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Element Unit and Failure Costs and Functional Improvement Costs for Use in the Mn/DOT Pontis Bridge Management System

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16. Abstract (Limit: 200 words)

Unit costs for bridge preservation maintenance, improvement actions and user benefits are required for network-level analysis in the Pontis bridge management system (BMS). This report describes the process and results for establishing these values for Mn/DOT. Also provided were the transition probabilities for modeling deterioration for the bridge elements.

Unit costs for preservation action performed by Mn/DOT maintenance crews were acquired from the Mn/DOT Estimating Unit. Work breakdown for maintenance actions and standard element definitions for converting cost units were developed as needed. Unit costs for preservation actions performed by contract were derived from cost data in the Mn/DOT WMS warehouse through the Mn/DOT Bridge Maintenance table. Work codes in WMS were mapped to maintenance actions in Pontis.

Estimates for bridge widening, raising, strengthening, and replacement costs were defined as were accident cost, vehicle operating cost, and travel time cost for calculating user-cost savings of functional improvement projects.

A Windows program was developed to calculate weighted average unit cost for maintenance actions using data available in Mn/DOT's WMS warehouse. The program can be used to review maintenance costs and for on-going update of the Mn/DOT Pontis database.

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Final Report

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Executive Summary

Mn/DOT is implementing Pontis Bridge Maintenance System (BMS) to develop preservation policies and improvement programs for network level bridge management. The use of Pontis requires the development of unit cost factors of sufficient accuracy and precision for credible budgeting and program planning. Prior to this project, the Mn/DOT Pontis BMS did not have representative unit costs and other parameters for preservation and improvement modeling. The primary objectives of this project were to (1) determine Mn/DOT specific costs for preservation actions for each element and condition state, (2) determine the Mn/DOT specific unit costs for functional improvements and the parameters used to calculate user-cost savings, and (3) develop an integrated data method for updating Pontis cost factors based on actual maintenance costs that are collected and managed in Mn/DOT's Work Management System (WMS). This research was conducted in cooperation with the University of Wisconsin–Madison under the direction of Professor Teresa M. Adams.

The project is related to three other process improvement initiatives at Mn/DOT. First, the development of WMS, a new system that stores maintenance work activities and costs had begun, and the previous database system was migrated from Paradox into Oracle Relational Database Management System (RDBMS). Second, Pontis version 4.0 was released with significantly improved database capabilities including the option of moving Pontis data into Oracle from Sybase. For the Mn/DOT Office of Bridges and Structures to make the most of these two improvements, a way to link the WMS cost data to Pontis was needed. This linkage provides a means for ongoing update of maintenance cost estimates for Pontis analysis. The Research Team established a way to map WMS Worktype codes to Pontis maintenance actions. The mapping of WMS Worktype to Pontis actions was used in the third process improvement initiative, a *Pontis Interface* project that brings bridge maintenance activities data from WMS into the Pontis Oracle database. The result is a "Mn/DOT Bridge Maintenance" table containing maintenance actions and costs. However, the WMS contains cost data for maintenance performed by district crews only. Another data source is required for unit cost of maintenance performed by contract, the Mn/DOT Office of Bridges and Structures Estimating Unit provided that data.

To achieve the first research objective, the Research Team used cost data for maintenance actions that are normally performed by contractors, from the Estimating Unit of the Mn/DOT Office of Bridges and Structures. The effort focuses on a scope of 30 most common elements in the Mn/DOT bridge inventory. The Research Team developed standard element definitions for converting cost units as needed (e.g. cost per linear ft to cost per each). The Research Team worked with the Estimating Unit to relate work breakdown to maintenance actions as defined in Pontis. Some of the maintenance costs that were not available were acquired from WisDOT. The Research Team also provided transition probabilities for modeling deterioration for of many bridge elements.

To achieve the second objective, the Research Team worked with the Estimating Unit of the Mn/DOT Office of Bridges and Structures and the Mn/DOT Office of Investment Management to collect supporting data to be used in the Pontis Functional Improvement model including user-cost savings for functional improvement actions. The goal was to determine the Mn/DOT-specific values of bridge widening, raising, strengthening and replacement actions for the Pontis Functional Improvement model, and estimates cost of Average Cost per Accident,

Vehicle Operating Cost, and Travel Time Cost for calculating user-cost savings of functional improvement projects.

To achieve the third objective, the Research Team created a *Pontis Cost Interface* program, a Windows-based interactive program to query maintenance cost information from the Mn/DOT Bridge Maintenance table. This program processes the data to calculate weighted average unit cost for each maintenance action. This program updates the Pontis database tables for expert elicitation based on actual maintenance costs recorded in the WMS.

This research delivered to Mn/DOT the following:

- Estimated unit costs for many of the predefined preservation maintenance actions in Pontis that are performed by contract, in database tables ready to be imported into Pontis
- Estimates of transition probabilities for modeling deterioration in Pontis, these were delivered as database tables ready to be imported to Pontis.
- Mn/DOT-specific estimates for bridge widening, raising, strengthening and replacement costs to be used for functional improvement modeling in Pontis. These values are to be entered in the *costmtrx* table in Pontis.
- Mn/DOT-specific cost estimates for Average Cost per Accident, Vehicle Operating Cost, and Travel Time Cost to be used for calculating user-cost savings of functional improvement project. These values are to be entered in the *costmtrx* table in Pontis.
- A Windows-based *Pontis Cost Interface* program for calculating weighted average unit costs for each maintenance actions performed by Mn/DOT maintenance crews. This program updates the expert elicitation tables in the Pontis database. A relational database table that maps WMS Worktype to Pontis maintenance actions was provided, and entered into Mn/DOT Pontis database.

The Research Team worked with Mn/DOT Office of Bridges and Structures to implement the results. The Research Team also visited Mn/DOT to test the implementation of the expert elicitation tables and the *Pontis Cost Interface* program. Mn/DOT will need to maintain the cost index table in Pontis (*costindx*) keeping it up to date by adding an entry each year for the annual FHWA Federal Aid Highway Construction Cost Index.

This research results in the following recommendation. To fully use the preservation modeling in Pontis, Mn/DOT must explore ways to use maintenance records in the Mn/DOT Bridge Maintenance table to update the transition probability matrices in the preservation deterioration models.

Chapter 1
Introduction

Problem Statement

The Minnesota Department of Transportation's (Mn/DOT) assets include 19,366 bridges. Of those, 3,689 bridges are maintained by the state through the Mn/DOT Office of Bridges and Structures. Currently, Mn/DOT uses the Pontis BMS to manage its bridge inventory. The agency also desires to use the system's analysis capabilities for planning and evaluating preservation maintenance and functional improvement strategies. Accordingly, Mn/DOT must develop cost factors of sufficient accuracy and precision for credible budgeting and program planning.

For analysis of preservation maintenance strategies, the Pontis BMS requires a database of unit costs for the various maintenance actions that are possible for each bridge element. A preservation policy is calculated for each bridge element (e.g. deck, pier, girder). Each element has an associated set of condition state definitions that describe the nature of physical deterioration of the element. For each element and condition state, a set of feasible preservation actions is defined, which includes a do-nothing action. The unit costs associated with preservation actions are intended to be accurate for predicting costs on a network of bridges. Mn/DOT has previously defined its bridge elements, condition states, and associated possible maintenance actions. Unit costs for these actions along with the transition probability matrices (models for repair effect and deterioration) have not been defined. This research focuses on developing unit costs for preservation maintenance actions.

Mn/DOT can gather its bridge maintenance cost data from several sources, including the Work Management System (WMS), recent bid prices, in-house programs to estimate costs based on past costs, bridge engineer's knowledge, and historical data. Mn/DOT is revising its Work Management System (WMS) that maintains detailed cost records of labor, materials, and equipment associated with bridge maintenance performed by maintenance crews in the districts. The new WMS data model needed to support the derivation of unit costs for bridge maintenance actions. A portion of bridge maintenance is performed by bided contract. Maintenance costs for these actions cannot be derived from the WMS, and thus other sources must be used.

The Mn/DOT Pontis Bridge Management System uses a functional improvement model to identify needs for bridge widening, raising, and strengthening as well as replacement. Determination of functional improvement needs is based upon design and level-of-service standards. Benefits of functional improvements are defined as the savings in user costs resulting from the implementation of an action. These include reductions in detour delays and accident costs. Values for these parameters were needed.

The performance of Mn/DOT's transportation asset management can be greatly improved by creating more accurate cost estimation techniques in the BMS. Integrating the currently existing Work Management System maintenance data into the Pontis BMS will allow Mn/DOT to fully utilize the computer models to best allocate Mn/DOT's financial resources. This research report explains how Mn/DOT specific bridge maintenance cost-factors have been developed for Pontis from contractual cost data and actual maintenance expenditures in the

WMS Bridge Maintenance Completion Reports. Additionally, the research has led to the development and installation of a computer program that assists in the process of inserting cost data into Pontis. The research also provides Mn/DOT specific functional improvement costs and user cost savings that will be utilized in future maintenance cost estimates.

Project Objectives

1. To determine Mn/DOT specific costs for each set of feasible preservation actions for each element and condition state, and the failure costs for each element.

2. To determine the Mn/DOT specific unit costs for functional improvements and the factors used to calculate benefits.

3. To explore the development of integrated data methods for updating Pontis cost factors based on actual maintenance costs.

Research Approach and Organization of this Report

The project is to be accomplished through the following eight research tasks:

1. The Research Team identified 30 significant elements as the scope for the research project. Count of elements in the network and count of bridges with the element were used to identify the elements. This task and its results are presented in Chapter 1. The scope of bridge maintenance actions identified in Task 1 was divided into two groups: 1) actions performed under bided contracts with Mn/DOT, and 2) actions performed by maintenance crews in the Mn/DOT districts. The process and results of this grouping are presented in Chapter 1.
2. Identify and evaluate existing Mn/DOT data sources for estimating Pontis BMS parameters including: unit cost of preservation maintenance actions for the bridge elements identified in Task 1, functional improvement costs (widening, strengthening, raising, and replacement), and user cost saving (accident cost, travel time cost, vehicle operating cost). The data sources are discussed in Chapter 1.
3. The unit cost of maintenance actions performed by bided contracts with Mn/DOT were obtained from Mn/DOT's estimating unit and, for a few actions, from Wisconsin DOT's Pontis database. Some costs were converted to units compatible with Pontis using standardized dimensions of the element. In order to use data from WisDOT, Mn/DOT element numbers were mapped to respective WisDOT numbers. The process and results obtaining unit cost of maintenance actions performed by bided contracts are presented in Chapter 2.
4. This task was originally proposed to determine element failure costs. With approval from the Technical Advisory Panel and Mn/DOT project manager, the task was eliminated because the new version of Pontis does not use failure costs. Instead, the research team is providing transition probabilities.
5. Aggregate cost for functional improvements actions (widen, raise, strengthen, and replace) were obtained from the Mn/DOT estimating unit. The results of this task are presented Chapter 4.

6. Parameters for determining the user benefits of functional improvements include global parameters: accident cost, vehicle operating cost, and travel time cost as well as bridge-specific parameters such as detour distance. Values for these parameters and user cost savings for functional improvements are presented in Chapter 4.
7. The unit cost of maintenance action performed by maintenance crews at the Mn/DOT districts can be derived from Mn/DOT's WMS (work management system) warehouse database. The critical success factor for this task is to relate WMS activity records to Pontis maintenance actions through "work type". Chapter 3 presents the conceptual design and database queries for computing these maintenance costs. If implemented, these queries provide the basis for ongoing updates to preservation costs.
8. Implementation Plan. All project data are presented in a format that correlates with the associated Pontis parameters. The costs would have to be entered into the Pontis cost models for preservation and functional improvements. Finally, a thorough systematic implementation plan is included that will guide bridge managers when they install and run the new integrated database system. The explanation is followed by the conclusions that were reached as a result of the research. The implementation plan is presented in Chapter 6.

Scope of Bridge Elements

Mn/DOT has 115 bridge elements defined in its database. The scope of this research is limited to maintenance actions in the Mn/DOT pocket manual for 30 bridge elements listed in Table 1-1. Considering the number of bridges that feature each element and the number of element units in the network lead to the identification of the scope of elements. Additionally, the bridge inventory for District 6 was considered because this district is leading piloting the new Work Management System (WMS).

Since each element has multiple possible actions, unit cost for 471 actions were developed. Due to limited available data, unit costs are associated with element and action; not element, action and condition state.

Table 1-1 Scope of bridge elements for this study

ELEMNUM	Element Description (units of measure)
106	Girder: Steel, Unpainted (LF)
107	Girder: Steel, Paint Type A (LF)
109	Girder: Prestressed Concrete (LF)
110	Girder: Reinforced Concrete (LF)
234	Pier Cap: Reinforced Concrete (LF)
373	Hinge Assembly: Steel, Painted (EA)
205	Column/Pile Extension: Reinforced Concrete (EA)
210	Pier Wall: Reinforced Concrete (LF)
215	Abutment: Reinforced Concrete (LF)
387	Wingwall: Abutment (EA)
388	Wingwall: Culvert (EA)
382	Cast-in-Place Piling (C-I-P) (EA)
300	Joint: Strip Seal Expansion Joint (LF)
301	Joint: Pourable Joint Seal (LF)
302	Joint: Compression Joint Seal (LF)
310	Bearing: Elastomeric (EA)
311	Bearing: Moveable (EA)
312	Bearing: Enclosed/Concealed (EA)
313	Bearing: Fixed (EA)
320	Approach Slab: Bituminous (EA)
321	Approach Slab: Concrete (EA)
330	Railing: Metal (LF)
331	Railing: Concrete (LF)
333	Railing: Miscellaneous, Combination (LF)
12	Deck: Concrete, Bare (EA)
22	Deck: Conc., Protected w/ Rigid Overlay (EA)
377	Deck: Conc., w/ Rigid Overlay and Coated Bars (EA)
26	Deck: Concrete, Protected w/ Coated Bars (EA)

Designation of Responsibility for Performing Bridge Maintenance

Mn/DOT has a database called the Work Management System (WMS) that contains bridge maintenance cost data that can be used to generate preservation maintenance costs for its AASHTO Pontis bridge management system. The WMS inventories labor, material, and equipment costs for maintenance work performed by Mn/DOT crews. The WMS does not contain maintenance costs if work was performed through a project contract.

The Minnesota Department of Transportation (Mn/DOT) employs a bridge maintenance supervisor in each of its eight district offices. The bridge maintenance supervisor considers each project's cost, size, and necessary construction expertise when determining which projects will be performed in house and which will be contracted out. Common practice at Mn/DOT has shown that maintenance projects valued at over $50,000 are contracted out, however the district supervisor has the final discretion.

Each of the bridge preservation maintenance actions was sorted into one of three categories based upon how the action was performed: actions performed as a part of a contract (C), actions performed by the maintenance crews (W), or actions performed by contractors and maintenance crews (WC). This categorization was obtained from a questionnaire to Mn/DOT's Office of Bridges and Structures. For example, Table 1-2 contains responsibility designation for maintenance actions on steel girder elements at Mn/DOT. Appendix A contains a full list of all maintenance actions for Mn/DOT Pontis elements and the responsible party for performing the work.

Table 1-2 Designation of responsibility for maintenance work on steel girder elements

ELEMNUM	Element Name	Maintenance Action	Maintenance. Crew (W)/ Contract (C)
106	Girder: Steel Unpainted	Rehab Unit	C
		Clean and Paint	C
		Replace Unit	C
107	Girder: Steel Paint Type A	Surface Clean	W
		Major Rehab Unit	C
		Replace Unit	C
		Surface Clean & Restore top coat of Paint	C
		Spot, Blast, Clean and Paint	C
		Replace Paint System	C

Data Sources

This project uses data from various sources to accomplish the project tasks. The unpublished agency data sources and their use are summarized below.

- Mn/DOT BRINFO data file was used as a data source for selecting the scope of 30 bridge elements (Task 1).
- WisDOT Pontis database was used as a source for some maintenance costs (Task 3) and for element transition probabilities.
- Mn/DOT Pontis Bridge Inspection Booklet was used to identify maintenance actions for Mn/DOT bridge elements (Task 3). Also used in conjunction with WisDOT Pontis Pocket Manual to map Mn/DOT element numbers to WisDOT element numbers.
- Mn/DOT Estimating Unit (contact Manjula Louis) provided estimated cost for maintenance actions performed by contract (Task 3) and some Functional Improvement Costs (Task 5).
- Mn/DOT Office of Information Management Website (contacts Loren Hill and Ed Idzorek) provided global parameters (accident cost, travel time cost, operating cost) for computing the user cost savings of functional improvements (Task 6). Also used Mn/DOT Accident Cost Data Facsimile (contact James Pierce) for Task 6.

- WMS Bridge Maintenance Completion Report and WMS/WHS schema (contact Mike Kangas and Steve Haider) used to design the queries for computing estimated cost of maintenance actions performed by maintenance crews (Task 7).

- Other project information was obtained from Jim Pierce, Mn/DOT Bridge Management Engineer, Gary Peterson, Mn/DOT Bridge Construction Maintenance Engineer, and Bruce Iwen, Mn/DOT South Region Construction Engineer.

Chapter 2
Development of Unit Costs for Contracted Bridge Maintenance

This Chapter deals with developing unit costs for maintenance actions performed on bridge elements through bided contracts. The unit costs represent the variable (direct) cost component of the total maintenance cost. Fixed (indirect) cost items such as for traffic control are not considered. However, the bridge portion of the mobilization is included (usually about 4% of bridge work cost).

Unit costs were developed for maintenance actions that are normally performed by contractors rather than by district maintenance crews. Unit cost for maintenance performed by district crews may be derived from the Mn/DOT's WMS warehouse database (see Chapter 3).

Mn/DOT developed its bridge element numbers before the Pontis program became established and widespread, thus Mn/DOT uses non-standard Pontis element numbers. The agency is converting to the standard Pontis element numbers. This report however, is written using Mn/DOT (non-standard) ELEMNUM.

The presentation of unit costs in this Chapter is organized according to sources of the cost information. The unit costs for each element are organized together in Appendix A.

Strategy for Estimating Costs of Maintenance Actions Performed by Contract

The unit costs in this Chapter are for maintenance actions listed in Mn/DOT Bridge Inspectors Pocket Manual and the 30 bridge elements listed in Table 1-1. The pocket manual has maintenance actions for each bridge element in the Mn/DOT bridge inventory along with element definitions having specified units of measure for costs ($/LF, $/SF, $/EA). The bridge elements and maintenance actions are part of the preservation maintenance modeling in Mn/DOT's Pontis Bridge Management System (BMS).

Figure 2-1 shows the process for developing unit costs for maintenance actions performed by contractors. The end node on each branch of the decision chart identifies the report section describing the indicated maintenance costs. Many of the costs are based on factors obtained from the Mn/DOT Estimating Unit by working with Jim Pierce and Manjula Louis to determine the applicability of Mn/DOT's contract cost data. Some of these costs had to be converted to cost units as defined for the element in the Pontis BMS. Another major source of cost is the Wisconsin Department of Transportation (WisDOT) Pontis databases. The WisDOT estimates were based on expert elicitation of bridge maintenance engineers (1).

Preservation Costs from Mn/DOT Estimating Unit

Maintenance costs from the Mn/DOT Estimating Unit having units that are compatible with Pontis are listed in Table 2-1. The following are notable comments regarding some of the unit costs in Table 2-1.

- 373 – Replace Paint System and Rehab/Replace Paint system. Use $500/EA for these actions (as per Jim Pierce on 4/22/03).
- 312 – Assume maintenance costs are twice the cost of maintenance on elements 311 and 313 (as per Jim Pierce on 4/22/03).

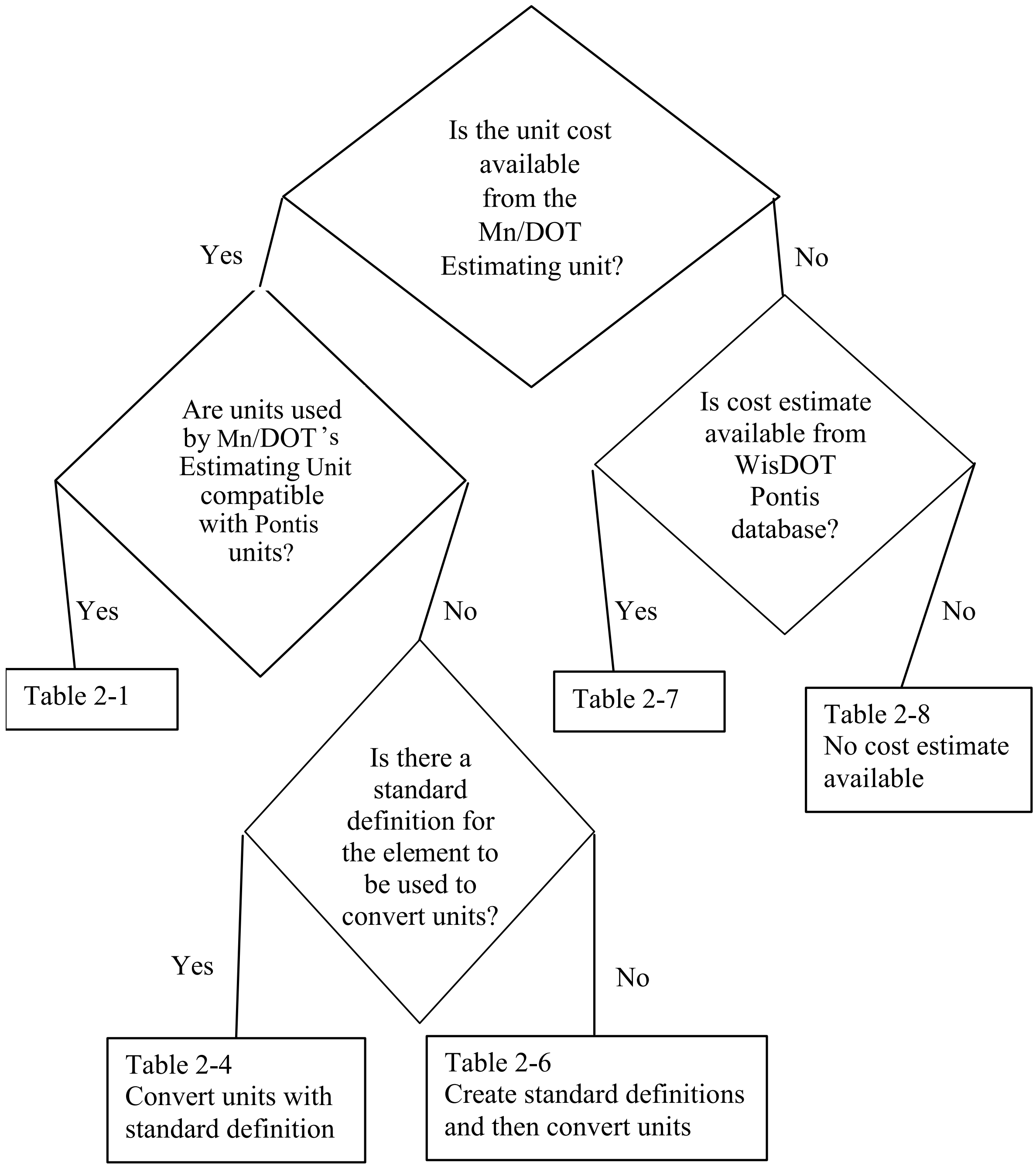

Figure 2-1 Decision logic for determining cost of maintenance actions performed by contract

Table 2-1 Maintenance costs from Mn/DOT Estimating Unit having units compatible with Pontis

ELEM NUM	Element	Pontis Action (condition state)	Unit Cost $2001 English	Unit Cost $2001 Metric
373	Hinge Assembly: Steel, Painted	Replace Paint System (4)	500/EA	500/EA
		Major Rehab Unit (5)	500/EA	500/EA
382	Cast-In-Place Piling	Clean and Paint Shell (2)	300/EA	300/EA
300	Joint: Strip Seal Expansion Joint	Replace Joint (3)	350/LF	1,148/m
302	Joint: Compression Joint Seal	Patch/Remove/Reseal/Clean (2)	100/LF	328/m
311	Bearing: Moveable	Rehab Supports (3)	600/EA	600/EA
		Replace Unit (3)	1,000/EA	1,000/EA
312	Bearing: Enclosed/Conceal	Rehab Unit (2,3)	1,200/EA	1,200/EA
		Replace Unit (3)	2,000/EA	2,000/EA
313	Bearing: Fixed	Rehab Supports or Bearings (3)	600/EA	600/EA
		Replace Unit (3)	1,000/EA	1,000/EA
320	Approach Slab: Bituminous	Replace Unit (3,4)	20,000/EA	20,000/EA
321	Approach Slab: Concrete	Replace Unit (3,4)	20,000/EA	20,000/EA
330	Railing: Metal	Clean and Coat (2,3)	35/LF	115/m
		Rehab Unit (4)	110/LF	361/m
		Replace Unit (3,4)	110/LF	361/m
331	Railing: Concrete	Rehab Unit (4)	80/LF	262/m
		Replace Unit (4)	80/LF	262/m
333	Railing: Misc., Combination	Replace Unit (3)	190/LF	623/m
12	Deck: Concrete, Bare	Replace Deck (5)	40/SF	431/sqm
22	Deck: Conc., Protected w/ Rigid Overlay	Replace Deck (5)	40/SF	431/sqm
377	Deck: Conc., w/ Rigid Overlay and Coated Bars	Replace Deck (5)	40/SF	431/sqm
26	Deck: Conc., Protected w/ Coated Bars	Replace Deck (5)	40/SF	431/sqm

Conversion of Unit Costs using Existing Standard Element Definitions

Some maintenance costs from Mn/DOT's Estimating Unit were provided in units of measure that are incompatible with cost units required for the Pontis system. Table 2-2 lists the maintenance costs that required units of measure to be converted to units that are compatible with Pontis. The method for converting cost units involves using standard element size definitions.

Maintenance costs in the Pontis system are expressed as independent of any particular bridge or element size. Standard element definitions describe to the most common size, not the average element size (2): "An average size may not necessarily be an actual, practical size used for the bridge, especially in the case of girder elements." The standard definition serves as a consistent basis for estimating maintenance costs. For example, the standard definition of a deck

(200ft long and 40ft. wide) can be used to estimate the cost of maintenance actions on decks. The method to convert costs from $/LF to $/SF of deck is to multiply $/LF by the *standard* width of a deck. Similarly, $/SF can be convert to $/EA by multiplying $/SF by the *standard* area of a deck.

Table 2-3 lists standard definitions that were developed as part of a study at Clemson University (2) and others developed for used by the WisDOT (1). Mn/DOT employees, Jim Pierce and Manjula Louis verified that the standard sizes in Table 2-3 are applicable for Mn/DOT's.

Table 2-2 Estimated maintenance costs expressed in incompatible units for use in Pontis BMS

ELEM NUM	Element	Pontis Action (condition state)	Unit Cost ($2001)	Pontis Unit
106	Girder: Steel, Unpainted	Clean and Paint (2,3)	9.50/SF	m
		Rehab Unit (4)	1,500/EA	m
107	Girder: Steel Paint Type A	Major Rehab Unit (5)	9.50/SF	m
		Replace Paint System (4)	9.50/SF	m
109	Girder: Prestressed Concrete	Rehab Unit (4)	250/EA	m
		Replace Unit (4)	275/SF	m
234	Pier Cap: Reinforced Concrete	Rehab Unit (4)	80/SF	m
373	Hinge Assembly: Steel, Painted	Replace Paint System (4)	9.50/SF	EA
205	Column/Pile Extension: Reinforced Concrete	Rehab Unit (4)	80/SF	EA
210	Pier Wall: Reinforced Concrete	Rehab Unit (4)	80/SF	m
215	Abutment: Reinforced Concrete	Rehab Unit (4)	80/SF	m
387	Wingwall: Abutment	Rehab Unit (3,4)	80/SF	EA
313	Bearing: Fixed	Clean and Paint or Reset Bearings and/or Rehab Supports (2)	9.50/SF	EA
320	Approach Slab: Bituminous	Place Overlay (3)	$2.50/SF	EA
321	Approach Slab: Concrete	Place Overlay (3)	$6/SF	EA
12	Deck: Concrete, Bare	Repair Spalled Areas and Add a Protective System on Entire Deck (3,4,5)	7/SF	sqm
22	Deck: Conc., Protected w/ Rigid Overlay	Replace Overlay (4,5)	9/SF	sqm
377	Deck: Conc., w/ Rigid Overlay and Coated Bars	Repair Spalled Areas and Add or Replace Overlay (3,4,5)	9/SF	sqm
26	Deck: Conc., Protected w/ Coated Bars	Repair Spalled Areas and Add or Replace Overlay (3,4,5)	9/SF	sqm

Table 2-3 Previously defined standard element definitions for estimating maintenance costs

ELEM NUM	Element Name	Standard Definition (units in feet unless indicated)
106, 107	Steel Open Girder	40" depth
109	Prestressed Concrete Open Girder	36" depth
234	Reinforced Concrete Cap	3 w, 3 deep, 40 l
205	Reinforced Concrete Column or Shaft	3 dia x 14 h
210	Reinforced Concrete Pier Wall	30 w, 3 t, 15 h
215	Reinforced Concrete Abutment	50 w, 4 h
313	Fixed Bearing	7" h, 12" x 24" pad
321	Reinforced Concrete Approach Slab	20 l, 24 w (2 – 12 lanes)
12, 22, 377, 26	Concrete Deck	200 l, 40 w

Table 2-4 lists the maintenance costs that were converted using the standard element definitions in Table 2-3. Pontis multiplies the unit cost times the quantity in a given condition state, which for decks/slabs is the entire deck area. The following computations adjust the unit cost for deck repair for each condition state based on the percentage of deck area in the condition for that condition state e.g. for C.S. 3 (up to 10% distressed area). The following notes explain the computations.

- 109 – Replace Unit: Standard element indicates yields 3 SF/LF (36"/12"*1')
  Cost = 3 SF/LF * $275/SF = $825 / LF
- 234 – Rehab Unit: The standard definition of a pier cap is 3' tall by 3' wide.
  1' length of pier cap translates to 3' * 1' = 3 SF/LF.
  Cost = $80/SF * 3 = $240/LF
- 205 – Rehab Unit: Mn/DOT spends $80/SF repairing spalls.
  A standard column is 14' tall and 3' in diameter. Area = π*d* h= 3.14*3*14 = 132 SF
  Assume 25% of column area has advanced deterioration in condition state 4.
  Cost = 132 SF * 0.25 * $80/SF = $2,640/E, say $3,000/EA (as per Jim Pierce on 4/22/03)
- 210 – Rehab Unit: The standard definition is 3' thick by 15' high.
  Area per linear foot = 15' X 1' = 15 SF. Cost = 15 SF/LF * $80/SF = $1,200/LF
- 215 – Rehab Unit: The standard definition is 4' high. Area per linear foot = 4' X 1' = 4 SF.
  Cost = 4 SF/LF * $80/SF = $320/LF
- 313 – Clean and Paint or Reset Bearing and/or Rehab Supports:
  Use $9.50/SF to paint bearing. The standard definition is 7" tall x 1' x 2'.
  Use 2 SF of flat base area + 3.5 SF of sides = 5.5 SF of surface area.
  Cost = 5.5 SF * $9.50/SF = $52/EA
- 320 – Place Overlay: Unit cost is $2.50/SF
  The standard definition of a slab is 2-12' lanes, so 12' x 24' = 288 SF
  Cost = 288 SF * $2.50/SF = $720/EA per slab
- 321 – Place Overlay: Unit cost is $6/SF
  The standard definition of a slab is 2-12' lanes, so 12' x 24' = 288 SF
  Cost = 288 SF * $6/SF = $1,728/EA per slab

- 12 – Add Protective System. The unit cost given is $6/SF ($65/sqm)
  Cost in $/EA are based on standard deck area of 200 ft long by 40 ft wide = 8,000 SF.
  Cost to add protective system over entire deck = 8,000 SF* $6/SF = $48,000
- 12 – Repair Spalled Areas and Add a Protective System on Entire Deck.
  Unit cost is $7/SF ($75/sqm)
  Cost in $/EA are based on standard deck area of 200 ft long by 40 ft wide = 8,000 SF.
  Cost = 8,000 SF* $7/SF = $56,000
- 22 –Replace Overlay. The unit cost given is $9/SF.
  Cost in $/EA are based on standard deck area of 200 ft long by 40 ft wide = 8,000 SF.
  Condition State 4 has 10% - 25% distressed area. Average distressed area = 17.5%
  Cost/SF = 0.175 * $9/SF= $1.58/SF ($17/sqm)
  Condition State 5 has 25% distressed area. Cost/SF= 0.25 * $9/SF= $2.25/SF ($24/sqm)
- 377, 26 – Repair Spalled Areas and Add or Replace Overlay. The unit cost given is $9/SF.
  Cost in $/EA are based on standard deck area of 200 ft long by 40 ft wide = 8,000 SF.
  Condition State 3 has 2% - 10% distressed area; use 10% (as per Jim Pierce on 4/22/03)
  Cost/SF = 0.10 * $9/SF= $0.90/SF ($9.7/sqm)
  Condition State 4 has 10% - 25% distressed area. Average distressed area = 17.5%
  Cost/SF = 0.175 * $9/SF= $1.58/SF ($17/sqm)
  Condition State 5 has 25% distressed area. Cost/SF = 0.25 * $9/SF= $2.25/SF ($24/sqm)

Table 2-4 Maintenance costs converted using existing standard element definitions

ELEM NUM	Element Description	Pontis Action (condition state)	Cost Unit $2001 English	Unit Cost $2001 Metric
109	Girder: Prestressed Concrete	Replace Unit (4)	825/LF	2,707/m
234	Pier Cap: Reinforced Concrete	Rehab Unit (4)	240/LF	787/m
205	Column/Pile Extension: Reinforced Concrete	Rehab Unit (4)	3,000/EA	3,000/EA
210	Pier Wall: Reinforced Concrete	Rehab Unit (4)	1,200/LF	3,937/m
215	Abutment: Reinforced Concrete	Rehab Unit (4)	320/LF	1,050/m
313	Bearing: Fixed	Clean and Paint or Reset Bearings and/or Rehab Supports (2)	52/EA	52/EA
320	Approach Slab: Bituminous	Place Overlay (3)	720/EA	720/EA
321	Approach Slab: Concrete	Place Overlay (3)	1,728/EA	1,728/EA
12	Deck: Concrete, Bare	Add a Protective System (1,2)	6/SF	65/sqm
		Repair Spalled Areas and Add a Protective System on Entire Deck (3,4,5)	7/SF	75/sqm
22	Deck: Conc., Protected w/ Rigid Overlay	Replace Overlay (4)	1.58/SF	17/sqm
		Replace Overlay (5)	2.25/SF	24/sqm
377	Deck: Conc., w/ Rigid Overlay and Coated Bars	Repair Spalled Areas and Add or Replace Overlay (3)	0.90/SF	10/sqm
		Repair Spalled Areas and Add or Replace Overlay (4)	1.58/SF	17/sqm
		Repair Spalled Areas and Add or Replace Overlay (5)	2.25/SF	24/sqm
26	Deck: Conc., Protected w/ Coated Bars	Repair Spalled Areas and Add or Replace Overlay (3)	0.90/SF	10/sqm
		Repair Spalled Areas and Add or Replace Overlay (4)	1.58/SF	17/sqm
		Repair Spalled Areas and Add or Replace Overlay (5)	2.25/SF	24/sqm

Element Standard Definitions: Steel Girders, and Abutment Wingwalls

The Research Team worked with Mn/DOT employees Jim Pierce and Manjula Louis to define the standard definitions (physical dimensions) in Table 2-5 for elements 106, 107, and 387.

A standard definition is required for the steel girder elements to convert SF used by Mn/DOT's Estimating Unit to meters used in the Pontis BMS. The standard definition assumes a 40-inch girder depth with 10 square feet of surface area per linear foot of the girder length.

A standard definition for Element 387 (abutment wingwall) is required to convert SF used by Mn/DOT's Estimating Unit to each used in the Pontis BMS. Each bridge has four abutment wingwall elements; two on each end of the bridge. Mn/DOT's abutment wingwall elements are defined as follows: 1) the abutment wingwalls are made of concrete 2) the outside surface of each wingwall has an area of 300 square feet 3) the shape of each abutment shall be assumed to be rectangular for the sake of simplicity.

Table 2-5 Standard element definitions developed by Mn/DOT

ELEMNUM	Element Description	Standard Definition
106, 107	Girder: Steel	40" depth; Total area = 3 times area of vertical face (= 10 ft^2/ft)
387	Wingwall: Abutment	One concrete wingwall on one end of bridge, 300 ft^2 total outside surface area

The standard definitions in Table 2-5 were used to compute the maintenance costs listed in Table 2-6. The following are comments regarding the use of standard definitions to convert cost units:

- 106, 107 – Clean and Paint; Major Rehab Unit; and Replace Paint System
  The standard depth of a girder is 40 inches. Thus, [40”/12”] * 1’ = 3 1/3 SF vertical area.
  Total area = 3*vertical area = 3 * 3 1/3 SF = 10 SF per linear foot.
  Cost = 10 SF / LF * $9.5/SF = $95 / LF

- 387 – Rehab Unit:
  The standard definition is 300 SF per wall. Mn/DOT spends $80/SF repairing spalls.
  Use distressed area for Condition State 3 at 10% (as per Jim Pierce on 4/22/03)
  Cost = $80/SF * 300 SF * 0.1 = $2,400 EA.
  Condition State 4 has 10% - 25% distressed area. Average distressed area = 17.5%
  Cost = 300 SF* 0.175 * $80/SF = $4,200/EA

Table 2-6 Maintenance costs converted using element definitions developed by Mn/DOT

ELEM NUM	Element	Pontis Action (condition state)	Cost Unit 2001 English	Cost Unit 2001 Metric
106	Girder: Steel, Unpainted	Clean and Paint (2,3)	95/LF	312/m
		Rehab Unit (4)	95/LF	312/m
107	Girder: Steel, Paint Type A	Replace Paint System (4)	95/LF	312/m
		Major Rehab Unit (5)	95/LF	312/m
71	Wingwall: Abutment	Rehab Unit (3)	2,400/EA	2,400/EA
		Rehab Unit (4)	4,200/EA	4,200/EA

Maintenance Costs from WisDOT’s Pontis Database

Table 2-7 lists the maintenance costs that were adopted or derived from unit costs in the WisDOT Pontis database. The WisDOT cost estimates are based on expert elicitation (1). The following are noted comments regarding some of the unit costs in Table 2-7.

- 106 – Rehab Unit: Assume cost to rehabilitate unpainted steel girder is the same as cost to rehabilitate painted steel girder. Use cost for Elements 007 and 008 – Rehab Unit.

- 109 – Rehab Unit: Assume cost to rehabilitate prestressed girder is the same as cost to rehabilitate reinforced girder. Use cost for Element 010 – Rehab Unit.

Table 2-7 Maintenance costs adapted from WisDOT Pontis database

ELEM NUM	Element Name	Pontis Action (condition state)	Unit Cost $1997 metric
106	Girder: Steel, Unpainted	Replace Unit (4)	1,615/m
107	Girder: Steel, Paint Type A	Replace Unit (5)	1,615/m
		Spot, Blast, Clean and Paint (3,4)	167/m
		Surface Clean & Restore Top Coat of Paint (2)	134/m
109	Girder: Prestressed Concrete	Rehab Unit (4)	669/m
110	Girder: Reinforced Concrete	Rehab Unit (4)	669/m
		Replace Unit (4)	1,560/m
234	Pier Cap: Reinforced Concrete	Replace Unit (4)	5,013/m
205	Column/Pile Extension: Reinforced Concrete	Replace Unit (4)	5,095/EA
210	Pier Wall: Reinforced Concrete	Replace Unit (4)	3,342/EA

Maintenance Actions for which Unit Costs are Unavailable

The maintenance actions listed in Table 2-8 are uncommon in Minnesota. Reliable maintenance costs could not be obtained for these actions.

Table 2-8 Maintenance actions for which unit costs are unavailable

ELEMNUM	Element Description	Pontis Action (condition state)	Pontis Units
373	Hinge Assembly: Steel, Painted	Replace Unit (5)	EA
215	Abutment: Reinforced Concrete	Replace Unit (4)	LF
387	Wingwall: Abutment	Replace Unit (4)	EA
388	Wingwall: Culvert	Rehab Unit (3,4)	EA
		Replace Unit (3,4)	EA
382	Cast-In-Place Piling	Rehab Unit (3,4)	EA
		Replace Unit (4)	EA

Implementation of Results for Maintenance Cost Modeling

Preservation cost modeling in Pontis requires unit costs for maintenance actions and transition probabilities. These are stored in expert elicitation tables. The Pontis Preservation Model desktop provides an Update button that takes data from the expert elicitation tables, adjusts costs according to the cost indices in the *costindx* table, and populates the *actmodls* and *condumdl* tables to be used by the cost model.

The Pontis *costindx* table contains the historical cost index (HCI) used to adjust costs for inflation. This index in maintained in the Pontis Configuration module. Table 2-9 lists values of the FHWA Federal Aid Highway Construction Cost Index (3) for years 1987 to 2001 compared to the Consumer Price Index.

Table 2-9 FHWA Federal Aid Highway Construction Costs (3)

INDEX	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Federal-Aid Highway Construction	100.0	106.6	107.7	108.5	107.5	105.1	108.3	115.1	121.9	120.2	130.6	126.9	136.5	145.6	144.8
Consumer Price Index	100.0	104.1	109.2	115.1	119.9	123.5	127.2	130.5	134.2	138.1	141.3	143.5	146.7	151.6	155.9

Unit costs for preservation maintenance actions are stored in the Pontis *expactc* and *expcnduc* tables. The *expactc* table contains maintenance costs for each combination of element, condition state, action and environment.

Transition probabilities for each preservation maintenance action are stored in the Pontis *expactn* and *expcondu* tables. The *expactn* table contains transition probabilities from state to state for every combination of element, condition state, action and environment.

The Research Team built *expactc* and *expcnduc* tables with the unit costs for 26 elements (see Appendix A). Unit cost for each action is the same for all environments. Unit costs from WisDOT (4) for 8 additional elements were included in the expert elicitation tables. These 8 elements are listed below.

- 126. Truss: Rest of Truss Paint Type A
- 235. Timber Cap
- 202. Column/Pile Extension: Steel Paint A
- 206. Column/Pile Extension: Timber
- 216. Abutment: Timber
- 14. Deck: Concrete, Membrane w/ AC Overlay
- 40. Slab: Concrete, Membrane w/ AC Overlay
- 48. Slab: Concrete, Protected w/ Rigid Overlay

The Research Team built *expactn* and *expcondu* tables with transition probabilities for 34 elements. The source of data for transition probabilities is the WisDOT Pontis database. Additional comments regarding the transition probabilities:

- No transition probabilities were identified for Elements 373 and 388.
- The transition probabilities for Element 382 are incomplete; transition probabilities for the actions in CS3 were not available.

The *expactc, expcnduc, expactn*, and *expcondu* tables were saved as an Oracle export file (name *expert.dmp*). The tables can be imported into the Mn/DOT Pontis databases using the Oracle import function.

Chapter 3
Estimating Unit Costs Using Data from the Mn/DOT Work Management System (WMS) Warehouse

This Chapter describes the results of Task 7 for developing a database process to estimate Pontis preservation maintenance costs using actual records for work done by Mn/DOT district maintenance crews. The product is a Visual Basic program, named *Pontis Cost Interface*.

Strategy

The purpose of the ***Pontis Cost Interface*** program is to provide a tool for estimating unit costs for Pontis preservation maintenance actions that are performed by District maintenance crews. The program is called *Pontis Cost Interface* because it provides an interface for updating Pontis maintenance costs based upon data from the WMS data warehouse.

Mn/DOT Bridge Office is developing a *MN/DOT_Bridge_Maintenance* table to keep track of maintenance work being done on bridges. The table is stored in the Mn/DOT Pontis database and will be updated annually with data from the WMS Warehouse.

The *Pontis Cost Interface* program computes weighted average unit costs using data from the *MN/DOT_Bridge_Maintenance* table. Actual unit costs are weighted according to the quantity of work in each sample. Costs are adjusted according to the cost indices in the Pontis *costindx* table. The program provides a delete button to prevent extraneous records from being included in the cost averaging process.

The *Pontis* C*ost Interface* program makes the unit costs available to the Pontis preservation prioritization module by storing them as updates to the *unitcost* field of the Pontis *expactc* table. In Pontis version 4.0 (5), the preservation module creates the *actmodls* from the expert elicitation tables (*expactc, expactn, expcondu, expcnduc)*.

The *Pontis Cost Interface* program can be also used as a tool for monitoring bridge maintenance costs without updating the Pontis database. The program also provides a way to save the results to a spreadsheet file for further analysis.

Conceptual Design for Estimating Maintenance Costs

The *Pontis Cost Interface* program uses the *MN/DOT_Bridge_Maintenance* table (see Table 3-1) as its data source for actual maintenance costs. The *Pontis Cost Interface* program uses the *Pontis_element_number, work_type, material_cost, labor_cost, equipment_cost,* and *work_date* for each maintenance action.

The concept for computing cost estimate is shown in Figure 3-1. The first step is to get information that is needed from the *MNDOT_Bridge_Maintenance* table, then to calculate the unit costs for each maintenance action by dividing the total costs by the repair quantity. The second step is to calculate the weighted average of the unit costs for all of the maintenance records for each worktype, then save it to a temporary table in the Pontis database named *MNDOT_WMS_unitcost*. The third and the last step is to update the Pontis *expactc* table by updating the unit cost field for the record resulted corresponding to element, condition state, and maintenance action.

Table 3-1 Data fields of *MNDOT_Bridge_Maintenanc*e table

Field	Format
BRKEY	Varchar2(15)
MAINTENANCE_ID	Varchar2(15)
BRIDGE_COUNTY	Varchar2(3)
WORK_TYPE	Varchar2(2)
BRIDGE_ITEM	Varchar2(3)
PONTIS_ELEMENT_NUMBER	Number (3)
WORK_REASON	Varchar2(1)
WORK_DATE	Use MM/DD/YYYY Format
MATERIAL_COST	Float
LABOR_HOURS	Float
LABOR_COST	Float
EQUIPMENT_COST	Float
PRODUCTION_UNITS	Float
MAINTENANCE_AREA	Varchar2(2)
WORK_AGENCY	Varchar2(1)
STATUS_INDICATOR	Varchar2(1)
BUILDER_CODE	Varchar2(4), Foreign Key to Builder
PONTIS_WORK_TYPE	Varchar2(2)
BRIDGE_MAIN_ID	Number(0)
UNIT_OF_MEASURE	Varchar2(4)
BRIDGE_CREW_NUMBER	Varchar2(6)
BATCH_ID	Number(0)
CREATEDATETIME	Date
CREATEUSERKEY	Varchar2(4)
MODTIME	Date
USERKEY	Varchar2(4)

To be able to do the update process, the relationship between work code in WMS and condition state and maintenance action key in Pontis must be established. Unit cost data in the MNDOT_*Bridge_Maintenance* table are identified by element number (*eleno*) and Pontis worktype code (*pontworkcode*), while cost data stored in *expactc* table is identified with element key (*elemkey*), condition state key (*skey*), and action key (*akey*). However, the newly proposed changes to the WMS database made it possible to create a one-to-one mapping of this relationship. The Research Team provided the translation table of *eleno* and *pontworkcode* fields from *MNDOT_Bridge_Maintenance* table to *elemkey*, *skey* and *akey* fields in *expactc* table in Appendix B. A portion of the translation table is shown in Table 3-2. This translation table is created in Pontis database as *MNDOT_WMS_PONTIS_action* table.

Cost Estimating Process and *Pontis Cost Interface* Program

The cost estimating process is the underlying procedure behind the cost-estimating program. It operates on data from the *MNDOT_Bridge_Maintenance* table to update the *expactc* table in Pontis database. The main idea of this cost estimating program is to enable cost data that has been stored in the *MNDOT_Bridge_Maintenance* table to be used as a basis to estimate unit cost factors in Pontis for future maintenance work.

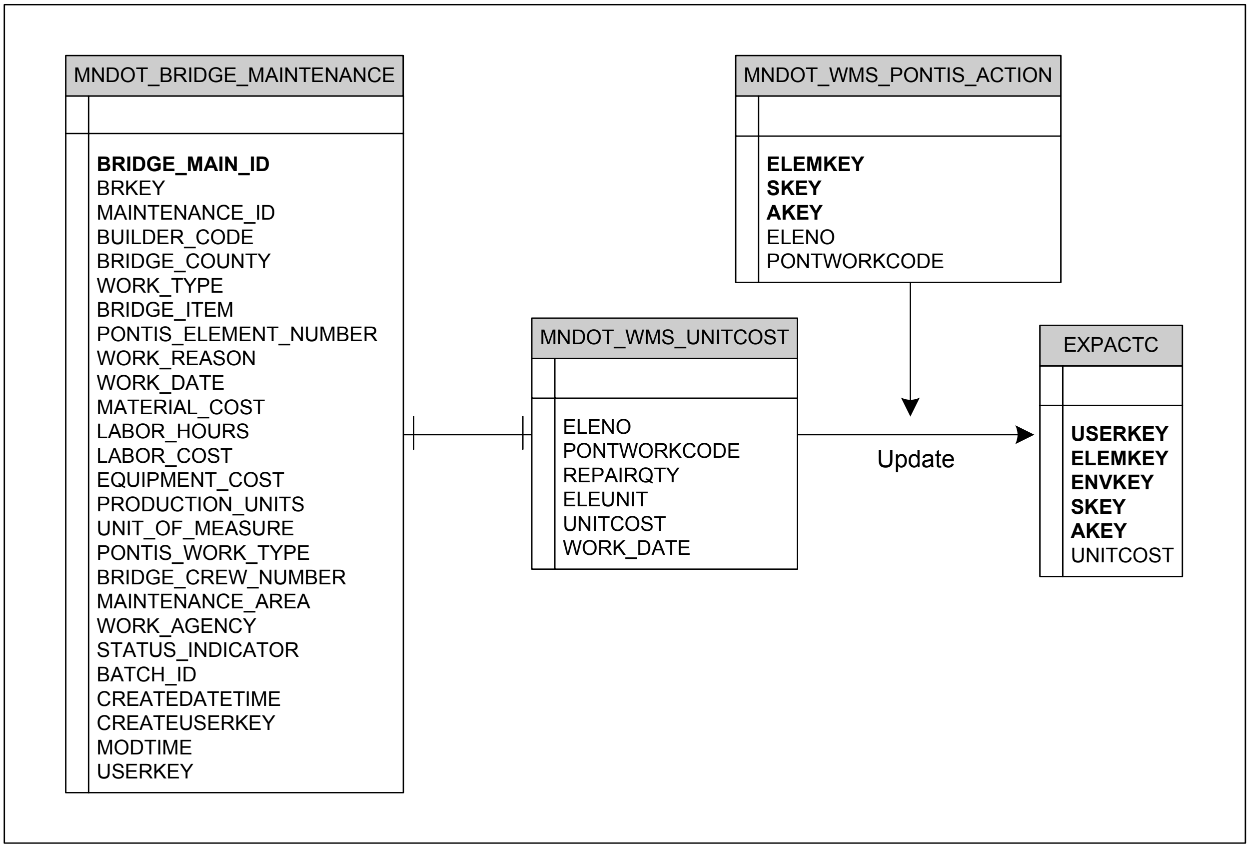

Figure 3-1 Diagram of cost estimating procedure

Table 3-2 Translation of WMS work codes to Pontis maintenance actions

WMS		Pontis		
eleno	pontworkcode	elemkey	skey	akey
106	3	106	2	1
106	3	106	3	1
106	1	106	4	1
106	2	106	4	2
107	1	107	1	1
107	1	107	2	1
107	4	107	2	2
107	5	107	3	1
107	5	107	4	1
107	6	107	4	2
107	2	107	5	1

The process uses two SQL queries. Query 1 creates a sorted list of the repair quantity, unit cost and Pontis element for each Pontis Worktype Code in the *MNDOT_Bridge_Maintenance* table. The total cost is calculated as a sum of equipment cost, material cost, and labor cost. The unit cost is computed by dividing the total cost by the repair quantity. The result of this query is saved in a temporary table in the Pontis database, named MN/DOT_WMS_unitcost.

```
SELECT PONTIS_ELEMENT_NUMBER         "Element No"
,NVL(PONTIS_WORK_TYPE, '1')          "Pontis Worktype Code"
,UNIT_OF_MEASURE
,TO_CHAR(WORK_DATE, 'YYYY')          "Work Year"
,SUM(NVL(PRODUCTION_UNITS,1))        "Repair Qty"
,SUM(NVL(MATERIAL_COST,0))           "Material Cost"
,SUM(NVL(LABOR_COST,0))              "Labor Cost"
,SUM(NVL(EQUIPMENT_COST,0))          "Equipment Cost"
,SUM(NVL(MATERIAL_COST,0)
   + NVL(LABOR_COST,0)
   + NVL(EQUIPMENT_COST,0))          "Total Cost"
,SUM(NVL(MATERIAL_COST,0)
   + NVL(LABOR_COST,0)
   + NVL(EQUIPMENT_COST,0))
   / SUM(NVL(PRODUCTION_UNITS,1))    "Unit Cost"
FROM MN/DOT_BRIDGE_MAINTENANCE
WHERE PONTIS_ELEMENT_NUMBER IS NOT NULL
AND NVL(PRODUCTION_UNITS,1) >= 1
GROUP BY
 TO_CHAR(WORK_DATE, 'YYYY')
,PONTIS_ELEMENT_NUMBER, PONTIS_WORK_TYPE
,UNIT_OF_MEASURE
ORDER BY
 TO_CHAR(WORK_DATE, 'YYYY')
,PONTIS_ELEMENT_NUMBER
,PONTIS_WORK_TYPE
,UNIT_OF_MEASURE;
```

Query 2 is run against the temporary table *MN/DOT_WMS_unitcost*. Query 2 selects the maintenance cost data, grouped by element number, Pontis Worktype Code and shows the element number, Pontis Worktype Code, and the Weighted Average Unit Costs, for each of the cost estimates. The weighted average unit costs are calculated as a sum of the unit costs multiplied by the repair quantity, divided by the sum of repair quantity. For the weighted average unit cost, the cost data is adjusted to the cost year for the element (*costyear* field of the *expactn* table). The result of this query, specifically the *eleno*, *pontworkcode* and *unitcost* field, are used to update the Pontis *expactc* table.

```
SELECT ELENO                               "Element No"
,PONTWORKCODE                              "Pontis Workcode",
,PONTWORKDESC                              "Pontis Work Description",
,ELEUNIT                                   "Element Unit",
,SUM(UNITCOST*REPAIRQTY)/SUM(REPAIRQTY)    "Unit cost",
,COUNT(ELENO)                              "Observations",
,SUM(REPAIRQTY)                            ”Total Units",
,MAX(WORKDATE)                             “Effective Date"
FROM MN/DOT_WMS_UNITCOST
GROUP BY
ELENO
,PONTWORKCODE
,PONTWORKDESC
,ELEUNIT;
```

This *Pontis Cost Interface* program is written in Visual Basic .NET programming language and uses Visual Studio .NET (6) Integrated Development Environment. A complete User Manual for the program is included in Appendix C.

Chapter 4
Functional Improvement Costs and User Cost Savings

Definitions and Purpose for Decision Making

When analyzing bridge needs, Pontis derives improvement needs from the consideration of functional standards and improvement feasibility. Rules and criteria that are used in the analysis are established in the Improvement model in Pontis. The purpose of this Improvement model is to address the level of service deficiencies that exists in a bridge due to an increase in traffic volume. Levels of service deficiencies include low load capacity, narrow width, and low vertical clearance.

Pontis Technical Manual describes the rules and criteria of improvement modeling logic in detail. The manual also defined four types of functional improvement actions in Pontis 4.0:

- Widening (unit cost of structure widening - $/m2 of deck)
- Raising (unit cost of raising a structure - $/m2 of deck)
- Strengthening (unit cost of strengthening a structure - $/m2 of deck)
- Replacement (unit cost of structure replacement - $/m2 of deck)

User cost savings is defined as the benefit gained by performing functional improvement actions. Pontis 4.0 Technical Manual specifies formulas for calculating the benefits of Functional Improvement Actions. The formulas calculate user benefits of Widening, Raising, Strengthening, and Replacement actions. Below is the brief explanation of each of the formula. The details can be found in Chapter 4 of Pontis Release 4 Technical Manual (5).

User Benefit of Widening

Pontis assumes that user benefits of Widening incur by reducing the accident rate on the widened bridge. The user benefit of Widening is calculated as the product of 365.25 (days per year), Average Daily Traffic (V_{ADT}), the Average Cost per Accident (C_{ACC}, from Pontis cost matrix, explained in 5.2), and the differences between Accident Rate before and after the improvement ($A_{current} - A_{improved}$).

$$U_{widening} = 365.25 * V_{ADT} * C_{ACC} * (A_{current} - A_{improved})$$

User Benefit of Raising

Pontis assumes that user benefits of Raising incur through a reduction of the number of vehicles that have to bypass the bridge. The user benefit of Raising is calculated as the product of 365.25 (days per year), V_{ADT}, truck percentage on traffic stream ($\tau/100$), fraction of trucks that have to make a detour because of vertical clearance ($F_{VclrInv}$), and detour cost per vehicle.

$$U_{raising} = 365.25 * V_{ADT} * (\tau/100) * F_{VclrInv} * DetourCostPerVehicle$$

The Detour Cost per Vehicle is used in calculating user benefit of Raising, Strengthening, and Replacement, and it is calculated as the travel time cost per hour for a truck (HrDetourCost) multiplied by the detour time (BypassLength/DetourSpeed) plus truck operating cost (KmDetourCost) multiplied by the detour length (BypassLength).

$$DetourCostPerVehicle = HrDetourCost * \left(\frac{BypassLength}{DetourSpeed}\right) + KmDetourCost * BypassLength$$

User Benefit of Strengthening

Pontis assumes that user benefits of strengthening incur through the reduction of the number of vehicles that have to bypass the bridge. The user benefit of Strengthening is calculated as the product of 365.25 (days per year), V_{ADT}, Truck percentage on traffic stream (τ/100), fraction of trucks that have to make a detour because of the load limit (F_{ld}), and detour cost per vehicle.

$$U_{strengthening} = 365.25 * V_{ADT} * (\tau/100) * F_{ld} * DetourCostPerVehicle$$

User Benefit of Replacement

Annual user benefit of Replacement is defined by Pontis as the reduced costs of detours incurring on all bridge's roadways. When Pontis evaluates the reduction of detours that will happen after the bridge will have been replaced, it combines the number of detours incurred due to the insufficient load rating and those incurred because of the vertical clearance deficiency. Therefore, the user benefit of Strengthening is calculated as the product of 365.25 (days per year) with ADT, truck percentage on traffic stream, fraction of trucks that must detour due to the load limit and/or vertical clearance deficiencies, and detour cost per vehicle.

$$U_{replacement} = 365.25 * V_{ADT} * (\tau/100) * F_{ld+VClrInv} * DetourCostPerVehicle$$

Functional Improvement Costs

This section presents Mn/DOT-specific functional improvement costs for Mn/DOT Pontis database. The costs for Widening and Replacement were obtained from the Mn/DOT Estimating Unit. Costs for Raising and Strengthening are Pontis default values. The reason for using the default value for the latter is that there are not many applications of these two actions, and therefore not enough data to extract an average value. WisDOT also uses Pontis default values for Raising and Strengthening (4). Table 4-1 shows the recommended costs for the four functional improvement actions and the associated Pontis database field.

Table 4-1 Costs for functional improvement actions

Functional Improvement	Cost $/ft^2 (2001)	Cost $/m^2 (2001)	Source	Pontis Table (table.column)
Replacement	95	1023	Mn/DOT*	*costmtrx.ucreplace*
Widening	110	1184	Mn/DOT*	*costmtrx.ucwidenvar*
Raising	30	320	Pontis default value	*costmtrx.ucraise*
Strengthening	30	320	Pontis default value	*costmtrx.ucstrength*

* Mn/DOT Estimating Unit: Manjula Louis, 2001

User Cost Savings

This section presents the Mn/DOT-specific user cost parameters for determining user-cost savings of functional improvement actions. The formulas for calculating user benefits of

Widening, Raising, Strengthening, and Replacement require two types of parameters: bridge-specific and global (all bridges). Table 4-2 lists the user-cost parameters, the database table where their value should be inserted, their type, and the user benefits they influence.

Table 4-2 Parameters for calculating user benefits of functional improvement actions

Parameter	Pontis Database *table.field*	Type	Used to compute user benefit of
Average cost per accident	*costmtrx.acccost*	Global	Widening
Vehicle Operating Cost (detour cost per km)	*costmtrx.kmdetourco*	Global	Raising, Strengthening, and Replacement
Travel Time Cost (detour cost per hour)	*costmtrx.hrdetourco*	Global	Raising, Strengthening, and Replacement
Bridge ID	*bridge.bridge_id*	Bridge	Widening, Raising, Strengthening, and Replacement
Average Daily Traffic	*roadway.adtttotal*	Bridge	Widening, Raising, Strengthening, and Replacement
Bridge Deck Width	*bridge.deckwidth*	Bridge	Widening
Approach Alignment Rating (NBI Rating)	*inspevnt.appralign*	Bridge	Widening
Proportion of Trucks in the traffic stream	*roadway.truckpct*	Bridge	Raising, Strengthening, and Replacement
Posted height limit	*br_bridge.under_clr_apprl*	Bridge	Raising and Replacement
Posted weight limit	*br_bridge.safe_load_capac_apprl*	Bridge	Strengthening and Replacement
Detour (increase) distance in miles	*roadway.bypasslen*	Bridge	Raising, Strengthening, and Replacement
Average speed on detour road (miles/hr)	*roadway.det_speed*	Bridge	Raising, Strengthening, and Replacement

Global parameters include accident cost, vehicle operating cost, and travel time cost. The Research Team worked with the Mn/DOT Office of Investment Management to identify values for the global parameters. Average Cost per accident comes from a calculation using data from Minnesota Department of Public Safety (7) and National Safety Council (8). Table 4-3 shows the calculation of the Average Cost per Accident. Table 4-4 shows the Vehicle Operating Cost in 1997 dollars and Travel Time Cost in 1995 dollars.

Table 4-5 summarizes the values of the global parameters that should be entered into the cost matrix table of the Pontis database.

1. Accident Cost (*acccost*) depends on the functional class of the roadway. Functional class is designated in the *dim2val* field of the *costmtrx* table. The Accident Cost value in Table 4-5 is for rural roads (*dim2val* = 00, 01, 02, 06, 07, 08, or 09). Pontis differentiates between accident cost on rural and urban roads. Pontis defines the default cost of an accident on urban roads (*dim2val* = 11,12,14, 16,17, or 19) at 30% of the cost of an accident on a rural road. The functional class for each bridge is defined in the *roadway* table *(roadway.funcclass).*

2. The Vehicle Operating Cost and Travel Time Cost values in Table 4-5 use the cost values for Trucks, because Truck traffic is the main concern of User Costs savings.
3. It may be necessary to convert the measurement units for the cost values in Table 4-5 to metric units before they are entered into the Mn/DOT Pontis database.

Table 4-3 Average cost per accident

Injury Type	Total Count (7) (1998-2000)	Cost per injury (8)	Total Cost
Death	1,901	$3,214,290	$6,110,365,290
Incapacitating Injury	10,043	$159,449	$1,601,346,307
Non-incapacitating Evident Injury	48,094	$41,027	$1,973,152,538
Possible Injury	76,256	$19,528	$1,489,127,168
No Injury (Property Damage Only)	199,951	$1,861	$372,108,811
		Total	$11,546,100,114
		Total Crashes	293,330
		Average Cost per Accident	$39,362.15

* Source: Minnesota Department of Public Safety, 2000
Table 1.02: Traffic Crash Trends

Table 4-4 Auto and truck vehicle operating and travel time costs (9)

Assumptions	Cost	Source
Auto variable operating costs	$0.262/mile (1997)	Derived from AAA, Your Driving Costs, 1997 edition
Truck variable operating costs	$1.34/mile (1997)	ATA Trucking Information Services
Auto operator time	$8.90/hour (1995)	U.S. DOT Guidance
Truck operator time	$16.50/hour (1995)	U.S. DOT Guidance

Table 4-5 Global parameters for computing user benefits of functional improvement actions

Parameter	Value	Pontis Table (*table.column*)
Average Cost per Accident	$39,362.15 per accident (2000)	*costmtrx.acccost*
Vehicle Operating Cost	$1.34 per mile (1997)	*costmtrx.kmdetourco*
Travel Time Cost	$16.50 per mile (1997)	*costmtrx.hrdetourco*

Most of the bridge-specific parameters are available from Mn/DOT's bridge inventory. Table 4-6 lists the Pontis default values for two bridge-specific parameters if they are not available along with the Pontis tables and columns where they are located. These two values can be changed from within Pontis.

Table 4-6 Bridge-specific user cost parameters that have default values

Parameter	Pontis Table (table.column)	Default Value
Truck Percentage	*imprmtrx.defaulttruckpct*	5.0 (5% of traffic stream)
Average Speed on Detour Road	*imprmtrx.detspeedfactor*	0.80 (80% speed on original roadway)

All of the parameters above should be inserted into the Mn/DOT Pontis database system. The Implementation Plan in Chapter 6 provides the steps that should be taken to update the parameters.

Chapter 5
Conclusions and Recommendations

Accomplishments

The primary products of this research are threefold. The first is estimates of unit costs for maintenance actions for 30 elements in the Mn/DOT bridge inventory and the associated transition probabilities for modeling deterioration of the elements. The unit costs and transition probabilities were delivered as input files for populating the 'expert elicitation' tables of Mn/DOT's Pontis database. These data are essential for running the Pontis Preservation Maintenance model. The Research Team worked with the Mn/DOT Estimating Unit to develop the cost estimates.

The second comprises the parameters for computing cost and benefits (user-cost savings) of functional improvement projects. The parameters are provided for populating the cost matrix table of the Mn/DOT Pontis database. These data are essential for running the Pontis Functional Improvement model.

The third part is the Pontis Cost Interface program, a Windows-based program that computes unit costs for bridge maintenance actions that are performed by Mn/DOT maintenance crews. The program gets its data from the Mn/DOT WMS warehouse (through the MnDOT_Bridge_Maintenance table in Pontis). The Pontis Cost Interface program updates the 'expert elicitation' tables dealing with maintenance costs. The program has a user-friendly interface for viewing and modifying intermediate values as needed.

Benefits

The primary and most significant benefit of this research is that it provides Mn/DOT with essential data for identifying bridge maintenance polices that minimizes total long-term costs. The research provides Mn/DOT with essential data for running the Pontis Preservation Maintenance and Functional Improvement models. Maintenance costs from the Mn/DOT Estimating Unit and WMS warehouse are now the input used by Pontis to calculate preservation maintenance policies and to evaluate functional improvement projects. By using costs and functional improvement parameters that are specific for Minnesota, the results of the Pontis models can be more confidently interpreted to influence bridge management decision-making.

A secondary benefit of the research is that Mn/DOT now has a convenient mechanism for keeping some maintenance costs up-to-date. Periodically running the *Pontis Cost Interface* program ensures that recent costs in the Mn/DOT Bridge Maintenance table are used to update the expert elicitation tables.

Next Steps

Mn/DOT will need to maintain the Pontis Cost Index (*costindx*) table. The *Pontis Cost Interface* program and the Pontis Preservation Maintenance model use the index to adjust costs as needed due to inflation. The Research Team provided the Mn/DOT Bridge Office with the most recent cost indices from Federal Highway Administration (FHWA).

To make full use of the Preservation Maintenance model in Pontis, Mn/DOT must explore ways to update the transition probabilities so they reflex actual bridge deterioration. A good source of data is being collected the Mn/DOT WMS warehouse.

Chapter 6
Implementation Plan

Evaluation

a) Do the results solve the problem?

The research identified Pontis preservation maintenance costs for selected maintenance actions performed by bided contracts. In addition, the research identified and developed a strategy for using Mn/DOT's WMS warehouse data to estimate Pontis preservation maintenance costs for bridge maintenance actions performed by maintenance crews in the districts. These unit costs are to be used for preservation optimization modeling in Mn/DOT's Pontis Bridge Management System.

The research identified agency parameters for computing user benefits of Widening, Raising, Strengthening, and Replacement improvement actions as well as agency's cost for replacement and widening. These parameters are essential for the improvement optimization model in Pontis.

b) Are the results implementable?

Implementation requires that the values in Table 6-1 be inserted into the Pontis *costmtrx* table; that the expert elicitation tables, *expactc*, *expcondu*, *expactn* and *expcnduc* (sent separately in the *expert.dmp* file) be imported into the Pontis database; and that the *Pontis Cost Interface* program be run against the Bridge Maintenance table (*MnDOT_bridge_maintenance*) in Pontis database. Results are used to update the *expactc* table.

c) Can implementation of the results yield benefits?

Implementation of results will allow the Mn/DOT agency to use the Pontis BMS as a tool for bridge program planning and evaluation. Results will customize the preservation optimization and the improvement planning modules with parameters that are representative of the Mn/DOT agency's maintenance actions and costs.

Implementation Tasks

The implementation plan has three tasks. Implementation Task 1 is to update the Pontis *costmtrx* table with parameters used in the Improvement Programming Module. Implementation Tasks 2 and 3 are to update the Pontis expert elicitation tables with unit costs and transition probabilities for maintenance actions. Task 2 focuses on loading transition probabilities for all maintenance actions and loading unit costs for contracted bridge maintenance. Implementation Task 3 focuses on running the *Pontis Cost Interface* program to compute unit costs for maintenance actions performed by maintenance crews in the districts, then loading these costs into the *expactc* table.

Task 1. Update Pontis ***costmtrx*** *Table*

a) Task description. This task updates the functional improvement costs and user cost savings parameter in the Pontis *costmtrx* table by inserting the values in Table 6.1. There are two alternative ways to accomplish this task:

   1. Manually. Open Pontis, go to *programming* module, click on ***Costs*** button, and change the cells manually. **OR.**
   2. Programmatically. Run an SQL query from SQL Plus or any other SQL console connected to Pontis database. Update process can also be automated with a simple script or program.

Table 6-1 Recommended values for Pontis *costmtrx* table

Roadway Functional Class (*costmtrx.dim2val*)	Pontis Table (*table.column*)	Cost (Year) for Units	
		English	Metric
00, 01, 02, 06, 07, 08, 09, 11,12,14, 16,17, 19	*costmtrx.ucreplace*	$95/ft^2 (2001)	$1023/m^2 (2001)
	costmtrx.ucwidenvar	$110/ft^2 (2001)	$1184/m^2 (2001)
	costmtrx.ucraise	$30/ft^2 (2001)	$320/m^2 (2001)
	costmtrx.ucstrength	$30/ft^2 (2001)	$320/m^2 (2001)
	costmtrx.hrdetourco	$16.50/hour (1995)	$16.50/hour (1995)
	costmtrx.kmdetourco	$1.34/mile (1997)	$2.16/km (1997)
00, 01, 02, 06, 07, 08, 09	*costmtrx.accost*	$39,400 (2000)	$39,400 (2000)
11,12,14, 16,17, 19	*costmtrx.accost*	$13,200 (2000)	$13,200 (2000)

b) Task purpose. To populate the Pontis cost matrix table with actual data for Mn/DOT.

c) Task responsibility. Bridge administrator/Database administrator will be responsible for this task.

d) Task resources & cost. Mn/DOT bridge section has the staff expertise. Updating the tables can be done quickly (about one hour). However, Mn/DOT should allocate 2-3 person days to this task to allow for documenting the processes, for running the Pontis improvement module, and for interpreting results.

e) Schedule of tasks. The task is done once upon receipt of the research results.

Task 2. Update Pontis ***expactc****,* ***expcondu****,* ***expcnduc****, and* ***expactn*** *Tables*

a) Task description. This task updates the expert elicitation table with unit cost factors derived form contracted bridge maintenance. Import expert.dmp file into Pontis database. Mn/DOT bridge managers can use the import facility from Oracle to import four expert elicitation tables that contains unit costs and transition probabilities into the Pontis database.

b) Task purpose. To populate the Pontis expert elicitation table.

c) Task responsibility. Tom Davidson (Mn/DOT) worked with the researchers to import the expert.dmp in June 2003. He has the expertise for implementing these results into Mn/DOT's Pontis database.

d) Task resources & cost. No special equipment is required. Mn/DOT bridge section has the staff expertise.

e) Schedule of tasks. The task is done once upon receipt of the research results.

Task 3. Run Pontis Cost Interface program to update Pontis ***expactc*** *Table*

a) Task description. The *Pontis Cost Interface* program uses data from the WMS to estimate cost of maintenance actions performed by maintenance crews. Run the *Pontis Cost Interface* program and use the results to update the Pontis **expactc** table.

   The *Pontis Cost Interface* program is written in Visual Basic .NET programming language. The .NET framework must be installed. The *Pontis Cost Interface* program requires read/write access to the Pontis database. The program prompts for user name and password for the database as needed by the queries.

   Step 1. Install the Microsoft NET framework. With connection to the Internet, go to http://windowsupdate.microsoft.com and click on 'scan for updates' link. Windows Update will then determine if there are updates available for that particular computer. Check all updates being recommended, if .NET Framework is not currently installed it will be available as a download.

   Step 2. Install the *Pontis Cost Interface* program by copying the *PontisInterface.exe* file onto the hard drive. The program is compiled into one executable file. Place the executable file anywhere in the hard drive; making sure it is accessible to the user. The program may also be run directly from the CD.

   Step 3. Run the *Pontis Cost Interface* program (*PontisInterface.exe*). From the Windows **Start Menu**, choose the **Run** and select *Pontis Cost Interface* or type in E:\pontisinterface.exe (assuming E: is the drive letter of the CD drive).

b) Task purpose. To generate estimated costs for maintenance actions performed by maintenance crews in the districts, and then load these costs into the Pontis ***expactc*** table for use by the Pontis preservation optimization model.

c) Task responsibility. Step 1 requires Administrator privilege on the Windows computer. . The Mn/DOT Pontis BMS administrator can be responsible for Steps 2 and 3.

d) Task resources & cost. Staff resources are required.

e) Schedule of tasks. Steps 1 and 2 are done once, before the program is run for the first time. Steps 3 and 4 are performed as needed to keep the Pontis database updated with maintenance cost values.

Measures to Evaluate Benefits

The expected benefits of implementing the research results are reduced long-term maintenance costs for bridges, improved forecasting of maintenance needs, and identification of minimum cost maintenance policies, and development of preservation and improvement program plans that are consistent and defensible. These expected benefits may be expressed in terms of performance measures for the Mn/DOT bridge programs.

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Appendix A
Responsible Party for Performing Maintenance Actions and Estimated Unit Cost for Maintenance Actions Performed by Contractors

Table A-1 Responsible party for maintenance including estimated cost of maintenance actions performed by contractors

ELEM NUM	Element	Pontis Maintenance Action (Condition State)	Maint. Crew (W) Contract (C)	Unit Cost ($)	Cost Year
106	Girder: Steel, Unpainted	Clean and Paint (2,3)	C	95/LF	2001
106	Girder: Steel, Unpainted	Rehab Unit (4)	C	95/LF	2001
106	Girder: Steel, Unpainted	Replace Unit (4)	C	492/LF	1997
107	Girder: Steel Paint Type A	Surface Clean (1,2)	W	LF	
107	Girder: Steel, Paint Type A	Surface Clean & Restore Top Coat of Paint (2)	C	41/LF	1997
107	Girder: Steel, Paint Type A	Spot, Blast, Clean and Paint (3,4)	C	51/LF	1997
107	Girder: Steel, Paint Type A	Replace Paint System (4)	C	95/LF	2001
107	Girder: Steel Paint Type A	Major Rehab Unit (5)	C	95/LF	2001
107	Girder: Steel Paint Type A	Replace Unit (5)	C	492/LF	1997
109	Girder: Prestressed Concrete	Seal Cracks Minor Patch (2)	W	LF	
109	Girder: Prestressed Concrete	Clean Steel & Patch, (and/or Seal) (3)	W	LF	
109	Girder: Prestressed Concrete	Rehab Unit (4)	C	204/LF	1997
109	Girder: Prestressed Concrete	Replace Unit (4)	C	825/LF	2001
110	Girder: Reinforced Concrete	Seal Cracks Minor Patch (2)	W	LF	
110	Girder: Reinforced Concrete	Clean Rebar & Patch, (and/or Seal) (3)	W	LF	
110	Girder: Reinforced Concrete	Rehab Unit (4)	C	204/LF	1997
110	Girder: Reinforced Concrete	Replace Unit (4)	C	476/LF	1997
234	Pier Cap: Reinforced Concrete	Seal Cracks Minor Patch (2)	W	LF	
234	Pier Cap: Reinforced Concrete	Clean Rebar & Patch, (and/or seal) (3)	W	LF	
234	Pier Cap: Reinforced Concrete	Rehab Unit (4)	C	240/LF	2001
234	Pier Cap: Reinforced Concrete	Replace Unit (4)	C	1,528/LF	1997
373	Hinge Assembly: Steel, Painted	Surface Clean (2)	W	EA	
373	Hinge Assembly: Steel, Painted	Spot, Blast, Clean and Paint (3)	W	EA	
373	Hinge Assembly: Steel, Painted	Replace Paint System (4)	C	500/EA	2001

ELEM NUM	Element	Pontis Maintenance Action (Condition State)	Maint. Crew (W) Contract (C)	Unit Cost ($)	Cost Year
373	Hinge Assembly: Steel, Painted	Major Rehab Unit (5)	C	500/EA	2001
373	Hinge Assembly: Steel, Painted	Replace Unit (5)	C	EA	?
205	Column/Pile Extension: Reinforced Concrete	Seal Cracks Minor Patch (2)	W	EA	
205	Column/Pile Extension: Reinforced Concrete	Clean Rebar & Patch, (and/or Seal) (3)	W	EA	
205	Column/Pile Extension: Reinforced Concrete	Rehab Unit (4)	C	3,000/EA	2001
205	Column/Pile Extension: Reinforced Concrete	Replace Unit (4)	C	5,095/EA	1997
210	Pier Wall: Reinforced Concrete	Seal Cracks Minor Patch (2)	W	LF	
210	Pier Wall: Reinforced Concrete	Rehab Unit (4)	C	1,200/LF	2001
210	Pier Wall: Reinforced Concrete	Replace Unit (4)	C	3,342.LF	2001
215	Abutment: Reinforced Concrete	Seal Cracks Minor Patch (2)	W	LF	
215	Abutment: Reinforced Concrete	Clean Rebar & Patch, (and/or Seal) (3)	W	LF	
215	Abutment: Reinforced Concrete	Rehab Unit (4)	C	320/LF	2001
215	Abutment: Reinforced Concrete	Replace Unit (4)	C	LF	?
387	Wingwall: Abutment	Patch Spalls, Seal Cracks (2)	W	EA	
387	Wingwall: Abutment	Patch Spalls (3)	W	EA	
387	Wingwall: Abutment	Rehab Unit (3)	C	2,400/EA	2001
387	Wingwall: Abutment	Rehab Unit (4)	C	4,200/EA	2001
387	Wingwall: Abutment	Replace Unit (4)	C	EA	?
388	Wingwall: Culvert	Patch Spalls, Seal Cracks (2)	W	EA	
388	Wingwall: Culvert	Patch Spalls (3)	W	EA	
388	Wingwall: Culvert	Rehab Unit (3,4)	C	EA	?
388	Wingwall: Culvert	Replace Unit (3,4)	C	EA	?
382	Cast-In-Place Piling	Clean and Paint Shell (2)	C	300/EA	2001
382	Cast-In-Place Piling	Rehab Unit (3,4)	C	EA	?
382	Cast-In-Place Piling	Replace Unit (4)	C	EA	?

ELEM NUM	Element	Pontis Maintenance Action (Condition State)	Maint. Crew (W) Contract (C)	Unit Cost ($)	Cost Year
300	Joint: Strip Seal Expansion Joint	Patch/Reset/Clean/Joint (2)	W	LF	
300	Joint: Strip Seal Expansion Joint	Replace Gland and Patch Concrete (3)	W	LF	
300	Joint: Strip Seal Expansion Joint	Replace Joint (3)	W,C	350/LF	2001
301	Joint: Pourable Joint Seal	Clean Joint and Replace Seal (2)	W	LF	
301	Joint: Pourable Joint Seal	Clean Joint, Patch Spalls & Replace seal	W	LF	
302	Joint: Compression Joint Seal	Patch/Remove/Reseal/Clean (2)	W,C	100/LF	2001
302	Joint: Compression Joint Seal	Replace Seal and/or Patch Spalls (3)	W	LF	
310	Bearing: Elastomeric	Reset Bearings (2,3)	W	EA	
310	Bearing: Elastomeric	Replace Unit and Reset Girders (3)	W	EA	
311	Bearing: Moveable	Rehab Supports and/or Reset Bearing Devices (2)	W	EA	
311	Bearing: Moveable	Rehab Supports (3)	C	600/EA	2001
311	Bearing: Moveable	Replace Unit (3)	C	1,000/EA	2001
312	Bearing: Enclosed/Conceal	Rehab Unit (2,3)	C	1,200/EA	2001
312	Bearing: Enclosed/Conceal	Replace Unit (3)	C	2,000/EA	2001
313	Bearing: Fixed	Clean & Paint or Reset Bearings and/or Rehab Supports (2)	C	52/EA	2001
313	Bearing: Fixed	Rehab Supports or Bearings (3)	C	600/EA	2001
313	Bearing: Fixed	Replace Unit (3)	C	1,000/EA	2001
320	Approach Slab: Bituminous	Perform Mudjacking Operations (2)	W	EA	
320	Approach Slab: Bituminous	Place Overlay (3)	C	720/EA	2001
320	Approach Slab: Bituminous	Replace Unit (3,4)	C	20,000/EA	2001
321	Approach Slab: Concrete	Perform Mudjacking Operations (2)	W	EA	
321	Approach Slab: Concrete	Place Overlay (3)	C	1,728/EA	2001
321	Approach Slab: Concrete	Replace Unit (3,4)	C	20,000/EA	2001
330	Railing: Metal	Clean and Coat (2,3)	C	35/LF	2001

ELEM NUM	Element	Pontis Maintenance Action (Condition State)	Maint. Crew (W) Contract (C)	Unit Cost ($)	Cost Year
330	Railing: Metal	Rehab Unit (4)	C	110/LF	2001
330	Railing: Metal	Replace Unit (3,4)	C	110/LF	2001
331	Railing: Concrete	Seal Cracks Minor Patch (2)	W	LF	
331	Railing: Concrete	Clean Rebar & patch, (and/or Seal) (3)	W	LF	
331	Railing: Concrete	Rehab Unit (4)	C	80/LF	2001
331	Railing: Concrete	Replace Unit (3,4)	C	80/LF	2001
333	Railing: Miscellaneous, Combination	Rehab and/or Apply Surface Treatment (2)	W	LF	
333	Railing: Miscellaneous, Combination	Replace Unit (3)	C	190/LF	2001
12	Deck: Concrete, Bare	Add a Protective System (1,2)	C	6/SF	2001
12	Deck: Concrete, Bare	Repair Spalled/Delam Areas (2)	W	EA	
12	Deck: Concrete, Bare	Repair Spalled Areas (3,4)	W	EA	
12	Deck: Concrete, Bare	Repair Spalled Areas & add a Protective System on Entire Deck (3,4,5)	W, C	7/SF	2001
12	Deck: Concrete, Bare	Replace Deck (5)	C	40/SF	2001
22	Deck: Conc, Protected w/ Rigid Overlay	Repair spalls/delams (2,3,4)	W	EA	
22	Deck: Conc., Protected w/ Rigid Overlay	Replace Overlay (4)	C	1.58/SF	2001
22	Deck: Conc., Protected w/ Rigid Overlay	Replace Overlay (5)	C	2.25/SF	2001
22	Deck: Conc., Protected w/ Rigid Overlay	Replace Deck (5)	C	40/SF	2001
377	Deck: Conc., w/ Rigid Overlay & Coated Bars	Patch Spalls/Delams (2)	W	EA	
377	Deck: Conc., w/ Rigid Overlay & Coated Bars	Repair Spalled Areas (3,4)	W	EA	
377	Deck: Conc., w/ Rigid Overlay & Coated Bars	Repair Spalled Areas and add or replace Overlay (3)	C	0.90/SF	2001
377	Deck: Conc., w/ Rigid Overlay & Coated Bars	Repair Spalled Areas and add or replace Overlay (4)	C	1.58/SF	2001
377	Deck: Conc., w/ Rigid Overlay & Coated Bars	Repair Spalled Areas and add or replace Overlay (5)	C	2.25/SF	2001
377	Deck: Conc., w/ Rigid Overlay & Coated Bars	Replace Deck (5)	C	40/SF	2001
26	Deck: Conc., Protected w/ Coated Bars	Patch Spalls/Delams (2)	W	EA	

ELEM NUM	Element	Pontis Maintenance Action (Condition State)	Maint. Crew (W) Contract (C)	Unit Cost ($)	Cost Year
26	Deck: Conc., Protected w/ Coated Bars	Repair Spalled Areas (3,4)	W	EA	
26	Deck: Conc., Protected w/ Coated Bars	Repair Spalled Areas and add or Replace Overlay (3)	C	0.90/SF	2001
26	Deck: Conc., Protected w/ Coated Bars	Repair Spalled Areas and add or Replace Overlay (4)	C	1.58/SF	2001
26	Deck: Conc., Protected w/ Coated Bars	Repair Spalled Areas and add or Replace Overlay (5)	C	2.25/SF	2001
26	Deck: Conc., Protected w/ Coated Bars	Replace Deck (5)	C	40/SF	2001

Appendix B
Translation of eleno and pontworkcode fields from Bridge Maintenance table to elemkey, skey and akey fields in expactc table

Table B-1 Translation table of eleno and pontworkcode fields from Bridge Maintenance table to elemkey, skey and akey fields in expactc table

eleno	pontworkcode	elemkey	skey	akey
106	3	106	2	1
106	3	106	3	1
106	1	106	4	1
106	2	106	4	2
107	1	107	1	1
107	1	107	2	1
107	4	107	2	2
107	5	107	3	1
107	5	107	4	1
107	6	107	4	2
107	2	107	5	1
107	3	107	5	2
365	1	365	1	1
365	1	365	2	1
365	4	365	2	2
365	5	365	3	1
365	5	365	4	1
365	6	365	4	2
365	2	365	5	1
365	3	365	5	2
109	1	109	2	1
109	2	109	3	1
109	3	109	4	1
109	4	109	4	2
234	1	234	2	1
234	2	234	3	1
234	3	234	4	1
234	4	234	4	2
205	1	205	2	1
205	2	205	3	1
205	3	205	4	1
205	4	205	4	2
210	1	210	2	1
210	2	210	3	1
210	3	210	4	1
210	4	210	4	2
215	1	215	2	1
215	2	215	3	1
215	3	215	4	1
215	4	215	4	2
387	1	387	2	1
387	2	387	3	1
387	3	387	3	2
387	3	387	4	1
387	4	387	4	2
388	2	388	2	1
388	1	388	3	1
388	3	388	3	2

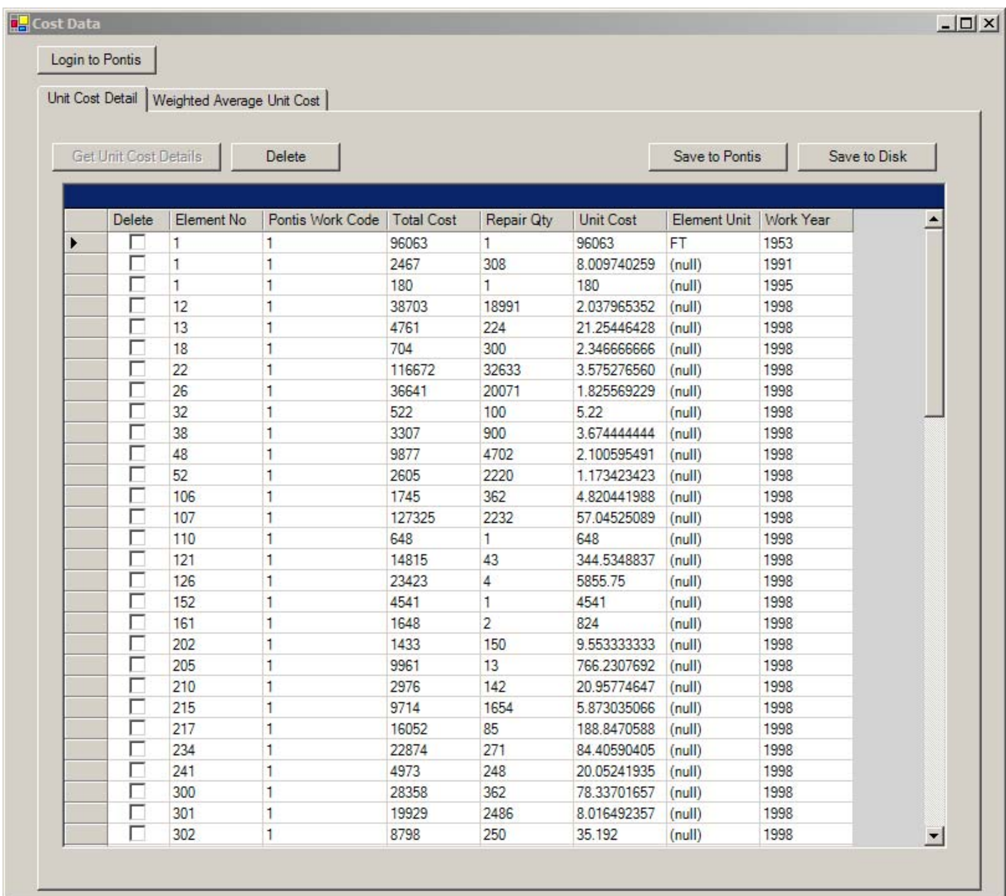
eleno	pontworkcode	elemkey	skey	akey
388	3	388	4	1
388	4	388	4	2
240	1	240	2	1
240	1	240	3	1
240	1	240	4	1
240	2	240	4	2
241	1	241	2	1
241	1	241	3	1
241	1	241	4	1
241	2	241	4	2
382	1	382	2	1
382	1	382	3	1
382	2	382	3	2
382	1	382	4	1
382	3	382	4	2
300	1	300	2	1
300	2	300	3	1
300	3	300	3	2
301	1	301	2	1
301	2	301	3	1
302	1	302	2	1
302	2	302	3	1
302	2	302	3	2
303	1	303	2	1
303	1	303	3	1
303	2	303	3	2
310	1	310	2	1
310	1	310	3	1
310	2	310	3	2
311	1	311	2	1
311	2	311	3	1
311	3	311	3	2
312	1	312	2	1
312	1	312	3	1
312	2	312	3	2
313	1	313	2	1
313	2	313	3	1
313	3	313	3	2
320	1	320	2	1
320	2	320	3	1
320	3	320	3	2
320	4	320	4	1
321	1	321	2	1
321	2	321	3	1
321	3	321	3	2
321	4	321	4	1
330	1	330	2	1
330	1	330	3	1
330	3	330	3	2
330	2	330	4	1
330	3	330	4	2

eleno	pontworkcode	elemkey	skey	akey
331	1	331	2	1
331	2	331	3	1
331	3	331	4	1
331	4	331	4	2
333	1	333	2	1
333	1	333	3	1
333	2	333	3	2
12	1	12	1	1
12	1	12	1	2
12	3	12	2	1
12	1	12	2	2
12	4	12	3	1
12	5	12	3	2
12	4	12	4	1
12	5	12	4	2
12	4	12	5	1
12	2	12	5	2
22	1	22	1	1
22	1	22	1	2
22	1	22	2	1
22	1	22	2	2
22	1	22	3	1
22	1	22	3	2
22	1	22	4	1
22	2	22	4	2
22	2	22	5	1
22	3	22	5	2
377	1	377	1	1
377	1	377	2	1
377	1	377	2	2
377	2	377	3	1
377	3	377	3	2
377	2	377	4	1
377	3	377	4	2
377	2	377	5	1
377	4	377	5	2
26	1	26	1	1
26	1	26	1	2
26	1	26	2	1
26	1	26	2	2
26	2	26	3	1
26	3	26	3	2
26	2	26	4	1
26	3	26	4	2
26	2	26	5	1
26	4	26	5	2

Appendix C
User Manual for Pontis Cost Interface Program

The interface for the *Pontis Cost Interface* program consists of two tabs each with a data grid: Unit Cost Detail tab, and Weighted Average Unit Cost tab. Figure C-1 shows the Unit Cost Detail tab. On the Unit Cost Detail tab, there are Get Unit Cost Details, Delete, Save to Disk, and Save to Pontis buttons. Click on the Login to Pontis button and fill in the user name, password, and the host string of the Pontis database to make the connection and gain access to the database. After the user logs into Pontis, then the Get Unit Cost Details button is enabled. The Get Unit Cost Details button queries the Bridge Maintenance table and displays in the data grid the element number, Pontis Worktype code, repair quantity(ies), unit cost, and work year for each Pontis work maintenance being done. This data can be used to compute the average cost for each maintenance activity.

The Save to Disk button provides the ability to save the values in the data grid to a file with an .xls extension. This enables further analysis by the user. The *.xls file is a tab-separated-value text file that can be opened with Microsoft Excel or other spreadsheet program. Clicking the Save to Disk button creates a file named C:\ MNDOT_WMS_PONTIS_ACTIONS.xls

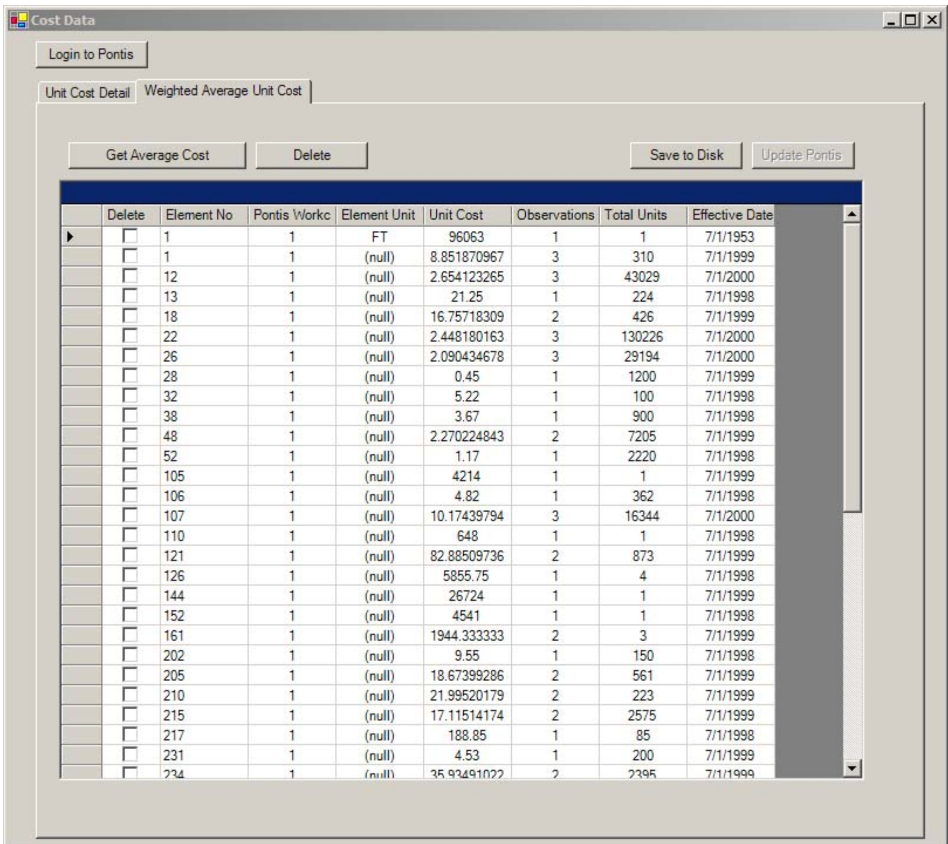


Delete	Element No	Pontis Work Code	Total Cost	Repair Qty	Unit Cost	Element Unit	Work Year
	1	1	96063	1	96063	FT	1953
	1	1	2467	308	8.009740259	(null)	1991
	1	1	180	1	180	(null)	1995
	12	1	38703	18991	2.037965352	(null)	1998
	13	1	4761	224	21.25446428	(null)	1998
	18	1	704	300	2.346666666	(null)	1998
	22	1	116672	32633	3.575276560	(null)	1998
	26	1	36641	20071	1.825569229	(null)	1998
	32	1	522	100	5.22	(null)	1998
	38	1	3307	900	3.674444444	(null)	1998
	48	1	9877	4702	2.100595491	(null)	1998
	52	1	2605	2220	1.173423423	(null)	1998
	106	1	1745	362	4.820441988	(null)	1998
	107	1	127325	2232	57.04525089	(null)	1998
	110	1	648	1	648	(null)	1998
	121	1	14815	43	344.5348837	(null)	1998
	126	1	23423	4	5855.75	(null)	1998
	152	1	4541	1	4541	(null)	1998
	161	1	1648	2	824	(null)	1998
	202	1	1433	150	9.553333333	(null)	1998
	205	1	9961	13	766.2307692	(null)	1998
	210	1	2976	142	20.95774647	(null)	1998
	215	1	9714	1654	5.873035066	(null)	1998
	217	1	16052	85	188.8470588	(null)	1998
	234	1	22874	271	84.40590405	(null)	1998
	241	1	4973	248	20.05241935	(null)	1998
	300	1	28358	362	78.33701657	(null)	1998
	301	1	19929	2486	8.016492357	(null)	1998
	302	1	8798	250	35.192	(null)	1998

Figure C-1 Unit Cost Detail tab with example list of unit costs

The Delete column provides the ability to delete the corresponding data row. By clicking the Delete button, the rows with the Delete column checked will be removed from the display. The remaining rows in the Unit Cost Detail data grid will be used to calculate average unit costs for each maintenance action in the Weighted Average Unit Cost tab.

Figure C-2 shows the Weighted Average Unit Cost tab including Get Average Cost, Delete, Delete, Save to Disk, and Update Pontis buttons. The Get Average Cost button uses the data in the Unit Cost Detail tab to calculate the weighted average unit cost for each element and Pontis workcode. Clicking the Get Average Cost button displays the element number, Pontis Workcode and unit cost for each of the cost estimates on the data grid, it will also display the number of unit costs being averaged (observations), the total number of units being repaired, and the cost year. The Delete column provides the ability to delete the corresponding data row. By clicking the Delete button, the rows with the Delete column checked will be removed from the display. Clicking the Save to Disk button saves the displayed unit cost table by creating a file named C:\ AVG_UNITCOST_FROM_PONTIS.xls.



Delete	Element No	Pontis Workc	Element Unit	Unit Cost	Observations	Total Units	Effective Date
	1	1	FT	96063	1	1	7/1/1953
	1	1	(null)	8.851870967	3	310	7/1/1999
	12	1	(null)	2.654123265	3	43029	7/1/2000
	13	1	(null)	21.25	1	224	7/1/1998
	18	1	(null)	16.75718309	2	426	7/1/1999
	22	1	(null)	2.448180163	3	130226	7/1/2000
	26	1	(null)	2.090434678	3	29194	7/1/2000
	28	1	(null)	0.45	1	1200	7/1/1999
	32	1	(null)	5.22	1	100	7/1/1998
	38	1	(null)	3.67	1	900	7/1/1998
	48	1	(null)	2.270224843	2	7205	7/1/1999
	52	1	(null)	1.17	1	2220	7/1/1998
	105	1	(null)	4214	1	1	7/1/1999
	106	1	(null)	4.82	1	362	7/1/1998
	107	1	(null)	10.17439794	3	16344	7/1/2000
	110	1	(null)	648	1	1	7/1/1998
	121	1	(null)	82.88509736	2	873	7/1/1999
	126	1	(null)	5855.75	1	4	7/1/1998
	144	1	(null)	26724	1	1	7/1/1999
	152	1	(null)	4541	1	1	7/1/1998
	161	1	(null)	1944.333333	2	3	7/1/1999
	202	1	(null)	9.55	1	150	7/1/1998
	205	1	(null)	18.67399286	2	561	7/1/1999
	210	1	(null)	21.99520179	2	223	7/1/1999
	215	1	(null)	17.11514174	2	2575	7/1/1999
	217	1	(null)	188.85	1	85	7/1/1998
	231	1	(null)	4.53	1	200	7/1/1999
	234	1	(null)	35.93491022	2	2395	7/1/1999

Figure C-2 Weighted Average Unit Cost screen

The Update Pontis button updates the unitcost field in the Pontis expactc table with the values shown in the Unit Cost field in the data grid on the tab.