IMPLEMENTING PONTIS AS A BRIDGE MANAGEMENT TOOL IN IDAHO

Final Report

February 2004

UI Budget No. KLK 490

ITD Project No. SPR-0003(014) 155

NIATT Report #N04-04

Prepared for

Idaho Transportation Department Bridge Section

Prepared by

National Institute for Advanced Transportation Technology

UNIVERSITY OF IDAHO

Jarrod H. Milligan, Richard J. Nielsen, Edwin R. Schmeckpeper

ABSTRACT

Engineers who hold responsibility for managing bridges face a daunting task because of the large number of bridges which need work and the limited funds with which to accomplish the work. Bridge management software, such as Pontis, provides a way to manage the large quantity of data available to the engineer. This report outlines the capabilities of Pontis to assist the Idaho Transportation Department (ITD) in their bridge management work. Currently, ITD uses only the inventory and inspection management capabilities of Pontis. In the future, ITD is planning to expand their use of Pontis at the Needs Analysis or Project Planning levels. The required input data is summarized, with the element unit costs and failure costs examined in detail.

Element unit costs developed for Idaho were similar to the default values from California, and resulted in similar recommendations in the Preservation Policy. However, the unit costs from Oregon were very different, reflecting a different approach to policy decisions by having non-zero costs specified for all of the “do-nothing” actions and very high costs for some other actions. As a result, the Preservation Policy based on element unit costs from Oregon resulted in very different recommendations.

As funding levels increase, the condition of the network also improves, as may be expected. However, for even “unlimited” levels of funding, the condition of the network always declines over time, indicating that the optimal condition of the bridges on the network is below the current condition based on current estimates of element unit costs, user costs and failure costs. The projected needs for Idaho’s bridge network using Oregon's cost data were substantially higher than those based on California’s and Idaho’s cost data. Projected benefits based on Oregon’s cost data were also much higher than those based on California’s and Idaho’s. The Preservation Policy derived from Oregon's element costs resulted in a slightly better network condition, based on the Sufficiency Rating and Bridge Health Index, although the differences are much smaller than the projected needs and benefits.

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CHAPTER 1: OVERVIEW

Introduction

Bridge management has become a major area of research as the focus of the bridge engineering world shifts from reactive to proactive maintenance. As the current stock of bridges ages, larger and larger investments must be made in order to maintain them in safe working order. Bridge maintenance is becoming a large part of many transportation agencies' budgets. The goal of a bridge manager is to optimize the way that these funds are expended.

A bridge management system (BMS) is a software tool to assist in the process of optimizing expenditures. These systems vary in sophistication from so-called "first-generation" systems, which were simply database storage systems, to "third-generation" systems, which incorporate deterioration and cost prediction abilities (*1*). Pontis, the BMS developed by AASHTO, and BRIDGIT, the BMS developed under the NCHRP 12-28 project, are current examples of third-generation systems.

The Idaho Transportation Department currently uses Pontis to manage inventory and inspection tasks. The capabilities of Pontis to forecast bridge deterioration and maintenance needs or to plan projects is not yet being fully utilized. This report presents the results of a project to begin implementing Pontis as a management tool in Idaho. As a part of this project, element unit cost data and failure cost data are estimated for use in Idaho, and the results of these changes are examined.

Background of Pontis

In December of 1967, the Silver Bridge between Kanauga, Ohio and Point Pleasant, West Virginia collapsed during a Christmas shopping rush hour due to a fractured eye bar in the suspension linkage. This tragedy highlighted the need for a more systematic approach to bridge maintenance. In fact, at that time the exact number of bridges in service in the United States was not known. As a result, the National Bridge Inspection Program was created in 1968. This program mandated that state agencies inspect and catalog bridges on principal highways, and to report the data to the Federal Highway Administration (FHWA). The data is stored in the National Bridge Inventory (NBI) database, which is still maintained today. Under early federal guidelines, a bridge became eligible for funding for replacement when its Sufficiency Rating, a measure of a bridge's condition and importance, dropped below 50.

A major change in management guidelines occurred in 1978 when the requirements for bridge inspection expanded from those on principal highways to all bridges on public roads. Along with this change, emphasis changed from replacing bridges which were no longer safe or serviceable to repairing bridges before they became unsafe. A bridge became eligible for federal funding for rehabilitation when its sufficiency rating fell below 80, much higher than the previous level of 50. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 legislated the next significant development in bridge management by requiring that all state departments of transportation and metropolitan planning organization implement a bridge management system (*2*).

Pontis, along with several other bridge management software programs, began development before ISTEA passed; development of Pontis began as a part of a FHWA Demonstration Project in 1989. The first release of the software, version 1.0, to state departments of transportation was in 1992. Further updates have been released as features have been added. The Idaho Transportation Department is currently using version 4.1.1, which was the version used for this project. The most recent release, in 2003, is version 4.2 (*3*).

Pontis Implementation

Currently thirty-eight states, the District of Columbia, Puerto Rico, several municipal agencies, and four overseas agencies use Pontis. The complexity of Pontis makes implementation a substantial effort. Four levels of implementation appear among different Pontis users. In order of increasing complexity, these are (1) managing inspections, (2) analyzing needs, (3) planning projects, and (4) special uses. Special uses include using Pontis in applications for which it was not specifically intended, such as comparing design alternatives during the planning phase of bridge design in order to compare life cycle maintenance costs.

The Idaho Transportation Department uses Pontis to manage inspections, and is looking for ways to implement Pontis for needs analysis and project planning tasks. Several other states are in a similar position of implementing Pontis beyond inspection management, or have recently completed the process. In September and October of 2002, researchers from Cambridge Systematics, the California Department of Transportation (Caltrans), and AASHTO conducted a survey of the agencies that licence Pontis to determine how these agencies were using the program (*4*). Their survey showed that half of the 34 agencies that were included in the survey used Pontis only to manage inspections, with the other half using Pontis for a combination of inspection management, program simulation, and project planning. Figure 1 below, from their report, shows a summary of the survey results. The survey also reported that 82% of the agencies surveyed have customized Pontis to some extent. Many of these customized changes allow the agencies to enter inspection data that

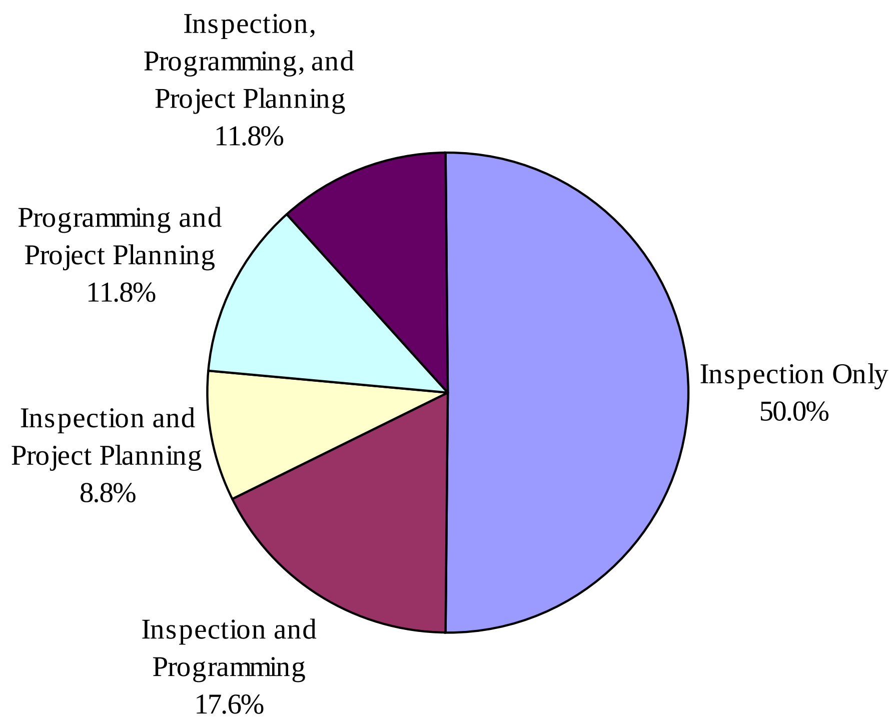


Figure 1 - Pontis Functionality Used by Licensing Agencies

are not included in the NBI data fields or as defaults in Pontis. Other customized features include adding elements, changing database access routines, adding multimedia capabilities, and interfacing with applications outside of Pontis.

Representation of Bridges in Pontis

A physical description of each bridge in a bridge network is stored in Pontis. Each bridge is divided into one or more separate structures, which in turn are described in terms of elements (see Figure 2 (*5*)). Elements are the fundamental unit in Pontis. Inspection information is recorded and work is recommended at the element level. The Deterioration Model in Pontis also works at the element level. A standard group of 98 elements is known

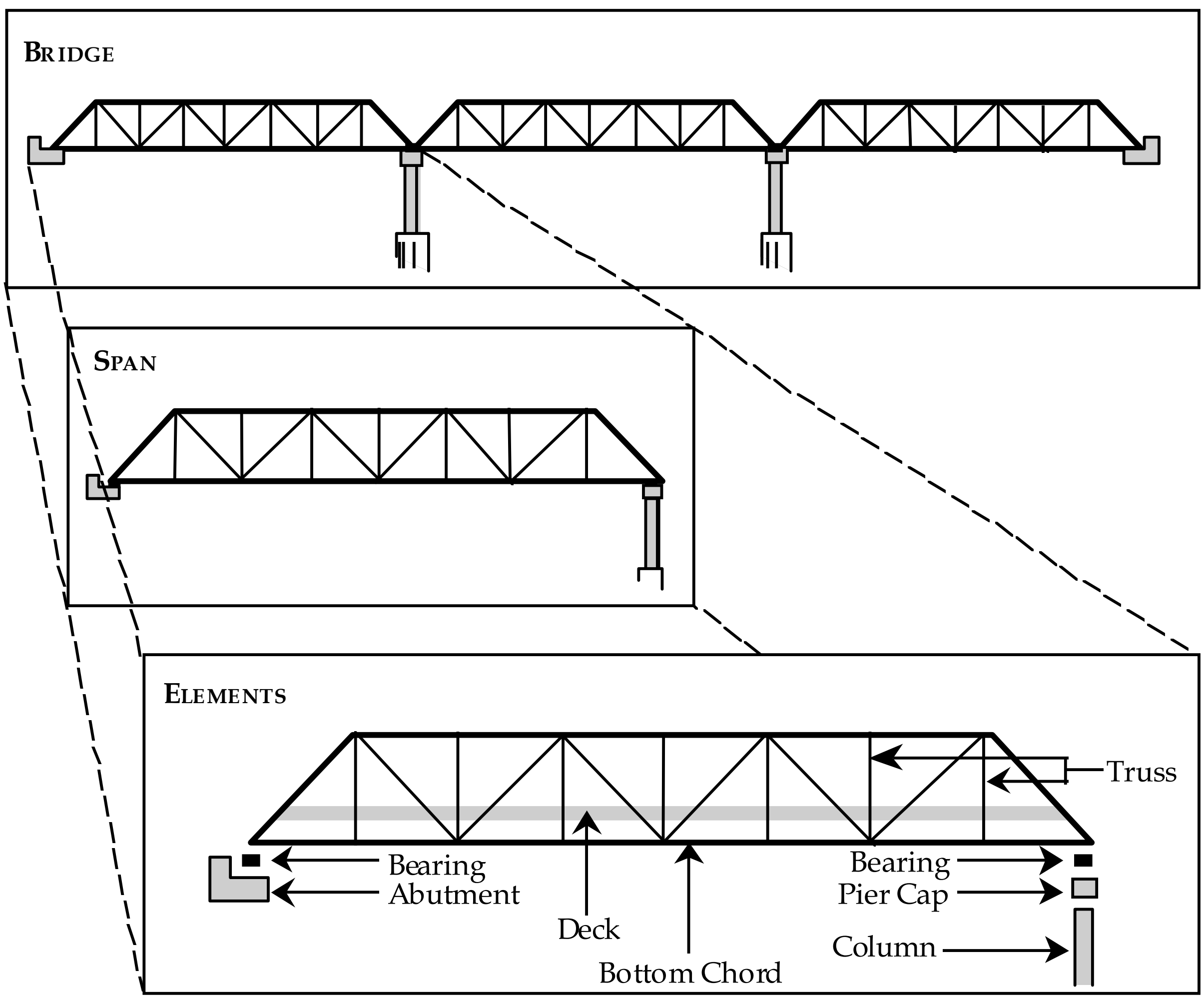


Figure 2 - Bridge Description in Pontis (*5*)

as the “Commonly Recognized Elements” or CoRe Elements, defined in the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* (*6*). Many states have created custom elements in addition to the CoRe Elements. Idaho uses 103 elements in its database. This includes all 98 of the CoRe Elements, although not all of these elements exist in Idaho.

Element condition is described in terms of Condition States. Three to five Condition States are defined for each element with Condition State 1 being pristine condition and Condition State 3, 4, or 5 being the worst condition before failure occurs. Pontis describes different exposure or usage conditions with an Environment category. Environment 1 is “benign,” and Environment 4 is “severe.” Deterioration rates differ for each Environment category for each element.

CHAPTER 2: PERFORMANCE MEASURES

A significant part of making bridge management decisions is the criteria, or performance measures, on which the decisions will be based. Many performance measures are available in Pontis, some of which are not commonly used elsewhere. This chapter will discuss the performance measures available in Pontis. The Sufficiency Rating, which is a common performance measure in widespread use, and the Bridge Health Index, which is a performance measure developed for use in Pontis, will be compared.

As a management tool, a performance measure may be expected to serve many purposes. At the simplest level, it should indicate the condition of a bridge or its elements. The performance measure should be able to show changes in bridge condition over time as well. It must be able to reflect a wide variety of bridges in sufficient detail to be useful while still being simple enough to be used on a large number of bridges. It may be used to determine if current levels of funding are adequate, or to determine if current management strategies and practices are producing the desired results. A performance measure could also be used to prioritize funding among competing states or bridges. Performance measures can also be used to explain bridge condition and maintenance needs to legislators and to the public in such a way that they can make policy and budget decisions without having to understand all of the details of the actual bridge condition (*7*, *8*).

Although most performance measures are a single number, some performance measures consist of multiple parameters. The National Bridge Inventory (NBI) condition ratings are an example of this type of performance measure, with separate values for deck, superstructure, substructure, and culvert ratings. In the U.S. the most common performance measure is the Sufficiency Rating. The California Department of Transportation (Caltrans) has developed a Bridge Health Index (BHI) based on the element-level inspection data. Other agencies have predefined Level-of-Service criteria (*9*), or have developed a proprietary indexing system to reflect bridge performance (*7*, *9*). Recently, there has been an attempt to use reliability theory to develop a performance measure for bridge management based on the reliability index, β. As reliability theory becomes more widely used with the increased use of Load and Resistance Factor Design (LRFD) methods, this may become a more common bridge performance measure (*10*).

Pontis records, calculates, and reports several different performance measures. The Bridge Health Index, Sufficiency Rating, and NBI ratings are the principal performance measures and are general indicators of bridge condition. Other more specialized performance measures include the deck and underclearance geometry ratings, status as Structurally Deficient/Functionally Obsolete, and eligibility status for the Highway Bridge Replacement and Rehabilitation (HBRR) Program.

The U.S. federal government uses the Sufficiency Rating for many of its bridge management tasks, including allocating funds for the HBRR Program. The Sufficiency Rating is a score from 0 (worst) to 100 (best) based on all of the NBI parameters. The calculation is based on structural adequacy and safety (55%), serviceability and functional obsolescence (30%), and essentiality for public use (15%), with special reductions for detour length and traffic safety features (*11*).

As an alternative means of measuring performance, Caltrans developed the Bridge Health Index (BHI). The BHI is meant to reflect the remaining asset value of a bridge. Like the Sufficiency Rating, the BHI gives a score between 0 (no remaining value) and 100 (new – full value) for each bridge or group of bridges. Instead of using the NBI data, the BHI uses element-level inspection data based on the *CoRe - AASHTO Guide for Commonly Recognized Structural Elements* (*6*). The Inspection Module of Pontis is also built around element-level inspection data. This method of collecting inspection data is more detailed than the NBI method. As a result, it addresses the problems of capturing both the severity and the extent of problems. For example, instead of a single rating for 'superstructure,' as in the NBI rating method, there are separate ratings for girders, floor beams, pins, bearings, and other superstructure elements. As part of the element-level inspection, typical of the Pontis inspection database, the total amount of each element is measured and the amount of each element in a particular condition state is recorded. In this manner, the total value of each element can be calculated, both in its current condition and as if the element were new. The ratio of these values for all of the elements in the bridge or bridge network is the BHI (*8*, *12*).

Two methods are available in Pontis to calculate the value of an element. The first method uses the element failure cost. This method was part of the original development of the Bridge Health Index. The second method uses a weighting factor multiplied by the most expensive element unit cost. This method is the default in Pontis and was developed later. The *Pontis Technical Manual* (*13*) contains more details and an example calculation of the Bridge Health Index.

When comparing the Bridge Health Index and the Sufficiency Rating, each has certain advantages and disadvantages. Advantages of the BHI include flexibility and consistency. The BHI can be applied to each element, to a single bridge, to a group of elements (such as all decks in a given area), or to a group of bridges. However, it is calculated based on element failure costs or element repair costs – which are difficult to determine – and inspectors' subjective judgement of element condition. The principal advantage of the Sufficiency Rating method is its widespread usage. All bridge managers and many legislators or administrators are familiar with this method, and the Federal Highway Administration bases its funding decisions on this parameter. The Sufficiency Rating method has certain weaknesses. Since it is based on all of the NBI data, it combines both functional and condition information; therefore, it is not strictly an indicator of bridge condition. The Sufficiency Rating considers all bridges to have the same location, use, and importance. Only bridges on STRAHNET (Strategic Highway Corridor Network) highways, which are considered critical for national defense purposes, are given a different importance factor. Since the Sufficiency Rating is based on the NBI data, it is prone to subjectivity problems because it is based more on inspectors' judgement and less on measured parameters.

The NBI data are also used to define two categories of deficient bridges. These categories are Structurally Deficient and Functionally Obsolete. To be considered Structurally Deficient, a bridge must have an NBI condition rating of 4 or less for the deck, superstructure, or substructure, a structural evaluation appraisal of 2 or less, or a waterway evaluation appraisal of 2 or less. To be considered Functionally Obsolete, a bridge must have a deck geometry evaluation appraisal of 3 or less, an underclearance appraisal rating of 3 or less, a structural evaluation appraisal of 3, or a waterway appraisal rating of 3 (*14*). The Structurally Deficient category generally reflects the strength or safety of the bridge, while the Functionally Obsolete category reflects the serviceability of the bridge.

CHAPTER 3: USER INPUT

The well-known saying “garbage in, garbage out” applies to Pontis. In order to get dependable forecasts or recommendations, the input data must be dependable. Pontis requires a large amount of input data in order to conduct its simulations. This chapter describes the input required to use Pontis as a decision support tool. The element unit costs and failure costs resulting from this project are described in detail, and the other input data items are discussed briefly. These input data are used in the Pontis Preservation Model, which utilizes deterioration data, cost data, and an optimization scheme for maintenance actions to set up scenario simulations and to organize projects. As a part of the process of implementing Pontis, these input data need to be verified and adapted to the policies and practices of ITD.

Deterioration Data

Pontis uses a probabilistic approach to predict the deterioration of bridges and their elements. These predictions are based on transition probabilities stored in its Deterioration Model. A transition probability is required for each element, in each environment, for each condition state, and for each feasible action. It reflects the likelihood of that element going from its current condition state to another in one year. Pontis has default values for all transition probabilities, but verifying and improving these values is a formidable task. Very little has been published about the development of transition probabilities for Pontis. Many articles have been written about the other major data inputs for Pontis, so the lack of research in this area is conspicuous. Two sources are available to develop transition probabilities for each element. These are an expert elicitation process and the inspection database. This section will describe how each of these sources is used to generate transition probabilities for the Preservation Model.

The expert elicitation process can be used to generate transition probabilities when an agency first implements Pontis. People with expert knowledge or experience in the deterioration of bridge elements predict transition probabilities for the various combinations of elements, environments, condition states, and feasible actions. These results are entered directly into the Pontis Preservation Model. Some states have constructed questionnaires to elicit deterioration information from their experts, while other states ask their experts to recommend transition probabilities directly (*15*, Richard Groff, Oregon Department of Transportation, unpublished data). Figure 3 shows the Pontis screen for an expert elicitation of transition probabilities.

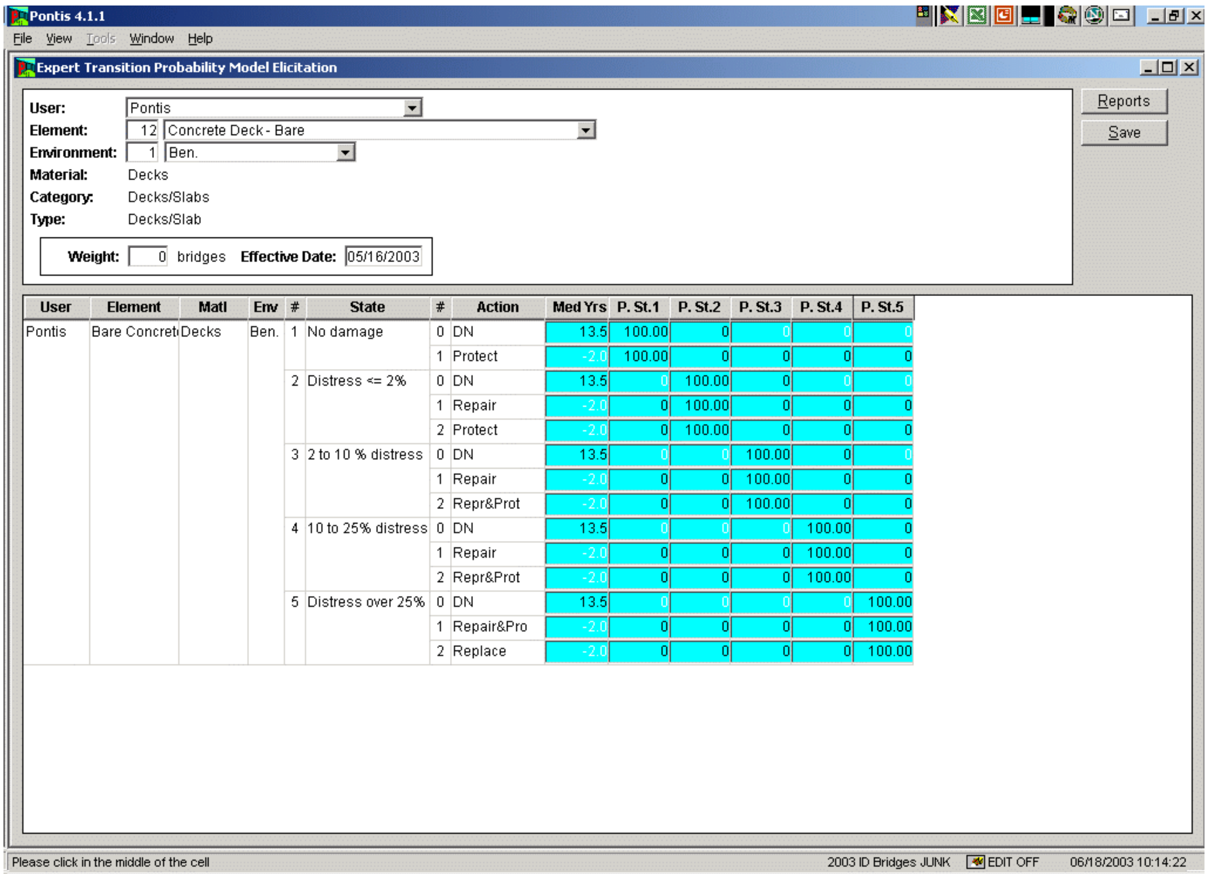


Figure 3 - Expert Elicitation Screen for Transition Probabilities in Pontis

The second major source of information about bridge deterioration is the inspection data that has been entered into Pontis after each bridge inspection. Idaho has been conducting element-level inspections since 1996 and has used Pontis to record inspection data since January 2000. These data provide the starting point for any assessment of the current bridge inventory, as well as for any simulations to predict future bridge condition. Over time, the changes in element condition reported in the inspection data can be used to update the transition probabilities through a regression analysis. This updating procedure is discussed further in Chapter 4.

Both historical data and expert elicitation can be combined to determine transition probabilities. Each type of data is given a weighting factor to determine how much influence it will have on the transition probability, or either type of data may be used alone for the calculation.

Researchers at the University of Wisconsin-Madison included a limited sensitivity analysis to determine the effects of transition probability on failure costs. Their analysis looked at the change in failure costs with a small (1%) increase or decrease in the transition probabilities for 24 elements. They selected elements which would have the greatest influence on failure costs based on the number of bridges that had the particular element, the total quantity of the element throughout the network, and the highest average expected maintenance cost for the element. The analysis showed that changing the transition probabilities produced changes in the failure costs of up to 12.5%. However, changing the transition probability did not affect the overall maintenance recommendations suggested by Pontis at a significant level (*16*).

Before investing a large amount of time and effort in improvements to the transition probabilities, it may be useful to examine how sensitive Pontis is to changes in transition probability and how accurately the expert elicitation process can determine these probabilities. This project used the default transition probabilities for all scenario simulations.

Cost Data

Cost data from several different sources are used to create the Cost Model within Pontis. The Cost Model considers the impact of bridge condition and repair projects on both the Agency and the roadway users. Agency costs include element unit costs, which are the costs to do Maintenance, Repair, and Rehabilitation (MR&R) actions, and the costs associated with functional improvements. Functional improvements are actions such as strengthening, raising, widening, or performing a seismic retrofit. User costs include the costs associated with travel time, accidents, and bridge capacity for heavy trucks. This section will describe the methods used to account for these costs and the methods of collecting the data.

Element Unit Costs

Element unit costs are the easiest costs to understand in the Pontis Cost Model. They represent the cost of repairing an element in a given condition state. In Pontis, the MR&R needs and actions are accounted for separately from the functional improvement needs and actions. Element unit costs consider only MR&R needs and actions. As with the transition probabilities, the element unit costs are gathered from expert elicitations or from historical repair costs. A cost may be developed for each possible combination of element, environment, and feasible action. Often these costs do not vary according to environment. The expert elicitation process for element unit costs may be somewhat different from that for deterioration data because many agencies have more complete historical cost data from which experts can determine unit costs for Pontis. The process for updating element costs from historical data is not included as a feature of the current version of Pontis (version 4.0), but the *Pontis User's Manual* (*17*) indicates that this feature will be included in a future version. Figure 4 shows the Pontis screen for an expert elicitation of element unit costs and

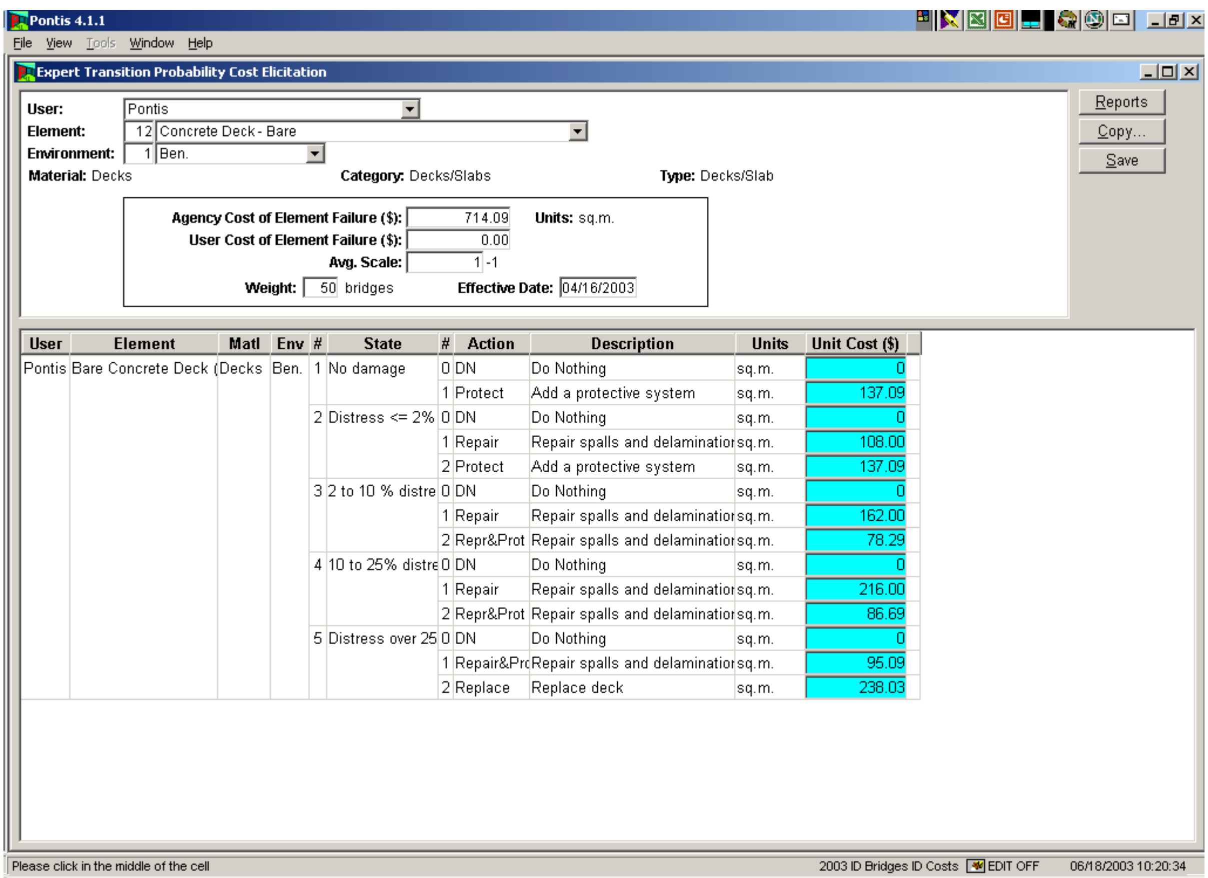


Figure 4 - Expert Elicitation Screen for Element Unit Costs in Pontis

failure costs.

A major portion of this project was to determine element unit costs for use in the Idaho database. Several methods were used for obtaining element unit costs. In some cases, the costs were provided by ITD based on data from previous maintenance projects or from expert opinions. A significant part of this procedure was to convert the cost information into the units of measurement that Pontis uses. For example, bid costs for asphalt overlays are often given as dollars per cubic meter of overlay, but Pontis calculates overlay costs on an area basis, so an overlay thickness must be assumed in order to convert costs from previous projects to Pontis units.

Costs for other elements were extrapolated from the costs provided by ITD. For example, the costs for Element 152, Painted Steel Floor Beam, were extrapolated from the costs for Element 107, Painted Steel Open Girder/Beam, which were obtained from ITD experts. It was assumed that the major factors in the element unit costs of steel elements were cleaning and painting, so surface area was used as the basis of the extrapolation for these elements. Railing elements were assumed to be replaced with concrete because of the code requirements for bridge railings. For a few elements, the default unit costs were used for the Idaho database because there were few or no bridges which had those elements or because an improved estimate was not available. The complete list of element unit costs and a description of the process used to obtain each one is found in Appendix 1. The calculations for unit conversions and extrapolations is found in Appendix 2. Chapter 4 contains a discussion of the impact that these derived element unit costs had on the scenario simulations.

A scale factor is available as a further refinement of element unit costs. The scale factor allows the program to accommodate differences in size between the same element on different bridges. As a part of the expert elicitation process for element unit costs, an average scale factor may be defined. In the inventory, each bridge with girder elements may be given a scale factor to reflect the difference in size between the average and the actual elements on the bridge. For example, the scale factor for girder elements reflects differences in depth. An average depth may be specified when element unit costs are specified in the expert elicitation process. In the inventory, each bridge with girder elements is given a scale factor to reflect the difference between the average girder depth and the depth of the actual girders on that bridge. The scale factor was not used in the element cost elicitations for this project because the geometric data, such as girder depth, were not available.

Failure Costs

Failure costs are not as intuitive as element unit costs. Each element has a failure cost assigned to it that represents the total penalty that the public would bear if an element failed, including all direct and indirect agency and user costs (*17*). Agency costs include the cost of replacement, damages resulting from the failure, and the other costs associated with construction work on the bridge. User costs include the cost of delays and detours associated with element failure. In Pontis' optimization procedure, the user costs and agency costs are simply added together, so they both have the same effect on the results. In practice, however, failure costs are usually specified as agency costs only because the data for the user costs are not readily obtainable. In addition, a study at the University of Wisconsin-Madison found that the maintenance policy recommended by Pontis is not affected by changes to the user cost portion of the failure cost (*16*). However, the user and agency failure costs affect the cost/benefit ratios of the projects, which determine the relative priority of each project. Life-cycle costs analyses based on this data would also be affected.

Failure costs are entered into Pontis through the expert elicitation process. Separate agency failure costs may be entered for each element in each environment. Pontis comes with default values for agency failure costs, but the default value for user failure cost is $0. Failure costs are included in the expert elicitation process for element unit costs. Therefore, although failure costs were not a major focus of this project, it became necessary to develop a procedure to estimate them.

The failure cost is used in the Pontis optimization scheme to determine whether it would be less expensive to let an element deteriorate to the point of failure rather than perform maintenance at an earlier time. If the failure costs are set too low, then Pontis will always recommend "do nothing" in the worst condition state, which is equivalent to letting the element fail before any action is taken. However, it is not considered appropriate to set failure costs arbitrarily high because they may be used in calculating benefits of a possible action. Recommendations based on a limited budget are based on benefit-cost ratio, so if the benefits associated with delayed or avoided failure costs are not reasonable, the decisions may not be correct (*16*).

The Florida Department of Transportation (FDOT) commissioned a research project to develop minimum and maximum failure costs for its Pontis database. Their minimum element failure cost calculations were based on work by Gurenich (*18*). The minimum failure cost was calculated as the lowest possible cost that would still preclude Pontis from recommending that an element be allowed to deteriorate to the point of failure. It is important to note that this minimum failure cost is not based on the actual consequences of failure. A method for calculating the maximum element failure cost was developed by Thompson (*19*). The maximum failure cost for each element was divided into an agency failure cost and a user failure cost, each of which was estimated by making assumptions about the consequences of element failure to the agency and to users. The FDOT study states that these estimates are quite rough. The minimum and maximum failure costs are combined on a weighted average basis to produce the recommended agency and user failure costs for each element. A spreadsheet showing the calculation procedure is provided at the Pontis User's Group Meeting web site (*20*).

This spreadsheet was used to estimate minimum failure costs based on Idaho element unit costs. However, the procedure tended to under-predict the minimum failure cost, resulting in Pontis recommending "do nothing" in the worst condition state. The *Pontis User's Manual* offers the suggestion that the minimum failure costs should be three to ten times the repair costs for elements in the worst condition state (*17*), so a second attempt was to set the failure costs to three times the most expensive repair cost. This was satisfactory for about half of the elements, and the rest were adjusted by trial and error until none of the elements had "do nothing" as a recommended action in the worst condition state. Similar revisions were also made to the Oregon element failure costs for the same reason. The most recent version of Pontis incorporates a well-tested version of Gurenich's procedure for calculating minimum costs, which should circumvent these difficulties (*18*).

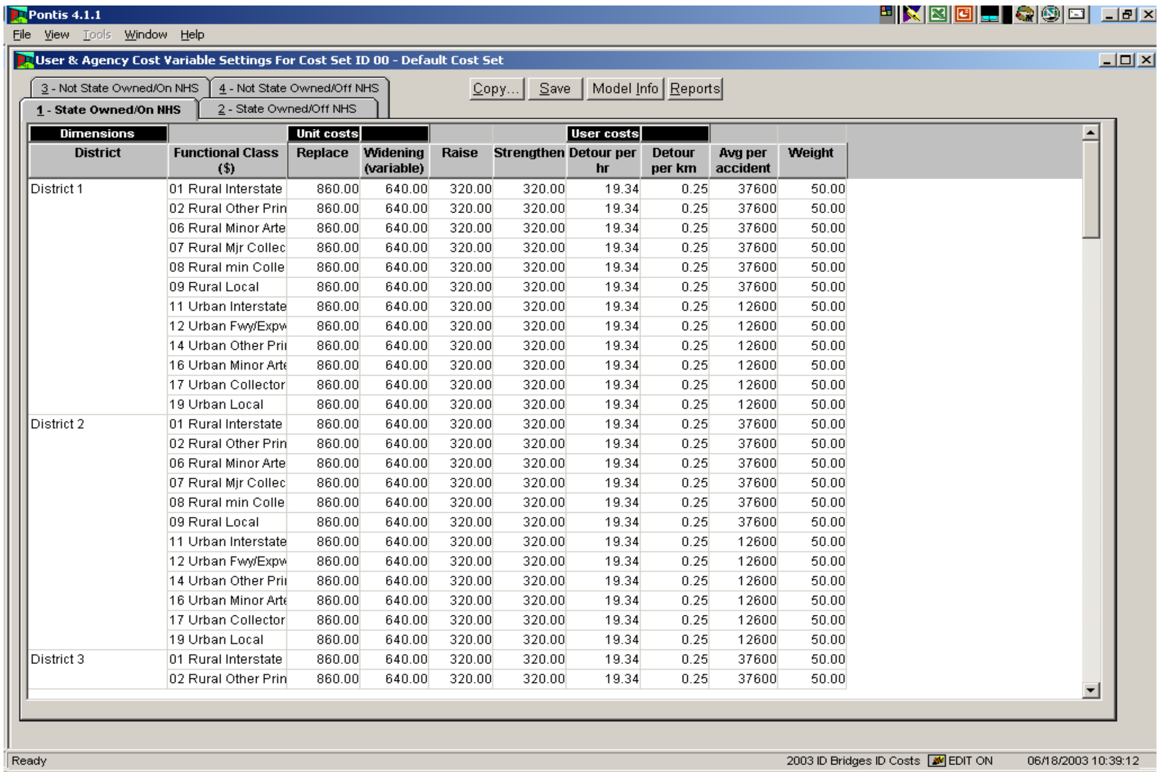
The process of estimating minimum failure costs highlighted some of the important issues of the Preservation Model. One of these was the interrelation between element unit costs, failure costs, and transition probabilities. The optimal action for any given element depends on all three types of data. When new transition probabilities or new element unit costs are generated, the Preservation Model's recommendations should be rechecked to make sure that "do nothing" is never a recommended action in the worst condition state for any element. Furthermore, since the minimum failure costs depend on transition probabilities, there may be a different minimum failure cost for each environment. If the "benign" environment is used to establish a minimum failure cost for each element, the same value of failure cost will produce the desired "do-something" recommendations for all of the other environment levels since the "benign" environment is the least likely to cause the element to fail.

The element unit costs and failure costs may be adjusted within the Preservation Module to account for inflation or to conduct a sensitivity analysis. Inflation adjustments are based on the Construction Cost Index, while adjustments for sensitivity analysis are specified by the "Adjust Costs" feature. These adjustments were not considered for this project.

Functional Improvement Costs

The costs associated with functional improvements are accounted for separately from the costs associated with MR&R actions, and are stored in the Cost Matrix in Pontis. The functional improvement costs can be specified according to ownership and National Highway System (NHS) status, and further broken down by administrative district and functional classification (Rural Interstate, Urban Collector, etc.). For each combination of categories, two types of costs are specified. The first type of cost is the unit costs for replacing, widening, raising, and strengthening the structure. These unit costs are specified per square meter of structure, except the unit cost for widening, which is specified based on the *new* square meters added to the structure. The second type of cost is the user costs associated with these improvement actions. User costs are associated with accidents and with detours on the basis of travel time and detour length. These costs are used to calculate the benefits attributed to improvement projects. Figure 5 shows a portion of the Cost Matrix in Pontis.

This data is difficult to collect. Agencies may be able to estimate the Agency Cost portion of the Functional Improvement Cost from past contract prices, but the units of measurement are rather imprecise. The User Cost portion is even more difficult to specify accurately because of the subjective and varied nature of the costs of delays, detours, and accidents. To offset this uncertainty, multiple cost matrices can be defined and assigned to different scenarios to conduct a sensitivity analysis.



Dimensions		Unit costs				User costs			
District	Functional Class ($)	Replace	Widening (variable)	Raise	Strengthen	Detour per hr	Detour per km	Avg per accident	Weight
District 1	01 Rural Interstate	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	02 Rural Other Prin	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	06 Rural Minor Arte	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	07 Rural Mjr Collec	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	08 Rural min Colle	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	09 Rural Local	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	11 Urban Interstate	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	12 Urban Fwy/Expw	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	14 Urban Other Pri	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	16 Urban Minor Arte	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	17 Urban Collector	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	19 Urban Local	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
District 2	01 Rural Interstate	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	02 Rural Other Prin	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	06 Rural Minor Arte	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	07 Rural Mjr Collec	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	08 Rural min Colle	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	09 Rural Local	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	11 Urban Interstate	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	12 Urban Fwy/Expw	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	14 Urban Other Pri	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	16 Urban Minor Arte	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	17 Urban Collector	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
	19 Urban Local	860.00	640.00	320.00	320.00	19.34	0.25	12600	50.00
District 3	01 Rural Interstate	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00
	02 Rural Other Prin	860.00	640.00	320.00	320.00	19.34	0.25	37600	50.00

Figure 5 - Cost Matrix Screen for Functional Improvement Costs in Pontis

This project used the default values for Functional Improvement Costs for most scenarios. However, including functional improvements can obscure the effects of the element costs if different sets of functional improvements are selected for the same budget level for the three sets of costs. Therefore scenarios comparing the effects of element costs were run both with and without functional improvements.

Indirect Costs

Indirect costs, also known as fixed costs, are distinguished from direct costs in Pontis. Direct costs, also known as variable costs, are those associated with specific actions taken on specific elements of a bridge, while indirect costs are associated with a project as a whole. These indirect costs include mobilization, traffic control, administration, and engineering, and are specified as a lump sum on the project level in the Project Planning Module (*17*). This project did not examine the effect of indirect costs on Pontis project recommendations.

Other Cost Parameters

Two other parameters related to cost calculations are available in Pontis. These are the Construction Cost Index and the Discount Rate. These are used to account for inflation, as mentioned earlier, and for the time value of money.

The default values of the Construction Cost Index that come with Pontis are from the Federal Highways Administration as reported in the U.S. Department of Transportation publication *Highway Statistics* (*21*), and are given through 1998, using 1987 as a base year. A Florida Department of Transportation study found that the Construction Cost Index for their state was slightly lower than the national average, so these default values were changed (*22*). A similar change may be warranted for use in Idaho. Inflation is not automatically considered in Pontis calculations, but it can be specified by the user. This project did not consider the effects of inflation or the Construction Cost Index on costs or recommendations.

The Discount Rate is a present worth factor for one year. Mathematically, it is written as $\alpha = 1/(1 + i)$ where i is the annual interest rate and is a decimal value between 0 and 1. This factor allows future costs or benefits to be adjusted to account for the time value of money. In Pontis, this value is defined as the variable DISCRATE on the Options tab of the Configuration Module. A Caltrans report stated that failure costs were sensitive to changes in the Discount Rate (*23*). This project did not investigate the effects of the Discount Rate on the scenario results from Pontis. The default value of 0.9525 was used, which corresponds to an annual interest rate of 4.99%.

Scenario and Project Parameters

Many other parameters must be specified in order to run a scenario to predict bridge network performance and to assemble work recommendations into actual projects. These parameters include policy and budget guidelines, rules to ensure Pontis recommends work that follows agency practices, and organizational parameters. This section will briefly discuss each of these groups of parameters.

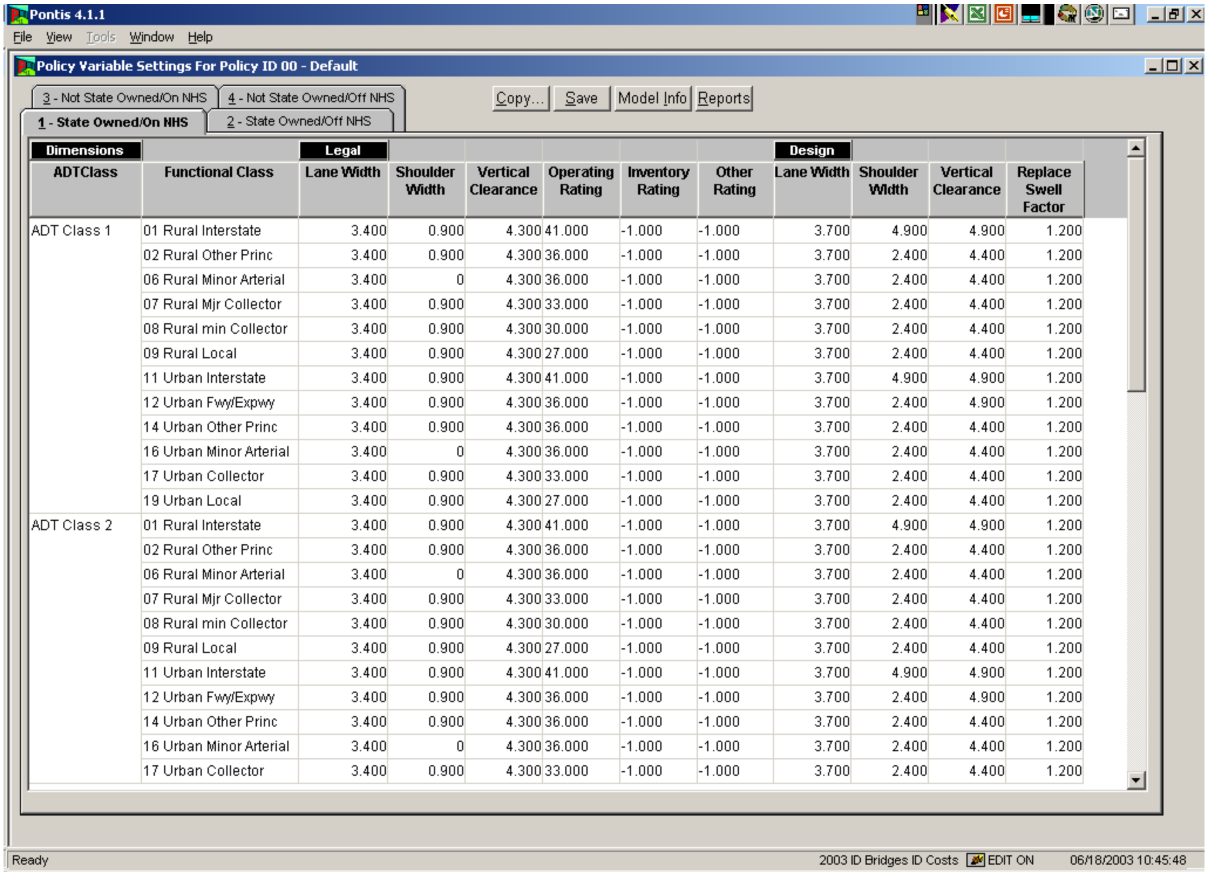
Policy Parameters

Pontis allows the user to specify policy decisions in the Policy Matrix and the Improvement Matrix. Both of these are part of the Programming Module. Roadway policies that establish service and design standards are entered and stored in the Policy Matrix. The Policy Matrix is divided into the same categories of ownership, functional class, and NHS status as the Cost Matrix, but instead of being divided by administrative district, the policy matrix items are divided by Average Daily Traffic (ADT) class. Each combination of categories contains legal parameters and design parameters. The Improvement Matrix contains other modeling assumptions that are necessary for scenario simulations and is discussed below.

The legal parameters in the Policy Matrix are lane width, shoulder width, vertical clearance, operating rating, and inventory rating. A data field is also available for another agency-specific rating, although Idaho does not use a separate rating classification. Only the operating rating is used by Pontis to determine functional improvement needs. The other two load rating data items are for agency reference only. The roadway geometry parameters define level-of-service standards only and are used to determine when functional improvements are needed.

The design parameters are lane width, shoulder width, vertical clearance, and replacement swell factor. These parameters determine the extent of improvement that will be recommended when the level-of-service standards are not met. The replacement swell factor specifies the average increase in deck area for a replacement bridge (*17*).

The legal parameters in the Policy Matrix are usually easy to determine because they are specified by state or federal laws. The design parameters, however, may be varied according to state practices. As with the Cost Matrix, multiple Policy Matrices may be defined in order to run different scenarios to determine the effect of different design policies on the overall bridge network. This project used the default parameters in the Policy Matrix. Figure 6 shows a portion of the Policy Matrix in Pontis.



Dimensions		Legal						Design			
ADTClass	Functional Class	Lane Width	Shoulder Width	Vertical Clearance	Operating Rating	Inventory Rating	Other Rating	Lane Width	Shoulder Width	Vertical Clearance	Replace Swell Factor
ADT Class 1	01 Rural Interstate	3.400	0.900	4.300	41.000	-1.000	-1.000	3.700	4.900	4.900	1.200
	02 Rural Other Princ	3.400	0.900	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	06 Rural Minor Arterial	3.400	0	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	07 Rural Mjr Collector	3.400	0.900	4.300	33.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	08 Rural min Collector	3.400	0.900	4.300	30.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	09 Rural Local	3.400	0.900	4.300	27.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	11 Urban Interstate	3.400	0.900	4.300	41.000	-1.000	-1.000	3.700	4.900	4.900	1.200
	12 Urban Fwy/Expwy	3.400	0.900	4.300	36.000	-1.000	-1.000	3.700	2.400	4.900	1.200
	14 Urban Other Princ	3.400	0.900	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	16 Urban Minor Arterial	3.400	0	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	17 Urban Collector	3.400	0.900	4.300	33.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	19 Urban Local	3.400	0.900	4.300	27.000	-1.000	-1.000	3.700	2.400	4.400	1.200
ADT Class 2	01 Rural Interstate	3.400	0.900	4.300	41.000	-1.000	-1.000	3.700	4.900	4.900	1.200
	02 Rural Other Princ	3.400	0.900	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	06 Rural Minor Arterial	3.400	0	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	07 Rural Mjr Collector	3.400	0.900	4.300	33.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	08 Rural min Collector	3.400	0.900	4.300	30.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	09 Rural Local	3.400	0.900	4.300	27.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	11 Urban Interstate	3.400	0.900	4.300	41.000	-1.000	-1.000	3.700	4.900	4.900	1.200
	12 Urban Fwy/Expwy	3.400	0.900	4.300	36.000	-1.000	-1.000	3.700	2.400	4.900	1.200
	14 Urban Other Princ	3.400	0.900	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	16 Urban Minor Arterial	3.400	0	4.300	36.000	-1.000	-1.000	3.700	2.400	4.400	1.200
	17 Urban Collector	3.400	0.900	4.300	33.000	-1.000	-1.000	3.700	2.400	4.400	1.200

Figure 6 - Policy Matrix Screen in Pontis

The Improvement Matrix parameters allow the user to specify assumptions about many aspects of roadway conditions. These include accident risk parameters, traffic parameters on both the roadway and any potential detours, and critical thresholds to trigger improvement needs. As with the Policy Matrix and Cost Matrix, multiple Improvement Matrices can be defined in order to determine the effect of different improvement parameters in the bridge network. The *Pontis Technical Manual* (*13*) recommends that the improvement matrix be modified sparingly and only with good data to justify the changes. This project used the default parameters in the Improvement Matrix.

Budget Parameters

Budgets may be specified for two purposes in Pontis. First, budgets may be established in the Programming Module for use with scenario simulations. Second, budgets may be determined in the Project Planning Module to establish sources of funding for actual projects.

The budgets established in the Programming Module are the annual funding available from all sources. This budget acts as a constraint on the amount of work that can be recommended for a scenario. Multiple budgets can be defined in order to examine the effect of funding levels on the bridge network. The budgets established in the Project Planning Module are quite different from these budgets. The Project Planning budgets are for information only. They provide no constraint on how work is recommended or assigned to programs. The user must compare the amount of work assigned to a particular program with the program budget to determine if funds are sufficient (*17*). For this project, several different budgets were defined in the Programming Module. These budgets will be explained in Chapter 4 along with the other parameters for the scenario simulations. No budgets were defined for this project in the Project Planning Module.

Rules

As an agency moves from analyzing needs on a network level to planning projects on a bridge level, some weaknesses of the Pontis optimization scheme come to light. Physical linkages between elements, such as deck elements and railing or joint elements, are not recognized by Pontis. Also, Pontis will recommend work on the same bridge for several years in a row without recognizing the possible efficiencies of doing all work on a bridge at the same time. Without additional guidelines, the projects recommended by Pontis are often not reasonable or practical. Five categories of rules have been created to deal with these weaknesses. These categories are Scoping rules, Look Ahead rules, Major Rehab rules, Agency Policy rules, and Painting rules. By using these rules, Pontis can recommend projects that follow practical guidelines and agency business procedures. More than one set of Scoping rules, Look Ahead rules, Major Rehab rules, and Agency Policy rules can be defined in order to run scenarios which apply different rules.

Scoping rules allow the user to specify work that should be done at the same time, whether because of a physical linkage or because of agency policy. They are defined as a statement that reads, “If action A is done to object B, then also do action C to object D.”

Scoping rules tend to upscale the amount of recommended work. An example of a scoping rule is “If REPLACE ELEMENT is done to DECKS/SLABS, then also do REPLACE ELEMENT to JOINTS.”

Look Ahead rules control the timing of recommended work to reflect agency practices. They are defined as a statement that reads, “If action A is scheduled for object B within *n* years, do <u>not</u> do action C to object D.” The scheduled actions are defined by the user in the Project Planning Module, and are intended to reflect the fact that agencies often schedule major maintenance work many years in advance and quit doing minor maintenance in the years leading up to the major project. Look Ahead rules tend to downscale the amount of recommended work. An example of a Look Ahead rule is “If REHAB SUPER (FLEX) to SUPERSTRUCTURE < 5 years, then no PAINTING to SUPERSTRUCTURE.” The (FLEX) portion of the rule statement refers to flexible actions.

Major Rehab rules force Pontis to schedule a major rehabilitation or replacement project based on the condition of the bridge, or based on the cost of recommended work. These rules account for the economies of scale in larger projects and for agency policies that dictate when major work must be performed. They are defined as a statement that reads, “If (trigger parameter) is less than/greater than (threshold), then do action C to object D. The objects may be the entire structure or an element category. Four trigger parameters are available: Bridge Health Index of the entire bridge or of an element category, cost of recommended work in dollars, cost of recommended work in percent of structure replacement cost, and cost of recommended work for a given element category as a percentage of the replacement cost for all elements in that category. Major Rehab rules tend to upscale the amount of recommended work. An example of a Major Rehab rule is “If Health Index for DECKS/SLABS is less than 70%, then do ELEMENT REHABILITATION to DECKS/SLABS.”

Agency Policy rules are the most general category of rules. They allow the agency to specify decisions based on agency practices that are not covered by one of the other types of rules. An Agency Policy rule is a statement that reads, “If object A has more than *x* percent in condition state B or worse, then for object C, do action D1 for the portion in condition state 1, action D2 for the portion in condition state 2, action D3 for the portion in condition state 3, action D4 for the portion in condition state 4, and action D5 for the portion in condition state 5." Special elements known as a Smart Flags are often used for this type of rule. Smart Flag elements do not correspond to an actual portion of the bridge but are status indicators for various conditions on a bridge, such as steel fatigue, pack rust, deck cracking, scour, settlement, and traffic impact. Smart Flags are used as trigger elements in Agency Policy rules to cause work to be performed on other elements. An example of such a rule is "If Scour Smart Flag has >= 50% in State 3 or worse, then for R/Conc Abutment do actions [S1] Do Nothing, [S2] Do Nothing, [S3] Element Rehabilitation, [S4] Element Rehabilitation, and [S5] Replace Element."

Paint rules specify thresholds for painting decisions. Thresholds can be established to determine what elements will be painted and whether the entire element or just a portion of the element will be painted. The logic of painting rules is explained in the *Pontis User's Manual* (*17*) in section 5.7, and in more detail in the *Pontis Technical Manual* (*13*).

The use of rules is not required to perform a scenario simulation. However, when they are used, there is a possibility of rules interacting in unexpected ways. For example, if one rule specifies "If a deck overlay is done, then also replace the joints," and a second rule specifies "If the joints are replaced, then also replace the deck," then a deck replacement is recommended by Pontis every time a deck overlay is recommended. Also, the order in which rules are applied may change the outcome. Rules that are applied later may change the results of rules that were applied earlier. Within each category of rules the user may specify a priority for each rule, and each category of rules is applied in the following order:

1. Paint rules
2. Agency Policy rules
3. Scoping rules
4. Major Rehab rules
5. Look Ahead rules.

Researchers from Cambridge Systematics, Caltrans, and AASHTO discussed the effects of rules on Pontis simulations (*24*). Their conclusions can be broken into network-level and bridge-level results. At the network level, the application of rules increases the projected needs, but the recommended work and overall condition of the network are not changed by applying rules. At the bridge level, the application of rules results in projects that appear more reasonable and practical. As a general trend, applying rules results in Pontis recommending fewer, but larger, projects. More work is recommended initially, as reflected in the higher projected needs at the network level, but the amount of work is reduced in later years. As a final conclusion, these researchers stated that rules should be used as an enhancement but not a substitute for developing accurate costs and deterioration rates for the Preservation Model.

This project looked briefly at the effect of rules on scenario simulations. Most simulations were run with no rules, but Scenario #3 was run with the default rules for comparison to Scenario #2, which was run without rules. These scenarios are discussed further in Chapter 4. A list of the default rules used for this project are included in Appendix 4.

Scenario Setup Parameters

Other parameters are required in order to set up and run a scenario simulation. The duration, type of projects, type of needs to address, and minimum project cost thresholds may all be specified in order to simulate actual bridge management practices. The user may also choose to run the scenario for only certain elements, and may also choose which bridges will be included in the simulation. This project used the default values in most cases, and any exceptions are explained in Chapter 4 in the discussion of the individual scenario simulations.

CHAPTER 4: MANAGEMENT OPERATIONS IN PONTIS

This chapter discusses the procedures to use Pontis for analyzing bridge network needs and planning projects. Most of the emphasis for this project was given to analyzing needs. These procedures are (1) developing an optimal preservation policy and (2) creating and running program simulations.

Optimal Preservation Policy

Pontis divides the problem of optimizing expenditures into two parts. First, the optimal preservation actions for each combination of element, environment, and condition state are determined; this set of optimal actions is known as the Preservation Policy. Second, the Preservation Policy is applied to the bridge network to prioritize the possible actions and determine the optimal expenditure of money. This section will discuss the procedures related to developing the Preservation Policy and how this policy is implemented in the other portions of the program. The prioritization of projects is discussed in this chapter in the section on Scenario Simulations.

The Preservation Policy is developed in the Preservation Module of Pontis. As was discussed in Chapter 3, this Module is used to acquire transition probabilities for the deterioration model and element unit costs and failure costs for the cost model. After the transition probabilities and element costs have been updated, the optimization procedure is run. The results of the optimization procedure can be viewed on screen in the Preservation Module or in the report “models002_preservation_details” available in Pontis. These show the input data and the values calculated by the optimization procedure and indicates the recommended action for each combination of element, environment, and condition state. The calculated values shown on this report are the long-term unit costs, the long-term optimal unit cost, the optimum percentage of the element in each condition state, and the failure probability from the last condition state. The recommended action for each condition state is based on the minimum long-term unit cost, which is the discounted sum of the action cost and all future costs that will be incurred after taking that action. The long-term optimal unit cost is the annual unit cost of maintaining the element in its optimal condition. The reports from the Preservation Module should be reviewed to be sure that the model’s recommendations are sensible. As mentioned in Chapter 3, it is especially important to be sure that the model does not recommend “do-nothing” for any element in its worst condition state, as this would imply that the element would be allowed to fail before action is taken.

The Pontis modeling approach, as implemented by the Preservation Policy, differs from other approaches to asset management because it does not address life-cycle costs. No salvage value is ever addressed, and it is assumed from a preservation standpoint that the bridges are going to keep operating at the same level of service indefinitely (or as updated by Functional Improvements). Maintenance and replacement actions are scheduled as needed to get the network to its optimum level, then continue in a steady-state condition. Decisions are made on a year-to-year time period, not a life-cycle period (*13*).

Scenario Simulations

One of the major purposes of this project was to familiarize ITD with the program simulation capabilities of Pontis. To carry out this objective, different scenarios were run to examine the effects of element unit costs, funding levels, and simulation rules on the simulation results. This section will discuss the structure of scenario simulations in general, as well as the input and results for the specific scenarios mentioned above.

Scenario Simulation Background

This section outlines the sequence of steps in a scenario simulation, highlighting the decisions and ranking criteria used by the program to generate and select projects. Both needs analysis and project planning operations use this procedure, and both Pontis-generated and user-generated projects may be considered.

Once the optimal Preservation Policy has been developed, it can be applied to the bridge network to identify potential preservation needs. The Improvement Policy also generates potential needs. The needs identified by Pontis are also known as Pontis Work Candidates. Preservation needs are generated by comparing the actual condition of the bridge network, as identified by the information in the Inspection Module, to the Preservation Policy to find elements which are not in their optimal condition state. Improvement needs are identified by comparing current levels of service, also obtained from the inventory data stored in the Inspection Module, to the standards specified in the Improvement and Policy Matrices. User-specified needs, known as Inspector Work Candidates, may also be entered and become part of the simulation.

After needs are identified, the benefits of each possible action are calculated. Benefits from preservation and improvement projects are calculated differently. Preservation benefits are based on the concept that the Preservation Policy recommends the optimal expenditure of money. Any deviation from this policy, such as delaying a maintenance project, will cost more money. This avoided cost of delay is considered a benefit of taking the recommended action now instead of waiting. Three options are available to calculate preservation benefits. These options vary in the method used to calculate the total asset value of a bridge, and are explained in detail in Chapter 4.5 of the *Pontis Technical Manual* (*13*). The default method of calculating preservation benefits was used for this project. Improvement benefits are calculated from reduced accidents and detours, based on assumptions made in the Improvement Matrix, Policy Matrix, and Cost Matrix. Models for calculating improvement feasibility, costs, and benefits are explained in detail in Chapter 4.4 of the *Pontis Technical Manual* (*13*).

The next step in the program simulation is to refine the work candidates based on the simulation rules. These rules are applied in the order described in Chapter 3 of this report. With the exception of the Look Ahead rules, these tend to increase the amount of recommended work. At this point, the work candidates are grouped into project alternatives for each bridge. The costs and benefits of the work candidates are summed to give the costs and benefits of each project alternative. It is possible that more than one alternative is generated for a single bridge, such as a replacement project and a non-replacement project. When this is the case, the alternatives for a single bridge are ranked according to incremental benefit-cost ratio, with the best alternative being selected for that bridge.

When the costs and benefits of all of the project alternatives have been calculated, the program ranks them according to cost-benefit ratio. Depending on the scenario setup parameters, user-defined projects can compete with or take priority over Pontis-generated projects. Projects are selected up to the budget limit. Performance measures and deterioration for one year are then calculated, and the process repeats for the next year.

It is important to note that this method of choosing optimal actions, generating work candidates, and choosing projects is not dependent on the time frame of the scenario. Optimal preservation actions are chosen by assuming a steady-state operating condition, and project decisions are made on a year-by-year basis. Also, recommendations are not dependent on funding levels. All projects are developed and ranked without considering the available funding.

"Unlimited" Budget Scenario

The first scenario was run with a very large budget ($200,000,000 per year) for 25 years. This budget was essentially an unlimited budget, since it exceeded the total projected needs of the network each year. No rules were applied for this scenario, and both preservation and improvement projects were included. Element unit costs for Idaho were used. This was an attempt to find an equilibrium or optimum level of the network. This scenario will also be used as a comparison for scenarios with more realistic funding levels. A report showing the input parameters for this scenario is included in Appendix 3.

As shown in Figure 7, the BHI appears to be approaching a value of 80 for the scenario with an unlimited budget. This shows the trend of the program to optimize the expenditure of money, even with an unlimited budget. The Preservation Policy almost never recommends work when an element is in the best condition states, so only the elements in the lower condition states have work performed on them. This policy leads to the decline of the BHI. If user costs are underestimated, the preservation module would underestimate the benefits of MR&R, and likewise underestimate the optimal element condition states,

Element Unit Cost Scenarios

Databases with element unit costs and failure costs from Idaho, Oregon, and California were used to determine the effect of element unit costs on simulation results. The element unit costs for Idaho were developed as a part of this project, as discussed in Chapter 3. The Oregon Department of Transportation (ODOT) developed unit costs through an expert elicitation process in December 2000 (Richard Groff, ODOT, unpublished data). The element unit costs for California are the default values that come with Pontis. A table

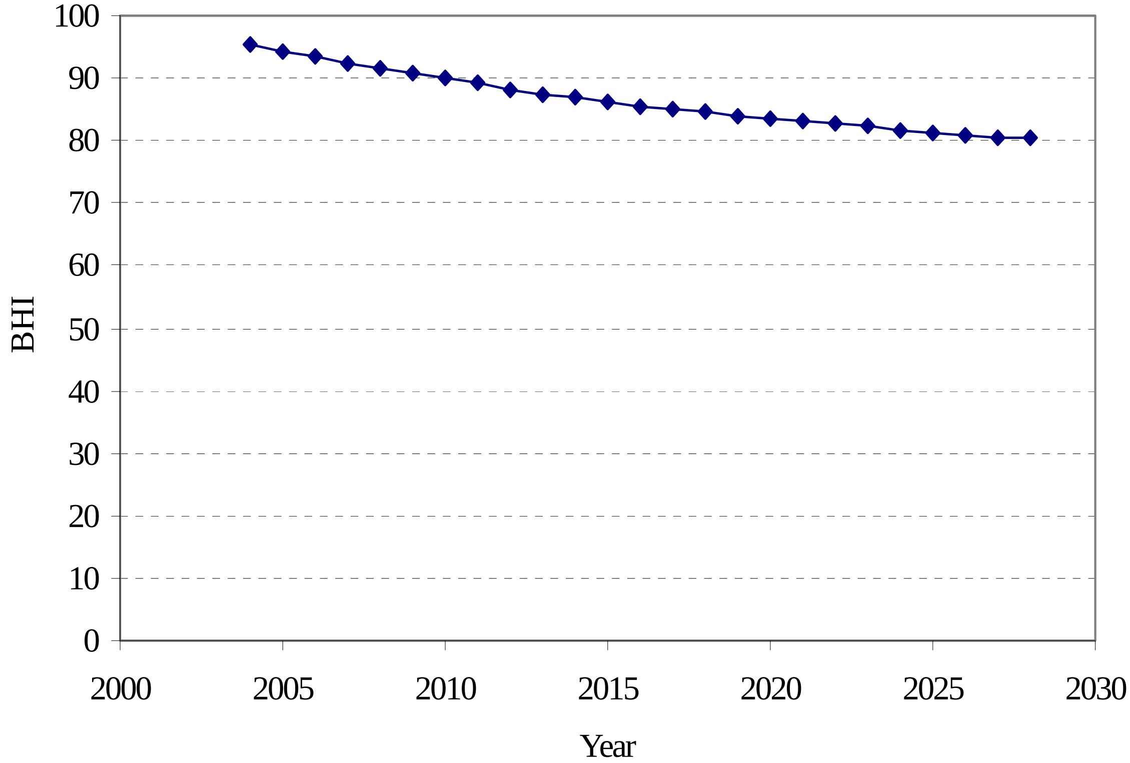


Figure 7 - Bridge Health Index with "Unlimited" Budget

showing the element unit costs for all three databases, as well as an explanation of the source for the costs for each element in the Idaho database, are found in Appendix 1. This table shows all feasible actions for each element except for the "do-nothing" actions, for which the unit cost is zero in the Idaho and California databases. The Oregon database assigns a cost to the "do-nothing" actions for most elements. The "do-nothing" cost has a value equal to the cost of replacing the element in its worst condition state. This value is included in the scenario simulations, but is not shown in the table in Appendix 1. A nonzero value for the "do-nothing" action significantly increases the minimum failure cost and makes the recommended action less sensitive to changes in failure cost.

As the element unit costs for each of the three databases are compared, certain trends can be noted. For over half of the feasible actions, the Oregon unit cost is greater than the other two states' costs. In fact, for some elements, the Oregon replacement cost is extremely high, such as Element 320, Prestressed Concrete Approach Slab, which is more than ten times greater than the other states' costs for that element. The truss-related elements, Element 120 through Element 126, also have very high costs in the Oregon database. This may indicate that these element unit costs were developed using different assumptions about model behavior and may be imposing an agency policy by making some actions too expensive to undertake. As a result, the failure costs for Oregon are also higher.

The recommended actions of the Preservation Policies based on each set of unit costs also have important trends. The recommendations based on the California and Idaho costs are very similar. In fact, for 62% of the elements the recommendations are the same, even when the unit costs are very different. However, the recommendations based on the Oregon costs have an entirely different pattern due to the Oregon practice of having a nonzero unit cost for the "do-nothing" action. As shown in Appendix 1, the Preservation Policy based on Oregon's unit costs recommends an action for nearly every condition state. In contrast, the Preservation Policies based on Idaho's and California's unit costs usually recommends "do-nothing" until the worst condition state.

The scenarios prepared to analyze the effects of element unit costs were run for a five-year period and considered preservation projects (MR&R). Scenarios were run with and without improvement projects. A range of budgets, from zero to $25 million per year, were used for each set of unit costs. The default values for most other scenario parameters were used, and no rules were applied. A report showing typical parameters for these scenarios can be found in Appendix 3. With the exception of the "Unlimited Budget" scenario discussed above, the five-year time frame was used for all of the simulations at the suggestion of ITD. Five years is a typical planning horizon for many bridge management operations. However, bridges typically have a much longer design life, often 75 years or more, so these simulations are very short in comparison to the life of the bridges that are being analyzed. Some aspects of bridge deterioration may not appear within this time frame.

These scenario comparisons were based on projected needs and benefits, Sufficiency Rating, and Bridge Health Index. Because it is not possible to compute a meaningful average Sufficiency Rating for the entire bridge network, this comparison was based on the number or percent of bridges with a Sufficiency Rating greater than 80 – the cutoff for federal funding for bridges.

Projected Needs - Figure 8 shows the projected needs for the three scenarios at a funding level of $10 million per year. The results are similar for other funding levels. Oregon's higher element unit costs – including the higher "do-nothing" costs – result in much higher projected needs. At the beginning of the simulation, the scenario based on Oregon element unit costs projects almost $100 million (59%) more in needs than the scenario based on California (default) unit costs, with the difference increasing to $132 million (500%) by the end of the simulation. A difference in projected needs of approximately $100 million based is also seen when functional improvements are ignored, although the difference remains relatively constant throughout the simulation. These relative differences are substantially greater than the relative differences between Oregon and California's element costs for most elements. The element unit costs for Idaho, though not consistently higher or lower than the element unit costs for California, also result in higher projected needs. The scenario with functional improvements based on Idaho element unit costs projects needs about $7 million (4.2%) higher than the corresponding California scenario at the

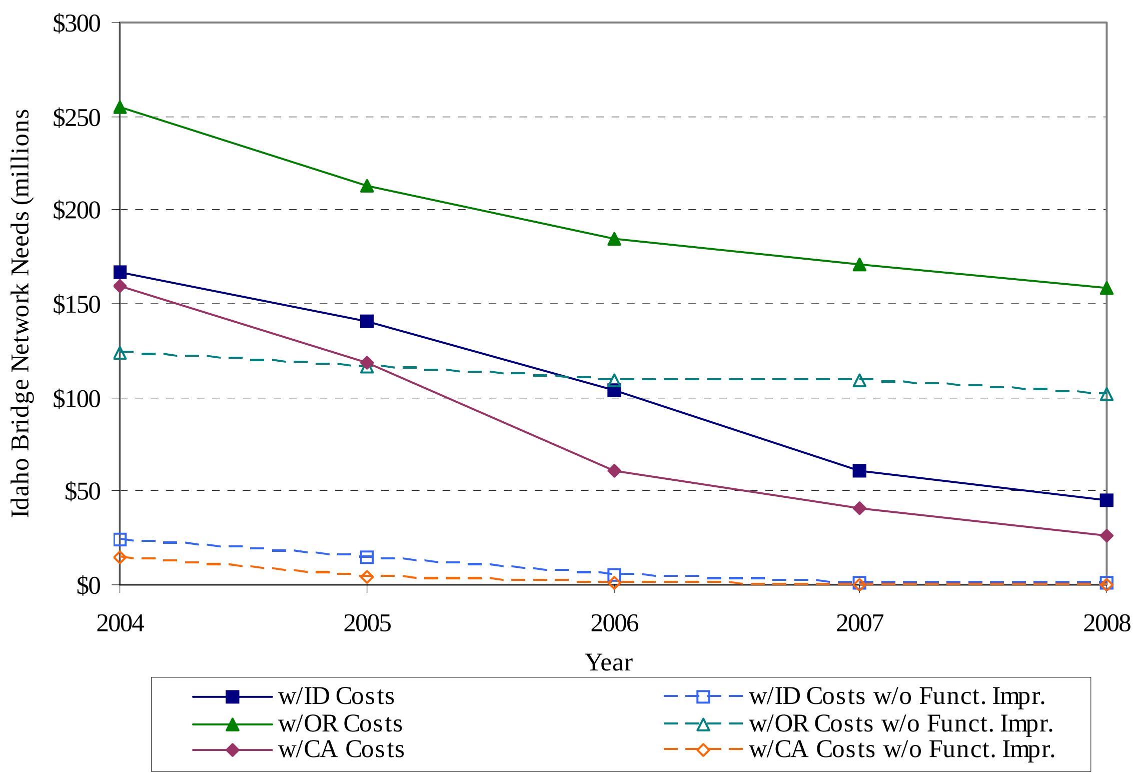


Figure 8 - Effect of Element Unit Cost on Projected Needs

beginning of the simulation, and about $19 million (71%) higher at the end of the simulation. Without functional improvements, the difference is about $6 million at the start of the simulation and is negligible at the end since both project approximately $0.5 million in needs.

Projected Benefits - Figure 9 indicates that for a $10 million annual budget, the projected benefits based on Oregon's element costs are substantially higher than those based on Idaho's or California's. This is true whether or not functional improvements are considered. At the beginning of the simulation with functional improvements included, the projected benefits based on Oregon's unit costs are $1.0 billion compared to $450 million based Idaho's and $234 million based on California's. At the end of the simulation, the differences are less dramatic, but projected benefits based on Oregon's costs are still higher than those based on Idaho's, or California's.

When functional improvements are ignored, benefits based on Oregon's costs remain relatively unchanged. At the beginning of the simulation, ignoring the functional

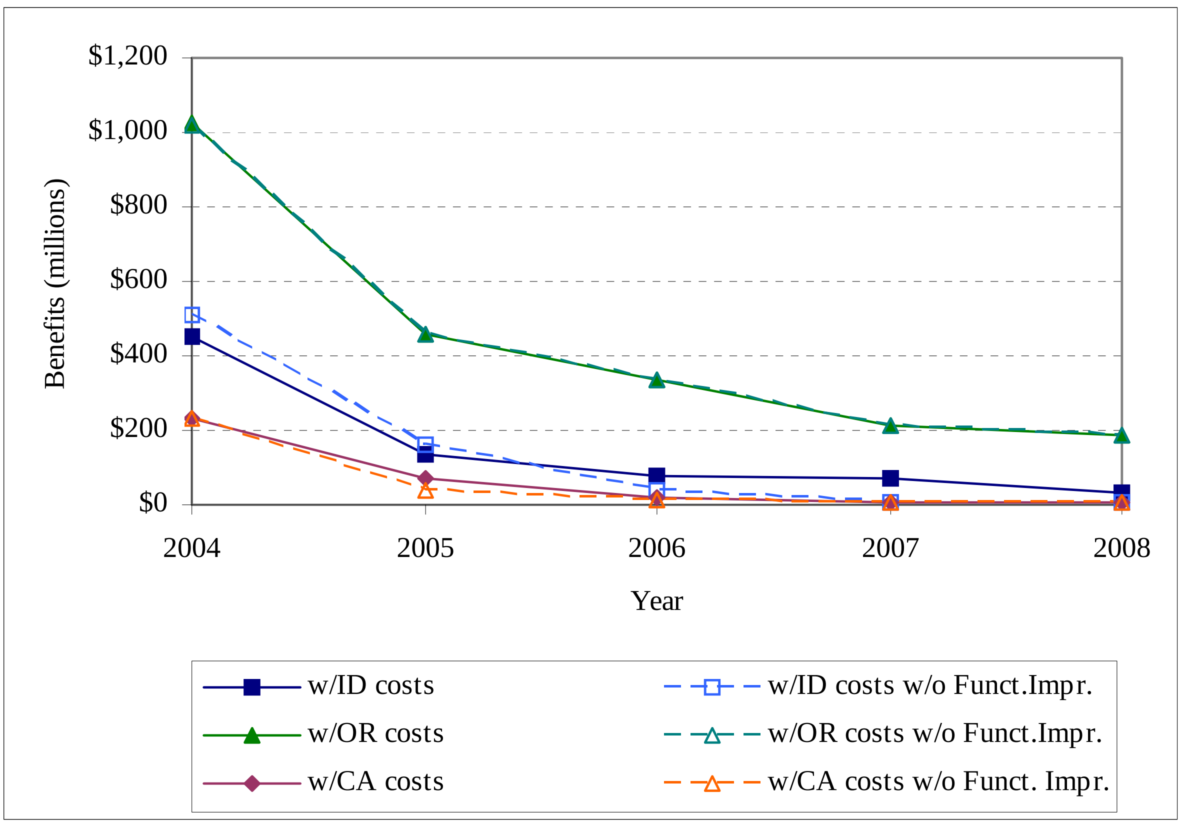


Figure 9 - Effect of Element Costs on Projected Benefits

improvements increases the benefits based on Idaho's costs from $450 to $500 million, and decreases those based on California's costs from $234 to $229 million. At the end of the simulation without functional improvements, both Idaho and California's predicted benefits are substantially below the $10 million annual MR&R budget. In years 2007 and 2008, Pontis has recommended all projects with a benefit-to-cost ratio greater than one without expending the available budget. This is reflected in the projected needs shown in Figure 8.

The results in this figure indicate that Oregon's use of non-zero "do-nothing" costs for their elements has a significant effect on the benefits calculated by Pontis. Since project selection is based on benefit-to-cost ratios, this will have a significant effect on the selection of MR&R projects.

Sufficiency Rating - Figure 10 shows the percentage of bridges with a Sufficiency Rating greater than 80 over the course of the simulation with the same annual budget of $10 million. Again, similar results are obtained at other funding levels. This is only a rough measure of network performance because each bridge’s Sufficiency Rating is given equal weight in this comparison. In reality, the bridges on the network have different size, importance, and needs. However, this comparison shows a general trend.

The Preservation Policy based on element unit costs from Idaho with functional improvements results in lower Sufficiency Ratings across the network, while the comparable Preservation Policy based on Oregon's costs results in higher Sufficiency Ratings. This may suggest that the Oregon policy of performing more work at an earlier state of deterioration may give higher Sufficiency Ratings. However, California's Preservation Policy with functional improvements maintains a comparable number of bridges with a Sufficiency Rating greater than 80, especially over time. With Oregon costs, the percent of bridges with a Sufficiency Rating greater than 80 does not change significantly when functional improvements are ignored. However with Idaho and California costs, the percent with a sufficiency rating greater than 80 drops two to four percent, respectively when functional improvements are ignored with the result that the Idaho and California cases are nearly indistinguishable when functional improvements are ignored.

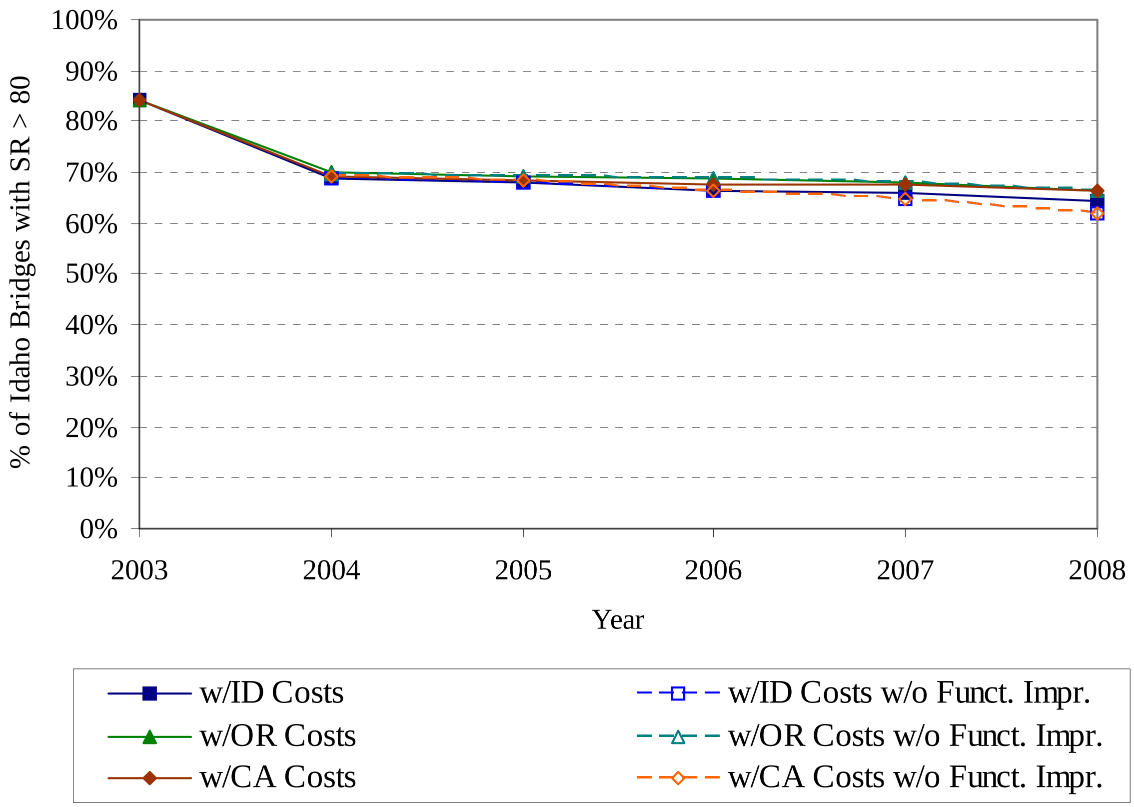


Figure 10 - Effect of Element Unit Costs on Sufficiency Rating

The comparison between the simulations based on Idaho and California unit costs without functional improvements suggests that the costs of maintaining a bridge network in Idaho are nearly the same as the costs of bridge maintenance in California. However, when the Preservation Policy includes functional improvements, California's element costs may lead a selection of MR&R projects that are more important to the Sufficiency Rating and presumably to the condition of the overall bridge network.

Many of the element unit costs from Idaho for this project were based on extrapolations or assumptions, not actual costs from past repair projects. Comparing the assumed and extrapolated costs from this project to historical cost data from Idaho would improve the accuracy of the simulations and would increase the level of confidence in the results.

Bridge Health Index- Figure 11 indicates that the Bridge Health Index is very similar for all three cost sets. Functional improvements also have very little impact on the Bridge Health Index. At the end of the simulation with or without functional improvements, Oregon's costs provide the highest Bridge Health index at 90. Using Idaho's costs, the Bridge Health Index is 88 at the end of the simulation, and 87 using California's. These differences are too small to reveal significant differences between the cost sets. Furthermore, the Bridge Health Index comparisons are problematic because the BHI is also based on element unit costs. Two possible explanations are possible for any difference in BHI between these scenarios. First, the BHI may be higher for one scenario because its element unit costs lead to a Preservation Policy that keeps the bridges in better condition. Second, the BHI may be higher simply because the element unit costs on which it is based are higher.

Funding Level Analysis

The scenario simulations that were used to compare the effects of element unit costs

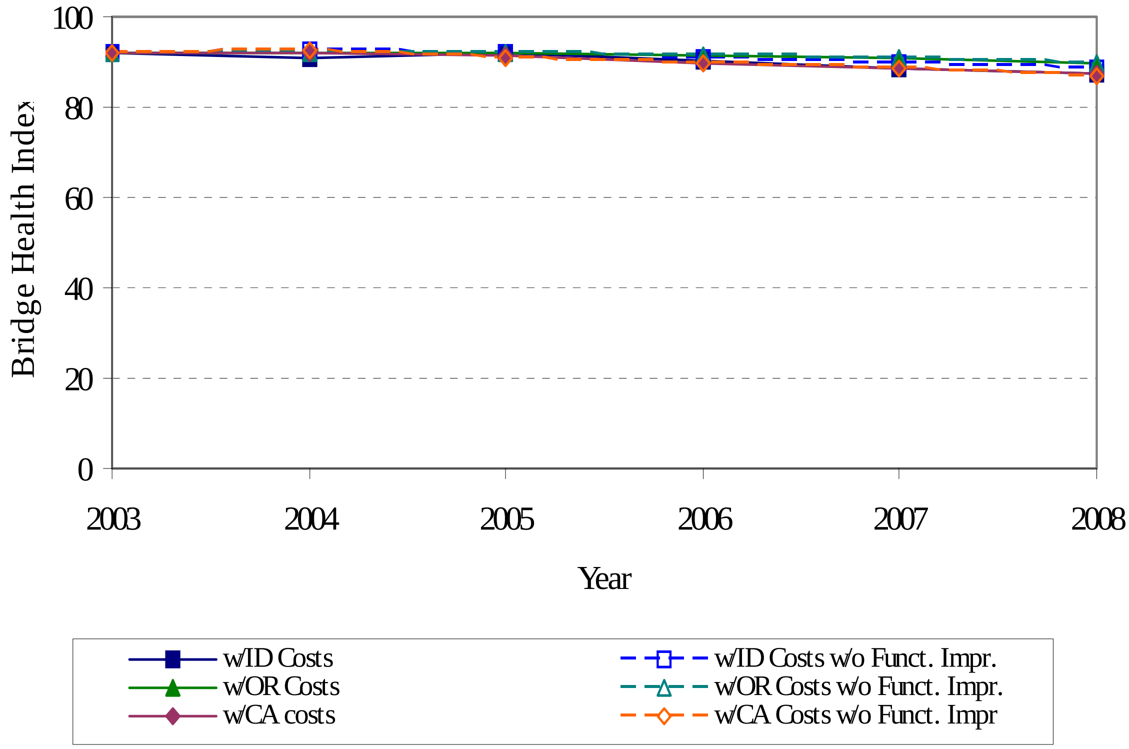


Figure 11 - Effect of Element Unit Costs on Bridge Health Index

were also used to examine the effects of different funding levels on the scenario outcome. Scenarios were run with annual funding levels of $0, $5 million, $10 million, $15 million, $20 million, and $25 million, each for a five-year time period. The scenario with an unlimited budget was also used for comparison in this analysis. Rules were not applied for these simulations. A report showing typical input parameters for these scenarios is included in Appendix 3. The analysis focused on the database with element unit costs from Idaho. These scenarios were compared on the basis of BHI, projected needs, and status as Structurally Deficient or Functionally Obsolete. The BHI is a valid basis for comparison for these scenarios because all of the scenarios are based on the same set of element unit costs.

Figure 12 shows the variation in BHI with funding level over a five-year time period. This figure shows the logical trend that a higher funding level will improve the condition of the network. It also shows a trend of diminishing returns. That is, the first money spent has a bigger impact on the condition of the network than the last money spent. The improvement from an annual budget of $0 to $5 million is much larger than the improvement between $5 million and $10 million, and an additional $15 million has an even smaller impact on the

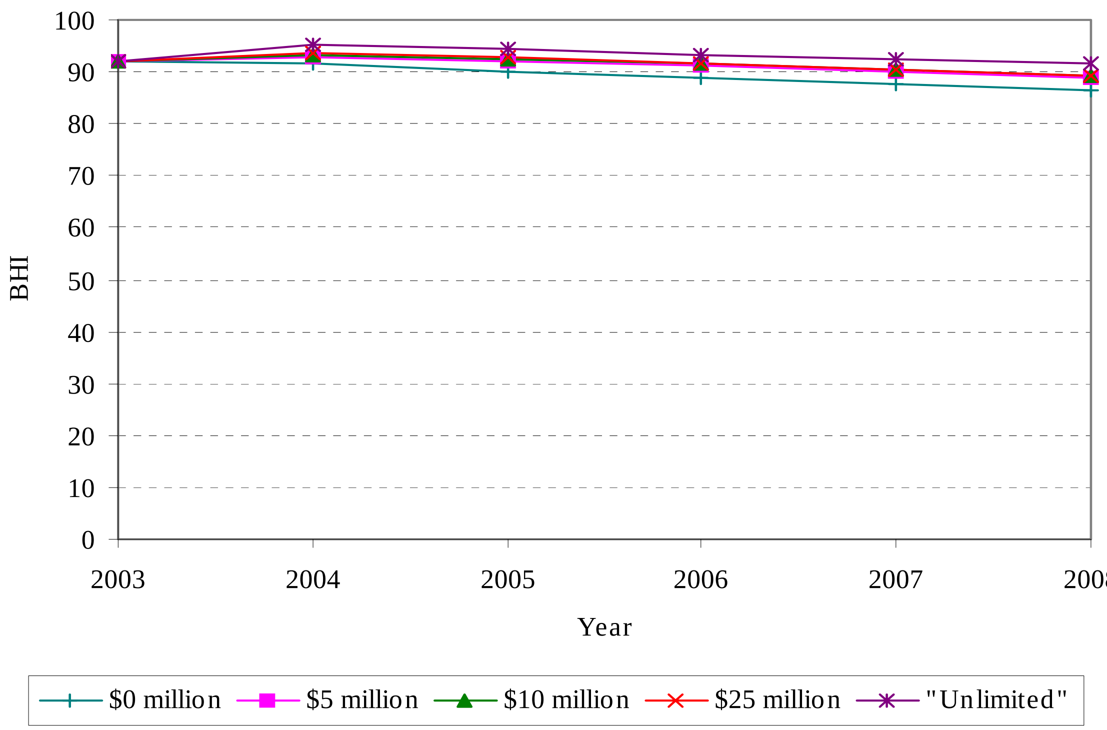


Figure 12 - Effect of Annual Funding Level on Bridge Health Index

condition of the bridge network. This trend is caused by the program selecting projects with a higher benefit/cost ratio first. Although the BHI is not tied directly to the project selection process, the first projects selected will be the most effective in improving network condition.

The downward trend in BHI indicates that the optimal condition for the network is somewhere below the current levels, at least for the current set of deterioration data, element unit costs, failure costs and user costs. However, this may not be a viable option for bridge managers. Political pressure may drive some maintenance decisions; letting bridges or bridge elements deteriorate is not likely to be a politically popular course of action.

Figure 13 shows the projected needs over the five-year simulation time frame at the same funding levels. Similar trends can be noted in this figure. An important trend can be noticed when the first two scenarios are compared. With no funding, the projected needs continue to rise. With annual funding of $5 million, the needs begin to decrease from year to year, indicating that this funding level is addressing more than just the annual deterioration and that previously postponed projects are being accomplished. However, the trend shown

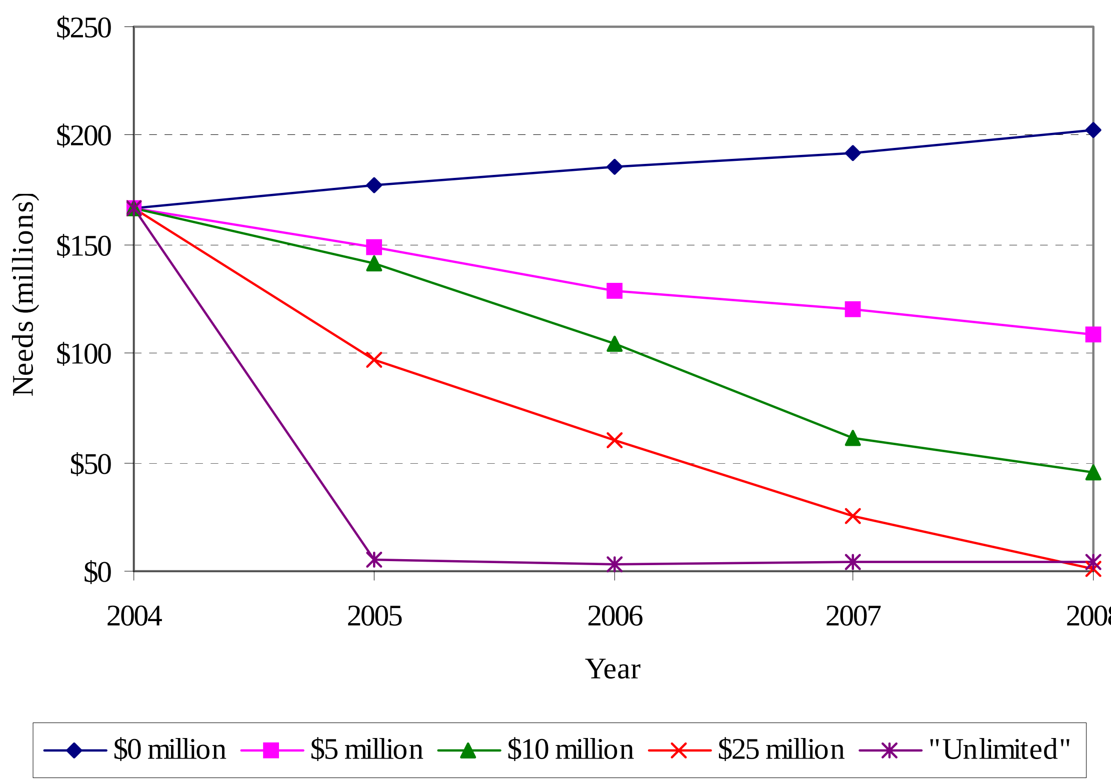


Figure 13 - Effect of Funding Level on Projected Needs

by the scenario with unlimited funding may be somewhat misleading. The projected needs decrease sharply in years 2005 and beyond because of the large amount of work performed in the first year of the simulation. This very low projection, about $4 million per year, would be the cost of maintaining the network at its optimum condition *once that optimum condition had already been reached*. A network which has not yet reached its optimum condition, will have higher costs in order to address the needs of previously postponed projects.

Figures 14 and 15 below show the variation in the percentage of Structurally Deficient and Functionally Obsolete bridges with funding level. These figures demonstrate that the number of Structurally Deficient or Functionally Obsolete bridges is not strongly dependent on the funding level indicating that these parameters are not good criteria to judge the effectiveness of a proposed budget. This may be due to the project selection criteria for this scenario. Projects were selected on the basis of the benefit/cost ratio, not status as Structurally Deficient or Functionally Obsolete. If an agency's policy was based on structures' status as Structurally Deficient or Functionally Obsolete, then Agency Rules should be included in the scenario to select projects based on these criteria.

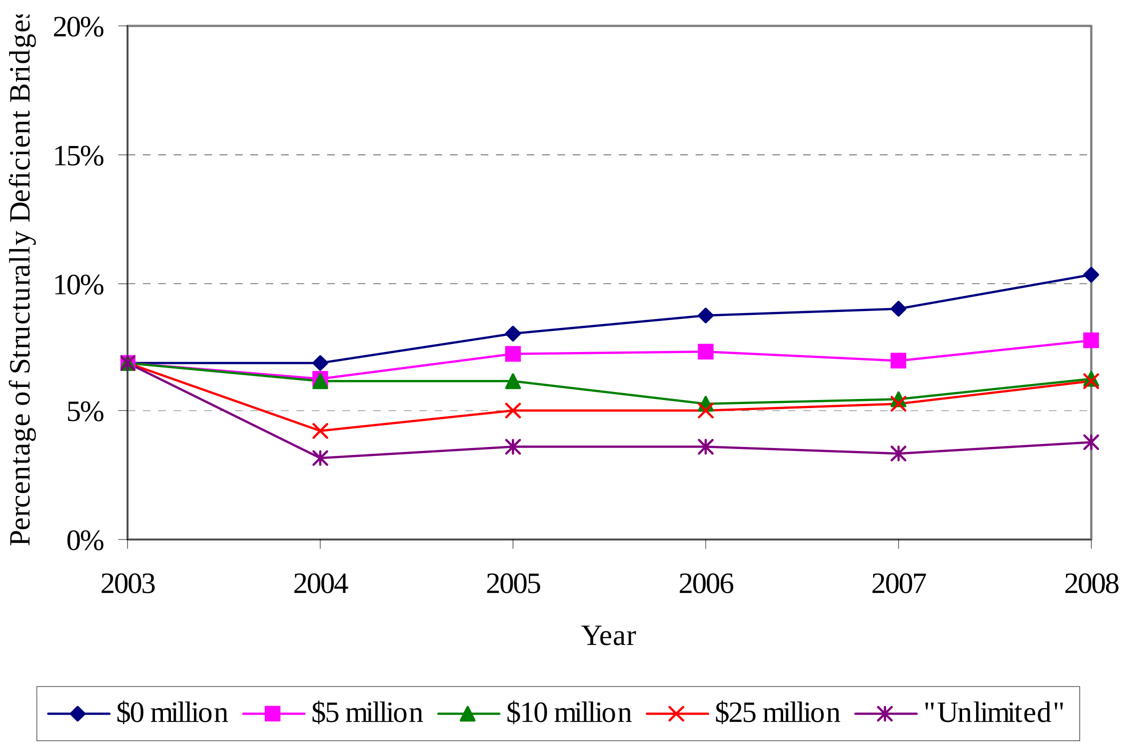


Figure 14 - Percentage of Structurally Deficient Bridges vs. Funding Level

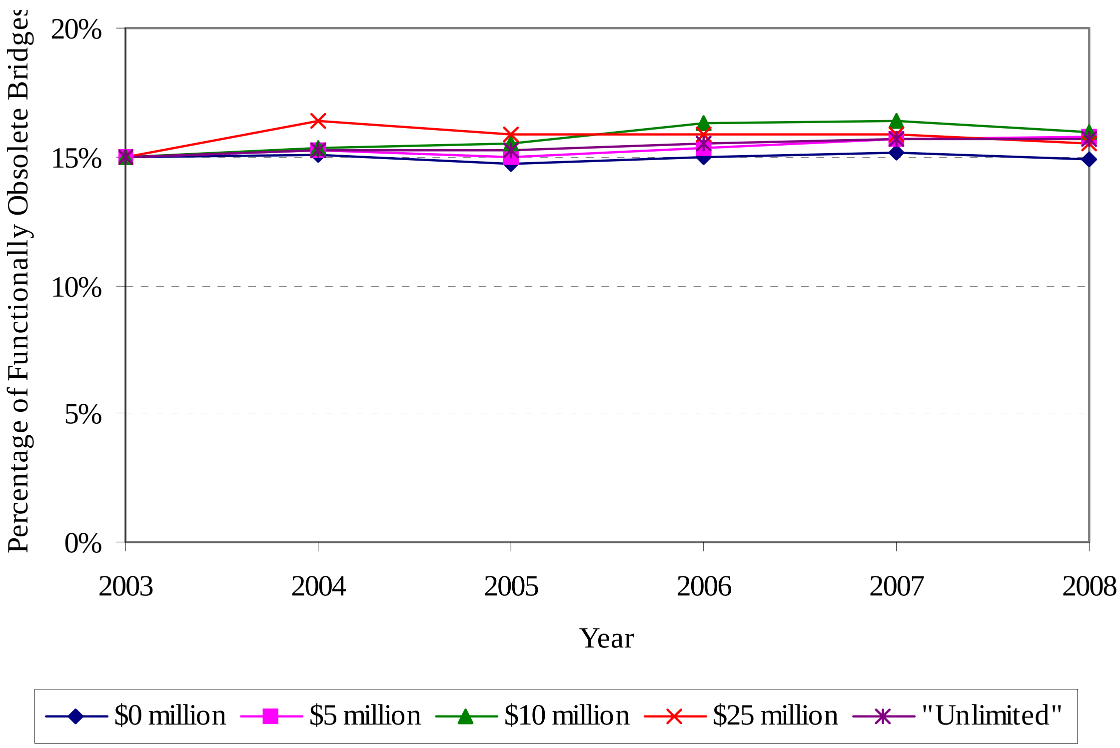


Figure 15 - Percentage of Functionally Obsolete Bridges vs. Funding Level

Rule Analysis

As discussed in Chapter 3, rules may be specified for scenario simulations in order to make the projects recommended by Pontis agree with physical linkages between elements, such as decks and joints, as well as follow agency policies and practices. While it was beyond the scope of this project to develop a comprehensive set of rules for scenario simulations in Idaho, the effect of basic rules was examined. A set of basic rules were applied to the scenario simulations that were used for the previous analyses. These rules were the Pontis default rule sets. There were no default Agency Policy Rules, and the default Look Ahead Rules did not apply because no projects had been previously defined. The Scoping Rules, Major Rehab Rules, and Painting Rules all applied and changed the recommended projects, as well as the bridge network condition over the duration of the simulation. All scenario parameters, including funding levels, were the same as the scenarios used above. A typical report for these scenarios is found in Appendix 3. A list of rules used for these scenarios is found in Appendix 4.

Figure 16 shows the variation of projected needs over the five-year duration of the simulation, comparing scenarios with an annual funding level of $5 million. Figure 17 shows the effect of rules on BHI for the same funding levels. These two figures show a general trend that simulations with rules tend to increase the projected needs, but even with the same budget, the simulation with rules projects an improvement of 1% in the condition of the network in the fifth year of the scenario. The increase in projected needs is to be expected because rules tend to upscope projects; that is, all rules except Look Ahead Rules include more work than the optimal Preservation Policy would recommend. Other funding levels produce similar results, with the scenarios with rules yielding better network condition and higher projected needs.

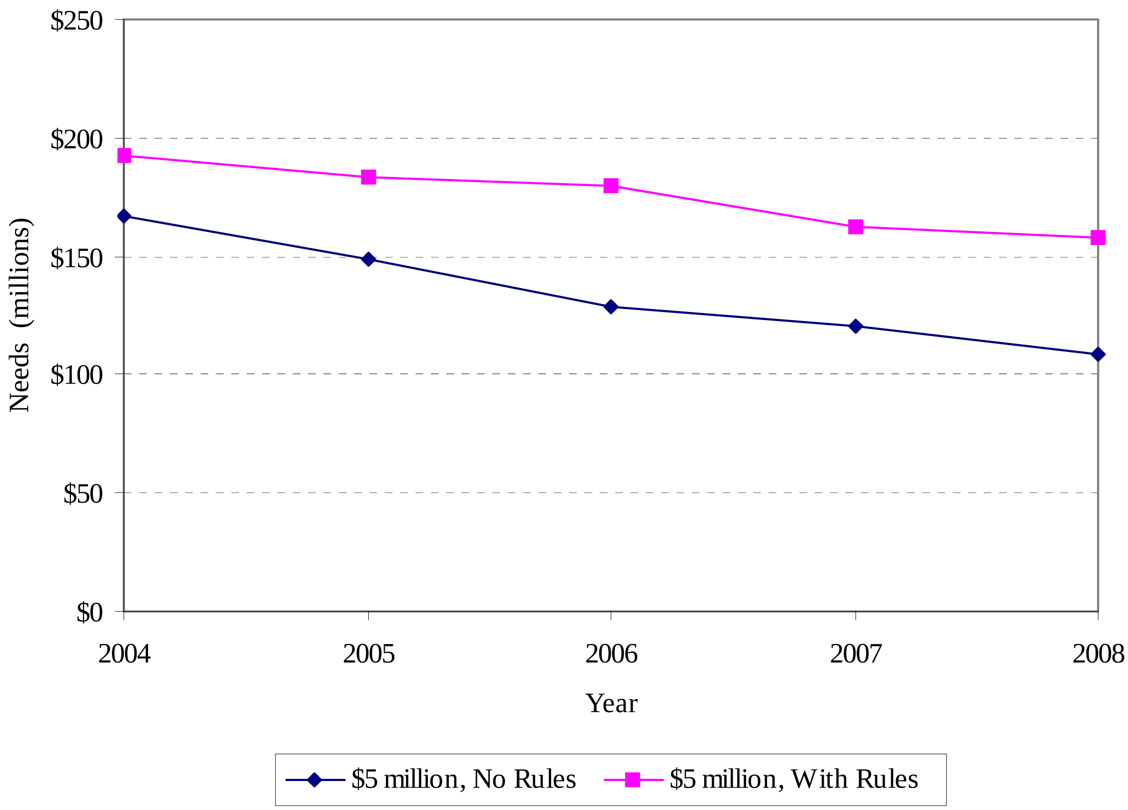


Figure 16 - Effect of Rules on Projected Needs

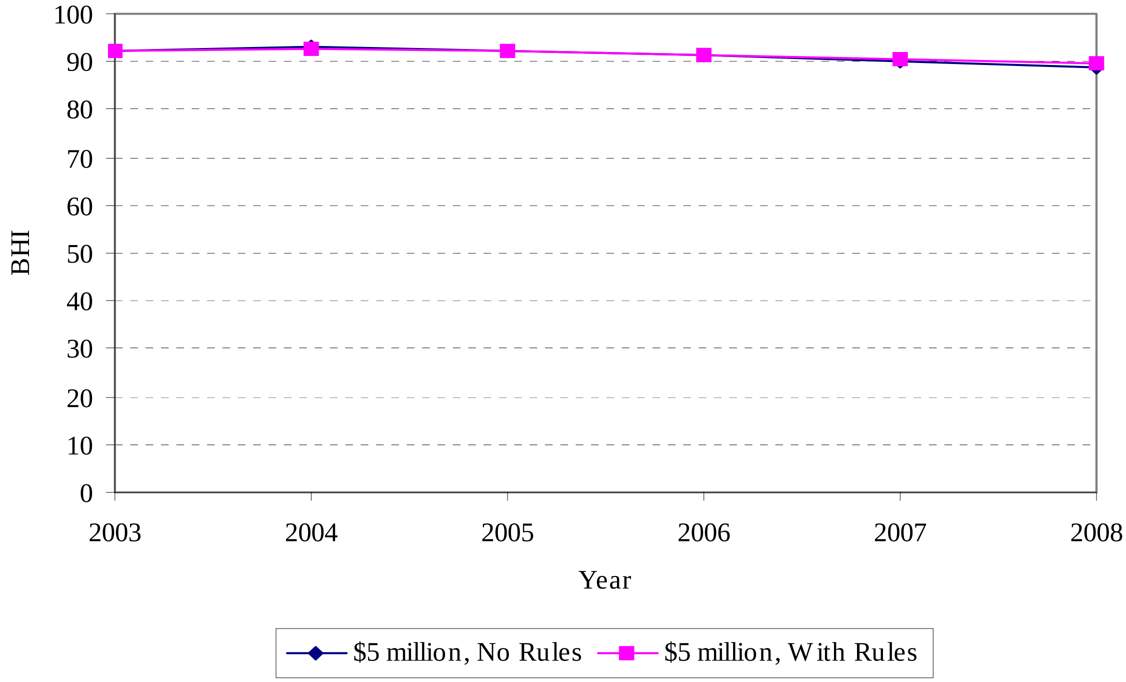


Figure 17 - Effect of Rules on Bridge Health Index

CHAPTER 5: SUMMARY AND CONCLUSION

Summary

Currently, ITD uses only the inventory and inspection management capabilities of Pontis. In the future, ITD is planning to expand their use of Pontis at the Needs Analysis or Project Planning levels. The information in this report has presented information needed to carry out this implementation. This report has outlined the capabilities of Pontis to assist the Idaho Transportation Department in their bridge management work. The required input data were summarized, with the element unit costs and failure costs examined in detail.

Element unit costs were estimated for Idaho based on information from ITD and other sources. These new element unit costs were compared to element unit costs from California and Oregon, and their effects on program simulations were examined. The unit costs developed for Idaho were similar to the default values from California, and resulted in similar recommendations in the Preservation Policy. However, the unit costs from Oregon were very different, reflecting a different approach to policy decisions by having non-zero costs specified for all of the “do-nothing” actions and very high costs for some other actions. As a result, the Preservation Policy based on element unit costs from Oregon resulted in very different recommendations.

The element costs from Idaho, Oregon and California were used to calculate the projected needs and benefits for Idaho’s bridge network; the effects of these element costs were also determined for the network’s Sufficiency Rating and Bridge Health Index. Comparative costs were also calculated with preservation needs (MR&R) alone, and with both preservation and functional improvement needs. The effects of funding levels and agency rules on program simulations were also analyzed.

Conclusions

As funding levels increase, the condition of the network also improves, as may be expected. However, for even “unlimited” levels of funding, the condition of the network always declines over time, indicating that the optimal condition of the bridges on the network is below the current condition based on current estimates of element unit costs, user costs and failure costs. Only element unit costs were examined in detail in this study. When the other costs are examined, the optimal condition may change.

Although Oregon's element costs were somewhat higher than Idaho's and California's, the biggest difference was the non-zero cost Oregon assigned to the "do-nothing" actions. The scenarios based on Oregon's element costs resulted in much higher projected needs. Specifically over the five-year scenario including functional improvements, the needs for the bridge network using Oregon's cost data ranged from 59 to 500% higher than those based on the California cost data. The projected needs using Idaho's cost data ranged from 4 to 71% higher than those based on California cost data. Projected benefits based on Oregon’s cost data were also much higher than those based on California’s and Idaho’s. Much of the increase can be attributed to the Preservation Policy derived from Oregon's element costs, which recommend an action for nearly every condition state. Politically speaking, it may be difficult to allow bridge elements to deteriorate to what Pontis designates as their "optimal condition" before undertaking repairs. In this case, Oregon's cost model may allow a bridge agency to better match some political realities even though it is not actually economically optimal compared to California's or Idaho's.

The Preservation Policy derived from Oregon's element costs resulted in a slightly better network condition, based on the Sufficiency Rating suggesting that suggest that the Oregon policy of performing more work at an earlier state of deterioration may improve Sufficiency Ratings. The sufficiency ratings without functional improvements indicate that Idaho and California costs sets produce similar MR&R recommendations. When functional improvements are included, the California costs produce a slightly higher portion of bridges with a sufficiency rating greater than 80. This suggests that the Preservation Policy based on California's costs may be more efficient in making repairs to elements that are more important to the Sufficiency Rating and presumably to the condition of the overall bridge network.

Applying rules to the simulations results in higher projected needs because the rules tend to include more work than would otherwise be recommended. However, applying rules also results in a slight increase in network condition, indicating that the actions recommended by the Preservation Policy are not based on maximizing network condition, but rather are based on benefit/cost calculations.

Further Research

As ITD's implementation of Pontis continues, three major areas may be of interest for additional study. These areas are verification of the results from this report, the cost data that were not addressed by this report, and the deterioration data.

This report shows several predictions from Pontis about bridge network condition over the next five years. Comparing results from inspections over this time period to the results from Pontis in this report would give ITD bridge managers a means of evaluating Pontis predictions.

Several types of cost data were not addressed as a part of this report. These include agency costs for functional improvements and user costs related to both functional improvements and failure costs. Agency costs for functional improvements are related to strengthening, widening, raising, and other items related to a bridge's level of service. User costs are somewhat more difficult to analyze, but they play a major role in the Pontis models because of their impact on benefit calculations since they are included in the benefit-to-cost ratios that Pontis uses to rank and select projects. If the default user costs used in these calculations are low, the benefits of a project will be underestimated. The default policy used in these calculations will not recommend projects with a benefit-to-cost ratio less than one, so fewer projects would be recommended if benefits are underestimated, which may account for the decreasing Bridge Health Index over time. User costs should be examined in some detail in order to have confidence in Pontis' calculations of the optimal condition for Idaho's bridge network and its elements.

As a final item related to costs, the failure costs developed for this project were intended only to represent the minimum failure cost required to force the model to take action instead of allowing an element to fail. They were not intended to reflect the actual consequences of failure in any way. Further study may be warranted to develop failure costs that would reflect these consequences, including the user cost component.

A major part of the Pontis Preservation Policy and its underlying models is the deterioration data. The inspection information and the transition probabilities were not addressed by this project. As ITD implements Pontis, two questions arise with respect to the deterioration data that bear further research. First, how much historical inspection data can ITD collect to enter into Pontis? Second, how long does it take for this historical inspection data to improve the deterioration model? Although Pontis has the capability of “learning” the true element deterioration probabilities from the inspection data over time, these two questions must be addressed in order for this capability to be put to full use. The interaction of transition probabilities with minimum failure costs and the recommended actions in the Preservation Policy should also be studied further.

As these areas are investigated, ITD will have the information to implement Pontis and make full use of its management capabilities. As Pontis is implemented and the input data are examined and calibrated, this program will be able to assist Idaho bridge managers in their tasks.

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APPENDIX 1 - IDAHO ELEMENT UNIT COSTS

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source

Note: Unit costs in boxes are the Pontis Recommended actions in each condition state. If no cost is selected for a condition state, the recommendation is "do nothing" which does not appear in this table.

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
12	Bare Concrete Deck	1 - No Damage	Add protective system	*N/A*	89.02	137.09	ITD Experts
		2 - Distress <= 2%	Repair spall/delams	250.00	284.17	108.00	
			Add protective system	150.00	73.63	137.09	
		3 - 2 to 10% distress	Repair spall/delams	**250.00**	307.74	162.00	
			Repair spall/delams+system	400.00	129.17	78.29	
		4 - 10 to 25% distress	Repair spall/delams	**250.00**	158.01	216.00	
			Repair spall/delams+system	400.00	151.23	86.69	
		5 - Distress over 25%	Repair spall/delams+system	**400.00**	**242.19**	**95.09**	
			Replace deck	600.00	301.50	238.03	
			Failure Cost	1800.00	600.00	714.09	
13	Unp Conc Deck/AC ovl	2 - Distress <= 2%	Repair potholes/substrate	**150.00**	337.99	9.25	ITD Experts
		3 - 2 to 10% distress	Repair potholes/substrate	**150.00**	180.30	9.25	
			Replace substrate/overlay	250.00	226.04	168.73	
		4 - 10 to 25% distress	Repair potholes/substrate	**150.00**	96.55	9.25	
			Replace substrate/overlay	250.00	186.43	222.73	
		5 - Distress over 25%	Replace substrate/overlay	**250.00**	**67.27**	276.73	
			Replace deck	600.00	331.10	**240.65**	
			Failure Cost	1800.00	600.00	1200.00	
14	P Conc Deck/AC ovly	2 - Distress <= 2%	Repair potholes/substrate	**150.00**	156.83	9.25	ITD Experts
		3 - 2 to 10% distress	Repair potholes/substrate	**150.00**	153.71	9.25	
			Replace substrate/overlay	250.00	64.58	180.73	
		4 - 10 to 25% distress	Repair potholes/substrate	**150.00**	43.06	9.25	
			Replace substrate/overlay	250.00	91.82	234.73	
		5 - Distress over 25%	Replace substrate/overlay	**250.00**	**57.05**	288.73	
			Replace deck	600.00	282.55	**240.65**	
			Failure Cost	1800.00	600.00	1200.00	
18	P Conc Deck/Thin ovl	2 - Distress <= 2%	Repair spall/delams	**100.00**	26.91	108.00	ITD Experts
		3 - 2 to 10% distress	Repair spall/delams	**100.00**	56.51	162.00	
		4 - 10 to 25% distress	Repair spall/delams	**100.00**	82.56	216.00	
			Replace overlay	150.00	113.02	269.82	
		5 - Distress over 25%	Replace overlay	**150.00**	984.90	323.82	
			Replace deck	600.00	**269.10**	**240.65**	
			Failure Cost	1800.00	1157.00	971.46	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
22	P Conc Deck/Rigid ovl	2 - Distress <= 2%	Repair spall/delams	**100.00**	29.82	108.00	ITD Experts
		3 - 2 to 10% distress	Repair spall/delams	**100.00**	68.89	162.00	
		4 - 10 to 25% distress	Repair spall/delams	**100.00**	95.58	216.00	
			Replace overlay	200.00	115.39	86.69	
		5 - Distress over 25%	Replace overlay	**200.00**	**80.73**	**95.09**	
			Replace deck	600.00	346.60	240.65	
			Failure Cost	1800.00	499.00	721.95	
26	Conc Deck/Coatd Bars	1 - No Damage	Add protective system	*N/A*	180.00	137.09	ITD Experts
		2 - Distress <= 2%	Repair spall/delams	1000.00	52.53	113.40	
			Add protective system	**150.00**	180.00	137.09	
		3 - 2 to 10% distress	Repair spall/delams	1000.00	30.68	170.10	
			Repair spall/delams+system	**175.00**	79.65	82.20	
		4 - 10 to 25% distress	Repair spall/delams	1100.00	83.96	226.80	
			Repair spall/delams+system	**175.00**	113.77	91.02	
		5 - Distress over 25%	Repair spall/delams+system	**175.00**	**108.28**	**99.84**	
			Replace deck	900.00	187.62	240.65	
			Failure Cost	3300.00	669.00	721.95	
27	Conc Deck/Cathodic	1 - No Damage	Add protective system	*N/A*	180.00	137.09	ITD Experts
		2 - Distress <= 2%	Repair spall/delams	**85.23**	80.73	113.40	Note: none in
			Add protective system	190.03	180.00	137.09	ID inventory
		3 - 2 to 10% distress	Repair spall/delams	**109.89**	104.09	170.10	
			Repair spall/delams+system	108.64	102.90	82.20	
		4 - 10 to 25% distress	Repair spall/delams	**125.00**	118.40	226.80	
			Repair spall/delams+system	183.18	173.51	91.02	
		5 - Distress over 25%	Repair spall/delams+system	**62.50**	**59.20**	**99.84**	
			Replace deck	633.44	430.56	238.03	
			Failure Cost	1900.32	469.80	714.09	
28	Steel Deck/Open grid	2 - Minor Deterioration	Surface clean	**100.00**	5.38	*None*	
		3 - Rust Formation	Surface clean and restore top coat	200.00	64.58	*In*	
			Rehab connectors	**400.00**	53.82	*ID*	
		4 - Moderate Corrosion	Spot blast, clean, and paint	**300.00**	134.55	*Inventory*	
			Rehab connectors	400.00	53.82		
		5 - Advanced Corrosion	Rehab connectors and replace paint system	**600.00**	**247.57**		
			Replace unit	1200.00	344.45		
			Failure Cost	3600.00	1863.00		

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
29	Steel Deck/Conc grid	2 - Minor Deterioration	Surface clean	**100.00**	1.00	1.00	Used CA costs
		3 - Rust Formation	Surface clean and restore top coat	200.00	3.00	3.00	Note: very few in
			Rehab connectors and concrete filler	**600.00**	8.00	8.00	ID inventory
		4 - Failed Connectors	Spot blast, clean, and paint	**300.00**	**2.00**	**2.00**	
			Rehab connectors and concrete filler	600.00	8.00	8.00	
		5 - Advanced Corrosion	Rehab connectors & conc filler & replace paint sys	**600.00**	**80.00**	**80.00**	
			Replace unit	1500.00	150.00	150.00	
			Failure Cost	4500.00	602.00	500.00	
30	Corrug/Orthotpc Deck	2 - Minor Deterioration	Seal cracks and/or repair potholes	**500.00**	10.76	*None*	
		3 - Rust Formation	Surface clean and replace top coat of paint	500.00	32.29	*In*	
			Repair potholes and cracks	**500.00**	10.76	*ID*	
		4 - Moderate Deterioration	Spot blast, clean, & paint -- repair potholes	**1000.00**	**43.06**	*Inventory*	
			Replace paint system and/or replace surfacing	1500.00	274.48		
		5 - Major Section Loss	Rehab, replace paint system, replace surfacing	**2000.00**	**1076.39**		
			Replace unit	1800.00	1614.59		
			Failure Cost	15000.00	8100.00		
31	Timber Deck	2 - Minor Decay	Rehab And/or Protect Deck	**60.00**	2.00	35.00	ITD Experts
		3 - Some Strength Loss	Rehab Deck	**60.00**	3.75	35.00	
			Replace Deck	120.00	10.38	74.00	
		4 - Major Strength Loss	Replace Deck	**120.00**	**10.38**	**74.00**	
			Failure Cost	2500.00	36.00	225.00	
32	Timber Deck/ AC ovly	2 - Minor Deterioration	Repair Potholes	**60.00**	12.49	17.00	ITD Experts
			Rehab and/or Protect Unit	120.00	23.36	35.00	
		3 - Some Strength Loss	Rehab Deck and replace or repair surfacing	**120.00**	43.06	35.00	
			Replace Deck & Surfacing	240.00	83.96	91.00	
		4 - Major Strength Loss	Replace Deck & Surfacing	**240.00**	**121.42**	**91.00**	
			Failure Cost	3500.00	424.00	275.00	
38	Bare Concrete Slab	1 - No Damage	Add protective system	*N/A*	55.22	137.09	ITD Experts
		2 - Distress <= 2%	Repair spall/delams	250.00	75.35	108.00	
			Add protective system	**150.00**	90.20	137.09	
		3 - 2 to 10% distress	Repair spall/delams	**250.00**	149.94	162.00	
			Repair spall/delams+system	400.00	111.73	78.29	
		4 - 10 to 25% distress	Repair spall/delams	**250.00**	150.69	216.00	
			Repair spall/delams+system	400.00	168.24	86.69	
		5 - Distress over 25%	Repair spall/delams+system	**400.00**	**177.60**	**95.09**	
			Replace deck	600.00	482.12	238.03	
			Failure Cost	1800.00	764.00	714.09	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
39	Unp Conc Slab/AC ovly	2 - Distress <= 2%	Repair potholes/substrate	**150.00**	15.28	9.25	ITD Experts
		3 - 2 to 10% distress	Repair potholes/substrate	**150.00**	17.87	9.25	
			Replace substrate/overlay	250.00	24.97	168.73	
		4 - 10 to 25% distress	Repair potholes/substrate	**150.00**	32.29	**9.25**	
			Replace substrate/overlay	250.00	32.29	222.73	
		5 - Distress over 25%	Replace substrate/overlay	**250.00**	**51.13**	276.73	
			Replace deck	600.00	702.35	**240.65**	
			Failure Cost	15000.00	220.00	850.00	
40	P Conc Slab/AC ovly	2 - Distress <= 2%	Repair potholes/substrate	**150.00**	12.49	9.25	ITD Experts
		3 - 2 to 10% distress	Repair potholes/substrate	**150.00**	19.70	9.25	
			Replace substrate/overlay	250.00	32.29	180.73	
		4 - 10 to 25% distress	Repair potholes/substrate	**150.00**	25.83	9.25	
			Replace substrate/overlay	250.00	94.72	234.73	
		5 - Distress over 25%	Replace substrate/overlay	**250.00**	**48.44**	288.73	
			Replace deck	600.00	466.40	**240.65**	
			Failure Cost	1800.00	299.00	1200.00	
44	P Conc Slab/Thin ovl	2 - Distress <= 2%	Repair spall/delams	**100.00**	26.91	108.00	ITD Experts
		3 - 2 to 10% distress	Repair spall/delams	**100.00**	53.82	162.00	
		4 - 10 to 25% distress	Repair spall/delams	**100.00**	62.43	216.00	
			Replace overlay	150.00	103.33	269.82	
		5 - Distress over 25%	Replace overlay	**150.00**	**67.27**	323.82	
			Replace deck	600.00	484.38	**240.65**	
			Failure Cost	1800.00	289.00	971.46	
48	P Conc Slab/Rigid ovl	2 - Distress <= 2%	Repair spall/delams	**100.00**	26.91	108.00	ITD Experts
		3 - 2 to 10% distress	Repair spall/delams	**100.00**	49.84	162.00	
		4 - 10 to 25% distress	Repair spall/delams	**100.00**	57.26	216.00	
			Replace overlay	200.00	116.25	86.69	
		5 - Distress over 25%	Replace overlay	**200.00**	**71.80**	**95.09**	
			Replace deck	600.00	484.38	240.65	
			Failure Cost	1800.00	444.00	721.95	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
52	Conc Slab/Coatd Bars	1 - No Damage	Add protective system	*N/A*	180.00	137.09	ITD Experts
		2 - Distress <= 2%	Repair spall/delams	1000.00	81.70	113.40	
			Add protective system	**150.00**	180.00	137.09	
		3 - 2 to 10% distress	Repair spall/delams	1000.00	88.16	170.10	
			Repair spall/delams+system	**175.00**	39.50	82.20	
		4 - 10 to 25% distress	Repair spall/delams	1100.00	99.57	226.80	
			Repair spall/delams+system	**175.00**	121.09	91.02	
		5 - Distress over 25%	Repair spall/delams+system	**175.00**	**75.35**	**99.84**	
			Replace deck	900.00	299.99	240.65	
			Failure Cost	3300.00	466.00	721.95	
53	Conc Slab/Cathodic	1 - No Damage	Add protective system	*N/A*	180.00	137.09	ITD Experts
		2 - Distress <= 2%	Repair spall/delams	**68.18**	64.58	113.40	Note: none in
			Add protective system	190.03	180.00	137.09	ID inventory
		3 - 2 to 10% distress	Repair spall/delams	**88.07**	83.42	170.10	
			Repair spall/delams+system	82.39	78.04	82.20	
		4 - 10 to 25% distress	Repair spall/delams	**102.28**	96.88	226.80	
			Repair spall/delams+system	843.77	799.22	91.02	
		5 - Distress over 25%	Repair spall/delams+system	**79.55**	**75.35**	**99.84**	
			Replace deck	633.44	466.40	238.03	
			Failure Cost	2531.31	598.60	714.09	
54	Timber Slab	2 - Minor Decay	Rehab and/or protect deck	**120.00**	1.00	*None*	
		3 - Some Strength Loss	Rehab deck	120.00	4.00	*In*	
			Replace deck	**120.00**	9.00	*ID*	
		4 - Major Strength Loss	Replace deck	**120.00**	**9.00**	*Inventory*	
			Failure Cost	3000.00	21.00		
55	Timber Slab/AC ovly	2 - Minor Deterioration	Repair potholes	**60.00**	2.00	17.00	Assumed same as
			Rehab and/or protect unit	150.00	2.00	35.00	Element 32
		3 - Some Strength Loss	Rehab deck & repair/replace surfacing	150.00	4.00	35.00	
			Replace deck and surfacing	**150.00**	32.00	91.00	
		4 - Major Strength Loss	Replace deck and surfacing	**150.00**	**32.00**	**91.00**	
			Failure Cost	3500.00	112.00	325.00	
101	Unpnt Stl Box Girder	2 - Minor Corrosion	Clean and paint	**300.00**	108.27	827.00	ITD Experts
		3 - Some section loss	Clean and paint	**300.00**	**108.27**	**827.00**	
		4 - Major section loss	Rehab unit	**5000.00**	1246.72	19348.00	
			Replace unit	15000.00	**902.23**	**14000.00**	
			Failure Cost	240000.00	6947.00	110000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
102	Paint Stl Box Girder	1 - No Corrosion	Surface clean	**5.00**	439.63	79.25	ITD Experts
		2 - Paint Distress	Surface clean	**5.00**	620.90	158.50	
			Clean and paint	50.00	3543.31	1340.88	
		3 - Rust Formation	Spot blast, clean, paint	**150.00**	6816.47	2681.75	
		4 - Active Corrosion	Spot blast, clean, paint	**150.00**	8620.93	4023.00	
			Replace paint system	500.00	10591.63	6704.00	
		5 - Section Loss	Rehab unit	**6000.00**	**21481.82**	**2940.41**	
			Replace unit	23000.00	102280.18	14000.00	
			Failure Cost	69000.00	165410.00	42000.00	
104	P/S Conc Box Girder	2 - Minor Cracks/Spalls	Seal Cracks & Minor Patching	**250.00**	699.90	696.78	Based on
		3 - Delams/Spalls	Clean Steel & patch (and/or seal)	**450.00**	869.42	902.00	Elem 105, 110
		4 - Analysis Warranted	Rehab Unit	9000.00	**1941.14**	**1529.00**	
			Replace Unit	**4500.00**	6492.72	3058.00	
			Failure Cost	95000.00	12278.00	9174.00	
105	R/Conc Box Girder	2 - Minor Cracks/Spalls	Seal cracks/patch	**190.00**	699.90	696.78	ITD Experts
		3 - Delams/Spalls	Clean rebar and patch	**450.00**	869.40	902.00	
		4 - Analysis Warranted	Rehab unit	**5300.00**	**1941.14**	**1529.00**	
			Replace unit	6000.00	6492.72	3058.00	repl. Cost is 2x rehab
			Failure Cost	150000.00	9000.00	9174.00	
106	Unpnt Stl Open Girder	2 - Minor Corrosion	Clean and paint	**200.00**	155.51	325.00	ITD Experts
		3 - Some Section Loss	Clean and paint	**200.00**	195.21	**487.00**	
		4 - Major Section Loss	Rehab unit	**3500.00**	1771.65	**10000.00**	
			Replace unit	10000.00	**938.88**	14000.00	
			Failure Cost	200000.00	7229.00	60000.00	
107	Paint Stl Open Girder	1 - No Corrosion	Surface clean	**2.00**	31.17	50.29	ITD Experts
		2 - Paint Distress	Surface clean	**2.00**	40.42	100.58	
			Clean and paint	20.00	112.63	425.47	
		3 - Rust Formation	Spot blast, clean, paint	**100.00**	164.24	638.21	
		4 - Active Corrosion	Spot blast, clean, paint	**100.00**	227.95	**1276.00**	
			Replace paint system	320.00	**198.16**	2127.00	
		5 - Section Loss	Rehab unit	**4000.00**	**639.76**	10000.00	
			Replace unit	15000.00	1197.41	**14000.00**	
			Failure Cost	45000.00	3500.00	42000.00	
109	P/S Conc Open Girder	2 - Minor Cracks/Spalls	Seal Cracks & Minor Patching	**170.00**	89.27	564.00	Same as 110,
		3 - Delams/Spalls	Clean Steel & patch (and/or seal)	**300.00**	203.84	902.00	but reduced
		4 - Analysis Warranted	Rehab Unit	6000.00	471.62	1127.00	repl. cost by
			Replace Unit	**3000.00**	**672.74**	**2478.60**	10%
			Failure Cost	70000.00	3000.00	9000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
110	R/Conc Open Girder	2 - Minor Cracks/Spalls	Seal Cracks & Minor Patching	**125.00**	112.50	564.00	ITD Experts
		3 - Delams/Spalls	Clean Steel & patch (and/or seal)	**300.00**	269.32	902.00	
		4 - Analysis Warranted	Rehab Unit	**3500.00**	**400.89**	**1127.00**	
			Replace Unit	4000.00	926.84	2754.00	
			Failure Cost	100000.00	2000.00	8262.00	
111	Timber Open Girder	2 - Minor Decay	Rehab and/or protect unit	**10.00**	492.13	160.00	ITD Experts
		3 - Some Strength Loss	Rehab Unit	**300.00**	984.25	160.00	
			Replace Unit	400.00	1668.31	302.00	
		4 - Major Strength Loss	Rehab Unit	3000.00	2788.71	160.00	
			Replace Unit	**400.00**	**2220.31**	**302.00**	
			Failure Cost	9000.00	5495.00	906.00	
112	Unpnt Stl Stringer	2 - Minor Corrosion	Clean and paint	**200.00**	114.83	108.00	ITD Experts
		3 - Some Section Loss	Clean and paint	**200.00**	114.83	**162.00**	
		4 - Major Section Loss	Rehab unit	**1500.00**	**426.51**	**3333.33**	
			Replace unit	4000.00	5840.44	4666.67	
			Failure Cost	70000.00	3284.00	21000.00	
113	Paint Stl Stringer	1 - No Corrosion	Surface clean	**1.00**	4.92	16.76	ITD Experts
		2 - Paint Distress	Surface clean	**1.00**	8.20	33.53	
			Clean and paint	10.00	58.23	141.82	
		3 - Rust Formation	Spot blast, clean, paint	**35.00**	186.19	283.65	
		4 - Active Corrosion	Spot blast, clean, paint	**35.00**	91.86	**425.00**	
			Replace paint system	100.00	124.67	709.00	
		5 - Section Loss	Rehab unit	**2300.00**	1301.80	**3333.33**	
			Replace unit	6000.00	**226.67**	4666.67	
			Failure Cost	18000.00	1745.00	21000.00	
115	P/S Conc Stringer	2 - Minor Cracks/Spalls	Seal Cracks & Minor Patching	**120.00**	112.50	*None*	
		3 - Delams/Spalls	Clean Steel & patch (and/or seal)	**210.00**	269.32	*In*	
		4 - Analysis Warranted	Rehab Unit	4200.00	**400.89**	*ID*	
			Replace Unit	**2100.00**	926.84	*Inventory*	
			Failure Cost	50000.00	3087.00		
116	R/Conc Stringer	2 - Minor Cracks/Spalls	Seal Cracks & Minor Patching	**90.00**	2.26	228.60	ITD Experts
		3 - Delams/Spalls	Clean Rebar & patch (and/or seal)	**210.00**	6.56	365.76	
		4 - Analysis Warranted	Rehab Unit	**2500.00**	**55.77**	**457.07**	
			Replace Unit	2800.00	173.88	1116.65	
			Failure Cost	50000.00	429.00	3349.95	

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Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
117	Timber Stringer	2 - Minor Decay	Rehab and/or protect unit	**20.00**	65.62	175.00	ITD Experts
		3 - Some Strength Loss	Rehab Unit	**300.00**	82.02	175.00	
			Replace Unit	400.00	114.83	340.00	
		4 - Major Strength Loss	Rehab Unit	**300.00**	**82.02**	**175.00**	
			Replace Unit	400.00	194.39	340.00	
			Failure Cost	6000.00	550.00	1200.00	
120	U/Stl Thru Truss/Bot	2 - Minor Corrosion	Clean and paint	**1000.00**	90.22	*None*	
		3 - Some Section Loss	Clean and paint	**1000.00**	**106.63**	*In*	
		4 - Major Section Loss	Rehab unit	17500.00	**1640.42**	*ID*	
			Replace unit	50000.00	2624.67	*Inventory*	
			Failure Cost	150000.00	12631.00		
121	P/Stl Thru Truss/Bot	1 - No Corrosion	Surface clean	**10.00**	17.45	28.00	Extrapolated
		2 - Paint Distress	Surface clean	**10.00**	29.53	56.00	See Appendix 2
			Clean and paint	100.00	95.14	236.80	
		3 - Rust Formation	Spot blast, clean, paint	**400.00**	216.54	414.93	
		4 - Active Corrosion	Spot blast, clean, paint	**400.00**	165.98	**709.90**	
			Replace paint system	640.00	449.48	1183.82	
		5 - Section Loss	Rehab unit	**8000.00**	**880.31**	**5565.65**	
			Replace unit	30000.00	2624.67	7791.90	
			Failure Cost	90000.00	6778.00	35000.00	
125	U/Stl Thru Truss/Top	2 - Minor Corrosion	Clean and paint	**1000.00**	328.08	*None*	
		3 - Some Section Loss	Clean and paint	**1000.00**	451.12	*In*	
		4 - Major Section Loss	Rehab unit	17500.00	**1215.55**	*ID*	
			Replace unit	50000.00	2952.76	*Inventory*	
			Failure Cost	150000.00	9360.00		
126	P/Stl Thru Truss/Top	1 - No Corrosion	Surface clean	**10.00**	84.22	28.00	Extrapolated
		2 - Paint Distress	Surface clean	**10.00**	95.14	56.00	See Appendix 2
			Clean and paint	100.00	682.41	236.80	
		3 - Rust Formation	Spot blast, clean, paint	**400.00**	708.20	414.93	
		4 - Active Corrosion	Spot blast, clean, paint	**400.00**	431.43	**709.90**	
			Replace paint system	640.00	570.31	1183.82	
		5 - Section Loss	Rehab unit	**8000.00**	**1429.36**	**5565.65**	
			Replace unit	30000.00	3116.80	7791.90	
			Failure Cost	90000.00	11006.00	35000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
130	Unpnt Stl Deck Truss	2 - Minor Corrosion	Clean and paint	**1000.00**	524.93	*None*	
		3 - Some Section Loss	Clean and paint	**1000.00**	574.15	*In*	
		4 - Major Section Loss	Rehab unit	17500.00	**1476.38**	*ID*	
			Replace unit	50000.00	2952.76	*Inventory*	
			Failure Cost	150000.00	11368.00		
131	Paint Stl Deck Truss	1 - No Corrosion	Surface clean	**10.00**	371.82	80.45	Extrapolated
		2 - Paint Distress	Surface clean	**10.00**	508.53	160.95	See Appendix 2
			Clean and paint	100.00	1361.55	680.80	
		3 - Rust Formation	Spot blast, clean, paint	**400.00**	1640.42	1192.90	
		4 - Active Corrosion	Spot blast, clean, paint	**400.00**	2247.38	**2040.95**	
			Replace paint system	640.00	2659.12	3403.45	
		5 - Section Loss	Rehab unit	**8000.00**	5643.04	**16000.00**	
			Replace unit	30000.00	**2952.76**	22400.00	
			Failure Cost	90000.00	22736.00	100000.00	
135	Timber Truss/Arch	2 - Minor Decay	Rehab and/or protect unit	**50.00**	656.17	*None*	
		3 - Some Strength Loss	Rehab Unit	**1500.00**	984.25	*In*	
			Replace Unit	2000.00	2296.59	*ID*	
		4 - Major Strength Loss	Rehab Unit	15000.00	**1312.34**	*Inventory*	
			Replace Unit	**2000.00**	2624.67		
			Failure Cost	45000.00	10105.00		
140	Unpnt Stl Arch	2 - Minor Corrosion	Clean and paint	**1000.00**	61.50	310.80	Extrapolated
		3 - Some Section Loss	Clean and paint	**1000.00**	1640.42	**466.20**	See Appendix 2
		4 - Major Section Loss	Rehab unit	17500.00	**1476.38**	**7304.90**	
			Replace unit	50000.00	2952.76	10227.00	
			Failure Cost	150000.00	11368.00	48000.00	
141	Paint Stl Arch	1 - No Corrosion	Surface clean	**10.00**	98.43	36.75	Extrapolated
		2 - Paint Distress	Surface clean	**10.00**	106.63	73.50	See Appendix 2
			Clean and paint	100.00	779.20	310.80	
		3 - Rust Formation	Spot blast, clean, paint	**400.00**	524.93	544.60	
		4 - Active Corrosion	Spot blast, clean, paint	**400.00**	1558.40	**931.75**	
			Replace paint system	640.00	1599.41	1553.75	
		5 - Section Loss	Rehab unit	**8000.00**	**2050.52**	**7304.90**	
			Replace unit	30000.00	2952.76	10227.00	
			Failure Cost	90000.00	15789.00	45000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
143	P/S Conc Arch	2 - Minor Cracks/Spalls	Seal Cracks & Minor Patching	**200.00**	49.21	*None*	
		3 - Delams/Spalls	Clean Steel & patch (and/or seal)	**360.00**	82.02	*In*	
		4 - Analysis Warranted	Rehab Unit	**7200.00**	**360.89**	*ID*	
			Replace Unit	3600.00	574.15	*Inventory*	
			Failure Cost	75000.00	2779.00		
144	R/Conc Arch	2 - Minor Cracks/Spalls	Seal cracks/patch	**150.00**	147.64	274.32	ITD Experts
		3 - Delams/Spalls	Clean rebar and patch	**360.00**	508.53	**438.91**	
		4 - Analysis Warranted	Rehab unit	**4200.00**	2334.84	**2334.84**	
			Replace unit	4800.00	5782.48	5782.48	
			Failure Cost	150000.00	10273.00	20000.00	
145	Other Arch	2 - Minor Deterioration	Rehab unit	**150.00**	**5782.48**	*None*	
		3 - Moderate Deterioration	Rehab unit	**360.00**	**5782.48**	*In*	
		4 - Major Deterioration	Rehab unit	**4200.00**	5782.48	*ID*	
			Replace unit	4800.00	**5782.48**	*Inventory*	
			Failure Cost	14400.00	10000.00		
146	Misc Cable Uncoated	2 - Surface Rust	Clean and coat	**150.00**	150.00	150.00	Used CA costs
		3 - Moderate Deterioration	Clean and coat	**150.00**	150.00	150.00	Note: very few in
		4 - Analysis Warranted	Rehab unit and coat	**500.00**	**500.00**	**500.00**	ID inventory
			Replace unit	1500.00	1500.00	1500.00	
			Failure Cost	30000.00	3850.00	4500.00	
147	Misc Cable Coated	2 - Surface Rust Forming	Clean and restore coating	**500.00**	**1500.00**	*None*	
		3 - Rust Prevalent	Clean and restore coating	**500.00**	**1500.00**	*In*	
		4 - Active Corrosion	Rehab unit and replace coating system	**1500.00**	1500.00	*ID*	
			Replace unit	4500.00	**1500.00**	*Inventory*	
		5 - Analysis Warranted	Rehab unit and replace coating system	**1500.00**	1500.00		
			Replace unit	4500.00	**1500.00**		
			Failure Cost	13500.00	4000.00		
151	Unpnt Stl Floor Beam	2 - Minor Corrosion	Clean and paint	**200.00**	84.48	170.20	Extrapolated
		3 - Some Section Loss	Clean and paint	**200.00**	**100.07**	**255.30**	See Appendix 2
		4 - Major Section Loss	Rehab unit	**1500.00**	1394.36	**4000.30**	
			Replace unit	4000.00	**984.25**	5600.40	
			Failure Cost	100000.00	7579.00	28000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
152	Paint Stl Floor Beam	1 - No Corrosion	Surface clean	**2.00**	27.53	17.50	Extrapolated
		2 - Paint Distress	Surface clean	**2.00**	35.01	35.00	See Appendix 2
			Clean and paint	20.00	120.28	148.00	
		3 - Rust Formation	Spot blast, clean, paint	**100.00**	184.68	259.35	
		4 - Active Corrosion	Spot blast, clean, paint	**100.00**	**152.00**	**443.70**	
			Replace paint system	320.00	204.66	739.90	
		5 - Section Loss	Rehab unit	**4000.00**	**1126.77**	**3478.50**	
			Replace unit	15000.00	2049.57	4869.95	
			Failure Cost	45000.00	8676.00	21000.00	
154	P/S Conc Floor Beam	2 - Minor Cracks/Spalls	Seal cracks/patch	**170.00**	850.00	*None*	
		3 - Delams/Spalls	Clean steel and patch (and/or seal)	**300.00**	1181.10	*In*	
		4 - Analysis Warranted	Rehab unit	**6000.00**	1656.82	*ID*	
			Replace unit	3000.00	**1710.96**	*Inventory*	
			Failure Cost	60000.00	12758.00		
155	R/Conc Floor Beam	2 - Minor Cracks/Spalls	Seal cracks/patch	**125.00**	1488.68	564.00	ITD Experts
		3 - Delams/Spalls	Clean rebar and patch	**300.00**	783.30	902.00	
		4 - Analysis Warranted	Rehab unit	**3500.00**	**1279.53**	**1051.23**	
			Replace unit	4000.00	2230.97	3754.41	
			Failure Cost	75000.00	9852.00	11263.23	
156	Timber Floor Beam	2 - Minor Decay	Rehab and/or protect unit	**10.00**	1066.27	175.00	Assumed same
		3 - Some Strength Loss	Rehab Unit	**300.00**	1312.34	175.00	as Elem 117
			Replace Unit	400.00	4939.86	340.00	Note: very few in
		4 - Major Strength Loss	Rehab Unit	3000.00	6561.68	**175.00**	ID inventory
			Replace Unit	**400.00**	**4939.86**	340.00	
			Failure Cost	9000.00	38037.00	1150.00	
160	Unpnt Stl Pin/Hanger	2 - Minor Corrosion	Clean and paint	**500.00**	683.33	*None*	
		3 - Some Section Loss	Clean and paint	**500.00**	1500.00	*In*	
		4 - Major Section Loss	Rehab unit	**25000.00**	**1750.00**	*ID*	
			Replace unit	30000.00	3000.00	*Inventory*	
			Failure Cost	700000.00	13475.00		

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
161	Paint Stl Pin/Hanger	1 - No Corrosion	Surface clean	**200.00**	390.00	390.00	Used CA costs
		2 - Paint Distress	Surface clean	**200.00**	390.00	390.00	Note: very few in
			Clean and paint	500.00	500.00	500.00	ID inventory
		3 - Rust Formation	Spot blast, clean, paint	**1000.00**	758.66	758.66	
		4 - Active Corrosion	Spot blast, clean, paint	**1000.00**	1150.00	1150.00	
			Replace paint system	1500.00	825.00	825.00	
		5 - Section Loss	Rehab unit	**25000.00**	**1350.00**	**1350.00**	
			Replace unit	30000.00	4906.10	4906.10	
			Failure Cost	150000.00	10395.00	14718.30	
201	Unpnt Stl Column	2 - Minor Corrosion	Clean and paint	**200.00**	393.32	187.50	Extrapolated
		3 - Some Section Loss	Clean and paint	**200.00**	543.75	281.25	See Appendix 2
		4 - Major Section Loss	Rehab unit	**3500.00**	**1156.40**	**1156.40**	CA data for rehab/replace
			Replace unit	10000.00	11416.66	11416.66	Note: very few in
			Failure Cost	150000.00	8904.00	34249.98	ID inventory
202	Paint Stl Column	1 - No Corrosion	Surface clean	**2.00**	83.00	22.15	Extrapolated
		2 - Paint Distress	Surface clean	**2.00**	117.00	44.30	See Appendix 2
			Clean and paint	20.00	197.86	187.50	
		3 - Rust Formation	Spot blast, clean, paint	**1000.00**	210.00	328.50	
		4 - Active Corrosion	Spot blast, clean, paint	**100.00**	**226.25**	562.00	
			Replace paint system	320.00	291.67	937.20	
		5 - Section Loss	Rehab unit	**4000.00**	**1626.55**	**1626.55**	CA data for rehab/replace
			Replace unit	15000.00	4493.75	4493.75	
			Failure Cost	45000.00	12524.00	13481.25	
204	P/S Conc Column	2 - Minor Cracks/Spalls	Seal cracks/patch	**170.00**	643.75	643.75	Used CA costs
		3 - Delams/Spalls	Clean steel and patch	**300.00**	868.75	868.75	Note: very few in
		4 - Analysis Warranted	Rehab unit	**6000.00**	**2868.75**	**2868.75**	ID inventory
			Replace unit	3000.00	9428.57	9428.57	
			Failure Cost	80000.00	22089.00	28285.71	
205	R/Conc Column	2 - Minor Cracks/Spalls	Seal cracks/patch	**125.00**	441.70	3283.46	ITD Experts
		3 - Delams/Spalls	Clean rebar and patch	**300.00**	659.38	5254.00	
		4 - Analysis Warranted	Rehab unit	**3500.00**	**3323.67**	**6753.54**	
			Replace unit	4000.00	11884.38	12000.00	
			Failure Cost	80000.00	25592.00	43000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
206	Timber Column	2 - Minor Decay	Rehab and/or protect unit	**2500.00**	410.00	160.00	Rehab costs
		3 - Some Strength Loss	Rehab Unit	**2500.00**	1143.00	160.00	from Elem 111
			Replace Unit	4000.00	2468.45	604.00	Replace costs
		4 - Major Strength Loss	Rehab Unit	**2500.00**	**1422.68**	**160.00**	2x Elem 111
			Replace Unit	4000.00	2140.00	604.00	Note: very few in
			Failure Cost	70000.00	10955.00	1812.00	ID inventory
210	R/Conc Pier Wall	2 - Minor Cracks/Spalls	Seal cracks/patch	**90.00**	1075.23	3083.00	ITD Experts
		3 - Delams/Spalls	Clean rebar and patch	**210.00**	1552.17	4933.00	
		4 - Analysis Warranted	Rehab unit	**2500.00**	**3857.05**	**9865.07**	
			Replace unit	2800.00	9742.78	25000.00	
			Failure Cost	60000.00	29699.00	75000.00	
211	Other Mtl Pier Wall	2 - Minor Deterioration	Rehab unit	**90.00**	606.96	25000.00	Assume replace
		3 - Moderate Deterioration	Rehab unit	**210.00**	738.19	25000.00	with RC
		4 - Major Deterioration	Rehab unit	**2500.00**	**1106.69**	25000.00	
			Replace unit	2800.00	2985.56	**25000.00**	Note: very few in
			Failure Cost	40000.00	8522.00	150000.00	ID inventory
215	R/Conc Abutment	2 - Minor Cracks/Spalls	Seal cracks/patch	**125.00**	330.81	1202.00	ITD Experts
		3 - Delams/Spalls	Clean rebar and patch	**300.00**	767.62	1923.00	
		4 - Analysis Warranted	Rehab unit	**3500.00**	**1700.00**	**3845.71**	
			Replace unit	4000.00	2560.17	9745.59	
			Failure Cost	80000.00	13400.00	29236.77	
216	Timber Abutment	2 - Minor Decay	Rehab and/or protect unit	**2500.00**	1367.03	9745.59	Assume replace
		3 - Some Strength Loss	Rehab Unit	**2500.00**	2594.59	9745.59	with RC
			Replace Unit	4000.00	4358.01	9745.59	Note: very few in
		4 - Major Strength Loss	Rehab Unit	**2500.00**	4055.12	9745.59	ID inventory
			Replace Unit	4000.00	**4398.69**	**9745.59**	
			Failure Cost	80000.00	31224.00	60000.00	
217	Other Mtl Abutment	2 - Minor Deterioration	Rehab unit	**125.00**	234.58	9745.59	Assume replace
		3 - Moderate Deterioration	Rehab unit	**300.00**	585.07	9745.59	with RC
		4 - Major Deterioration	Rehab unit	**3500.00**	**1777.40**	9745.59	Note: very few in
			Replace unit	4000.00	2737.53	**9745.59**	ID inventory
			Failure Cost	100000.00	13686.00	60000.00	
220	R/C Sub Pile Cap/Ftg	2 - Minor Cracks/Spalls	Seal cracks/patch	1900.00	**2737.53**	1900.00	Used OR costs
		3 - Delams/Spalls	Clean rebar and patch (and/or seal)	4500.00	**2737.53**	4500.00	Note: very few in
		4 - Analysis Warranted	Rehab unit	52500.00	2737.53	52500.00	ID inventory
			Replace unit	60000.00	**2737.53**	60000.00	
			Failure Cost	180000.00	150000.00	180000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
225	Unpnt Stl Sub Cap	2 - Rust Formation	Clean and paint	**200.00**	**2737.53**	200.00	Used OR costs
		3 - Surface Pitting	Clean and paint	**200.00**	**2737.53**	200.00	
		4 - Major Section Loss	Rehab unit	**3500.00**	2737.53	3500.00	
			Replace unit	10000.00	**2737.53**	10000.00	
			Failure Cost	30000.00	10000.00	30000.00	
226	P/S Conc Submgd Pile	2 - Minor Cracks/Spalls	Seal cracks/patch	**250.00**	**2737.53**	*None*	
		3 - Delams/Spalls	Clean steel and patch (and/or seal)	**450.00**	**2737.53**	*In*	
		4 - Analysis Warranted	Rehab unit	9000.00	2737.53	*ID*	
			Replace unit	**4500.00**	**2737.53**	*Inventory*	
			Failure Cost	27000.00	10000.00		
227	R/C Submerged Pile	2 - Minor Cracks/Spalls	Seal cracks/patch	**190.00**	**2737.53**	190.00	Used OR costs
		3 - Delams/Spalls	Clean rebar and patch (and/or seal)	**450.00**	**2737.53**	450.00	Note: very few in
		4 - Analysis Warranted	Rehab unit	**5300.00**	2737.53	5300.00	ID inventory
			Replace unit	6000.00	**2737.53**	6000.00	
			Failure Cost	18000.00	10000.00	18000.00	
228	Timber Submerged Pile	2 - Minor Decay	Rehab and/or protect unit	**40000.00**	**2737.53**	2000.00	ITD Experts
		3 - Some Strength Loss	Rehab Unit	40000.00	2737.53	10000.00	Note: very few in
			Replace Unit	**40000.00**	**2737.53**	20000.00	ID inventory
		4 - Major Strength Loss	Rehab Unit	40000.00	2737.53	10000.00	
			Replace Unit	**40000.00**	**2737.53**	20000.00	replace cost is
			Failure Cost	120000.00	10000.00	60000.00	2x rehab cost
230	Unpnt Stl Cap	2 - Rust Formation	Clean and paint	**200.00**	150.92	150.92	Used CA costs
		3 - Some Section Loss	Clean and paint	**200.00**	161.58	161.58	Note: very few in
		4 - Major Section Loss	Rehab unit	**3500.00**	**683.50**	**683.50**	ID inventory
			Replace unit	10000.00	1738.85	1738.85	
			Failure Cost	150000.00	5263.00	5216.55	
231	Paint Stl Cap	1 - No Corrosion	Surface clean	**2.00**	22.97	22.97	Used CA costs
		2 - Paint Distress	Surface clean	**2.00**	26.25	26.25	Note: very few in
			Clean and paint	20.00	98.98	98.98	ID inventory
		3 - Rust Formation	Spot blast, clean, paint	**100.00**	144.36	144.36	
		4 - Active Corrosion	Spot blast, clean, paint	**100.00**	**172.54**	**172.54**	
			Replace paint system	320.00	220.34	220.34	
		5 - Section Loss	Rehab unit	**4000.00**	3202.10	3202.10	
			Replace unit	10000.00	**1796.49**	**1796.49**	
			Failure Cost	30000.00	13833.00	19500.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
233	P/S Conc Cap	2 - Minor Cracks/Spalls	Seal cracks/patch	**170.00**	16.40	564.00	Used costs
		3 - Delams/Spalls	Clean steel and patch (and/or seal)	**300.00**	**152.56**	902.00	for Elem 234
		4 - Analysis Warranted	Rehab unit	**6000.00**	**2624.67**	**1051.23**	
			Replace unit	3000.00	7930.87	3754.41	
			Failure Cost	80000.00	20210.00	11263.23	
234	R/Conc Cap	2 - Minor Cracks/Spalls	Seal cracks/patch	**125.00**	185.56	564.00	ITD Experts
		3 - Delams/Spalls	Clean rebar and patch (and/or seal)	**300.00**	405.84	902.00	
		4 - Analysis Warranted	Rehab unit	**3500.00**	**1114.47**	**1051.23**	
			Replace unit	4000.00	1577.49	3754.41	
			Failure Cost	80000.00	7049.00	11263.23	
235	Timber Cap	2 - Minor Decay	Rehab and/or protect unit	**450.00**	672.57	672.57	Used CA costs
		3 - Some Strength Loss	Rehab Unit	450.00	639.11	639.11	Note: very few in
			Replace Unit	**450.00**	767.72	767.72	ID inventory
		4 - Major Strength Loss	Rehab Unit	450.00	**475.72**	**475.72**	
			Replace Unit	**450.00**	583.99	583.99	
			Failure Cost	12000.00	3663.00	3500.00	
240	Steel Culvert	2 - Minor Corrosion	Rehab unit	**2000.00**	328.08	126.00	www.get-a-quote.net
		3 - Moderate Corrosion	Rehab unit	**2000.00**	368.08	126.00	rehab assumes
		4 - Major Corrosion	Rehab unit	**1300.00**	**1709.32**	**126.00**	70% of replace
			Replace unit	3000.00	2545.57	180.00	
			Failure Cost	60000.00	13162.00	800.00	
241	Concrete Culvert	2 - Minor Deterioration	Rehab unit	**2000.00**	1066.27	1912.50	ITD Experts
		3 - Moderate Deterioration	Rehab unit	**2000.00**	677.82	1215.50	
		4 - Major Deterioration	Rehab unit	**1300.00**	3677.82	6596.00	
			Replace unit	5000.00	**2369.88**	**4250.00**	
			Failure Cost	60000.00	18248.00	42000.00	
242	Timber Culvert	2 - Minor Decay	Rehab Unit	**2000.00**	328.08	*None*	
		3 - Moderate Deterioration	Rehab Unit	**2000.00**	656.17	*In*	
		4 - Major Deterioration	Rehab Unit	**1300.00**	**984.25**	*ID*	
			Replace Unit	3000.00	1640.42	*Inventory*	
			Failure Cost	60000.00	7579.00		
243	Misc Culvert	2 - Minor Deterioration	Rehab unit	2000.00	322.60	1912.50	Used costs for elem 241
		3 - Moderate Deterioration	Rehab unit	2000.00	820.21	1215.50	Note: very few in
		4 - Major Deterioration	Rehab unit	1500.00	**1394.36**	6596.00	ID inventory
			Replace unit	**2000.00**	8858.27	**4250.00**	
			Failure Cost	40000.00	10737.00	42000.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
300	Strip Seal Exp Joint	2 - Minor Leakage	Patch, Reset, & Clean Joint	**150.00**	108.92	115.00	50% of replacement
		3 - Major Leakage	Replace Gland and/or Patch Concrete	**300.00**	165.12	**161.00**	70% of replacement
			Replace Joint	500.00	658.17	230.00	Mike Ebright (ITD)
			Failure Cost	30000.00	456.00	690.00	
301	Pourable Joint Seal	2 - Minor Leakage	Clean Joint & Replace Seal	**75.00**	**84.25**	150.00	M. Ebright, no header
		3 - Leakage Problems	Clean Joint, Patch Spalls, & Replace Seal	**125.00**	**243.90**	**310.00**	M. Ebright, with header
			Failure Cost	3750.00	717.00	930.00	
302	Compression Joint Seal	2 - Minor Deterioration	Patch/remove & reseal/clean joint	**80.00**	209.88	50.00	50% of replacement
		3 - Major Deterioration	Replace gland and/or patch spalls	**100.00**	**250.79**	**70.00**	70% of replacement
			Replace joint	120.00	350.00	100.00	Mike Ebright (ITD)
			Failure Cost	3600.00	1100.00	300.00	
303	Assembly Joint/Seal	2 - Minor Deterioration	Rehab unit	**1000.00**	417.09	2310.00	rehab assumes
		3 - Advanced Corrosion	Rehab unit	**1000.00**	**612.20**	**2310.00**	70% of replace
			Replace unit	2000.00	1286.91	3300.00	Mike Ebright (ITD)
			Failure Cost	70000.00	4500.00	9900.00	
304	Open Expansion Joint	2 - Minor Deterioration	Rehab unit	**50.00**	263.29	263.29	Used CA costs
		3 - Advanced Corrosion	Rehab unit	**50.00**	**579.59**	**579.59**	Note: very few in
			Replace unit	75.00	996.88	996.88	ID inventory
			Failure Cost	2000.00	1750.00	2990.64	
310	Elastomeric Bearing	2 - Minor Deterioration	Reset bearings	10000.00	933.33	933.33	Used CA costs
		3 - Major Deterioration	Reset bearings	**1000.00**	**933.33**	**933.33**	
			Replace unit and reset girders	5000.00	1055.43	1055.43	
			Failure Cost	150000.00	5000.00	4750.00	
311	Moveable Bearing	2 - Minor Deterioration	Clean & paint or reset bearings and/or rehab unit	**500.00**	713.58	713.58	Used CA costs
		3 - Advanced Corrosion	Rehab supports or bearings	**3000.00**	**895.88**	**895.88**	
			Replace unit	7500.00	1359.57	1359.57	
			Failure Cost	300000.00	3500.00	4078.71	
312	Enclosed Bearing	2 - Minor Deterioration	Rehab unit	**500.00**	1350.00	1350.00	Used CA costs
		3 - Bearing Failures	Rehab unit	**3000.00**	3733.33	3733.33	Note: very few in
			Replace unit	7500.00	**3900.00**	**3900.00**	ID inventory
			Failure Cost	225000.00	10000.00	11700.00	
313	Fixed Bearing	2 - Minor Deterioration	Clean & paint or reset bearings and/or rehab unit	**500.00**	673.97	673.97	Used CA costs
		3 - Advanced Corrosion	Rehab supports or bearings	**3000.00**	**1341.31**	**1341.31**	
			Replace unit	7500.00	1758.81	1758.81	
			Failure Cost	150000.00	4500.00	5276.43	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
314	Pot Bearing	2 - Minor Deterioration	Rehab supports or bearing devices	**3500.00**	3000.00	3000.00	Used CA costs
		3 - Advanced Corrosion	Rehab bearing devices	**5000.00**	3500.00	3500.00	Note: very few in
			Replace unit	75000.00	1808.29	**1808.29**	ID inventory
			Failure Cost	225000.00	4994.00	10500.00	
315	Disk Bearing	2 - Minor Deterioration	Rehab supports or bearing devices	**3500.00**	90.00	90.00	Used CA costs
		3 - Advanced Corrosion	Rehab bearing devices	**5000.00**	150.00	**150.00**	Note: very few in
			Replace unit	7500.00	300.00	300.00	ID inventory
			Failure Cost	225000.00	414.00	900.00	
320	P/S Conc Appr Slab	2 - Minor Cracks/Spalls	Perform mudjacking operations	20000.00	10.00	2500.00	Used costs for elem 321
		3 - Major Cracks/Spalls	Place overlay	90000.00	575.00	10836.21	
			Replace unit	120000.00	1366.50	10034.00	
		4 - Broken/Unstable	Replace unit	120000.00	**1498.32**	**10034.00**	
			Failure Cost	900000.00	11013.00	66000.00	
321	R/Conc Approach Slab	2 - Cracks/Spalls	Perform mudjacking operations	20000.00	5200.00	2500.00	ITD Experts
		3 - Major Cracks/Spalls	Place overlay	90000.00	3534.00	10836.21	
			Replace unit	90000.00	14400.00	10034.00	
		4 - Broken/Unstable	Replace unit	90000.00	14400.00	**10034.00**	
			Failure Cost	900000.00	39000.00	60000.00	
330	Metal Rail Coated	2 - Rust Formation	Clean and restore coating	300.00	43.70	43.70	Used CA for
		3 - Active Corrosion	Clean and restore coating	300.00	49.25	49.25	cleaning costs
			Replace unit	300.00	199.38	225.00	Replace w/ RC
		4 - Section Loss	Rehab unit	*N/A*	**123.23**	225.00	
			Replace unit	*N/A*	199.38	225.00	
			Failure Cost	900.00	1000.00	675.00	
331	Conc Bridge Railing	2 - Minor Cracks/Spalls	Seal cracks, minor patching	*N/A*	128.44	367.00	ITD Experts
		3 - Delam/spalls Pres	Clean rebar and patch (and/or seal)	300.00	361.32	587.00	
		4 - Analysis Warranted	Rehab unit	300.00	**180.00**	**135.00**	
			Replace unit	**275.00**	300.00	225.00	
			Failure Cost	10000.00	650.00	1761.00	
332	Timb Bridge Railing	2 - Minor Decay	Rehab and/or apply surface treatment	**30.00**	55.00	225.00	Replace w/ RC
		3 - Some Strength Loss	Replace Unit	**270.00**	**204.66**	**225.00**	Note: very few in
			Failure Cost	10000.00	650.00	675.00	ID inventory
333	Other Bridge Railing	2 - Minor Cracks/Spalls	Rehab unit	**300.00**	86.75	135.00	Used costs for elem 331
		3 - Major Deterioration	Rehab unit	**300.00**	**119.88**	**135.00**	
			Replace unit	600.00	425.92	225.00	
			Failure Cost	80000.00	450.00	675.00	

Elem. No.	Description	Condition State	Feasible Actions	OR costs	CA costs	ID costs	ID cost source
334	Metal Rail Uncoated	2 - Surface Rust Forming	Clean and coat	**210.00**	**425.92**	43.70	Replace with RC
		3 - Rust Prevalent	Clean and coat	**21.00**	425.92	49.25	cleaning costs
			Replace unit	21.00	**425.92**	225.00	from elem 330
		4 - Active Corrosion	Rehab unit	**21.00**	425.92	225.00	Note: very few in
			Replace unit	210.00	**425.92**	225.00	ID inventory
			Failure Cost	630.00	1500.00	675.00	

APPENDIX 2 - IDAHO ELEMENT UNIT COST CALCULATIONS

Cost Extrapolations for Element Unit Costs

Elements addressed in this worksheet:

- 121 - Painted Steel Thru Truss/Bottom Chord
- 126 - Painted Steel Thru Truss/Top Chord
- 131 - Painted Steel Deck Truss
- 140 - Unpainted Steel Arch
- 141 - Painted Steel Arch
- 151 - Unpainted Steel Floor Beam
- 152 - Painted Steel Floor Beam
- 201 - Unpainted Steel Column
- 202 - Painted Steel Column

Element 121

Painted Steel Thru Truss/Bottom chord

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area

$D_g := 60\ \text{in}$ *assumed depth of girder* $b_g := 18\ \text{in}$ *assumed width of girder flanges*

$D_s := 18\ \text{in}$ *assumed depth of stringer* $b_s := 7\ \text{in}$ *assumed width of stringer flanges*

$D_t := 27\ \text{in}$ *assumed depth of truss chord* $b_t := 14\ \text{in}$ *assumed width of truss chord*

$A_p(D,b) := 2\cdot D + 3\cdot b$ *surface area per meter to paint, clean, etc.*

Condition State 1: No Corrosion

Surface clean

$Cost_{c\_g} := 50.29$ *cost per meter for girder*

$Cost_{c\_s} := 16.76$ *cost per meter for stringer*

$\frac{A_p(D_g, b_g)}{A_p(D_s, b_s)} = 3.05$ $\frac{Cost_{c\_g}}{Cost_{c\_s}} = 3$

$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 27.75$ *based on girder cost*

$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 28.23$ *based on stringer cost*

$Cost_{c\_t} := 28.00$ *average value*

Condition State 2: Paint Distress

Surface clean

$Cost_{c\_g} := 100.58$ *cost per meter for girder*

$Cost_{c\_s} := 33.53$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 55.49$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 56.47$$ *based on stringer cost*

$Cost_{c\_t} := 56.00$ *average value*

Clean & paint

$Cost_{cp\_g} := 425.47$ *cost per meter for girder*

$Cost_{cp\_s} := 141.82$ *cost per meter for stringer*

$$Cost_{cp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 234.74$$ *based on girder cost*

$$Cost_{cp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 238.85$$ *based on stringer cost*

$Cost_{c\_t} := 236.80$ *average value*

Condition State 3: Rust Formation

Spot blast, clean, & paint

$Cost_{bcp\_g} := 638.21$ *cost per meter for girder*

$Cost_{bcp\_s} := 283.65$ *cost per meter for stringer*

$$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 352.12$$ *based on girder cost*

$$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 477.73$$ *based on stringer cost*

$Cost_{bcp\_t} := 414.93$ *average value*

Condition State 4: Active Corrosion

Spot blast, clean, & paint

$Cost_{bcp\_g} := 1276.00$ *cost per meter for girder*

$Cost_{bcp\_s} := 425.00$ *cost per meter for stringer*

$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 704$ *based on girder cost*

$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 715.79$ *based on stringer cost*

$Cost_{bcp\_t} := 709.90$ *average value*

Replace paint system

$Cost_{rps\_g} := 2127.00$ *cost per meter for girder*

$Cost_{rps\_s} := 709.00$ *cost per meter for stringer*

$Cost_{rps\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 1173.52$ *based on girder cost*

$Cost_{rps\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 1194.11$ *based on stringer cost*

$Cost_{rps\_t} := 1183.82$ *average value*

Condition State 5: Section Loss

Rehab unit

$Cost_{rhb\_g} := 10000$ *cost per meter for girder*

$Cost_{rhb\_s} := 3333.33$ *cost per meter for stringer*

$Cost_{rhb\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 5517.24$ *based on girder cost*

$Cost_{rhb\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 5614.03$ *based on stringer cost*

$Cost_{rhb\_t} := 5565.65$ *average value*

Replace unit

$Cost_{rpl\_g} := 14000$ *cost per meter for girder*

$Cost_{rpl\_s} := 4666.67$ *cost per meter for stringer*

$$Cost_{rpl\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 7724.14$$ *based on girder cost*

$$Cost_{rpl\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 7859.65$$ *based on stringer cost*

$Cost_{rpl\_t} := 7791.90$ *average value*

Element 126

Painted Steel Thru Truss/Top chord

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 27\ \text{in}$ *assumed depth of truss chord* $b_t := 14\ \text{in}$ *assumed width of truss chord*

Condition State 1: No Corrosion

Surface clean

$Cost_{c\_g} := 50.29$ *cost per meter for girder*

$Cost_{c\_s} := 16.76$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 27.75$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 28.23$$ *based on stringer cost*

$Cost_{c\_t} := 28.00$ *average value*

Condition State 2: Paint Distress

Surface clean

$Cost_{c\_g} := 100.58$ *cost per meter for girder*

$Cost_{c\_s} := 33.53$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 55.49$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 56.47$$ *based on stringer cost*

$Cost_{c\_t} := 56.00$ *average value*

Clean & paint

$Cost_{cp\_g} := 425.47$ *cost per meter for girder*

$Cost_{cp\_s} := 141.82$ *cost per meter for stringer*

$Cost_{cp\_g} \cdot \dfrac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 234.74$ *based on girder cost*

$Cost_{cp\_s} \cdot \dfrac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 238.85$ *based on stringer cost*

$Cost_{c\_t} := 236.80$ *average value*

Condition State 3: Rust Formation

Spot blast, clean, & paint

$Cost_{bcp\_g} := 638.21$ *cost per meter for girder*

$Cost_{bcp\_s} := 283.65$ *cost per meter for stringer*

$Cost_{bcp\_g} \cdot \dfrac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 352.12$ *based on girder cost*

$Cost_{bcp\_s} \cdot \dfrac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 477.73$ *based on stringer cost*

$Cost_{bcp\_t} := 414.93$ *average value*

Condition State 4: Active Corrosion

Spot blast, clean, & paint

$Cost_{bcp\_g} := 1276.00$ *cost per meter for girder*

$Cost_{bcp\_s} := 425.00$ *cost per meter for stringer*

$Cost_{bcp\_g} \cdot \dfrac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 704$ *based on girder cost*

$Cost_{bcp\_s} \cdot \dfrac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 715.79$ *based on stringer cost*

$Cost_{bcp\_t} := 709.90$ *average value*

Replace paint system

$Cost_{rps\_g} := 2127.00$ *cost per meter for girder*

$Cost_{rps\_s} := 709.00$ *cost per meter for stringer*

$$Cost_{rps\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 1173.52$$ *based on girder cost*

$$Cost_{rps\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 1194.11$$ *based on stringer cost*

$Cost_{rps\_t} := 1183.82$ *average value*

Condition State 5: Section Loss

Rehab unit

$Cost_{rhb\_g} := 10000$ *cost per meter for girder*

$Cost_{rhb\_s} := 3333.33$ *cost per meter for stringer*

$$Cost_{rhb\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 5517.24$$ *based on girder cost*

$$Cost_{rhb\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 5614.03$$ *based on stringer cost*

$Cost_{rhb\_t} := 5565.65$ *average value*

Replace unit

$Cost_{rpl\_g} := 14000$ *cost per meter for girder*

$Cost_{rpl\_s} := 4666.67$ *cost per meter for stringer*

$$Cost_{rpl\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 7724.14$$ *based on girder cost*

$$Cost_{rpl\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 7859.65$$ *based on stringer cost*

$Cost_{rpl\_t} := 7791.90$ *average value*

Element 131

Painted Steel Deck Truss

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 4 \cdot 18\ \text{in}$ *assumed depth of truss chord; four members*

$b_t := 4 \cdot 11\ \text{in}$ *assumed width of truss chord; four members*

Condition State 1: No Corrosion

Surface clean

$Cost_{c\_g} := 50.29$ *cost per meter for girder*

$Cost_{c\_s} := 16.76$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 79.77$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 81.15$$ *based on stringer cost*

$Cost_{c\_t} := 80.45$ *average value*

Condition State 2: Paint Distress

Surface clean

$Cost_{c\_g} := 100.58$ *cost per meter for girder*

$Cost_{c\_s} := 33.53$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 159.54$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 162.36$$ *based on stringer cost*

$Cost_{c\_t} := 160.95$ *average value*

Clean & paint

$Cost_{cp\_g} := 425.47$ *cost per meter for girder*

$Cost_{cp\_s} := 141.82$ *cost per meter for stringer*

$$Cost_{cp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 674.88$$ *based on girder cost*

$$Cost_{cp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 686.71$$ *based on stringer cost*

$Cost_{c\_t} := 680.80$ *average value*

Condition State 3: Rust Formation

Spot blast, clean, & paint

$Cost_{bcp\_g} := 638.21$ *cost per meter for girder*

$Cost_{bcp\_s} := 283.65$ *cost per meter for stringer*

$$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 1012.33$$ *based on girder cost*

$$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 1373.46$$ *based on stringer cost*

$Cost_{bcp\_t} := 1192.90$ *average value*

Condition State 4: Active Corrosion

Spot blast, clean, & paint

$Cost_{bcp\_g} := 1276.00$ *cost per meter for girder*

$Cost_{bcp\_s} := 425.00$ *cost per meter for stringer*

$$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 2024$$ *based on girder cost*

$$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 2057.89$$ *based on stringer cost*

$Cost_{bcp\_t} := 2040.95$ *average value*

Replace paint system

$Cost_{rps\_g} := 2127.00$ *cost per meter for girder*

$Cost_{rps\_s} := 709.00$ *cost per meter for stringer*

$$Cost_{rps\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 3373.86$$ *based on girder cost*

$$Cost_{rps\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 3433.05$$ *based on stringer cost*

$Cost_{rps\_t} := 3403.45$ *average value*

Condition State 5: Section Loss

Rehab unit

$Cost_{rhb\_g} := 10000$ *cost per meter for girder*

$Cost_{rhb\_s} := 3333.33$ *cost per meter for stringer*

$Cost_{rhb\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 15862.07$ *based on girder cost*

$Cost_{rhb\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 16140.33$ *based on stringer cost*

$Cost_{rhb\_t} := 16000$ *average value*

Replace unit

$Cost_{rpl\_g} := 14000$ *cost per meter for girder*

$Cost_{rpl\_s} := 4666.67$ *cost per meter for stringer*

$Cost_{rpl\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 22206.9$ *based on girder cost*

$Cost_{rpl\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 22596.51$ *based on stringer cost*

$Cost_{rpl\_t} := 22400$ *average value*

Element 140
Unpainted Steel Arch

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 36 \text{ in}$ *assumed depth of arch member* $b_t := 18 \text{ in}$ *assumed width of arch member*

Condition State 2: Minor Corrosion

Clean & paint

$Cost_{c\_g} := 425.47$ *cost per meter for girder*

$Cost_{c\_s} := 141.82$ *cost per meter for stringer*

$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 308.1$ *based on girder cost*

$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 313.5$ *based on stringer cost*

$Cost_{c\_t} := 310.80$ *average value*

Condition State 3: Some Section Loss

Clean & paint

Increase costs from Condition State 2 by 50%

$1.5 \cdot Cost_{c\_t} = 466.20$

Condition State 4: Major Section Loss

Rehab unit

$Cost_{rhb\_g} := 10000$ *cost per meter for girder*

$Cost_{rhb\_s} := 3333.33$ *cost per meter for stringer*

$Cost_{rhb\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 7241.38$ *based on girder cost*

$Cost_{rhb\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 7368.41$ *based on stringer cost*

$Cost_{rhb\_t} := 7304.90$ *average value*

Replace unit

$\mathrm{Cost}_{rpl\_g} := 14000$ *cost per meter for girder*

$\mathrm{Cost}_{rpl\_s} := 4666.67$ *cost per meter for stringer*

$\mathrm{Cost}_{rpl\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 10137.93$ *based on girder cost*

$\mathrm{Cost}_{rpl\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 10315.8$ *based on stringer cost*

$\mathrm{Cost}_{rpl\_t} := 10227$ *average value*

Element 141

Painted Steel Arch

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 36\ \text{in}$ *assumed depth of arch member* $b_t := 18\ \text{in}$ *assumed width of arch member*

Condition State 1: No Corrosion

Surface clean

$Cost_{c\_g} := 50.29$ *cost per meter for girder*

$Cost_{c\_s} := 16.76$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 36.42$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 37.05$$ *based on stringer cost*

$Cost_{c\_t} := 36.75$ *average value*

Condition State 2: Paint Distress

Surface clean

$Cost_{c\_g} := 100.58$ *cost per meter for girder*

$Cost_{c\_s} := 33.53$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 72.83$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 74.12$$ *based on stringer cost*

$Cost_{c\_t} := 73.50$ *average value*

Clean & paint

$Cost_{cp\_g} := 425.47$ *cost per meter for girder*

$Cost_{cp\_s} := 141.82$ *cost per meter for stringer*

$$Cost_{cp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 308.1$$ *based on girder cost*

$$Cost_{cp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 313.5$$ *based on stringer cost*

$Cost_{c\_t} := 310.80$ *average value*

Condition State 3: Rust Formation

Spot blast, clean, & paint

$Cost_{bcp\_g} := 638.21$ *cost per meter for girder*

$Cost_{bcp\_s} := 283.65$ *cost per meter for stringer*

$$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 462.15$$ *based on girder cost*

$$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 627.02$$ *based on stringer cost*

$Cost_{bcp\_t} := 544.60$ *average value*

Condition State 4: Active Corrosion

Spot blast, clean, & paint

$Cost_{bcp\_g} := 1276.00$ *cost per meter for girder*

$Cost_{bcp\_s} := 425.00$ *cost per meter for stringer*

$$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 924$$ *based on girder cost*

$$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 939.47$$ *based on stringer cost*

$Cost_{bcp\_t} := 931.75$ *average value*

Replace paint system

$Cost_{rps\_g} := 2127.00$ *cost per meter for girder*

$Cost_{rps\_s} := 709.00$ *cost per meter for stringer*

$$Cost_{rps\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 1540.24$$ *based on girder cost*

$$Cost_{rps\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 1567.26$$ *based on stringer cost*

$Cost_{rps\_t} := 1553.75$ *average value*

Condition State 5: Section Loss

Rehab unit

$Cost_{rhb\_g} := 10000$ *cost per meter for girder*

$Cost_{rhb\_s} := 3333.33$ *cost per meter for stringer*

$Cost_{rhb\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 7241.38$ *based on girder cost*

$Cost_{rhb\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 7368.41$ *based on stringer cost*

$Cost_{rhb\_t} := 7304.90$ *average value*

Replace unit

$Cost_{rpl\_g} := 14000$ *cost per meter for girder*

$Cost_{rpl\_s} := 4666.67$ *cost per meter for stringer*

$Cost_{rpl\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 10137.93$ *based on girder cost*

$Cost_{rpl\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 10315.8$ *based on stringer cost*

$Cost_{rpl\_t} := 10227$ *average value*

Element 151

Unpainted Steel Floor Beam

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 18\ \text{in}$ *assumed depth of floor beam* $b_t := 11\ \text{in}$ *assumed width of floor beam*

Condition State 2: Minor Corrosion

Clean & paint

$Cost_{c\_g} := 425.47$ *cost per meter for girder*

$Cost_{c\_s} := 141.82$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 168.72$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 171.68$$ *based on stringer cost*

$Cost_{c\_t} := 170.20$ *average value*

Condition State 3: Some Section Loss

Clean & paint

Increase costs from Condition State 2 by 50%

$1.5 \cdot Cost_{c\_t} = 255.30$

Condition State 4: Major Section Loss

Rehab unit

$Cost_{rhb\_g} := 10000$ *cost per meter for girder*

$Cost_{rhb\_s} := 3333.33$ *cost per meter for stringer*

$$Cost_{rhb\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 3965.52$$ *based on girder cost*

$$Cost_{rhb\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 4035.08$$ *based on stringer cost*

$Cost_{rhb\_t} := 4000.30$ *average value*

Replace unit

$Cost_{rpl\_g} := 14000$ *cost per meter for girder*

$Cost_{rpl\_s} := 4666.67$ *cost per meter for stringer*

$$Cost_{rpl\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 5551.72$$ *based on girder cost*

$$Cost_{rpl\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 5649.13$$ *based on stringer cost*

$Cost_{rpl\_t} := 5600.40$ *average value*

Element 152

Painted Steel Floor Beam

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 12\ \text{in}$ *assumed depth of floor beam* $b_t := 12\ \text{in}$ *assumed width of floor beam*

Condition State 1: No Corrosion

Surface clean

$Cost_{c\_g} := 50.29$ *cost per meter for girder*

$Cost_{c\_s} := 16.76$ *cost per meter for stringer*

$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 17.34$ *based on girder cost*

$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 17.64$ *based on stringer cost*

$Cost_{c\_t} := 17.50$ *average value*

Condition State 2: Paint Distress

Surface clean

$Cost_{c\_g} := 100.58$ *cost per meter for girder*

$Cost_{c\_s} := 33.53$ *cost per meter for stringer*

$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 34.68$ *based on girder cost*

$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 35.29$ *based on stringer cost*

$Cost_{c\_t} := 35.00$ *average value*

Clean & paint

$Cost_{cp\_g} := 425.47$ *cost per meter for girder*

$Cost_{cp\_s} := 141.82$ *cost per meter for stringer*

$Cost_{cp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 146.71$ *based on girder cost*

$Cost_{cp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 149.28$ *based on stringer cost*

$Cost_{c\_t} := 148.00$ *average value*

Condition State 3: Rust Formation

Spot blast, clean, & paint

$Cost_{bcp\_g} := 638.21$ *cost per meter for girder*

$Cost_{bcp\_s} := 283.65$ *cost per meter for stringer*

$$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 220.07$$ *based on girder cost*

$$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 298.58$$ *based on stringer cost*

$Cost_{bcp\_t} := 259.35$ *average value*

Condition State 4: Active Corrosion

Spot blast, clean, & paint

$Cost_{bcp\_g} := 1276.00$ *cost per meter for girder*

$Cost_{bcp\_s} := 425.00$ *cost per meter for stringer*

$$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 440$$ *based on girder cost*

$$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 447.37$$ *based on stringer cost*

$Cost_{bcp\_t} := 443.70$ *average value*

Replace paint system

$Cost_{rps\_g} := 2127.00$ *cost per meter for girder*

$Cost_{rps\_s} := 709.00$ *cost per meter for stringer*

$$Cost_{rps\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 733.45$$ *based on girder cost*

$$Cost_{rps\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 746.32$$ *based on stringer cost*

$Cost_{rps\_t} := 739.90$ *average value*

Condition State 5: Section Loss

Rehab unit

$Cost_{rhb\_g} := 10000$ *cost per meter for girder*

$Cost_{rhb\_s} := 3333.33$ *cost per meter for stringer*

$$Cost_{rhb\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 3448.28$$ *based on girder cost*

$$Cost_{rhb\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 3508.77$$ *based on stringer cost*

$Cost_{rhb\_t} := 3478.50$ *average value*

Replace unit

$Cost_{rpl\_g} := 14000$ *cost per meter for girder*

$Cost_{rpl\_s} := 4666.67$ *cost per meter for stringer*

$$Cost_{rpl\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 4827.59$$ *based on girder cost*

$$Cost_{rpl\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 4912.28$$ *based on stringer cost*

$Cost_{rpl\_t} := 4869.95$ *average value*

Element 201

Unpainted Steel Column

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 14\ \text{in}$ *assumed depth of column* $b_t := 16\ \text{in}$ *assumed width of column*

Condition State 2: Minor Corrosion

Clean & paint

$Cost_{c\_g} := 425.47$ *cost per meter for girder*

$Cost_{c\_s} := 141.82$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 185.84$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 189.09$$ *based on stringer cost*

$Cost_{c\_t} := 187.50$ *average value*

Condition State 3: Some Section Loss

Clean & paint

Increase costs from Condition State 2 by 50%

$1.5 \cdot Cost_{c\_t} = 281.25$

CA data used for rehabilitation/replacement costs.

Element 202

Painted Steel Column

Costs for this element will be scaled from the costs for elements 107 (painted steel girder) & 113 (painted steel stringer) based on surface area.

$D_t := 14\ \text{in}$ *assumed depth of column* $b_t := 16\ \text{in}$ *assumed width of column*

Condition State 1: No Corrosion

Surface clean

$Cost_{c\_g} := 50.29$ *cost per meter for girder*

$Cost_{c\_s} := 16.76$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 21.97$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 22.35$$ *based on stringer cost*

$Cost_{c\_t} := 22.15$ *average value*

Condition State 2: Paint Distress

Surface clean

$Cost_{c\_g} := 100.58$ *cost per meter for girder*

$Cost_{c\_s} := 33.53$ *cost per meter for stringer*

$$Cost_{c\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 43.93$$ *based on girder cost*

$$Cost_{c\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 44.71$$ *based on stringer cost*

$Cost_{c\_t} := 44.30$ *average value*

Clean & paint

$Cost_{cp\_g} := 425.47$ *cost per meter for girder*

$Cost_{cp\_s} := 141.82$ *cost per meter for stringer*

$$Cost_{cp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 185.84$$ *based on girder cost*

$$Cost_{cp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 189.09$$ *based on stringer cost*

$Cost_{c\_t} := 187.50$ *average value*

Condition State 3: Rust Formation

Spot blast, clean, & paint

$Cost_{bcp\_g} := 638.21$ *cost per meter for girder*

$Cost_{bcp\_s} := 283.65$ *cost per meter for stringer*

$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 278.76$ *based on girder cost*

$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 378.2$ *based on stringer cost*

$Cost_{bcp\_t} := 328.50$ *average value*

Condition State 4: Active Corrosion

Spot blast, clean, & paint

$Cost_{bcp\_g} := 1276.00$ *cost per meter for girder*

$Cost_{bcp\_s} := 425.00$ *cost per meter for stringer*

$Cost_{bcp\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 557.33$ *based on girder cost*

$Cost_{bcp\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 566.67$ *based on stringer cost*

$Cost_{bcp\_t} := 562.00$ *average value*

Replace paint system

$Cost_{rps\_g} := 2127.00$ *cost per meter for girder*

$Cost_{rps\_s} := 709.00$ *cost per meter for stringer*

$Cost_{rps\_g} \cdot \frac{A_p(D_t, b_t)}{A_p(D_g, b_g)} = 929.03$ *based on girder cost*

$Cost_{rps\_s} \cdot \frac{A_p(D_t, b_t)}{A_p(D_s, b_s)} = 945.33$ *based on stringer cost*

$Cost_{rps\_t} := 937.20$ *average value*

CA data used for rehabilitation/replacement costs.

APPENDIX 3 - SCENARIO REPORTS

YourState Department of Transportation

Bureau of Bridges and Structures
Bridge Maintenance

Scenario Specification Report

QZ #1 Large Budget

Overview

Last Modified: 11/8/1999 15:44:24

By: Pontis - Pontis Pontis

Scenario Notes:

This scenario is #1 on my list of scenarios. It has a very large budget (an attempt at an unlimited budget) to see how much is spent on maintenance in the later years of the scenario.

Simulation Time Frame

First Sim. Year: 2004

First Proj. Year: 2004

Sim. Duration: 25 years

Simulation Parameters

Current Functional Needs Only: ☐

Current MR&R Needs Only: ☐

MR&R Projects Only: ☐

Prohibit Replacements: ☐

Optimal Only : ☐

Optimal User Only ☐

Replacement Critical Cutoff: 75 %

Minimum Project Cost: 5000

Deferment Years: 1

Improvement Standards

00 - Default Rev. Date 03/14/95

Policy Notes:

Improvement Costs:

00 - Default Cost Set Rev. Date 02/06/95

Index 1.00

Imp. Cost Notes:

Discount Rate

.9525

Improvement Model

00 Default Improvement Set **Rev. Date** 03/27/97

Default Improvement Set

Critical ADT for Raising:	50
Critical Bypass Length for Raising:	8
Critical ADT for Replacement:	50
Critical Bypass Length for Replacement:	8
Minimum Threshold for Strength Detours Model:	2.300
Maximum Threshold for Strength Detours Model:	41.000
Detour Speed Factor:	0.80

PROG012_Scenario_Report

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YourState Department of Transportation

Bureau of Bridges and Structures
Bridge Maintenance

Scenario Specification Report

Budget Levels

FZ Unlimited Budget **Rev. Date** 08/12/98

Budget Notes:

Budget to accompany the #1 scenario

Progyear	Budget	Progyear	Budget
2004	200,000,000	2005	200,000,000
2006	200,000,000	2007	200,000,000
2008	200,000,000	2009	200,000,000
2010	200,000,000	2011	200,000,000
2012	200,000,000	2013	200,000,000
2014	200,000,000	2015	200,000,000
2016	200,000,000	2017	200,000,000
2018	200,000,000	2019	200,000,000
2020	200,000,000	2021	200,000,000
2022	200,000,000	2023	200,000,000
2024	200,000,000	2025	200,000,000
2026	200,000,000	2027	200,000,000
2028	200,000,000		

User Cost and Policy Input

(Shown only for District 1 and ADT Class 3)

Functional Class	Unit Cost of Replacement	Replacement Swell Factor	Detour Cost per Hour	Detour Cost per Km	Average Cost per Accident
01 Rural Interstate	860.00	1.200	19.34	0.25	37,600
02 Rural Other Princ	860.00	1.200	19.34	0.25	37,600
06 Rural Minor Arterial	860.00	1.200	19.34	0.25	37,600
07 Rural Mjr Collector	860.00	1.200	19.34	0.25	37,600
08 Rural min Collector	860.00	1.200	19.34	0.25	37,600
09 Rural Local	860.00	1.200	19.34	0.25	37,600
11 Urban Interstate	860.00	1.200	19.34	0.25	12,600
12 Urban Fwy/Expwy	860.00	1.200	19.34	0.25	12,600
14 Urban Other Princ	860.00	1.200	19.34	0.25	12,600
16 Urban Minor Arterial	860.00	1.200	19.34	0.25	12,600
17 Urban Collector	860.00	1.200	19.34	0.25	12,600
19 Urban Local	860.00	1.200	19.34	0.25	12,600

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YourState Department of Transportation

Bureau of Bridges and Structures
Bridge Maintenance

Scenario Specification Report

Agency Preservation Policy

Policy Set: Default Agency Pol Set

Rule	Priority	Description
1	1	If Section Loss SmFlag has >= 100% in State 5 or worse, then for Section Loss SmFlag do actions [S1] Do Nothing, [S2] Do Nothing, [S3] Do Nothing, [S4] Do Nothing, and [S5] Do Nothing

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YourState Department of Transportation

Bureau of Bridges and Structures
Bridge Maintenance

Scenario Specification Report

AX #2 Budget Analysis

Overview

Last Modified: 11/8/1999 15:44:24

By: Pontis - Pontis Pontis

Scenario Notes:

This scenario is #2 on my list of scenarios. Compare to Scenario #2 with CA & OR costs. This will also be compared to Scenario #3 to examine the effects of rules.

Simulation Time Frame

First Sim. Year: 2004

First Proj. Year: 2004

Sim. Duration: 5 years

Simulation Parameters

Current Functional Needs Only: ☐

Current MR&R Needs Only: ☐

MR&R Projects Only: ☐

Prohibit Replacements: ☐

Optimal Only : ☐

Optimal User Only ☐

Replacement Critical Cutoff: 75 %

Minimum Project Cost: 5000

Deferment Years: 5

Improvement Standards

00 - Default Rev. Date 03/14/95

Policy Notes:

Improvement Costs:

00 - Default Cost Set Rev. Date 02/06/95

Index 1.00

Imp. Cost Notes:

Discount Rate

.9525

Improvement Model

00 Default Improvement Set **Rev. Date** 03/27/97

Default Improvement Set

Critical ADT for Raising:	50
Critical Bypass Length for Raising:	8
Critical ADT for Replacement:	50
Critical Bypass Length for Replacement:	8
Minimum Threshold for Strength Detours Model:	2.300
Maximum Threshold for Strength Detours Model:	41.000
Detour Speed Factor:	0.80

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YourState Department of Transportation

Bureau of Bridges and Structures
Bridge Maintenance

Scenario Specification Report

Budget Levels

MF Ten Million **Rev. Date** 08/12/98

Budget Notes:

Progyear	Budget	Progyear	Budget
2004	10,000,000	2005	10,000,000
2006	10,000,000	2007	10,000,000
2008	10,000,000		

User Cost and Policy Input *(Shown only for District 1 and ADT Class 3)*

Functional Class	Unit Cost of Replacement	Replacement Swell Factor	Detour Cost per Hour	Detour Cost per Km	Average Cost per Accident
01 Rural Interstate	860.00	1.200	19.34	0.25	37,600
02 Rural Other Princ	860.00	1.200	19.34	0.25	37,600
06 Rural Minor Arterial	860.00	1.200	19.34	0.25	37,600
07 Rural Mjr Collector	860.00	1.200	19.34	0.25	37,600
08 Rural min Collector	860.00	1.200	19.34	0.25	37,600
09 Rural Local	860.00	1.200	19.34	0.25	37,600
11 Urban Interstate	860.00	1.200	19.34	0.25	12,600
12 Urban Fwy/Expwy	860.00	1.200	19.34	0.25	12,600
14 Urban Other Princ	860.00	1.200	19.34	0.25	12,600
16 Urban Minor Arterial	860.00	1.200	19.34	0.25	12,600
17 Urban Collector	860.00	1.200	19.34	0.25	12,600
19 Urban Local	860.00	1.200	19.34	0.25	12,600

Agency Preservation Policy

Policy Set: Default Agency Pol Set

Rule	Priority	Description
1	1	If Section Loss SmFlag has >= 100% in State 5 or worse, then for Section Loss SmFlag do actions [S1] Do Nothing, [S2] Do Nothing, [S3] Do Nothing, [S4] Do Nothing, and [S5] Do Nothing

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YourState Department of Transportation

Bureau of Bridges and Structures
Bridge Maintenance

Scenario Specification Report

AV #3 Rule Analysis

Overview

Last Modified: 11/8/1999 15:44:24 By: Pontis - Pontis Pontis

Scenario Notes:

This scenario is #3 on my list of scenarios. It will be compared with Scenario #2 to determine the effect of rules on the scenario outcome.

Simulation Time Frame

First Sim. Year: 2004

First Proj. Year: 2004

Sim. Duration: 5 years

Simulation Parameters

Current Functional Needs Only: ☐

Current MR&R Needs Only: ☐

MR&R Projects Only: ☐

Prohibit Replacements: ☐

Optimal Only : ☐

Optimal User Only ☐

Replacement Critical Cutoff: 75 %

Minimum Project Cost: 5000

Deferment Years: 5

Improvement Standards

00 - Default Rev. Date 03/14/95

Policy Notes:

Improvement Costs:

00 - Default Cost Set Rev. Date 02/06/95

Index 1.00

Imp. Cost Notes:

Discount Rate

.9525

Improvement Model

00 Default Improvement Set **Rev. Date** 03/27/97

Default Improvement Set

Critical ADT for Raising:	50
Critical Bypass Length for Raising:	8
Critical ADT for Replacement:	50
Critical Bypass Length for Replacement:	8
Minimum Threshold for Strength Detours Model:	2.300
Maximum Threshold for Strength Detours Model:	41.000
Detour Speed Factor:	0.80

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YourState Department of Transportation

Bureau of Bridges and Structures
Bridge Maintenance

Scenario Specification Report

Budget Levels

GJ Five Million **Rev. Date** 08/12/98

Budget Notes:

Progyear	Budget	Progyear	Budget
2004	5,000,000	2005	5,000,000
2006	5,000,000	2007	5,000,000
2008	5,000,000	2009	5,000,000
2010	5,000,000	2011	5,000,000
2012	5,000,000	2013	5,000,000

User Cost and Policy Input *(Shown only for District 1 and ADT Class 3)*

Functional Class	Unit Cost of Replacement	Replacement Swell Factor	Detour Cost per Hour	Detour Cost per Km	Average Cost per Accident
01 Rural Interstate	860.00	1.200	19.34	0.25	37,600
02 Rural Other Princ	860.00	1.200	19.34	0.25	37,600
06 Rural Minor Arterial	860.00	1.200	19.34	0.25	37,600
07 Rural Mjr Collector	860.00	1.200	19.34	0.25	37,600
08 Rural min Collector	860.00	1.200	19.34	0.25	37,600
09 Rural Local	860.00	1.200	19.34	0.25	37,600
11 Urban Interstate	860.00	1.200	19.34	0.25	12,600
12 Urban Fwy/Expwy	860.00	1.200	19.34	0.25	12,600
14 Urban Other Princ	860.00	1.200	19.34	0.25	12,600
16 Urban Minor Arterial	860.00	1.200	19.34	0.25	12,600
17 Urban Collector	860.00	1.200	19.34	0.25	12,600
19 Urban Local	860.00	1.200	19.34	0.25	12,600

Agency Preservation Policy

Policy Set: Default Agency Pol Set

Rule	Priority	Description
1	1	If Section Loss SmFlag has >= 100% in State 5 or worse, then for Section Loss SmFlag do actions [S1] Do Nothing, [S2] Do Nothing, [S3] Do Nothing, [S4] Do Nothing, and [S5] Do Nothing

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APPENDIX 4 - DEFAULT SIMULATION RULES

DEFAULT SCOPING RULES

1.) If REPLACE ELEMENT is done to DECKS/SLABS, then also do REPLACE ELEMENT to JOINTS.

2.) If REPLACE ELEMENT is done to DECKS/SLABS, then also do REPLACE ELEMENT to RAILINGS/BARRIERS.

3.) If ELEMENT REHABILITATION is done to DECKS/SLABS, then also do REPLACE ELEMENT to STRIP SEAL EXP JOINT.

4.) If ELEMENT REHABILITAT1ON is done to DECKS/SLABS, then also do REPLACE ELEMENT to COMPRESSN.

5.) If ELEMENT REHABILITATION is done to DECKS/SLABS, then also do REPLACE ELEMENT to OPEN EXPANSION JOINTS.

6.) If ELEMENT REHABILITATION is done to DECKS/SLABS, then also do REPLACE ELEMENT to POURABLE JOINT SEAL.

7.) If ELEMENT REHABILITATION is done to DECKS/SLABS, then also do REPLACE ELEMENT to ASSEMBLY JOINT/SEAL.

DEFAULT MAJOR REHAB RULES

1.) If Health Index for BRIDGE is < 70%, then do REPLACE STRUCTURE to BRIDGE.

DEFAULT PAINTING RULES

1.) Paint all when PCI is <= 50%.

2.) Paint S2-S5 when PCI is <= 75%.