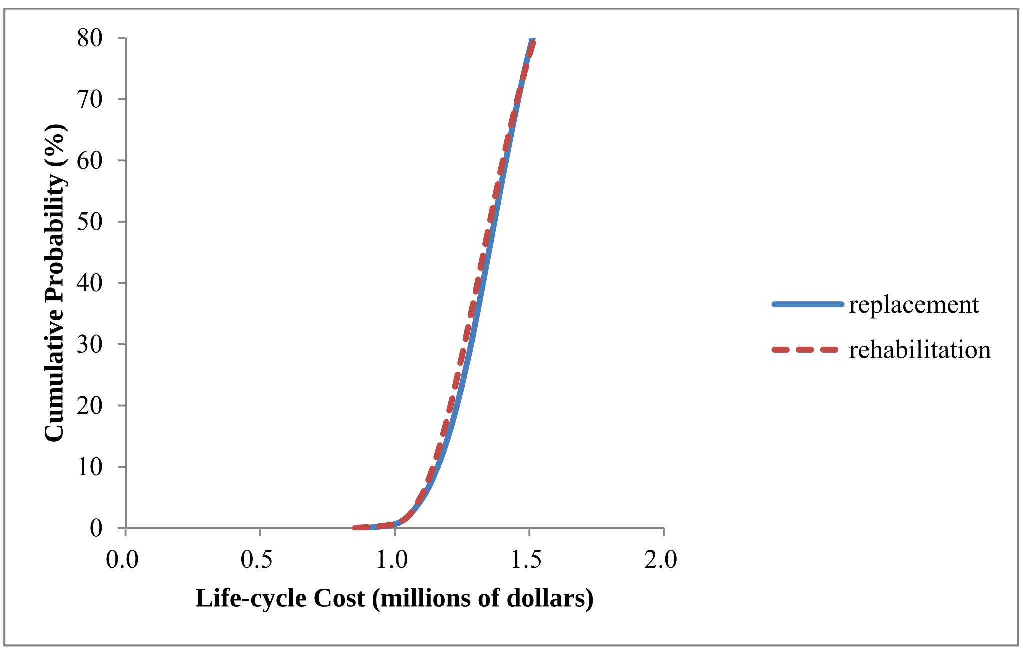


Figure E.146-Ascending cumulative probability distributions for waterway bridge ADT Case 1, 2, 3 (Table 3.6)

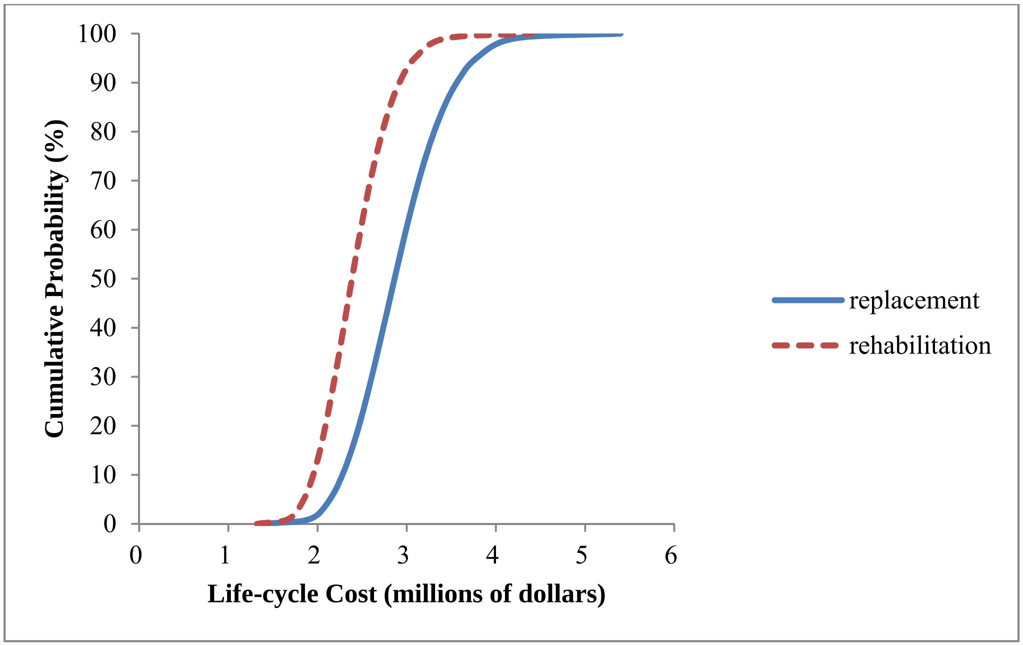


Figure E.147-Ascending cumulative probability distributions for waterway bridge ADT case 4, 5, 6 (Table 3.6)

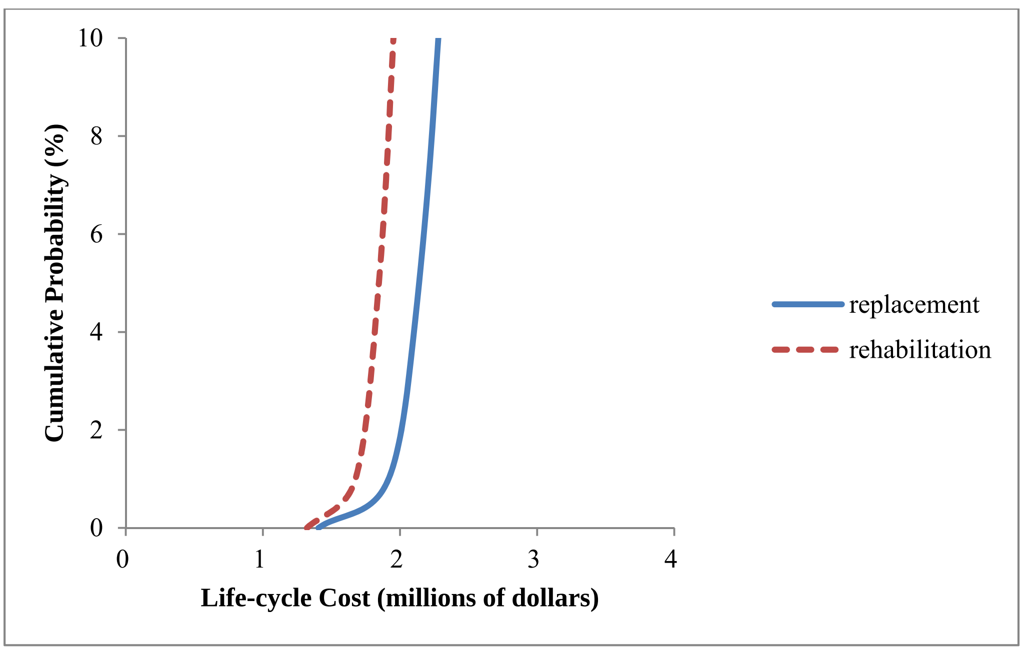


Figure E.148-Ascending cumulative probability distributions for waterway bridge ADT case 4, 5, 6 (Table 3.6)

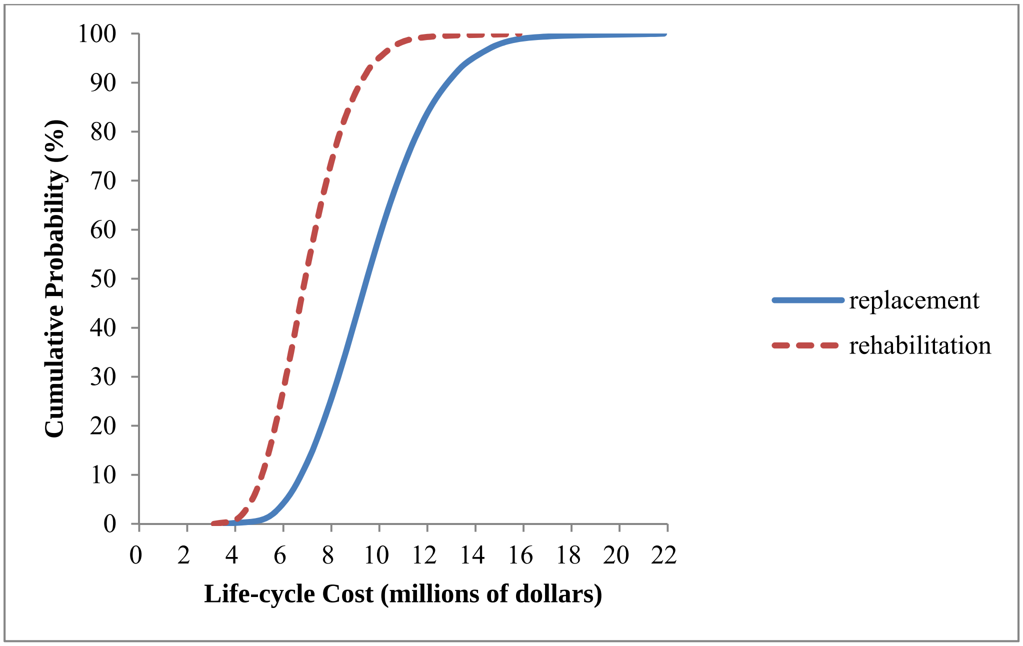


Figure E.149-Ascending cumulative probability distributions for waterway bridge ADT case 7, 8, 9 (Table 3.6)

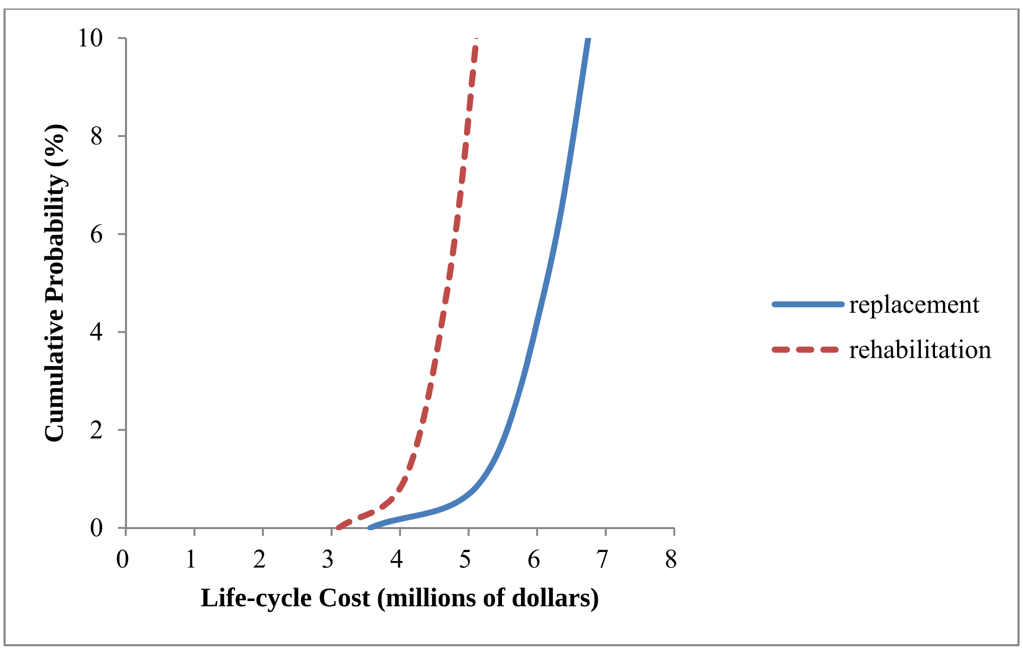


Figure E.150-Ascending cumulative probability distributions for waterway bridge ADT case 7, 8, 9 (Table 3.6)

Bridge over Waterway with Modified Bridge Construction Time and Cost

Table E.76-Risk profile statistics for waterway bridge with modification 1a ADT case 1, 2, 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	50,462	878,697	786,562	37,023	844,252
Maximum	1,886,683	318,976	2,045,934	2,215,473	223,416	2,322,575
Mean	1,203,246	135,950	1,339,196	1,250,895	94,874	1,345,769
Std Dev	156,504	34,486	161,082	176,045	23,339	180,518
Percentile						
1%	873,490	72,026	995,642	918,986	52,318	1,003,432
5%	944,947	85,399	1,075,061	989,239	61,317	1,076,928
10%	998,467	94,017	1,129,640	1,034,196	66,938	1,123,153
15%	1,036,577	100,444	1,167,716	1,067,266	71,083	1,157,207
20%	1,066,694	105,939	1,199,980	1,095,370	74,662	1,186,684
25%	1,093,671	110,844	1,226,823	1,120,827	77,922	1,212,716
30%	1,117,573	115,419	1,251,272	1,145,079	80,938	1,237,875
35%	1,139,495	119,871	1,273,624	1,168,546	83,790	1,261,860
40%	1,160,819	124,157	1,294,753	1,191,641	86,603	1,285,743
45%	1,180,699	128,404	1,315,628	1,213,326	89,350	1,308,208
50%	1,200,602	132,696	1,336,446	1,235,845	92,258	1,331,598
55%	1,221,005	136,998	1,357,312	1,259,393	95,266	1,354,812
60%	1,241,661	141,479	1,378,422	1,283,146	98,393	1,379,027
65%	1,263,269	146,278	1,400,320	1,308,004	101,615	1,404,645
70%	1,285,361	151,486	1,423,473	1,335,033	105,134	1,432,535
75%	1,309,835	157,321	1,448,159	1,364,473	109,127	1,462,076
80%	1,336,248	163,969	1,476,105	1,397,719	113,660	1,496,003
85%	1,367,322	171,806	1,508,923	1,436,754	119,076	1,536,803
90%	1,407,246	182,362	1,549,870	1,488,415	126,197	1,588,580
95%	1,465,450	198,289	1,608,450	1,563,780	137,366	1,666,087
99%	1,574,505	229,168	1,720,538	1,709,471	159,461	1,813,068

Table E.77-Risk profile statistics for waterway bridge with modification 1a ADT case 4, 5, 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	504,623	1,367,381	786,562	370,228	1,293,643
Maximum	1,886,683	3,189,762	4,473,098	2,215,473	2,234,163	3,773,227
Mean	1,203,246	1,359,503	2,562,749	1,250,895	948,737	2,199,632
Std Dev	156,504	344,861	382,190	176,045	233,395	309,790
Percentile						
1%	873,490	720,262	1,800,877	918,986	523,176	1,591,370
5%	944,947	853,994	1,983,348	989,239	613,168	1,734,404
10%	998,467	940,172	2,092,779	1,034,196	669,378	1,820,516
15%	1,036,577	1,004,441	2,169,886	1,067,266	710,829	1,881,749
20%	1,066,694	1,059,391	2,233,208	1,095,370	746,623	1,932,811
25%	1,093,671	1,108,442	2,289,556	1,120,827	779,219	1,977,809
30%	1,117,573	1,154,192	2,342,139	1,145,079	809,378	2,019,624
35%	1,139,495	1,198,711	2,391,608	1,168,546	837,903	2,059,645
40%	1,160,819	1,241,574	2,439,186	1,191,641	866,029	2,098,634
45%	1,180,699	1,284,045	2,486,845	1,213,326	893,501	2,136,824
50%	1,200,602	1,326,962	2,535,272	1,235,845	922,582	2,175,215
55%	1,221,005	1,369,979	2,584,441	1,259,393	952,662	2,215,582
60%	1,241,661	1,414,791	2,634,951	1,283,146	983,933	2,255,127
65%	1,263,269	1,462,780	2,687,483	1,308,004	1,016,153	2,298,383
70%	1,285,361	1,514,857	2,742,879	1,335,033	1,051,340	2,345,443
75%	1,309,835	1,573,207	2,804,908	1,364,473	1,091,270	2,396,356
80%	1,336,248	1,639,689	2,876,218	1,397,719	1,136,595	2,453,672
85%	1,367,322	1,718,057	2,960,598	1,436,754	1,190,760	2,521,701
90%	1,407,246	1,823,621	3,069,533	1,488,415	1,261,972	2,609,220
95%	1,465,450	1,982,885	3,236,658	1,563,780	1,373,657	2,748,404
99%	1,574,505	2,291,682	3,569,357	1,709,471	1,594,609	3,017,879

Table E.78-Risk profile statistics for waterway bridge with modification 1a ADT case 7, 8, 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	2,523,113	3,400,785	786,562	1,851,139	2,954,448
Maximum	1,886,683	15,948,811	17,232,147	2,215,473	11,170,816	12,678,953
Mean	1,203,246	6,797,514	8,000,760	1,250,895	4,743,686	5,994,581
Std Dev	156,504	1,724,305	1,735,211	176,045	1,166,973	1,202,224
Percentile						
1%	873,490	3,601,310	4,757,595	918,986	2,615,882	3,775,001
5%	944,947	4,269,971	5,447,293	989,239	3,065,840	4,251,908
10%	998,467	4,700,861	5,892,111	1,034,196	3,346,888	4,553,437
15%	1,036,577	5,022,204	6,217,744	1,067,266	3,554,144	4,769,096
20%	1,066,694	5,296,956	6,492,414	1,095,370	3,733,115	4,953,753
25%	1,093,671	5,542,211	6,736,375	1,120,827	3,896,095	5,123,665
30%	1,117,573	5,770,960	6,968,443	1,145,079	4,046,891	5,279,485
35%	1,139,495	5,993,554	7,192,082	1,168,546	4,189,513	5,427,788
40%	1,160,819	6,207,871	7,410,809	1,191,641	4,330,147	5,570,745
45%	1,180,699	6,420,223	7,622,902	1,213,326	4,467,506	5,716,492
50%	1,200,602	6,634,811	7,838,297	1,235,845	4,612,910	5,866,043
55%	1,221,005	6,849,893	8,056,223	1,259,393	4,763,310	6,018,669
60%	1,241,661	7,073,957	8,285,443	1,283,146	4,919,666	6,176,606
65%	1,263,269	7,313,899	8,520,860	1,308,004	5,080,763	6,346,734
70%	1,285,361	7,574,285	8,786,388	1,335,033	5,256,700	6,532,484
75%	1,309,835	7,866,035	9,077,445	1,364,473	5,456,352	6,729,995
80%	1,336,248	8,198,443	9,414,293	1,397,719	5,682,976	6,960,087
85%	1,367,322	8,590,287	9,807,257	1,436,754	5,953,798	7,241,111
90%	1,407,246	9,118,105	10,340,163	1,488,415	6,309,862	7,605,528
95%	1,465,450	9,914,427	11,131,725	1,563,780	6,868,283	8,174,185
99%	1,574,505	11,458,411	12,688,674	1,709,471	7,973,047	9,313,334

Table E.79-Risk profile statistics for waterway bridge with modification 1b ADT case 1, 2, 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	814,445	50,462	908,436	803,479	37,023	856,142
Maximum	1,931,128	318,976	2,090,379	2,242,801	223,416	2,349,903
Mean	1,247,349	135,950	1,383,299	1,272,992	94,874	1,367,866
Std Dev	157,159	34,486	161,720	177,439	23,339	181,981
Percentile						
1%	910,355	72,026	1,033,715	937,342	52,318	1,021,347
5%	987,360	85,399	1,117,199	1,008,814	61,317	1,096,408
10%	1,042,592	94,017	1,173,545	1,054,312	66,938	1,143,348
15%	1,080,966	100,444	1,211,972	1,087,896	71,083	1,177,845
20%	1,111,106	105,939	1,244,323	1,116,296	74,662	1,207,596
25%	1,138,098	110,844	1,271,247	1,141,945	77,922	1,233,993
30%	1,162,017	115,419	1,295,700	1,166,642	80,938	1,259,188
35%	1,183,939	119,871	1,318,069	1,190,207	83,790	1,283,446
40%	1,205,263	124,157	1,339,191	1,213,547	86,603	1,307,543
45%	1,225,144	128,404	1,360,066	1,235,535	89,350	1,330,272
50%	1,245,047	132,696	1,380,890	1,258,215	92,258	1,353,794
55%	1,265,450	136,998	1,401,756	1,281,871	95,266	1,377,149
60%	1,286,106	141,479	1,422,866	1,305,830	98,393	1,401,702
65%	1,307,713	146,278	1,444,765	1,330,715	101,615	1,427,359
70%	1,329,806	151,486	1,467,918	1,357,969	105,134	1,455,444
75%	1,354,279	157,321	1,492,603	1,387,360	109,127	1,485,031
80%	1,380,693	163,969	1,520,550	1,420,865	113,660	1,519,330
85%	1,411,766	171,806	1,553,368	1,460,507	119,076	1,560,504
90%	1,451,690	182,362	1,594,315	1,512,227	126,197	1,612,240
95%	1,509,895	198,289	1,652,895	1,587,923	137,366	1,690,023
99%	1,618,949	229,168	1,764,982	1,734,741	159,461	1,838,539

Table E.80-Risk profile statistics for waterway bridge with modification 1b ADT case 4, 5, 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	814,445	504,623	1,408,298	803,479	370,228	1,312,095
Maximum	1,931,128	3,189,762	4,517,543	2,242,801	2,234,163	3,799,729
Mean	1,247,349	1,359,503	2,606,852	1,272,992	948,737	2,221,730
Std Dev	157,159	344,861	382,464	177,439	233,395	311,185
Percentile						
1%	910,355	720,262	1,842,715	937,342	523,176	1,610,334
5%	987,360	853,994	2,026,660	1,008,814	613,168	1,754,317
10%	1,042,592	940,172	2,136,318	1,054,312	669,378	1,840,943
15%	1,080,966	1,004,441	2,213,706	1,087,896	710,829	1,902,220
20%	1,111,106	1,059,391	2,277,286	1,116,296	746,623	1,953,307
25%	1,138,098	1,108,442	2,333,615	1,141,945	779,219	1,999,003
30%	1,162,017	1,154,192	2,386,331	1,166,642	809,378	2,040,882
35%	1,183,939	1,198,711	2,435,742	1,190,207	837,903	2,081,244
40%	1,205,263	1,241,574	2,483,476	1,213,547	866,029	2,120,216
45%	1,225,144	1,284,045	2,530,965	1,235,535	893,501	2,158,819
50%	1,245,047	1,326,962	2,579,477	1,258,215	922,582	2,197,247
55%	1,265,450	1,369,979	2,628,681	1,281,871	952,662	2,237,712
60%	1,286,106	1,414,791	2,679,162	1,305,830	983,933	2,277,386
65%	1,307,713	1,462,780	2,731,749	1,330,715	1,016,153	2,321,023
70%	1,329,806	1,514,857	2,787,158	1,357,969	1,051,340	2,368,419
75%	1,354,279	1,573,207	2,849,166	1,387,360	1,091,270	2,419,301
80%	1,380,693	1,639,689	2,920,544	1,420,865	1,136,595	2,477,126
85%	1,411,766	1,718,057	3,004,902	1,460,507	1,190,760	2,545,269
90%	1,451,690	1,823,621	3,113,742	1,512,227	1,261,972	2,632,848
95%	1,509,895	1,982,885	3,281,090	1,587,923	1,373,657	2,772,554
99%	1,618,949	2,291,682	3,613,802	1,734,741	1,594,609	3,043,057

Table E.81-Risk profile statistics for waterway bridge with modification 1b ADT case 7, 8, 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	814,445	2,523,113	3,445,229	803,479	1,851,139	2,971,340
Maximum	1,931,128	15,948,811	17,276,592	2,242,801	11,170,816	12,705,455
Mean	1,247,349	6,797,514	8,044,863	1,272,992	4,743,686	6,016,678
Std Dev	157,159	1,724,305	1,735,276	177,439	1,166,973	1,203,206
Percentile						
1%	910,355	3,601,310	4,801,679	937,342	2,615,882	3,794,834
5%	987,360	4,269,971	5,491,229	1,008,814	3,065,840	4,273,246
10%	1,042,592	4,700,861	5,936,345	1,054,312	3,346,888	4,574,195
15%	1,080,966	5,022,204	6,261,742	1,087,896	3,554,144	4,790,036
20%	1,111,106	5,296,956	6,536,457	1,116,296	3,733,115	4,974,944
25%	1,138,098	5,542,211	6,780,449	1,141,945	3,896,095	5,145,445
30%	1,162,017	5,770,960	7,012,545	1,166,642	4,046,891	5,300,820
35%	1,183,939	5,993,554	7,236,223	1,190,207	4,189,513	5,449,547
40%	1,205,263	6,207,871	7,455,047	1,213,547	4,330,147	5,592,891
45%	1,225,144	6,420,223	7,667,158	1,235,535	4,467,506	5,738,158
50%	1,245,047	6,634,811	7,882,593	1,258,215	4,612,910	5,887,744
55%	1,265,450	6,849,893	8,100,204	1,281,871	4,763,310	6,040,812
60%	1,286,106	7,073,957	8,329,510	1,305,830	4,919,666	6,199,064
65%	1,307,713	7,313,899	8,565,004	1,330,715	5,080,763	6,369,028
70%	1,329,806	7,574,285	8,830,672	1,357,969	5,256,700	6,554,640
75%	1,354,279	7,866,035	9,121,479	1,387,360	5,456,352	6,752,595
80%	1,380,693	8,198,443	9,458,364	1,420,865	5,682,976	6,982,787
85%	1,411,766	8,590,287	9,851,033	1,460,507	5,953,798	7,265,447
90%	1,451,690	9,118,105	10,384,198	1,512,227	6,309,862	7,629,221
95%	1,509,895	9,914,427	11,176,042	1,587,923	6,868,283	8,198,402
99%	1,618,949	11,458,411	12,733,119	1,734,741	7,973,047	9,341,598

Table E.82-Risk profile statistics for waterway bridge with modification 1c ADT case 1, 2, 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	844,185	50,462	938,176	815,708	37,023	868,033
Maximum	1,975,490	318,976	2,134,741	2,270,078	223,416	2,377,180
Mean	1,291,442	135,950	1,427,392	1,295,084	94,874	1,389,958
Std Dev	157,697	34,486	162,244	178,841	23,339	183,451
Percentile						
1%	947,834	72,026	1,072,240	956,108	52,318	1,039,688
5%	1,030,505	85,399	1,160,063	1,028,309	61,317	1,115,854
10%	1,086,610	94,017	1,217,487	1,074,461	66,938	1,163,499
15%	1,125,246	100,444	1,256,192	1,108,358	71,083	1,198,351
20%	1,155,457	105,939	1,288,657	1,137,138	74,662	1,228,490
25%	1,182,460	110,844	1,315,609	1,163,136	77,922	1,255,202
30%	1,206,379	115,419	1,340,053	1,188,173	80,938	1,280,621
35%	1,228,301	119,871	1,362,431	1,211,917	83,790	1,305,009
40%	1,249,625	124,157	1,383,542	1,235,386	86,603	1,329,146
45%	1,269,506	128,404	1,404,428	1,257,768	89,350	1,352,301
50%	1,289,409	132,696	1,425,252	1,280,426	92,258	1,375,904
55%	1,309,812	136,998	1,446,118	1,304,081	95,266	1,399,247
60%	1,330,468	141,479	1,467,228	1,328,370	98,393	1,424,195
65%	1,352,075	146,278	1,489,127	1,353,555	101,615	1,450,083
70%	1,374,167	151,486	1,512,280	1,380,785	105,134	1,478,135
75%	1,398,641	157,321	1,536,965	1,410,323	109,127	1,508,107
80%	1,425,054	163,969	1,564,912	1,443,877	113,660	1,542,537
85%	1,456,128	171,806	1,597,730	1,484,062	119,076	1,584,119
90%	1,496,052	182,362	1,638,677	1,536,174	126,197	1,636,298
95%	1,554,257	198,289	1,697,256	1,612,251	137,366	1,714,758
99%	1,663,311	229,168	1,809,344	1,760,364	159,461	1,864,628

Table E.83-Risk profile statistics for waterway bridge with modification 1c ADT case 4, 5, 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	844,185	504,623	1,452,660	815,708	370,228	1,325,058
Maximum	1,975,490	3,189,762	4,561,905	2,270,078	2,234,163	3,826,182
Mean	1,291,442	1,359,503	2,650,945	1,295,084	948,737	2,243,822
Std Dev	157,697	344,861	382,693	178,841	233,395	312,586
Percentile						
1%	947,834	720,262	1,885,296	956,108	523,176	1,629,933
5%	1,030,505	853,994	2,069,895	1,028,309	613,168	1,774,224
10%	1,086,610	940,172	2,179,969	1,074,461	669,378	1,860,886
15%	1,125,246	1,004,441	2,257,723	1,108,358	710,829	1,922,803
20%	1,155,457	1,059,391	2,321,350	1,137,138	746,623	1,974,241
25%	1,182,460	1,108,442	2,377,727	1,163,136	779,219	2,020,011
30%	1,206,379	1,154,192	2,430,359	1,188,173	809,378	2,062,161
35%	1,228,301	1,198,711	2,479,922	1,211,917	837,903	2,102,555
40%	1,249,625	1,241,574	2,527,637	1,235,386	866,029	2,141,639
45%	1,269,506	1,284,045	2,575,203	1,257,768	893,501	2,180,679
50%	1,289,409	1,326,962	2,623,694	1,280,426	922,582	2,219,270
55%	1,309,812	1,369,979	2,672,880	1,304,081	952,662	2,259,868
60%	1,330,468	1,414,791	2,723,477	1,328,370	983,933	2,299,902
65%	1,352,075	1,462,780	2,776,029	1,353,555	1,016,153	2,343,527
70%	1,374,167	1,514,857	2,831,443	1,380,785	1,051,340	2,391,253
75%	1,398,641	1,573,207	2,893,452	1,410,323	1,091,270	2,442,514
80%	1,425,054	1,639,689	2,964,732	1,443,877	1,136,595	2,500,408
85%	1,456,128	1,718,057	3,049,147	1,484,062	1,190,760	2,568,741
90%	1,496,052	1,823,621	3,158,091	1,536,174	1,261,972	2,656,862
95%	1,554,257	1,982,885	3,325,260	1,612,251	1,373,657	2,797,479
99%	1,663,311	2,291,682	3,658,164	1,760,364	1,594,609	3,068,157

Table E.84-Risk profile statistics for waterway bridge with modification 1c ADT case 7, 8, 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	844,185	2,523,113	3,489,591	815,708	1,851,139	2,988,201
Maximum	1,975,490	15,948,811	17,320,953	2,270,078	11,170,816	12,731,907
Mean	1,291,442	6,797,514	8,088,956	1,295,084	4,743,686	6,038,771
Std Dev	157,697	1,724,305	1,735,333	178,841	1,166,973	1,204,191
Percentile						
1%	947,834	3,601,310	4,845,478	956,108	2,615,882	3,815,402
5%	1,030,505	4,269,971	5,534,964	1,028,309	3,065,840	4,293,929
10%	1,086,610	4,700,861	5,980,510	1,074,461	3,346,888	4,594,950
15%	1,125,246	5,022,204	6,306,051	1,108,358	3,554,144	4,811,630
20%	1,155,457	5,296,956	6,580,191	1,137,138	3,733,115	4,996,409
25%	1,182,460	5,542,211	6,824,662	1,163,136	3,896,095	5,166,636
30%	1,206,379	5,770,960	7,056,622	1,188,173	4,046,891	5,322,168
35%	1,228,301	5,993,554	7,280,243	1,211,917	4,189,513	5,471,363
40%	1,249,625	6,207,871	7,499,256	1,235,386	4,330,147	5,614,406
45%	1,269,506	6,420,223	7,711,190	1,257,768	4,467,506	5,760,322
50%	1,289,409	6,634,811	7,926,715	1,280,426	4,612,910	5,909,693
55%	1,309,812	6,849,893	8,144,472	1,304,081	4,763,310	6,063,023
60%	1,330,468	7,073,957	8,373,729	1,328,370	4,919,666	6,220,997
65%	1,352,075	7,313,899	8,609,177	1,353,555	5,080,763	6,391,481
70%	1,374,167	7,574,285	8,874,549	1,380,785	5,256,700	6,577,295
75%	1,398,641	7,866,035	9,165,665	1,410,323	5,456,352	6,775,681
80%	1,425,054	8,198,443	9,502,627	1,443,877	5,682,976	7,005,468
85%	1,456,128	8,590,287	9,895,395	1,484,062	5,953,798	7,289,360
90%	1,496,052	9,118,105	10,428,502	1,536,174	6,309,862	7,652,709
95%	1,554,257	9,914,427	11,219,729	1,612,251	6,868,283	8,221,137
99%	1,663,311	11,458,411	12,773,673	1,760,364	7,973,047	9,366,168

Table E.85-Risk profile statistics for waterway bridge with modification 2a ADT case 1, 2, 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	45,949	859,920	786,562	34,432	836,343
Maximum	1,886,683	216,853	1,988,698	2,215,473	153,217	2,293,340
Mean	1,203,246	100,290	1,303,536	1,250,895	72,019	1,322,914
Std Dev	156,504	21,120	158,712	176,045	14,550	178,854
Percentile						
1%	873,490	61,426	968,061	918,986	45,570	984,594
5%	944,947	69,841	1,042,670	989,239	51,326	1,056,620
10%	998,467	74,952	1,096,395	1,034,196	54,800	1,102,368
15%	1,036,577	78,775	1,134,441	1,067,266	57,305	1,136,131
20%	1,066,694	82,011	1,166,032	1,095,370	59,484	1,165,066
25%	1,093,671	84,916	1,192,744	1,120,827	61,483	1,190,834
30%	1,117,573	87,607	1,216,565	1,145,079	63,302	1,215,615
35%	1,139,495	90,260	1,238,994	1,168,546	65,052	1,239,876
40%	1,160,819	92,868	1,259,737	1,191,641	66,752	1,263,093
45%	1,180,699	95,461	1,280,255	1,213,326	68,500	1,285,692
50%	1,200,602	98,045	1,300,966	1,235,845	70,264	1,308,333
55%	1,221,005	100,641	1,321,292	1,259,393	72,130	1,331,773
60%	1,241,661	103,397	1,342,273	1,283,146	74,061	1,355,893
65%	1,263,269	106,406	1,363,672	1,308,004	76,105	1,381,257
70%	1,285,361	109,571	1,387,266	1,335,033	78,334	1,408,731
75%	1,309,835	113,240	1,411,186	1,364,473	80,831	1,438,135
80%	1,336,248	117,309	1,438,297	1,397,719	83,672	1,471,716
85%	1,367,322	122,286	1,470,588	1,436,754	87,100	1,511,936
90%	1,407,246	128,886	1,511,022	1,488,415	91,559	1,563,631
95%	1,465,450	138,838	1,569,277	1,563,780	98,669	1,640,693
99%	1,574,505	158,060	1,679,685	1,709,471	112,620	1,787,086

Table E.86-Risk profile statistics for waterway bridge with modification 2a ADT case 4, 5, 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	459,493	1,329,434	786,562	344,323	1,222,185
Maximum	1,886,683	2,168,532	3,471,023	2,215,473	1,532,168	3,155,651
Mean	1,203,246	1,002,901	2,206,147	1,250,895	720,187	1,971,082
Std Dev	156,504	211,204	267,580	176,045	145,501	244,984
Percentile						
1%	873,490	614,263	1,652,597	918,986	455,701	1,484,464
5%	944,947	698,406	1,792,727	989,239	513,261	1,599,599
10%	998,467	749,517	1,873,505	1,034,196	547,997	1,668,806
15%	1,036,577	787,753	1,930,772	1,067,266	573,054	1,718,006
20%	1,066,694	820,113	1,977,010	1,095,370	594,840	1,758,253
25%	1,093,671	849,160	2,017,401	1,120,827	614,832	1,795,811
30%	1,117,573	876,067	2,055,018	1,145,079	633,024	1,829,819
35%	1,139,495	902,595	2,089,796	1,168,546	650,522	1,861,001
40%	1,160,819	928,677	2,123,745	1,191,641	667,523	1,892,244
45%	1,180,699	954,605	2,157,465	1,213,326	684,998	1,922,740
50%	1,200,602	980,450	2,191,485	1,235,845	702,639	1,953,652
55%	1,221,005	1,006,408	2,224,884	1,259,393	721,300	1,985,052
60%	1,241,661	1,033,966	2,259,707	1,283,146	740,608	2,017,136
65%	1,263,269	1,064,055	2,296,040	1,308,004	761,048	2,051,227
70%	1,285,361	1,095,710	2,334,639	1,335,033	783,338	2,088,616
75%	1,309,835	1,132,398	2,377,762	1,364,473	808,306	2,128,712
80%	1,336,248	1,173,087	2,426,109	1,397,719	836,723	2,174,004
85%	1,367,322	1,222,864	2,484,964	1,436,754	870,998	2,227,706
90%	1,407,246	1,288,855	2,559,643	1,488,415	915,589	2,296,077
95%	1,465,450	1,388,383	2,671,593	1,563,780	986,693	2,401,356
99%	1,574,505	1,580,604	2,893,080	1,709,471	1,126,196	2,604,266

Table E.87-Risk profile statistics for waterway bridge with modification 2a ADT case 7, 8, 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	784,705	2,297,467	3,232,298	786,562	1,721,617	2,797,876
Maximum	1,886,683	10,842,662	12,125,998	2,215,473	7,660,839	9,189,605
Mean	1,203,246	5,014,507	6,217,753	1,250,895	3,600,933	4,851,828
Std Dev	156,504	1,056,021	1,073,389	176,045	727,503	774,292
Percentile						
1%	873,490	3,071,315	4,216,187	918,986	2,278,503	3,410,110
5%	944,947	3,492,029	4,657,607	989,239	2,566,305	3,732,198
10%	998,467	3,747,585	4,927,894	1,034,196	2,739,985	3,926,433
15%	1,036,577	3,938,764	5,127,752	1,067,266	2,865,271	4,066,385
20%	1,066,694	4,100,565	5,288,688	1,095,370	2,974,201	4,187,635
25%	1,093,671	4,245,799	5,437,469	1,120,827	3,074,159	4,293,871
30%	1,117,573	4,380,337	5,576,315	1,145,079	3,165,121	4,392,024
35%	1,139,495	4,512,976	5,710,067	1,168,546	3,252,612	4,485,442
40%	1,160,819	4,643,384	5,844,339	1,191,641	3,337,615	4,579,187
45%	1,180,699	4,773,025	5,976,721	1,213,326	3,424,988	4,674,102
50%	1,200,602	4,902,250	6,108,769	1,235,845	3,513,196	4,768,216
55%	1,221,005	5,032,041	6,243,040	1,259,393	3,606,499	4,865,763
60%	1,241,661	5,169,828	6,381,822	1,283,146	3,703,042	4,969,404
65%	1,263,269	5,320,276	6,531,544	1,308,004	3,805,242	5,078,406
70%	1,285,361	5,478,550	6,697,417	1,335,033	3,916,688	5,197,719
75%	1,309,835	5,661,988	6,878,859	1,364,473	4,041,531	5,326,433
80%	1,336,248	5,865,433	7,086,533	1,397,719	4,183,616	5,474,104
85%	1,367,322	6,114,321	7,337,039	1,436,754	4,354,989	5,652,049
90%	1,407,246	6,444,277	7,665,598	1,488,415	4,577,947	5,886,920
95%	1,465,450	6,941,916	8,167,642	1,563,780	4,933,467	6,248,513
99%	1,574,505	7,903,018	9,150,922	1,709,471	5,630,981	6,986,954

Table E.88-Risk profile statistics for waterway bridge with modification 2b ADT case 1, 2, 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	844,185	45,949	919,400	815,708	34,432	860,124
Maximum	1,975,490	216,853	2,077,505	2,270,078	153,217	2,347,945
Mean	1,291,442	100,290	1,391,732	1,295,084	72,019	1,367,103
Std Dev	157,697	21,120	159,889	178,841	14,550	181,760
Percentile						
1%	947,834	61,426	1,042,838	956,108	45,570	1,020,654
5%	1,030,505	69,841	1,127,323	1,028,309	51,326	1,095,908
10%	1,086,610	74,952	1,184,418	1,074,461	54,800	1,142,439
15%	1,125,246	78,775	1,223,027	1,108,358	57,305	1,177,174
20%	1,155,457	82,011	1,254,765	1,137,138	59,484	1,206,732
25%	1,182,460	84,916	1,281,533	1,163,136	61,483	1,233,258
30%	1,206,379	87,607	1,305,350	1,188,173	63,302	1,258,600
35%	1,228,301	90,260	1,327,800	1,211,917	65,052	1,282,931
40%	1,249,625	92,868	1,348,543	1,235,386	66,752	1,306,464
45%	1,269,506	95,461	1,369,061	1,257,768	68,500	1,329,802
50%	1,289,409	98,045	1,389,773	1,280,426	70,264	1,352,683
55%	1,309,812	100,641	1,410,098	1,304,081	72,130	1,376,461
60%	1,330,468	103,397	1,431,080	1,328,370	74,061	1,400,978
65%	1,352,075	106,406	1,452,478	1,353,555	76,105	1,426,684
70%	1,374,167	109,571	1,476,072	1,380,785	78,334	1,454,494
75%	1,398,641	113,240	1,499,992	1,410,323	80,831	1,484,098
80%	1,425,054	117,309	1,527,104	1,443,877	83,672	1,518,448
85%	1,456,128	122,286	1,559,395	1,484,062	87,100	1,559,118
90%	1,496,052	128,886	1,599,829	1,536,174	91,559	1,611,614
95%	1,554,257	138,838	1,658,083	1,612,251	98,669	1,689,328
99%	1,663,311	158,060	1,768,491	1,760,364	112,620	1,838,009

Table E.89-Risk profile statistics for waterway bridge with modification 2b ADT case 4, 5, 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	844,185	459,493	1,414,713	815,708	344,323	1,245,966
Maximum	1,975,490	2,168,532	3,559,829	2,270,078	1,532,168	3,211,298
Mean	1,291,442	1,002,901	2,294,343	1,295,084	720,187	2,015,271
Std Dev	157,697	211,204	268,288	178,841	145,501	248,120
Percentile						
1%	947,834	614,263	1,735,549	956,108	455,701	1,522,149
5%	1,030,505	698,406	1,879,361	1,028,309	513,261	1,638,921
10%	1,086,610	749,517	1,960,829	1,074,461	547,997	1,708,892
15%	1,125,246	787,753	2,018,429	1,108,358	573,054	1,759,037
20%	1,155,457	820,113	2,064,920	1,137,138	594,840	1,799,803
25%	1,182,460	849,160	2,105,756	1,163,136	614,832	1,837,570
30%	1,206,379	876,067	2,143,213	1,188,173	633,024	1,872,192
35%	1,228,301	902,595	2,178,261	1,211,917	650,522	1,903,718
40%	1,249,625	928,677	2,212,229	1,235,386	667,523	1,935,768
45%	1,269,506	954,605	2,245,993	1,257,768	684,998	1,966,372
50%	1,289,409	980,450	2,280,017	1,280,426	702,639	1,997,782
55%	1,309,812	1,006,408	2,313,450	1,304,081	721,300	2,029,464
60%	1,330,468	1,033,966	2,348,335	1,328,370	740,608	2,062,097
65%	1,352,075	1,064,055	2,384,731	1,353,555	761,048	2,096,651
70%	1,374,167	1,095,710	2,423,175	1,380,785	783,338	2,134,411
75%	1,398,641	1,132,398	2,466,418	1,410,323	808,306	2,174,809
80%	1,425,054	1,173,087	2,514,841	1,443,877	836,723	2,220,930
85%	1,456,128	1,222,864	2,573,751	1,484,062	870,998	2,274,986
90%	1,496,052	1,288,855	2,648,409	1,536,174	915,589	2,344,216
95%	1,554,257	1,388,383	2,760,328	1,612,251	986,693	2,450,573
99%	1,663,311	1,580,604	2,981,886	1,760,364	1,126,196	2,655,872

Table E.90-Risk profile statistics for waterway bridge with modification 2b ADT Case 7, 8, 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	844,185	2,297,467	3,321,104	815,708	1,721,617	2,831,629
Maximum	1,975,490	10,842,662	12,214,804	2,270,078	7,660,839	9,242,559
Mean	1,291,442	5,014,507	6,305,949	1,295,084	3,600,933	4,896,017
Std Dev	157,697	1,056,021	1,073,575	178,841	727,503	776,718
Percentile						
1%	947,834	3,071,315	4,304,327	956,108	2,278,503	3,451,207
5%	1,030,505	3,492,029	4,744,706	1,028,309	2,566,305	3,772,223
10%	1,086,610	3,747,585	5,016,132	1,074,461	2,739,985	3,967,527
15%	1,125,246	3,938,764	5,215,765	1,108,358	2,865,271	4,107,815
20%	1,155,457	4,100,565	5,376,692	1,137,138	2,974,201	4,229,460
25%	1,182,460	4,245,799	5,525,769	1,163,136	3,074,159	4,336,340
30%	1,206,379	4,380,337	5,664,613	1,188,173	3,165,121	4,434,409
35%	1,228,301	4,512,976	5,797,975	1,211,917	3,252,612	4,528,767
40%	1,249,625	4,643,384	5,932,466	1,235,386	3,337,615	4,622,710
45%	1,269,506	4,773,025	6,064,869	1,257,768	3,424,988	4,718,106
50%	1,289,409	4,902,250	6,196,795	1,280,426	3,513,196	4,812,761
55%	1,309,812	5,032,041	6,331,335	1,304,081	3,606,499	4,910,798
60%	1,330,468	5,169,828	6,469,970	1,328,370	3,703,042	5,014,422
65%	1,352,075	5,320,276	6,619,538	1,353,555	3,805,242	5,123,340
70%	1,374,167	5,478,550	6,785,726	1,380,785	3,916,688	5,243,263
75%	1,398,641	5,661,988	6,967,174	1,410,323	4,041,531	5,371,613
80%	1,425,054	5,865,433	7,174,693	1,443,877	4,183,616	5,520,330
85%	1,456,128	6,114,321	7,425,733	1,484,062	4,354,989	5,698,947
90%	1,496,052	6,444,277	7,753,532	1,536,174	4,577,947	5,933,554
95%	1,554,257	6,941,916	8,256,361	1,612,251	4,933,467	6,297,195
99%	1,663,311	7,903,018	9,239,728	1,760,364	5,630,981	7,034,622

Table E.91-Risk profile statistics for waterway bridge with modification 2c ADT case 1, 2, 3 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	909,896	45,949	985,120	839,311	34,432	883,904
Maximum	2,064,296	216,853	2,166,311	2,324,683	153,217	2,402,550
Mean	1,379,872	100,290	1,480,162	1,339,390	72,019	1,411,409
Std Dev	158,496	21,120	160,679	181,686	14,550	184,711
Percentile						
1%	1,023,595	61,426	1,120,739	993,354	45,570	1,058,336
5%	1,118,214	69,841	1,214,863	1,067,949	51,326	1,135,029
10%	1,175,202	74,952	1,272,967	1,114,835	54,800	1,183,164
15%	1,214,014	78,775	1,311,795	1,149,658	57,305	1,218,281
20%	1,244,247	82,011	1,343,561	1,179,435	59,484	1,248,831
25%	1,271,267	84,916	1,370,329	1,205,478	61,483	1,275,533
30%	1,295,186	87,607	1,394,156	1,231,215	63,302	1,301,452
35%	1,317,108	90,260	1,416,607	1,255,319	65,052	1,326,321
40%	1,338,432	92,868	1,437,350	1,278,975	66,752	1,350,260
45%	1,358,312	95,461	1,457,868	1,301,968	68,500	1,373,933
50%	1,378,215	98,045	1,478,579	1,324,922	70,264	1,397,287
55%	1,398,619	100,641	1,498,905	1,348,819	72,130	1,421,200
60%	1,419,274	103,397	1,519,886	1,373,112	74,061	1,446,199
65%	1,440,882	106,406	1,541,285	1,398,954	76,105	1,472,385
70%	1,462,974	109,571	1,564,879	1,426,604	78,334	1,500,249
75%	1,487,448	113,240	1,588,799	1,456,370	80,831	1,530,237
80%	1,513,861	117,309	1,615,910	1,490,684	83,672	1,565,132
85%	1,544,935	122,286	1,648,202	1,531,113	87,100	1,606,617
90%	1,584,859	128,886	1,688,635	1,584,222	91,559	1,659,381
95%	1,643,063	138,838	1,746,890	1,660,925	98,669	1,738,614
99%	1,752,118	158,060	1,857,298	1,810,143	112,620	1,890,035

Table E.92-Risk profile statistics for waterway bridge with modification 2c ADT case 4, 5, 6 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	909,896	459,493	1,498,659	839,311	344,323	1,269,747
Maximum	2,064,296	2,168,532	3,648,636	2,324,683	1,532,168	3,266,945
Mean	1,379,872	1,002,901	2,382,773	1,339,390	720,187	2,059,577
Std Dev	158,496	211,204	268,762	181,686	145,501	251,286
Percentile						
1%	1,023,595	614,263	1,820,420	993,354	455,701	1,559,675
5%	1,118,214	698,406	1,966,727	1,067,949	513,261	1,678,130
10%	1,175,202	749,517	2,048,974	1,114,835	547,997	1,748,955
15%	1,214,014	787,753	2,106,578	1,149,658	573,054	1,800,121
20%	1,244,247	820,113	2,153,405	1,179,435	594,840	1,841,607
25%	1,271,267	849,160	2,194,148	1,205,478	614,832	1,879,366
30%	1,295,186	876,067	2,231,724	1,231,215	633,024	1,914,385
35%	1,317,108	902,595	2,266,838	1,255,319	650,522	1,946,249
40%	1,338,432	928,677	2,300,814	1,278,975	667,523	1,979,189
45%	1,358,312	954,605	2,334,662	1,301,968	684,998	2,010,053
50%	1,378,215	980,450	2,368,618	1,324,922	702,639	2,042,135
55%	1,398,619	1,006,408	2,402,189	1,348,819	721,300	2,074,291
60%	1,419,274	1,033,966	2,437,081	1,373,112	740,608	2,107,216
65%	1,440,882	1,064,055	2,473,374	1,398,954	761,048	2,142,198
70%	1,462,974	1,095,710	2,511,913	1,426,604	783,338	2,180,131
75%	1,487,448	1,132,398	2,555,127	1,456,370	808,306	2,221,227
80%	1,513,861	1,173,087	2,603,640	1,490,684	836,723	2,267,773
85%	1,544,935	1,222,864	2,662,542	1,531,113	870,998	2,322,614
90%	1,584,859	1,288,855	2,737,216	1,584,222	915,589	2,393,079
95%	1,643,063	1,388,383	2,849,134	1,660,925	986,693	2,499,746
99%	1,752,118	1,580,604	3,070,693	1,810,143	1,126,196	2,707,795

Table E.93-Risk profile statistics for waterway bridge with modification 2c ADT case 7, 8, 9 (Table 3.6)

Basic Statistic	Life-cycle Costs, Dollars					
	Replacement Alternative			Rehabilitation Alternative		
	Agency	User	Total	Agency	User	Total
Minimum	844,185	2,523,113	3,489,591	815,708	1,851,139	2,988,201
Maximum	1,975,490	15,948,811	17,320,953	2,270,078	11,170,816	12,731,907
Mean	1,291,442	6,797,514	8,088,956	1,295,084	4,743,686	6,038,771
Std Dev	157,697	1,724,305	1,735,333	178,841	1,166,973	1,204,191
Percentile						
1%	947,834	3,601,310	4,845,478	956,108	2,615,882	3,815,402
5%	1,030,505	4,269,971	5,534,964	1,028,309	3,065,840	4,293,929
10%	1,086,610	4,700,861	5,980,510	1,074,461	3,346,888	4,594,950
15%	1,125,246	5,022,204	6,306,051	1,108,358	3,554,144	4,811,630
20%	1,155,457	5,296,956	6,580,191	1,137,138	3,733,115	4,996,409
25%	1,182,460	5,542,211	6,824,662	1,163,136	3,896,095	5,166,636
30%	1,206,379	5,770,960	7,056,622	1,188,173	4,046,891	5,322,168
35%	1,228,301	5,993,554	7,280,243	1,211,917	4,189,513	5,471,363
40%	1,249,625	6,207,871	7,499,256	1,235,386	4,330,147	5,614,406
45%	1,269,506	6,420,223	7,711,190	1,257,768	4,467,506	5,760,322
50%	1,289,409	6,634,811	7,926,715	1,280,426	4,612,910	5,909,693
55%	1,309,812	6,849,893	8,144,472	1,304,081	4,763,310	6,063,023
60%	1,330,468	7,073,957	8,373,729	1,328,370	4,919,666	6,220,997
65%	1,352,075	7,313,899	8,609,177	1,353,555	5,080,763	6,391,481
70%	1,374,167	7,574,285	8,874,549	1,380,785	5,256,700	6,577,295
75%	1,398,641	7,866,035	9,165,665	1,410,323	5,456,352	6,775,681
80%	1,425,054	8,198,443	9,502,627	1,443,877	5,682,976	7,005,468
85%	1,456,128	8,590,287	9,895,395	1,484,062	5,953,798	7,289,360
90%	1,496,052	9,118,105	10,428,502	1,536,174	6,309,862	7,652,709
95%	1,554,257	9,914,427	11,219,729	1,612,251	6,868,283	8,221,137
99%	1,663,311	11,458,411	12,773,673	1,760,364	7,973,047	9,366,168

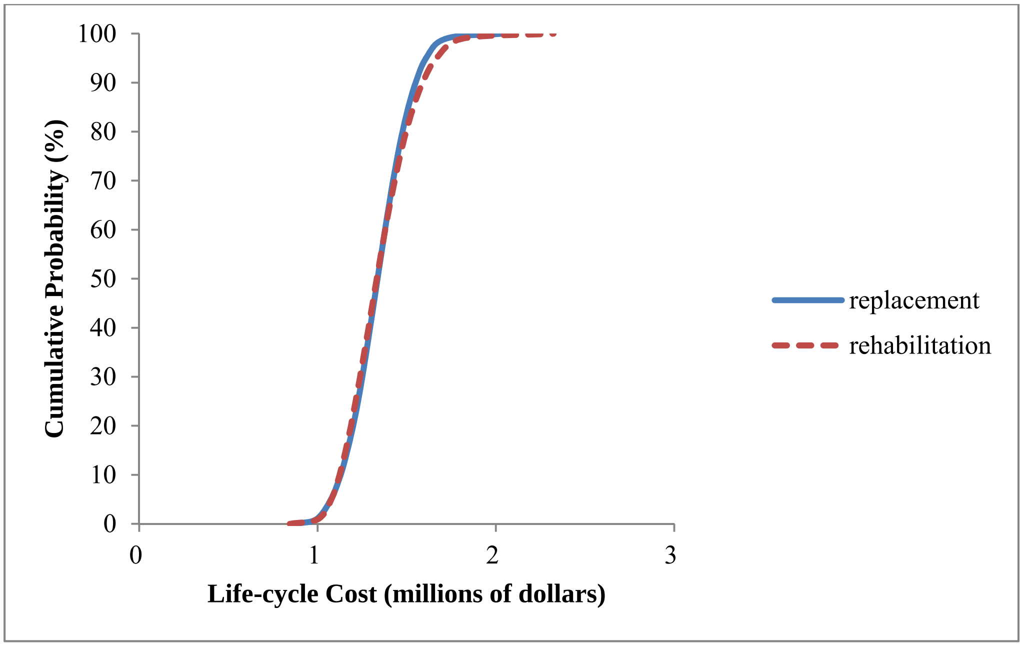


Figure E.151-Ascending cumulative probability distributions for waterway bridge with modification 1a ADT case 1, 2, 3 (Table 3.6)

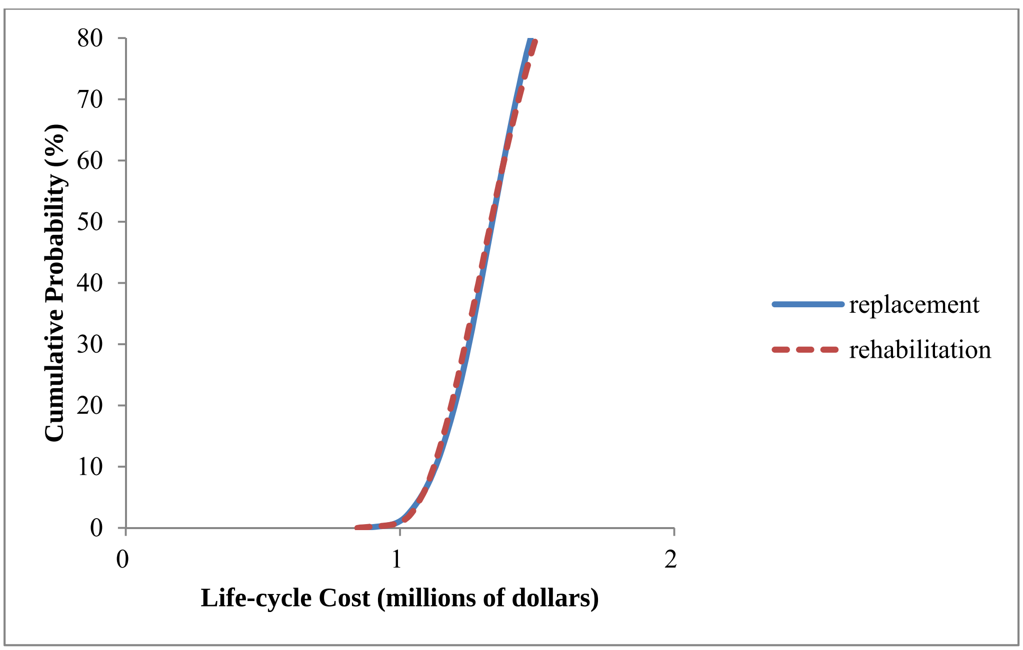


Figure E.152-Ascending cumulative probability distributions for waterway bridge with modification 1a ADT case 1, 2, 3 (Table 3.6)

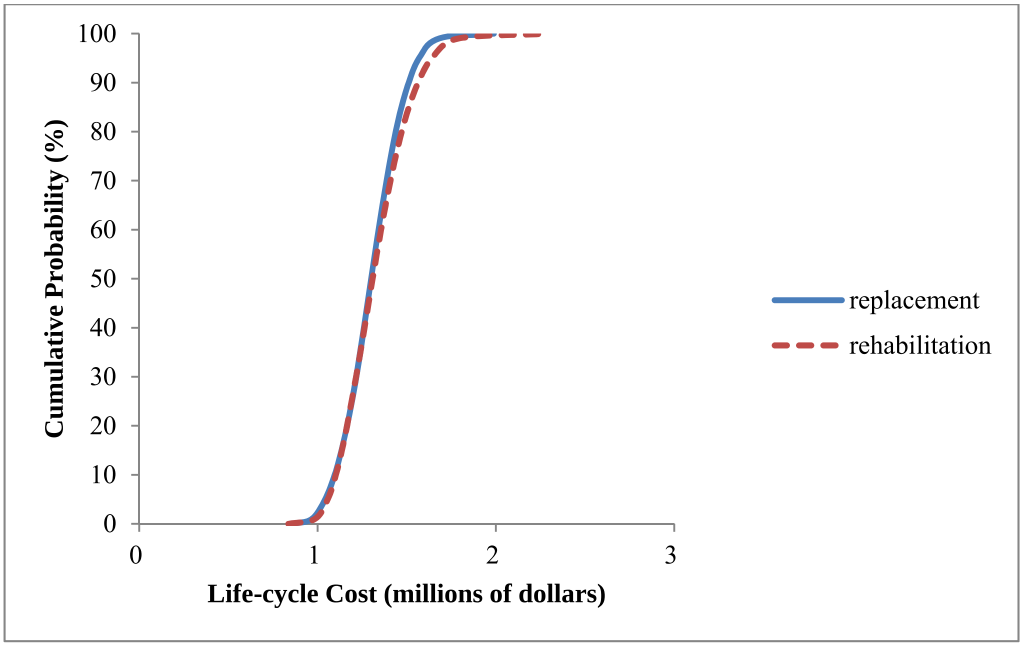


Figure E.153-Ascending cumulative probability distributions for waterway bridge with modification 2a ADT case 1, 2, 3 (Table 3.6)

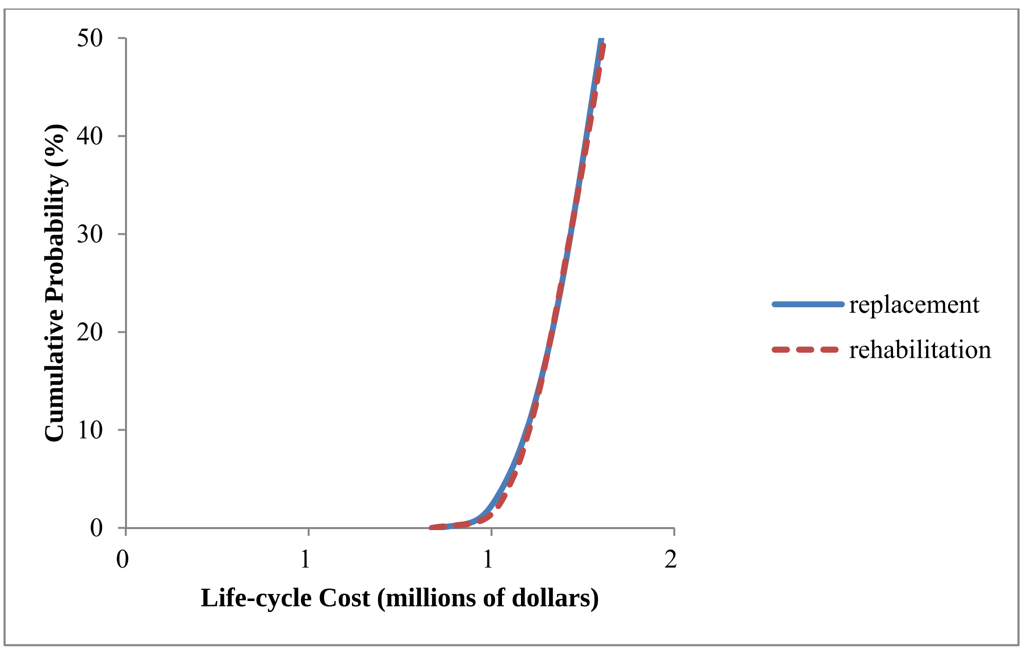


Figure E.154-Ascending cumulative probability distributions for waterway bridge with modification 2a ADT case 1, 2, 3 (Table 3.6)

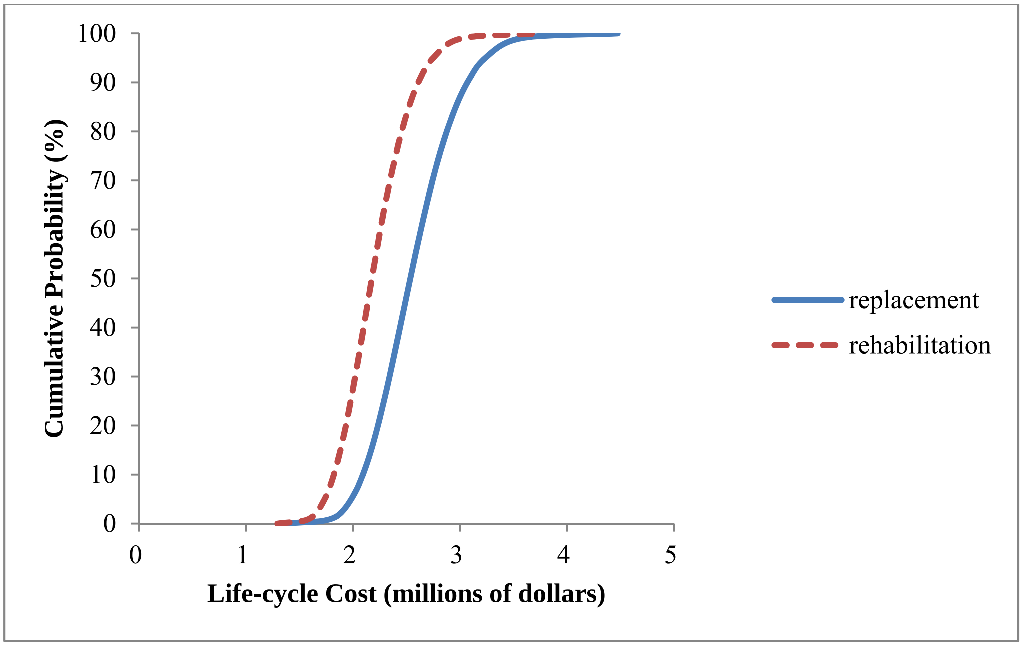


Figure E.155-Ascending cumulative probability distributions for waterway bridge with modification 1a ADT case 4, 6, 6 (Table 3.6)

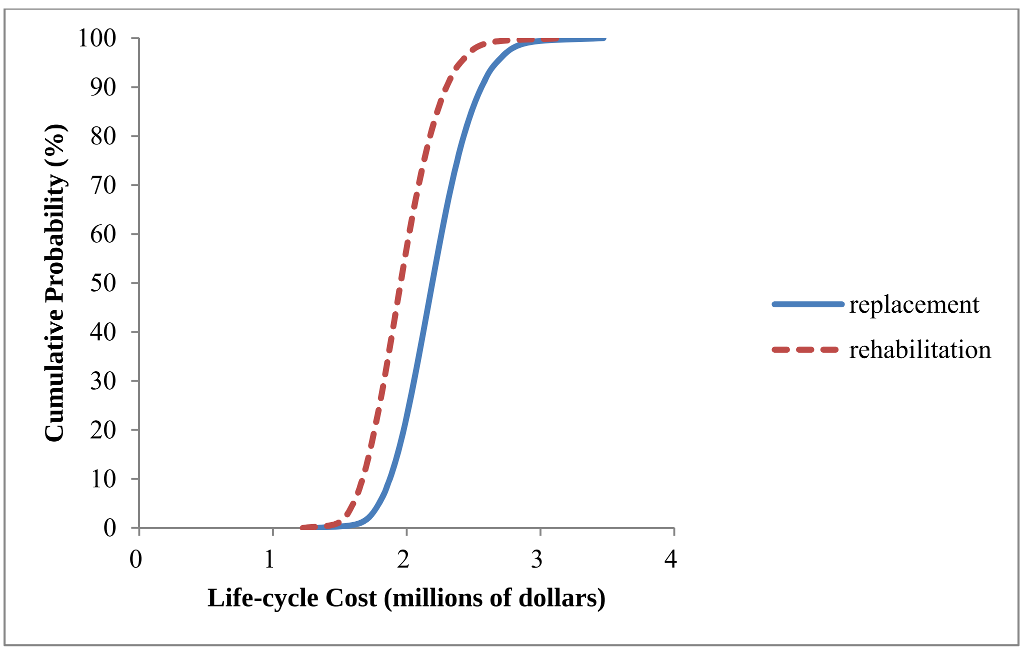


Figure E.156-Ascending cumulative probability distributions for waterway bridge with modification 2a ADT case 4, 5, 6 (Table 3.6)

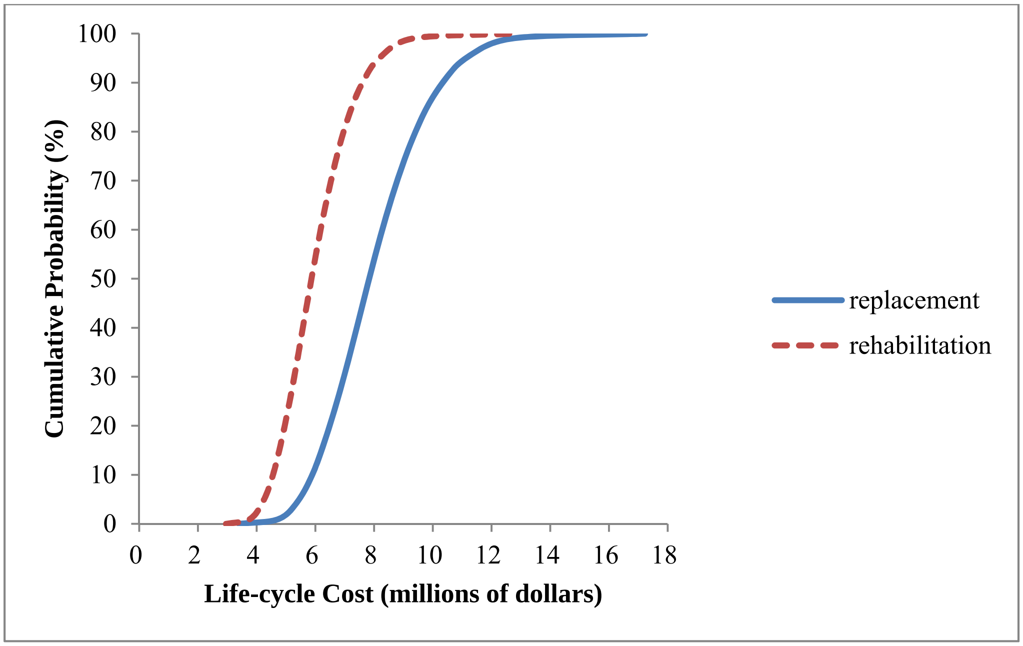


Figure E.157-Ascending cumulative probability distributions for waterway bridge with modification 1a ADT case 7, 8, 9 (Table 3.6)

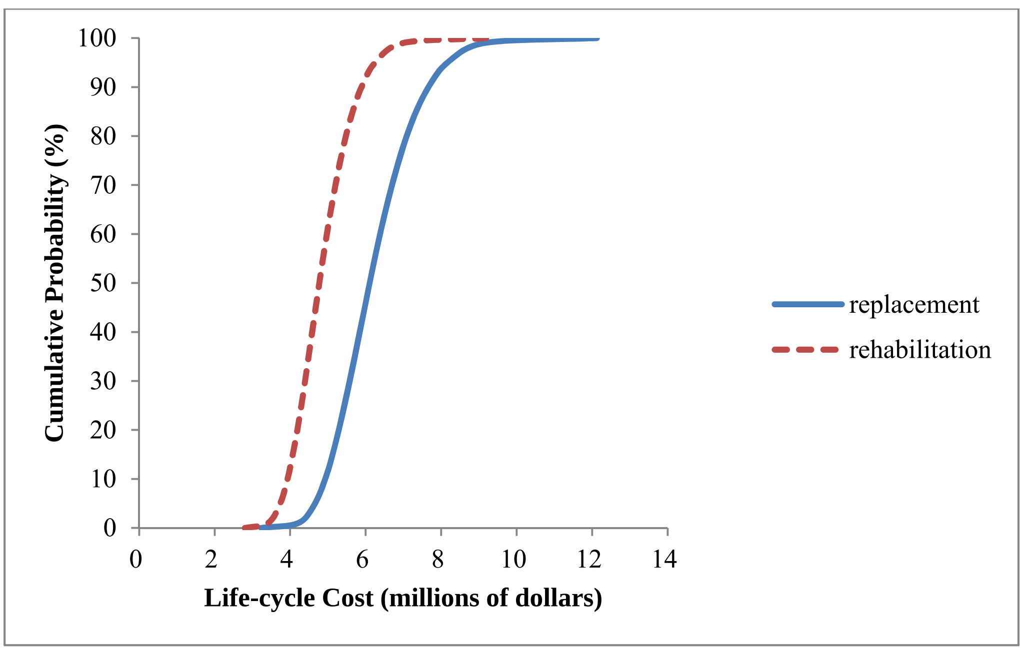


Figure E.158-Ascending cumulative probability distributions for waterway bridge with modification 2a ADT Case 7, 8, 9 (Table 3.6)

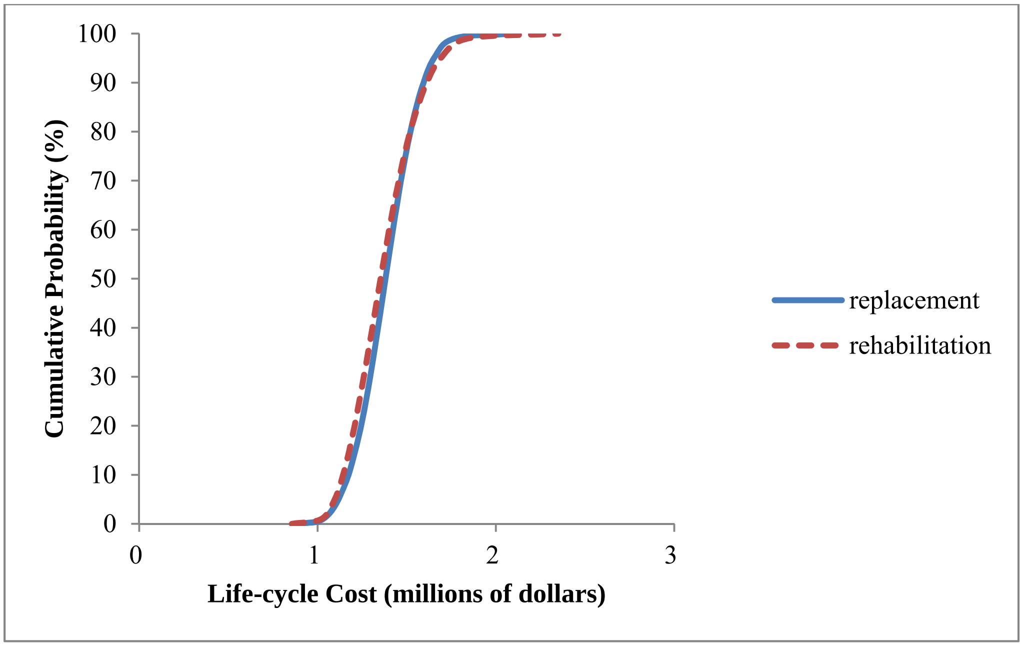


Figure E.159-Ascending cumulative probability distributions for waterway bridge with modification 1b ADT case 1, 2, 3 (Table 3.6)

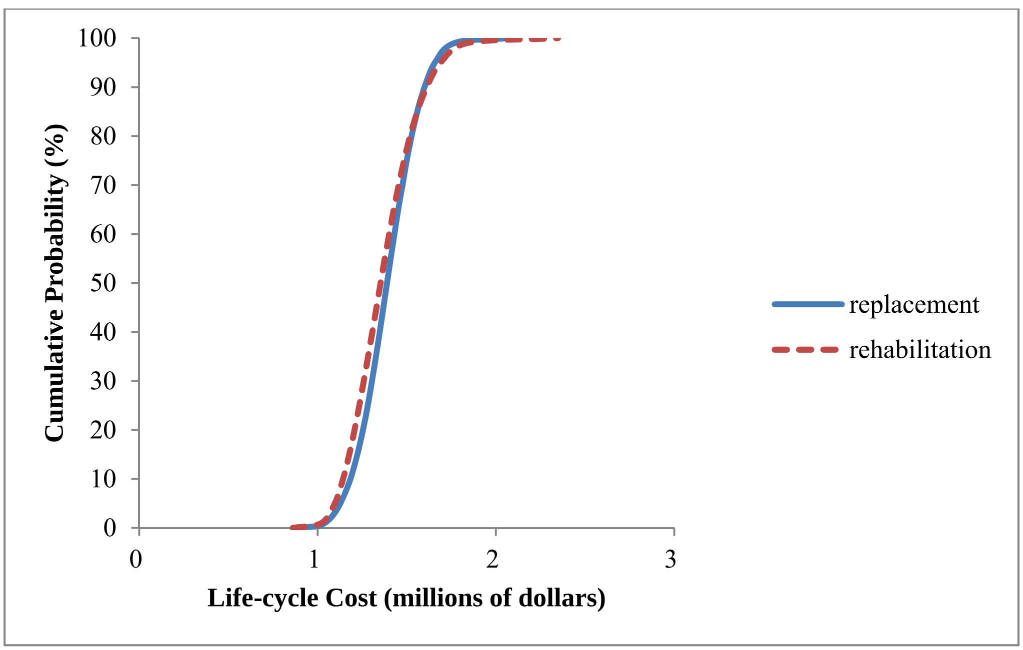


Figure E.160-Ascending cumulative probability distributions for waterway bridge with modification 2b ADT case 1, 2, 3 (Table 3.6)

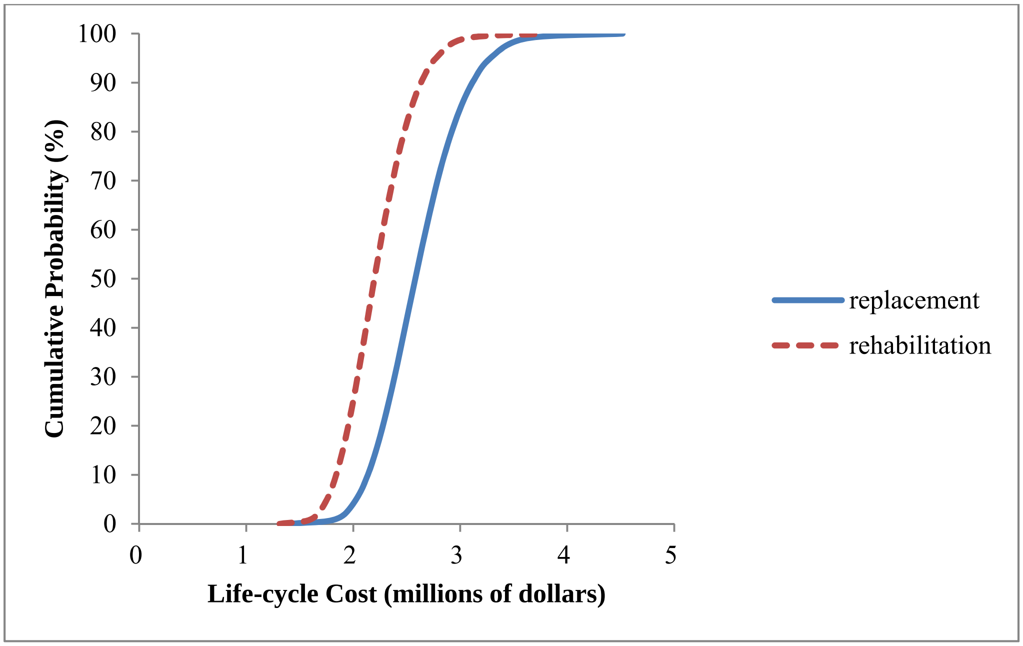


Figure E.161-Ascending cumulative probability distributions for waterway bridge with modification 1b ADT case 4, 5, 6 (Table 3.6)

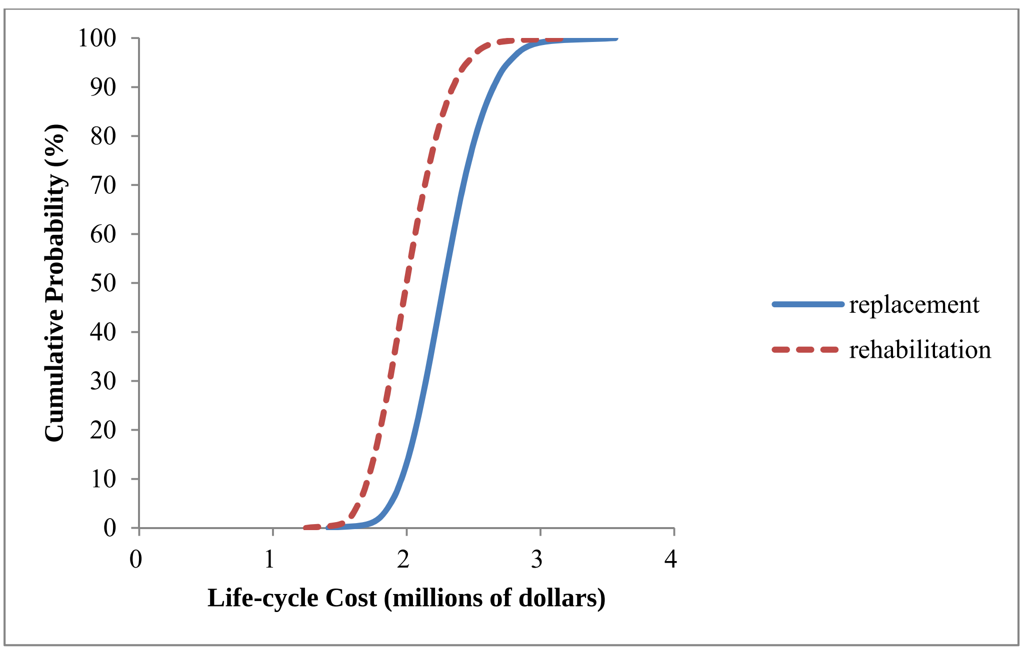


Figure E.162-Ascending cumulative probability distributions for waterway bridge with modification 2b ADT case 4, 5, 6 (Table 3.6)

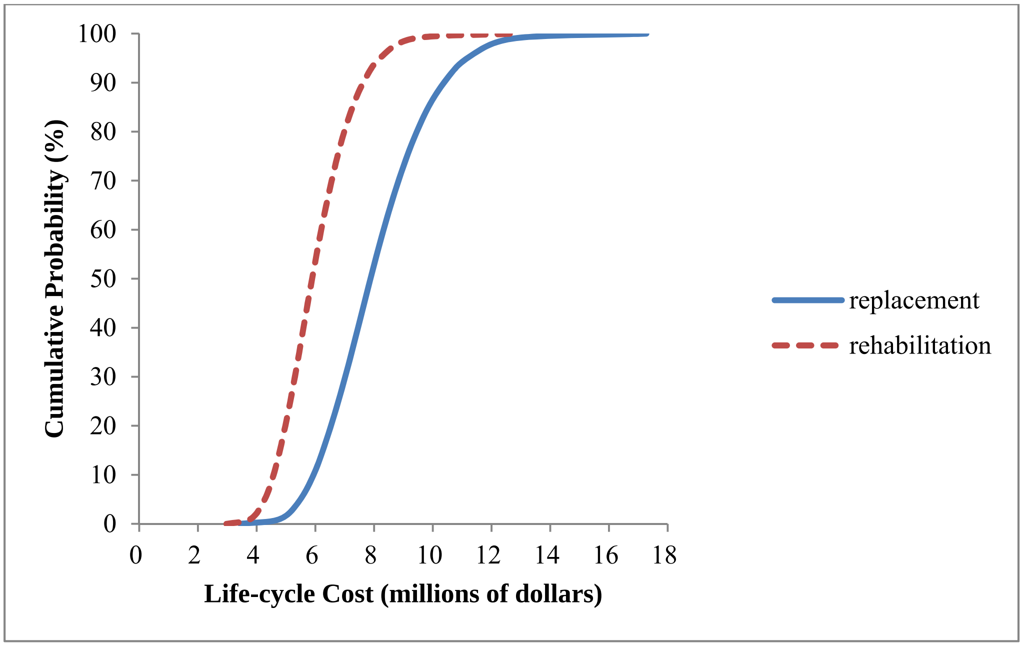


Figure E.163-Ascending cumulative probability distributions for waterway bridge with modification 1b ADT case 7, 8, 9 (Table 3.6)

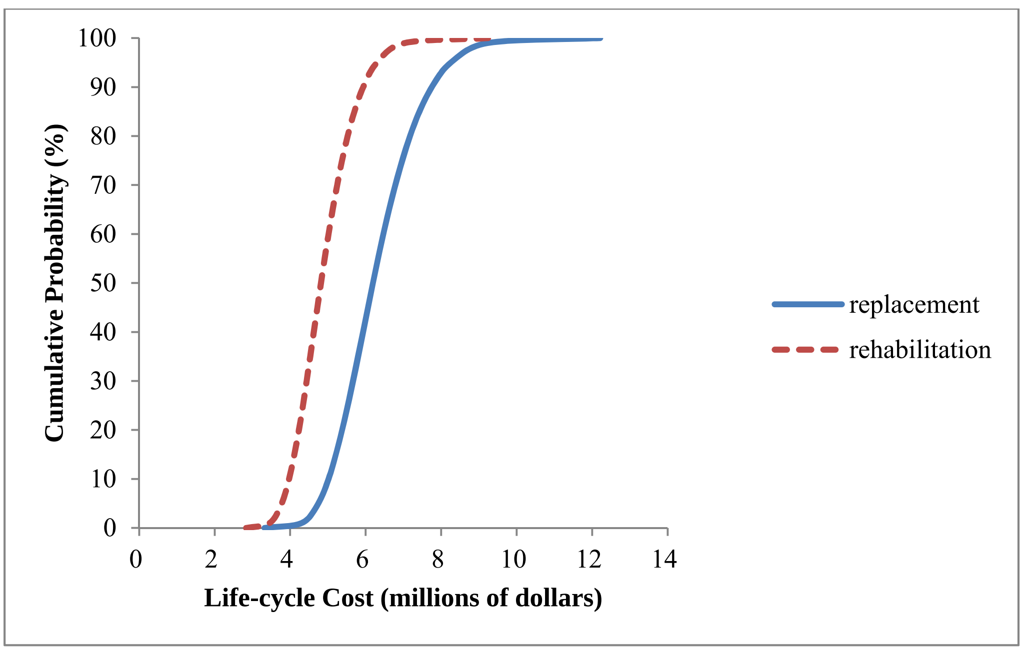


Figure E.164-ascending cumulative probability distributions for waterway bridge with modification 2b ADT case 7, 8, 9 (Table 3.6)

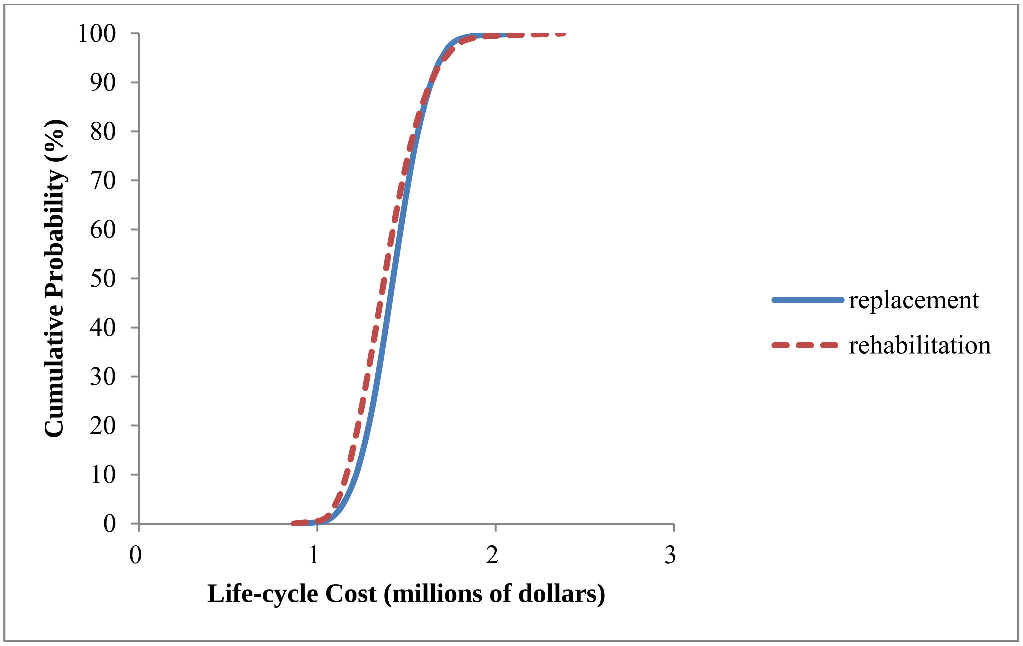


Figure E.165-ascending cumulative probability distributions for waterway bridge with modification 1c ADT Case 1, 2, 3 (Table 3.6)

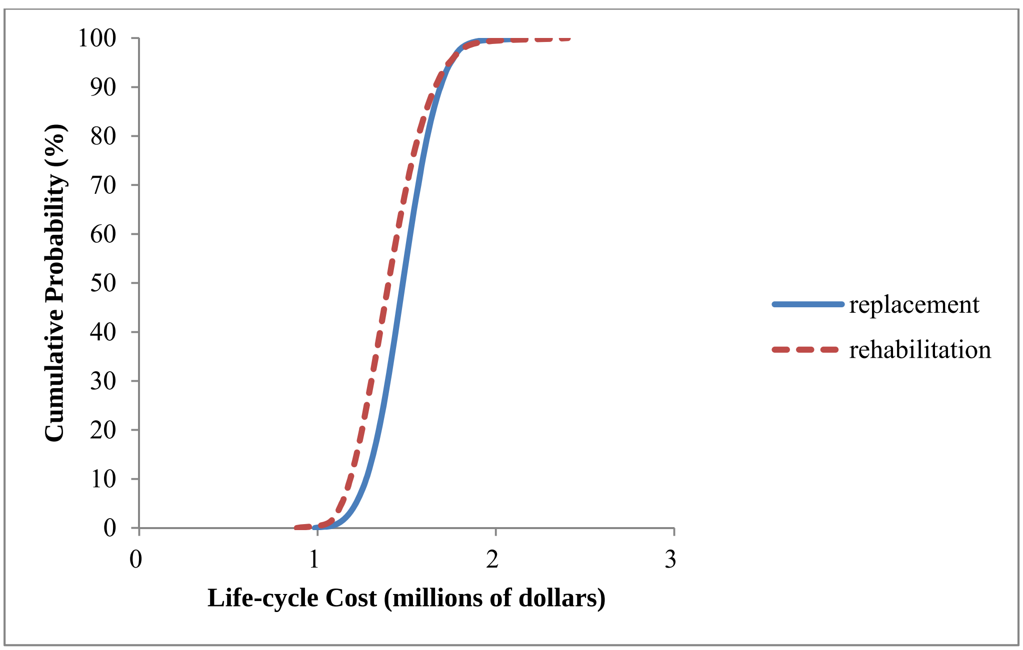


Figure E.166-Ascending cumulative probability distributions for waterway bridge with modification 2c ADT Case 1, 2, 3 (Table 3.6)

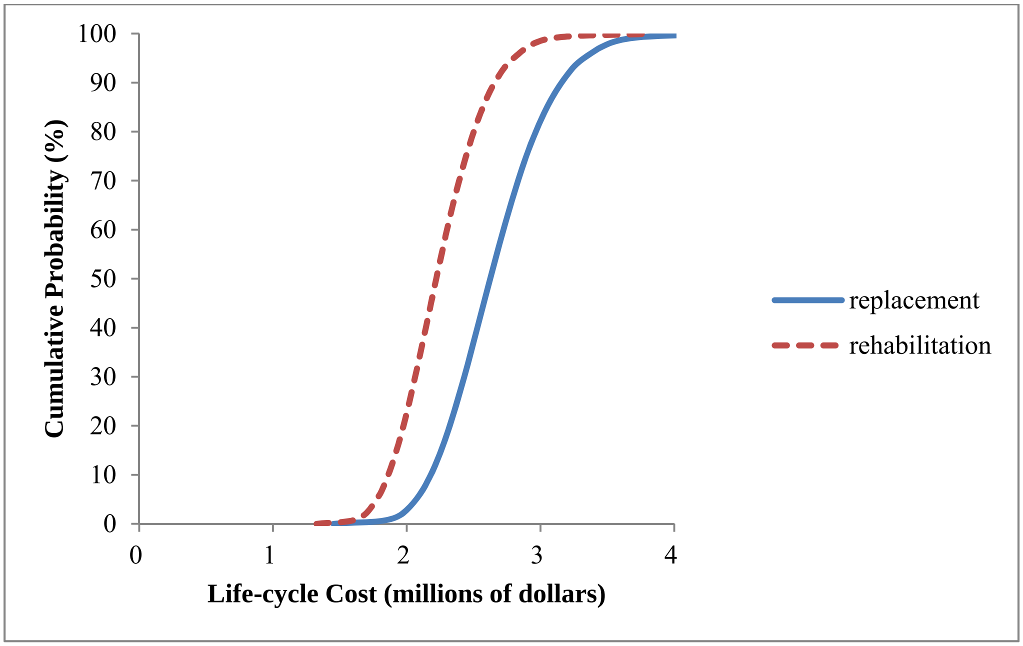


Figure E.167-Ascending cumulative probability distributions for waterway bridge with modification 1c ADT case 4, 5, 6 (Table 3.6)

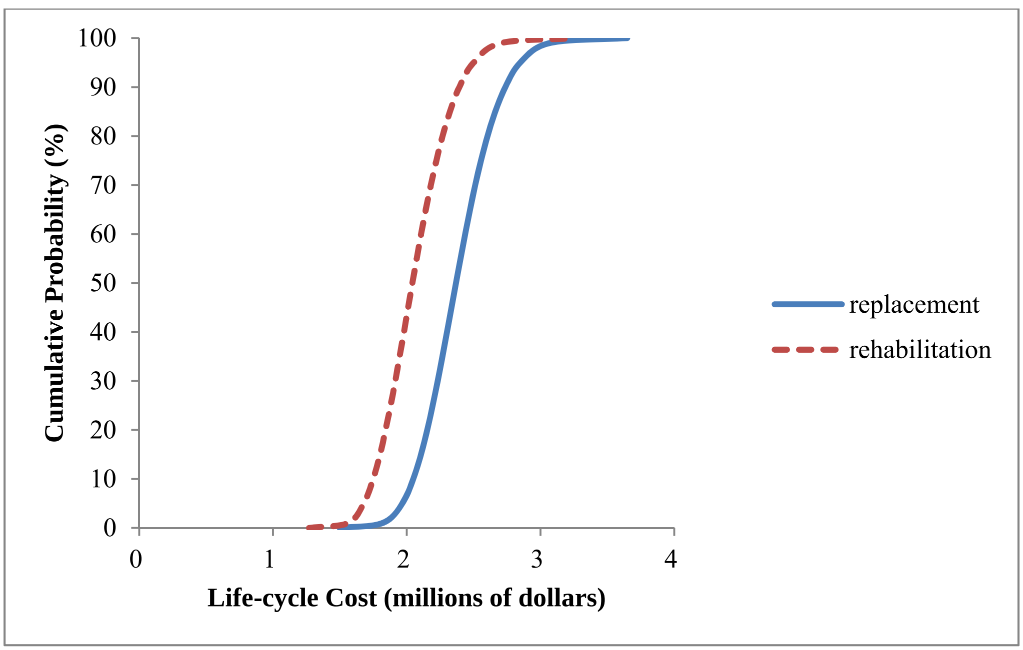


Figure E.168-Ascending cumulative probability distributions for waterway bridge with modification 2c ADT case 4, 5, 6 (Table 3.6)

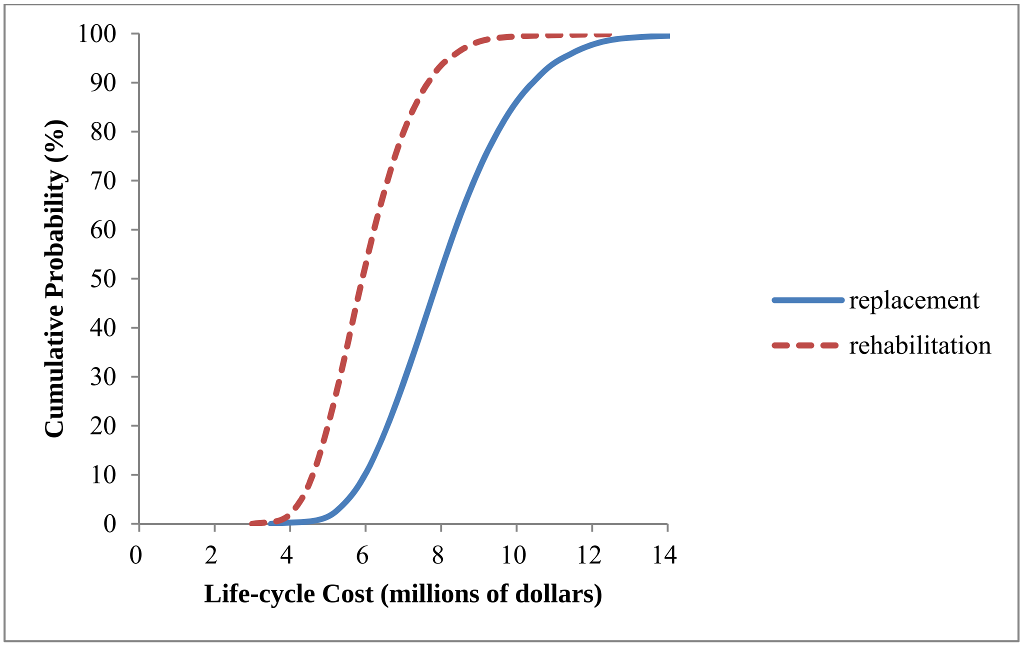


Figure E.169-Ascending cumulative probability distributions for waterway bridge with modification 1c ADT Case 7, 8, 9 (Table 3.6)

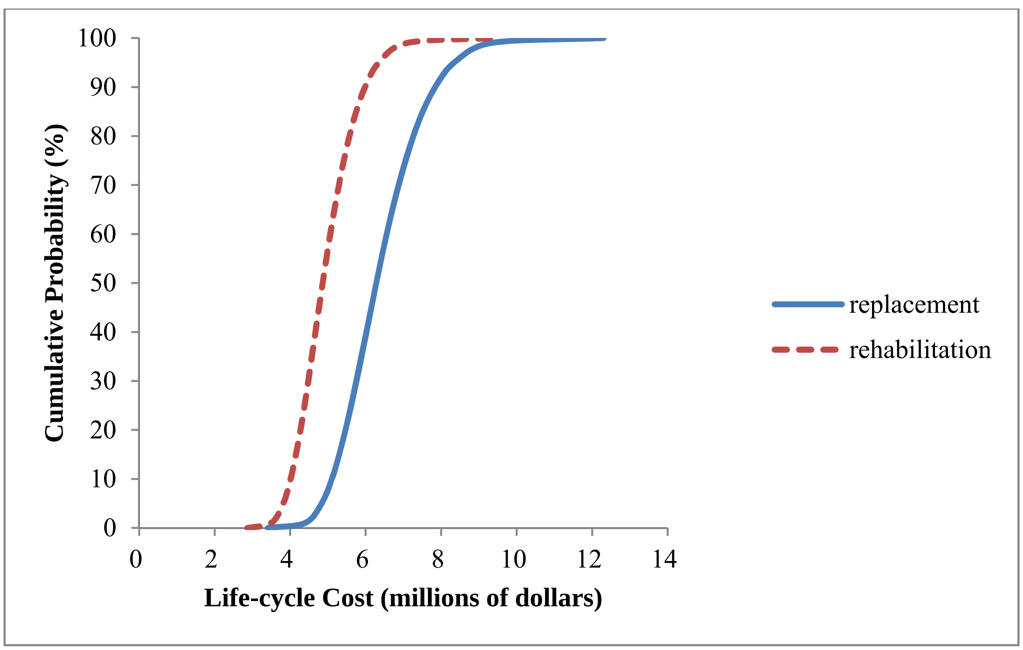


Figure E.170-Ascending cumulative probability distributions for waterway bridge with modification 2c ADT case 7, 8, 9 (Table 3.6)

APPENDIX F: SPREADSHEET INPUT

Appendix F contains a summary of the required spreadsheet input.

Analysis Period (years)	75

Discount Rates	
Short term	0.035
Long term	0.025

Agency Costs	
Preliminary Engineering (%)	10
Construction Engineering (%)	11
Maintenance of Traffic - replacement (%)	3.41
Maintenance of Traffic - rehabilitation (%)	15.12
Bridge replacement ($/SF)	107.52
Deck overlay - new bridge ($/SF)	16.54
Deck overlay - old bridge ($/SF)	16.54
Overlay approach pavement - new bridge ($/SY)	40.01
Overlay approach pavement - old bridge ($/SY)	54.83
Deck replacement ($/SF)	38.17
FRP wrap - 1 layer ($/SF)	54.39
Bridge rail retrofit with thrie beam ($/LF)	76.99
Bridge removal ($/SF)	14.13
Deck removal ($/SF)	4.87
Routine annual maintenance - new bridge ($/SF)	0.10
Routine annual maintenance - old bridge ($/SF)	0.15

Bridge Replacement	
New Bridge	
Roadway width (ft)	28
Total width (ft)	31
Length (ft)	204
Approach roadway (%)	5
Overlay approach pavement area (SY)	355

Bridge Rehabilitation	
Existing bridge	
Roadway width (ft)	25
Total width (ft)	28
Length (ft)	204
Area of applied FRP - 1 layer (SF)	5700
Overlay approach pavement area (SY)	278

Activity - Replacement Alternative	Duration (d)	Timing (yr)
Bridge replacement	240	0
Deck overlay	30	20
Deck replacement	45	40
Deck overlay	30	60

Activity - Rehabilitation Alternative	Duration (d)	Timing (yr)
Bridge rehabilitation	30	0
Bridge replacement	240	20
Deck overlay	30	40
Deck replacement	45	60

User Costs	
Length of detour (miles)	
Replacement	2.00
Rehabilitation	0.00
Average daily traffic, ADT, initial	
On bridge	100
Under bridge	5000
Truck traffic, ADTT (%)	
On bridge	5
Under bridge	12
Annual traffic growth rate (%)	
On bridge	1
Under bridge	2
Value of time, VOT ($/hr)	
Cars	16.28
Trucks	25.30
Vehicle Operating Cost, VOC ($/mile)	
Cars	0.27
Trucks	0.74
Vehicle occupancy rate (persons/vehicle)	
Cars	1.5
Trucks	1.05
User Time Delay (min)	
Bridge replacement-on bridge	10
Bridge replacement-under bridge	5
Bridge rehabilitation-on bridge	5
Bridge rehabilitation-under bridge	5
Deck overlay-on bridge	5
Deck overlay-under bridge	0
Deck replacement-on bridge	10
Deck replacement-under bridge	0
Cost per crash ($)	
Non-fatal	126,870
Fatal	9,100,000
Crash and fatality rates (per million vehicle-miles)	
Non-fatal crashes	2.65
Fatalities	0.015

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Benefit-Cost Methodology for Moses Wheeler Bridge TIGER Application

The methodology and assumptions underlying the benefit-cost analysis are described herein.

Time Horizon

All benefits and costs were based on a forecast horizon of 35 years, from 2009 through 2043. Bridge construction was assumed to be eight years in duration, beginning in 2009 and completing in 2016. User benefits were assumed to begin in January 2017, immediately after the completion of the bridge, and last through the end of the forecast horizon.

Discount Rate

Consistent with USDOT guidelines, the benefits and costs in this analysis were discounted at a rate of 7 percent.

Project Costs

The bridge was assumed to cost $299 million in 2009 dollars to design and construct. Construction would begin in 2009 and complete in 2016. The annual construction expenditures expected per year is shown in Exhibit A-1.

Exhibit A-1: Breakdown of Contract E Construction Costs by Scenario (Million 2009 Dollars)

2009	2010	2011	2012	2013	2014	2015	2016	TOTAL
$4.1	$23.1	$51.9	$68.3	$68.0	$38.5	$35.0	$10.2	**$299.1**

Source: STV Incorporated, Connecticut Department of Transportation

In the no-build scenario, the following capital expenditures would be needed to keep the bridge at a minimum level of functionality:

Exhibit A-2: Breakdown of Moses Wheeler Bridge No-Build Capital Costs

Year	Capital Cost Description	Estimated Cost (2009 $)
2010	Bridge drainage, fender system repairs	$6.5 million
2020 - 2023	Full deck & bearing replacement, steel repairs, substructure repairs, superstructure painting	$82 million
2035 - 2041	Full bridge replacement	$299 million
Total No-Build Capital Costs		**$387.5 million**

Source: STV Incorporated, Connecticut Department of Transportation

With major repairs scheduled in 2010 and again in 2020, the useful life of the bridge could be extended to 2035, but would need to be completely replaced at that time. Thus, the same annual construction costs in the build scenario from 2009 to 2016 also appear in the no-build scenario from 2035 to 2042.

The total capital costs in the build scenario are estimated to be $230 million in discounted 2009 dollars (using the 7 percent discount rate), and the capital costs in the no-build scenario are estimated to be $77 million in discounted 2009 dollars.

Operations & Maintenance Costs

In the build scenario, the annual bridge operations & maintenance (O & M) costs were estimated to be $115,000 throughout the forecast horizon (see Exhibit A-3 below). No-build operation and maintenance costs were estimated to be $670,000 from 2009 to 2020, and $190,000 from 2021 until the bridge replacement construction begins in 2035. From 2035 to 2045, no-build O & M costs were estimated to be $115,000, equivalent to the O & M costs in the build scenario. When discounted at a 7 percent rate, the total differential O & M costs between the build and no-build scenarios would carry a $4 million benefit to the state throughout the forecast period in the form of lower relative costs.

Exhibit A-3: Breakdown of Moses Wheeler Bridge Operations & Maintenance Costs

O & M Cost Description	Estimated Cost (2009 $)			
	Build Scenario	No-Build Scenario (2010 to 2020)	No-Build Scenario (2021 to 2035)	No-Build Scenario (2036 to 2045)
Drainage	40,000	40,000	40,000	40,000
Crack Sealing	20,000	40,000	20,000	20,000
Bridge Collision Repairs	5,000	10,000	10,000	5,000
Joint Repairs	-	50,000	20,000	-
Added Inspections	-	100,000	-	-
Deck Patching	-	150,000	-	-
Loose Concrete Removal	-	40,000	-	-
Substructure Patching	-	40,000	25,000	-
Minor Steel Repairs	-	100,000	25,000	-
Spot Painting	50,000	100,000	50,000	50,000
Total O & M Costs	**$ 115,000**	**$ 670,000**	**$ 190,000**	**$ 115,000**

Source: STV Incorporated, Connecticut Department of Transportation

Residual Value of Bridge – Negative Cost

The useful life of the replaced Moses Wheeler Bridge is estimated to be 75 years. At the end of the forecast horizon in 2045, the bridge will have approximately 46 years remaining before major rehabilitation and replacement would be necessary. Therefore, the bridge will carry a residual value past the forecast horizon that has been estimated as a negative cost for this analysis.

The residual value has been estimated at $16 million in discounted 2009 dollars. Underlying this estimate is the assumption that the bridge will depreciate on a straight-line basis, with the residual value of the bridge equal to the real value of its construction cost multiplied by the share of its useful life remaining at the end of the forecast period.

User Benefits

Construction-Related Vehicle Travel Time Benefits

The major quantifiable benefit of the bridge replacement project is the elimination of future travel time delays that would occur if the bridge was not replaced today. These delays would be caused by the future capital replacement projects needed just to maintain the Bridge at its current state of good repair rating, which would require lane closures for significant periods of time and cause major delays on I-95 for most of the day.

In particular, the current deck would need to be completely replaced in 2020 if the replacement project was not implemented. Such a replacement would require at least one lane of traffic to be closed in both directions at all times for roughly three years, which would cause severe delays on a daily basis and likely draw heavy opposition from the trucking industry and the residents of Connecticut.

In order to determine the impact of the lane closures during this deck replacement project several methodologies were used to determine the average delay time over the 24 hour period. The peak hourly demand at the bridge has been estimated at 6,600 vehicles in each direction. A lane closure would reduce the capacity to 3,300 veh./hr. in each direction. Based on manual calculations for the daily demand volume across the Moses Wheeler Bridge, the following data was determined:

1) The northbound direction of the bridge would experience a maximum queue of approximately 8,200 vehicles from 2-7 PM, the period when vehicle demand exceeds roadway capacity (total two-lane capacity = 3,330 veh/hr). Given a per vehicle spacing of 30 feet over 3 lanes, the queue length would be approximately 82,000 feet (15.5 miles).
2) The southbound direction of the bridge would experience a maximum queue of approximately 2,730 vehicles from 6:30-9 AM, the period when demand exceeds roadway capacity. Given a per vehicle spacing of 30 feet over 3 lanes, the queue length would be approximately 27,300 feet (5.2 miles).

This information was then analyzed using the Highway Capacity Manual and VISSIM simulation models to develop average delay times over the 24 hour period. The two methods revealed peak period delays ranging from 40 minutes to an hour with average hourly delays over the 24 hour period of 22 minutes in the northbound direction and 15 minutes in the southbound direction. Using weighted averages based on the volumes, an average delay time of 18.3 minutes was estimated over the 24 hour period.

This average delay per vehicle per day on the Moses Wheeler Bridge in the no-build scenario was applied to the forecasted ADT volumes from 2020 to 2022 to arrive at annual travel time savings over the forecast period. Annual ADT projections were based on a study by CTDOT in 2001 that computed historical volumes on the bridge in 1999 and projected volumes in 2025. Applying the compound annual growth rate used in the study to 1999 volumes allowed for an annual ADT forecast to be created from 2009 to 2043.

Applying the projected volumes from 2020 to 2022 to the computed per-vehicle delays during this period led to the computation of total daily vehicle travel time savings. These benefits were then converted to total daily passenger travel time savings (see Exhibit A-4) using a vehicle-occupancy rate of 1.0 for commercial vehicles, estimated to be 13 percent of total ADT, along with a passenger vehicle occupancy rate of 1.424 for the 87 percent passenger share of total ADT[1].

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[1] Source: Connecticut Department of Transportation.

Exhibit A-4: Annual Hours of Passenger Travel Time Savings in Build Scenario, 2009 Dollars

Benefit Description	2020	2021	2022	TOTAL
Passenger Trips	16,185,111	16,290,800	16,397,179	48,873,090
Commercial Trips	1,698,360	1,709,450	1,720,613	5,128,424
TOTAL	**17,883,471**	**18,000,250**	**18,117,792**	**54,001,514**

Source: Parsons Brinckerhoff

The estimated travel time savings in the build scenario were converted into dollar benefits for commercial vehicles, passenger work trips, and passenger non-work trips. Commercial vehicle travel time savings were valued at 100 percent of the hourly truck driver wages plus fringe benefits, according to USDOT guidelines. Truck driver wage data was obtained by inflating the 2008 Bureau of Labor Statistics (BLS) wage data for truck drivers in Connecticut to 2009 dollars, and using a fringe benefits factor of 33 percent of hourly wages. Total hourly 2009 commercial vehicle compensation was estimated to be $32.22.

Passenger work trips, defined by USDOT as non-commute work trips occurring for business purposes, was assumed to represent 5.6 percent of total passenger vehicle travel time savings. This estimate was taken from USDOT estimates of the share of local passenger travel comprising business trips in its 2003 publication "Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis." These trips were valued at 100 percent of hourly passenger wages plus fringe benefits, which was estimated to be $37.50. Passenger wage data was obtained by inflating the 2008 average wage for all Connecticut employees from the BLS to 2009 dollars, and using a fringe benefits factor of 33 percent of hourly wages.

Passenger non-work trips, defined as all "off-the-clock" commute or leisure trips, represent the remainder of total passenger vehicle travel time savings. These trips were valued at 50 percent of hourly passenger wages, which were estimated to be $28.20. Passenger wage data was obtained by inflating the 2008 average wage for all Connecticut employees from the BLS to 2009 dollars.

The total travel time benefits in discounted 2009 dollars are shown in selected years in Exhibit A-5. When discounted at a 7 percent annual rate, such benefits total $73 million for commercial vehicles, $41 million for passenger work trips, and $291 million for passenger non-work trips.

Exhibit A-5: Total Annual Travel Time Benefits, Discounted 2009 Dollars

Benefit Description	2020	2021	2022	TOTAL
Passenger Work Trips	$ 14,419,988	$ 13,564,626	$ 12,760,003	$ 40,744,617
Passenger Non-Work Trips	$ 102,999,911	$ 96,890,187	$ 91,142,879	$ 291,032,977
Commercial Trips	$ 25,997,026	$ 24,454,941	$ 23,004,328	$ 73,456,295
TOTAL	**$ 143,416,924**	**$ 134,909,754**	**$ 126,907,210**	**$ 405,233,889**

Source: Parsons Brinckerhoff

Accident-Related Vehicle Travel Time Benefits

Users of the bridge would also benefit from reduced delays caused by vehicle accidents, since the replaced bridge will have much wider shoulders to efficiently move damaged vehicles. As previously mentioned, the current bridge does not have adequate shoulders, which leads to major backups and travel time delays during accidents due to damaged vehicles remaining in one or more lanes. This problem will be resolved by the new design of the replacement bridge.

To estimate the benefits associated with more efficient accident management on the bridge, historical bridge vehicle accident data from 2003 to 2007 was analyzed and used to derive an annual estimate (65) of accidents. It was assumed that this historical average number of accidents would increase throughout the forecast horizon at the projected annual growth rate of vehicle traffic.

For each projected accident, it was assumed that the accident would create, on average, a 45 minute travel time delay for all vehicles during a two hour window of the day, after which the damaged vehicles would presumably be cleared from the roadway. The costs of this delay were quantified using the same approach and data described in the previous section.

The replaced bridge was assumed to reduce average travel delays from 45 minutes to 15 minutes during accidents, though the bridge is not expected to reduce the overall number of accidents in the future.