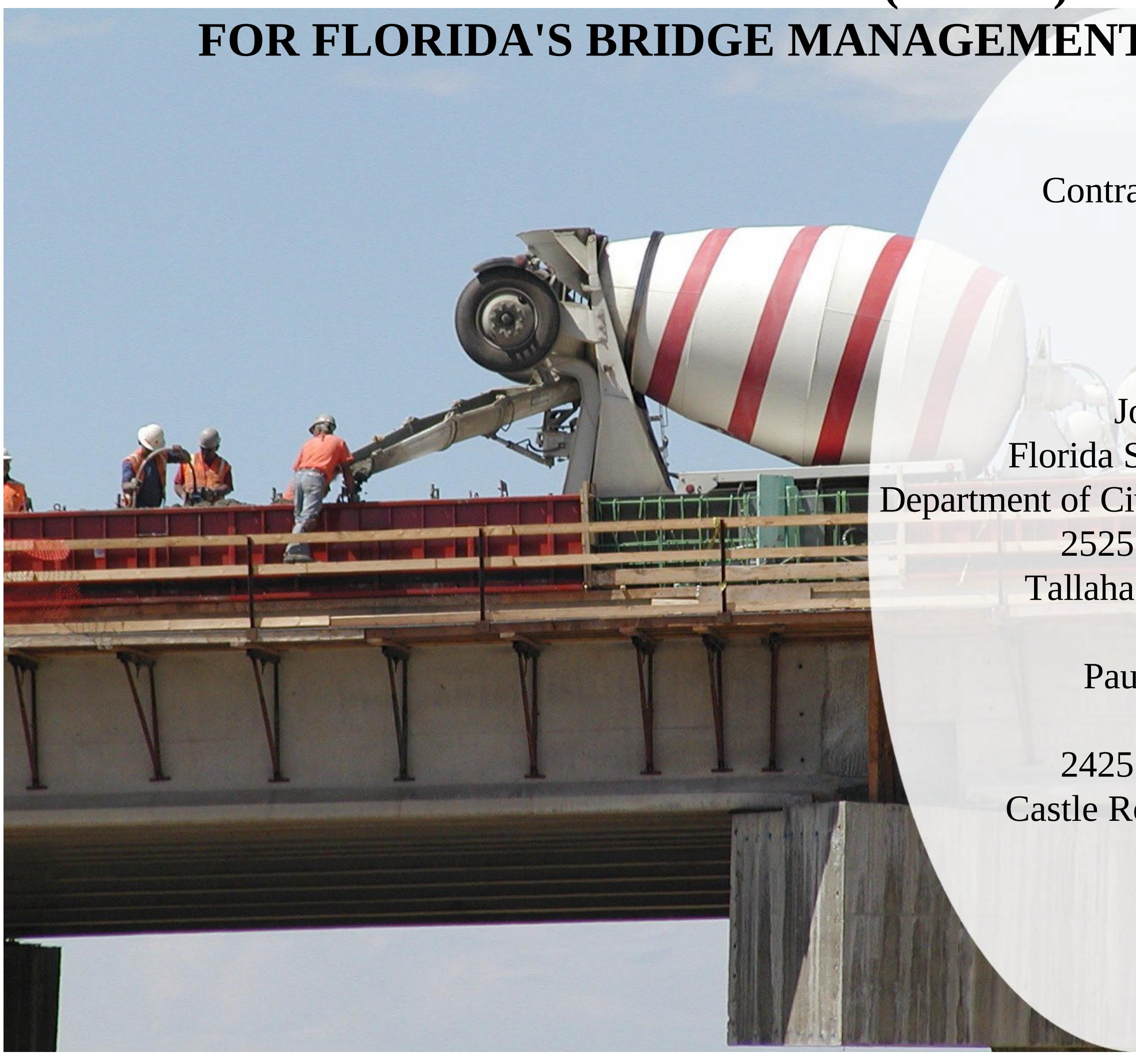
FINAL REPORT

DEVELOPMENT OF AGENCY MAINTENANCE, REPAIR & REHABILITATION (MR&R) COST DATA FOR FLORIDA'S BRIDGE MANAGEMENT SYSTEM



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16. Abstract

Florida State University and Paul D. Thompson were engaged by the Florida Department of Transportation (FDOT) to develop agency cost models and deterioration models for Florida's implementation of the AASHTOWare Pontis® Bridge Management System. The two-year study analyzed three existing information systems on maintenance and construction history, and supplemented it with the judgment of a panel of experts from the districts and head office. The results were delivered in electronic form for import into the Pontis database.

The expert panel proved essential to the completion of the study. Although the panel found the computerized data to be useful for 70% of the actions considered, only 50% of them had a statistically significant sample, and only 15% were usable directly from a statistical analysis. The main issues concerning usability of the automated data were differences in data collection units, and differences or uncertainties in the scope of recorded actions. The report includes recommendations for improvements in the automated systems to enhance the usability of the data in future updates of the agency cost model.

Like most state DOTs, FDOT lacked historical data for development of Pontis transition probabilities. Therefore, an expert elicitation process was used. A panel of district and head office engineers was asked a series of structured questions about deterioration, and their answers were converted to transition probabilities using a statistical process recommended in the Pontis Technical Manual.

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METRIC CONVERSIONS

ft x 0.3048 = m

ft^2 x 0.09290 = m^2

yd^2 x 0.000008361 = m^2

yd^3 x 0.7646 = m^3

DISCLAIMER

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Florida Department of Transportation (FDOT) is implementing the AASHTOWare Pontis® Bridge Management System (BMS) as a decision support tool for planning and programming maintenance, repairs, rehabilitation, improvements, and replacement for more than 6,000 bridges on the state highway network. A BMS stores inventory and inspection data in a database, and uses engineering and economic models to predict the possible outcomes of policy and program decisions.

Agency cost data are necessary for a functional BMS. Agency, or FDOT costs typically include direct costs of construction and maintenance, such as labor, materials, and equipment usage; and indirect costs such as maintenance of traffic and engineering. This study has provided the agency cost input, and the methodology to routinely determine the agency cost input, required for the use of Pontis. In addition, the project developed Pontis deterioration models based on the judgment of district and head office bridge engineers.

FDOT selected Florida State University (FSU), with subcontract support from Paul D. Thompson, to analyze the applicability of the Pontis model to Florida and to customize it as needed so it will work effectively in support of FDOT decision-making. The two-year project included a detailed analysis of the Pontis model, an extensive review of literature on agency costs for bridges and related topics, a search of Florida-specific data to quantify the model, and the development of a new agency cost model for Florida bridges. With Pontis, there is a finite number of combinations of bridge element, environment, condition, and feasible action. A numeric index (MR&R Action Subcategory) was used to group those unique combinations in a way that simplified the process of determining unit costs. This study focused on providing the agency cost data for the selected MR&R Indices that were applicable to Florida's BMS.

FDOT has three excellent sources of historical project data that were relied upon for preliminary unit cost estimates. A rather elaborate statistical analysis was required in order to extract useful numbers from the available data sources. An expert review process proved essential to the successful development of final costs. The panel of experts identified weaknesses in the available data, reconciled conflicting results from the several data sources, and provided insights that filled in the many data gaps that were found. Only 50 percent of the Pontis actions were covered with a statistically significant number of data points in any of the three FDOT information systems, and only 15 percent of the Pontis actions ended up using the results from one of the information systems directly. About 70 percent of the Pontis actions had relevant data from FDOT systems, in terms of being helpful in the considerations of the panel experts, including data that were adjusted, or used directly for the final results. These also included some relevant data that were recorded in units incompatible with those of the Pontis actions. This does not reflect on the quality of the existing FDOT systems, since it was impossible to judge the quality of data collection and processing from this perspective. One of the biggest problems was the inability to match the scope of activities in the FDOT databases, to Pontis elements, condition states, and actions.

This problem also influences the recommended strategy for keeping unit cost numbers up-to-date over time. Other than periodic use of Pontis’ built-in inflation feature, it is clear that it will not soon be possible to substantially automate major updates to the unit cost models. Certain enhancements to the three FDOT project information systems may lead to the possibility of partial automation in the future, but it is likely that an expert review will still be required. The implementation strategy in this report addresses possible approaches to improving the ability to update agency unit costs. The final costs are included.

The deterioration model was added to the project scope during the course of the study. An expert elicitation process was used to generate the source data, following the recommended Pontis procedure. An Excel spreadsheet model was used to prepare questionnaires and to process the results into Pontis transition probabilities. These were then delivered to FDOT for import into the Florida Pontis database.

1. Research Background

1.1. Introduction

This section of the report presents a brief introduction to the research project and the results of the initial task: literature review and questionnaire, to document the current status of knowledge both in terms of research activities and industry practice in the area of agency cost study for bridge management systems.

The aging and decay of the nation's transportation facilities led to the recent development of management systems for bridge maintenance and rehabilitation, or simply BMS. A BMS allows transportation agencies to perform economic analyses on a large number of bridges in order to establish priorities and to make preliminary selection of maintenance and rehabilitation options. A BMS includes a database and active program for collecting and maintaining bridge element and condition data, along with tools to analyze network-level target funding levels, to identify and describe bridge maintenance needs, and to provide information needed for the development of cost-effective programs for bridge maintenance, rehabilitation, and repair (MR&R).

The Florida Department of Transportation (FDOT) is implementing the AASHTOWare Pontis® BMS as a decision support tool for planning and programming maintenance, repairs, rehabilitation, improvements, and replacement for more than 6,000 bridges on the state highway network. Pontis resulted from an FHWA-sponsored study to develop a BMS flexible enough to be usable by most transportation agencies in the United States.

Pontis considers bridges as being composed of elements. Elements are bridge components that are essential from the standpoint of structural performance and cost. Examples of elements are decks, girders, bearings, and joints. Pontis uses condition states to identify the type and extent of deterioration. Based on the bridge element's condition state and environment, a set of feasible MR&R actions are considered. Pontis estimates the cost of these actions by use of network-level unit costs, expressed according to the same unit quantities as are used in bridge inspection.

1.2. Literature Search and Review

The literature review was started with a computerized search of the university libraries' catalogs including databases such as the Applied Science and Engineering, Compendex and Engineering Index, and the Elsevier Science Journals. Also utilized in the search was the Online Computer Library Center (OCLC) through First Search services (Dissertation Abstracts). Various search engines were also utilized to search the Internet for related documents, including Internet-based libraries maintained by the Federal Highway Administration (FHWA) and the United States Department of Transportation (USDOT), i.e., the National Transportation Library and the Transportation Research Information Service (TRIS). In addition to the literature sources mentioned above, individuals were also contacted by telephone and email at various universities and government agencies, to inquire about their experience regarding collection and analysis of agency cost data on bridge MR&R actions.

Many of the identified works in the area of bridge maintenance or rehabilitation costs were found to be related to the formulation of economic models, particularly, life-cycle cost models for bridges. A significant number of literature sources were found, related to bridge cost data collection and analysis, but only relatively few sources were identified as being related directly to the collection and analysis of agency unit cost data compatible with the Pontis BMS software requirements.

Despite being about five years old, perhaps the most revealing and reliable document about the status of efforts by the various agencies towards the collection and analysis of agency cost data for BMS is NCHRP Synthesis 227 [Thompson and Markow 1996]. This report is based on an extensive literature review and results of a set of questionnaires distributed to U.S. transportation agencies.

Prior to the NCHRP Synthesis 227, notable efforts on the collection and analysis of general bridge costs are mentioned in NCHRP Synthesis 227, including Wipf et al. [1987], James et al. [1993], Saito and Sinha [1980, 1989]. About the same time (1994 - 1996) as the NCHRP 227 project, the following concurrent documented efforts were identified: Gannon et al. [1995], Abed-Al-Rahim and Johnston [1995], and Van Lund [1995]. After the NCHRP 227, pertinent documented efforts on the collection and analysis of bridge cost data include: Elzarka et al. [1996], Chengalur-Smith et al. [1997], Appleman [1997], Adams and Sianipar [1998], and Adams and Barut [1998]. Chengalur-Smith et al. [1997] and Appleman [1997] were relevant but not particularly on cost data compatible with Pontis. Elzarka et al. [1996] documents a study by Clemson University to develop a national database of bridge management system unit costs for maintenance, repair, and rehabilitation. Also identified during the literature search were unpublished efforts including Ph.D. dissertations and information obtained through telephone conversations with US-based experts familiar with the agency costs of bridge MR&R.

One recent documented effort directly related to developing agency unit costs of bridge MR&R actions which are compatible with the Pontis software, is the Wisconsin DOT study (Principal Investigator: Teresa Adams, University of Wisconsin) as partially reported by Adams and Sianipar [1998], and Adams and Barut [1998].

Another relevant ongoing study is underway at the Iowa Department of Transportation. The methodology was presented in a poster session at the 8th International Bridge Management Conference in Denver, April 1999, but no paper was published.

Related efforts are currently underway in Ontario and Switzerland to develop agency cost information for BMS. The Swiss effort is only at the conceptual stage so far, as described in Ludescher and Hajdin [1999]. The Ontario study uses element-level condition data to define a project scope of work, but develops cost estimates based on a list of “tender items” (bid or pay items) for each project, not broken out at the element level. By performing this analysis for one or more “typical” projects involving just one element, then dividing by element quantities, Ontario develops an element-level “benchmark cost.” The methodology is described in Thompson et.al. [1999]. Ontario’s project-level cost estimation methodology, because of its focus on tender items, would not fit the network-level orientation of Pontis. However, the source data in Ontario is organized in a manner very similar to the available sources in Florida. Ontario’s system is very good in its accounting for indirect costs such as maintenance of traffic and environmental protection. A similar methodology would be quite appropriate for FDOT’s project-level modeling system.

Agency cost data reported in the various studies, can generally be classified as follows: contract bid tabulations; contract bid tabulations supplemented with expert opinions; actual cost data (historical); actual cost data (historical) supplemented with expert opinions; and cost data based entirely on expert opinions. These agency cost studies have been either for state-level or national-level cost data collection. Most agencies have difficulty utilizing their historical cost data as-is because of many factors including its incompatibility with the direct requirements of the Pontis BMS. There is also a need to adjust cost estimates for geographic location and time factors.

Information about the most relevant studies is presented in the following sections. First the NCHRP 227 Synthesis is discussed, followed by a mention of some selected efforts prior to or going on at the time of the effort reported in the Synthesis. Finally, recent efforts after the Synthesis are presented in terms of both published and unpublished (dissertations and telephone conversations) documents.

NCHRP 227 Synthesis [Thompson and Markow 1996]

With the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) as a background for justification, this report presented the state of current practice on cost data collection and management for bridge management systems. Despite the recent National Highway System Act of 1997, which removed the mandate on the states to develop BMS, most states are still going ahead with their efforts to develop and maintain a BMS.

This synthesis of the current state of practice was based primarily on a literature review and a comprehensive survey of state transportation agencies through a set of questionnaires. The main conclusion in this report was that:

“Few state departments of transportation (DOTs) have adequate data on which to base their bridge management system cost estimates, few monitor actual expenditures in order to validate their estimation procedures at the system wide level, and many DOTs have no organizational mechanisms or systems in place to uncover and solve problems in cost estimation.”

It was revealed that at the time of this study (1994 - 1996):

- Cost data issues of a BMS were not a focus or priority of most researchers or agencies.

- Quality of cost data is now the greatest determining factor in improving bridge management.
- Cost data management practices vary widely among the states.
- Most of the agencies were dissatisfied with their ability to provide unit costs to their BMS, with the least satisfied states being those with already established cost-related planning models on a system wide basis.
- Only a few states collect unit cost data on maintenance, repair, and rehabilitation (MR&R) at the bridge element and action level, especially as required by the Pontis software. Though many state agencies have reliable data on bridge replacement costs, only a few have reliable data on bridge maintenance costs. The existing maintenance management systems and contract management systems, though with good quality data, did not specifically cover bridge work.

NCHRP 227 addresses cost data requirements, data collection, cost-estimation, and the development of network-level models for bridge management systems. The synthesis establishes a context for the application of cost models and the strict definitions of terms and assumptions inherent in economic quantities. The report starts by describing the structure of BMS cost data and requirements in terms of network-level agency unit costs, project-level- agency unit costs, agency cost components, user costs, user cost components, and the desired attributes of cost models. A literature review was presented with short descriptions of each of twelve examples of previous efforts done to develop agency cost data for bridge maintenance or construction, and user costs data. A survey was prepared in the form of a 20-page questionnaire, and distributed to 50 states, the District of Columbia, and Puerto Rico. The response to the survey was reasonable; 35 respondents (including 33 state DOTs) out of 52 agencies.

The synthesis considered the use of project-level estimation as a source of cost models for BMSs. Most cost estimation capabilities at DOTs are at the project level, rather than at the desired network level for a BMS. The availability of cost data management procedures in the various states were presented in terms of work done by contract or by the agency's own forces. For contract work, there was no state responding to the survey that indicated availability of cost data at the bridge Element/Condition State/Action level. Less than one-quarter of the states indicated cost availability linking each action to a specific project, bridge, element, or element condition state. For the work done by state forces, the availability of compatible cost data was similarly low.

The survey also revealed that from the 33 reporting state DOTs, eight states have contract maintenance cost data on all (100%) of the state-owned bridges while eight also have similar data from force account or day labor sources, on almost all (90% to 100%) of their state-owned bridges. Element-level data were available in 10 states for contract maintenance costs and available in 12 states for force account or day labor maintenance costs. The cost was available in a computerized form for most of the states responding, for contract maintenance but only in a third of the states, for force account or day labor cost of maintenance.

Network-level analyses of costs, according to the NCHRP 227, are useful for comparing predicted policy outcomes against actual results, hence helping managers with their decision process for bridge investments. The unit costs of agency actions for new bridge construction, rehabilitation, maintenance, and replacement should be consistent with the objective, scope, and use of network-level analyses. Unit costs should represent, as closely as possible, the full costs of an activity or a project. Furthermore, they should reflect accurately the relative costs among a set of competing activities to address a problem or deficiency. Unit costs need to be sufficiently accurate for investigating management and investment options. A comprehensive set of unit costs also contributes to a management system's ability to provide feedback on the effectiveness of policy decisions. The trends in unit cost among different bridge activities can capture the effects of changes in local economic conditions, resources available, engineering standards, regulatory requirements and advances in technology. Since the network-level analyses often presume a life-cycle analysis, preventive as well as corrective treatments can be included in the definition of unit costs.

The synthesis indicated that network-level unit costs of bridge MR&R need to be broad in scope but how they satisfy this criterion depends on how bridge management or investment policies are represented. One approach defines separate unit costs for activities to prevent or correct particular types of deficiencies and materials-related problems, such as corrosion. Unit costs can be developed for activities as listed in the following examples:

Sealing a deck or applying corrosion inhibitor, $/sq. m;
Replacing bridge railing, $/m;
Lubricating bearings, $/bearing.

A BMS predicated on this approach would need not only the unit costs of MR&R activities and projects to address individual deficiencies, but also corresponding decision rules and models of impacts or consequences of these actions. For each of the MR&R activities, decision rules govern when the activity should take place, and the degree of repair. While this approach requires work to develop the unit cost data and models for each activity, it is advantageous in its ability to evaluate a wide range of options and tradeoffs.

A second approach is to choose one or two categories of deficiencies as the dominant ones, and develop unit costs only for relevant preventive or corrective activities. This approach depends on an agency's design and construction practices, and on historical observations of the performance of its bridges. This approach identifies the most common and dominant source of deterioration on its bridges, and then defines the unit cost for the activity. This approach is advantageous in its simplicity, but fewer tradeoffs can be analyzed.

A third approach is to develop composite costs that represent a combined set of activities based on historical experience with particular combinations of bridge structure materials. An example of this approach is the unit cost of deck work that includes patching, overlaying, and corrosion prevention or repair in a single, composite cost. While this approach is simpler, reflective of current practices, technology, and factors affecting bridge performance, it limits the tradeoffs that can be studied.

Project-level analyses explore in detail the alternatives in performing major maintenance, repairs, rehabilitation, or reconstruction of a particular bridge. These analyses are site specific, targeting individual bridges rather than groups of bridges or bridge elements. Project-level analyses also contribute to technical studies such as, predictions of remaining service life, data supporting structural capacity analyses, or development of concepts or data to be used in project design. Project-level unit costs generally must consider dis-aggregation of unit costs, site-specific information, coordination of work, and consistency with project-level review. Since the project-level analysis deals with an individual bridge as an entity, it is able to deal with various components and elements in an integrated, coordinated way.

Agency cost components encompass the total costs of performing bridge maintenance activities or construction projects, whether analyzed at the network or project levels. Force account work is work performed by the agency's own crew. This includes crew labor, materials and supplies consumed in work performance, equipment operating costs, and other costs such as administration, travel time to and from the site, special equipment purchases, and overhead activities. Contract work generally includes the same costs as performed by the private sector, but the information available through contracting is different from that of force account work. Agency costs also include site costs (land acquisition for right-of-way, any mobilization and demobilization to be borne by the agency, traffic control, and environmental mitigation costs) and project support costs (project planning and design, construction supervision, and inspection).

Project-level cost estimation capabilities of some kind exist in every state DOT, so they are the most obvious source of models for bridge management systems. Cost estimates follow a continuum of detail, ranging from long-range estimates used for resource planning, to planning, design, and construction budget estimates, to engineer's estimates used for contracting, and cash flow estimates for tactical management of in-house forces. The synthesis authors noted, from the survey results, that most states are not satisfied with their bridge management system's cost estimation capability. They believe that it would be cost-effective to increase the level of detail in their data gathering. Most of the states have capabilities to estimate cost components of projects, but very few have ongoing procedures to track and update cost factors that might be used for network-level or project-level cost estimates. Accuracy in cost estimation is central to the credibility of project programming and network-level bridge management systems analyses. It is also conclusive that most agencies are not capable of measuring the accuracy of their cost data. Even though costs tend to vary from one agency to another, the development of cost models for MR&R activities is usually beyond the resources of individual states.

As a result of this study, suggestions for future research included:

- Development of user cost models, MR&R unit cost models (especially for unusual elements), project-level fixed costs (such as traffic control and mobilization), and local bridge costs.
- A national scope project as an effort to collect relevant data and analyze them in network-level and project-level cost models.
- With the Clemson University's FHWA's project as a starting example, the establishment of a national clearinghouse to serve individuals and agencies involved in cost data collection and management for BMS.

- The preparation of a handbook, narrating an overview for top managers and covering enough details on the implementation of the procedure.
- Extension of the concepts developed to an integrated management approach.
- Quality guidance for managers and cost estimators on the acceptable degree of accuracy in cost estimation.

Concrete Bridge Rehabilitation Costs (SHRP Project) [Gannon et al.1995]

As results of a Strategic Highway Research Program (SHRP) project, Gannon et al. [1995] presented cost models based on statistical regression analysis, relating cost of protection and rehabilitation techniques of concrete bridges to various factors. The following seven feasible activities were considered: deck patching, deck protection systems, experimental deck protection systems, structural patching, structural protection systems, “new” deck protection systems, and “new” structural patching. The main source of data was bid tabulations from state highway and toll road agencies (12 agencies). It was proposed that appropriate components of a total cost estimate such as: engineering costs, installation costs, user costs, effects on regional economy, and environmental impact, be consistent for all the MR&R activities before a valid comparison can be made based on life-cycle cost analysis.

Variations in cost estimates were identified as due to traffic control (traffic volume related), contractor-related costs (work volume and regional business climate), and time-related change in costs (inflation or deflation). The authors mentioned the difficulty of finding an exact match of the desired cost data system both by structure and the data contents. Historical data utilized for the research was contract bid tabulations, indicating contractor’s unit costs without any details on the cost components. Visiting the transportation agencies, attempts were made to collect cost data from records of contract work (cost components -- preliminary engineering costs, maintenance and protection of traffic costs, inspection, testing and construction engineering costs, and salvage values) and work by department maintenance forces (cost components -- materials, equipment, labor and supervision, preliminary engineering, inspection, testing, construction engineering, and salvage values).

The data obtained from the transportation agencies were 829 bid tabulations for the period 1981 to 1991. Relevant standard specifications and contract special provisions were also obtained along with the data, to ensure similarities of the activities being analyzed. Attempts to collect data from maintenance records were futile, either because of unspecific cost centers established in the existing systems at the agencies, or that the information was not enough to identify the exact maintenance activity.

Engineering cost and salvage were ignored in the data collection effort for the life cycle cost model for the following reasons. First, the engineering costs were considered to be small on bridge deck repairs (a standardized operation), when compared to MR&R actions on the superstructure or substructure. Second, there were insufficient historical data on engineering costs. Third, engineering cost affects all activities in the same way (life cycle cost comparisons). Except for more experimental and new treatment techniques; the costs for the latter were estimated. Salvage was also not considered as a cost component because the disposal or resale of bridge components is usually included in contractor's bids.

The data analysis involved an adjustment of the national data estimates for geographic and inflation factors. It was necessary to convert archival cost data from different locations and times, into mid-1991 national average values. This was done using cost indexes. Cost indexes are factors utilized in cost estimating procedures to establish functional relationships between average cost (national, state), cost in a particular location (state, city), and cost for a given time (year, month). For example, in this SHRP study, a general relationship for determining national average cost is

$$N_n = [C_{a,m}] [L_a] [T_m / T_n] \quad (1.1)$$

where

N = national average cost,
C = cost in a particular city (or state),
L = geographical conversion factor for particular city (or state),
T = time conversion factor to convert to mod-1991 value,
a,b = particular cities (or states), and
m,n = particular years.

To estimate the cost $C_{a,m}$, in a particular city (or state) a and a particular year m, given the cost data $C_{,b,n}$, for another city b and year n, the following relationship is used

$$C_{a,m} = [C_{,b,n}] [L_b / L_a] [T_n/ T_m] \quad (1.2)$$

If the national average N is known, the cost $C_{a,m}$ can be estimated as

$$C_{a,m} = [N/ L_a] [T_m] \quad (1.3)$$

The location factor (L) and time factor (T), as illustrated above, were derived from R.S. Means City and Historical Cost Indexes.

Cost indexes are typically compiled by construction-related organizations to indicate variations in the cost of goods or services due to time (inflation or deflation) or geographical location. The sources of such indexes considered by this SHRP study included the following:

FHWA Federal-Aid Highway Construction Price Index,
FHWA Highway Maintenance and Operating Cost Index,
Engineering News Record (ENR) Construction Cost Index, and
R.S. Means City Construction Cost Index.

After a consideration of the various indexes, the R.S. Means Index was adopted to adjust costs for both location and time factors when applied in the various states and times (years). The FHWA indexes were found to be too highly influenced by costs of activities outside the scope of bridge MR&R. The ENR index was also determined to be less comprehensive and less complete than the R.S. Means index.

Based on literature review and expert opinions of the transportation agencies' maintenance engineers, the original seven activities were broken down into 44 more specific work items. Total data observations for all the activities were 10,820, i.e. each observation represented one bid price on each activity from one contract by one bidder. Data were then normalized by modifying pay units and adjusting for inflation and location.

An understanding of the source of data (bidding) was utilized in formulating four variables (quantity of work, number of bids, total contract costs, and maintenance and protection of traffic costs) which might influence the adjusted national cost. It was suggested that:

- As quantity increases, the unit cost decreases -- a basic relationship.
- As the ratio of traffic control costs to total contract amount increases, the unit cost increases. The cost of traffic control (in contractors' bids) is a good measure of the difficulty of a bridge repair project, especially difficulties due to poor access or remoteness of the job location. The ratio indicates how much effort is being expended on the project site activities rather than the bridge repair.
- As the number of bids increases, the unit cost decreases
- As the total contract amount increases, the unit cost decreases. Increase in contract size allows the contractor to spread the overhead and profit over more items and quantities.

These assumptions were then used to develop eight factors, which that could be responsible for variations in a cost estimate:

Factor 1 = quantity
Factor 2 = (quantity * contract amount)/Traffic Control Amount
Factor 3 = quantity * contract amount
Factor 4 = quantity * number of bidders
Factor 5 = [quantity) * (contract amount)^2]/Traffic Control Amount
Factor 6 = (quantity * number of bidders * contract amount)/Traffic Control Amount
Factor 7 = quantity * number of bidders * contract amount
Factor 8 = (quantity * number of bidders)/Traffic Control Amount

Statistical analysis of the data was done to produce regression models (recommended price equations) in the form of inverse power models, relating the estimated cost to these eight factors. For example, Item 210, Latex Modified Concrete Overlay, a Deck Protection System, has a cost model (R^2 = 0.899):

$$C = 38 - 0.0012 * (\text{Factor } 8) + 0.028/[(\text{Factor } 8)^{1.44}] \ \$/\text{SY} \quad (1.4)$$

The equation implies that the average cost of latex-modified concrete overlay is $38/SY minus a variable cost which is a function of factor 8 or quantity of the item, number of bidders, and traffic control costs. The high value of R^2 indicates a good data fit to the model. Location factors were also established for activities with unit costs varying significantly with location on the bridge, i.e. beams, piers, wingwalls, etc. For example on item 421 Shallow repairs with quick-set hydraulic mortar/concrete patches, the price equation on a bridge beam will be

[1,226/Quantity] + 65 $/SY

but the same Item 421 on pier cap will be estimated to cost

[1,398/Quantity] + 112 $/SY.

North Carolina DOT BMS Study (Abed-Al-Rahim and Johnston 1995)

This paper looks into the allocation of funding needs among the three bridge improvement alternatives of maintenance, rehabilitation, and replacement by developing new analytical procedures for estimating the costs of the bridge structure, and engineering for budgeting purposes. Methodologies were developed for predicting the new length, width, and maximum span length, which were found to affect the total cost of bridge replacement, on the basis of existing bridge and roadway characteristics. Cost indexes were used for factoring costs to the latest year.

To develop a model for bridge replacement costs, this study used data compiled by the state of North Carolina on overall bridge replacement and related costs of bridge construction. These costs on items ranging from the bridge structure to design to surveying served as the basis for establishing unit cost estimates for new bridges. The pattern for developing a comprehensive replacement cost model is to include factors such as roadway, engineering, and structure costs plus the miscellaneous costs such as right-of-way acquisition and field operations. These costs were adjusted for inflation using a linear regression model based on a ratio of the cost index for the year in which the bridge was constructed, to the cost index for the present year. The roadway approach characteristic used for developing the unit cost of the bridge structure was based on the total length, width, and maximum span of the new structure.

To develop a reasonable model for bridge replacement, it was suggested that characteristics of the new bridge that differ from the one being replaced should be predicted because they will affect the total cost of replacement.

Using NCDOT-provided cost data for 32 bridge replacement projects, unit structure cost was first computed for each bridge based on the present value of the structure construction cost, the total length, and the out-to-out width of the new bridge. Unit costs were converted to 1990 values using cost indexes. Regression models were then formulated to relate unit costs to the maximum span of the new bridge, resulting in the following equation

$$UNITSTR = 919 - 40.6[MAXSPAN] + [MAXSPAN]^2 \qquad (1.5)$$

where

UNITSTR = the structure unit cost ($\$/m^2$ of deck area), and
MAXSPAN = the maximum span length of the new bridge (m)

The lowest structure unit cost was found to occur at a maximum span of about 25 m (75 ft). The model established for the roadway construction cost was as follows:

$$ROADCOST = [177{,}900(NBWID)] - 1{,}198{,}500 \qquad (1.6)$$

where

ROADCOST = the total roadway construction cost ($), and
NBWID = the new bridge's width (m).

Regression models were also formulated to relate miscellaneous costs, total roadway improvement costs, and total engineering costs, to other variables such as the total bridge structure construction costs, the new bridge's width, and the new bridge's length. The R^2 values , indicating how the model fits the data, ranged from 0.60 to 0.7 on these models. Statistically, an R^2 value of 1.0 is considered a perfect fit while $R^2 = 0$ indicates no fit. Also using regression analyses, variable factors were developed for predicting the new length, width, and maximum span of new bridges based on the original bridge parameters, both for North Carolina and the United States

Abed-Al-Rahim and Johnston [1995] indicate that the ratio for roadway costs and miscellaneous costs as compared to the structure costs were 2.6 to 1.0 respectively. This shows that bridge replacement costs are being inflated by the costs of roadway improvements. The authors suggested that for funding purposes, a BMS should consider funding roadway improvements separately.

Clemson Study [Elzarka et al. 1996]

An FHWA-sponsored study was conducted at Clemson University to create and test a standardized cost database that would provide Pontis users with preliminary cost data [Elzarka et al. 1996]. The first phase of the research determined that some cost data have large variability (standard deviation) because of the limited amount of available data and other contributing factors. It was recommended therefore that the various states implementing BMS use the results of the first phase as a guide or starting point, instead of the data being adopted as the only cost estimate.

Each state was advised to implement a Pontis-compatible cost data collection effort. Phase II of the study developed a Data Analysis and Generation System (DAGS) for Pontis. In response to the problems identified in phase I of the study, DAGS has the capability of accounting for the factors affecting unit costs and generating Pontis-compatible unit cost data files. DAGS operates with two databases: a national database containing data collected by Clemson University; and the state database which is empty, created to accept the particular state's own cost data.

At the current state of the practice, the Clemson study is widely regarded as the only quantitative source of unit costs directly applicable to Pontis on a large scale. In fact, unit costs derived from the Clemson study are included as the default cost model in Pontis. Care should be exercised in the application of the Clemson data to Florida, however. Most actions addressed in the study have uncomfortably low sample sizes and high coefficients of variation. The Clemson report discusses these issues in detail. Also, a large number of elements are left unaddressed in the study. The DAGS methodology requires that historical or judgmental data be available in the Pontis element-level form, which in general is not the case for historical data in FDOT.

One way in which the Clemson results can be quite useful in the current study is to contribute to the validation of Florida-specific cost models. After the development of an initial set of Florida-specific unit costs, these results can be compared with the Clemson results. Where the two sets of unit costs differ significantly, an analysis of the reasons for the differences may help to clarify or improve the Florida models.

Lead-Based Paint Removal for Steel Highway Bridges [Appleman 1997]

As an update to a previous NCHRP Synthesis 176: Bridge Paint: Removal, Containment, and Disposal, this report, NCHRP Synthesis 251: Lead-Based Paint Removal for Steel Highway Bridges, assesses the state of the technology and practice for removal of lead-containing paint from highway bridges. According to this report, major efforts by transportation agencies to maintain and protect lead-coated bridges, have resulted in the following:

- New alternative strategies and materials,
- Innovative and variable approaches for contracts and specifications, and
- Increased levels of expenditure for paint removal under maintenance painting and deck rehabilitation.

A survey was conducted among agencies to estimate costs associated with lead paint removal. The unit costs (per area) varied enormously, by a factor of 10 or more, for nominally similar work. This variation is due to uncertainty factors such as the degree of containment, extent of worker protection, quality of work, degree of inspection, and overall compliance with regulations. For full removal, the unit cost ranges from less than \$32/m^2 (\$3.00/ft^2) to \$247/m^2 (\$23.00/ft^2), with a median of \$115/m^2 (\$10.70/ft^2). For overcoating, the cost range is \$12/m^2 (\$1.12/ft^2) to \$138/m^2 (\$12.80/ft^2), with a median of \$49/m^2 (\$4.56/ft^2).

Targeting 51 agencies, including state DOTs, four Canadian provinces, and seven other bridge agencies, a survey was developed and distributed to identify practices and costs for lead paint removal from bridges for the period 1993 to 1996. Responses were received from 38 agencies. The cost information was elicited in three categories: overall agency costs for bridge painting over four years; specific case histories representative of full removal, overcoating, and steel replacement; and the agency's contracting process. The detailed response to this survey and its analysis were presented in the form of tables and charts, showing variations by type of bridge structure and state DOT/agency.

In addition, this study identified the key issues regarding the strong impact of contracting practices on the quality and cost of lead paint removal. Some of the issues are listed as follows:

- Bid prices are extremely variable.
- Variability in cost and contractor's performance may be due to the excessive risk borne by the contractors for bridge painting.
- The newly competitive nature of bridge painting can affect quality as costs decrease.
- Vulnerability of contractors to claims because most of them do not have pollution liability coverage.
- Bridge agencies have shown willingness to try new alternative approaches to contracting in an innovative way, to save money.

An especially relevant conclusion from this work is a caveat on the applicability of the Clemson study or other non-Florida unit costs. Lead paint removal might not be the only repair action whose cost is extremely sensitive to agency standards and practices.

New York DOT Bridge Rehabilitation Costs [Chengalur-Smith et al. 1997]

Chengalur-Smith et al. [1997] reported an effort to model the costs of bridge rehabilitation, including activities of maintenance and replacement, on New York State bridges. The New York Department of Transportation (NYSDOT) component condition index (CCI) is used to rate the inspected or deteriorated condition of the bridge component. The scale used — 1 for worst and 7 for new — is significantly different from the Pontis or NBI scales of condition rating. This paper identified some problems associated with collection and analysis of MR&R costs for a BMS. First it was indicated that there were no historical cost data available at the NYSDOT, creating problems that could only be avoided with a system designed to collect actual cost data.

Contractors' lowest responsible bids were collected and analyzed with statistical multiple regression models and expert opinions from NYSDOT personnel. Normally, the bids are very randomly distributed even for similar bridges. The authors attempted to model the randomness or effects of using the low bids. Bid items are not usually designated by bridge component. For example, concrete for deck, superstructure, and substructure are combined into one bid item

“Concrete.” Expert opinions were used to assign such costs to the various components. The approach was considered imprecise, time-consuming, and costly. The integrity of the data utilized was questionable. Three classes of data quality were defined as follows:

Reliability 1 — very reliable: measured data
Reliability 2 — qualitative judgment of trained inspectors
Reliability 3 — estimated value using best judgment available

Only the bridge inventory data qualified for Reliability category 1. Condition state data were the only records in category 2 while the important cost data qualified for the relatively most unreliable, category 3. Regression models, patterned after Indiana’s models described in Saito et al. [1991], were used to relate total costs and unit costs (Deck, Superstructure, and Substructure) to the following variables: type of work (monolithic deck work, other deck work, superstructure and deck work); high cost region; medium cost region; minimum previous deck rating; minimum previous superstructure rating; minimum previous substructure rating; difference in minimum deck rating; difference in minimum superstructure rating; difference in minimum substructure rating; deck area; substructure area; average annual daily traffic, age, and rural road classification. The variables on condition ratings describe the condition before rehabilitation, and minimum condition to trigger rehabilitation. Some of the other variables are indicator variables (0 or 1). With coefficients of determination (R-squared) being very high, ranging from 0.94 to 0.95, the regression models (nonlinear) were developed as predictive tools for costs associated with bridge deck, superstructure, and substructure. With an adjustment using the area as a unit of measure, corresponding unit cost models were also developed for the NYSDOT.

Wisconsin DOT BMS [Adams and Sianipar 1998, Adams and Barut 1998]

A telephone conversation with Wisconsin DOT (Stan Woods 1999) indicated that a Pontis BMS implementation project is still ongoing but with no finalized cost database yet available to share. The cost data are based on expert opinions elicited by Teresa Adams of the University of Wisconsin (Principal Investigator). Since the release of the NCHRP Synthesis 227 and the Clemson study in 1996, this study is the most important documented effort identified so far on this type of work, i.e., specifically, to collect and analyze MR&R costs directly compatible with Pontis requirements at the element, condition state, and action levels of detail. The following discussion about the Wisconsin study is based primarily on the paper by Adams and Barut [1998].

As observed in most of the states [Thompson and Markow 1996], and also mentioned in the Wisconsin DOT study, there is no historical data available in a standardized format compatible with Pontis. The Wisconsin DOT study emphasized that despite the need to develop a reliable MR&R cost database for a network-level BMS, the reliable data are difficult to obtain. Wisconsin DOT developed a set of questionnaires to elicit expert opinions on the required unit costs. Starting with the ordinary costs (an average cost), direct and indirect factors were identified and organized into scenarios leading to two extreme costs (minimum and maximum) estimates. Simple statistical analyses were then done to the collected cost data, to assess its variability.

The objectives of the questionnaire developed were to: assess the validity of an existing cost database; recommend base costs for MR&R actions; and to assess variability of cost estimates for MR&R actions. In Wisconsin, maintenance activities in historically maintained records were found to be too generalized or unspecific, and therefore incompatible with Pontis' unique MR&R actions for network-level analyses in a BMS.

In developing questionnaires for the MR&R costs, the following tasks were done: selection of 25 bridge elements; development of standard definitions for the selected bridge elements; assembling the list of applicable MR&R actions for the selected elements; and identifying scenarios for direct and indirect factors that affect the total cost of each MR&R action. In addition, the selection of 25 elements satisfied the following criteria: maximize the scope of the MR&R actions; include deck, superstructure, and substructure element types; and maximize the number of elements with alternative MR&R actions for a single condition state.

In eliciting the cost estimates from experts on bridge maintenance and construction, cost ranges were asked for each MR&R action, accounting for the variations in project characteristics, element materials, and extent of deterioration within a condition state. Scenarios were developed based on a combination of direct and indirect factors. Direct factors relate to the element characteristics, e.g., material type, depth of deterioration, etc. Indirect factors are due to project characteristics, e.g., traffic volume, traffic control, project size, site preparation, and mobilization. The scenarios corresponded to extreme high and low cost of each action. For example, the MR&R action “Replace overlay” has a high cost scenario under the following conditions: when the traffic volume is high, the project is small, and the material used is exotic and quick setting. For the low cost scenario the following conditions were defined for the same MR&R action: use of asphaltic or conventional material, low traffic volume, and large project.

As a starting point, the questionnaire presented the respondents with an initial list of ordinary costs for each MR&R action, i.e., an acceptable or average situation cost. This initial list of costs was generated by adopting the unit costs of MR&R actions of Minnesota DOT, and then modifying the costs as found necessary by Wisconsin DOT maintenance engineers. Based on the ordinary costs, the respondents provided low and high cost estimates for each action. In addition, the respondents were given the option to modify the ordinary cost. A sample of the questionnaire was presented for an MR&R action. Scenarios were also illustrated in a table.

The 75% response rate to the questionnaire can be considered reasonable. The collected data were analyzed to estimate the relative variability of the cost estimates, determine whether the variations in the cost estimates among the different elements and MR&R actions are significantly greater than the variations expected; and identify the elements and MR&R actions with the greatest and least variations in cost. The results presented include estimates of cost ranges, and one-way analysis of variance (ANOVA) to estimate the mean coefficient of variance (COV). Multiple Comparisons with the Best (MCB) analysis was also used to identify elements and MR&R actions with greatest and least variations in cost. The various results obtained and obstacles encountered in estimating MR&R actions were listed. Recommended costs were given for the MR&R actions on the 25 bridge elements in the Wisconsin Pontis BMS.

Another publication identified from this Wisconsin DOT study was on the sensitivity analysis of the MR&R actions to the variations in cost estimate, transition probability, and discount factor [Adams and Sianipar 1998]. The objectives of this analysis were to identify and evaluate the sensitivity of the optimal actions and policies due to variation in maintenance costs and transition probabilities, and to compare the BMS optimal policies to current practices. In the analysis, MR&R costs and transition probabilities were the uncertain input data sets. The sensitivity analysis is based on values of cost and transition probability for three scenarios. The ordinary scenario reflects engineering judgment on the expected maintenance costs and deterioration rates of bridge elements. The optimistic and pessimistic transition probability scenarios represent slow and fast deterioration rates, respectively. The low and high cost project scenarios represent maintenance costs for extreme low and high cost project circumstances due to construction environment and materials. The analysis identified the elements with optimal MR&R policies that are sensitive to changes in the discount factor by identifying the critical discount factor for each element's optimal policy.

Ontario Bridge Management System [Thompson et.al. 1999]

The Ontario Ministry of Transportation (MTO) is in the process of developing a new BMS that will have a particularly strong project-level costing capability. Since development is still underway, no results have been published other than a general description in Thompson et.al. [1999]. A distinctive aspect of the system is that the entire life cycle of cost data has been taken into account. Almost all work considered by the BMS is performed by contractors in Ontario, but similar considerations apply to force account work. The main processes and subsystems addressed in the Ontario system are:

> Tendering (bidding) process. MTO requires all bidders to submit cost data in a standardized way, organized according to a master catalog of "tender items," which are basically line items of labor, materials, equipment, and other identifiable cost factors. In most cases, bidders must provide estimated quantities and unit costs. This information is used immediately to detect unbalanced bids, but is also entered in a Ministry database as described in the next step.
>
> Estimating Office. All bids are forwarded to the MTO Estimating Office, a group of five people who maintain the Ministry's cost estimation capability. The three lowest bids from each procurement are entered into an analytical process consisting of a set of spreadsheet models and other computer programs to analyze the bid data. These models detect outliers and impute certain adjustment factors for market conditions, difficult locations, and other special project attributes. An adjusted unit cost for each bid item is then entered into a database accessible to all design engineers. The database uses averaging to make it impossible to determine the bids of specific firms, in order to protect confidentiality of bids. In many cases, unit costs are separately developed for each of the 20 Districts in the province.

Bridge Management System – project level costs. The Ontario BMS accesses the Estimating Office database to keep an up-to-date list of unit costs for each of about 90 tender items relevant to bridge work. User-customizable formulas and decision trees examine each project in the BMS to map the element-level treatment recommendations onto tender items. For example, a deck overlay might include tender items for asphalt removal, concrete patching, application of a waterproofing membrane, application of a binder course, and application of a wearing surface. The quantities and unit costs for each of these tender items is computed separately based on bridge attributes and element inspection data. Certain tender items may apply to multiple elements: for example, concrete patching may apply to the deck surface, soffit, railings, girders, and substructure elements. Also, certain tender items apply to the project as a whole, such as traffic control. The total cost of all tender items is the estimated project cost. This process roughly approximates the estimating method used by MTO's project engineers.

Bridge Management System – network-level costs. Although the Ontario BMS uses project-level cost estimates for most network-level purposes as well, it does use a network-level cost factor, called a "benchmark cost," to estimate the long-term life-cycle costs of each element on a bridge after the 10th year (the end of MTO's programming horizon). This benchmark cost is quite similar to a Pontis unit cost. The Ministry developed estimated benchmark costs by use of a worksheet process that estimates the costs of "typical" projects involving only one main element. This typical project cost is divided by an element quantity to yield a cost per unit of deteriorated element.

The first two steps of the above process apply to all MTO capital projects, not just bridges. This is an important feature of the process, as it keeps the staff cost of the estimating process reasonable. It does, however, make implementation more difficult since more groups within MTO must be willing to accept the new process. It should be pointed out that MTO is a decentralized agency with an allocation of responsibilities very similar to that of FDOT.

Unpublished Doctoral Dissertations [Various 1991-1998]

A review (based on the abstracts) of unpublished work related to bridge costs included the following recent doctoral dissertations:

(I) A Life-cycle Cost Model For Use in The Optimization of Concrete Bridge Deck Repair And Rehabilitation, Author: Gannon, Edward John, Degree: Ph.D., Year: 1998 Institution: The Pennsylvania State University, Adviser: Philip D. Cady; 176 Pages.
This study presented the formulation of a life-cycle cost model, including the development of a cost model of bridge repair alternatives using data from state highway agencies. The data were corrected for time and location.

(II) Pavement And Bridge Cost Allocation Analysis of The Ontario Intercity Highway Network, Author: Ghaeli, Mohammad Reza Degree: Ph.D., Year: 1998, Institution: University of Waterloo (Canada); Advisers: Bruce Hutchinson and Ralph Haas; 225 Pages.

The objectives of this research were primarily to build an economic analysis model for pavement and bridges. Some cost data were collected and analyzed. For example, the initial capital cost of construction was identified as the major element of a bridge life-cycle cost, with maintenance costs less than 0.2% of the initial construction costs. Bridge construction costs were estimated at about \$1000/m^2 (present worth) on average for most of the Ontario bridges.

(III) A Methodology For Modeling The Cost And Duration of Concrete Highway Bridges, Author: Panzeter, Andrea Angela Degree: Ph.D., Year: 1993, Institution: Purdue University; Major Professor: Luh Maan Chang, 180 Pages.

The study developed a detailed project-level model for estimating the cost and construction time duration of concrete highway bridge projects in terms of five categories of work packages — Substructure, Superstructure, Road Approach, Traffic, and "Other." The cost of each category was modeled with multiple regression statistical techniques, considering the physical aspects of the projects and the material quantities.

(IV) Allocation of Bridge Construction Costs in Kentucky, Author: Saad, Charles Georges Degree: Ph.D., Year: 1991, Institution: University of Kentucky; Adviser: Jack A. Deacon, 276 Pages.

This is not a cost data collection study. The research developed a cost allocation methodology for legislative actions on raising revenues for bridge construction in the state of Kentucky.

Telephone Conversations [Various 1999]

Telephone conversation with Iowa DOT (Ms. Marlee Walton) indicated that most of the cost data used to populated Pontis for the first time use, were based on expert opinion elicitation. Iowa DOT has been collecting the data (Pontis-structured) but also has a general database of maintenance costs (highways and bridges).

Telephone discussion with Mr. George Romack of the FHWA provided information on the status of the Clemson Study and the IOWA DOT efforts. A computer program and report resulting from the Clemson Study was sent.

Dr. Carl Kurt was also contacted at Kansas University to discuss his experience with Pontis. He sent a report (inspection manual) presenting the Pontis bridge element definition and condition states, for Kansas local government bridges.

1.3. Questionnaire Preparation and Execution

In order to obtain an awareness of the current status of the national practice of cost data collection and analysis for bridge management systems (BMS), a survey was developed by the research team for the Florida Department of Transportation (FDOT) BMS study. The survey was prepared initially as a draft questionnaire to solicit information from the state Departments of Transportation (DOT), on recent work they may have performed to develop agency cost factors for a BMS. Following the receipt of feedback and approval from FDOT, the final questionnaires were prepared. A mailing list was then generated for one person in each DOT of the 50 states, to receive the questionnaire. The simple one-page questionnaire was distributed in December 1998 by U.S. mail, with FDOT's Richard Kerr providing a cover letter indicating FDOT's sponsorship of the questionnaire and promising respondents a copy of the results.

The questionnaire responses were received by the research team, tabulated, and analyzed. The summary of the results are shown in Table 1.1. The basic issues covered in the questionnaire were the following:

- Identification of the agency, the survey respondent, and the agency's current status or progress in terms of undertaking agency cost model development for its BMS. This inquiry included the status (or future plan) of any study or work already undertaken to develop the cost model, the completion date of the study, and also the availability of any report on such work.
- Information about the agency's cost data in terms of specific cost factors quantified or planned for its BMS. The following nine options were provided as possible specific cost factors: Preservation (MR&R) unit costs; Pontis element failure costs; Bridge replacement unit costs; Bridge widening, raising, or strengthening unit costs; Demolition and approach road work; Project engineering and administration; Mobilization and demobilization; Approach road work; and Other.
- General comments on the agency's cost research or plans.

Responses to the survey were received from 27 state DOTs, indicating about a 55% response rate. The responses varied regarding the types of agency cost model/factors developed, but most states do have specific cost factors quantified or to be quantified for their BMS. Most states were not specific on their BMS software. But New York and Maine indicated use of non-Pontis BMS; Maine uses BRIDGIT.

Six states (Alaska, Connecticut, Indiana, Utah, Virginia, and Wyoming) indicated their agency was currently working towards developing cost models or factors for a BMS. Five states (Alabama, California, Maine, Montana, and New York) responded that they have completed such as study. The state DOTs at Georgia, Hawaii, Mississippi, New Hampshire, and South Dakota (five states) indicated no current effort at the time, but that they intend to do so in the near future. Eleven states (Arizona, Idaho, Kansas, Missouri, Nevada, Rhode Island, Tennessee, Vermont, and West Virginia) responded that they were currently not doing such a study, and do not intend to do so in the near future. This implies that 16 states (60%) of the responding 27 states, translating to about 30% of the 50 state DOTs in the country, either have a cost model/factor in place, currently developing it, or plan to do it in the near future.

Preservation (MR&R) unit cost was indicated as a factor quantified or to be quantified by 15 out these 16 state DOTs. Quantification of bridge replacement unit costs and widening, raising, or strengthening unit costs was also very popular among the responding states. About half of these 16 states also indicate quantification of project engineering and administration costs, mobilization and demobilization costs, approach road work costs, and Pontis element failure costs, as factors in their BMS. As shown in Table 1.1, the general comments from the various responding states also indicate various approaches taken by the agencies in developing the cost models or factors for their BMS.

Table 1.1. Summary of Survey Responses

State	Agency's Work Towards Developing Agency Cost Models/ Factors for a BMS		Specific Agency Cost Factors Quantified/ Plan to Quantify in BMS*									Additional Comments
	Status: Undertaken any work? Completion Date?	Available Reports?	a	b	c	d	e	f	g	h	i	
AK	Yes, work underway	N			x	x		x	x	x		Not a research study
AL	Yes, work completed	Y	x		x	x		x		x		
AZ	No, no work planned											
CA	Yes, work completed (1996)	N	x	x								Reports available upon request. See AASHTO's Pontis Forum
CT	Yes, work underway	N	x	x								Initial element level cost elicitation developed.
GA	No, planned in near future	N	x		x	x						
HI	No, planned in near future	N	x	x	x	x	x	x	x			
ID	No, no work planned											
IN	Yes, work underway	Y	x		x	x				x		Report on Indiana BMS cost module. BMS manual not final.
KS	No, no work planned											
ME	Yes, work completed (1998)	N	x	x	x	x		x	x			BMS used is BRIDGIT. Expert opinions used to adjust default values of costs. Field visits used in cost calibration
MN	Yes, work completed (1994)	N	x		x	x						Future work planned (12/99)
MS	No, planned in near future	N	x		x	x						
MO	No, no work planned											
NC		Y										Cover letter advises to contact Dr. David Johnston (NC State Univ.). 1987 Report attached.
NE	No, no work planned											Comparison done of costs for Overlay vs. Redecking based on condition of bridge deck. Previous year's average unit costs utilized.
NH	No, planned in near future	N	x	x	x	x	x	x	x	x		Hopefully work starts 1999
NV	No, no work planned											
NY	Yes, work completed	Y	x		x			x		x		BMS used is not Pontis. Replacement costs estimated from contract bid -- "bare" cost + "add-ons." Rehabilitation costs estimated

												from deck area unit cost models based on type of rehab. Costs based on regions (11 total). Sample preliminary cost worksheet attached.
RI	No, no work planned											
SD	No, planned in near future	N	x	x	x	x	x	x	x	x		
TN	No, no work planned											
UT	Yes, work underway (2000)	N	x	x	x	x	x	x	x	x	x	Other specific factor: scour / foundation work. Materials ready in Spring 2000.
VT	No, no work planned											
VA	Yes, work underway	N	x		x	x	x	x	x	x		
WV	No, no work planned											
WY	Yes, work underway	N	x	x	x	x		x	x	x		For preservation unit costs, previous two years rehab. projects had bid item costs converted to element costs, and applied to four environments. Currently trying to automate this conversion process — appears to be a large undertaking.

* Specific factors:
a. Preservation (MR&R) unit costs
b. Pontis element failure costs
c. Bridge replacement unit costs
d. Bridge widening, raising, or strengthening unit costs
e. Demolition and approach road work
f. Project engineering and administration
g. Mobilization and demobilization
h. Approach road work
i. Other:

2. Agency Cost Requirements of Pontis

This section summarizes the agency cost requirements of Pontis and the results of a sensitivity analysis conducted to determine the priorities for agency cost research. Pontis contains two main types of agency cost inputs:

- Preservation unit costs, which are given for each feasible action of each condition state of each element.
- Functional improvement and replacement unit costs, for each type of improvement.

The current research effort focuses on preservation costs. Pontis provides a user interface for entering preservation unit costs in the form of an expert elicitation. This allows multiple engineers to independently provide judgmental estimates of the unit costs, in the manner of a delphi process. Pontis then computes a weighted average of the experts' estimates. When historical element-level data are available, Pontis also has a means of including this information in the weighting scheme. The sensitivity analysis focuses on the resulting unit costs, without regard to how they are derived. Pontis does not have a user interface for entering unit costs directly, but this is easily done by means of InfoMaker.

Functional improvement and replacement costs are entered directly into Pontis by means of the Cost Matrix. This can be done at any time, and does not depend on any other data in the database. At the time of the analysis, Florida's Pontis database lacked some of the element-level bridge data, deterioration models, and cost models. Element-level data collection began in November, 1998, and deterioration models were developed in Task 6 of the current study. Therefore, the analysis was performed with the default data provided with Pontis release 3.4. Pontis is packaged with a set of deterioration models developed in California, and a set of preservation cost models developed by Clemson University as an average of several states' data. The functional improvement unit costs are based on California experience.

After completing a network optimization, Pontis applies the optimal maintenance, repair, and rehabilitation (MR&R) actions to each bridge. The network-level unit costs are then used to develop project-level cost estimates. Since this analysis requires element-level bridge data, it is not possible to carry the preservation cost sensitivity analysis to the project level at this time. The analysis will therefore focus on network-level long-term cost and recommended action as the outputs to be investigated for preservation. The Pontis software itself was used to perform the sensitivity analysis.

2.1 Preservation Cost Analysis

The network-level preservation cost analysis is performed as an integral part of the Pontis network optimization. Every possible action that can be chosen for each observed condition state has a long-term cost, calculated as follows:

Long-term cost $$LTC_{ia} = C_{ia} + a \sum_{j} P_{aij} LTC_{jA_j} \tag{2.1}$$

Where: C_{ia} is the unit cost of action *a* when the element is in state *i* (Pontis preservation cost model)

a is a discount rate for costs incurred one year in the future (calculated below)

P_{aij} is the transition probability of an element to be in state *j* in one year given state *i* and action *a* this year (Pontis deterioration model)

A_j is the optimal action for state j (determined as described below)

LTC_{jA_j} is the long-term cost which would be calculated next year if state *j* occurs and the optimal action for that state is selected (calculated again by equation 1)

The discount rate is based on the forecast real interest rate, i.e. the interest rate with inflation removed. It is calculated as follows:

Discount rate $$a = \frac{1}{1 + \text{int}} \tag{2.2}$$

Where: int is the real interest rate

The real interest rate is usually based on agency policy and is the same for all capital project analyses. The optimal action for a given condition state is the action that results in the lowest long-term cost according to equation (2.1).

Equation (2.1) is recursive, because it depends on a term which itself is calculated according to the same equation. It is not circular, however, because the long-term cost term on the right-hand side is for one year later than the left-hand side. When fully expanded, the equation is potentially an infinite series, because the time horizon of the analysis is not strictly limited. However, because of discounting, the contribution of each subsequent term is less than the previous one, approaching zero.

Pontis simplifies the problem by assuming that in the long-term, the equation reaches a steady-state, where the conditions and actions remain in the same proportions from one year to the next. The probability of any given state in year *t* is equal to the probability of the same state in year *t+1*. In other words, for each meter of girder moving out of a particular condition state, another meter from the same bridge or another bridge moves in to replace it. This allows the equation to be re-stated as a linear program, which can be solved efficiently. The linear program formulation, however, remains consistent with Equation (2.1) and thus does not affect the long-term cost calculation.

Equation (2.1) is not in itself sufficient to create a bounded model, because the cost-minimizing solution to the equation is to choose the do-nothing action, whose cost is zero. If this policy were to be followed, bridges would not merely gather in the worst condition state defined by the CoRe elements or the Florida Elements, but would, in fact, proceed to an even worse state, denoted as the failure state. The failure state is defined as a condition even worse than any that would be observed in an inspection, where the element no longer satisfies its intended purpose. Equation (2.1) can be applied to this concept if the state indexes *i* and *j* include the failure state, and if the only action allowed in the failure state has a very high penalty cost making it economically unattractive to allow the element to deteriorate to that level. Because if its role in the optimization model, the failure cost has three requirements:

- It must prevent the optimization from recommending a do-nothing action in the worst defined condition state;
- It should reflect the relative importance of each element to the continuing functionality of the bridge, or the relative level of damage that would be caused if the element were to fail.
- It should reflect the impact of element failure on the road users.

For the purposes of a network-level sensitivity analysis, only the first of these points can be investigated.

Pontis displays all the inputs and outputs of this analysis on the Preservation screen. When any of the inputs are changed in the database, the user has only to press the Optimize button to develop new long-term costs and a new optimal solution.

2.2 Data Preparation and Preliminary Analysis

The particular elements and data utilized for the sensitivity analysis were restricted to a representative sample, since it would be excessive to analyze every possible element in the Florida bridge inventory. This representative sample of elements were chosen based on some important bridge-related criteria: element deterioration rate; quantity of bridge element in the Florida inventory; and inclusion of major material types for bridge elements.

Based on the optimization algorithm as shown in equation 2.1, the selected optimal MR&R action under the preservation model, and the overall result of the sensitivity analysis is expected to depend very much on the bridge element deterioration rate, in terms of the transition probabilities. Therefore, a great effort was made in the data preparation stage to include elements with varied rates of deterioration.

Generating an MR&R optimization run under an “ordinary” scenario, using the Pontis sample database, a report was produced listing the relevant input and output variables. The failure probabilities of all elements were first considered, for the worst environment (4), under “Do Nothing” actions. The fastest deteriorating elements such as Nos. 301 Pourable Joint Seal, 12 Concrete Deck - Bare, 111 Timber Open Girder/Beam, 300 Strip Seal Expansion Joint, 302 Compression Joint Seal, 303 Assembly Joint /Seal (modular), etc., were selected for the sensitivity analysis. On the other extreme, using the same criterion (failure probability) slow-deteriorating elements such as Nos. 204 P/S Conc. Column or Pile extension, 205 reinforced Conc. Column or

Pile Extension, 206 Timber Column or Pile Extension, 210 Reinforced Conc. Pier Wall, 215 Reinforced Conc. Abutment, etc., were also included. Other deterioration-related considerations include initial slow deterioration rates (transition probability out of state 1), and moderately deteriorating elements at the middle states (2 and 3), both for “Do Nothing” actions on the elements. This evaluation identified some elements in the potential list, being representative of the variety of deterioration rates.

Secondly, the quantities of the bridge elements were considered, based on Florida’s inventory of highway bridges. From a combination of the Florida inventory listing and the California Cost Database, an initial list of 164 elements were generated and then reduced to 50 significant elements. In addition to including major bridge elements (deck, superstructures, substructures), it was also ensured that the major material types were included in the selected list of elements, i.e., concrete, steel, timber, etc. Finally, incorporating the elements identified in the deterioration rate evaluation above, the 50 elements were reduced to the 35 elements to be utilized in the sensitivity analysis (Table 2.1).

2.3 Sensitivity Analysis

The main objective of the sensitivity analysis was to observe and explain the effects of varying the values of model input variables such as overall agency costs (maintenance, repair, and replacement (MR&R) costs, failure agency costs), and discount factor (α), on the preservation model output. The focus on the model output was on the optimal MR&R actions recommended, and their respective calculated long term costs. Differences in long-term cost affect the relative priorities given to competing elements and bridges.

It should be noted that one additional type of model sensitivity is the linear proportional relationship between unit agency costs and project-level cost estimates, as evidenced in equation (2.1) above. Because of this proportionality, project-level and program-level budgetary requirements are directly sensitive to errors in unit costs.

Several issues in terms of variations were investigated for each of the 35 representative bridge elements, with the analysis being conducted for the “ordinary” scenario in Pontis MR&R optimization, under the various environments and condition states. The sensitivity analysis was carried out under seven categories of input variation: (1) Variation in all MR&R Unit Costs; (2) Variation in only element replacement unit costs; (3) Variation in only element rehabilitation unit costs; (4) Variation in only element repair unit costs; (5) Variation in only element minor maintenance unit costs; (6) Variation in only Failure Agency Unit Costs; and (7) Variation in only Discount Rate Factors. The procedures and results from each of the variation categories of the study are discussed in each of the following sections.

Table 2.1. List of Representative Bridge Elements (35) in Sensitivity Analysis

Elem ID#	Element Long Name	FDOT Total Quantity[a]	Units of Meas.
12	Concrete Deck - Bare	6,966,853	sq.m.
13	Concrete Deck - Unprotected w/ AC Overlay	3,140,288	sq.m.
28	Steel Deck - Open Grid	93,656	sq.m.
31	Timber Deck - Bare	42,871	sq.m.
38	Concrete Slab - Bare	418,725	sq.m.
39	Concrete Slab - Unprotected w/ AC Overlay	267,473	sq.m.
102	Painted Steel Closed Web/Box Girder	29,570	m.
104	P/S Conc. Closed Web/Box Girder	2,162,405	m.
107	Painted Steel Open Girder/Beam	1,420,963	m.
109	P/S Conc. Open Girder/Beam	3,835,152	m.
110	Reinforced Conc. Open Girder/Beam	304,191	m.
111	Timber Open Girder/Beam	129,287	m.
113	Painted Steel Stringer	193,255	m.
116	Reinforced Conc. Stringer	21,013	m.
121	Painted Steel Bottom Chord Thru Truss	8,088	m.
152	Painted Steel Floor Beam	57,561	m.
161	Painted Steel Pin and/or Pin and Hanger Assembly	8	ea.
202	Painted Steel Column or Pile Extension	3,188	ea.
204	P/S Conc. Column or Pile Extension	84,413	ea.
205	Reinforced Conc. Column or Pile Extension	14,666	ea.
206	Timber Column or Pile Extension	8,743	ea.
210	Reinforced Conc. Pier Wall	17,359	m.
215	Reinforced Conc. Abutment	228,089	m.
234	Reinforced Conc. Cap	489,493	m.
235	Timber Cap	24,263	m.
241	Reinforced Concrete Culvert	146,251	m.
300	Strip Seal Expansion Joint	17,011	m.
301	Pourable Joint Seal	314,769	m.
302	Compression Joint Seal	240,365	m.
303	Assembly Joint/Seal (modular)	10,670	m.
304	Open Expansion Joint	51,554	ea.
310	Elastomeric Bearing	361,016	ea.
311	Moveable Bearing (roller, sliding, etc.)	140,205	ea.
313	Fixed Bearing	33,926	ea.
331	Reinforced Conc. Bridge Railing	1,491,165	m.

[a] Based on 1998 FDOT Pontis-Format Bridge Inventory

2.3.1 Variation in all MR&R Unit Costs

Using the Pontis 3.4 Preservation Model screen, through the Cost Adj(ustment) Button, all MR&R costs (except the failure user costs) were varied from 25% to 300% of the default unit costs in the database. With the discount rate set as the default 0.9525 (an equivalent of about 5.0% annual discount rate), optimization results were calculated by using the Pontis Optimize Button. The results of the optimization run, in a report, included the recommended action for each element-environment-state combination, and calculated long term unit costs for each feasible action. Table 2.2 summarizes, for a set of selected elements, the sensitivity of actions recommended to a variation in these input variables. It was observed that there was no change in action recommended regardless of the increase or decrease in the unit costs.

Element deterioration rates were also observed as being non-influential on the results. Graphs were also constructed to show the percentage change in the long-term unit cost relative to the percentage change in default initial unit costs. Figure 2.1 shows a sample of such graph for Element No. 12 Concrete deck - Bare in Environment 3, Condition State 5. As observed in the various graphs, there is a linear relationship between the long-term unit costs and the initial unit costs. So, since the optimal actions were selected based on the lowest long-term costs, the recommended actions remained the same despite global proportional changes in all the initial costs. As evident from equation 1, upon which the Pontis preservation model is based, this linear relationship is not unexpected. The calculated long term cost (LTC) is linearly related to the direct unit cost (C), and the second term of the equation mathematically converges to a steady value.

It is important to recognize that this result does not in any way imply that the Pontis models are insensitive to costs. It only confirms that the results depend on the ratios among the costs of competing actions. When the unit costs of all actions are changed by the same multiplier, there is no change in the ratios among actions, so there is no change in the action recommendations. The following sections investigate the effect of changing any one category of actions while holding the others constant.

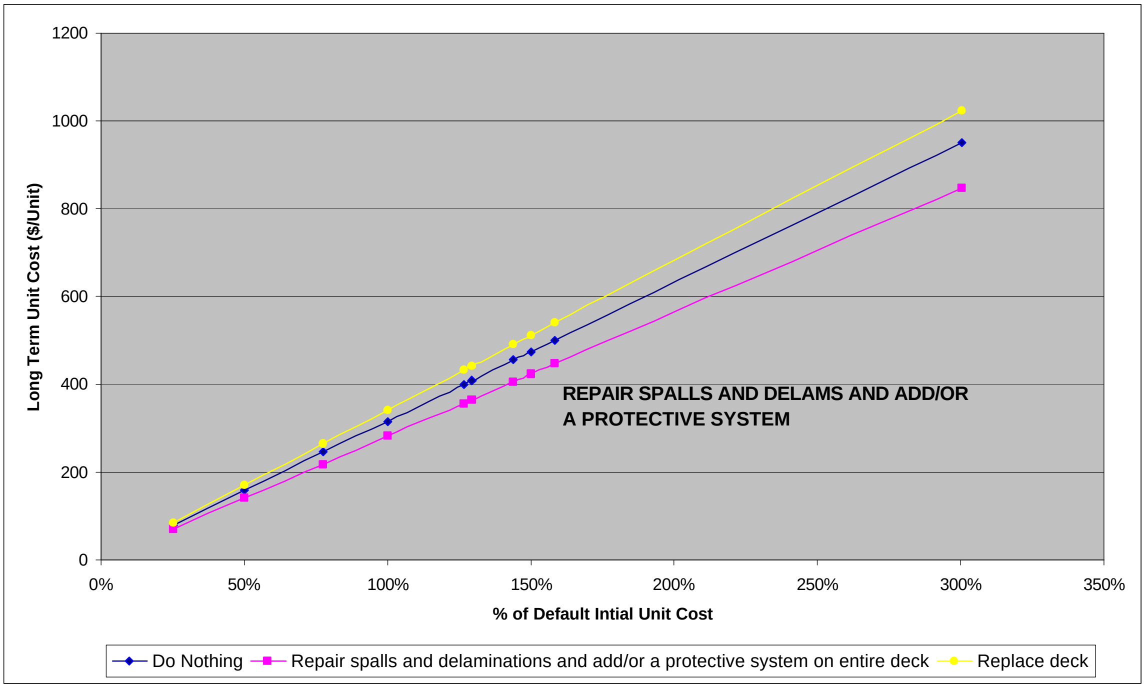

Figure 2.1. Variation of Long Term Unit Cost with % Changes in Unit Costs (Elem # 12 - Concrete Deck - Bare: Environment 3 Condition State 5)

Table 2.2. Change in Action Recommended Due To Variation in All Initial Unit Costs (Selected Element-Environment-Condition State Indices)

ELEMENT	MR&R INDEX	ACTION RECOMMENDED (SENSITIVITY)
Elem # 12 - Concrete Deck - Bare	Environment 1 Condition State 1	Do Nothing (SAME)
	Environment 3 Condition State 5	Repair spalls and delaminations and add/or a prot (SAME)
	Environment 4 Condition State 5	Repair spalls and delaminations and add/or a prot (SAME)
Elem # 31 - Timber Deck - Bare	Environment 1 Condition State 3	Do Nothing (SAME)
	Environment 4 Condition State 4	Replace deck (SAME)
Elem # 38 - Concrete Slab - Bare	Environment 2 Condition State 5	Repair spalls and delaminations and add/or a prot (SAME)
	Environment 4 Condition State 5	Repair spalls and delaminations and add/or a prot (SAME)
Elem # 152 - Painted Steel Floor Beam	Environment 2 Condition State 4	Spot blast, clean, and paint (SAME)
	Environment 4 Condition State 5	Rehab unit (SAME)
Elem # 300 - Strip Seal Expansion Joint	Environment 3 Condition State 3	Replace gland and/or patch concrete (SAME)
	Environment 4 Condition State 3	Replace gland and/or patch concrete (SAME)
Elem # 310 - Elastometric Bearing	Environment 3 Condition State 3	Reset bearings (SAME)
	Environment 4 Condition State 3	Reset bearings (SAME)

2.3.2 Variation in Only Element Replacement Unit Costs

To perform this particular sensitivity analysis, a set of Structured Query Language (SQL) commands (sample shown in Figure 2.2) were executed inside the Infomaker v 5.0 Database Administration module, to adjust only the element replacement unit costs in the Pontis 3.4 cost database, while leaving maintenance, rehabilitation, repair costs, and other input variables fixed. Variation was introduced in the range of 50% to 150% of the original default replacement unit cost. The optimization was then run in the Pontis preservation model, at the default discount factor of 0.9525, to obtain results of the calculated long term unit costs for each element-environment-state-action combination, and the recommended actions.

Sample results are presented in Table 2.3 and Figure 2.3 to show the variation in long term unit costs relative to changes in the element replacement unit costs, and also the changes in recommended actions as the costs are adjusted from the default unit cost values. Generally, the "replace element" option is the least-cost and recommended action when the replacement unit cost is reduced to below about 75% of its original cost. The observation from the graph in figure 2.3 is that for Element No. 12 Concrete Deck -- Bare in Environment 4 State 5, the recommended optimal MR&R action is sensitive to cost reduction to about 80% of the original cost. In other words, if the replacement unit cost is reduced enough (by about 20%), it is better to replace the deck than to repair spalls and delaminations, or to add a protective system. As also shown in Table 2.3 and Figure 2.4, if replacement unit cost is reduced to just below 75% of its original value, it is optimally justified to replace a Steel Deck- Open Grid element in Environment 4 Condition State 5.

In addition to results at the element-environment-state-action levels, summary results are also presented at the network level for the selected elements, in Table 2.4 and Figure 2.5. The table and graph show that action recommendations are sensitive to element replacement costs in a large number of cases.

Table 2.5 and Figure 2.6 show estimated costs of preservation for all the 35 sample elements (shown in Table 2.1) on all bridges on the Florida state highway network. The network level results were computed using the Florida bridge inventory data (1998). Utilizing the optfrac (optimum fraction values among the states in any one element/environment, computed as an optimization output in the Pontis MR&R preservation model), the total network preservation agency costs for Florida bridges were calculated for the various environments. Two scenarios were considered in the network sensitivity study: Case I — assuming all bridge elements in environment 1; and Case 2 — assuming all bridge elements in environment 4. Deterioration rates (which differ dramatically between environments 1 and 4) obviously make a very large difference in long-term costs.

```
UPDATE actmodls
SET      varunitco=varunitco*0.75
FROM actmodls,
     mrractdf
WHERE actmodls.varunitco > 0 AND
 actmodls.elemkey = mrractdf.elemkey and
      actmodls.skey = mrractdf.skey and
      actmodls.akey = mrractdf.akey and
      (mrractdf.acttype = 31 or
       mrractdf.acttype = 35) ;

SELECT   mrractdf.elemkey,
         actmodls.envkey,
         mrractdf.skey,
         mrractdf.akey,
         mrractdf.actshort,
         mrractdf.actlong,
         mrractdf.acttype,
         actmodls.varunitco
FROM actmodls,
     mrractdf
WHERE
 actmodls.elemkey = mrractdf.elemkey and
      actmodls.skey = mrractdf.skey and
      actmodls.akey = mrractdf.akey and
      (mrractdf.acttype = 31 or
       mrractdf.acttype = 35) ;
```

Figure 2.2. Infomaker SQL Commands for Element Replacement Unit Costs Analysis

Table 2.3. Expected Long-Term Unit Costs For Varied Element Replacement Unit Costs

			EXPECTED LONG-TERM UNIT COST AT VARIED REPLACEMENT UNIT COSTS				
	Element	Element Replacement Unit Cost Variation:	50%	75%	100%	125%	150%
12	Concrete Deck - Bare,	Element Replacement Unit (First) Cost:	$150.75	$226.13	$301.50	$376.88	$452.25
	Env. 1 - State 5	Do Nothing	$159.91	$229.69	$244.56	$244.56	$244.56
		Repair spalls and delaminations and add/or a prot	$243.37	$243.96	$244.09	$244.09	$244.09
		Replace deck	$151.93	$227.90	$303.40	$378.78	$454.15
		Action Recommended:	Replace deck	Replace deck	Repair spalls and d	Repair spalls and d	Repair spalls and del
12	Concrete Deck - Bare,	Element Replacement Unit (First) Cost:	$150.75	$226.13	$301.50	$376.88	$452.25
	Env. 4 - State 5	Do Nothing	$313.92	$382.47	$393.28	$393.28	$393.28
		Repair spalls and delaminations and add/or a prot	$309.00	$335.39	$335.39	$335.39	$335.39
		Replace deck	$217.56	$319.33	$394.70	$470.08	$545.45
		Action Recommended:	Replace deck	Replace deck	Repair spalls and d	Repair spalls and d	Repair spalls and del
28	Steel Deck - Open Grid,	Element Replacement Unit (First) Cost:	$172.23	$258.34	$344.45	$430.58	$516.68
	Env. 4 - State 5	Do Nothing	$327.79	$394.19	$394.19	$394.19	$394.19
		Rehab connectors and replace paint system	$262.61	$262.61	$262.61	$262.61	$262.61
		Replace unit	$185.62	$271.73	$357.84	$443.97	$530.07
		Action Recommended:	Replace unit	Rehab conn. & repl p	Rehab conn. & repl	Rehab conn. & repl	Rehab conn. & repl pa
31	Timber Deck - Bare,	Element Replacement Unit (First) Cost:	$5.19	$7.79	$10.38	$12.98	$15.57
	Env. 1 - State 4	Do Nothing	$5.75	$8.19	$10.63	$12.12	$12.12
		Replace deck	$5.26	$7.89	$10.51	$13.13	$15.72
		Action Recommended:	Replace deck	Replace deck	Replace deck	Do Nothing	Do Nothing
31	Timber Deck - Bare,	Element Replacement Unit (First) Cost:	$5.19	$7.79	$10.38	$12.98	$15.57
	Env. 4 - State 3	Do Nothing	$6.57	$9.86	$13.14	$16.43	$17.99
		Rehab deck	$8.93	$11.52	$14.11	$16.70	$17.69
		Replace deck	$8.21	$12.32	$16.42	$20.53	$23.70
		Action Recommended:	Do Nothing	Do Nothing	Do Nothing	Do Nothing	Rehab deck
107	Painted Steel Open Girder/Beam	Element Replacement Unit (First) Cost:	$598.71	$898.06	$1,197.41	$1,496.76	$1,796.12
	Env. 4 - State 5	Do Nothing	$1,252.91	$1,460.37	$1,460.37	$1,460.37	$1,460.37
		Rehab unit	$956.63	$1,021.98	$1,021.98	$1,021.98	$1,021.98
		Replace unit	$747.56	$1,046.91	$1,346.26	$1,645.61	$1,944.97
		Action Recommended:	Replace unit	Rehab unit	Rehab unit	Rehab unit	Rehab unit
215	Reinforced Conc Abutment,	Element Replacement Unit Cost: (First Cost)	$1,280.09	$1,920.13	$2,560.17	$3,200.21	$3,840.26
	Env. 4 - State 4	Do Nothing	$2,544.66	$3,167.08	$3,167.08	$3,167.08	$3,167.08
		Rehab unit	$2,273.36	$2,407.11	$2,407.11	$2,407.11	$2,407.11
		Replace unit	$1,694.12	$2,428.49	$3,068.53	$3,708.57	$4,348.62
		Action Recommended:	Replace unit	Rehab unit	Rehab unit	Rehab unit	Rehab unit
234	Reinforced Conc Cap,	Element Replacement Unit Cost: (First Cost)	$788.75	$1,183.12	$1,577.49	$1,971.86	$2,366.24
	Env. 4 - State 4	Do Nothing	$1,548.26	$1,904.58	$2,136.86	$2,136.86	$2,136.86
		Rehab unit	$1,597.94	$1,693.16	$1,741.90	$1,741.90	$1,741.90
		Replace unit	$1,059.46	$1,472.58	$1,866.95	$2,261.32	$2,655.70
		Action Recommended:	Replace unit	Replace unit	Rehab unit	Rehab unit	Rehab unit
302	Compression Joint Seal,	Element Replacement Unit Cost:	$175.00	$262.50	$350.00	$437.50	$525.00
	Env. 4 - State 3	Do Nothing	$648.99	$820.05	$875.63	$875.63	$875.63
		Replace gland and/or patch spalls	$607.88	$786.43	$844.44	$844.44	$844.44
		Replace joint	$507.95	$761.92	$903.51	$991.01	$1,078.51
		Action Recommended:	Replace joint	Replace joint	Replace gland and/	Replace gland and/	Replace gland and/or

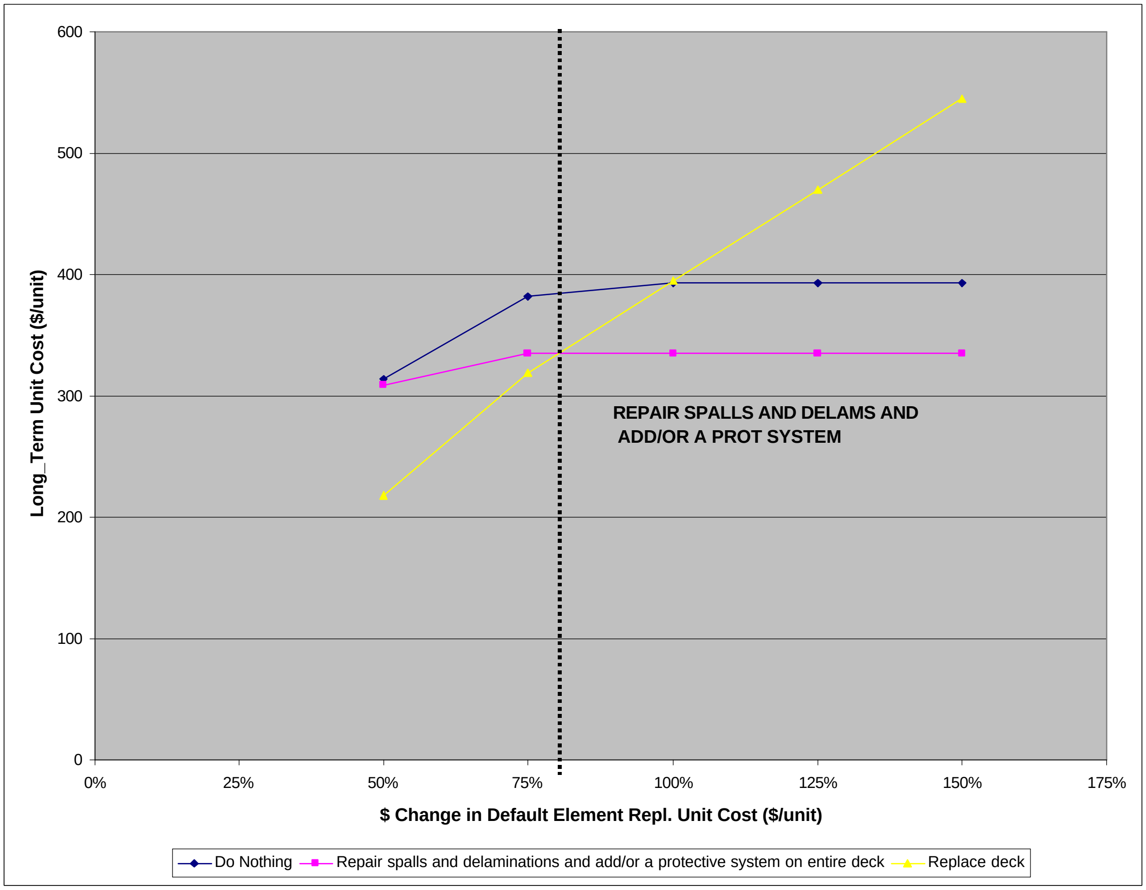

Figure 2.3. Long-Term Unit Cost Vs % Change in Element Replacement Unit Cost (Elem # 12 Concrete Deck - Bare Env. 4 - State 5)

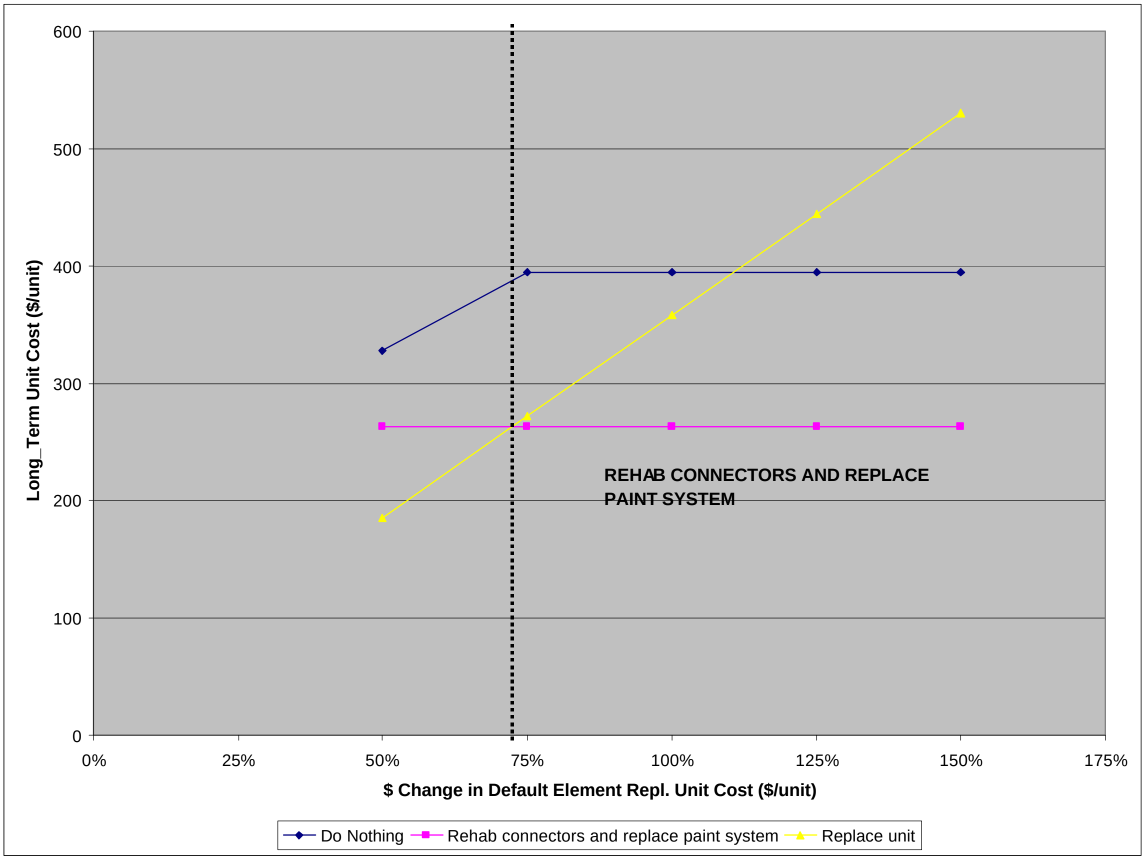

Figure 2.4. Long-Term Unit Cost Vs % Change in Element Replacement Unit Cost (Elem # 28 Steel Deck - Open Grid, Env. 4 - State 5)

Table 2.4. Summary Of Bridge Elements' Sensitivity To Element Replacement Unit Cost

Elem ID#	Element Long Name	***CHANGE IN ACTION RECOMMENDED? (AT % OF DEFAULT COST)***			
		50%	**75%**	**125%**	**150%**
12	Concrete Deck - Bare	YES	YES	NO	NO
13	Concrete Deck - Unprotected w/ AC Overlay	NO	NO	NO	NO
28	Steel Deck - Open Grid	YES	YES	YES	YES
31	Timber Deck - Bare	NO	NO	YES	YES
38	Concrete Slab - Bare	NO	NO	NO	NO
39	Concrete Slab - Unprotected w/ AC Overlay	NO	NO	NO	NO
102	Painted Steel Closed Web/Box Girder	NO	NO	NO	NO
104	P/S Conc Closed Web/Box Girder	NO	NO	NO	NO
107	Painted Steel Open Girder/Beam	YES	YES	NO	NO
109	P/S Conc Open Girder/Beam	YES	YES	YES	YES
110	Reinforced Conc Open Girder/Beam	YES	NO	NO	NO
111	Timber Open Girder/Beam	NO	NO	YES	YES
113	Painted Steel Stringer	YES	YES	YES	YES
116	Reinforced Conc Stringer	NO	NO	NO	NO
121	Painted Steel Bottom Chord Thru Truss	YES	NO	NO	NO
152	Painted Steel Floor Beam	YES	YES	NO	NO
161	Painted Steel Pin and/or Pin and Hanger Assembly	NO	NO	NO	NO
202	Painted Steel Column or Pile Extension	YES	NO	NO	NO
204	P/S Conc Column or Pile Extension	NO	NO	NO	NO
205	Reinforced Conc Column or Pile Extension	NO	NO	NO	NO
206	Timber Column or Pile Extension	YES	YES	NO	NO
210	Reinforced Conc Pier Wall	NO	NO	NO	NO
215	Reinforced Conc Abutment	YES	NO	NO	NO
234	Reinforced Conc Cap	YES	YES	NO	NO
235	Timber Cap	YES	YES	YES	YES
241	Reinforced Concrete Culvert	YES	YES	YES	YES
300	Strip Seal Expansion Joint	NO	NO	NO	NO
301	Pourable Joint Seal	YES	NO	YES	YES
302	Compression Joint Seal	YES	YES	NO	NO
303	Assembly Joint/Seal (modular)	NO	NO	NO	NO
304	Open Expansion Joint	YES	NO	NO	NO
310	Elastomeric Bearing	NO	NO	NO	NO
311	Moveable Bearing (roller, sliding, etc.)	YES	NO	NO	NO
313	Fixed Bearing	YES	YES	NO	NO
331	Reinforced Conc Bridge Railing	YES	YES	NO	NO
	TOTAL ELEMENTS SENSITIVE (YES COUNT)	20	13	8	8
	% OF ALL ELEMENTS (35)	57%	37%	23%	23%

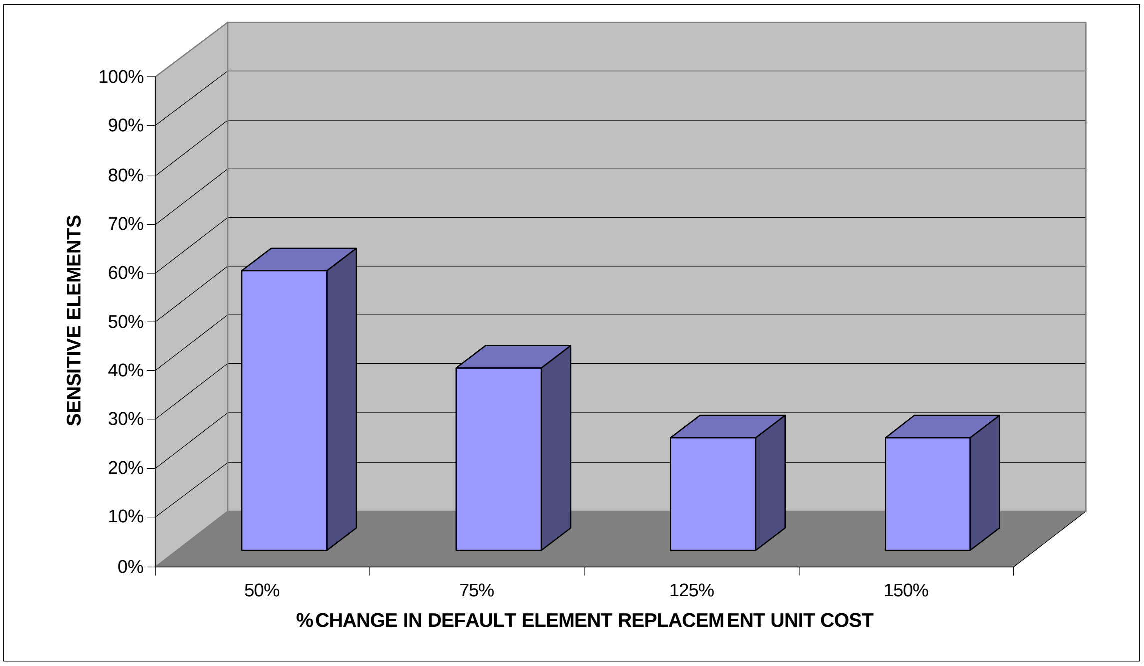

Figure 2.5. Summary Of Bridge Elements' Sensitivity To Element Replacement Unit Cost

Table 2.5. Network Total MR&R Costs Vs. Change In Element Replacement Unit Cost

	VARIATION IN ELEMENT REPLACEMENT UNIT COST				
	50%	75%	100%	125%	150%
TOTAL FIRST COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$7,893,391	$12,946,994	$12,097,900	$8,533,068	$8,549,228
ALL BRIDGES IN ENVIRONMENT 4	$6,519,787,950	$7,184,430,128	$7,292,750,302	$7,292,013,619	$7,292,041,402
TOTAL LONG TERM COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$374,577,328	$440,207,612	$431,541,536	$405,534,666	$406,763,765
ALL BRIDGES IN ENVIRONMENT 4	$7,115,639,120	$7,292,624,133	$7,292,750,302	$7,292,750,302	$7,292,750,302

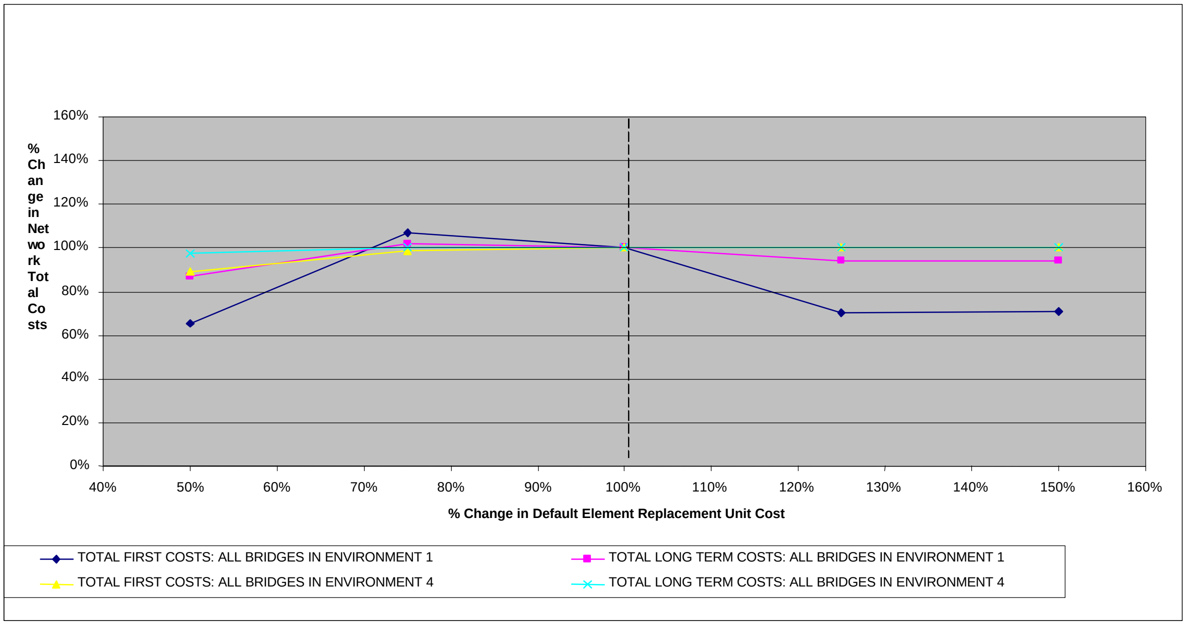

Figure 2.6. Sensitivity of Network Total MR&R Costs To Element Replacement Unit Cost

As mentioned earlier, bridge elements' sensitivity can be defined in terms of change in action recommended by the MR&R preservation model, relative to that action recommended at a default unit cost. Looking at Table 2.4, the following five bridge elements were observed to be individually sensitive to element replacement unit costs at all ranges of increase and decrease to the original default cost (sensitive to both high and low costs) increases: Element Nos. 28 Steel Deck - Open Grid, 109 P/S Conc Open Girder/Beam, 113 Painted Steel Stringer, 235 Timber Cap, and Reinforced Concrete Culvert. More of the sensitive bridge elements were sensitive to low costs (decrease from default cost), than to high costs (increase in default cost). Table 2.4 and Figure 2.5 show that 20 of the 35, or about 60% of the sample elements became sensitive when the replacement cost is reduced to 50% of the original cost, while only about 8 of the 35 sample elements are sensitive to all forms of increase in the cost.

As shown in Figure 2.6, the network total long-term cost was observed to remain in an approximately constant ratio to the network long-term total cost at the default replacement unit cost. It can be concluded that the network total long-term costs are relatively insensitive to variation in element replacement unit costs. The first costs, however, showed sensitivity at low cost and high cost values. The reduction in first costs at lower unit cost levels is to be expected. The reduction at higher replacement cost levels can be attributed to the shift in action recommendations toward less expensive element rehabilitation, rather than replacement.

2.3.3 Variation in Only Element Rehabilitation Unit Costs

Using SQL commands very similar to those utilized above for the element replacement unit costs study, agency unit costs were adjusted for only actions of element rehabilitation in the Pontis 3.4 cost database, while leaving maintenance, repair, and replacement costs fixed. Variation of the input was also in the same range (50% to 150%). The optimization was then run in the Pontis preservation model, at the default discount factor of 0.9525, to obtain results of the calculated long term unit costs for each element-environment-state-action combination, and the recommended action. The variation in long term costs relative to changes in the element rehabilitation unit costs, are shown in Tables 2.6 and 2.7 and graphs in Figures 2.7 – 2.8. The results include the changes in recommended actions as the costs are adjusted from the default cost values. The summary results at the network level also show costs and variations for the two environment scenarios described above for the study of element replacement unit costs.

It was observed that 14 of the 35 elements (40%) are individually sensitive to both very low and very high variations in rehabilitation cost (Table2.6). Bridge elements such as Nos. 12 Concrete Bare, 116 Reinforced Conc. Stringer, and 161 Painted Steel Pin were sensitive to high costs while Element Nos. 31 Timber Deck Bare, 311 Moveable Bearing (roller, sliding, etc.), and 313 Fixed Bearing, are sensitive to low cost values. Figure 2.7 also shows that the selection of optimal action for significant numbers of the bridge elements (50% to 60% of sample elements) is sensitive to all forms of variation in cost: from large decrease to large increase in cost values.

On the network level, the total first costs demonstrate high sensitivity at lower cost variations, but more importantly, the total long term costs were observed to be somewhat sensitive to both increase and decrease in cost (see Figure 2.8). As rehabilitation unit costs are decreased, the first costs and long-term costs are reduced, just as would be expected. As rehabilitation unit costs are increased, many elements switch to replacement, which is more expensive. A smaller number of elements switch to less expensive repairs. In the Pontis CoRe elements, the competition between rehabilitation and replacement is much more significant to the analysis, than the competition between repair and rehabilitation. Therefore, the overall effect is an increase in first costs and long-term costs as rehabilitation costs increase.

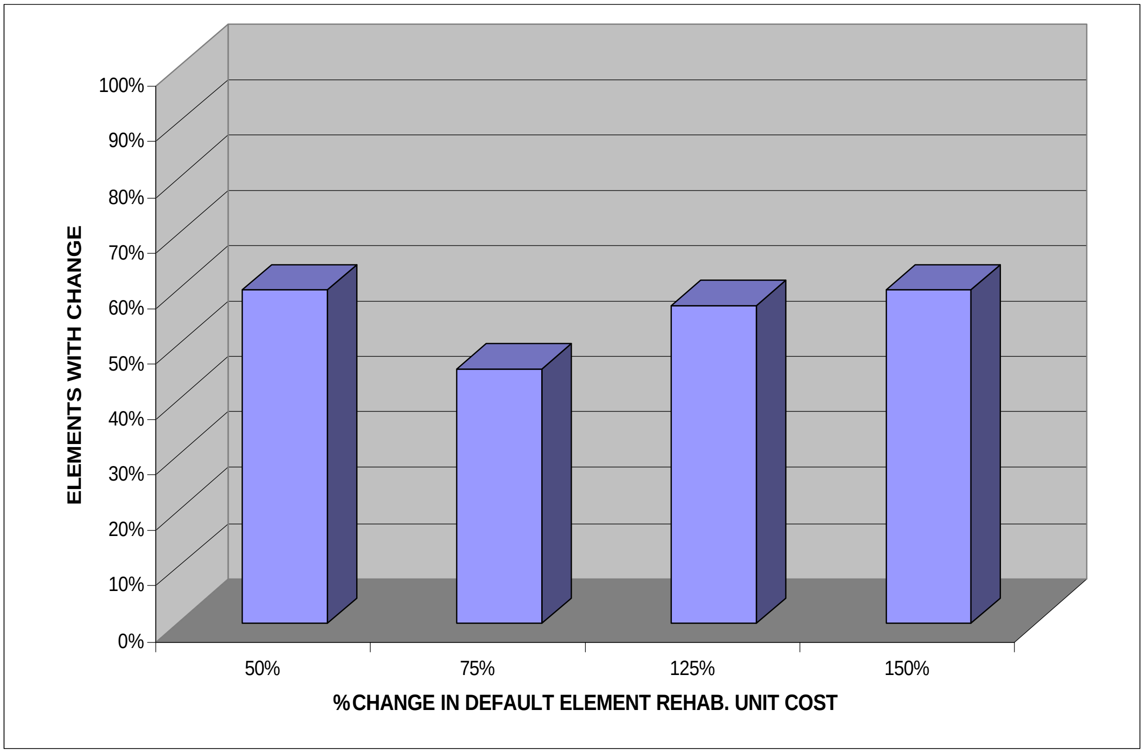

Figure 2.7. Summary Of Bridge Elements' Sensitivity To Element Rehabilitation Unit Cost

Table 2.6. Summary Of Bridge Elements' Sensitivity To Element Rehabilitation Unit Cost

Elem ID#	***Element Long Name***	***CHANGE IN ACTIONS RECOMMENDED? (AT % OF DEFAULT COST)***			
		50%	**75%**	**125%**	**150%**
12	Concrete Deck - Bare	NO	NO	YES	YES
13	Concrete Deck - Unprotected w/ AC Overlay	NO	NO	NO	NO
28	Steel Deck - Open Grid	YES	YES	YES	YES
31	Timber Deck - Bare	YES	NO	NO	NO
38	Concrete Slab - Bare	NO	NO	YES	YES
39	Concrete Slab - Unprotected w/ AC Overlay	YES	YES	YES	YES
102	Painted Steel Closed Web/Box Girder	YES	YES	YES	YES
104	P/S Conc Closed Web/Box Girder	YES	YES	YES	YES
107	Painted Steel Open Girder/Beam	YES	NO	YES	YES
109	P/S Conc Open Girder/Beam	YES	NO	NO	NO
110	Reinforced Conc Open Girder/Beam	YES	YES	YES	YES
111	Timber Open Girder/Beam	YES	YES	NO	NO
113	Painted Steel Stringer	NO	NO	NO	NO
116	Reinforced Conc Stringer	NO	NO	YES	YES
121	Painted Steel Bottom Chord Thru Truss	NO	NO	YES	YES
152	Painted Steel Floor Beam	YES	YES	YES	YES
161	Painted Steel Pin and/or Pin and Hanger Assembly	NO	NO	YES	YES
202	Painted Steel Column or Pile Extension	YES	YES	NO	YES
204	P/S Conc Column or Pile Extension	YES	YES	YES	YES
205	Reinforced Conc Column or Pile Extension	YES	YES	YES	YES
206	Timber Column or Pile Extension	YES	NO	YES	YES
210	Reinforced Conc Pier Wall	YES	YES	YES	YES
215	Reinforced Conc Abutment	YES	YES	YES	YES
234	Reinforced Conc Cap	YES	YES	YES	YES
235	Timber Cap	YES	YES	YES	YES
241	Reinforced Concrete Culvert	YES	YES	YES	YES
300	Strip Seal Expansion Joint	NO	NO	NO	NO
301	Pourable Joint Seal	NO	NO	NO	NO
302	Compression Joint Seal	NO	NO	NO	NO
303	Assembly Joint/Seal (modular)	NO	NO	NO	NO
304	Open Expansion Joint	NO	NO	NO	NO
310	Elastomeric Bearing	NO	NO	NO	NO
311	Moveable Bearing (roller, sliding, etc.)	YES	NO	NO	NO
313	Fixed Bearing	YES	YES	NO	NO
331	Reinforced Conc Bridge Railing	NO	NO	NO	NO
	TOTAL ELEMENT SENSITIVE (YES COUNT)	21	16	20	21
	% OF ALL ELEMENTS (35)	60%	46%	57%	60%

Table 2.7. Network Total MR&R Costs Vs. Change In Element Rehabilitation Unit Cost

	VARIATION IN ELEMENT REHABILITATION UNIT COST				
	50%	75%	100%	125%	150%
TOTAL FIRST COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$8,016,149	$10,634,805	$12,097,900	$12,314,867	$12,816,654
ALL BRIDGES IN ENVIRONMENT 4	$135,028,101	$269,644,928	$285,840,740	$290,369,056	$356,205,372
TOTAL LONG TERM COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$351,670,643	$388,247,684	$431,541,536	$444,939,678	$456,394,746
ALL BRIDGES IN ENVIRONMENT 4	$5,952,498,607	$6,940,132,197	$7,292,750,302	$7,566,686,005	$8,022,748,278

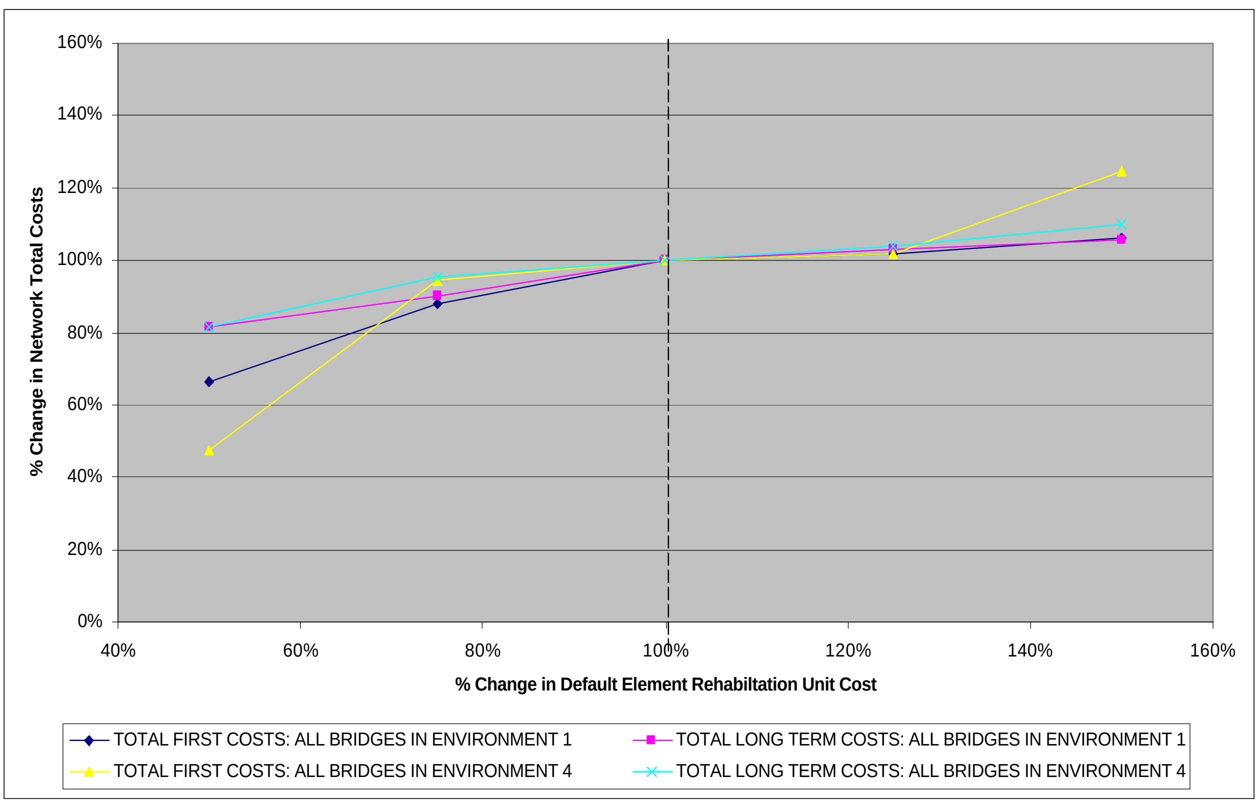

Figure 2.8. Sensitivity of Network Total MR&R Costs To Element Rehabilitation Unit Cost

2.3.4 Variation in Only Element Repair Unit Costs

Similar to the previous cases, the data were manipulated using SQL commands, adjusting only the element repair unit costs in the Pontis 3.4 cost database, while leaving maintenance, rehabilitation, and replacement costs fixed. The optimization was run in the Pontis preservation model, at the default discount factor of 0.9525, to obtain results of the calculated long term unit costs for each element-environment-state-action combination, and the recommended action. These results are presented in Tables 2.8 and 2.9 and Figures 2.9 – 2.10 to show the variation in action recommended based on the long term costs, relative to changes in the element repair unit costs.

On average, about 50% of the sample bridge elements show some form of sensitivity to all possible cost variations (see Table 2.8 and Figure 2.9). Most of the bridge elements are very sensitive to both very high costs (54% of elements) and very low costs (63% of elements). Ten elements were observed to be individually sensitive to all ranges of cost variations, i.e., both increase and decrease in cost. Element Nos. 12 Concrete Deck - Bare, 28 Steel Deck - Open Grid, 116 Reinforced Conc. Stringer, 205 Reinforced Conc. Column or Pile Extension, 331 Reinforced Conc. Bridge Railing, are individually sensitive to all forms of cost reductions while Element Nos. 152 Painted Steel Floor Beam, 301 Pourable Joint Seal, 302 Compression Joint Seal, 304 Open Expansion Joint, and 313 Fixed Bearing, are individually sensitive to any increase in costs. Element Nos. 13 Concrete Deck - Unprotected w/ AC Overlay, 31 Timber Deck - Bare, 206 Timber Column or Pile Extension, 235 Timber Cap, 241 Reinforced Concrete Culvert, and 303 Assembly Joint/Seal (modular), are observed to be insensitive to all variations in repair unit cost.

In addition to results at the element-environment-state-action levels, summary results are also presented at the network level. On the network level, the total long-term costs were observed to be reasonably sensitive to both increase and decrease in cost (see Figure 2.8). Decrease and increase in repair unit cost was found to be proportionately related to a resulting decrease and increase in network total long term costs respectively.

Table 2.8. Summary Of Bridge Elements' Sensitivity To Element Repair Unit Cost

Elem ID#	***Element Long Name***	***CHANGE IN ACTIONS RECOMMENDED? (AT % OF DEFAULT COST)***			
		50%	**75%**	**125%**	**150%**
12	Concrete Deck – Bare	YES	YES	NO	NO
13	Concrete Deck - Unprotected w/ AC Overlay	NO	NO	NO	NO
28	Steel Deck – Open Grid	YES	YES	NO	NO
31	Timber Deck - Bare	NO	NO	NO	NO
38	Concrete Slab - Bare	YES	NO	NO	NO
39	Concrete Slab - Unprotected w/ AC Overlay	YES	YES	YES	YES
102	Painted Steel Closed Web/Box Girder	YES	YES	YES	YES
104	P/S Conc Closed Web/Box Girder	YES	YES	YES	YES
107	Painted Steel Open Girder/Beam	YES	NO	NO	NO
109	P/S Conc Open Girder/Beam	YES	YES	YES	YES
110	Reinforced Conc Open Girder/Beam	YES	YES	YES	YES
111	Timber Open Girder/Beam	NO	NO	NO	NO
113	Painted Steel Stringer	YES	YES	YES	YES
116	Reinforced Conc Stringer	YES	YES	NO	NO
121	Painted Steel Bottom Chord Thru Truss	YES	YES	NO	NO
152	Painted Steel Floor Beam	NO	NO	YES	YES
161	Painted Steel Pin and/or Pin and Hanger Assembly	YES	NO	NO	NO
202	Painted Steel Column or Pile Extension	YES	YES	YES	YES
204	P/S Conc Column or Pile Extension	YES	YES	NO	YES
205	Reinforced Conc Column or Pile Extension	YES	YES	NO	NO
206	Timber Column or Pile Extension	NO	NO	NO	NO
210	Reinforced Conc Pier Wall	YES	YES	YES	YES
215	Reinforced Conc Abutment	YES	YES	YES	YES
234	Reinforced Conc Cap	YES	YES	NO	YES
235	Timber Cap	NO	NO	NO	NO
241	Reinforced Concrete Culvert	NO	NO	NO	NO
300	Strip Seal Expansion Joint	YES	YES	YES	YES
301	Pourable Joint Seal	NO	NO	YES	YES
302	Compression Joint Seal	NO	NO	YES	YES
303	Assembly Joint/Seal (modular)	NO	NO	NO	NO
304	Open Expansion Joint	NO	NO	YES	YES
310	Elastomeric Bearing	YES	NO	YES	YES
311	Moveable Bearing (roller, sliding, etc.)	NO	NO	NO	YES
313	Fixed Bearing	NO	NO	YES	YES
331	Reinforced Conc Bridge Railing	YES	YES	NO	NO
	TOTAL ELEMENTS SENSITIVE (YES COUNT)	22	18	16	19
	% OF ALL ELEMENTS (35)	63%	51%	46%	54%

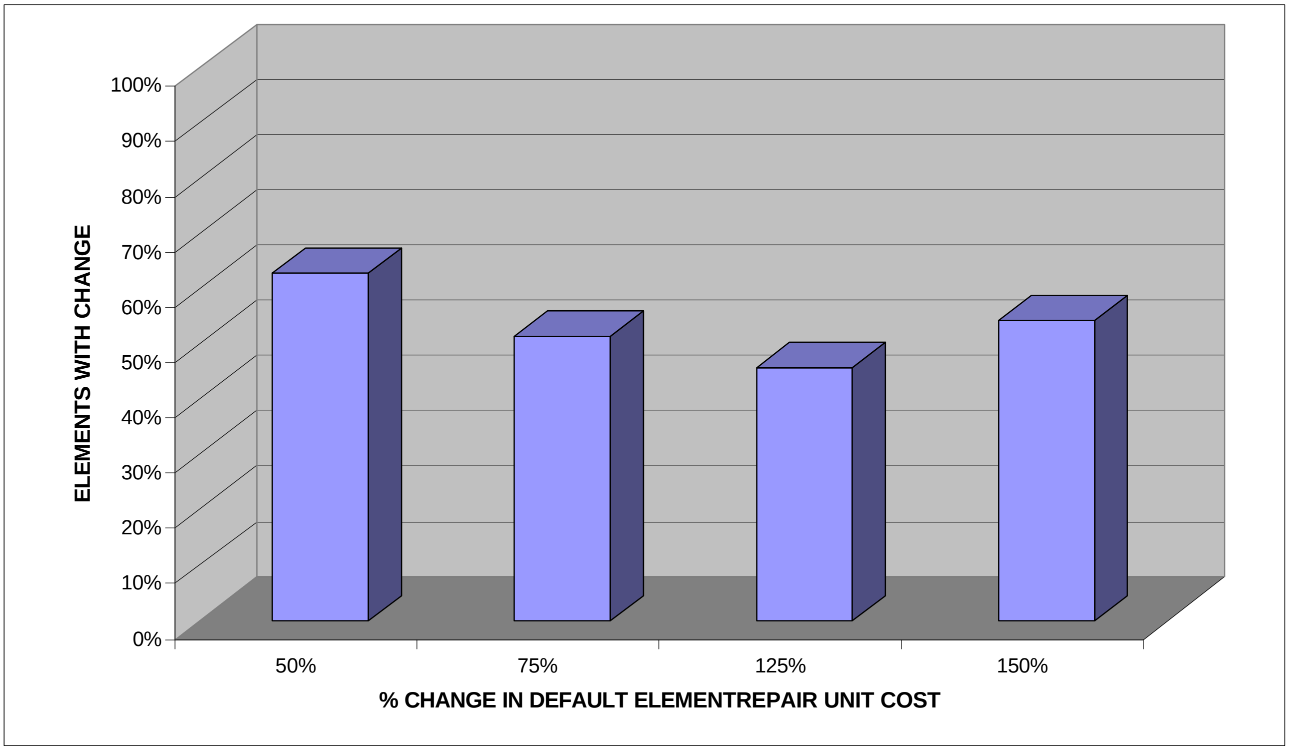

Figure 2.9. Summary Of Bridge Elements' Sensitivity To Element Repair Unit Cost

Table 2.9. Network Total MR&R Cost Vs. Change In Element Repair Unit Cost

	VARIATION IN ELEMENT REPAIR UNIT COST				
	50%	75%	100%	125%	150%
TOTAL FIRST COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$7,638,206	$8,656,911	$12,097,900	$16,050,886	$14,830,400
ALL BRIDGES IN ENVIRONMENT 4	$192,872,923	$227,244,938	$285,842,638	$319,226,421	$337,669,917
TOTAL LONG TERM COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$376,694,598	$355,629,618	$431,541,536	$510,690,906	$500,467,266
ALL BRIDGES IN ENVIRONMENT 4	$4,357,342,673	$5,881,397,512	$7,292,787,286	$8,492,616,502	$9,545,044,032

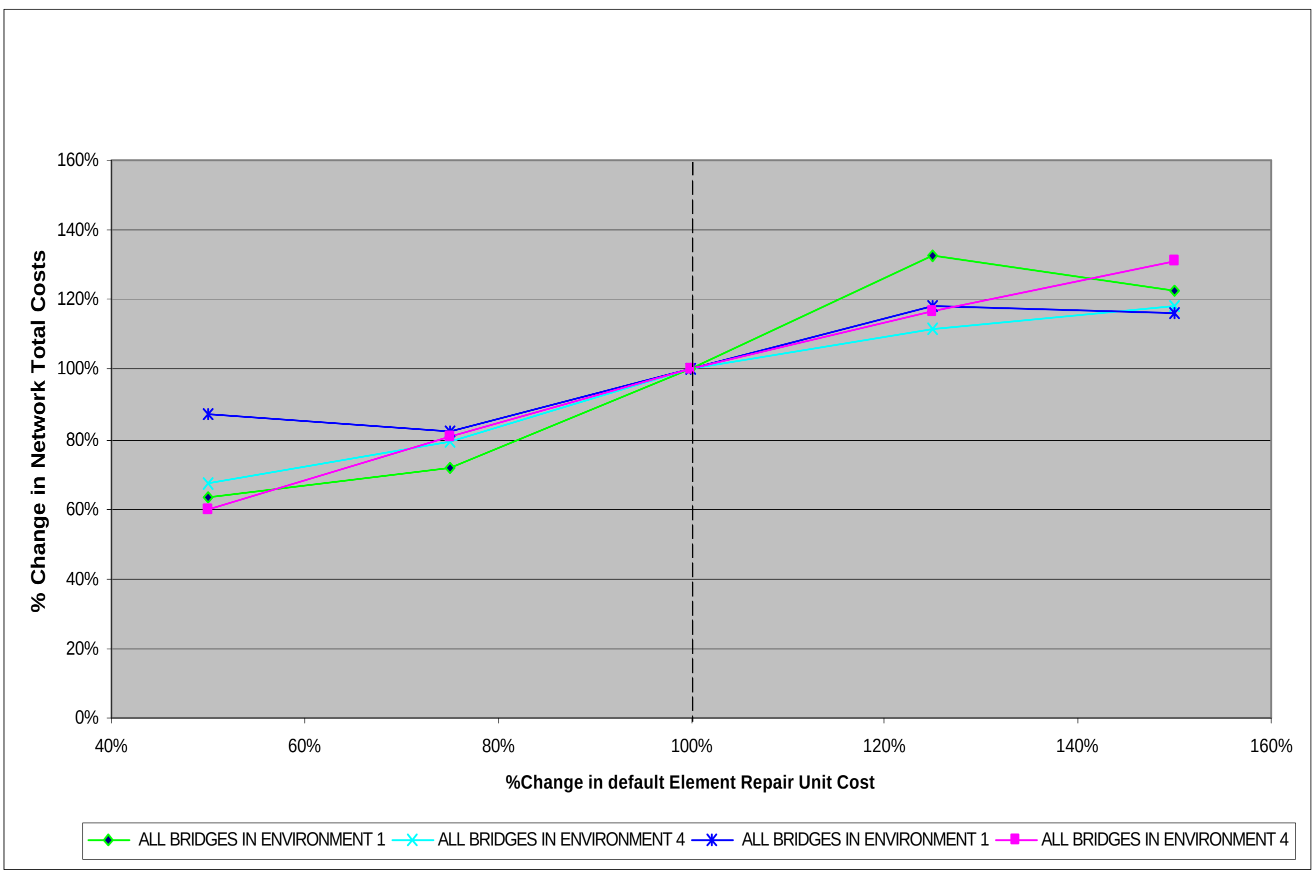

Figure 2.10. Sensitivity of Network Total MR&R Costs To Element Repair Unit Cost

2.3.5 Variation in only Element Minor Maintenance Unit Costs

Finally, for this subcategory, using SQL commands very similar to those utilized above for the element replacement unit costs, agency unit costs were adjusted for only actions of element minor maintenance in the Pontis 3.4 cost database, while leaving rehabilitation, repair, and replacement costs fixed. The optimization was run in the Pontis preservation model, at the default discount rate of 0.9525, to obtain results of the calculated long-term unit costs for each element-environment-state-action combination, and the recommended action. The variation in long term costs relative to changes in the element replacement unit costs, are shown in Tables 2.9 and 2.10 and graphs in Figures 2.11 and 2.12. The results include the changes in recommended actions as the costs are adjusted from the default cost values, in addition to summary results at the network level.

Less than 20% of the bridge elements showed any sensitivity to variation in minor maintenance unit costs. Element Nos. 102, and 202 were observed to be sensitive to all ranges of cost variation. Element Nos. 113, 152, 161, and 311 were sensitive to cost reductions while only Element No. 28 was found to be sensitive to cost increases.

Often in the Florida customization of the Pontis CoRe elements, minor maintenance actions are considered feasible in condition state 1, where they compete against the zero-cost alternative of do-nothing and thus are never selected at any non-zero unit cost. In other cases where minor maintenance is considered in state 2, the action is given very little effect on deterioration, and therefore also is not selected. It is not surprising, then, that minor maintenance actions have little effect on the Pontis results.

The network level results also show costs and variations for the two environment scenarios described above. Figure 2.11 indicates that network total long-term costs are relatively insensitive to variations in minor maintenance unit costs.

Table 2.10. Summary Of Bridge Elements' Sensitivity To Element Maintenance Unit Cost

Elem ID#	***Element Long Name***	**CHANGE IN ACTION RECOMMENDED? *(AT % OF DEFAULT COST)***			
		50%	**75%**	**125%**	**150%**
12	Concrete Deck – Bare	NO	NO	NO	NO
13	Concrete Deck - Unprotected w/ AC Overlay	NO	NO	NO	NO
28	Steel Deck - Open Grid	NO	NO	NO	YES
31	Timber Deck - Bare	NO	NO	NO	NO
38	Concrete Slab - Bare	NO	NO	NO	NO
39	Concrete Slab - Unprotected w/ AC Overlay	NO	NO	NO	NO
102	Painted Steel Closed Web/Box Girder	YES	YES	YES	YES
104	P/S Conc Closed Web/Box Girder	NO	NO	NO	NO
107	Painted Steel Open Girder/Beam	NO	NO	NO	YES
109	P/S Conc Open Girder/Beam	NO	NO	NO	NO
110	Reinforced Conc Open Girder/Beam	NO	NO	NO	NO
111	Timber Open Girder/Beam	NO	NO	NO	NO
113	Painted Steel Stringer	YES	YES	NO	NO
116	Reinforced Conc Stringer	NO	NO	NO	NO
152	Painted Steel Floor Beam	YES	YES	NO	NO
161	Painted Steel Pin and/or Pin and Hanger Assembly	YES	YES	NO	NO
121	Painted Steel Bottom Chord Thru Truss	NO	NO	NO	NO
202	Painted Steel Column or Pile Extension	YES	YES	YES	YES
204	P/S Conc Column or Pile Extension	NO	NO	NO	NO
205	Reinforced Conc Column or Pile Extension	NO	NO	NO	NO
206	Timber Column or Pile Extension	NO	NO	NO	NO
210	Reinforced Conc Pier Wall	NO	NO	NO	NO
215	Reinforced Conc Abutment	NO	NO	NO	NO
234	Reinforced Conc Cap	NO	NO	NO	NO
235	Timber Cap	NO	NO	NO	NO
241	Reinforced Concrete Culvert	NO	NO	NO	NO
300	Strip Seal Expansion Joint	NO	NO	NO	NO
301	Pourable Joint Seal	NO	NO	NO	NO
302	Compression Joint Seal	NO	NO	NO	NO
303	Assembly Joint/Seal (modular)	NO	NO	NO	NO
304	Open Expansion Joint	NO	NO	NO	NO
310	Elastomeric Bearing	NO	NO	NO	NO
311	Moveable Bearing (roller, sliding, etc.)	YES	YES	NO	NO
313	Fixed Bearing	NO	NO	NO	NO
331	Reinforced Conc Bridge Railing	NO	NO	NO	NO
	TOTAL ELEMENTS SENSITIVE (YES COUNT)	6	6	2	4
	% OF ALL ELEMENTS (35)	17%	17%	6%	11%

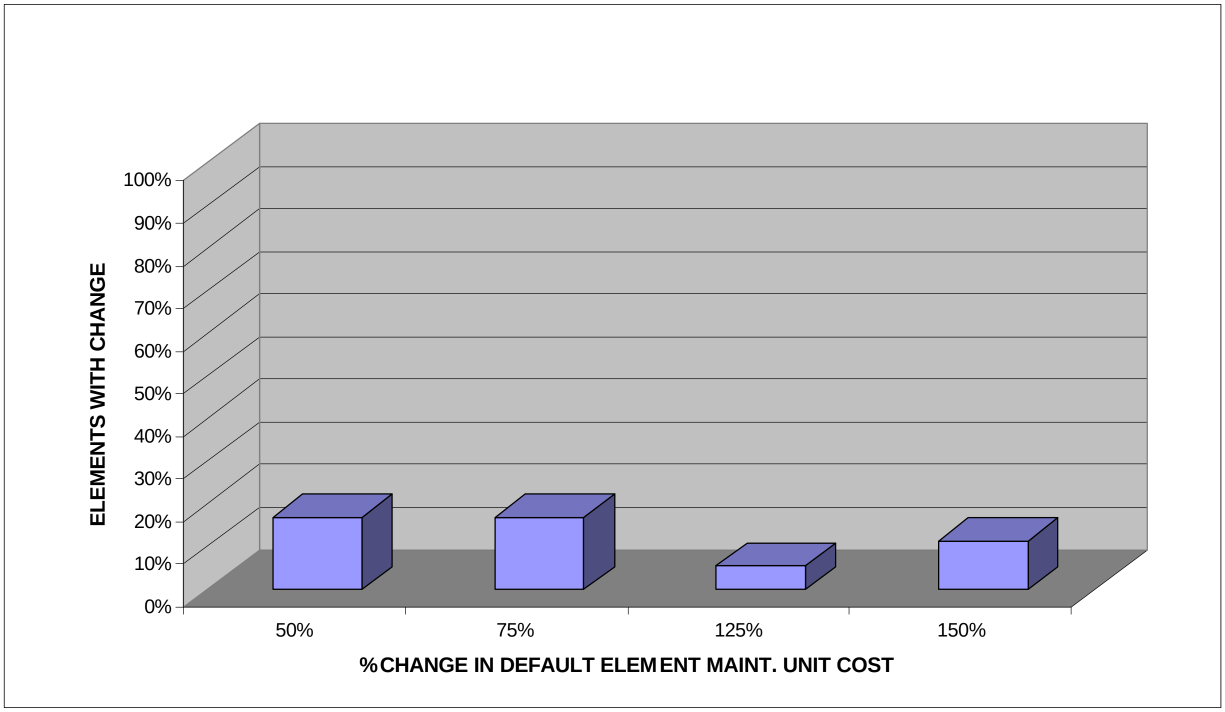

Figure 2.11. Summary of Bridge Elements' Sensitivity To Element Maintenance Unit Cost

Table 2.11. Network Total MR&R Costs Vs. Change In Element Maintenance Unit Cost

	VARIATION IN ELEMENT MAINTENANCE UNIT COST				
	50%	75%	100%	125%	150%
TOTAL FIRST COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$9,745,841	$10,310,203	$12,097,900	$9,875,958	$9,875,958
ALL BRIDGES IN ENVIRONMENT 4	$274,463,957	$280,536,503	$285,842,638	$271,393,754	$271,393,754
TOTAL LONG TERM COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$393,039,443	$404,871,348	$431,541,536	$398,728,980	$402,709,992
ALL BRIDGES IN ENVIRONMENT 4	$7,025,437,177	$7,177,773,465	$7,292,787,286	$7,278,527,180	$7,327,497,281

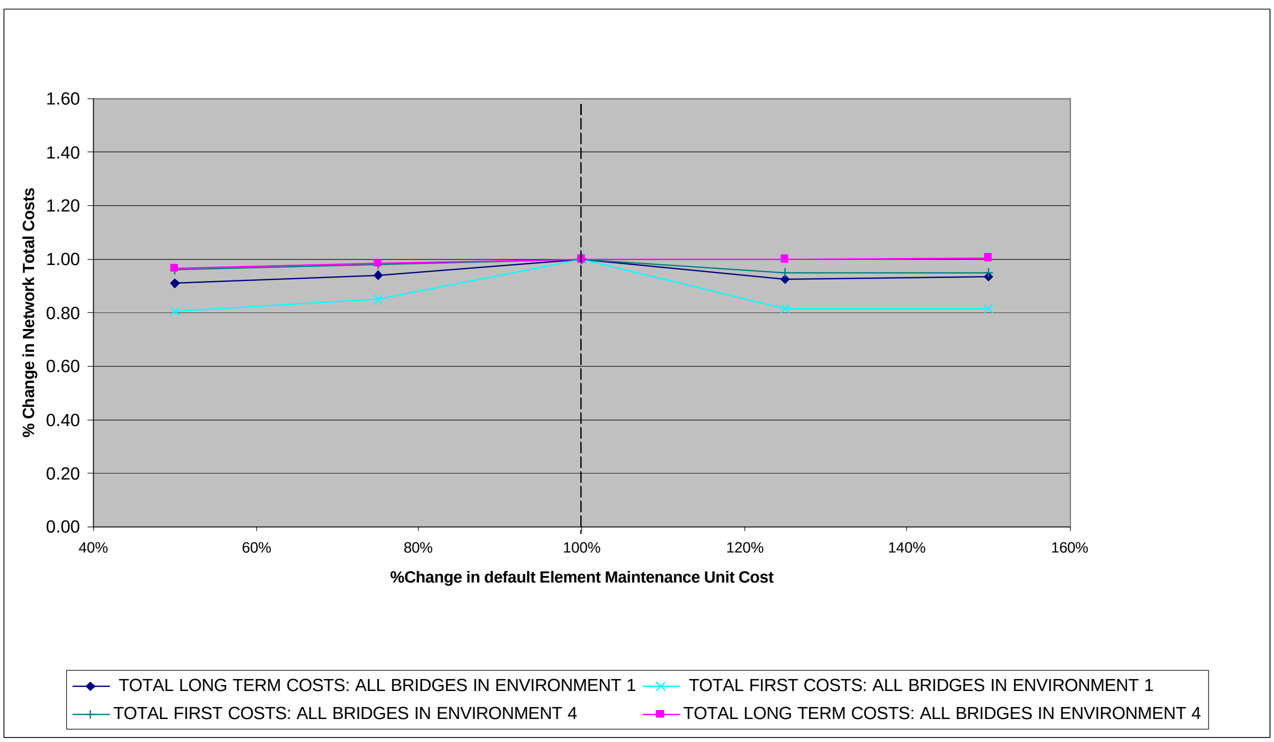

Figure 2.12. Sensitivity Of Network Total MR&R Costs To Element Maintenance Unit Cost

2.3.6 Variation in only Failure Agency Unit Costs

As mentioned earlier in this report, failure agency costs play a major role in the optimal selection of MR&R actions in the Pontis preservation model. To perform the sensitivity analysis, a set of SQL commands were utilized to adjust only the element failure agency unit costs in the Pontis 3.4 cost database, while leaving all MR&R costs fixed. With variation the range of 50% to 150% of the default cost, the optimization was run in the Pontis preservation model, at the default discount factor of 0.9525, to obtain results of the calculated long term unit costs for each element-environment-state-action combination, and the recommended action. Table 2.12 shows the sensitivity of each element considered, while figures 2.13 and 2.14 show, for selected elements, the variation in long-term costs relative to changes in the element replacement unit costs. Also indicated in graphs (Figures 2.13 and 2.14) are the changes in recommended actions as the costs are adjusted from the default cost values.

This study of the failure agency costs showed the most sensitivity of all the variables considered so far, with about 90% of the bridge elements in the sample showing some form of sensitivity, mostly because lower failure costs allow the failure state to occur. The only insensitive elements are Nos. 13 Concrete Deck - Unprotected w/ AC Overlay, 116 Reinforced Conc Stringer, 121 Painted Steel Bottom Chord Thru Truss, and 303 Assembly Joint/Seal (modular). As expected, almost all the sensitivities observed were due to cost reduction; only element No. 300 Strip Seal Expansion Joint in environment 1 State 3, showed sensitivity to cost increase. (This case was the only one that had a do-nothing recommendation for its worst condition state in the base-case model.)

In addition to results at the element-environment-state-action levels, summary results are also presented at the network level. The network total costs are only sensitive at low cost values, specifically, at costs lower than about 90% of the default original cost. Above this threshold, the network total costs are insensitive to failure agency costs.

Element Failure Agency Cost is technically defined as the cost to restore the element to serviceable condition after failure as well as to restore any other element that might be affected by failure. This cost is generally very high relative to element replacement, thus causing the Pontis network optimization to find replacement to be a more cost-effective alternative. The effect of lowering the failure cost is to cause the models to select failure. Since this is considered undesirable, it is important to make sure the failure costs are large enough to prevent failure of all elements. The lower long-term costs shown in the graph for lower failure costs, result from the fact that Pontis does not model element behavior following failure, and therefore does not have any life cycle cost allowance for future work following the failure.

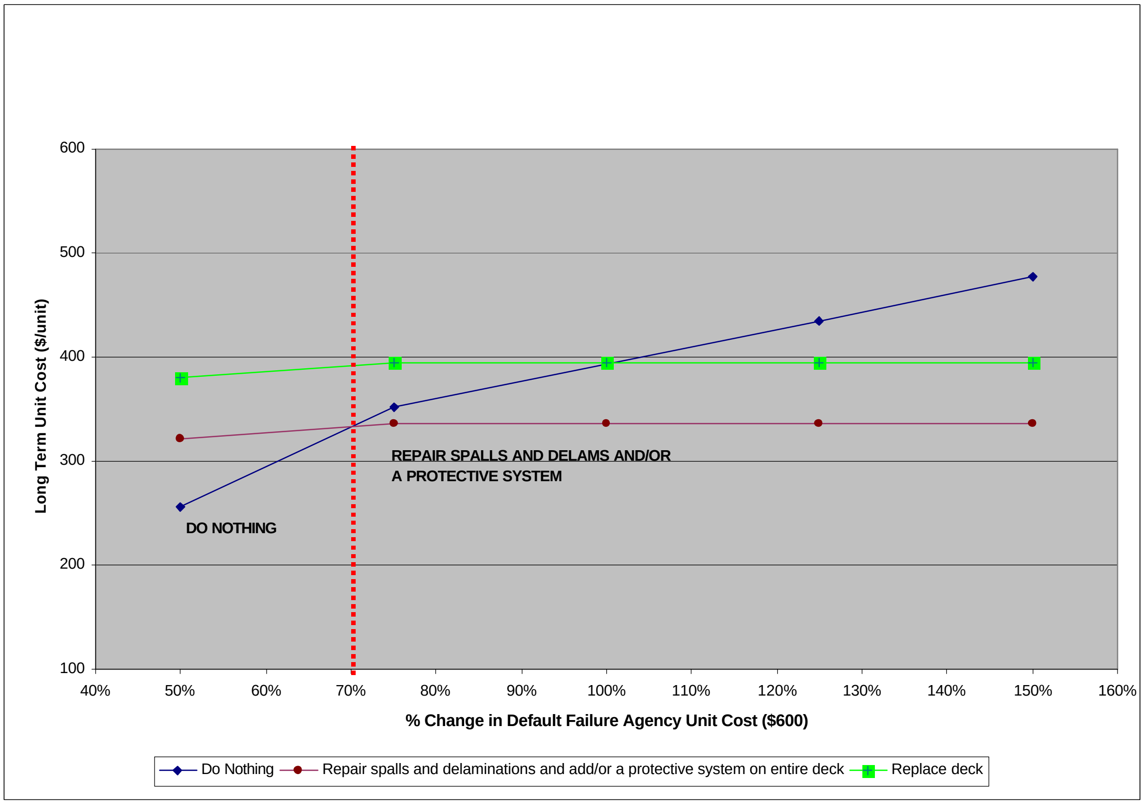

Figure 2.13. Long-term Unit Cost Vs. % Change in Default Failure Agency Unit Cost (Element #12 - Concrete Deck - Bare: Environment 4 Condition State 5, Failure Probability = 29.29%)

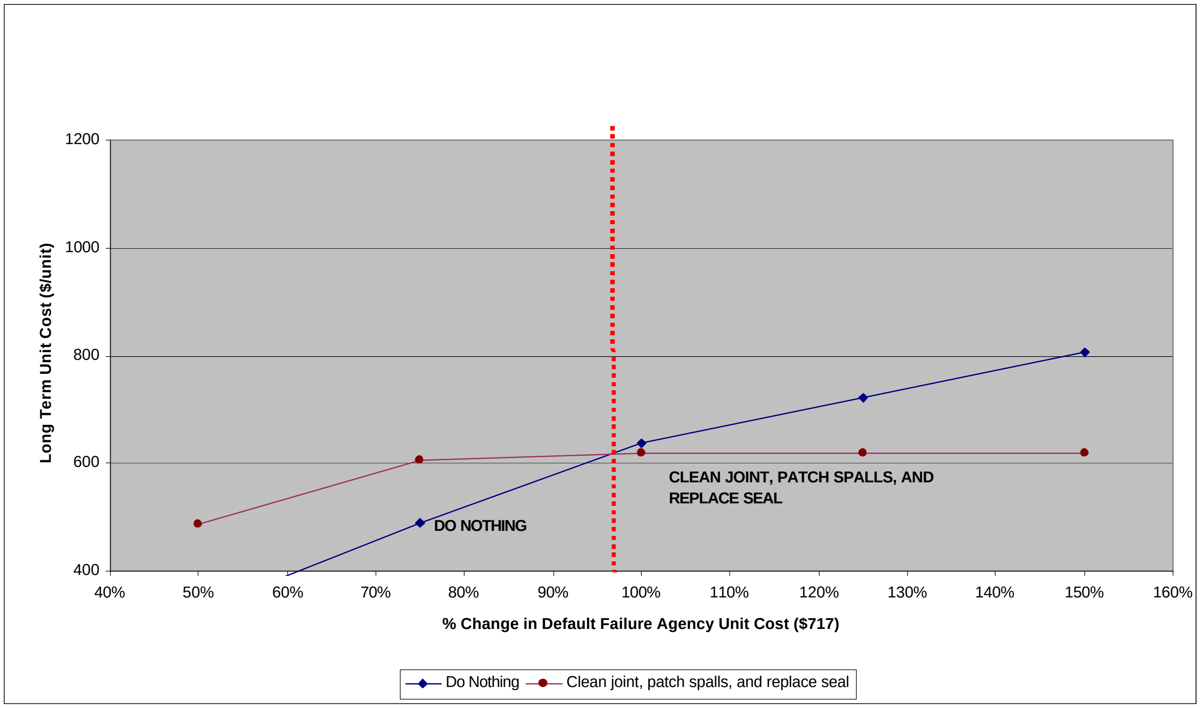

Figure 2.14. Long-term Unit Cost Vs. % Change in Default Failure Agency Unit Cost

(Element #301- Pourable Joint Seal: Environment 4 Condition State 3, Failure Probability = 50.00%)

Table 2.12. Summary Of Bridge Elements' Sensitivity To Element Failure Agency Unit Cost

Elem ID#	***Element Long Name***	**CHANGE IN ACTIONS RECOMMENDED? *(AT % OF DEFAULT COST)***			
		50%	**75%**	**125%**	**150%**
12	Concrete Deck - Bare	YES	YES	NO	NO
13	Concrete Deck - Unprotected w/ AC Overlay	NO	NO	NO	NO
28	Steel Deck - Open Grid	YES	YES	NO	NO
31	Timber Deck - Bare	YES	YES	NO	NO
38	Concrete Slab - Bare	YES	YES	NO	NO
39	Concrete Slab - Unprotected w/ AC Overlay	YES	YES	NO	NO
102	Painted Steel Closed Web/Box Girder	YES	YES	NO	NO
104	P/S Conc Closed Web/Box Girder	YES	YES	NO	NO
107	Painted Steel Open Girder/Beam	YES	YES	NO	NO
109	P/S Conc Open Girder/Beam	YES	YES	NO	NO
110	Reinforced Conc Open Girder/Beam	YES	YES	NO	NO
111	Timber Open Girder/Beam	YES	YES	NO	NO
113	Painted Steel Stringer	YES	YES	NO	NO
116	Reinforced Conc Stringer	NO	NO	NO	NO
152	Painted Steel Floor Beam	YES	NO	NO	NO
161	Painted Steel Pin and/or Pin and Hanger Assembly	YES	YES	NO	NO
121	Painted Steel Bottom Chord Thru Truss	NO	NO	NO	NO
202	Painted Steel Column or Pile Extension	YES	YES	NO	NO
204	P/S Conc Column or Pile Extension	YES	YES	NO	NO
205	Reinforced Conc Column or Pile Extension	YES	YES	NO	NO
206	Timber Column or Pile Extension	YES	YES	NO	NO
210	Reinforced Conc Pier Wall	YES	YES	NO	NO
215	Reinforced Conc Abutment	YES	YES	NO	NO
234	Reinforced Conc Cap	YES	YES	NO	NO
235	Timber Cap	YES	YES	NO	NO
241	Reinforced Concrete Culvert	YES	YES	NO	NO
300	Strip Seal Expansion Joint	YES	YES	YES	YES
301	Pourable Joint Seal	YES	YES	NO	NO
302	Compression Joint Seal	YES	YES	NO	NO
303	Assembly Joint/Seal (modular)	NO	NO	NO	NO
304	Open Expansion Joint	YES	YES	NO	NO
310	Elastomeric Bearing	YES	YES	NO	NO
311	Moveable Bearing (roller, sliding, etc.)	YES	NO	NO	NO
313	Fixed Bearing	YES	YES	NO	NO
331	Reinforced Conc Bridge Railing	YES	YES	NO	NO
	TOTAL ELEMENTS SENSITIVE (YES COUNT)	31	29	1	1
	% OF ALL ELEMENTS (35)	89%	83%	3%	3%

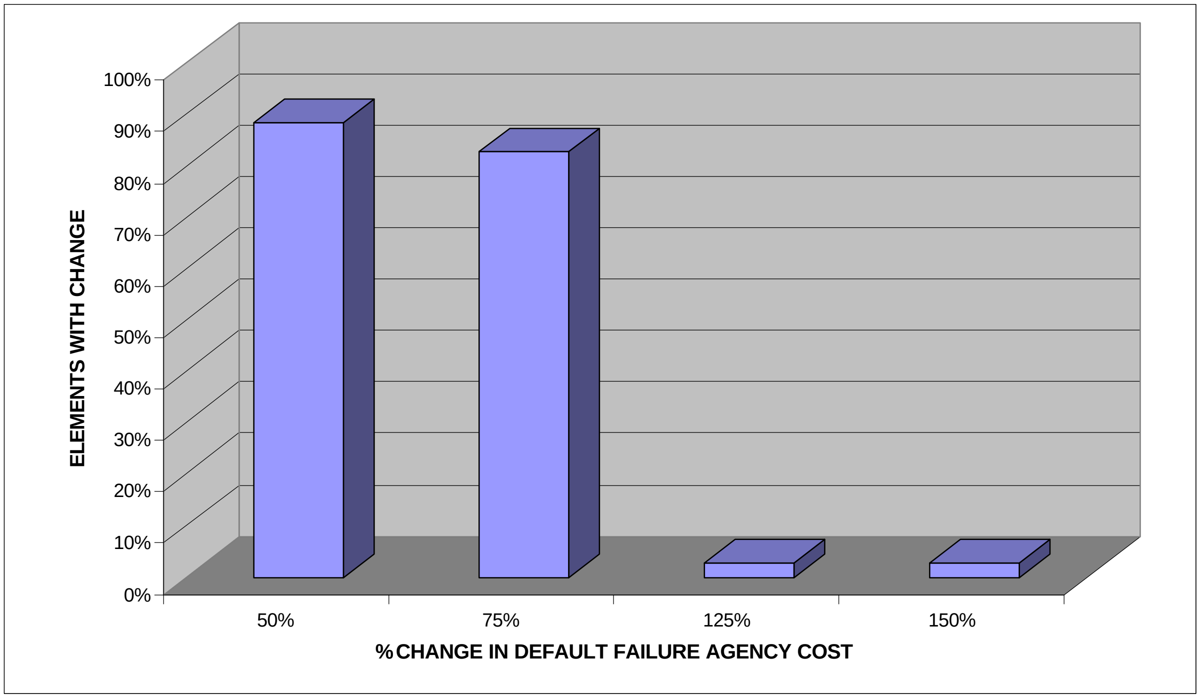

Figure 2.15. Summary Of Bridge Elements' Sensitivity To Element Failure Agency Unit Cost

Table 2.13. Network Total MR&R Costs Vs. Element Failure Agency Unit Costs

	VARIATION IN ELEMENT FAILURE AGENCY UNIT COST				
	50%	75%	100%	125%	150%
TOTAL FIRST COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$2,091,435	$8,206,750	$12,097,900	$12,125,426	$12,125,426
ALL BRIDGES IN ENVIRONMENT 4	$209,872,598	$222,078,178	$285,840,740	$285,840,740	$289,511,009
TOTAL LONG TERM COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$305,352,070	$394,515,025	$431,541,536	$431,571,582	$431,571,582
ALL BRIDGES IN ENVIRONMENT 4	$6,437,552,058	$7,115,639,120	$7,292,750,302	$7,292,750,302	$7,292,750,302

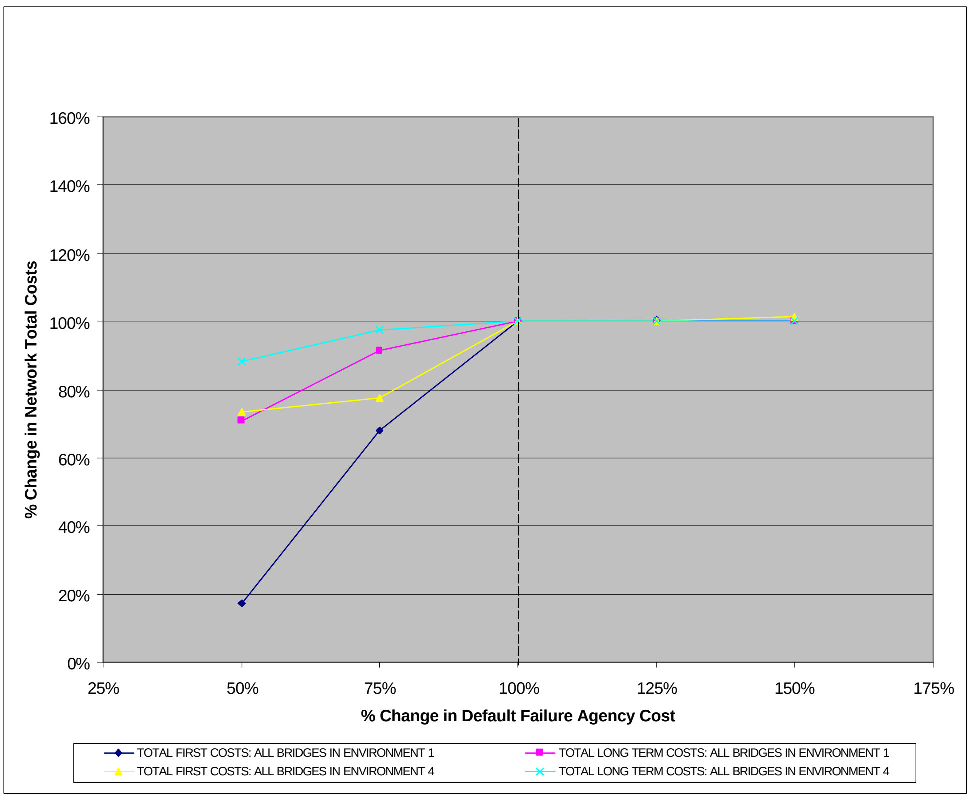

Figure 2.16. Sensitivity Of Network Total MR&R Costs To Element Failure Agency Unit Cost

2.3.7 Variation in only Discount Rate Factors

The data manipulation for the last category of sensitivity analysis considered (effect of the discount rate factor) was easily carried out by using the Configuration button of the Pontis 3.4 main screen. All costs were left at their default values while the discount rate was varied from 0.925 to 0.990, representing a range of interest rate between 1.0% and about 8.0%. Again, an optimization of the preservation model was done by using the Pontis Optimize button. At each discount rate, the results of the optimization run, in a report, included the calculated long-term unit costs for each element-environment-state-action combination, and the recommended action.

As observed in the various graphs in Figures 2.17 to 2.19, there is an expected increasing nonlinear relationship between the long-term costs and discount rate factors. The sensitivity is shown for sample elements, indicating change of action recommended for both cases of lower and higher discount rates. In addition to results at the element-environment-state-action levels, summary results are also presented at the network level.

As indicated in equation 1 presented earlier in this report, any increase in the discount rate factor α will increase the long-term Cost (LTC) of each bridge element. The effect of the discount rate factor α is predictable, based on the nonlinear increase expected in a typical discounting function. Table 2.14 shows that almost all the elements were sensitive to discount rates except for Element No. 13, which was insensitive to all changes in discount rates. Element nos. 38, 107, 202, 205, and 302 were barely sensitive. The least sensitivity (about 30% of the elements) was observed at discount rates close to the default value of 0.95252. The sensitivity was observed to be predominant at extreme low and high α values, with over 80% of the bridge elements being sensitive to very high and very low values of the discount rate factor.

At the network level, the sensitivity demonstrated in Figure 2.21 is as expected, particularly for the total long-term costs.

When the discount rate is increased (moving closer to 1.0), the effect of long-term costs becomes more important in the optimization. As a result, the model is more likely to recommend actions that reduce long-term costs, even if they are initially more expensive. When the discount rate is decreased, the future implications of decisions become less important, and the model is more likely to recommend doing nothing. It was also observed that the total network MR&R first cost is slightly sensitive to increase in the discount rate factor. Being the initial costs of actions recommended based on their optimal long-term unit costs, this sensitivity is not unexpected. However, for bridge elements in environment 4 (worst), the model tends to recommend cheaper actions (including do-nothing) at high discount rates.

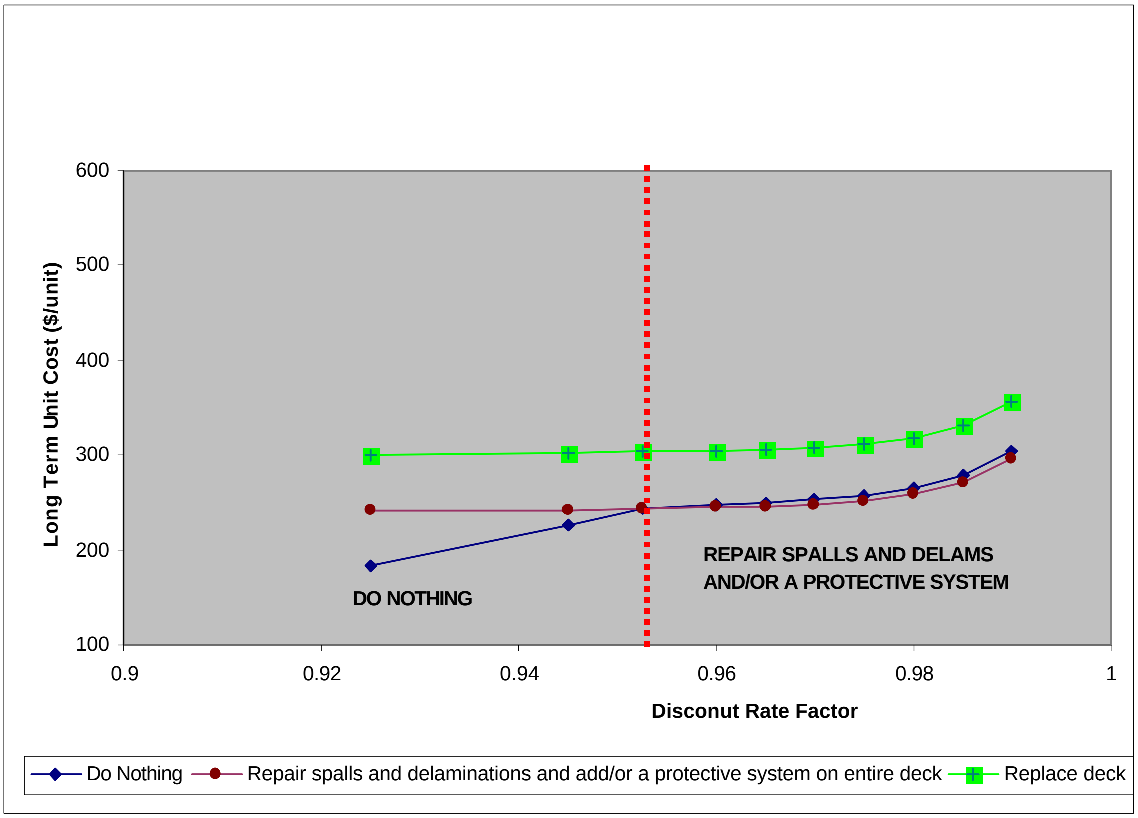

Figure 2.17. Long-Term Unit Cost Vs. Discount Rate Factor

(Element #12 - Concrete Deck - Bare: Environment 1 Condition State 5, Failure Probability = 3.56%)

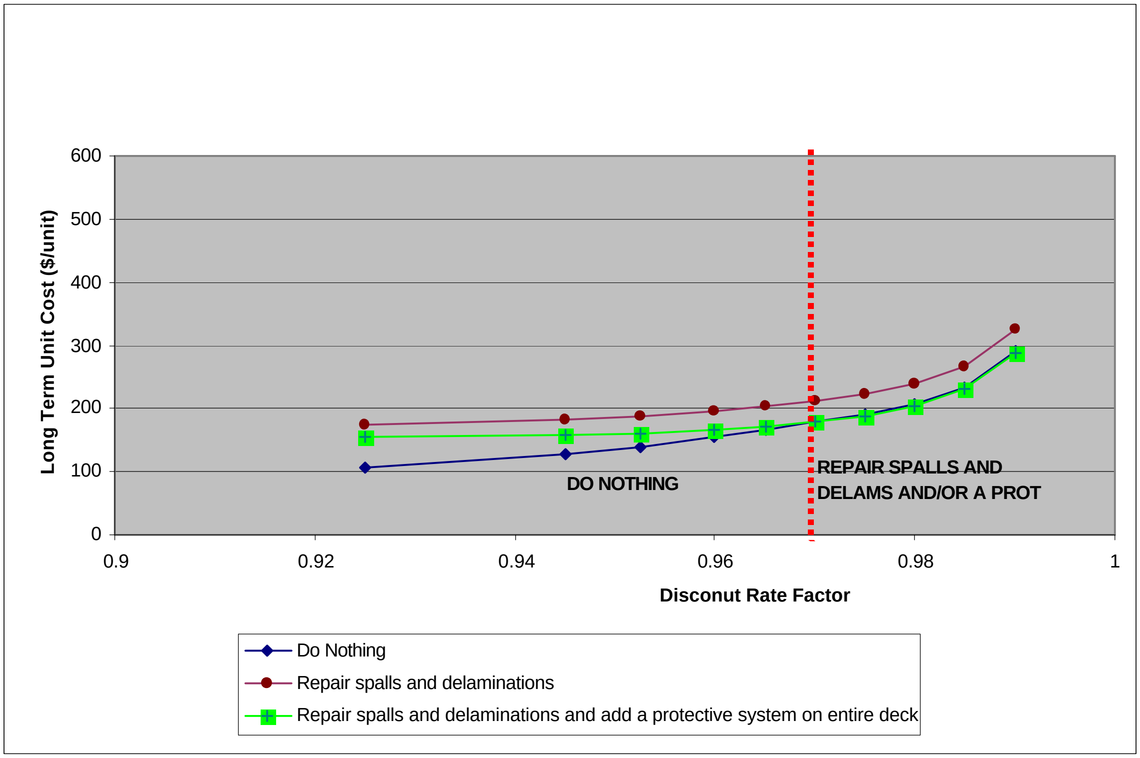

Figure 2.18. Long-Term Unit Cost Vs. Discount Rate Factor

(Element #12 - Concrete Deck - Bare: Environment 2 Condition State 4, Failure Probability = 7.26%)

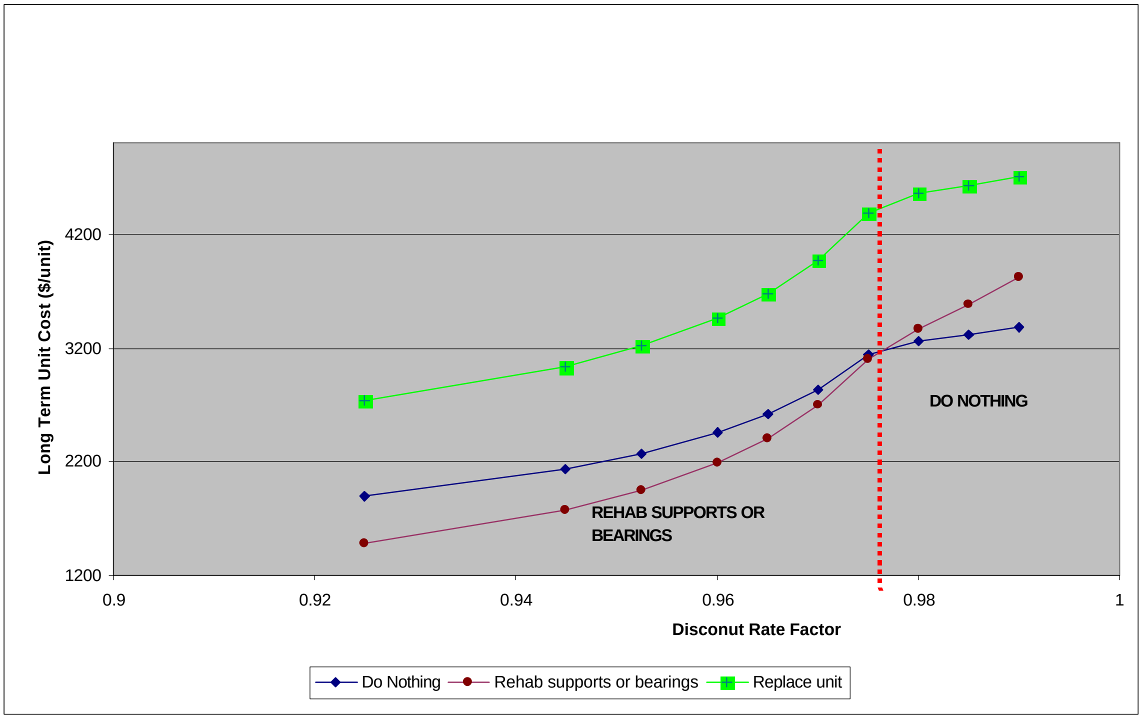

Figure 2.19. Long-Term Unit Cost Vs. Discount Rate Factor

(Element #311 - Moveable Bearing (roller, sliding, etc.): Environment 4 Condition State 3, Failure Probability = 27.89%)

Table 2.14. Summary Of Bridge Elements' Sensitivity To Discount Rate Factor (a)

Elem ID#	***Element Long Name***	**CHANGE IN ACTIONS RECOMMENDED? *(COMPARED TO DEFAULT DISCOUNT RATE 0.9525)***								
		0.925	**0.945**	**0 .960**	**0.965**	**0.970**	**0.975**	**0.980**	**0.985**	**0.990**
12	Concrete Deck - Bare	YES	YES	NO	NO	YES	YES	YES	YES	YES
13	Concrete Deck - Unprotected w/ AC Overlay	NO	NO	NO	NO	NO	NO	NO	NO	NO
28	Steel Deck - Open Grid	YES	YES	YES	YES	YES	YES	YES	YES	YES
31	Timber Deck - Bare	YES	NO	NO	NO	NO	NO	NO	YES	YES
38	Concrete Slab - Bare	YES	NO	NO	NO	NO	NO	NO	NO	NO
39	Concrete Slab - Unprotected w/ AC Overlay	YES	YES	NO	YES	YES	YES	YES	YES	YES
102	Painted Steel Closed Web/Box Girder	YES	NO	NO	YES	YES	YES	YES	YES	YES
104	P/S Conc Closed Web/Box Girder	YES	YES	NO	YES	YES	YES	YES	YES	YES
107	Painted Steel Open Girder/Beam	YES	YES	NO	NO	NO	NO	NO	NO	NO
109	P/S Conc Open Girder/Beam	YES	YES	NO	YES	YES	YES	YES	YES	YES
110	Reinforced Conc Open Girder/Beam	YES	NO	YES	YES	YES	YES	YES	YES	YES
111	Timber Open Girder/Beam	YES	NO	NO	YES	YES	YES	YES	YES	YES
113	Painted Steel Stringer	YES	NO	NO	NO	NO	YES	YES	YES	YES
116	Reinforced Conc Stringer	YES	NO	YES	YES	YES	YES	YES	YES	YES
121	Painted Steel Bottom Chord Thru Truss	YES	NO	YES	YES	YES	YES	YES	YES	YES
152	Painted Steel Floor Beam	YES	NO	NO	NO	NO	YES	YES	YES	YES
161	Painted Steel Pin and/or Pin and Hanger Assembly	YES	NO	NO	NO	NO	NO	YES	YES	YES
202	Painted Steel Column or Pile Extension	YES	NO	NO	NO	NO	NO	NO	NO	NO
204	P/S Conc Column or Pile Extension	YES	NO	YES	YES	YES	YES	YES	YES	YES
205	Reinforced Conc Column or Pile Extension	YES	NO	NO	YES	YES	YES	YES	YES	YES
206	Timber Column or Pile Extension	YES	NO	NO	NO	NO	NO	NO	NO	YES
210	Reinforced Conc Pier Wall	YES	YES	NO	NO	NO	YES	YES	YES	YES
215	Reinforced Conc Abutment	YES	NO	YES	YES	YES	YES	YES	YES	YES
234	Reinforced Conc Cap	YES	YES	YES	YES	YES	YES	YES	YES	YES
235	Timber Cap	YES	NO	NO	YES	YES	YES	YES	YES	YES
241	Reinforced Concrete Culvert	YES	NO	NO	NO	NO	YES	YES	YES	YES
300	Strip Seal Expansion Joint	NO	NO	YES	YES	YES	YES	YES	YES	YES
301	Pourable Joint Seal	NO	NO	YES	YES	YES	YES	YES	YES	YES
302	Compression Joint Seal	NO	NO	YES	YES	YES	YES	YES	YES	YES
303	Assembly Joint/Seal (modular)	NO	NO	NO	NO	NO	NO	NO	NO	YES
304	Open Expansion Joint	YES	YES	NO	YES	YES	YES	YES	YES	YES
310	Elastomeric Bearing	YES	YES	NO	NO	YES	YES	YES	YES	YES
311	Moveable Bearing (roller, sliding, etc.)	NO	NO	NO	NO	NO	NO	YES	YES	YES
313	Fixed Bearing	YES	YES	NO	NO	NO	YES	YES	YES	YES
331	Reinforced Conc Bridge Railing	YES	YES	NO	YES	YES	YES	YES	YES	YES
	TOTAL ELEMENTS SENSITIVE (YES COUNT)	29	12	10	19	21	26	28	29	31
	% OF ALL ELEMENTS (35)	83%	34%	29%	54%	60%	74%	80%	83%	89%

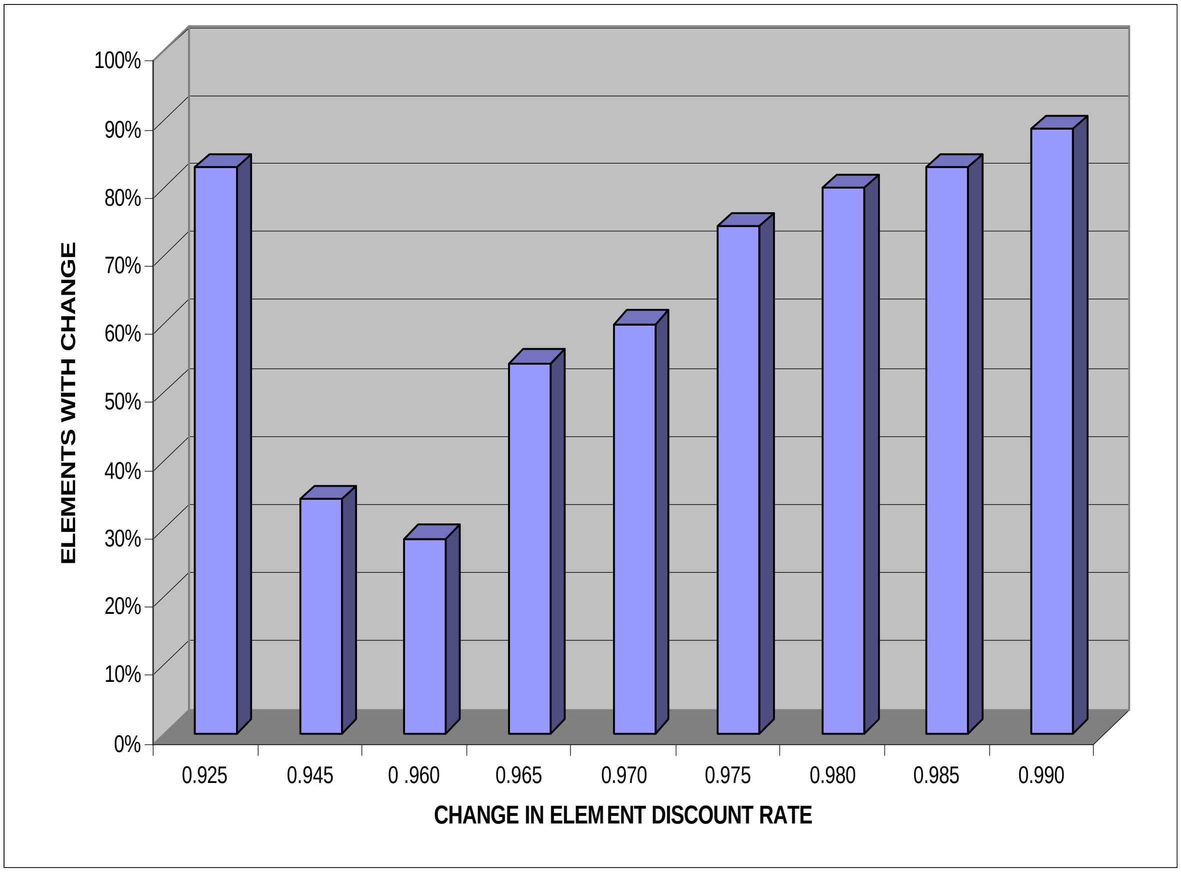

Figure 2.20. Summary Of Bridge Elements' Sensitivity To Discount Rate Factor (a)

Table 2.15. Network Total MR&R Costs Vs. Change In Discount Rate Factor (a)

	VARIATION IN DISCOUNT RATE (DEFAULT a = 0.9525)				
	0.925	0.9525	0.965	0.975	0.985
TOTAL FIRST COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$5,956,911	$12,097,900	$12,195,079	$12,209,192	$12,416,869
ALL BRIDGES IN ENVIRONMENT 4	$268,092,008	$285,840,740	$267,365,160	$232,491,628	$220,364,927
TOTAL LONG TERM COSTS:					
ALL BRIDGES IN ENVIRONMENT 1	$205,816,123	$431,541,536	$691,466,457	$1,177,407,639	$2,490,013,403
ALL BRIDGES IN ENVIRONMENT 4	$4,465,215,172	$7,292,750,302	$9,969,220,031	$13,623,598,477	$21,213,565,245

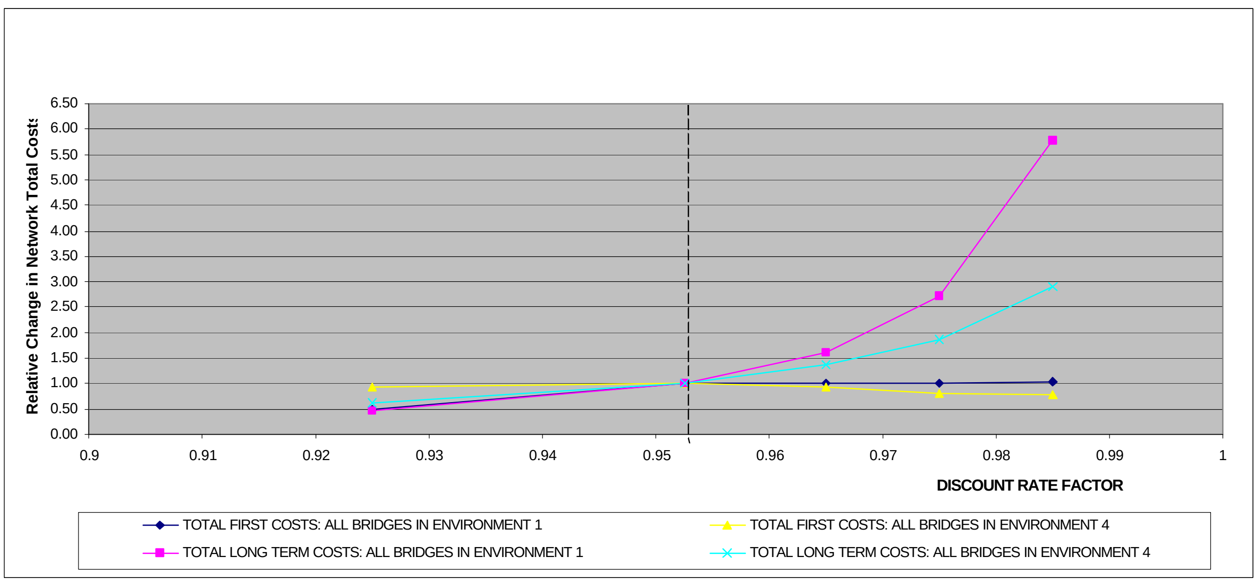

Figure 2.21. Sensitivity Of Network Total MR&R Costs To Discount Rate Factor (a)

2.4 Comments and Conclusions on BMS Requirements

Table 2.16 summarizes the sensitivity analysis, identifying the parts of the preservation cost model that are most sensitive to input data. The table shows that rehabilitation and repair unit costs are of greatest importance, demanding the highest level of precision. Element replacement costs can suffice with somewhat less precision, and minor maintenance costs even less.

Failure costs are not significant in the network-level model as long as the cost is high enough to prevent the recommendation of do-nothing in the worst condition state. However, failure costs do contribute to the long-term cost calculation and thus they do affect the relative priorities among elements at the program level of Pontis.

Discount rates are very significant to the analysis. The evident sensitivity of this variable underscores the importance of having a standard policy discount rate that is applied to all types of assets.

All of the agency unit costs directly affect project-level cost estimates. Through this relationship, all Pontis results at the project and program levels are linearly sensitive to unit costs.

The sensitivity of each of the 35 sample elements is summarized in Table 2.17. While some elements are insensitive to any variation in the input parameters, other elements were sensitive to all forms of variations (low or high). Also, some elements are sensitive to only low values and some to only high values. These results can be utilized as guide in expert judgment adjustment of original cost values utilized in running the Pontis preservation model . The level of precision needed, and the effect of increasing or decreasing default cost values, is indicated by the summarized sensitivity indicated in Table 2.17.

Table 2.16. Summary Of Network Total MR&R Costs' Sensitivity

Varied MR&R Parameter	**SENSITIVITY OF TOTAL LONG-TERM COSTS**	**SENSITIVITY OF TOTAL FIRST (INITIAL) COSTS**
Element MR&R Unit Costs (All varied)	Not Sensitive	Not Sensitive
Element Replacement Unit Cost	Negligibly Sensitive	Reasonably Sensitive
Element Rehabilitation Unit Cost	Slightly Sensitive	Reasonably Sensitive
Element Repair Unit Cost	Reasonably Sensitive	Reasonably Sensitive
Element Maintenance Unit Cost	Slightly Sensitive	Slightly Sensitive
Failure Agency Unit Cost	Reasonably Sensitive (Only at Low Costs)	Very Sensitive (Only at Low Costs)
Discount Rate Factor	Very Sensitive	Slightly Sensitive

Table 2.17. General Summary of Bridge Elements' Sensitivity To MR&R Decision Variables

Elem ID#	Element Long Name	MR&R Unit Costs (All varied)	Element Replacement Unit Cost	Element Rehabilitation Unit Cost	Element Repair Unit Cost	Element Maintenance Unit Cost	Failure Agency Unit Cost	Discount Rate Factor
12	Concrete Deck - Bare	None	Low Costs	High Costs	Low Costs	None	Low Costs	High/Low
13	Concrete Deck - Unprotected w/ AC Overlay	None	None	None	None	None	None	None
28	Steel Deck - Open Grid	None	All Costs	All Costs	Low Costs	High Costs	Low Costs	All
31	Timber Deck - Bare	None	High Costs	Low Costs	None	None	Low Costs	High/Low
38	Concrete Slab - Bare	None	None	High Costs	Low Costs	None	Low Costs	Very Low
39	Concrete Slab - Unprotected w/ AC Overlay	None	None	All Costs	All Costs	None	Low Costs	High/Low
102	Painted Steel Closed Web/Box Girder	None	None	All Costs	All Costs	All Costs	Low Costs	High/Low
104	P/S Conc Closed Web/Box Girder	None	None	All Costs	All Costs	None	Low Costs	High/Low
107	Painted Steel Open Girder/Beam	None	Low Costs	All Costs	Low Costs	High Costs	Low Costs	Very Low
109	P/S Conc Open Girder/Beam	None	All Costs	Low Costs	All Costs	None	Low Costs	High/Low
110	Reinforced Conc Open Girder/Beam	None	Low Costs	All Costs	All Costs	None	Low Costs	High/Low
111	Timber Open Girder/Beam	None	High Costs	Low Costs	None	None	Low Costs	High/Low
113	Painted Steel Stringer	None	All Costs	None	All Costs	Low Costs	Low Costs	High/Low
116	Reinforced Conc Stringer	None	None	High Costs	Low Costs	None	None	High/Low
121	Painted Steel Bottom Chord Thru Truss	None	Low Costs	High Costs	Low Costs	None	None	High/Low
152	Painted Steel Floor Beam	None	Low Costs	All Costs	High Costs	Low Costs	Low Costs	High/Low
161	Painted Steel Pin and/or Pin and Hanger Assembly	None	None	High Costs	Low Costs	Low Costs	Low Costs	High/Low
202	Painted Steel Column or Pile Extension	None	Low Costs	All Costs	All Costs	All Costs	Low Costs	Very Low
204	P/S Conc Column or Pile Extension	None	None	All Costs	All Costs	None	Low Costs	High/Low
205	Reinforced Conc Column or Pile Extension	None	None	All Costs	Low Costs	None	Low Costs	High/Low
206	Timber Column or Pile Extension	None	Low Costs	All Costs	None	None	Low Costs	High/Low
210	Reinforced Conc Pier Wall	None	None	All Costs	All Costs	None	Low Costs	High/Low
215	Reinforced Conc Abutment	None	Low Costs	All Costs	All Costs	None	Low Costs	High/Low
234	Reinforced Conc Cap	None	Low Costs	All Costs	All Costs	None	Low Costs	All
235	Timber Cap	None	All Costs	All Costs	None	None	Low Costs	High/Low
241	Reinforced Concrete Culvert	None	All Costs	All Costs	None	None	Low Costs	High/Low
300	Strip Seal Expansion Joint	None	None	None	All Costs	None	All Costs	High
301	Pourable Joint Seal	None	All Costs	None	High Costs	None	Low Costs	High
302	Compression Joint Seal	None	Low Costs	None	High Costs	None	Low Costs	High
303	Assembly Joint/Seal (modular)	None	None	None	None	None	None	Very High
304	Open Expansion Joint	None	Low Costs	None	High Costs	None	Low Costs	High/Low
310	Elastomeric Bearing	None	None	None	All Costs	None	Low Costs	High/Low
311	Moveable Bearing (roller, sliding, etc.)	None	Low Costs	Low Costs	High Costs	Low Costs	Low Costs	Very High
313	Fixed Bearing	None	Low Costs	Low Costs	High Costs	None	Low Costs	High/Low
331	Reinforced Conc Bridge Railing	None	Low Costs	None	Low Costs	None	Low Costs	High/Low

None → Elements not sensitive to Variation in Costs/Discount Rate Factor.
Low/Low Costs→ Elements Sensitive to only low values.
All/All Costs → Elements Sensitive to all values.
High/High Costs→ Elements Sensitive to only high values

3. Determination of Existing Agency Cost Data

This section summarizes the determination of existing agency cost data at the Florida Department of Transportation (FDOT), including the interview of relevant FDOT personnel, inquiry into FDOT computerized database systems, gathering of documentation, and linkages to FDOT Bridge Management System (BMS) requirements. Through contact by telephone calls, review of Internet web pages, and scheduled meetings, the researcher interviewed various FDOT employees to explore existing sources of agency cost data within the department, data that are relevant to the Pontis- Bridge Management System (BMS) for Florida bridges. At these meetings, the types of data available were ascertained in terms of their appropriateness to BMS, their quality and timeliness, and the degree to which their availability is affected by new systems under development. In addition, the technical and procedural accessibility of the data was determined, for use in this project and also for routine use by the BMS. The results are described in the following major sections: (1) Departmental Contact and Interviews; (2) Gathering of Documentation; and (3) Linkages to Florida BMS Requirements.

3.1. Departmental Contact and Interviews

Initially, the FDOT Internet web site at address http://www.dot.state.fl.us was studied to learn about the agency's practice of cost data management, to identify relevant sources of bridge cost data, and also to locate the various personnel in charge of these data. In addition to the study project manager, Rich Kerr, the following personnel were directly contacted at the FDOT to inquire about existing agency cost data:

Bridge Maintenance Office: Frank Day, John Clark, Kirk Hutchinson, Mike Sprayberry, and Elizabeth Birrel.
Planning Office: Bob Weinstein.
Office of Information Systems: Rebecca Clemans, and Vicki Bradford.

Interviews were then conducted either by email and phone (Clemans and Bradford) or in person at FDOT premises (Weinstein, Kerr, Clark, Hutchinson, Sprayberry, and Birrel) with each of the above-listed people. The interviews revealed the location, relevance, and database access authorization issues on the various potential sources of cost data. After the interviews, the sources identified include the following categories:

A. Contract Estimating System (CES): Located on the Internet at the web site address http://www.dot.state.fl.us/estimates/CES/contract.htm, this is primarily a system for managing construction cost data related to FDOT projects procured through bidding contracts. The CES, maintained by the FDOT State Estimates Office, is defined as a group of computer programs that are used to automate the various reports, procedures, and computations necessary to produce accurate, timely cost estimates. Related systems, programs, and files include: CES Master Pay Item, CES Job Estimate File, CES Cross Reference File, Contract Administration System (CAS),

Contract Reporting System (CRS), and Bid Analysis Management System (BAMS). The system also provides CES Output/Reports.
After a review of the programs and files available, it was decided that the CES Master Pay Item and CES Output/Reports files would be relevant to the study of agency costs. The Master Pay Item is a dictionary of contract Pay Items, describing the types of contract work items and units of measurement (both Metric and English units), as typically bid on FDOT construction projects. The CES Output has information on Construction Contract History, including the Pay Item Average Unit Cost Report, and Price Trends. The Pay Item Average Unit Cost Report (alias "Akbar") provides historical data. Another document, the Basis of Estimates, published by the FDOT's Engineering Support Services of the Estimates Office, contains a comprehensive list of the pay item structure and definitions.

B. Maintenance Management System (MMS): Identified through meetings with the FDOT Bridge Maintenance personnel, this system captures and stores the costs of maintenance-related operations by FDOT, on its highways and bridges. The work was typically performed by contractors, in-house crews, or prison crews. It is considered a good source of historical data on bridge maintenance activities.

C. District Contract Prototype (DCP): Identified through meetings with the FDOT Bridge Maintenance personnel, this system is very similar to the CES (Akbar) system, except that DCP is designed to capture only maintenance-related costs from contract-bid projects.

D. District Paper Records: Each FDOT district also partially maintains hardcopies or paper records of their maintenance operations, especially those done by in-house crews.

E. Transportation Costs Report: Located on the FDOT Internet web site at the address http://www.dot.state.fl.us/planning/, this is basically a report or a handbook used as guide for estimating preliminary costs of transportation facilities in Florida. It is not a documented record of past or actual costs.

F. Project Objectives and Accomplishments Report: Produced for planning purposes, this report indicates the fund amount allocated to projects on the bridge rehabilitation and replacement program (BRRP). This report is primarily for planning purposes based on programmed fund estimates, not a record of actual costs. Also closely related to this report, and from the same source of data, are the Bridge Unit Cost Report, and a report on the FDOT Executive Committee Workshop, Program Development Issues, May 18 & 19, 1999. The cost estimates in these three reports are based on programmed funds.

The first three sources of cost data, i.e., Akbar from the Contract Estimating System (CES), Maintenance Management System (MMS), and the District Contract Prototype (DCP), were found to be the most relevant to the study on agency cost, and available in a computerized database format that could be easily downloaded from the FDOT mainframe computers. These three databases are based on actual costs of bridge construction and maintenance operations. The Akbar database utilized for this study contained historical data from 1996 to 1999 while the MMS and DCP data ranged from 1993 to 1999. Interviews with Clemans and Bradford of the Office of

Information Systems indicated an already-established procedure for Database access authorization by FDOT consultants.

3.2. Gathering of Documentation

Relevant documents such as instruction manuals, reports, internet site downloads, and sample output reports, were collected on the potential sources of agency cost data, including Akbar, MMS, and the other sources. Initially, the paper copies of the sample reports were converted into electronic spreadsheets and databases, to evaluate their ease of manipulation. Formal application for external access (using outside computer terminals) was not necessary because of the direct identification of the source and the type of data needed. Eventually, access to the mainframe computers was obtained, with the permission to directly download the data at FDOT Bridge Maintenance Office computer terminals. The various documentation collected in the effort to find existing agency cost data include the following:

- Routine Maintenance Cost Handbook, Published by the FDOT State Maintenance Office;
- Bridge Work Order Handbook, Published by the FDOT State Maintenance Office;
- Basis of Estimate, Published by the FDOT Estimate Office;
- FDOT Procedures for the State Office of Maintenance:
  No. 000-525-001 Construction, Maintenance, and Operation of Other Facilities
  No. 325-010-001 Maintenance Management System
  No. 350-020-002 Routine Maintenance Cost Collection
  No. 375-020-002 Contract Maintenance Inspection and Reporting
  No. 850-000-001 Transportation Data Collection, Storage and Reporting
  No. 850-005-001 Reporting Incidents and Management of Damage Repair
  No. 850-010-031 Bridge Operations and Maintenance Manual
  No. 850-015-001 Bridge Maintenance Manual - Planning & Repair Methods
  No. 850-050-003 Guardrail Inspection and Maintenance
  No. 850-065-002 Maintenance Rating Program;
- FDOT Procedures for the State Office of Comptroller – Financial Management:
  No. 360-050-005 Project Cost Reporting
- Bridge Inventory 1997 Annual Report, Published by the FDOT State Maintenance Office;
- Deficient Bridge List – 1997 Repairs and Replacements, Published by the FDOT State Maintenance Office;
- Highway System Overview – Briefing Notebook, Published by the FDOT Office of Management and Budget Program Development Office;
- Executive Committee Workshop, Program Development Issues, May 18 & 19, 1999;
- 1998 Transportation Costs, Published by the FDOT Office of Policy Planning;
- Sample Output Print from Pay Item Average Unit Cost Report;
- Sample Output Print from MMS;
- Sample Output Print from Project Objectives and Accomplishments Report (Bridges: Repair and Replace on the State System); and
- Sample Output Print from the Bridge Unit Cost Report (Four-year Report Sorted by Workmix).

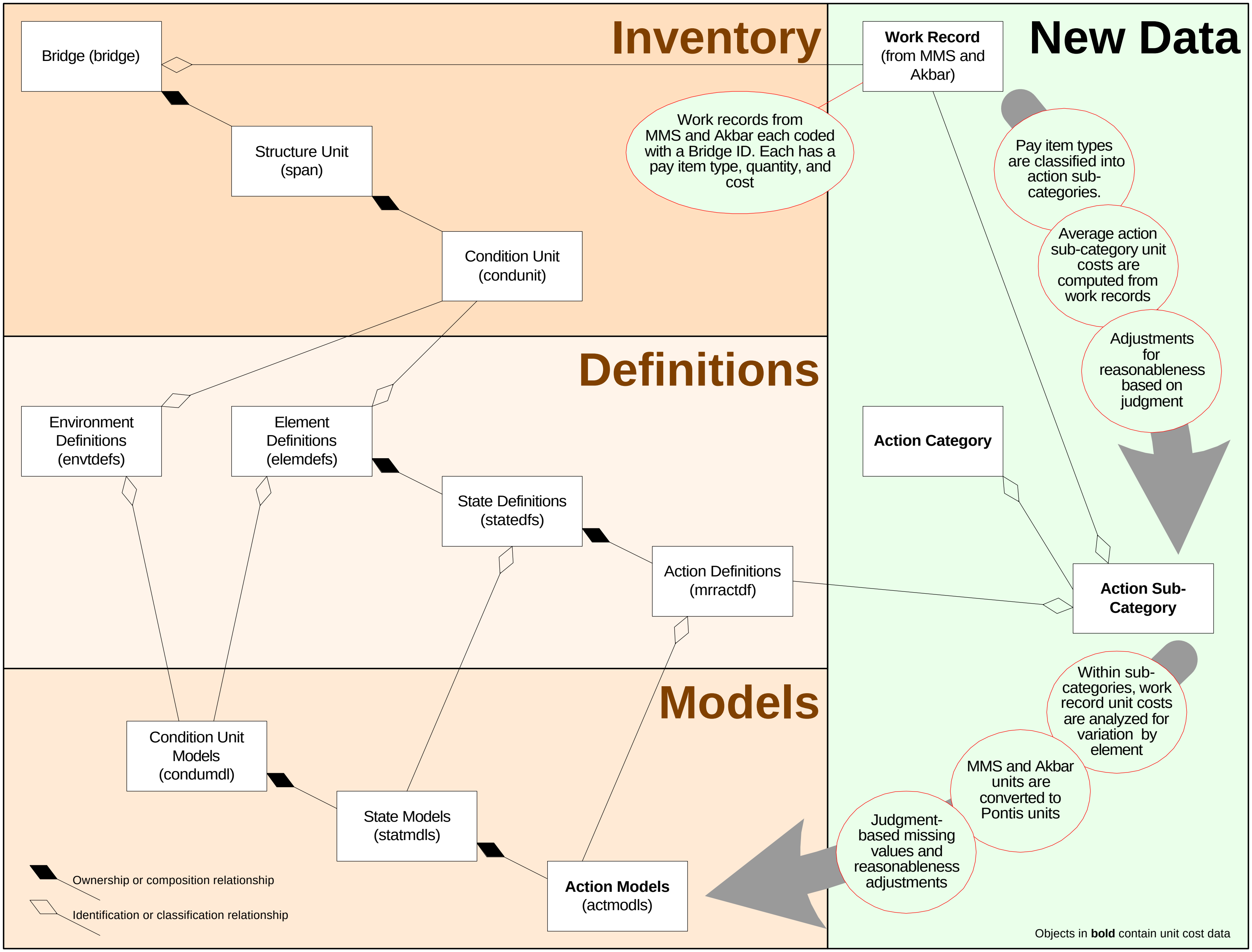

Figure 3-1. Linkages to BMS Requirements

3.3. Linkages to Florida BMS Requirements

A plan was developed for linking the available data to FDOT bridge management system requirements, to serve as a guide during the remainder of the study as well as for future updating. Required are: (1) the definition of linkage formulas or procedures for on-going or one-time computations; and (2) organization of Pontis-required unit costs into a smaller set of action types which can be mapped to FDOT Activity codes and pay items. The categorization has to be refined to reflect an emphasis on the common structure types and also to ensure that each category has a statistically significant sample of historical project data wherever possible.

MMS, DCP, and Akbar are rich sources of project history data, containing the essential data items needed for the analysis. The three systems contain the following essential data:

- Bridge identifier, consistent with the identifiers used in Pontis (only MMS has this information);
- Pay item type or activity code, indicating the nature of the work performed;
- Description, a brief passage of text describing the work;
- Quantity of work;
- Estimated cost of the work.

The estimated cost of the work is estimated by FDOT staff based on an allocation of the total project cost. The MMS cost database contains data on overall highway maintenance operations, including pavement and bridge maintenance. The cost data is based on projects executed in the following ways: (1) using in-house FDOT crews; (2) using prison crews; and (3) by contract with an external company. The last category (contract work) did not have total units of work item recorded in the MMS database. So it was eliminated from the data analyzed in this study, The costs from the first two categories (in-house and prison crews) are more relevant to the study; they include costs of overhead and fringes, built from labor, materials, and equipment usage, using a cost model already developed inside in the MMS. The cost of Maintenance of Traffic (MOT) is also included in the MMS costs. These costs were therefore judged adequate for use in the Pontis MR&R model. Akbar and DCP costs are based on previous contractors' low bids for construction projects which were contracted out. The Akbar and DCP data do not include project engineering costs. Also, mobilization is typically bid by the Contractor as a separate item, so it is not included in the data.

Although the data are potentially valuable, two particular problems must be overcome in order to use them to derive network-level unit costs for Pontis:

- The pay item codes in MMS, DCP, and Akbar are often incompatible with the MR&R action definitions in Pontis;
- MMS, DCP, and Akbar unit costs are often expressed in measurement units different from Pontis.

Because of these problems, it is not possible to use MMS, DCP, or Akbar data directly in Pontis to establish unit costs. Instead, a process of analysis, supplemented by expert judgment, has been developed to estimate the required data. The process involves creation of an intermediate categorization of actions that is compatible with all three systems - MMS, Akbar, and Pontis – thus providing a conduit through which the data may be converted.

Figure 3.1. describes this process. The figure is called a class diagram, because it classifies the various types of data used in the process, and shows how the classes of data relate to each other. The boxes on the left-hand side of the diagram contain the existing Pontis 3.4.3 data related to the analysis, with the Pontis database table names given in parentheses. The lines between classes indicate how the classes are related. For example, a bridge contains structure units, each of which contains condition units. Each condition unit is classified by an environment and an element.

In the bottom center of the diagram, the Action Models class is the one of greatest concern, because it holds the unit cost figures that are to be developed. As the diagram indicates, there is a set of action models for each condition state model, and a set of state models for each condition unit model. The condition unit models differ by element and environment. The result is that there are a very large number of Action Models, and therefore a large number of unit cost factors to be developed. In fact, in the FDOT Pontis database, which adds considerably to the standard AASHTO CoRe Elements, there are potentially 6,504 unit costs to be developed.

The right-hand side of Figure 3.1 shows the new data classes to be developed in this study. The work record class holds the raw MMS and Akbar data, including the items listed above. Action Sub-Category, the most important class in the analysis, holds the new intermediate categorization of actions. In order for the process to work, it must be possible to collapse the work records into action sub-categories, computing an average unit cost that is reasonably consistent within each sub-category. Moreover, it must be possible to then map each and every Pontis MR&R action definition to a sub-category, to determine an initial estimate of unit cost for each Action Model.

Action sub-categories were initially developed judgmentally, based on a detailed review of all three information systems. An attempt was then made to fit the sub-categories to the detailed work records from MMS and Akbar, and then to the MR&R action definitions in Pontis. Fitting the sub-categories to MMS and Akbar relied heavily on the brief text descriptions provided for each work record. Following the initial attempt to fit all three systems, the action sub-category definitions were adjusted to improve the fit.

Choosing the optimal number of action sub-categories depends on balancing two competing factors:

- A small number of large sub-categories improves the sample size used in the statistical calculation of average unit costs; and
- A larger number of smaller sub-categories increases the resolution of the estimates, making it possible to distinguish the costs of more elements.

In addition, it was desired to keep the categorization relatively general, so it would not have to be changed in the future if FDOT data capture capabilities change. The process described in Figure 3.1 allows for the possibility that, if a subcategory turns out to have a large sample size, further analysis may be conducted to try to distinguish individual elements within the sub-category.

Table 3.1. Preliminary Action Sub-Categories

White cells represent valid sub-categories; numbers refer to footnotes

			Action Category			
		Object	100-Replace	200-Rehab	300-Repair	400-Maint
Materials	0	Other material				1
	1	Deck		2	3	4
	2	Steel/coat (incl metal)	5		6	7
	3	Concrete			8	9
	4	Timber				
	5	Masonry				
	6	MSE				
Hi-Maint	10	Other element				
	11	Joint				
	12	Joint seal				
	13	Bearing (incl p/h)				
	14	Railing				
Drainage	21	Slope prot				
	22	Channel				
	23	Drain sys				
Machinery	31	Machinery	10	10	10,11	10
	32	Cath prot				
Major	41	Beam				
	42	Truss/arch/box				
	43	Cable				
	44	Substr elem (exc cap)	12			
	45	Culvert				
	46	Appr slab		13		
Appurtenances	51	Pole/sign				

Footnotes

1. Wash structure
2. Rehab deck and replace overlay
3. Repair deck and substrate
4. Repair potholes
5. Replace paint system
6. Spot paint
7. Restore top coat
8. Clean rebar and patch
9. Patch minor spalls
10. Includes electrical, hydraulic, and mechanical elements
11. Repair and lubricate
12. Includes fenders, dolphins, and pile jackets
13. Mudjacking

The structure of 49 action sub-categories is given in Table 3.1. In general, it was found that an optimal classification compatible with all three systems could best be derived by appealing to the physical nature of the work, dividing the range of possibilities by action category, shown in the columns of the table, and by the object of the action, shown in the rows of the table. Each action sub-category is designated by a number based on the category and object: for example, sub-category 203 is concrete rehabilitation, and 446 is approach slab maintenance.

It was desired that the sub-category definitions be chosen to minimize the variance of unit costs within sub-categories while maximizing the variance among sub-categories. This was done judgmentally in Task 3, but analyzed more formally in Task 4. For example, it was hypothesized that all concrete repair activities, regardless of element or condition state, would have similar unit costs, so all were grouped into sub-category 303.

After coding all MMS and Akbar work records with appropriate sub-categories, Table 3.2 was developed to show the coverage for each sub-category. The numbers in the table count the work records classified into each sub-category. Certain sub-categories are very well represented in the source data, while others have little or no coverage. Those with sparse coverage will need to be estimated from expert judgment until more complete data can be captured. Every Pontis MR&R action definition was mapped to a sub-category, as shown in the complete list in Appendix A.

Table 3.2. Coverage of Sub-Categories in MMS and Akbar

Table shows number of work records in MMS and/or Akbar

			Action Category			
		Object	100-Replace	200-Rehab	300-Repair	400-Maint
Materials	0	Other material				240
	1	Deck	1	7	22	227
	2	Steel/coat (incl metal)	1	8	47	2
	3	Concrete		0	203	2296
	4	Timber		9		0
	5	Masonry		0		0
	6	MSE		0		0
Hi-Maint	10	Other element				
	11	Joint	26	594	122	81
	12	Joint seal	268			
	13	Bearing (incl p/h)	4	41		14
	14	Railing	257			
Drainage	21	Slope prot	1	477		
	22	Channel		714		0
	23	Drain sys	6	3		102
Machinery	31	Machinery	202	4	5	2
	32	Cath prot	7			
Major	41	Beam	1			
	42	Truss/arch/box	0			
	43	Cable	0	0		
	44	Substr elem (exc cap)	35			
	45	Culvert	0			
	46	Appr slab	115	56		474
Appurtenances	51	Pole/sign	0			

Because the classification scheme described in Table 3.1 is quite general, it is useful for many purposes related to bridge costing. For example, it was decided to re-run the Task 2 sensitivity analysis using action categories, to uncover the cost sensitivity of each category. Task 2 found that network optimization results for element replacement, rehabilitation, and repair were quite sensitive to unit costs, while maintenance results were relatively insensitive. Most of the activities classified as “maintenance” at FDOT are minor or routine maintenance, defined as feasible in condition state 1. Most of these do not appear in the AASHTO CoRe elements. These were added for analysis purposes outside of Pontis, and Pontis tends to ignore them. As a result, the 400-series sub-categories are of somewhat lower priority for subsequent analysis in this study.

4. Development of Agency Unit Costs

This section provides a detailed description of the methodology used to develop Pontis agency unit costs. FDOT has three excellent sources of historical project data that were relied upon for preliminary unit cost estimates. For reasons that will become clear in this report, a rather elaborate statistical analysis was required in order to extract useful numbers from the available data sources. The results of a study by Clemson University also provided valuable input.

An expert review process proved essential to the successful development of final costs. The panel of experts identified weaknesses in the available data, reconciled conflicting results from the several data sources, and provided insights that filled in the many data gaps that were found. It was found during this study that nearly all of the unit costs required a detailed review and substantial modification before they could be accepted for use in Pontis. Only 50 percent of the Pontis actions were covered with a statistically significant number of data points in any of the three FDOT information systems, and only 15 percent of the Pontis actions ended up using the results from one of the information systems directly. About 70 percent of the Pontis actions had relevant data from FDOT systems, in terms of being helpful in the considerations of the panel experts, including data that were adjusted, or used directly for the final results. These also included some relevant data that were recorded in units incompatible with those of the Pontis actions. This does not reflect on the quality of the existing FDOT systems, since it was impossible to judge the quality of data collection and processing from this perspective. One of the biggest problems was the inability to match the scope of activities in MMS, Akbar, and DCP to Pontis elements, condition states, and actions.

This problem also influences the recommended strategy for keeping unit cost numbers up-to-date over time. Other than periodic use of Pontis' built-in inflation feature, it is clear that it will not soon be possible to substantially automate major updates to the unit cost models. Certain enhancements to the three FDOT project information systems may lead to the possibility of partial automation in the future, but it is likely that an expert review will still be required. The implementation report addresses possible approaches to improving the ability to update agency unit costs. The final costs are summarized in Appendix A of this report.

4.1. Gathering of Data

The scope of this study included identifying relevant existing agency cost data at FDOT, performing statistical analyses to model the cost data in terms of bridge characteristics, and organizing historical unit costs into a small set of Action Sub-Categories which can be mapped into Pontis-defined actions of bridge elements' maintenance, rehabilitation, and repair (MR&R).

4.1.1. FDOT's Historical Data

An evaluation of the FDOT bridge maintenance data collection systems indicated initially that the historical data collected by the state of Florida with regards to agency unit costs was not completely compatible with the Pontis model. Data were obtained from three in-house sources and had to be supplemented with expert elicitation (questionnaires). The three in-house sources are: the Maintenance Management System (MMS); the Contract Estimating System (CES) also referred to as “Akbar”; and the District Contract Prototype (DCP) System. Each of these sources records slightly different cost information. However, all three have historical project data that are essential to the development of cost data for Pontis.

Maintenance Management System (MMS)

This source of data stores the costs of maintenance activities for highways and bridges in the state of Florida. FDOT Procedure Topic No.: 325-010-001-f (Maintenance), states the purpose of the MMS as “To provide a management system for collecting information necessary to effectively plan, organize, direct and control maintenance operations on the state highway system.” Generally, the work recorded in this system is performed by force account crews (in-house), prison work crews, or some contractors. MMS cost data include overhead and fringe, and the cost of maintenance of traffic (MOT).

MMS activities are represented by a three-digit code such as 805 or 845. The MMS data required some manipulation to obtain workable files for analysis. The MMS data were downloaded from the FDOT mainframe computer in two distinct file types: “scope” and “cost”. The “scope” data included such information as the Bridge Number, the date the activity was completed, the MMS Activity Code and most importantly, a short description of the work done. The “cost” data include primarily, the quantity of work done, and the costs of material, equipment, and labor. These two file types were merged to create one new file.

Contract Estimating System (CES) or “Akbar”

The Contract Estimating System (CES) is a group of programs developed to automatically and accurately produce cost estimates from necessary reports and computations. There are three types of files used to maintain the data collected in this system, the Master Pay Item file, the Job Estimate file, and the Cross Reference file. CES is only accessible through authorized FDOT personnel. However, for this study, the researchers were able to use an in-house computer at the DOT to download necessary information.

CES costs are based on previous contractors’ low bids for construction projects that were contracted out. The records are stored and identified by bid item (pay item) numbers. Mobilization and Maintenance of Traffic costs are generally listed separately as pay items, rather than being included in other individual pay items numbers. Project engineering costs are not listed in the CES.

District Contract Prototype (DCP) System

This data source, like the other two, has relevant data regarding past bridge maintenance projects. This source is very similar to the CES data, but provides data that are focused primarily on bridge maintenance activities, and not overall roadway construction projects. The DCP system is maintained by each District. Periodically, data from each District’s database are compiled into one database maintained by the State. The DCP data are organized by pay item numbers that are in the same format as those used in the CES data.

4.1.2. Relationship Among Historical Data Files

In order to develop a model of bridge cost data that could be further analyzed, the various source data files were merged using relational database methods. Some of the data collected required some manipulation or merging to combine necessary information. The queries that were executed during the research using Microsoft Access will be described and shown in this section.

Relational databases operate through relationships between separate tables. The database schema is made up of many tables that have a relationship through unique attributes or primary keys. Using the primary keys, information in one table can “relate” to information in another table. Each row of a table is a record, and a column represents the values of a single attribute of the records in the table. A primary key acts as a unique identifier for each row in the table. When a query or search is performed, the database uses the primary key from one table and searches the other table(s) that have the same attribute (foreign key) to complete the relation.

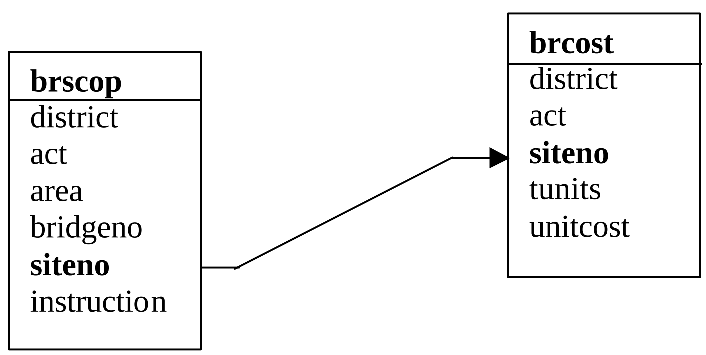

Figure 4.1. Joining of brscop and brcost Tables

Figure 4.1 shows an example of a primary key relationship. This example is one of the actual steps performed using the MMS data. Two tables were initially created from the MMS data: the “scope” file and the “cost” file. The two were merged together to get one new file. A query was run using a primary key/foreign key relationship. The primary key in this instance is *siteno.* Both sides contained the *siteno* field so the data could be easily related. The relationship is a right join type, which means the *siteno* from table **brscop** will only search for those *siteno* in table **brcost** that are exactly the same. In order for there to be a relationship, both tables must contain or share at least one of the same *siteno*. The two files are combined to make **brscop_cost.**

Microsoft Access was also used to join Florida’s bridge inventory data to MMS data by using the field *bridgeno* (same as the bridge identifier field *brkey* in pontis) in Figure 4.2. Florida’s bridge inventory data includes physical attributes and FHWA classifications such as total length, functional class, deck material, etc. This file was itself the result of merging two Pontis tables, bridge and span. This new file resulting from the merge of inventory and MMS data, contained very useful information that was eventually used for the basic data analysis to find the mean, standard deviation, and coefficient of variation for each specific analysis, and general element analysis involving regression and ANOVA.

The MMS cost data and several Pontis tables were combined to run a query that resulted in a table that was used for general element analysis.

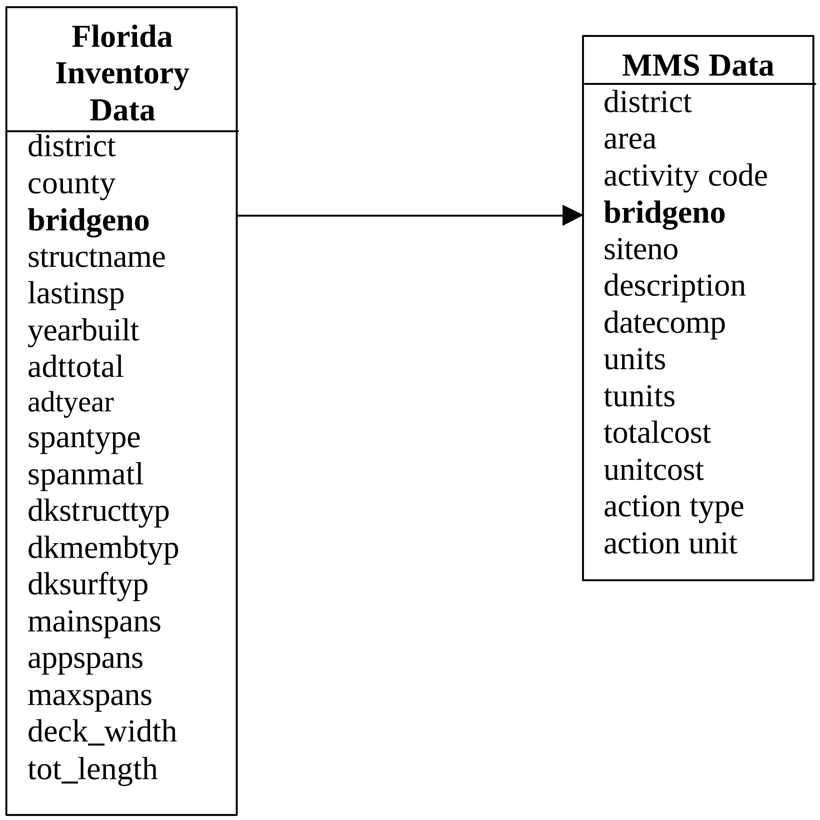

Figure 4.2. Merging of Florida Inventory Data and MMS Data

4.1.3. Sub-Categories: Transition from FDOT Data to Pontis Tables

To achieve a unit cost for each of the elements chosen for this study, a process had to be developed that would relate cost data from the FDOT databases to those in Pontis. There were two key issues that must be addressed. First, Pontis definitions for MR&R actions are not entirely compatible with the pay item codes found in MMS, CES or DCP. A way to group similar elements and similar actions taken needed to be developed. Second, the unit costs from all three sources express units of measure differently from Pontis.

The solution was the creation of a transition table containing a list of Action Sub-categories, as shown in Table 4.1. This list provides a broader grouping of “like” activities so that they are more easily recognizable and easier to analyze. This categorization of actions is compatible with all three data sources and with Pontis. Each Action Sub-Category is a three-digit number. The first digit represents the primary category of the action; Replace (100), Rehab (200), Repair (300) and Minor Maintenance (400). For example, any Action Sub-Category beginning with a 2 is known to be a Rehabilitation activity. A matrix was formed to assign Action Sub-Categories to each element chosen. The left side of the matrix lists the objects or elements and the top portion lists the four primary categories. For instance, any activity involving a joint replacement is numbered as 111. The Action Sub-Category is in the one hundred (100) category and eleven (11) is the element or object number on the matrix. Note that this object number is not the same as the element type number used in Pontis. The number inside each cell indicates how many bridges have elements that may need the indicated action at some time during its life. For example, concrete rehabilitation (203) may be feasible on 10,824 bridges.

Table 4.1. Action Subcategories Matrix

			Action Category			
	Object		100-Replace	200-Rehab	300-Repair	400-Maint
Materials	0	Other material				4,714
	1	Deck	8,675	7,727	3,863	8,675
	2	Steel/coat (incl metal)	1,275	5,539	3,900	3,062
	3	Concrete		10,824	8,759	10,838
	4	Timber		1,258		1,225
	5	Masonry		3,034		7,210
	6	MSE		146		146
Hi-Maint	10	Other element				
	11	Joint	3,773	5,654	3,094	7,929
	12	Joint seal	7,544			
	13	Bearing (incl p/h)	6,879	6,878		3,878
	14	Railing	9,122			
Drainage	21	Slope prot	7,132	3,786		
	22	Channel		8,259		8,259
	23	Drain sys	3,969	24		3,969
Machinery	31	Machinery	201	201	154	201
	32	Cath prot	4,474			
Major	41	Beam	8,598			
	42	Truss/arch/box	234			
	43	Cable	41	41		
	44	Substr elem (exc cap)	11,286			
	45	Culvert	2,076			
	46	Appr slab	7,260	7,260		7,260
Appurtenances	51	Pole/sign	180			

Another key issue for many researchers regarding cost data for MR&R activities was unit compatibility. Many States, including Florida, do not collect data with units that are compatible with those used in Pontis.

By reading the short description (instruction) of work in each MMS record, or the pay item description in CES and DCP, the appropriate Action Sub-Category was matched to each record. After the data collected for this project was separated into the respective Action Sub-Categories, it was noticed that several Action Sub-Categories contained activities with different units of measure.

To solve this problem, a list of Action Sub-Category-Units were created. Action Sub-Category-Units essentially broke down the data even more into a recognizable set by incorporating the units for each activity. For instance, Action Sub-Category *302 – Clean/Paint Steel*, may have data recorded with units of linear feet (LF), Man Hours (MH), and square feet (SF). The Action Sub-Category-Units would simply be 302LF, 302MH, and 302SF, respectively. As another example, an activity involving the replacement of joints (111-Replace Joint) may have recorded data with units of linear feet, LF, square feet, SF, or man hours, MH. Each of the actions performed were assigned the same Action Sub-Category-Unit as the units that were recorded with it. In other words, if a joint was replaced and the cost was recorded in terms of linear feet, the Action Sub-Category-Unit would be 111LF. The use of units could also help in the development of an automated system to match Action Sub-Categories with pay item numbers. Now the data could be sorted by Action Sub-Category-Units and statistical results would be recognizable by this convention.

A key issue for this research was to match Action Sub-Categories with the activity codes and pay item numbers within the MMS, CES and DCP data sources. This is necessary in order to further relate the historical data with the Pontis system. Due to the fact that there are many Action Sub-Categories that match up or correspond to many activity code pay item numbers it can become complex. In the future this step could possibly become automated using SQL commands to search for keywords in the instructions or descriptions of each activity or by establishing a base for these Action Sub-Categories within each data source. For now, to match Action Sub-Categories with pay item numbers and activity codes, it was necessary to manually and tediously read each individual activity description that was performed.

To determine which MMS (activity codes), CES, and DCP (pay item numbers) data matched or contributed to certain Action Sub-Categories, the data from each source were separated by Action Sub-Category-Units. Consequently, this separation of data by Action Sub-Category-Units also became the format in which statistical analysis would be carried out. Each Action Sub-Category-Unit may have several pay item numbers or activity codes that correspond or contribute. For example, Action Sub-Category-Unit 303LF-Clean rebar & patch includes MMS Activity Codes 805 and 810 contributing to the data. Each MMS Activity Code can correspond to many Action Sub-Category-Units. The same holds true for CES and DCP pay item numbers. Pay item numbers are treated slightly differently. There are several formats that they can take, but the most general form is four numbers, then two then one or two, such as XXXX XX XX. Only the first four numbers along with the next one or two numbers were considered to create pay item groups (i.e., 2440 7X X). Simplifying and broadening the pay item groups increased the number corresponding to each Action Sub-Category-Unit and made it easier to recognize them.

The final number of Action Sub-Category-Units that had MMS code matches was 73. Of these 73 Action Sub-Category-Units, 40 had more than one MMS code contributing. There were a total of 17 Action Sub-Category-Units in the CES data, with four having more than one pay item group contributing. The DCP data contained 51 total Action Sub-Category-Units with matches, and 32 with more than one contributing. In each of three data sources, the final count of Action Sub-Category-Units are both directly and indirectly usable regarding unit compatibility.

Table 4.2. MMS Data Showing Various Activity Codes w/Action Sub-Categories

DISTRICT	MMS ACT.	ACTION TYPE	ACTION TYPE UNIT	BRIDGE NO.	DATE COMP	TUNITS	TOTAL COST	UNIT COST
7	810	303	303LF	100069	12/5/96	10	754.84	75.48
7	810	303	303LF	100106	4/27/94	50	181.29	3.63
7	805	303	303LF	100121	6/23/98	7	475.67	67.95
7	810	303	303LF	100167	7/21/95	25	275.37	11.01
7	810	303	303LF	100167	5/18/98	1	68.47	68.47
7	810	303	303LF	100452	4/9/97	14	120.49	8.61
7	810	303	303LF	100461	7/31/96	4	64.38	16.10
8	805	303	303LF	110006	5/25/95	50	7380.43	147.61
5	810	303	303LF	110034	4/7/97	3	105.64	35.21
8	805	303	303LF	110070	2/2/98	16	1761.5	110.09
7	810	303	303LF	150018	11/17/94	60.25	732.56	12.16
1	805	303	303LF	170129	9/20/95	241	2457.09	10.20

4.1.4. Size of Available Data

The raw data were refined to remove statistical outliers, and also matched to Pontis data tables. These two actions resulted in reduction of the available size of the data. The table below summarizes size of data as utilized in this study.

Table 4.3. Summary of Data Manipulation

Data Information	**Maintenance Management System (MMS)**	**Contract Estimating System (CES)**	**District Contract Prototype (DCP)**
Year Range of Data	1993 - 1999	1993 – 1999	1996 - 1999
Raw Data Size	10,649	1,034	1,972
Data Size After Removal of Statistical Outliers	10,014	1,012	1,941
Data Size with Direct Match to Pontis Elements	2,404	359	1,141

4.1.5. Problems Encountered and Solutions

The major problem encountered was the inability to match the historical cost data record for MR&R action on a bridge with the deteriorated state of the bridge when this action was performed. Pontis cost tables require this. The solution to this problem was to elicit expert opinions coupled with prorating the same cost between different states, using the ratio in the Pontis cost data from the Clemson study.

Another problem involved "cleaning" the data by eliminating obvious erroneous entries such as negative numbers, zeroes, unusually large numbers (outliers), etc. Also, in preparation for the analysis of variance (ANOVA), it was necessary to merge each of the cost data (MMS, CES, and DCP), with bridge inventory data, using the bridge id as the primary key. This data merge resulted in allocating some Action Sub-Category cost values to multiple elements (if present) instead of a single element, on an individual bridge. This may not be exactly true, but it is a good and reasonable assumption, which does not affect the ANOVA outputs. On the other hand, due to multiple elements having the same costs, the number of data points is exaggerated and a misleading number may be generated for the average unit costs (overall) for Action Sub-Categories, during the ANOVA. It is therefore more accurate to use the Action Sub-Category average unit costs computed from the basic statistical analyses.

4.1.6. Overhead and Indirect Costs

Based on conversations with Chris Laughlin and Kirk Hutchinson of the State Maintenance Office, Table 4.4 represents the values of overhead rates utilized in MMS:

It was reported by the State Maintenance Office that MMS raw data has no overhead factor incorporated in the original database format. But when the data is extracted as a standard report, which was the form used to collect the data in this study, then some of the overhead may have been included. *(Based on a conversation with Chris Laughlin on 10/27/2000, it seems only labor overhead and fringe are included in the standard reports, but not material overhead).*

Being a product of the traditional bid estimate, the CES and DCP data should contain the contractor's overhead and fringes, distributed over each pay item. It should also be noted that contractor's overhead and fringes are usually different from FDOT's values.

Table 4. 4. Estimated values of overhead and fringe values.

Parameter	Financial Year						
	1994/95	*1995/96*	*1996/97*	*1997/98*	*1998/99*	*1999/00*	*2000/01*
Labor Overhead	0.4307	0.4307	0.4307	0.4984	0.3320	0.1291	0.0828
Labor Fringe	0.5922	0.5922	0.5647	0.5647	0.5488	0.6507	0.7522
Material Overhead	0.1845	0.1845	0.1845	0.1845	0.1845	0.1845	0.1845

Source: State Comptroller's Office Through FDOT's Chris Laughlin and Kirk Hutchinson

4.1.7. Unit Compatibility

In Pontis, only certain units of measure are standard such as square feet and linear feet. Historical data collected from the Florida Department of Transportation has a variety of unit types. Some of these unit types are compatible with Pontis, some are not. One of the primary goals of this study is to determine a way to convert the non-compatible unit types into those that are.

A count was obtained from each of the three sources for specific Action Sub-Categories that were consistent or inconsistent with Pontis. This count or summary is described as unit compatibility. Only the adjusted cost data without outliers were used for this process. Those that matched were labeled "Direct Use" and those that were not compatible were labeled "Indirect Use". The activities such as *Replace Joint* or *Wash Structure* may be compatible, but the units may not, which can greatly affect the average unit cost. Those Action Sub-Category-Units, both Direct Use and Indirect Use that had at least 10 data points were analyzed using

ANOVA.

During this study, the unit compatibility problem was not completely addressed. However, some possible solutions are recommended, to increase the amount of usable data in future updates of the unit costs. Actions with units such as man-hours could be converted into units of linear feet or square feet by using a conversion factor. For example, a factor to convert the number of man-hours it takes to complete a particular amount of linear feet of work may be one solution. Standard unit conversion rates obtained from a sample MMS Standard Report (MMS Detailed Unit Cost by Activity (for 1997-1998) are shown in Table 4.5.

*Table 4.5. Sample Man-hour/Unit Values for the Pertinent Maintenance Costs**

MMS Activity Code	Activity Description (unit)	Standard MH/Unit	Engineered Unit Cost	Actual Overall MH/Unit	Actual Overall Unit Cost
423	Conc. Pavement Joint Repair (LF)	0.030	$1.43	0.042	$1.15
424	Conc. Slope Pavement (LF)	0.030	$0.83	0.064	$1.00
425	Conc. Pavement Surface Repair (SF)	0.880	$21.49	1.959	$30.32
436	Rework Non-Paved Shldr Slopes (Acre)	23.710	$664.64	26.521	$664.52
437	Misc. Slope & Ditch Repair (CY)	0.430	$13.05	0.439	$10.81
451	Clean Drainage Structures (LF)	0.100	$2.50	0.098	$1.93
457	Conc. Repair (CY)	9.460	$226.98	5.100	$103.75
459	Conc. Sidewalk Repair (SY)	2.750	$60.80	2.666	$53.43
461	Roadside Ditches – Clean&Reshape (LF)	0.090	$2.28	0.070	$1.72
520	Signs – Ground Signs, <= 30 SF. (Unit)	0.670	$23.40	0.693	$27.11
526	Guardrail Repair (LF)	0.330	$9.79	0.297	$7.37
540	Graffiti Removal (SF)	0.030	$0.58	0.032	$0.56
541	Roadside Litter Removal (Acre)	0.660	$9.55	0.857	$12.76
805	Bridge Joint Repair (LF)	0.220	$6.15	0.371	$8.87
806	Bridge Deck Maint. & Repair (SF)	0.090	$2.66	0.097	$1.69
810	Bridge Handrail Maint. & Repair (LF)	0.830	$20.12	0.418	$6.88

*Source: 1997-98 MMS Report.

It should be noted that some important bridge maintenance activities are recorded originally in the MMS in units of Man-hours, e.g. Activity Nos. 825 Superstructure Maintenance and Repair, 845 Substructure Maintenance and Repair, 859 Channel Maintenance, 861 Bridge Electrical Maintenance, 865 Movable Bridge Mechanical Maintenance, 869 Movable Bridge Structural Maintenance, 888 Bridge Damage Repair, 896 Ferry Slip Maintenance and Repair, and 898 Tunnel Repair.

4.1.8. Statewide Cost Index (Inflation) Adjustments

Cost Index factors are very common in the engineering and construction fields. They are dimensionless numbers that help estimators account for changes in prices of materials, labor, services and/or inflation over time. A cost index can estimate the cost of an item or activity for any year, either past or future. The following Equation 4.1 is standard for calculating the desired cost:

$$C_c = C_r(I_c/I_r) \tag{4.1}$$

where C_c = desired cost in dollars, past, present or future
C_r = reference cost in dollars
I_r = corresponding index to time period of C_r
I_c = corresponding index to time period of C_c

All data collected corresponds to the period of time from 1993 to 1999, meaning that the actual date of completion for each activity falls within these dates. The given cost data had to be converted or adjusted to present-day costs (1999) by means of an index factor. The indices for the Annual Averages for Highway Construction in the state of Florida, Engineering News Record (ENR), FDOT and FHWA were collected from years 1977 to 2000, compiled into table format and plotted against one another.

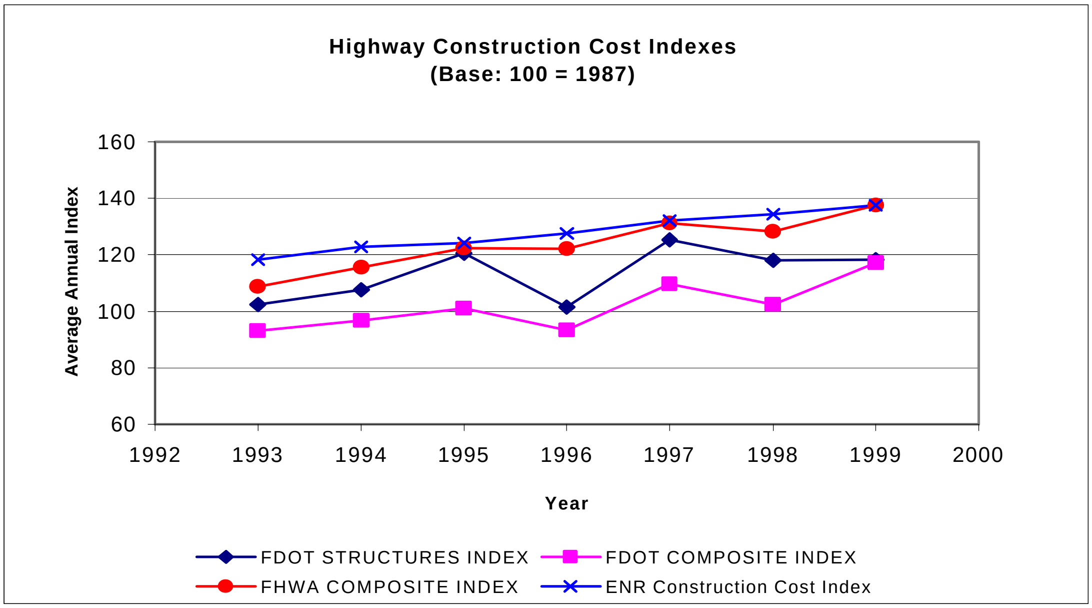

Figure 4.3. Cost Indices for FDOT, FHWA and ENR

Due to price variations nationwide, the FHWA and ENR Composite Index were both slightly higher than those from the FDOT. These were not considered because they do not represent bridge-related activities in Florida. The FDOT Composite Index was determined to be most relevant with the year 1999 being the base (1.00) because it was more reflective of overall time value of money and it included indirect costs such as mobilization and traffic control. The 1999

Index Factor or multiplier for 1993 to 2000 is found by dividing the FDOT Composite Index Factor for 1999 by those from 1993 to 2000. The FDOT Composite Index includes all highway and structures projects, whereas the FDOT Structures Index includes only those projects related to highway structures, primarily new bridge construction.

For this study, Table 4.6 was used to adjust the unit cost values in the statistical analysis spreadsheet before any correlation, regression and analysis of variance was carried out. For the MMS data, the date of completion for each activity is known, therefore a separate column is created to convert the date format into purely a year format. For example, if the date of completion were given in a MM/DD/YY format such as **10/29/97** (October 29, 1997) then the new column (Year Complete) would use the YEAR statement to convert the date to read **1997** only. For the CES and DCP data, date of activity completion was assumed to be the same as the estimate date recorded in the FDOT database.

Table 4.6. Cost Index Listing From 1993 to 2000

YEAR	FDOT COMPOSITE INDEX	FDOT COMPOSITE 99 INDEXFACTOR
1993	93.0	1.26
1994	96.8	1.21
1995	101.1	1.16
1996	93.4	1.25
1997	109.6	1.07
1998	102.4	1.14
1999	117.1	1.00
2000	126.8	0.92

4.2. Statistical Analysis and Results

Using historical data from FDOT, statistical analyses such as regression analysis and analysis of variance (ANOVA) were performed to determine the reliability and model agency unit costs on bridge characteristics, and Pontis elements. For reliability and elimination of outliers, the data were tested to assure they fell within ±3 standard deviations of the mean. After the analysis was completed using Excel, the Minitab statistical software was used to verify and compare the results obtained from Excel. Minitab was used solely to run statistical calculations.

4.2.1. Basic Data Analysis

To begin the data analysis, descriptive statistics such as the average, standard deviation, coefficient of variation (CV), and required total number of data points were calculated. Also, statistical outliers were removed to assure the data were within ±3 standard deviations (99.7% of observations within this range) from the average unit cost. The procedures for the MMS data are slightly different from those for CES and DCP data. MMS data are distinguishable by eight FDOT Districts, and so the descriptive statistics were found for each. However, the data for all eight districts were eventually combined to provide another view. The data from each district were sorted by Action Sub-Category and by units of measure. The descriptive statistics mentioned above were found for each Action Sub-Category-Unit. A summary listing only the District number, Action Sub-Category, Action Sub-Category-Unit, and statistical results was created on a separate worksheet within the same file.

The coefficient of variation (CV) was first reviewed for each Action Sub-Category-Unit; CV is a unit-less measure of the variability of random variables, estimated by dividing the standard deviation by the mean. Setting a threshold of CV as 1.6, Action_Subcategory Units with higher CVs were identified, and a scatter plot generated to show the outliers. Action Sub-Category-Unit *401SF – Repair Potholes* had a recorded coefficient of variation of 3.07. The plot in Figure 4.4 illustrates outliers and the reason for such a high CV value. Such data points represent the extreme data points that will be eliminated, typically due to erroneous entries. After removal of two outliers, the average unit cost dropped dramatically from $117.29/SF to $33.75/SF (Figure 4.5).

Once the coefficients of variation and scatter plots were developed, the revised data were produced in another worksheet in the same file. Because some data points were deleted, the descriptive statistics needed to be found again for each Action Sub-Category-Unit. A second summary was also created to exhibit the newly found results. Several of the coefficients of variation analyzed were still above the mark of 1.6. This was allowed because further, more accurate procedures would take place to eliminate even more outliers.

To further eliminate outliers, the use of OR and IF statement formulas were used in the spreadsheet to identify those data points that were not within the ±3 standard deviations of the mean. Two columns or fields called *Outlier?* and *Data/Outlier* were added to the data files for each source. The logical statements were then inserted and equipped with the proper parameters. In three steps, the logical statements were used for the mathematical elimination of statistical outliers from the raw MMS data. Because the sample data used during the Clemson study resulted in high coefficients of variation, the FDOT wanted to obtain lower results with their data. The results showed that the removal of outliers was helpful in slightly lowering the coefficients of variation

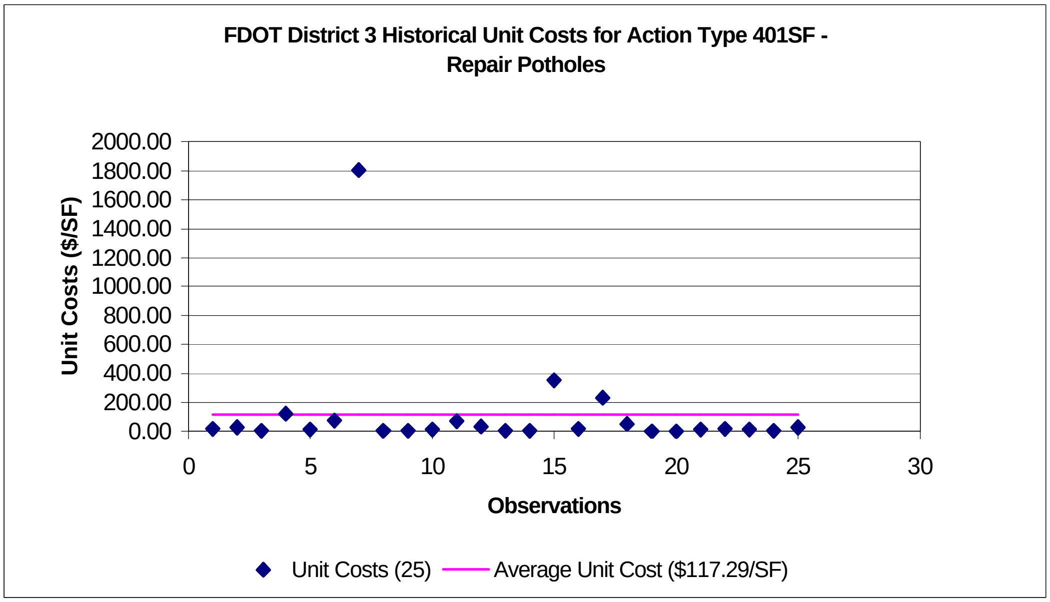

Figure 4.4. MMS Data Plot with Statistical Outliers

The CES data were grouped together and sorted by Action Sub-Category-Units. The descriptive statistics were then found for each Action Sub-Category-Unit and scatter plots, just like those from the MMS data, were created to show the distribution of unit costs. The use of logical formulas to identify and eliminate outliers was only performed once due to the small number of total data. The same process used to remove outliers from the CES data was used for the DCP data. The logical formulas were used once to identify any outliers in the data, and were promptly removed.

A summary was created for each of the data sources showing the results of the elimination of outliers using the logical statements. These summaries were later used in the identification of compatible units, which is explained in the following section. Each summary included the District Number, Action Sub-Category, Action Sub-Category-Unit, units of measure, standard deviation, coefficient of variation, and the total number of data points.

The final step of the initial data analysis was to adjust the unit costs for each of the three data sources into current dollar amounts. In this case, the year 1999 was chosen as the desired year. Using the FDOT Composite Cost Indexes discussed above, an index factor was found for each year starting with 1993 and ending with 1999 (See Table 4.6). Since each maintenance record came with a year of completion, it was very convenient to match up the index factor for each year. The raw unit cost of each record was then multiplied by the corresponding index factor to obtain the adjusted 1999 unit cost. Now that this step was completed, the MMS, CES, and DCP data must be sorted by Action Sub-Category-Unit, and the new 1999-average unit cost, standard deviation, and coefficient of variation must be found. These new values were used in future regression analysis and ANOVA.

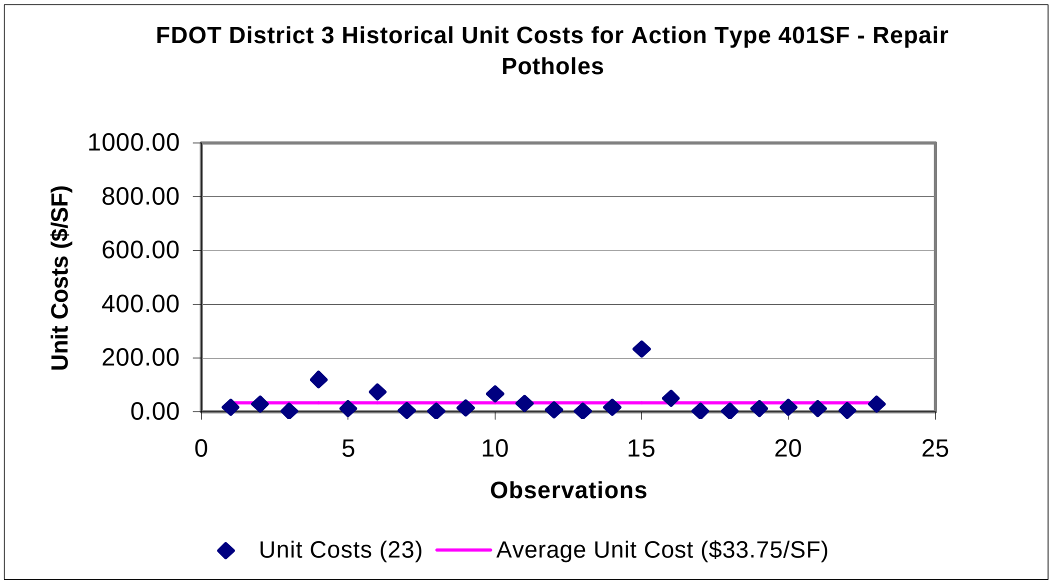

Figure 4.5. MMS Data Plot Without Statistical Outliers

4.2.2. District Location Factors

As part of the data analysis, a comparison of the MMS data from the eight districts within FDOT was carried out regarding the variation of the average unit cost for each Action Sub-Category-Unit. With District 3 (Chipley) as the base district (index = 1.00), location cost indices were estimated, subject to data availability, for the other seven districts. The information from the summaries of each district was compiled to create plots like those seen in Figure 4.6. and Table 4.7. This plot represents the variation of unit costs between FDOT Districts. One of the possible applications of location indices is that of estimating the cost for one desired district, using the available cost data from another district in the state. For Districts 1 through 7, the unit costs appeared quite consistent; however, District 8 shows a much higher average unit cost. District 8 represents the Florida Turnpike. In fact, District 8 continuously shows much higher average unit costs than the other seven districts for most of the Action Sub-Category-Units analyzed. The reasons for this occurrence are not exactly known, although, it may be due to contract administration and data entry responsibilities for work on the turnpike, higher design standards that apply to Interstate bridges, or site limitations due to heavy traffic. Some Districts do not have any data for some Action Sub-Category-Units; possibly because they do not perform this activity. Appendix B shows more values estimated for district location factors.

Table 4.7. District Location Cost Indices for Action Sub-Category 112LF Replace Joint Seal

DISTRICT	Units	1999_Avg. Unit Cost	Std. Dev.	C.V.	No. of Data	Location Factor
1	LF	$15.02	14.84	0.99	16	1.85
2	LF	$15.18	10.76	0.71	13	1.86
3	LF	$8.14	8.08	0.99	21	1.00
4	LF	$41.19	21.98	0.53	5	5.06
5	LF	$28.39	39.53	1.39	4	3.49
6	LF	$8.01	5.65	0.71	69	0.98
7	LF	$23.56	22.26	0.94	14	2.89
8	LF	$77.94	44.77	0.57	22	9.57

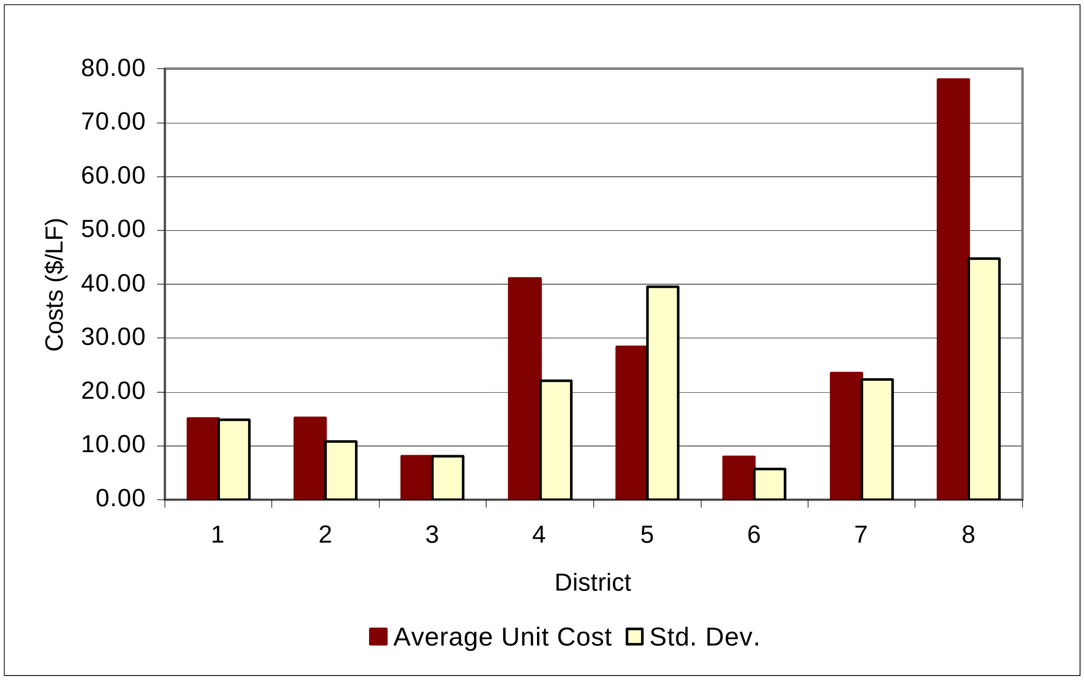

Figure 4.6. Cost Variation by District for Action Sub-Category 112LF – Replace Joint Seal

4.2.3. Regression Analysis: Modeling Bridge Characteristics

Simple linear regression is used to show a correlation or relationships between two variables: an independent and dependent. Regression evaluates the degree of change in one variable due to the change in another variable. There is a base model upon which linear regression is formed for a population, but most often, the lack of complete data due to time constraints or the nature of the research allows researchers to use only sample data or a representation of the complete population. The basic model for simple linear regression is as follows:

$$y = A + Bx \tag{4.2}$$

where A = constant (Y-intercept), and
B = slope

Sometimes, when the use of simple linear regression may not fully explain the relationship, non-linear regression analysis may be needed. The use of logarithmic models helped to make a better fit to some regression plots that showed decent R^2 values. Those factors such as total quantity or repair age that were used as variables to determine if a relationship existed with the unit costs were slightly improved if a non-linear model was utilized. The logarithmic function is based on the following equation:

$$Y = B\,ln\,x + A \tag{4.3}$$

where B = slope, and
A = constant (the Y-intercept)

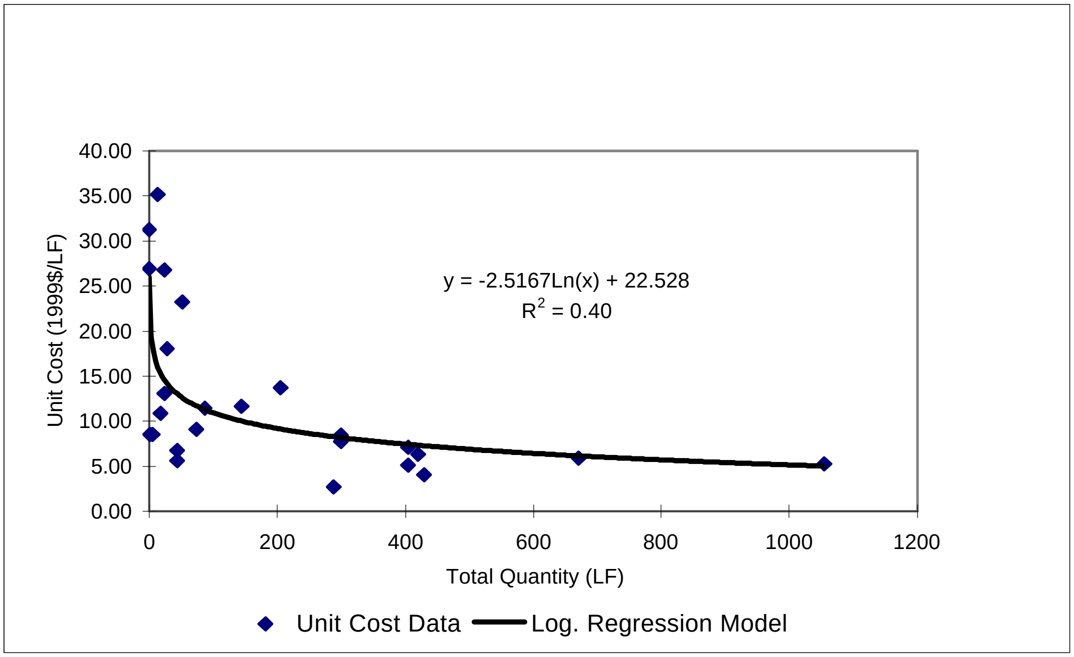

Figure 4.7. Regression Plot – Unit Cost vs. Total Quantity

Using the Clemson University Study as a guide, regression analysis was performed on all Action Sub-Category-Units with sufficient data to show what, if any, characteristics and factors may influence the average unit cost. Some of the factors that were used in the Clemson research include quantity, structure type, and materials. The MMS data along with Florida's Bridge Inventory data provided many of these same factors to use in analysis. The factors chosen for this study had to be logically sound for each element or maintenance activity. For example, it must make sense to analyze bridge joints by total quantity because the total amount could conceivably vary the average unit cost.

As a specific example, Action Sub-Category-Unit 111LF – *Replace Joint*, factors such as total quantity and repair age were used for regression analysis (see Figure 4.7). Linear regression analysis gave an R^2 value of 26%. This means that 26% of the variation in unit costs is explained by the total quantity. Twenty-six percent is a fair R^2 value. However, by applying a logarithmic regression model, a better-fit line can be found with R^2 value of 40%. This logarithmic model is shown in Figure 4.7.

Action Sub-Category 221 – *Rehab Slope Protection* might be varied by a factor such as total bridge length since the side slopes can usually be a function of the bridge length.

4.2.4. Statistical Sample Size

Due to the fact the data collected from the FDOT is only samples from a larger population, the issue of sample size must be dealt with. Confidence interval theory gives the equation to derive upper limit (U) and lower limit (L) as follows:

$$\{U, L\} = \bar{x} \pm z\, s_{\bar{x}} \tag{4.4}$$

where $\bar{x}$ = sample mean
z = fractile of the Standard Normal Distribution
$s_{\bar{x}}$ = sample standard deviation

For a 95% confidence interval, z = 1.96. The right hand side of the equation above is called the maximum error of estimate for the mean (μ or $\bar{x}$). This error illustrates the possible variation in sampling from the population. To determine a sample size that would yield results within the 95% confidence interval, the following equation is given:

$$N = z^2[s^2/d^2] \tag{4.5}$$

where N = sample size
z = 1.96 for 95% C.I.
s = sample standard deviation
d = set tolerance (±$5.00/unit in this study)

Table 4.8 below shows an example of three different joint seals that were tested using analysis of variance and shows the number of data points for each. The column labeled "N" is the number of data points required to fall within a tolerance or error (d) of ±$5.00/unit. So, for Element 301

– Pourable Joint Seal, the actual number of data points collected was 11, and the required number to fall within the set tolerance is 18. The last column in the table shows the error for these two values of "N", as \$6.47/unit. This error is outside the set tolerance of ±\$5.00/unit. Therefore, the average unit cost for Element 301 can be used, but there is a strong indication that it is not accurate. To determine the upper and lower limits of the confidence interval, simply add/subtract the error term to the average unit cost for each type. For 301 – Pourable Joint Seal, \$15.45 ± 6.47 would result in a confidence interval of \$8.98 to \$21.92. The same process can be done for the overall data results.

Table 4.8. Minimum Sample Size Determination Activity 111LF – Replace Joint

Element	Actual N	Required N	Error (d) in Mean Estimate*	Avg. Unit Cost
301 - Pourable Joint Seal	11	18	6.47	15.45
302 - Compression Joint Seal	14	18	5.67	14.08
304 - Open Expansion Joint	5	0	1.45	9.57
Overall Data	30	15	3.55	13.83

*At 95% Confidence level (Z=1.96)

4.2.5. Analysis of Variance (ANOVA)

In simple terms, the Analysis of Variance (ANOVA)is a statistical tool that enables an experimenter to make inferences, at a level of significance, on the means from unknown populations, based on the data sets comprising samples from each of the populations. The ANOVA assumes a normal distribution for each population, and also computes an F-statistic at the specified level of significance. There are two hypotheses relevant to the ANOVA; the first is the null hypothesis (H_o), which states that all means of the populations or treatments are equal; and the second is the alternative hypothesis (H_1), which states that at least one pair of the means are not equal.

$$H_o: \mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k \quad (4.6)$$

$$H_1: \mu_1 \neq \mu_2 \neq \mu_3 \neq \ldots \neq \mu_k \quad (4.7)$$

In the ANOVA, the F statistic is compared to the $F_{critical}$ value to help determine the outcome. The value of $F_{critical}$ is based upon the degrees of freedom. If the value of F is greater than the value of $F_{critical}$ then the null hypothesis is rejected. If it is less than $F_{critical}$ then the null hypothesis is accepted.

A probability value approach or p-value is also calculated in the ANOVA Table. This value can also help determine whether to reject or accept the null hypothesis. If the p-value is less than the level of significance, the null hypothesis is generally rejected. The p-value is the probability that a TYPE I Error will occur. A TYPE I Error is when a true null hypothesis is rejected. When a false null hypothesis is not rejected a TYPE II Error has occurred. The level of significance adopted for this study was 5%.

The analysis of variance was used to determine the unit cost for specific elements rather than for a set of Action Sub-Category-Units. The overall average unit cost for each Action Sub-Category-Unit was found prior to the ANOVA when the descriptive statistics were found. The analysis of variance provided a count of the total number of data for each element, the average unit cost per element and the variance of the costs for that element.

The value of the F term and the p-value are the primary indicators as to whether or not a null hypothesis is accepted or rejected. The null hypothesis (Ho) is assuming that the means for each treatment on bridge elements are equal ($\mu_{Elem1} = \mu_{Elem2} = \mu_{Elem3}$). If the null hypothesis is rejected ($F<F_{crit}$) for a certain Action Sub-Category-Unit, it implies that the average unit costs for the elements tested are not equal, and that the individual average unit cost of each element should be used. For example the null hypothesis was accepted in the case of 111LF (Replace Joint), which implies the means are equal and the average unit cost ($13.03/LF) for the whole group should be used.

The MMS data were analyzed using ANOVA. There were a total of 34 Action Sub-Category-Units considered in the Pontis element analysis, based on the direct or indirect unit compatibility between FDOT data and Pontis action units. Seven were from the 100 series; 111LF-Replace Joint, 112LF-Replace Joint Seal, 114LF, 114MH-Replace Railing, 121MH-Replace Slope Protection, 131MH-Replace Machinery, and 144MH-Replace Substructure. Six were from the 200 series; 211LF, 211MH-Rehab Joint, 213MH-Rehab Bearing, 221SF, 221MH-Rehab Slope Protection, and 231MH-Rehab Machinery. Seven were analyzed from the 300 series; 301MH, 301SF-Repair Deck & Substrate, 302LF, 302MH, 302SF-Spot Paint, 303LF, 303MH-Clean Rebar & Patch, and 311LF-Repair Joint. Finally, there were twelve taken from the 400 series; 400LF, 400MH, 400SF-Wash Structure, 401MH, 401SF-Repair Potholes, 402MH-Restore Topcoat, 403LF, 403MH, 403SF-Patch Minor Spalls, 431MH-Maintain Machinery, and 446MH, 446SF-Maintain Approach Slab. This includes direct and indirect use Action Sub-Category-Units.

Of the seven from the 100-series, six resulted in an acceptable null hypothesis and one rejection. There were 3 that accepted the null hypothesis and 3 that rejected the null hypothesis in the 200-series. The 300-series had 6 that accepted the null hypothesis and one that rejected it. The 400-series had 9 that accepted the null hypothesis and 3 that rejected the null hypothesis. Some Action Sub-Category-Units do not have ANOVA results because they were not available or the null hypothesis was accepted for that particular one, implying that the overall average unit cost was recommended.

An example of the MMS data output from ANOVA Pontis element analysis is shown in Table 4.9. The Action Sub-Category-Unit 114LF-Replace Railing accepted the null hypothesis. This implies that the overall unit cost of $18.01/LF for the group should be used. The average unit cost for element 331, 333, and 334 do not seem as though they are equal being $19.93, $16.73, and $14.71, respectively. However, the standard deviation for each of these is fairly large. So there is a possibility of overlapping of values, which means that the average unit costs are considered statistically equal.

Table 4.9. Action Sub-Category-Unit 114LF (Replace Railing) Model for Pontis Elements

Treatments	Count	Avg	C.V.	Required N**	Error (d) in Mean Estimate*	
331 - Reinforced Conc Railing	75	19.93	0.69	29	3.13	
333 - Other Bridge Railing	61	16.73	0.78	26	3.27	
334 - Metal Bridge Railing - Coated	20	14.71	0.61	12	3.91	
	156					
Overall Data:	156	18.01	0.73	26	2.05	
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	595.23	2	297.61	1.758	0.1759	3.055
Within Groups	25904.43	153	169.31			
Total	26499.65	155				
* 95% Confidence Level						
** Based on tolerance of +/-5						

There is a noticeable difference between the total data count in ANOVA and the Action Sub-Category-Unit data count before ANOVA was performed, which was much lower. This is due to the merge of MMS data with Pontis inventory data; a bridge may have multiple elements. For example, bridge number XXXX in the original MMS data may have its single record of unit cost allocated to two elements like 301 and 302. This results in two records instead of the original one record for this bridge. Thus the new count is more than the original MMS count. Another Action Sub-Category-Unit with good results is 112LF-Replace Joint Seal. Shown in Table 4.10, it too has rejected the null hypothesis because the F-value is greater than the F_{crit} value.

The p-value is another approach to evaluating the outcome of the ANOVA test. The p-value is smaller than the chosen alpha value of 0.5, which also indicates that the average unit costs are not equal. There are four joint seal types included in the analysis, pourable joint seal, compression joint seal, assembly joint/seal, and open expansion joint. The average unit costs have a wide range indicating that they are not equal by inspection. Although the results reveal individual unit costs should be chosen, the sample sizes must be determined reliable so that the error value is not too high. Only element 301-Pourable joint seal has sufficient data to stay within the ±5 tolerance with 74 data points collected and 65 required. Element 302-Compression joint seal is well below the required minimum of 211. Elements 303-Assembly joint/seal and 304-Open expansion joint are just under their respective minimums. Given these circumstances, the error values are not extremely high, but are beyond the range that was set for this study. Also listed is the coefficient of variation for each element. For elements 301 and 302 they are still above 1.00, even after three steps to remove outliers were performed.

The next example, in Table 4.11, represents unit costs for rehabilitation data for Action Sub-Category-Unit 221MH-Rehab Slope Protection. The three elements include a metal uncoated bulkhead/seawall, a reinforced concrete abutment, and an abutment of another material.

There was a significant amount of data collected for elements 394 and 396, but the variance was considerably high, so the minimum required sample size increased. This example shows that even though ANOVA can provide average unit costs for elements, the sample size may not be large enough to fall within the specified tolerance. For example, the data may state that it costs $89.89/MH to rehabilitate a concrete abutment, but it is not completely reliable. Only element 393 is above the minimum sample size (N) of 6 with 16 data points. The coefficient of variation for elements 394 and 396 as well as the overall data are high. This indicates that the variability of these elements is very high. A similar model of the unit costs is presented in Table 4.10 for Action Sub-Category-Unit 112LF (Replace Joint Seal).

In Table 4.12, many elements are shown, related to Action Sub-Category-Unit 403MH-Patch Minor Spalls. They range from girders to fender systems to culverts. Several elements had data records numbering into the thousands such as 215-Reinforced Concrete Abutment and 331-Reinforced Concrete Bridge Railing. The overall average unit cost is $22.33, and many of the elements listed have a similar average unit cost. However, the F-value is greater than the F_{crit} value indicating the average unit costs are not statistically equal. Elements 115, 144, and 154 are probably the reasons for this rejection of the null hypothesis with average unit costs of $6.80, $14.95, and $6.80, respectively. Since the standard deviation for each element was very low, the sample sizes that were obtained were overwhelmingly sufficient. Even though elements 115, 116, 144, and 154 have only one data point each, it should be safe to state that this Action Sub-Category-Unit has very reliable data. The coefficient of variation for each element is also very low also indicating low standard deviations.

Appendices C and D contain more detailed results on results of ANOVA and basics statistical analyses conducted, and also the results of expert opinions elicited.

Table 4.10. Action Sub-Category-Unit 112LF (Replace Joint Seal) Model for Pontis Elements

Treatments	Count	Avg	C.V.	Required N**	Error (d) in Mean Estimate*	
301 - Pourable Joint Seal	74	13.29	1.55	65	4.68	
302 - Compression Joint Seal	94	30.98	1.20	211	7.50	
303 - Assembly Joint/Seal	9	14.38	0.82	21	7.71	
304 - Open Expansion Joint	7	9.79	0.77	9	5.56	
	184					
Overall Data:	184	22.25	1.39	147	4.47	
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	19014.08	4	4753.52	5.339	0.00044	2.422
Within Groups	160269.45	180	890.39			
Total	179283.53	184				

* 95% Confidence Level
** Based on tolerance of +/-5

Table 4.11. Action Sub-Category-Unit 221MH (Rehab Slope Protection) Model for Pontis Elements

Treatments	**Count**	**Avg**	**C.V.**	**Required N****	**Error (d) in Mean Estimate***	
393 - Bulkhead/Seawall Metal Uncoated	16	13.77	0.46	6	3.12	
394 - Abutment Slope Protection Reinforced Concrete	422	89.89	1.22	1849	10.47	
396 - Abutment Slope Protection Other Material	378	68.71	1.35	1331	9.38	
	816					
Overall Data:	816	78.59	1.30	1601	7.00	
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	157995.59	2	78997.79	7.7080	0.0005	3.0068
Within Groups	8332226.4	813	10248.74			
Total	8490221.9	815				
* 95% Confidence Level						
** Based on tolerance of +/- 5						

Table 4.12. Action Sub-Category-Unit 403MH (Patch Minor Spalls) Model for Pontis Elements

Data Summary of Element Analysis @ 95% Confidence Level

Treatments	**Count**	**Avg**	**C.V.**	**Required N**	**Error (d)**
104 - P/S Conc Closed Web/Box Girder	9	22.69	0.32	8	4.77
105 - Rein. Concrete Closed Webs/Box Girder	2	30.46	0.76	82	31.98
109 - P/S Conc Open Girder/Beam	914	20.67	0.40	10	0.53
110 - Reinforced Conc Open Girder/Beam	102	18.31	0.36	7	1.28
115 - P/S Conc Stringer	1	6.80	0.00	0	0.00
116 - Reinforced Conc Stringer	1	49.81	0.00	0	0.00
144 - Reinforced Conc Arch	1	14.95	0.00	0	0.00
154 - P/S Conc Floor Beam	1	6.80	0.00	0	0.00
155 - Reinforced Conc Floor Beam	11	25.20	0.36	13	5.35
204 - P/S Conc Column or Pile	398	20.78	0.39	10	0.80
205 - Reinforced Conc Column or Pile	923	20.36	0.40	10	0.52
207 - Hollow Core Pile	13	14.25	0.37	4	2.86
210 - Reinforced Conc Pier Wall	84	20.15	0.30	6	1.31
215 - Reinforced Conc Abutment	1283	20.31	0.40	10	0.44
220 - Pile Cap/Footing	436	20.08	0.36	8	0.68
233 - P/S Conc Cap	4	18.45	0.23	3	4.15
234 - Reinforced Conc Cap	1166	20.39	0.39	10	0.46
241 - Reinforced Concrete Culvert	68	17.80	0.41	8	1.75
Protection	54	19.68	0.33	7	1.76
299 - Pile Jacket with Cathodic Protection	9	21.81	0.20	3	2.79
321 - Rein. Conc Approach Slab w/ or w/o AC Ovly	1281	20.48	0.40	10	0.45
331 - Reinforced Conc Bridge Railing	1050	20.50	0.39	10	0.48
387 - Fender Dolphin System Prestressed Conc	57	19.81	0.28	5	1.46
388 - Fender Dolphin System Reinforced Conc	4	29.77	0.10	1	2.78
394 - Abutment Slope Protection Rein. Conc	723	20.27	0.42	11	0.62
475 - Wingwall/Retaining Wall Reinforced Conc	449	19.40	0.40	9	0.73
564 - Counterweight	30	20.80	0.19	2	1.43
	9074				
Overall Data:	9074	20.33	0.39	10	0.16

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4220.63	26	162.33	2.5439	0.000	1.4968
Within Groups	577301	9047	63.81			
Total	581522	9073				

4.2.6. Discussion on Statistical Results

The study has investigated the variation among agency unit costs for MR&R activities through statistical analysis. Much of the information regarding regression factors was taken from the Clemson University Study. Clemson's study primarily focused on the collection of unit cost data and the development of a cost database. The Florida study closely examined several topics that other agencies or universities have noted, such as high coefficients of variation, sample sizes, and unit compatibility.

The results from the Pontis element analysis provide a sense of the type of data being collected by FDOT both historically and currently. Although the Action Sub-Category-Units discussed in the previous section show good results, the units still present a compatibility problem in some instances. Many data collected from FDOT are recorded in man-hours, which is not directly compatible with Pontis. However, the elements that have a matching Action Sub-Category-Unit with these incompatible units most often have units such as "linear feet" or "each". These units may provide for simple conversion from man-hours if a time factor is found for completing given amount of linear feet or each particular element.

The Clemson University study stated that the data collected and analyzed produced very high coefficients of variation. For the FDOT study, it was important that the coefficient of variation values be much lower. By removing statistical outliers (three steps for MMS, one step for CES and DCP) the final coefficient values are reasonably lower than those presented in the Clemson study. Of the examples discussed in the previous section, all but four Pontis elements have a coefficient of variation below 1.00. This was the intended goal as the research began. Since the coefficient of variation is a representation of the standard deviation, a value that is closer to zero implies that the data or unit costs are statistically similar and close to the mean. The coefficient of variation values for the Pontis elements analyzed are mostly below the value of 1.00. The DCP values are also good with only a few Action Sub-Category-Units having a coefficient of variation slightly above 1.00. In such cases where the coefficient of variation remains above 1.5, the number of data points is usually low and does not meet the minimum sample size required. A direct comparison with the Clemson results is difficult since each unit cost is accompanied by a condition state. The data collected from the FDOT does not have a condition state attached. To compare the two, the Pontis element, the units, and the action description had to match exactly, otherwise, the values could be for different actions for a different condition state. At a glance, the coefficient of variation for the Pontis elements from the FDOT are generally lower than those presented in the Clemson study.

The DCP data offered 17 Action Sub-Category-Units that were tested using ANOVA. Only four had a null hypothesis that was rejected and were directly compatible with Pontis units. These included 111LF-Replace Joint, 112LF-Replace Joint Seal, 114LF-Replace Railing, and 121SF-Replace Slope Protection. The other thirteen provided only an overall average unit cost because of an accepted null hypothesis or the data that was collected did not match with the Pontis elements required.

For the CES data, only five Action Sub-Category-Units provided specific element average unit costs. In other words, the null hypothesis was rejected in the ANOVA, and the individual average unit costs should be chosen. Even when the null hypothesis was accepted, average unit costs were available, but were not investigated as thoroughly. They were 111LF-Replace Joint, 112LF-Replace Joint Seal, 114LF-Replace Railing, 131EA-Replace Machinery, and 132SF-Replace Cathodic Protection. Like the MMS and DCP data, there were several Action Sub-Category-Units tested using ANOVA, but the null hypothesis may have been acceptable. The Clemson study provided a good starting point as far as framework is concerned, however, the data samples collected in that study were quite small.

A study by Gannon et al, (1995) provided a report showing the use of statistical analysis to develop cost models for concrete bridge rehabilitation. By collecting bid tabulations from twelve state highway agencies, several activities were analyzed such as deck patching, deck protection systems, structural patching, etc. The variations in cost for these activities were assumed to be due to quantity, maintenance of traffic, number of bidders and the contract amount. Also, inflation adjustments and location adjustments were made to obtain a more accurate or present worth dollar amount.

The FDOT study utilized some of the steps mentioned above such as the adjustments for inflation as well as cost variation factors for each activity. Although each study has different goals, the methodology is very similar. The Florida study utilizes historical data relating to many MR&R Activities to analyze and find agency unit costs for each. Using Analysis of Variance (ANOVA), the variations of costs by each element type (e.g., compression joint, open joint, etc.) were determined, if the data were available. Also studied were physical bridge factors such as deck material type, span material type, deck structure type, and functional classification. ANOVA was used here as well to see if there were variations in unit costs of certain activities.

4.2.7. Consistency Among Results (MMS, CES, and DCP)

For the majority, the average unit costs from the MMS data are lower than those from CES and DCP.. The reason for this variation cannot be easily ascertained but it is suspected that the each of the data sources employ different values of overhead and fringe rates. It is also possible that MMS data (from standard FDOT MMS reports) does not adequately incorporate all the overhead and fringe rates. These average unit costs listed in these tables represent those unit costs that could be used if specific average unit costs were not found using ANOVA. Overall, there were 24 directly compatible Action Sub-Category-Units from MMS, 11 directly compatible from CES, and 20 from DCP. This implies that a conversion of non-compatible units should be performed in order to obtain more compatible results. The results for specific average unit costs for Pontis elements and NBI data, found from ANOVA, are shown in Appendix D.

Overall, there were a reasonably good number of reliable unit costs found from the FDOT data. The initial data analysis, after adjustment for inflation and removal of outliers, produced 131 average unit costs (131 Action Sub-Category-Units) from the MMS data with 24 Action Sub-Category-Units with directly compatible units and 45 with indirect units. Of the 24 direct use, only three had a coefficient of variation over 1.00, and of the 45 indirect use, only two had a coefficient of variation over 1.00. The CES data had eleven directly compatible units and seven indirect with only five total coefficients of variation over 1.00. The DCP data had twenty directly compatible units and 25 indirectly compatible, with only 10 total coefficients of variation over 1.00. The coefficient of variation for specific elements from the analysis of variance was very good (below 1.00), with only Action Sub-Category-Units 400MH – Wash Structure, 403SF-Patch Minor Spalls, and 446SF – Maintain Approach Slab having very high coefficients of variation for each element.

A very important limitation to the FDOT data collected for the study is that neither the MMS, CES or DCP data has a recorded condition state of the element that was repaired. The current condition state of an element greatly affects what action the preservation model in Pontis will recommend. The data collected for this study does not contain condition state information. If maintenance records were recorded with a condition state, the unit costs of the past data could be analyzed by the specific condition states.

The compatibility of units was identified and reported. There was a considerable amount of data that corresponded to Pontis elements, however, in several cases the historical data units were measured in Man Hours when the Pontis units were Each. There were cases in which the historical data was measured in terms of square yards and the Pontis units were each, but the most prevalent was man-hours. Converting these Action Sub-Category-Units into Pontis-compatible units is a possibility for future research.

A procedure to estimate unit costs from historical data is also explained and an entity relationship diagram is presented as well. The matching of Pay item numbers and Activity Codes with Action Sub-Categories was a crucial step in developing this procedure. By knowing which Pay items and Activity Codes contribute to each Action Sub-Category, a more reasonable unit cost can be determined. This schema was not tested for functionality, but is a framework for future development.

4.3. Missing Data and Expert Review

To supplement the results of the data analyses using FDOT's historical data, bridge maintenance experts from the various districts were assembled at three different meetings to review the data and provide their suggestions. The flow chart show below in Figure 4.8 indicates the feedback-flow pattern of the reviews.

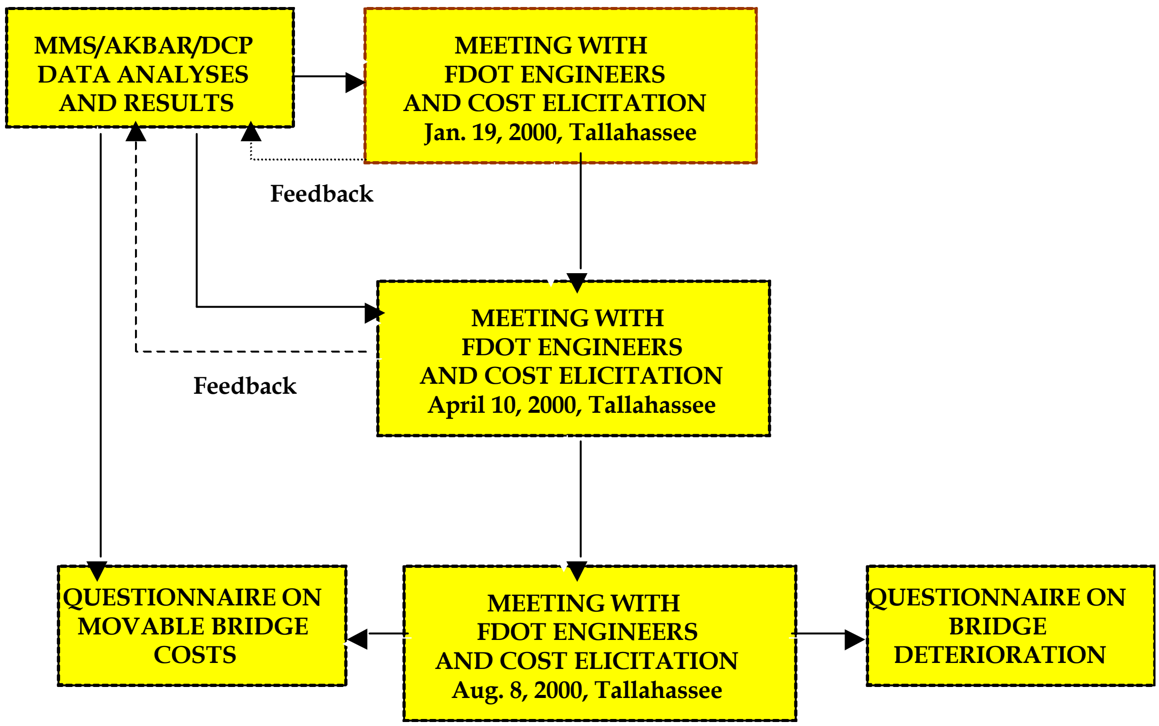

Figure 4.8. Flow chart illustrating the data collection and expert reviews

4.3.1. Description of Expert Interviews

The first of the meetings between the research team and the FDOT engineers took place at the State Maintenance Office, in Tallahassee, on January 19 and 20, 2000. Present at this meeting were the following: Richard Kerr (State Maintenance Office); Todd Hammerle (District 5); Debbie Myers (District 4); Mike Sprayberry (State Maintenance Office); John Clark (State Maintenance Office); Paul Thompson (Researcher); and John Sobanjo (Researcher).

The main issues discussed included familiarization of the FDOT engineers with the progress of the research team's effort on the study, a review of the raw data obtained from FDOT data bases and the accompanying results, as well as a comparison of these results with existing data from the Clemson study (default cost data in Pontis). Each bridge cost item was reviewed, by Pontis element number, and various suggestions on cost were obtained from the FDOT. The review included detailed examination of the typical crew needed to execute certain bridge MR&R actions, with the objective of estimating the labor required relative to the unit cost. Bridge items that were not utilized or rarely present on the Florida inventory, were identified by the team and noted by the research team for possible elimination from future consideration. Other pertinent sources of expert opinions within FDOT, were also suggested to the research team, including visiting Districts, and other offices such as the Structures Office to discuss specialized costs such as the moveable bridges.

On April 10, 2000, the second meeting took place, at the State Maintenance Office, in Tallahassee. Present at this meeting were the following: Frank Day, Richard Kerr, John Clark, and Jean Ducher (all from the State Maintenance Office); Paul Thompson, and John Sobanjo (both Researchers). The purpose of this meeting was to present the current results by the research team, and elicit the comments of the FDOT engineers on these results.

The reasonableness of the research team's data results were reviewed by the FDOT engineers, and suggested cost revisions were again obtained. In addition, suggestions also included removal of some items from future consideration; investigation of other FDOT sources of raw data,; contacting the FDOT districts and the use of questionnaires for difficult-to-obtain costs on moveable bridges.

The last major meeting between the research team and the FDOT engineers took place between August 8 and 11, 2000, also at the State Maintenance Office, in Tallahassee. Present at this meeting were the following: Richard Kerr (State Maintenance Office); Many Finns (District 6); Mario Bizzio (District 5); Keith Campbell (District 2); Alberto Sardinas (District 4); Paul Thompson (Researcher); Matt Lewis (Student- Researcher); and John Sobanjo (Researcher). The costs were deliberated on and refined based on expert judgment. Suggestions were made by the FDOT engineers on the development and dissemination of the questionnaires for costs on moveable bridges, and also for data on bridge deterioration.

4.3.2. Consistency Between Data Analysis and Expert Judgment

There were some differences between the results of the statistical analyses of the FDOT data, and the experts' opinions on the corresponding costs. Some of the data analysis results were accepted by the experts as being reasonable, while some were adjusted. A few results were rejected. Comparing the results by virtue of its source, the MMS data were usually lower than the other sources, and also considered low most of the times, by the experts.

5. Deterioration Model Results

This section describes the results of our expert elicitation process for Pontis condition predictive models, performed by FDOT request under subtask 6.4 (On-Going Assistance) of the FDOT Pontis Agency Cost Study. Like all states that have implemented Pontis, FDOT came into the effort lacking historical bridge element condition state data. The Department began collecting such data in late 1998, so there is not yet a sufficient history to develop Pontis predictive models. In order to put Pontis to use in the near future for project planning and policy analysis, it is necessary to use an alternative method of estimating these models specific to Florida conditions.

Anticipating that all states would face a similar situation, the developers of Pontis specified a procedure for gathering expert opinion data on the rate of bridge element deterioration, which can be converted to a form directly usable in Pontis. This method, known as the Expert Elicitation Process, is described in Golabi, Thompson, and Hyman (1992). Most of the states implementing Pontis have followed some variation of this original procedure.

A complete effort to develop Pontis predictive models is necessarily lengthy. FDOT uses 136 bridge element types, each having an average of 4.0 condition states and 5.8 feasible actions other than do-nothing. (Such actions are termed “do-something” throughout this report.)

The expert elicitation process began with a meeting in Tallahassee on 10 October, 2000 involving the consultants, FDOT headquarters staff, and representatives of several FDOT District offices. A questionnaire was prepared to seek the desired expert opinion data. Appendix E.1 has the survey instructions and an example form for one of the 136 elements. The full survey was provided as a loose-leaf binder. Over two days, the District engineers were led through numerous examples of the thought process required in order to answer the questions.

Following the completion of the questionnaires by four District engineers, the consultants analyzed the data to produce the final models of bridge element deterioration and action effectiveness. As requested by FDOT, the results will be transmitted to the Department electronically in the form of Microsoft Excel worksheets. This written report includes tables and graphs summarizing the results, but does not contain the full details, which are too voluminous to be printed. The worksheets contain 5,882 records of data ready to be imported into the FDOT Pontis database.

5.1. How Deterioration is Modeled in Pontis

Bridge deterioration is a complex process of physical and chemical changes that occur in bridge components and materials due to time, traffic, and environmental effects. Each element in a bridge deteriorates at its own rate influenced by its immediate environment. Each element also has its own unique effect on the functionality of a bridge, and ultimately its ability to serve the needs of road users.

For example, the corrosion of a primary element such as a steel girder, if allowed to proceed without intervention, may eventually reduce the load-carrying capacity of the bridge, forcing heavier trucks to detour. Certain secondary elements, such as joint seals, may not have a direct effect on road users but do have an indirect effect by delaying the corrosion of primary elements.

When an element is in the early stages of deterioration, it usually has little or no effect on road users. However, the ability to predict its condition is still very important. In many cases early intervention can be less expensive and more effective than treatments applied to elements in more advanced states of deterioration. To find the best opportunities for cost-effective preventive maintenance, bridge management systems such as Pontis use life-cycle cost models, whose major inputs are:

- Unit costs for maintenance, repair, rehabilitation, and replacement actions
- Models to predict the deterioration of each bridge element
- Models to predict the improvement in condition that may result from an action

The latter two inputs together are commonly known as the condition predictive model, since both predict changes in condition of an element as a result of decisions about what, if any, action to take.

Because of the inherent complexity of bridges, it is necessary to employ a simplified framework to measure and analyze condition. The level of simplification is a careful balance between realism of the models and expense of data collection. The approach developed for Pontis, which has subsequently been adopted by nearly all of the states, is to divide a bridge into “elements,” which are parts of a bridge having distinct characteristics of deterioration, feasible treatments, and costs. Florida uses a system of 136 elements which are listed with some of the project results in Appendix E.2. Elements include various types of decks, girders, beams, railings, expansion joints, bearings, columns, walls, sign structures, light poles, and moveable bridge equipment. Most of the FDOT elements follow the AASHTO standard for Commonly Recognized (CoRe) elements, but the Department has added many of its own elements to fit its own inventory and policy concerns.

During a bridge inspection, each element is characterized by dividing it into “condition states.” Because of the great expense of routinely measuring deterioration processes such as chloride infiltration, corrosion potential, and paint peeling, AASHTO opted to specify a simpler condition rating process that describes only three to five classes of condition for each element. The condition state definitions were designed to be consistent and repeatable when used by suitably trained bridge inspectors in a visual inspection process. As an example, here are the definitions of the condition states of painted steel girders:

1. There is no evidence of active corrosion, and the paint system is sound and functioning as intended to protect the metal surface.
2. There is little or no active corrosion. Surface corrosion has formed or is forming. The paint system may be chalking, peeling, curling or showing other early evidence of paint system distress but there is no exposure of metal.
3. Surface corrosion is prevalent. There may be exposed metal but there is no active corrosion which is causing loss of section.
4. Corrosion may be present but any section loss due to active corrosion does not yet warrant structural review of either the element or the bridge.
5. Corrosion has caused section loss and is sufficient to warrant structural review to ascertain the impact on the ultimate strength and/or serviceability of either the element or the bridge.

At any given time the condition of the steel girders on a bridge is described by allocating the total length of girders among the five condition states. For example, a given bridge may have 10% of its girder length in state 3, 25% in state 2, and the rest in state 1.

In addition, every element has a condition state called “Failure.” This state is not recognized in bridge inspections but is a possible outcome of deterioration. Generally, the Failure state is considered to be condition that is so bad that the element is no longer able to serve its intended function. Usually a failed element must be replaced because of the effect on road users or because of agency policy (or both). It is therefore considered to be the unacceptable end result of deterioration if no action is ever taken.

This description of element condition is convenient for bridge inspectors, and is also convenient for expressing predicted conditions in a life cycle cost analysis. Because of the complexity of deterioration, no engineer can reliably predict the condition of a specific bridge many years in the future. However, based on experience or analysis of historical data, an engineer can reasonably judge the likelihood of each condition state in the future. Just like current condition, future condition can also be expressed as a percent in each condition state, the percent representing a probability.

The tools available for predicting future condition are limited by the types of data that can reliably and economically be collected to describe current condition. The predictive model in Pontis therefore must make best use of condition state data, without requiring that anything else be known about the existing state of the bridge. A simple probabilistic model called a Markovian model is an exact fit to these requirements. The assumptions behind a Markovian model are as follows:

- The state of an element is described at any point in time as a distribution among a small number of condition states.
- The opportunity to make a decision that changes the condition of the element happens at evenly-spaced intervals in time (in Pontis, once a year).
- The likelihood of an element moving from one condition state to another is constant: it

doesn't depend on any other information about the condition of the element or on past condition states.

The last of these assumptions can be relaxed if more data are available, but so far the cost of additional data collection for bridge management has been prohibitive for most agencies. However, one additional piece of data that is available is a classification of the environment in which the element resides. Pontis provides four environments, defined generally as follows:

Benign – Neither environmental factors nor operating practices are likely to significantly change the condition of the element over time, or their effects have been mitigated by past non-maintenance actions or the presence of highly effective protective systems.

Low – Environmental factors and/or operating practices either do not adversely influence the condition of the element or their effects are substantially lessened by the application of effective protective systems.

Moderate – Any change in the condition of the element is likely to be quite normal as measured against those environmental factors and/or operating practices that are considered typical by the agency.

Severe – Environmental factors and/or operating practices contribute to the rapid decline in the condition of the element. Protective systems are not in place or are ineffective.

All of these definitions are relative to conditions typical of the inventory in which they are used. Thus, a Severe environment in Florida is far different from one in New Hampshire. Florida uses three of these categories (omitting Low) and interprets them in a Florida context. A severe environment indicates exposure to salt water or pollution, while a benign environment is relatively dry, protected, and rural.

Accepting these assumptions, a Markovian deterioration model can be expressed very simply as a matrix of transition probabilities. Figure 5.1 is an example from the study results, for a painted steel girder in a severe environment.

		To Condition State					
		1	2	3	4	5	Fail
From State	1	93.5	6.5	0.0	0.0	0.0	0.0
	2		88.6	11.4	0.0	0.0	0.0
	3			91.2	8.8	0.0	0.0
	4				88.2	11.8	0.0
	5					82.8	17.2

Figure 5.1. Example transition probability matrix

This table says, for example, that a girder starting in condition state 1 has a 6.5% chance of moving to state 2 in one year, and a 93.5% chance of staying in state 1. A girder in state 5 has a 17.2% chance of failure in one year. Because this is a deterioration model assuming no action is taken, there is no probability of any improvement in condition, such as a movement from state 5 to state 1. Note that all rows must sum to 100%.

When an action is taken, the effect on condition can be expressed in a similar way, as a "do-something" matrix. Each possible condition state has zero, one or more feasible actions. Each feasible action results in a distribution of condition states immediately following the action. For the painted steel girder element, Figure 5.2 has the study results for the action effectiveness model.

From State	Action	To Condition State 1	2	3	4	5
1	1 Surface clean	100.0	0.0	0.0	0.0	0.0
1	2 Misc Maintenance	100.0	0.0	0.0	0.0	0.0
2	1 Surface clean	0.0	100.0	0.0	0.0	0.0
2	2 Clean and paint	91.3	8.8	0.0	0.0	0.0
3	1 Spot blast, clean, and paint	93.8	6.3	0.0	0.0	0.0
4	1 Spot blast, clean, and paint	48.8	22.5	3.8	25.0	0.0
4	2 Replace paint system	72.5	2.5	0.0	25.0	0.0
5	1 Rehab unit	86.3	11.3	2.5	0.0	0.0
5	2 Replace unit	100.0	0.0	0.0	0.0	0.0

Figure 5.2. Example action effectiveness model

For example, if a girder is in state 4 and its paint system is replaced, 72.5% will be in state 1, 2.5% in state 2, and 25% in state 4 immediately after the action. Note that repainting does not remedy section loss, which is why a significant fraction remains in state 4. Florida defines two types of minor maintenance actions in state 1, that are not intended to be modeled in Pontis but are used for other bridge management purposes. The 100% in state 1 indicates that the activity does not change the condition state. Again, all rows must sum to 100%. (The numbers in the table are rounded.)

A convenient feature of Markovian models is that it is easy to use them to calculate an estimate of condition for any future point in time, by matrix multiplication. Figure 5.3 shows the painted steel girder example carried out 30 years. The condition each year is expressed probabilistically. For example, after 30 years there is a 19.2% chance of failure if no action is taken up to then. All of the columns sum to 100% (allowing for rounding).

Predicted State	Year 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	100.0	93.5	87.4	81.7	76.4	71.5	66.8	62.5	58.4	54.6	51.1	47.7	44.6	41.7	39.0	36.5
2		6.5	11.8	16.2	19.6	22.4	24.5	26.0	27.1	27.8	28.2	28.3	28.2	27.9	27.4	26.8
3			0.7	2.0	3.7	5.6	7.7	9.8	11.9	13.9	15.9	17.7	19.4	20.9	22.2	23.4
4				0.1	0.2	0.5	1.0	1.5	2.2	3.0	3.9	4.8	5.8	6.8	7.8	8.9
5					0.0	0.0	0.1	0.2	0.3	0.5	0.8	1.1	1.5	1.9	2.4	2.9
Fail						0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.8	1.1	1.5

Predicted State	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	34.1	31.9	29.8	27.9	26.1	24.4	22.8	21.3	19.9	18.6	17.4	16.3	15.2	14.2	13.3
2	26.1	25.4	24.6	23.7	22.8	21.9	21.0	20.1	19.2	18.3	17.4	16.6	15.7	14.9	14.1
3	24.4	25.2	25.9	26.4	26.8	27.0	27.1	27.1	27.0	26.9	26.6	26.2	25.8	25.3	24.8
4	9.9	10.9	11.8	12.7	13.5	14.3	15.0	15.6	16.1	16.6	17.0	17.3	17.6	17.8	17.9
5	3.5	4.0	4.6	5.2	5.8	6.4	7.0	7.6	8.1	8.6	9.1	9.5	9.9	10.3	10.6
Fail	2.0	2.6	3.3	4.1	5.0	6.0	7.1	8.3	9.6	11.0	12.5	14.1	15.7	17.4	19.2

Figure 5.3. Example of long-term prediction

If an action is taken at any point, this may cause an immediate change in condition according to the action effectiveness model, but subsequent deterioration resumes using the same deterioration matrix with the new starting conditions.

The ability to use matrix multiplication to make such predictions owes to a simple rule of probability. If a group of events all must occur in order to result in a desired outcome, the probability of the outcome is equal to the product of the probabilities of each of the required events. For example, the probability of a flipped coin landing on the head side is 0.5. Therefore the probability of three heads in a row is $0.5 \times 0.5 \times 0.5 = 0.125$. In the 30-year example above, the only way to have condition state 1 after 30 years is to "transition" from state 1 to state 1 every year for 30 years. From the deterioration model, the odds of one of these transitions is 93.5%. Therefore the odds of 30 in a row is 93.5% to the 30^{th} power, which is 13.3%, the result shown in the 30-year table.

This property leads to a simple way to derive do-nothing transition probabilities from expert opinion, in a way that is much simpler than asking engineers to estimate these probabilities directly. Just ask for the median number of years to transition out of a given condition state. This is the way the questionnaire is formulated in Appendix E.1. The median number of years to transition out of a state is the amount of time before the probability of remaining in the starting condition state falls to 50%. This was between 10 and 11 years in state 1 in the example above. If the unknown “stay-the-same” transition probability is P, and if the number of years is Y, then

$$P^{Y} = 50\% \tag{5.1}$$

This means that, if Y is the engineer’s estimate of the number of years, then P is calculated by

$$P = 0.5^{(1/Y)} \tag{5.2}$$

Now if we assume that it is unlikely for an element to transition by more than one state in any given year, and impossible to transition to a better state if no action is taken, then we can also estimate the probability of transitioning to the next-worse state as 100%-P, because the outcomes of any state must sum to 100%. All other elements of the matrix are zero, so this completely estimates the matrix.

Unfortunately, no such simplification exists for the do-something probabilities, so the engineers were asked about these directly in the questionnaire. This is made easier by the fact that we are asking about conditions immediately following the action, not at some far-away time in the future.

5.2. Processing of Expert Elicitation Data

Four District engineers (Districts 2, 4, 5, and 8) completed the entire questionnaire binder, turning in an amazing performance. Only 19 of the 136 elements lacked responses from at least one engineer. All of these were very uncommon elements. Each engineer completed an average of 55% of the 1,334 questions from his or her own personal experience.

After entering the results into a Microsoft Excel worksheet, the responses were checked for obvious errors, such as probabilities failing to sum to 100% or entries for non-existent condition states on elements having fewer than 5. Only two such errors were found.

For do-nothing probabilities, engineers provided the median number of years for each state, so these were converted to transition probability matrices using the method described above. Since the questionnaire asked only about the Severe environment, the other two environments were calculated by applying an adjustment factor to the median year responses. The engineers provided some guidance on what factors to use.

The worksheet model calculated coefficients of variation for each question. The coefficient of variation is the population standard deviation of the responses divided by the mean value of the responses. This is zero if there is only one response, or if all the responses agree. The model flagged unusually high values for later review. An analysis of these results is provided later in this report.

For the do-something probabilities, the answers were averaged over the number of responses received for each question. A separate coefficient of variation was computed for each individual probability, then these were averaged to provide a summary number for the whole question. The do-something results were assumed to be the same across all environments.

5.3. Summary of FDOT Results

Since each engineer completed the questionnaire without consulting the others after the initial meeting, the coefficient of variation and response rate of each question is useful for assessing the reliability of responses. It was expected that response rates would be lower, and CVs larger, for elements that are less common in Florida. This proved to be the case.

Figure 5.4 summarizes the results by element category, for the Severe environment. The highest CV was for moveable bridge elements, as expected. The next highest was for decks. This may seem counter-intuitive, but in Florida, where deicing salts are not used, deck problems are relatively less common than in other states with harsher climates. Superstructure elements had a low response rate, due to a number of very uncommon elements in this category, such as cables and unpainted steel elements. In general, the do-something questions had similar response rates and lower CVs than the do-nothing responses.

		Do-Nothing		Do-Something		Median Years Out of State					
Category	Element Count	Average Coef of Variation	Response Rate	Average Coef of Variation	Response Rate	1	2	3	4	5	Median Time to Failure
Decks/Slabs	12	0.28	65%	0.22	72%	11.5	8.8	8.1	4.7	3.0	50
Superstructure	32	0.14	38%	0.09	42%	17.6	10.4	6.6	4.7	4.0	59
Substructure	31	0.22	58%	0.16	56%	18.7	9.2	6.7	4.7		52
Joints	6	0.29	71%	0.14	67%	7.4	5.0	2.8			21
Bearings	5	0.20	75%	0.14	74%	18.3	12.5	7.8			50
Railing	5	0.19	62%	0.09	59%	17.1	13.3	9.0	8.3		64
Movable	29	0.43	71%	0.23	68%	7.9	6.9	4.9	4.1		33
Other Elements	16	0.20	44%	0.10	37%	17.1	14.6	11.5	6.8		68
Total	136	0.25	55%	0.15	55%						

Figure 5.4. Summary of results by element category

The right-hand side of this table provides averages of responses given. These should be considered to be very rough, because elements differ in their condition state definitions and even in the number of defined states. Based on these averages, the final column gives the median time to failure, the number of years when the probability of failure reaches 50%. Note that this is not the same as the sum of the median transition times, but is instead the result of multiplication of the full derived transition probability matrix.

Figure 5.5 provides similar results, organized by material type. Unpainted steel and timber had low response rates, as these are uncommon on the state highway system. Moveable bridge elements again had the highest CVs. In both of these tables, it is apparent that joints and moveable bridge elements have the shortest lives, and concrete elements have the longest lives.

The coefficients of variation overall are somewhat lower than expected, indicating better-than-expected agreement among the four engineers. Figures 5.6 and 5.7 show the pattern of variation. A large number of questions had zero variation, especially for do-something probabilities. Many of these are cases where everyone agreed that replacement actions raise 100% of the element to state 1, or cases where minor maintenance actions leave the condition state unchanged. Only 10 questions had CVs greater than 1, where the standard deviation exceeded the mean.

Material	Element Count	Do-Nothing: Average Coef of Variation	Do-Nothing: Response Rate	Do-Something: Average Coef of Variation	Do-Something: Response Rate	Median Years Out of State: 1	2	3	4	5	Median Time to Failure
Unpainted Steel	17	0.08	18%	0.04	18%	17.6	11.9	8.2	5.2		58
Painted Steel	17	0.22	59%	0.12	57%	14.0	8.1	7.2	5.2	4.8	55
Prestressed Concrete	8	0.26	62%	0.14	58%	25.1	11.5	7.5	4.6		63
Reinforced Concrete	18	0.29	78%	0.24	78%	24.0	13.4	9.0	5.8		69
Timber	11	0.12	29%	0.08	28%	11.4	9.8	6.1	4.7		44
Other	24	0.20	48%	0.10	46%	12.6	10.5	6.9			40
Decks	7	0.32	70%	0.25	77%	12.6	9.0	7.4	4.0	2.9	50
Slabs	5	0.24	58%	0.17	65%	9.9	8.6	9.1	5.9	3.2	51
Electrical	9	0.54	72%	0.20	67%	8.7	6.3	4.2			26
Hydraulic	4	0.39	75%	0.30	73%	4.7	4.1	3.0	2.7		21
Mechanical	16	0.37	69%	0.23	68%	8.3	7.9	5.7	4.6		37
Total	136	0.25	55%	0.15	55%						

Figure 5.5. Summary of results by material type

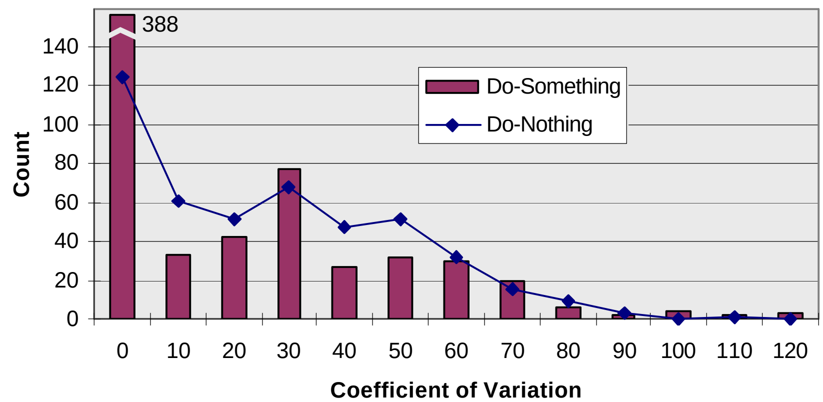

Figure 5.6. Number of questions having each level of C.V.

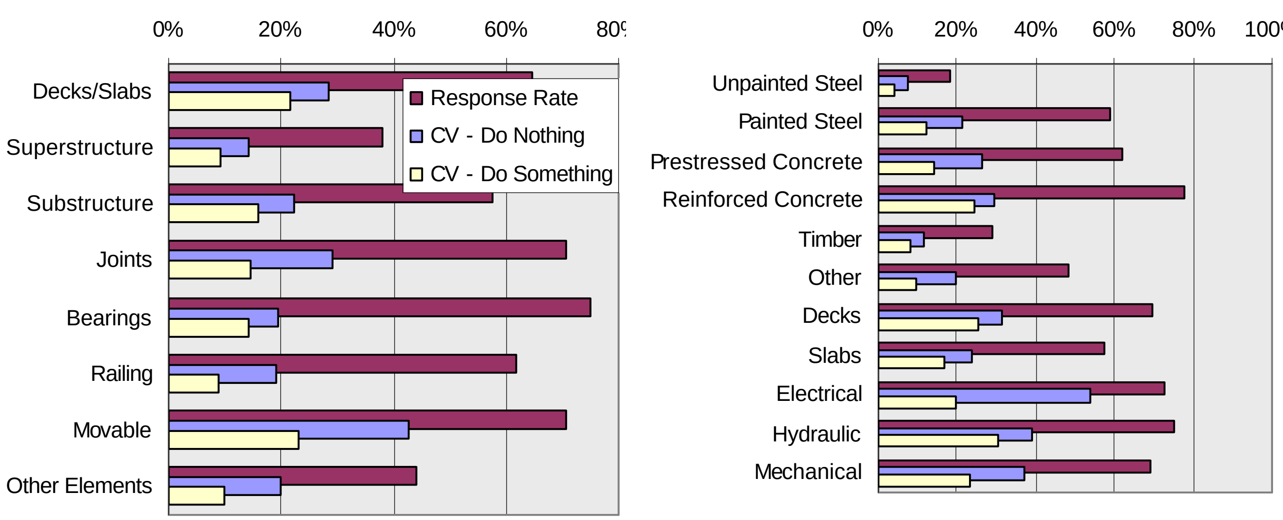

Figure 5.7. Coefficients of variation by category and material

Finally, Figure 5.8 shows how some of the category average results look when the resulting Markov models are extended over 100 years. The graph shows the probability that an element will be above the failed state each year. This is known as a survival probability curve. It is a useful way of graphing bridge condition because it is not affected by differences in condition state definitions among elements.

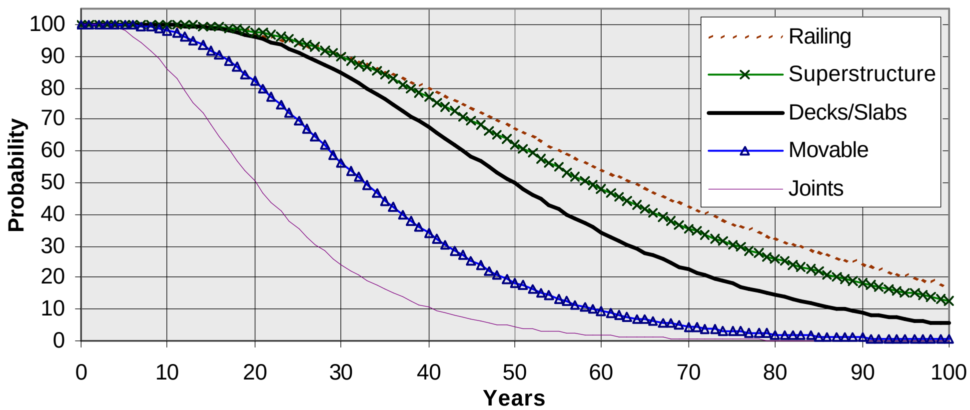

Figure 5.8. Typical survival probability curves

5.4. Importing the Results into a Pontis Database

The Deterioration Analysis Results workbook provided to FDOT includes two worksheets called actmodls and condumdl. These are named after the Pontis tables into which the data should be imported. Column headings on each worksheet match the Pontis columns that should hold the data. For compatibility with other parts of the FDOT Pontis database, these tables have all four environments. However, they include only the elements that are used in Florida. The condumdl table holds the failure probability (which applies only to do-nothing), while the actmodls table holds all the other probabilities by condition state and action.

To import these tables into Pontis, separate the worksheets into their own workbooks, then use InfoMaker's Pipeline feature to copy the data into the Pontis database. Other utilities such as those provided with Oracle can also accomplish this task. Normally these utilities require that an Excel ODBC driver be installed on the system.

6. Implementation Report

This section presents the implementation report as mandated by the FDOT Research Center Program Manual, to provide guidance and concrete steps to help the research results to be put into practice as broadly as possible. The following sections describe the implementation plan.

6.1. Technical Summary

The purpose of this research has been to analyze the Pontis agency cost model in the context of Florida DOT requirements, to locate data that can be used to customize the model for Florida purposes, to develop new agency unit costs to be made operational within FDOT's implementation of Pontis, and to develop a strategy for keeping these costs up-to-date over time.

All of these objectives have been met. Appendix A of this report presents the detailed results of the data analysis and the final unit costs that have been selected for input to Pontis.

All of the data analysis and tabulation of unit costs was performed on Microsoft Excel spreadsheets, using raw data extracted from FDOT's Pontis database, which is implemented in Oracle. Upon completion of the analysis, the results must be imported back into the Oracle database. In agreement with FDOT it was decided to provide the results to FDOT as an Excel worksheet, with appropriate primary keys for the Pontis actmodls table. FDOT will create an ODBC data source profile for the worksheet and then use InfoMaker's pipeline feature to transfer the unit costs into the Pontis database. This process minimizes the amount of work to be done by FDOT staff and satisfies the Department's data security requirements.

In considering the implementation of these research results, it is important to distinguish the Pontis network level analysis from the project-level analysis. A couple of examples will serve to illustrate the differences:

The handling of project indirect costs (mobilization, maintenance of traffic, project engineering, etc.) differs substantially between the network level and project level. Unit costs developed in this project include allowances for typical indirect costs in order to ensure that the network-level analysis produces correct total costs for comparison to budget constraints. Though accurate at the network level, these allowances may be highly inaccurate when interpreted at the project level. Therefore, a correct project-level analysis should consider indirect costs separately, and not necessarily disaggregated by elements.

The cost structure of certain activities is not apparent at the network level, particularly economies of scale. For example, the unit cost of paint system replacement is always lower than the unit cost of spot painting, so in the network optimization paint system replacement will always be selected when the two alternatives compete in the same condition state. However, at the project level on elements where paint system distress is not extensive, spot painting may well be the more cost-effective choice.

Loading the unit costs into Pontis as described above is all that is necessary to satisfy the network-level requirements of the system. However, Pontis does not have the ability to clearly evaluate the costs of project-level alternatives. In addition, as was noted in the earlier FDOT Pontis User Cost Study, Pontis does not have the flexibility to incorporate new user cost models to evaluate the project-level benefits of bridge functional improvements.

To enable the results of these two research projects to be implemented by FDOT at the project level, a separate task has been identified to develop an outside Project level analysis model. This model will extract its inputs from Pontis, perform an analysis of costs and benefits for an individual bridge using the new FDOT agency and user cost models, and present the alternatives and evaluation results to the decision-maker. The engineer decides on a course of action and indicates this in the new model. The engineer's decision may involve using the default Pontis recommendation derived from the network level, or may include project-specific changes to the scope, cost, and/or benefit of the project. The new model will automatically adjust costs and benefits to reflect changes in project scope or action selection.

To help the engineer in this decision-making process, the model will include a graphic presentation of current conditions and the effect of the planned activity on future conditions. The presentation of life cycle costs resulting from the work will be in a form that is familiar to professionals trained in traditional project level life cycle cost analysis. Because the model will be presented in Microsoft Excel, the engineer will be able to take advantage of spreadsheet formulas for the scoping of projects, estimating work quantities, and calculating indirect costs. These formulas can be as simple or elaborate as needed in order to be realistic for their intended purpose.

When the engineer has finished his manipulation of a project, he may elect to save the results into Pontis. This creates a user-defined project that can subsequently participate in the program simulation and results reports in Pontis.

The original vision for this study assumed that the wealth of historical project data in existing FDOT information systems would make it possible to automate the updating of unit costs in the future. This vision has changed substantially in light of the expert panel's review of the analysis results derived from these systems. It was found during this study that nearly all of the unit costs required a detailed review and substantial modification before they could be accepted for use in Pontis. Only 50 percent of the Pontis actions were covered with a statistically significant number of data points in any of the three information systems, and only 15 percent of the Pontis actions ended up using the results from one of the information systems directly. This does not reflect on the quality of the existing FDOT systems, since it was impossible to judge the quality of data collection and processing from this perspective. One of the biggest problems was the inability to match the scope of activities in MMS, Akbar, and DCP to Pontis elements, condition states, and actions.

In the long term, several enhancements to the existing FDOT systems could help to better identify bridge activities and match them to Pontis actions:

- Akbar and DCP could provide a bridge identifier for each activity. MMS already does so.

In order to accomplish this, it may be necessary to have a contractual requirement in each maintenance contract for recording of this information.

- All three systems could identify the bridge elements that were worked on, as well as other activities not related to bridge elements. This would not always be practical but would be very helpful even if done on a fraction of the work records.
- All three systems could use the Action Subcategory system developed within this project, as a simplified means of relating activity codes to Pontis actions.
- None of these enhancements would be easy to accomplish, though all would be possible if done as part of the design of major system enhancements or replacement systems in the future.

Even after these enhancements are performed, it is certain that an expert review of cost data will be required, using methods similar to those used under this study. If it is desired to institutionalize this process within FDOT, one possible approach is to establish a process within a Cost Estimating Office to maintain unit cost figures over time for all FDOT business processes that require this information. Such an office would provide data to the Districts and headquarters for preparation of engineer's estimates for construction projects, for updating of all asset management systems, for market analysis of the construction market, for forecasting inflation, and for ad hoc management analysis. The scope of this office would by no means be limited to bridges, but would encompass all aspects of the Department's mission for which cost data are useful.

Ontario's Ministry of Transportation has an Estimating Office that is a good example of this approach. A staff of five analysts collects data from the agency's information systems and contractor bids, and analyzes them in detail. They look for patterns of irregular or unbalanced bids as a part of the procurement process, as well as developing unit costs for future projects and for asset management systems. Regional project engineers rely heavily on this information for project design and estimating. An automatic linkage is under development to connect the tabulated data to the Ministry's new Bridge Management System. The office is supported by contracting policies that require all Ministry contractors to supply the data required for unit cost development.

In many ways the activities of the Ontario Estimating Office are similar to the processes undertaken in this Florida study. Analysts maintain various spreadsheet models that analyze the typical work activities within projects and perform various statistical analyses. The outputs are periodically reviewed by users of the data to ensure that they remain realistic for their intended purposes. Centralizing this expertise helps the Ministry to stay ahead of the bidding practices of the contractors, reduces the overall cost of collecting and managing these data, and increases their reliability.

Florida's current effort to satisfy the requirements of GASB Statement 34 regarding asset management may present a good opportunity to establish a capability similar to Ontario's within FDOT. If this is desired, it may be worthwhile to conduct an investigative study, including interviews with Ontario and several State DOTs that have experience with this process. Now that FDOT has excellent inventory and condition data collection processes in place for several types of assets, the accuracy of cost data would seem to be the next major concern in the GASB 34 implementation.

6.2. Technology Transfer Plan

A paper based on the final report of this study will be submitted to the Transportation Research Board by August 1, 2001 for publication and for presentation at the January 2002 Annual Meeting. No other major conferences related to bridge management are anticipated before that date, but a TRB specialty conference on bridge management may occur in 2003. There also is an opportunity to present a paper on this research at the First International Conference on Bridge Maintenance, Safety, and Management in Barcelona, Spain in July 2002.

Under subtask 6.2 of this study, a presentation was prepared, and has already been presented to FDOT staff on October 10, 2000.

Upon FDOT acceptance of the final report, it will be distributed electronically to all agencies that responded to the Task 1 survey. Respondents to the survey were asked to provide e-mail addresses for that purpose. If FDOT concurs, the researchers would also like to distribute the deliverable worksheet with final unit costs with the report. Other DOTs will then have a second authoritative source of agency cost data in addition to the Clemson study when they prepare their own Pontis models.

6.3. Implementation Test Plan

The agency cost model developed in this study is just one small part of FDOT’s overall effort to implement the Pontis bridge management system. Pontis is intended to support improved bridge program decision-making by presenting objective information on the costs and benefits of policy and project decisions.

Many of the most difficult Pontis implementation steps, such as the establishment of a client-server database and the institution of a new bridge inspection process, have already been accomplished by FDOT. A completely populated database is nearly complete, at which time the system may begin to enter production usage for decision support. An additional study, recently launched, will develop the tools needed for project-level implementation of the results.

An important feature of a bridge management system is the ability to estimate the costs and benefits of alternative bridge program decisions. Using this capability, it is possible to measure the benefits of the system by comparing its recommended decisions with those that might have been pursued without the aid of the system. Since Pontis measures only the economic benefits of bridge projects, the system does not consider non-economic factors such as political mandates. The actual programs implemented with the help of Pontis might therefore vary from those that the system would recommend on purely economic grounds. The agency cost model developed in this study is an important part of the system’s ability to measure the economic benefits of bridge investments.

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Appendix A. Detailed Rationale and Final Cost Results

101 - Replace deck

This activity is very uncommon in Florida, since deicing salt is not used. Bridge replacement due to traffic growth typically occurs long before the deck needs replacement. An initial decision to use the Clemson study results was later revised to use estimates based on expert judgment. FDOT tracking systems did not have sufficient data to estimate a unit cost.

Element	State	Action	Final Cost	
12 - Bare Concrete Deck Based on expert judgment	5 - Distress over 25%	2 - Replace deck	30	(SF)
13 - Unp Conc Deck/AC Ovl Based on expert judgment	5 - Distress over 25%	2 - Replace deck	31	(SF)
28 - Steel Deck/Open Grid Based on expert judgment	5 - Advanced corrosion	2 - Replace unit	35	(SF)
29 - Steel Deck/Conc Grid Based on expert judgment	5 - Advanced corrosion	2 - Replace unit	40	(SF)
31 - Timber Deck Based on expert judgment	3 - Some strength loss	2 - Replace deck	10	(SF)
31 - Timber Deck Based on expert judgment	4 - Major strength loss	1 - Replace deck	10	(SF)
32 - Timber Deck/AC Ovly Used Clemson data	3 - Some strength loss	2 - Replace deck & surfa	8	(SF)
32 - Timber Deck/AC Ovly Used Clemson data	4 - Major strength loss	1 - Replace deck & surfa	12	(SF)
38 - Bare Concrete Slab Based on expert judgment	5 - Distress over 25%	2 - Replace deck	30	(SF)
39 - Unp Conc Slab/AC Ovl Based on expert judgment	5 - Distress over 25%	2 - Replace deck	31	(SF)
54 - Timber Slab Used Clemson data	3 - Some strength loss	2 - Replace deck	1	(SF)
54 - Timber Slab Used Clemson data	4 - Major strength loss	1 - Replace deck	1	(SF)
55 - Timber Slab/AC Ovly Used Clemson data	3 - Some strength loss	2 - Replace deck and sur	3	(SF)
55 - Timber Slab/AC Ovly Used Clemson data	4 - Major strength loss	1 - Replace deck and sur	3	(SF)
98 - Conc Deck on PC Pane Based on expert judgment	5 - Distress over 25 %	2 - Replace Deck	30	(SF)
99 - PS Conc Slab Based on expert judgment	5 - Dist >25%	2 - Replace unit	31	(SF)

102 - Replace paint system

Relatively few data points were available in FDOT systems. For element #107, the expert panel had anecdotal evidence of $170/m, which translates to $52 per foot. This is consistent with the DCP average of $4.74 per square foot, assuming that this applies to typical steel I-beams. With relatively little experience repainting other steel elements, it was decided to scale all CoRe elements from #107 according to the Clemson unit costs. Non-Core elements were determined from expert judgment.

Element	State	Action	Final Cost
102 - Paint Stl Box Girder	4 - Active corrosion	2 - Replace paint system	2800 (LF)
Scaled relative to #107 based on Clemson data			
107 - Paint Stl Opn Girder	4 - Active corrosion	2 - Replace paint system	52 (LF)
Based on anecdotal project evidence and checked against DCP data			
113 - Paint Stl Stringer	4 - Active corrosion	2 - Replace paint system	33 (LF)
Scaled relative to #107 based on Clemson data			
121 - P/Stl Thru Truss/Bot	4 - Active corrosion	2 - Replace paint system	118 (LF)
Scaled relative to #107 based on Clemson data			
126 - P/Stl Thru Truss/Top	4 - Active corrosion	2 - Replace paint system	150 (LF)
Scaled relative to #107 based on Clemson data			
131 - Paint Stl Deck Truss	4 - Active corrosion	2 - Replace paint system	700 (LF)
Scaled relative to #107 based on Clemson data			
141 - Paint Stl Arch	4 - Active corrosion	2 - Replace paint system	420 (LF)
Scaled relative to #107 based on Clemson data			
152 - Paint Stl Floor Beam	4 - Active corrosion	2 - Replace paint system	54 (LF)
Scaled relative to #107 based on Clemson data			
161 - Paint Stl Pin/Hanger	4 - Active corrosion	2 - Replace paint system	708 (EA)
Scaled relative to #107 based on Clemson data			
202 - Paint Stl Column	4 - Active corrosion	2 - Replace paint system	250 (EA)
Scaled relative to #107 based on Clemson data			
231 - Paint Stl Cap	4 - Active corrosion	2 - Replace paint system	58 (LF)
Scaled relative to #107 based on Clemson data			
487 - Sign Member Horiz	4 - Surf Pits	2 - Replace paint system	52 (LF)
Non-CoRe element, based on judgment			
488 - Sign Member Vertical	4 - Surf Pits	2 - Repaint	52 (LF)
Non-CoRe element, based on judgment			
496 - Painted High Mast L.	4 - Surf Pits	2 - Repaint	5000 (EA)
Non-CoRe element, based on judgment			
497 - Galvan. High Mast L.	4 - Surf Pits	2 - Repaint	5000 (EA)
Non-CoRe element, based on judgment			
550 - Hopkins Frame	4 - Surf Pits	2 - Repaint	5000 (EA)
Non-CoRe element, based on judgment			
562 - Counterweight Suppor	4 - Surf Pits	2 - Repaint	5000 (EA)
Non-CoRe element, based on judgment			
563 - Acc Ladd & Plat	4 - Surf Pits	2 - Repaint	2500 (EA)
Non-CoRe element, based on judgment			

111 - Replace joint

Although project data were available in MMS, the unit costs were found to be unreasonably low (average $12.54/lf). The reason for this has not yet been determined, but may be due to omission of important cost factors in the recorded data. As a result, the expert panel decided to use Clemson data with certain adjustments based on Florida experience.

Element	State	Action	Final Cost
300 - Strip Seal Exp Joint	3 - Major leakage	2 - Replace joint	122 (LF)
Akbar data indicates specific element average of $85/lf. Estimated based on Clemson data but adjusted downward based on experience			
302 - Compressn Joint Seal	3 - Major deterioration	2 - Replace joint	152 (LF)
Akbar data indicates specific element average of $42/lf. Estimated based on Clemson data but adjusted downward based on experience			
303 - Assembly Joint/Seal	3 - Advanced corrosion	2 - Replace unit	420 (LF)
Used Akbar data			
304 - Open Expansion Joint	3 - Advanced corrosion	2 - Replace unit	304 (LF)
Used Clemson data			
399 - Other Expansion Join	3 - Maj Deter	2 - Replace unit	304 (LF)
Assumed to be the same as element #304			

112 - Replace joint seal

All three of FDOT's tracking systems contained relevant data, as did the Clemson data set. However, in most cases none of the data sources were in agreement. In each case the expert panel chose one of the data sources based on judgment.

Element	State	Action	Final Cost
300 - Strip Seal Exp Joint	3 - Major leakage	1 - Replace gland and pa	50 (LF)

MMS, Akbar, and DCP had relevant data ($88/lf, 85/lf, and $1400/lf respectively) but were judged to be too high. The panel decided to use the Clemson result.

Element	State	Action	Final Cost
301 - Pourable Joint Seal	2 - Minor leakage	1 - Clean joint and repl	26 (LF)

MMS contained relevant data, but it was judged to be too low, due to omission of important cost factors. The panel decided to use the Clemson result.

Element	State	Action	Final Cost
302 - Compressn Joint Seal	3 - Major deterioration	1 - Replace gland and/or	46 (LF)

Relevant data were found in MMS ($31/lf), Akbar ($42/lf), DCP ($55/lf), and Clemson ($76/lf). The panel felt that the true unit cost should be somewhat higher than the Akbar number, and so $46/lf was chosen.

113 - Replace bearing

Of the FDOT data sources, only MMS had data on bearing replacement, but there were only four data points. The panel decided to analyze these elements based on typical crew sizes and costs.

Element	State	Action	Final Cost
161 - Paint Stl Pin/Hanger	5 - Section loss	2 - Replace unit	100000 (EA)
This has not been done in Florida. The cost was estimated by judgment based on characteristics of the few Florida bridges having this element (difficult sites and access).			
310 - Elastomeric Bearing	3 - Major deterioration	2 - Replace unit and res	527 (EA)
Based on an analysis of typical crew sizes and costs			
311 - Moveable Bearing	3 - Advanced corrosion	2 - Replace unit	527 (EA)
Based on an analysis of typical crew sizes and costs			
312 - Enclosed Bearing	3 - Bearing failures	2 - Replace unit	527 (EA)
Based on an analysis of typical crew sizes and costs			
313 - Fixed Bearing	3 - Advanced corrosion	2 - Replace unit	527 (EA)
Based on an analysis of typical crew sizes and costs			
314 - Pot Bearing	3 - Advanced corrosion	2 - Replace unit	1800 (EA)
No experience in Florida, so Clemson data were used			

114 - Replace railing

Although all three FDOT systems had relevant data, many of the data points were strongly skewed by project-specific factors. When obvious outliers were excluded, all three systems yielded unit costs that were unrealistically low. The expert panel found none of the system-derived unit costs to be suitable for planning purposes. On the other hand, the panel found the Clemson unit costs to be too high. The final unit costs were based on anecdotal project experience and the panel's analysis of typical crew sizes and costs.

Element	State	Action	Final Cost
330 - Metal Rail Uncoated	3 - Active corrosion	2 - Replace unit	70 (LF)
Akbar and DCP data indicate specific element averages of $33/lf and $39/lf respectively. Estimated based on an analysis of typical crew sizes and costs			
330 - Metal Rail Uncoated	4 - Section loss	2 - Replace unit	70 (LF)
Based on an analysis of typical crew sizes and costs			
331 - Conc Bridge Railing	4 - Analysis warranted	2 - Replace unit	50 (LF)
Relevant data were found in MMS ($19/lf), Akbar ($54/lf), DCP ($190/lf). Estimated based on an analysis of typical crew sizes and costs.			
332 - Timb Bridge Railing	3 - Some strength loss	1 - Replace unit	33.5 (LF)
Relevant data were found in MMS ($19/lf) and Akbar ($29/lf). Estimated based on an analysis of typical crew sizes and costs.			
333 - Other Bridge Railing	3 - Major deterioration	2 - Replace unit	60 (LF)
Relevant data were found in MMS ($19/lf), Akbar ($70/lf), DCP ($18/lf). Estimated based on an analysis of typical crew sizes and costs.			
334 - Metal Rail Coated	4 - Active corrosion	2 - Replace unit	70 (LF)
Relevant data were found in MMS ($19/lf) and Akbar ($33/lf). Estimated based on an analysis of typical crew sizes and costs.			
334 - Metal Rail Coated	5 - Analysis warranted	2 - Replace unit	70 (LF)
Based on an analysis of typical crew sizes and costs			

121 - Replace slope protection

The districts have been using $4.18 per sq. ft. ($45/sm) for project estimation. DCP shows a unit cost more than twice as large, but this is believed to be due to inclusion of non-bridge maintenance work. The panel decided that all slope paving materials should have the same unit cost.

Element	State	Action	Final Cost
394 - R/Conc Abut Slope Pr Used DCP data.	4 - Adv Corros	2 - Replace unit	8 (SF)
395 - Timber Abut Slope Pr Used DCP data.	3 - Minor Loss	2 - Replace unit	10 (SF)
395 - Timber Abut Slope Pr Used DCP data.	4 - Adv Deter	2 - Replace unit	10 (SF)
396 - Other Abut Slope Pro Used DCP data.	3 - Mod Deter	2 - Replace unit	7 (SF)
396 - Other Abut Slope Pro Used DCP data.	4 - Maj Deter	2 - Replace unit	7 (SF)

123 - Replace drainage system

These costs were based on an analysis of typical crew sizes and costs.

Element	State	Action	Final Cost
397 - Drain. Syst Metal	5 - Sect Loss	2 - Replace unit	820 (EA)
DCP data indicate $600/ea. Panel estimated based on an analysis of typical crew sizes and costs			
398 - Drain. Syst Other	4 - Maj Deter	2 - Replace unit	820 (EA)
Based on an analysis of typical crew sizes and costs			

131 - Replace machinery

Survey

Element	State	Action	Final Cost
540 - Open Gearing	3 - Mod Deter	2 - Replace unit	28500 (EA)
Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. One open gearing cost of $429,000. Survey used.			
540 - Open Gearing	4 - Maj Deter	1 - Replace unit	28500 (EA)
Survey used.			
541 - Speed Reducers	3 - Mod Deter	2 - Replace unit	39000 (EA)
Survey used.			
541 - Speed Reducers	4 - Maj Deter	1 - Replace unit	39000 (EA)
Survey used.			
542 - Shafts	3 - Mod Deter	2 - Replace unit	2900 (EA)
Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. Survey used.			
542 - Shafts	4 - Maj Deter	1 - Replace unit	2900 (EA)
Survey used.			
543 - Shaft Brgs and Coupl	3 - Mod Deter	2 - Replace unit	750 (EA)
Survey used.			
543 - Shaft Brgs and Coupl	4 - Maj Deter	1 - Replace unit	750 (EA)
Survey used.			
544 - Brakes	3 - Mod Deter	2 - Replace unit	980 (EA)
Survey used.			
544 - Brakes	4 - Maj Deter	2 - Replace unit	980 (EA)
Survey used.			
545 - Emergency Drive	3 - Mod Deter	2 - Replace System	4500 (EA)
Survey used.			
545 - Emergency Drive	4 - Maj Deter	1 - Replace System	4500 (EA)
Survey used.			
546 - Span Drive Motors	3 - Mod Deter	2 - Replace unit	6700 (EA)
Survey used.			
546 - Span Drive Motors	4 - Maj Deter	1 - Replace unit	6700 (EA)
Survey used.			
547 - Hydraulic Power Unit	3 - Mod Deter	2 - Replace unit	41500 (EA)
Survey used.			
547 - Hydraulic Power Unit	4 - Maj Deter	1 - Replace unit	41500 (EA)
Survey used.			
548 - Hydraulic Piping Sys	3 - Maj Deter	2 - Replace unit	3200 (EA)
Survey used.			
549 - Hydraulic Cylinders	3 - Mod Deter	2 - Replace unit	9000 (EA)
Survey used.			
549 - Hydraulic Cylinders	4 - Maj Deter	1 - Replace unit	9000 (EA)
Survey used.			
550 - Hopkins Frame	5 - Sect Loss	2 - Replace unit	35000 (EA)
Survey used.			
560 - Locks	3 - Mod Deter	2 - Replace unit	2800 (EA)
Survey used.			
560 - Locks	4 - Maj Deter	1 - Replace unit	2800 (EA)
Survey used.			
561 - Live Load Shoes	3 - Maj Deter	2 - Replace unit	7000 (EA)
Survey used.			
562 - Counterweight Suppor	5 - Sect Loss	2 - Replace unit	3000 (EA)
Survey used.			
563 - Acc Ladd & Plat	5 - Sect Loss	2 - Replace unit	2900 (EA)

Survey used.

564 - Counterweight	4 - Adv Corros	2 - Replace unit	9000 (EA)

Survey used.

565 - Trun/Str and Cur Trk	3 - Mod Deter	2 - Replace unit	9000 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. Akbar data shows a specific element average of $121,000/ea for Trunnion. Survey used.

565 - Trun/Str and Cur Trk	4 - Maj Deter	1 - Replace unit	9000 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. Akbar data shows a specific element average of $121,000/ea for Trunnion. Survey used.

570 - Transformers	3 - Maj Deter	2 - Replace unit	1500 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. DCP data shows a specific element average of $1,800/ea. Survey used.

571 - Submarine Cable	3 - Maj Deter	2 - Replace unit	10800 each

Survey

572 - Conduit & Junc. Box	3 - Maj Deter	2 - Replace unit	600 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. DCP data shows a specific element average of $160/ea. and one cost of $3700. Survey used.

573 - PLCs	3 - Maj Deter	2 - Replace unit	40400 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. Akbar data shows a specific element average of $28,000/ea. Survey used.

574 - Control Console	3 - Maj Deter	2 - Replace unit	30900 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. Akbar data shows a specific element average of $94,000/ea. Survey used.

580 - Navigational Lights	3 - Maj Deter	2 - Replace unit	1000 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. Akbar and DCP data show specific element averages of $32,000/ea. and $5,800/ea. respectively. Survey used.

581 - Operator Facilities	2 - Mod Deter	2 - Replace unit	28000 (EA)

Akbar and DCP data indicate action subcategory averages of $41,000/ea, and $160/ea respectively. Survey used.

581 - Operator Facilities	3 - Maj Deter	2 - Replace unit	28000 (EA)

Survey used.

582 - Lift Bridge Spec. Eq	3 - Maj Deter	2 - Replace unit	50000 (EA)

Survey used.

583 - Swing Bridge Spec. E	3 - Maj Deter	2 - Replace unit	50000 (EA)

Survey used.

590 - Resistance Barriers	3 - Maj Deter	2 - Replace unit	800 (EA)

Survey used.

591 - Warning Gates	3 - Maj Deter	2 - Replace unit	7000 (EA)

Survey used.

592 - Traffic Signals	3 - Maj Deter	2 - Replace unit	5200 (EA)

Survey used.

141 - Replace beam

FDOT has no usable data sources for these uncommon actions, so all results were based on the expert panel's discussion of anecdotal project evidence and judgment. All of these costs are highly dependent on historical FDOT construction practice. For example, replacement of prestressed box girders has a very high cost because in Florida nearly all of these bridges are single unit boxes. In general the panel found that none of the Clemson numbers were suitable for use in Florida for these actions.

Element	State	Action	Final Cost
106 - Unpnt Stl Opn Girder	4 - Major section loss	2 - Replace unit	900 (LF)
Based on anecdotal project evidence and judgment			
107 - Paint Stl Opn Girder	5 - Section loss	2 - Replace unit	900 (LF)
Based on anecdotal project evidence and judgment			
109 - P/S Conc Open Girder	4 - Analysis warranted	2 - Replace unit	370 (LF)
Based on anecdotal project evidence and judgment			
110 - R/Conc Open Girder	4 - Analysis warranted	2 - Replace unit	370 (LF)
Based on anecdotal project evidence and judgment			
111 - Timber Open Girder	3 - Some strength loss	2 - Replace unit	150 (LF)
Based on anecdotal project evidence and judgment			
111 - Timber Open Girder	4 - Major strength loss	2 - Replace unit	150 (LF)
Based on anecdotal project evidence and judgment			
112 - Unpnt Stl Stringer	4 - Major section loss	2 - Replace unit	210 (LF)
Based on anecdotal project evidence and judgment			
113 - Paint Stl Stringer	5 - Section loss	2 - Replace unit	210 (LF)
Based on anecdotal project evidence and judgment			
116 - R/Conc Stringer	4 - Analysis warranted	2 - Replace unit	270 (LF)
Based on anecdotal project evidence and judgment			
117 - Timber Stringer	3 - Some strength loss	2 - Replace unit	114 (LF)
Based on anecdotal project evidence and judgment			
117 - Timber Stringer	4 - Major strength loss	2 - Replace unit	114 (LF)
Based on anecdotal project evidence and judgment			
151 - Unpnt Stl Floor Beam	4 - Major section loss	2 - Replace unit	460 (LF)
Based on anecdotal project evidence and judgment			
152 - Paint Stl Floor Beam	5 - Section loss	2 - Replace unit	460 (LF)
Based on anecdotal project evidence and judgment			
155 - R/Conc Floor Beam	4 - Analysis warranted	2 - Replace unit	270 (LF)
Based on anecdotal project evidence and judgment			
156 - Timber Floor Beam	3 - Some strength loss	2 - Replace unit	114 (LF)
Based on anecdotal project evidence and judgment			
156 - Timber Floor Beam	4 - Major strength loss	2 - Replace unit	114 (LF)
Based on anecdotal project evidence and judgment			
230 - Unpnt Stl Cap	4 - Major section loss	2 - Replace unit	460 (LF)
Based on anecdotal project evidence and judgment			
231 - Paint Stl Cap	5 - Section loss	2 - Replace unit	460 (LF)
Based on anecdotal project evidence and judgment			
233 - P/S Conc Cap	4 - Analysis warranted	2 - Replace unit	460 (LF)
Based on anecdotal project evidence and judgment			
234 - R/Conc Cap	4 - Analysis warranted	2 - Replace unit	460 (LF)
Based on anecdotal project evidence and judgment			
235 - Timber Cap	3 - Some strength loss	2 - Replace unit	150 (LF)
Based on anecdotal project evidence and judgment			
235 - Timber Cap	4 - Major strength loss	2 - Replace unit	150 (LF)
Based on anecdotal project evidence and judgment			

142 - Replace truss/arch

FDOT has no usable data sources for these uncommon actions. Since FDOT has not replaced any trusses or arches, the panel decided to use the Clemson numbers in most cases.

Element	State	Action	Final Cost
101 - Unpnt Stl Box Girder	4 - Major section loss	2 - Replace unit	1500 (LF)
Based on anecdotal project evidence and judgment			
102 - Paint Stl Box Girder	5 - Section loss	2 - Replace unit	1500 (LF)
Based on anecdotal project evidence and judgment			
104 - P/S Conc Box Girder	4 - Analysis warranted	2 - Replace unit	3000 (LF)
Based on anecdotal project evidence and judgment			
105 - R/Conc Box Girder	4 - Analysis warranted	2 - Replace unit	610 (LF)
Based on anecdotal project evidence and judgment			
120 - U/Stl Thru Truss/Bot	4 - Major section loss	2 - Replace unit	800 (LF)
Clemson results			
121 - P/Stl Thru Truss/Bot	5 - Section loss	2 - Replace unit	800 (LF)
Clemson results			
125 - U/Stl Thru Truss/Top	4 - Major section loss	2 - Replace unit	900 (LF)
Clemson results			
126 - P/Stl Thru Truss/Top	5 - Section loss	2 - Replace unit	950 (LF)
Clemson results			
131 - Paint Stl Deck Truss	5 - Section loss	2 - Replace unit	900 (LF)
Clemson results			
135 - Timber Truss/Arch	3 - Some strength loss	2 - Replace unit	700 (LF)
Clemson results			
135 - Timber Truss/Arch	4 - Major strength loss	2 - Replace unit	800 (LF)
Clemson results			
140 - Unpnt Stl Arch	4 - Major section loss	2 - Replace unit	900 (LF)
Clemson results			
141 - Paint Stl Arch	5 - Section loss	2 - Replace unit	900 (LF)
Clemson results			
143 - P/S Conc Arch	4 - Analysis warranted	2 - Replace unit	175 (LF)
Clemson results			
144 - R/Conc Arch	4 - Analysis warranted	2 - Replace unit	1700 (LF)
Clemson results			

143 - Replace cable

These results were based on the panel's discussion of anecdotal project experience since there were no relevant data points in any of the automated systems.

Element	State	Action	Final Cost
146 - Misc Cable Uncoated Anecdotal project evidence	4 - Analysis warranted	2 - Replace unit	160000 (EA)
147 - Misc Cable Coated Anecdotal project evidence	4 - Active corrosion	2 - Replace unit	160000 (EA)
147 - Misc Cable Coated Anecdotal project evidence	5 - Analysis warranted	2 - Replace unit	160000 (EA)

144 - Replace substructure element

Although MMS has project data, the costs are all expressed in units of man-hours, so they are not directly usable for planning. Most of the actions in this group were extremely uncommon, with the exception of timber pile and pile jacket replacement. Costs were based on anecdotal project experience and expert judgment.

Element	State	Action	Final Cost
201 - Unpnt Stl Column	4 - Major section loss	2 - Replace unit	20000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
202 - Paint Stl Column	5 - Section loss	2 - Replace unit	20000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
204 - P/S Conc Column	4 - Analysis warranted	2 - Replace unit	20000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
205 - R/Conc Column	4 - Analysis warranted	2 - Replace unit	20000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
206 - Timber Column	3 - Some strength loss	2 - Replace unit	1000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
206 - Timber Column	4 - Major strength loss	2 - Replace unit	1000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
207 - P/S Conc Holl Pile	4 - Adv Corros	2 - Replace unit	20000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
210 - R/Conc Pier Wall	4 - Analysis warranted	2 - Replace unit	3000 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment			
211 - Other Mtl Pier Wall	4 - Major deterioration	2 - Replace unit	3000 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment			
215 - R/Conc Abutment	4 - Analysis warranted	2 - Replace unit	820 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment			
216 - Timber Abutment	3 - Some strength loss	2 - Replace unit	620 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment			
216 - Timber Abutment	4 - Major strength loss	2 - Replace unit	620 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment			
217 - Other Mtl Abutment	4 - Major deterioration	2 - Replace unit	820 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment			
220 - R/C Sub Pile Cap/Ftg	4 - Analysis warranted	2 - Replace unit	100000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
298 - Pile Jacket Bare	4 - Maj Deter	2 - Replace unit	500 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
299 - Pile Jacket/Cath Pro	4 - Maj Deter	2 - Replace unit	1000 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
386 - Fender/Dolphin Uncoa	4 - Adv Corros	2 - Replace unit	240 (LF)

Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

387 - P/S Fender/Dolphin 4 - Adv Corros 2 - Replace unit 240 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

388 - R/Conc Fender/Dolphi 4 - Adv Corros 2 - Replace unit 240 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

389 - Timber Fender/Dolphi 4 - Adv Deter 2 - Replace unit 240 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

390 - Other Fender/Dolphin 3 - Mod Deter 2 - Replace unit 240 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

390 - Other Fender/Dolphin 4 - Maj Deter 2 - Replace unit 240 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

393 - Blkhd Sewl Metal Unc 4 - Adv Corros 2 - Replace unit 9.3 (SF)
Based on anecdotal project evidence and judgment

474 - Walls Uncoated 4 - Adv Corros 2 - Replace unit 61 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

475 - R/Conc Walls 4 - Adv Deter 2 - Replace unit 610 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

476 - Timber Walls 3 - Minor Loss 2 - Replace unit 305 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

476 - Timber Walls 4 - Adv Deter 2 - Replace unit 305 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

477 - Other Walls 4 - Maj Deter 2 - Replace unit 610 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

478 - MSE Walls 4 - Maj Deter 2 - Replace unit 366 (LF)
Akbar data average for action subcategory ($132/lf) too low. Panel estimated based on anecdotal project evidence and judgment

489 - Sign Foundation 4 - Adv Corros 2 - Replace unit 460 (EA)
DCP data average for action subcategory ($300/ea) too low. Panel estimated based on anecdotal project evidence and judgment

145 - Replace culvert

Since FDOT has no automated data on these uncommon actions, the panel decided to use Clemson data.

Element	State	Action	Final Cost	
240 - Metal Culvert Clemson results	4 - Major corrosion	2 - Replace unit	780	(LF)
241 - Concrete Culvert Clemson results	4 - Major deterioration	2 - Replace unit	720	(LF)
243 - Misc Culvert Clemson results	4 - Major deterioration	2 - Replace unit	2700	(LF)

146 - Replace approach slab

The Akbar average cost was found to be reasonable for all types of approach slabs.

Element	State	Action	Final Cost
320 - P/S Conc Appr Slab Akbar results	3 - Major cracks/spalls	2 - Replace unit	13000 (EA)
320 - P/S Conc Appr Slab Akbar results	4 - Broken/Unstable	1 - Replace unit	13000 (EA)
321 - R/Conc Approach Slab Akbar results	3 - Major cracks/spalls	2 - Replace unit	13000 (EA)
321 - R/Conc Approach Slab Akbar results	4 - Broken/Unstable	1 - Replace unit	13000 (EA)

151 - Replace pole/sign

Although DCP has relevant data, the numbers are far too small for planning purposes. The final numbers were chosen based on anecdotal project experience and expert judgment.

Element	State	Action	Final Cost
487 - Sign Member Horiz	5 - Sect Loss	2 - Replace unit	210 (LF)
Based on anecdotal project evidence and judgment			
488 - Sign Member Vertical	5 - Sect Loss	2 - Replace unit	210 (LF)
Based on anecdotal project evidence and judgment			
495 - Uncoat High Mast L.	4 - Adv Corros	2 - Replace unit	10000 (EA)
DCP data average for action subcategory ($740/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
496 - Painted High Mast L.	5 - Sect Loss	2 - Replace unit	10000 (EA)
DCP data average for action subcategory ($740/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
497 - Galvan. High Mast L.	5 - Sect Loss	2 - Replace unit	10000 (EA)
DCP data average for action subcategory ($740/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
498 - Other High Mast L.P.	4 - Maj Deter	2 - Replace unit	10000 (EA)
DCP data average for action subcategory ($740/ea) too low. Panel estimated based on anecdotal project evidence and judgment			
499 - H. M. L. P. Found.	4 - Adv Corros	2 - Replace unit	2000 (EA)
DCP data average for action subcategory ($740/ea) too low. Panel estimated based on anecdotal project evidence and judgment			

201 - Rehab deck/replace overlay

The MMS unit costs were found to be reasonable.

Element	State	Action	Final Cost
13 - Unp Conc Deck/AC Ovl MMS results	3 - 2 to 10% distress	2 - Replac substrate and	37.8 (SF)
13 - Unp Conc Deck/AC Ovl MMS results	4 - 10-25% distress	2 - Repair substrate and	37.8 (SF)
13 - Unp Conc Deck/AC Ovl MMS results	5 - Distress over 25%	1 - Repair substrate and	37.8 (SF)
39 - Unp Conc Slab/AC Ovl MMS results	3 - 2-10% distress	2 - Repair substrate & r	37.8 (SF)
39 - Unp Conc Slab/AC Ovl MMS results	4 - 10-25% distress	2 - Repair substrate and	37.8 (SF)
39 - Unp Conc Slab/AC Ovl MMS results	5 - Distress over 25%	1 - Repair substrate and	37.8 (SF)
98 - Conc Deck on PC Pane MMS results	1 - No Damage	1 - Protective Coating	37.8 (SF)
320 - P/S Conc Appr Slab MMS results	2 - Minor cracks/spalls	2 - Seal Cracks	37.8 (EA)
320 - P/S Conc Appr Slab MMS results	3 - Major cracks/spalls	1 - Place overlay	37.8 (EA)
321 - R/Conc Approach Slab MMS results	2 - Cracks/spalls	2 - Seal Cracks	37.8 (EA)
321 - R/Conc Approach Slab MMS results	3 - Major cracks/spalls	1 - Place overlay	37.8 (EA)

202 - Rehab steel

There were too few data points in the tracking systems for meaningful analysis of costs by element. The panel decided to develop prices based on a discussion of typical crew sizes and costs. These numbers were significantly higher than the Clemson results.

Element	State	Action	Final Cost
28 - Steel Deck/Open Grid	3 - Rust formation	2 - Rehab connectors	9 (SF)
Based on an analysis of typical crew sizes and costs			
28 - Steel Deck/Open Grid	4 - Moderate corrosion	2 - Rehab connectors	15 (SF)
Based on an analysis of typical crew sizes and costs			
28 - Steel Deck/Open Grid	5 - Advanced corrosion	1 - Rehab connectors+rep	20 (SF)
Based on an analysis of typical crew sizes and costs			
29 - Steel Deck/Conc Grid	3 - Rust formation	2 - Rehab connectors+con	10.8 (SF)
Based on an analysis of typical crew sizes and costs			
29 - Steel Deck/Conc Grid	4 - Failed connectors	2 - Rehab connectors+con	18 (SF)
Based on an analysis of typical crew sizes and costs			
29 - Steel Deck/Conc Grid	5 - Advanced corrosion	1 - Rehab connectors+con	24 (SF)
Based on an analysis of typical crew sizes and costs			
101 - Unpnt Stl Box Girder	4 - Major section loss	1 - Rehab unit	20000 (LF)
Based on an analysis of typical crew sizes and costs			
102 - Paint Stl Box Girder	5 - Section loss	1 - Major rehab unit	20000 (LF)
Based on an analysis of typical crew sizes and costs			
106 - Unpnt Stl Opn Girder	4 - Major section loss	1 - Rehab unit	6000 (LF)
Based on an analysis of typical crew sizes and costs			
107 - Paint Stl Opn Girder	5 - Section loss	1 - Major rehab unit	6000 (LF)
Based on an analysis of typical crew sizes and costs			
112 - Unpnt Stl Stringer	4 - Major section loss	1 - Rehab unit	4000 (LF)
Based on an analysis of typical crew sizes and costs			
113 - Paint Stl Stringer	5 - Section loss	1 - Major rehab unit	4000 (LF)
Based on an analysis of typical crew sizes and costs			
120 - U/Stl Thru Truss/Bot	4 - Major section loss	1 - Rehab unit	30000 (LF)
Based on an analysis of typical crew sizes and costs. (Florida has fewer but larger trusses than most states.)			
121 - P/Stl Thru Truss/Bot	5 - Section loss	1 - Major rehab unit	30000 (LF)
Based on an analysis of typical crew sizes and costs. (Florida has fewer but larger trusses than most states.)			
125 - U/Stl Thru Truss/Top	4 - Major section loss	1 - Rehab unit	30000 (LF)
Based on an analysis of typical crew sizes and costs. (Florida has fewer but larger trusses than most states.)			
126 - P/Stl Thru Truss/Top	5 - Section loss	1 - Major rehab unit	30000 (LF)
Based on an analysis of typical crew sizes and costs. (Florida has fewer but larger trusses than most states.)			
131 - Paint Stl Deck Truss	5 - Section loss	1 - Major rehab unit	25000 (LF)
Based on an analysis of typical crew sizes and costs. (Florida has fewer but larger trusses than most states.)			
140 - Unpnt Stl Arch	4 - Major section loss	1 - Rehab unit	25000 (LF)
Based on an analysis of typical crew sizes and costs			
141 - Paint Stl Arch	5 - Section loss	1 - Major rehab unit	25000 (LF)
Based on an analysis of typical crew sizes and costs			
151 - Unpnt Stl Floor Beam	4 - Major section loss	1 - Rehab unit	4000 (LF)
Based on an analysis of typical crew sizes and costs			
152 - Paint Stl Floor Beam	5 - Section loss	1 - Major rehab unit	4000 (LF)
Based on an analysis of typical crew sizes and costs			
161 - Paint Stl Pin/Hanger	5 - Section loss	1 - Major rehab unit	75000 (EA)

DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.

201 - Unpnt Stl Column	4 - Major section loss	1 - Rehab unit	1000 (EA)
DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.			
202 - Paint Stl Column	5 - Section loss	1 - Major rehab unit	1000 (EA)
Based on an analysis of typical crew sizes and costs			
230 - Unpnt Stl Cap	4 - Major section loss	1 - Rehab unit	1000 (LF)
Based on an analysis of typical crew sizes and costs			
231 - Paint Stl Cap	5 - Section loss	1 - Major rehab unit	1000 (LF)
Based on an analysis of typical crew sizes and costs			
240 - Metal Culvert	2 - Minor corrosion	1 - Rehab unit	1500 (LF)
Based on an analysis of typical crew sizes and costs			
240 - Metal Culvert	3 - Moderate corrosion	1 - Rehab unit	1500 (LF)
Based on an analysis of typical crew sizes and costs			
240 - Metal Culvert	4 - Major corrosion	1 - Rehab unit	1500 (LF)
Based on an analysis of typical crew sizes and costs			
298 - Pile Jacket Bare	4 - Maj Deter	1 - Rehabilitate unit	200 (EA)
DCP data average for action subcategory ($980/ea) too high. Panel estimated based on an analysis of typical crew sizes and costs.			
299 - Pile Jacket/Cath Pro	4 - Maj Deter	1 - Rehabilitate unit	200 (EA)
DCP data average for action subcategory ($980/ea) too high. Panel estimated based on an analysis of typical crew sizes and costs.			
330 - Metal Rail Uncoated	4 - Section loss	1 - Rehab unit	129 (LF)
Based on an analysis of typical crew sizes and costs			
334 - Metal Rail Coated	4 - Active corrosion	1 - Rehab unit	129 (LF)
Based on an analysis of typical crew sizes and costs			
334 - Metal Rail Coated	5 - Analysis warranted	1 - Rehab unit	129 (LF)
Based on an analysis of typical crew sizes and costs			
386 - Fender/Dolphin Uncoa	4 - Adv Corros	1 - Rehabilitate unit	144 (LF)
The expert panel set this at 60% of replacement cost.			
393 - Blkhd Sewl Metal Unc	4 - Adv Corros	1 - Rehabilitate unit	5.6 (SF)
The expert panel set this at 60% of replacement cost.			
398 - Drain. Syst Other	4 - Maj Deter	1 - Rehabilitate unit	492 (EA)
DCP data average for action subcategory ($980/ea) too high. Panel estimated based on an analysis of typical crew sizes and costs.			
474 - Walls Uncoated	4 - Adv Corros	1 - Rehabilitate unit	120 (LF)
Based on an analysis of typical crew sizes and costs			
487 - Sign Member Horiz	5 - Sect Loss	1 - Rehabilitate unit	102 (LF)
Based on an analysis of typical crew sizes and costs			
488 - Sign Member Vertical	5 - Sect Loss	1 - Rehabilitate unit	102 (LF)
Based on an analysis of typical crew sizes and costs			
495 - Uncoat High Mast L.	4 - Adv Corros	1 - Rehabilitate unit	6000 (EA)
DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.			
496 - Painted High Mast L.	5 - Sect Loss	1 - Rehabilitate unit	6000 (EA)
DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.			
497 - Galvan. High Mast L.	5 - Sect Loss	1 - Rehabilitate unit	6000 (EA)
DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.			
498 - Other High Mast L.P.	2 - Min Deter	1 - Rehabilitate unit	6000 (EA)
DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.			

498 - Other High Mast L.P.	3 - Mod Deter	1 - Rehabilitate unit	6000 (EA)

DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.

498 - Other High Mast L.P.	4 - Maj Deter	1 - Rehabilitate unit	6000 (EA)

DCP data average for action subcategory ($980/ea) too low. Panel estimated based on an analysis of typical crew sizes and costs.

203 - Rehab concrete

Concrete rehabilitation in Florida is typically carbon fiber wrapping. These costs were based on anecdotal project experience and checked against a small number of data points in DCP. These numbers were significantly higher than the Clemson results.

Element	State	Action	Final Cost
104 - P/S Conc Box Girder	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience. (DCP has 682.14/lf for rehabilitation of concrete beams, but it is impossible to identify which type of element is involved in each project.)			
105 - R/Conc Box Girder	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
109 - P/S Conc Open Girder	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
110 - R/Conc Open Girder	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
116 - R/Conc Stringer	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
143 - P/S Conc Arch	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
144 - R/Conc Arch	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
155 - R/Conc Floor Beam	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
204 - P/S Conc Column	4 - Analysis warranted	1 - Rehab unit	5000 (EA)
Based on anecdotal project experience. (DCP has $300 ea. for rehab of concrete columns, but the panel felt this was too low.)			
205 - R/Conc Column	4 - Analysis warranted	1 - Rehab unit	5000 (EA)
Based on anecdotal project experience.			
207 - P/S Conc Holl Pile	4 - Adv Corros	1 - Rehabilitate unit	5000 (EA)
Based on anecdotal project experience.			
210 - R/Conc Pier Wall	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
215 - R/Conc Abutment	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
220 - R/C Sub Pile Cap/Ftg	4 - Analysis warranted	1 - Rehab unit	5000 (EA)
Based on anecdotal project experience.			
233 - P/S Conc Cap	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
234 - R/Conc Cap	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
241 - Concrete Culvert	2 - Minor deterioration	1 - Rehab unit	300 (LF)
Based on anecdotal project experience. This is believed to vary by condition state.			
241 - Concrete Culvert	3 - Moderate deteriorati	1 - Rehab unit	610 (LF)
Based on anecdotal project experience. This is believed to vary by condition state.			
241 - Concrete Culvert	4 - Major deterioration	1 - Rehab unit	910 (LF)
Based on anecdotal project experience. This is believed to vary by condition state.			
331 - Conc Bridge Railing	4 - Analysis warranted	1 - Rehab unit	500 (LF)
Based on anecdotal project experience.			
387 - P/S Fender/Dolphin	4 - Adv Corros	1 - Rehabilitate unit	500 (LF)
Based on anecdotal project experience.			
388 - R/Conc Fender/Dolphi	4 - Adv Corros	1 - Rehabilitate unit	500 (LF)
Based on anecdotal project experience.			
394 - R/Conc Abut Slope Pr	4 - Adv Corros	1 - Rehabilitate unit	2.5 (SF)
The expert panel set this at 60% of replacement cost.			
475 - R/Conc Walls	4 - Adv Deter	1 - Rehabilitate unit	370 (LF)

The expert panel set this at 60% of replacement cost.

489 - Sign Foundation	4 - Adv Corros	1 - Rehabilitate unit	1000 (EA)
Based on anecdotal project experience.			
499 - H. M. L. P. Found.	4 - Adv Corros	1 - Rehabilitate unit	1000 (EA)
Based on anecdotal project experience.			
564 - Counterweight	4 - Adv Corros	1 - Rehabilitate unit	4500 (EA)
Survey			

204 - Rehab timber

FDOT does not have standardized procedures for timber rehabilitation because opportunities seldom arise for a cost-effective rehabilitation-type action. Therefore, costs can vary widely. MMS, Akbar, and DCP each contain a few relevant data points, but the average unit costs in all three systems were judged to be too low. On the other hand, the Clemson costs were generally too high. The expert panel decided to use 60% of replacement cost for planning purposes. These numbers are assumed not to vary by condition state.

Element	State	Action	Final Cost
31 - Timber Deck	2 - Minor decay	1 - Rehab and/or protect	6 (SF)
The expert panel set this at 60% of replacement cost.			
31 - Timber Deck	3 - Some strength loss	1 - Rehab deck	(SF)
The expert panel set this at 60% of replacement cost.			
32 - Timber Deck/AC Ovly	2 - Minor deterioration	2 - Rehab and/or protect	5 (SF)
The expert panel set this at 60% of replacement cost.			
32 - Timber Deck/AC Ovly	3 - Some strength loss	1 - Rehab deck+repair/re	5 (SF)
The expert panel set this at 60% of replacement cost.			
54 - Timber Slab	2 - Minor decay	1 - Rehab and/or protect	0.6 (SF)
The expert panel set this at 60% of replacement cost.			
54 - Timber Slab	3 - Some strength loss	1 - Rehab deck	(SF)
The expert panel set this at 60% of replacement cost.			
55 - Timber Slab/AC Ovly	2 - Minor deterioration	2 - Rehab and/or protect	2 (SF)
The expert panel set this at 60% of replacement cost.			
55 - Timber Slab/AC Ovly	3 - Some strength loss	1 - Rehab deck and surfa	(SF)
The expert panel set this at 60% of replacement cost.			
111 - Timber Open Girder	2 - Minor decay	1 - Rehab &/or protect u	90 (LF)
MMS, Akbar, DCP data indicate action subcategory averages of $47/lf, $23/lf and $21/lf respectively. The expert panel set this at 60% of replacement cost.			
111 - Timber Open Girder	3 - Some strength loss	1 - Rehab unit	90 (LF)
The expert panel set this at 60% of replacement cost.			
111 - Timber Open Girder	4 - Major strength loss	1 - Rehab unit	90 (LF)
The expert panel set this at 60% of replacement cost.			
117 - Timber Stringer	2 - Minor decay	1 - Rehab &/or protect u	68 (LF)
The expert panel set this at 60% of replacement cost.			
117 - Timber Stringer	3 - Some strength loss	1 - Rehab unit	68 (LF)
The expert panel set this at 60% of replacement cost.			
117 - Timber Stringer	4 - Major strength loss	1 - Rehab unit	68 (LF)
The expert panel set this at 60% of replacement cost.			
135 - Timber Truss/Arch	2 - Minor decay	1 - Rehab &/or protect u	420 (LF)
The expert panel set this at 60% of replacement cost.			
135 - Timber Truss/Arch	3 - Some strength loss	1 - Rehab unit	420 (LF)
The expert panel set this at 60% of replacement cost.			
135 - Timber Truss/Arch	4 - Major strength loss	1 - Rehab unit	420 (LF)
The expert panel set this at 60% of replacement cost.			
156 - Timber Floor Beam	2 - Minor decay	1 - Rehab &/or protect u	68 (LF)
The expert panel set this at 60% of replacement cost.			
156 - Timber Floor Beam	3 - Some strength loss	1 - Rehab unit	68 (LF)
The expert panel set this at 60% of replacement cost.			
156 - Timber Floor Beam	4 - Major strength loss	1 - Rehab unit	68 (LF)
The expert panel set this at 60% of replacement cost.			
206 - Timber Column	2 - Minor decay	1 - Rehab &/or protect u	600 (EA)
The expert panel set this at 60% of replacement cost.			
206 - Timber Column	3 - Some strength loss	1 - Rehab unit	600 (EA)
The expert panel set this at 60% of replacement cost.			
206 - Timber Column	4 - Major strength loss	1 - Rehab unit	600 (EA)
The expert panel set this at 60% of replacement cost.			

216 - Timber Abutment	2 - Minor decay	1 - Rehab &/or protect u	370 (LF)
The expert panel set this at 60% of replacement cost.			
216 - Timber Abutment	3 - Some strength loss	1 - Rehab unit	370 (LF)
The expert panel set this at 60% of replacement cost.			
216 - Timber Abutment	4 - Major strength loss	1 - Rehab unit	370 (LF)
The expert panel set this at 60% of replacement cost.			
235 - Timber Cap	2 - Minor decay	1 - Rehab &/or protect u	90 (LF)
The expert panel set this at 60% of replacement cost.			
235 - Timber Cap	3 - Some strength loss	1 - Rehab unit	90 (LF)
The expert panel set this at 60% of replacement cost.			
235 - Timber Cap	4 - Major strength loss	1 - Rehab unit	90 (LF)
The expert panel set this at 60% of replacement cost.			
332 - Timb Bridge Railing	2 - Minor decay	1 - Rehab and/or apply s	20 (LF)
The expert panel set this at 60% of replacement cost.			
389 - Timber Fender/Dolphi	2 - Min Defect	1 - Rehab and/or protect	144 (LF)
The expert panel set this at 60% of replacement cost.			
389 - Timber Fender/Dolphi	3 - Minor Loss	1 - Rehabilitate unit	144 (LF)
The expert panel set this at 60% of replacement cost.			
389 - Timber Fender/Dolphi	3 - Minor Loss	2 - Replace unit	144 (LF)
The expert panel set this at 60% of replacement cost.			
389 - Timber Fender/Dolphi	4 - Adv Deter	1 - Rehabilitate unit	144 (LF)
The expert panel set this at 60% of replacement cost.			
395 - Timber Abut Slope Pr	2 - Min Defect	1 - Rehab and/or protect	2.5 (SF)
The expert panel set this at 60% of replacement cost.			
395 - Timber Abut Slope Pr	3 - Minor Loss	1 - Rehabilitate unit	2.5 (SF)
The expert panel set this at 60% of replacement cost.			
395 - Timber Abut Slope Pr	4 - Adv Deter	1 - Rehabilitate unit	2.5 (SF)
The expert panel set this at 60% of replacement cost.			
476 - Timber Walls	2 - Min Defect	1 - Rehab and/or Protect	180 (LF)
The expert panel set this at 60% of replacement cost.			
476 - Timber Walls	3 - Minor Loss	1 - Rehabilitate unit	180 (LF)
The expert panel set this at 60% of replacement cost.			
476 - Timber Walls	4 - Adv Deter	1 - Rehabilitate unit	180 (LF)
The expert panel set this at 60% of replacement cost.			

205 - Rehab masonry/other

All of these are relatively uncommon actions. Those applying to masonry were set by the expert panel at 75% of replacement cost. Others were set according to anecdotal project evidence and judgment.

Element	State	Action	Final Cost
211 - Other Mtl Pier Wall	2 - Minor deterioration	1 - Rehab unit	1800 (LF)
The expert panel set this at 60% of replacement cost.			
211 - Other Mtl Pier Wall	3 - Moderate deteriorati	1 - Rehab unit	1800 (LF)
The expert panel set this at 60% of replacement cost.			
211 - Other Mtl Pier Wall	4 - Major deterioration	1 - Rehab unit	1800 (LF)
The expert panel set this at 60% of replacement cost.			
217 - Other Mtl Abutment	2 - Minor deterioration	1 - Rehab unit	490 (LF)
The expert panel set this at 60% of replacement cost.			
217 - Other Mtl Abutment	3 - Moderate deteriorati	1 - Rehab unit	490 (LF)
The expert panel set this at 60% of replacement cost.			
217 - Other Mtl Abutment	4 - Major deterioration	1 - Rehab unit	490 (LF)
The expert panel set this at 60% of replacement cost.			
243 - Misc Culvert	2 - Minor deterioration	1 - Rehab unit	225 (LF)
The expert panel set this at 75% of concrete.			
243 - Misc Culvert	3 - Moderate deteriorati	1 - Rehab unit	460 (LF)
The expert panel set this at 75% of concrete.			
243 - Misc Culvert	4 - Major deterioration	1 - Rehab unit	680 (LF)
The expert panel set this at 75% of concrete.			
333 - Other Bridge Railing	2 - Minor cracks/spalls	1 - Rehab unit	45 (LF)
Based on anecdotal project evidence and judgment			
333 - Other Bridge Railing	3 - Major deterioration	1 - Rehab unit	45 (LF)
Based on anecdotal project evidence and judgment			
390 - Other Fender/Dolphin	2 - Min Deter	1 - Rehabilitate unit	200 (LF)
Based on anecdotal project evidence and judgment			
390 - Other Fender/Dolphin	3 - Mod Deter	1 - Rehabilitate unit	200 (LF)
Based on anecdotal project evidence and judgment			
390 - Other Fender/Dolphin	4 - Maj Deter	1 - Rehabilitate unit	200 (LF)
Based on anecdotal project evidence and judgment			
477 - Other Walls	2 - Min Deter	1 - Rehabilitate unit	400 (LF)
Based on anecdotal project evidence and judgment			
477 - Other Walls	3 - Mod Deter	1 - Rehabilitate unit	400 (LF)
Based on anecdotal project evidence and judgment			
477 - Other Walls	4 - Maj Deter	1 - Rehabilitate unit	400 (LF)
Based on anecdotal project evidence and judgment			

206 - Rehab MSE

Not a standard FDOT activity. Set by the expert panel based on anecdotal project evidence.

Element	State	Action	Final Cost
478 - MSE Walls	2 - Min Deter	1 - Rehabilitate unit	300 (LF)
Based on anecdotal project evidence and judgment			
478 - MSE Walls	3 - Mod Deter	1 - Rehabilitate unit	300 (LF)
Based on anecdotal project evidence and judgment			
478 - MSE Walls	4 - Maj Deter	1 - Rehabilitate unit	300 (LF)
Based on anecdotal project evidence and judgment			

211 - Rehab joint

MMS has a significant number of data points, but the costs there are unrealistically low, averaging $8.11/lf. The DCP average was higher, at $18.74, but still too low. It is likely that these numbers include only material costs. The expert panel felt that the Clemson results were more realistic for planning purposes.

Element	State	Action	Final Cost
301 - Pourable Joint Seal	3 - Leakage problems	1 - Clean joint; patch s	74 (LF)
MMS and DCP data indicate action subcategory averages of $8/lf and $19/lf respectively. Clemson results used.			
303 - Assembly Joint/Seal	2 - Minor deterioration	1 - Rehab unit	130 (LF)
Clemson results used.			
303 - Assembly Joint/Seal	3 - Advanced corrosion	1 - Rehab unit	190 (LF)
Clemson results used.			
304 - Open Expansion Joint	2 - Minor deterioration	1 - Rehab unit	80 (LF)
Clemson results used.			
304 - Open Expansion Joint	3 - Advanced corrosion	1 - Rehab unit	180 (LF)
Clemson results used.			
399 - Other Expansion Join	2 - Min Deter	1 - Rehabilitate unit	80 (LF)
Assumed to be the same as element #304			
399 - Other Expansion Join	3 - Maj Deter	1 - Rehabilitate unit	180 (LF)
Assumed to be the same as element #304			

213 - Rehab bearing

MMS costs are given in man-hours, so they were not directly applicable. Akbar has 2 data points averaging $3453 each, but it was not possible to determine which type of bearing was involved. It was decided to use the Clemson results, except for pot bearings.

Element	State	Action	Final Cost
310 - Elastomeric Bearing	2 - Minor deterioration	1 - Reset bearings	930 (EA)
Akbar data indicate action subcategory averages of $3,500/ea. Clemson results used.			
310 - Elastomeric Bearing	3 - Major deterioration	1 - Reset bearings	930 (EA)
Clemson results used.			
311 - Moveable Bearing	3 - Advanced corrosion	1 - Rehab supports	900 (EA)
Clemson results used.			
312 - Enclosed Bearing	2 - Minor deterioration	1 - Rehab unit	1350 (EA)
Clemson results used.			
312 - Enclosed Bearing	3 - Bearing failures	1 - Rehab unit	3700 (EA)
Clemson results used.			
313 - Fixed Bearing	2 - Minor deterioration	1 - Clean and paint or r	670 (EA)
Clemson results used.			
313 - Fixed Bearing	3 - Advanced corrosion	1 - Rehab supports or be	1340 (EA)
Clemson results used.			
314 - Pot Bearing	2 - Minor deterioration	1 - Rehab supports or be	1500 (EA)
Clemson results used.			
314 - Pot Bearing	3 - Advanced corrosion	1 - Rehab bearing device	1500 (EA)
Clemson results used.			

221 - Rehab slope protection

MMS data were found to be too high, probably because they contain activities not related to the slope protection element. DCP results were more consistent with other costs, so they were chosen.

Element	State	Action	Final Cost
396 - Other Abut Slope Pro DCP Results	2 - Min Deter	1 - Rehab and/or Protect	3.22 (SF)
396 - Other Abut Slope Pro DCP Results	3 - Mod Deter	1 - Rehabilitate unit	3.22 (SF)
396 - Other Abut Slope Pro DCP Results	4 - Maj Deter	1 - Rehabilitate unit	3.22 (SF)

222 - Rehab channel

These costs were based on anecdotal project evidence.

Element	State	Action	Final Cost	
290 - Channel Based on anecdotal project evidence	2 - Min Deter	1 - Rep. Banks/Prot	600	(EA)
290 - Channel Based on anecdotal project evidence	3 - Mod Deter	1 - Rep. Banks/Prot	1000	(EA)
290 - Channel Based on anecdotal project evidence	3 - Mod Deter	2 - Countermeasures	100000	(EA)
290 - Channel Based on anecdotal project evidence	4 - Maj Deter	1 - Countermeasures	300000	(EA)

223 - Rehab drainage system

These costs were based on anecdotal project evidence.

Element	State	Action	Final Cost	
397 - Drain. Syst Metal	5 - Sect Loss	1 - Rehabilitate unit	600	(EA)

Based on anecdotal project evidence

231 - Rehab machinery

Survey

Element	State	Action	Final Cost
540 - Open Gearing	3 - Mod Deter	1 - Rehabilitate unit	11300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
541 - Speed Reducers	3 - Mod Deter	1 - Rehabilitate unit	16300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
542 - Shafts	3 - Mod Deter	1 - Rehabilitate unit	900 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
543 - Shaft Brgs and Coupl	3 - Mod Deter	1 - Rehabilitate unit	700 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
544 - Brakes	3 - Mod Deter	1 - Rehabilitate unit	900 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
544 - Brakes	4 - Maj Deter	1 - Rehabilitate unit	2700 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
545 - Emergency Drive	3 - Mod Deter	1 - Rehabilitate System	1900 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
546 - Span Drive Motors	3 - Mod Deter	1 - Rehabilitate unit	2900 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
547 - Hydraulic Power Unit	3 - Mod Deter	1 - Rehabilitate unit	5500 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
548 - Hydraulic Piping Sys	3 - Maj Deter	1 - Rehabilitate unit	1400 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
549 - Hydraulic Cylinders	3 - Mod Deter	1 - Rehabilitate unit	3000 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
550 - Hopkins Frame	5 - Sect Loss	1 - Rehabilitate unit	5600 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
560 - Locks	3 - Mod Deter	1 - Rehabilitate unit	5500 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
561 - Live Load Shoes	3 - Maj Deter	1 - Rehabilitate unit	3000 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
562 - Counterweight Suppor	5 - Sect Loss	1 - Rehabilitate unit	1600 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
563 - Acc Ladd & Plat	5 - Sect Loss	1 - Rehabilitate unit	1800 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
565 - Trun/Str and Cur Trk	3 - Mod Deter	1 - Rehabilitate unit	1300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
570 - Transformers	3 - Maj Deter	1 - Rehabilitate unit	300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
571 - Submarine Cable	2 - Min Deter	1 - Rehabilitate unit	1150 each
Relevant MMS data available but in units of Man-hours. Survey used.			
571 - Submarine Cable	3 - Maj Deter	1 - Rehabilitate unit	2300 each
Relevant MMS data available but in units of Man-hours. Survey used.			
572 - Conduit & Junc. Box	2 - Min Deter	1 - Rehabilitate unit	400 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
572 - Conduit & Junc. Box	3 - Maj Deter	1 - Rehabilitate unit	1650 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
573 - PLCs	3 - Maj Deter	1 - Rehabilitate unit	25300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
574 - Control Console	3 - Maj Deter	1 - Rehabilitate unit	20300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
580 - Navigational Lights	3 - Maj Deter	1 - Rehabilitate unit	1930 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			

581 - Operator Facilities	2 - Mod Deter	1 - Rehabilitate unit	8700 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
581 - Operator Facilities	3 - Maj Deter	1 - Rehabilitate unit	21200 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
582 - Lift Bridge Spec. Eq	2 - Mod Deter	2 - Rehabilitate unit	25000 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
582 - Lift Bridge Spec. Eq	3 - Maj Deter	1 - Rehabilitate unit	25000 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
583 - Swing Bridge Spec. E	2 - Mod Deter	2 - Rehabilitate unit	25000 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
583 - Swing Bridge Spec. E	3 - Maj Deter	1 - Rehabilitate unit	25000 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
590 - Resistance Barriers	2 - Mod Deter	2 - Rehabilitate unit	500 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
590 - Resistance Barriers	3 - Maj Deter	1 - Rehabilitate unit	750 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
591 - Warning Gates	2 - Mod Deter	2 - Rehabilitate unit	1300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
591 - Warning Gates	3 - Maj Deter	1 - Rehabilitate unit	4100 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
592 - Traffic Signals	2 - Mod Deter	2 - Rehabilitate unit	1200 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
592 - Traffic Signals	3 - Maj Deter	1 - Rehabilitate unit	3300 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			

243 - Rehab cable

These costs were based on anecdotal project evidence.

Element	State	Action	Final Cost
146 - Misc Cable Uncoated	4 - Analysis warranted	1 - Rehab unit and coat	120000 (EA)
Relevant MMS data available but in units of Man-hours. Survey used.			
147 - Misc Cable Coated	4 - Active corrosion	1 - Rehab unit and repla	120000 (EA)
Based on anecdotal project evidence			
147 - Misc Cable Coated	5 - Analysis warranted	1 - Rehab unit and repla	120000 (EA)
Based on anecdotal project evidence			

246 - Mudjacking

The available data in MMS are in square feet, and Akbar in cubic yards, but approach slabs are eaches. It was decided to rely on the MMS costs assuming typical work situations.

Element	State	Action	Final Cost	
320 - P/S Conc Appr Slab	2 - Minor cracks/spalls	1 - Perform mudjacking o	6000	(EA)
Based on MMS and anecdotal project characteristics				
321 - R/Conc Approach Slab	2 - Cracks/spalls	1 - Perform mudjacking o	6000	(EA)
Based on MMS and anecdotal project characteristics				

301 - Repair deck and substrate

MMS costs were far too high, so the panel decided to base the unit costs on anecdotal project experience. Because the unit costs apply to the entire deck, they differ by condition state.

Element	State	Action	Final Cost	
13 - Unp Conc Deck/AC Ovl	2 - Distress <= 2%	1 - Repair potholes and	5	(SF)
Based on anecdotal project evidence				
13 - Unp Conc Deck/AC Ovl	3 - 2 to 10% distress	1 - Repair potholes and	10	(SF)
MMS data result ($74/sf) too high. Estimated based on anecdotal project evidence				
13 - Unp Conc Deck/AC Ovl	4 - 10-25% distress	1 - Repair potholes and	20	(SF)
Based on anecdotal project evidence.				
39 - Unp Conc Slab/AC Ovl	2 - Distress under 2%	1 - Repair potholes and	5	(SF)
Based on anecdotal project evidence.				
39 - Unp Conc Slab/AC Ovl	3 - 2-10% distress	1 - Repair potholes and	10	(SF)
Based on anecdotal project evidence.				
39 - Unp Conc Slab/AC Ovl	4 - 10-25% distress	1 - Repair potholes and	20	(SF)
Based on anecdotal project evidence.				
98 - Conc Deck on PC Pane	3 - 2-10 % Distress	2 - Repair and Protect	12	(SF)
Based on anecdotal project evidence.				
98 - Conc Deck on PC Pane	4 - 10-25 % Distress	2 - Repair & Protect	22	(SF)
Based on anecdotal project evidence.				
98 - Conc Deck on PC Pane	5 - Distress over 25 %	1 - Repair & Protect	25	(SF)
Based on anecdotal project evidence.				
99 - PS Conc Slab	3 - Dist 2-10%	2 - Repair and protect	13	(SF)
Based on anecdotal project evidence.				
99 - PS Conc Slab	4 - Dist 10-25%	2 - Repair and protect	25	(SF)
Based on anecdotal project evidence.				
99 - PS Conc Slab	5 - Dist >25%	1 - Repair and protect	34	(SF)
Based on anecdotal project evidence.				

302 - Spot paint

The panel found the MMS costs to be too low, perhaps because they do not include all cost components. They decided to set the spot painting costs at a fixed ratio to the cost of repainting the paint system. The ratio depended on the unit of measurement (lf or each) and on whether spot blasting was included. These costs on average were one-fifth higher than the Clemson results.

Element	State	Action	Final Cost
28 - Steel Deck/Open Grid	4 - Moderate corrosion	1 - Spot blast, clean an	10 (SF)
MMS data result ($29/sf) too high. Estimated based on anecdotal project evidence			
29 - Steel Deck/Conc Grid	4 - Failed connectors	1 - Spot blast, clean an	12 (SF)
Based on anecdotal project evidence.			
101 - Unpnt Stl Box Girder	2 - Minor corrosion	1 - Clean & paint	3640 (LF)
MMS data result ($19/lf) too low. Set by the expert panel at 1.3 times the cost of replacing the paint system.			
101 - Unpnt Stl Box Girder	3 - Some section loss	1 - Clean & paint	3640 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
102 - Paint Stl Box Girder	2 - Paint distress	2 - Clean & paint	3640 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
102 - Paint Stl Box Girder	3 - Rust formation	1 - Spot blast, clean &	4200 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
102 - Paint Stl Box Girder	4 - Active corrosion	1 - Spot blast, clean &	4200 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
106 - Unpnt Stl Opn Girder	2 - Minor corrosion	1 - Clean & paint	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
106 - Unpnt Stl Opn Girder	3 - Some section loss	1 - Clean & paint	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
107 - Paint Stl Opn Girder	2 - Paint distress	2 - Surface clean and re	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
107 - Paint Stl Opn Girder	3 - Rust formation	1 - Spot blast,clean & p	78 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
107 - Paint Stl Opn Girder	4 - Active corrosion	1 - Spot blast, clean &	78 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
112 - Unpnt Stl Stringer	2 - Minor corrosion	1 - Clean & paint	43 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
112 - Unpnt Stl Stringer	3 - Some section loss	1 - Clean & paint	43 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
113 - Paint Stl Stringer	2 - Paint distress	2 - Clean & paint	43 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
113 - Paint Stl Stringer	3 - Rust formation	1 - Spot blast, clean &	50 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
113 - Paint Stl Stringer	4 - Active corrosion	1 - Spot blast, clean &	50 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
120 - U/Stl Thru Truss/Bot	2 - Minor corrosion	1 - Clean & paint	153 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
120 - U/Stl Thru Truss/Bot	3 - Some section loss	1 - Clean & paint	153 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
121 - P/Stl Thru Truss/Bot	2 - Paint distress	2 - Clean & paint	153 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
121 - P/Stl Thru Truss/Bot	3 - Rust formation	1 - Spot blast, clean &	177 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
121 - P/Stl Thru Truss/Bot	4 - Active corrosion	1 - Spot blast, clean &	177 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
125 - U/Stl Thru Truss/Top	2 - Minor corrosion	1 - Clean & paint	195 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
125 - U/Stl Thru Truss/Top	3 - Some section loss	1 - Clean & paint	195 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

126 - P/Stl Thru Truss/Top	2 - Paint distress	2 - Clean & paint	195 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

126 - P/Stl Thru Truss/Top	3 - Rust formation	1 - Spot blast, clean &	225 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

126 - P/Stl Thru Truss/Top	4 - Active corrosion	1 - Spot blast, clean &	225 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

131 - Paint Stl Deck Truss	2 - Paint distress	2 - Clean & paint	910 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

131 - Paint Stl Deck Truss	3 - Rust formation	1 - Spot blast, clean &	1050 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

131 - Paint Stl Deck Truss	4 - Active corrosion	1 - Spot blast, clean &	1050 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

140 - Unpnt Stl Arch	2 - Minor corrosion	1 - Clean & paint	550 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

140 - Unpnt Stl Arch	3 - Some section loss	1 - Clean & paint	550 (LF)

MMS data result ($19/lf) too low. Set by the expert panel at 1.3 times the cost of replacing the paint system.

141 - Paint Stl Arch	2 - Paint distress	2 - Clean & paint	550 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

141 - Paint Stl Arch	3 - Rust formation	1 - Spot blast, clean &	630 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

141 - Paint Stl Arch	4 - Active corrosion	1 - Spot blast, clean &	630 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

146 - Misc Cable Uncoated	2 - Surface rust	1 - Clean & coat	7500 (EA)

Based on expert judgment

146 - Misc Cable Uncoated	3 - Moderate deteriorati	1 - Clean & coat	10000 (EA)

Based on expert judgment

151 - Unpnt Stl Floor Beam	2 - Minor corrosion	1 - Clean & paint	70 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

151 - Unpnt Stl Floor Beam	3 - Some section loss	1 - Clean & paint	70 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

152 - Paint Stl Floor Beam	2 - Paint distress	2 - Clean & paint	70 (LF)

Set by the expert panel at 1.3 times the cost of replacing the paint system.

152 - Paint Stl Floor Beam	3 - Rust formation	1 - Spot blast, clean &	81 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

152 - Paint Stl Floor Beam	4 - Active corrosion	1 - Spot blast, clean &	81 (LF)

Set by the expert panel at 1.5 times the cost of replacing the paint system.

161 - Paint Stl Pin/Hanger	2 - Paint distress	2 - Clean & paint	71 (EA)

Set by the panel at 10% of replace paint system.

161 - Paint Stl Pin/Hanger	3 - Rust formation	1 - Spot blast, clean an	142 (EA)

Set by the panel at 20% of replace paint system.

161 - Paint Stl Pin/Hanger	4 - Active corrosion	1 - Spot blast, clean an	142 (EA)

Set by the panel at 20% of replace paint system.

201 - Unpnt Stl Column	2 - Rust formation	1 - Clean & paint	25 (EA)

Set by the panel at 10% of replace paint system.

201 - Unpnt Stl Column	3 - Some section loss	1 - Clean & paint	25 (EA)

Set by the panel at 10% of replace paint system.

202 - Paint Stl Column	2 - Paint distress	2 - Clean & paint	25 (EA)

Set by the panel at 10% of replace paint system.

202 - Paint Stl Column	3 - Rust formation	1 - Spot blast, clean &	50 (EA)

Set by the panel at 20% of replace paint system.

202 - Paint Stl Column	4 - Active corrosion	1 - Spot blast, clean &	50 (EA)

Set by the panel at 20% of replace paint system.

230 - Unpnt Stl Cap	2 - Rust formation	1 - Clean & paint	75 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
230 - Unpnt Stl Cap	3 - Some section loss	1 - Clean & paint	75 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
231 - Paint Stl Cap	2 - Paint distress	2 - Clean & paint	75 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
231 - Paint Stl Cap	3 - Rust formation	1 - Spot blast, clean &	87 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
231 - Paint Stl Cap	4 - Active corrosion	1 - Spot blast, clean &	87 (LF)
Set by the expert panel at 1.5 times the cost of replacing the paint system.			
311 - Moveable Bearing	2 - Minor deterioration	1 - Clean & paint	720 (EA)
Used Clemson data			
334 - Metal Rail Coated	2 - Surface rust forming	1 - Clean and Restore Co	19 (LF)
MMS data			
334 - Metal Rail Coated	3 - Rust prevalent	1 - Clean and Restore Co	29 (LF)
MMS data, adjusted for condition state			
386 - Fender/Dolphin Uncoa	2 - Surf Rust	1 - Clean and paint	(LF)
386 - Fender/Dolphin Uncoa	3 - Minor Loss	1 - Clean and paint	(LF)
393 - Blkhd Sewl Metal Unc	2 - Surf Rust	1 - Clean and paint	29 (SF)
MMS data			
393 - Blkhd Sewl Metal Unc	3 - Minor Loss	1 - Clean and paint	44 (SF)
MMS data, adjusted for condition state			
397 - Drain. Syst Metal	3 - Surf Rust	1 - Spot paint	(EA)
397 - Drain. Syst Metal	4 - Surf Pits	1 - Spot paint	(EA)
474 - Walls Uncoated	2 - Surf Rust	1 - Clean and paint	19 (LF)
MMS data			
474 - Walls Uncoated	3 - Minor Loss	1 - Clean and paint	29 (LF)
MMS data, adjusted for condition state			
487 - Sign Member Horiz	2 - Paint Dist	2 - Clean and paint	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
487 - Sign Member Horiz	3 - Surf Rust	1 - Spot paint	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
487 - Sign Member Horiz	4 - Surf Pits	1 - Clean and paint	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
488 - Sign Member Vertical	3 - Surf Rust	1 - Spot Paint	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
488 - Sign Member Vertical	4 - Surf Pits	1 - Spot Paint	68 (LF)
Set by the expert panel at 1.3 times the cost of replacing the paint system.			
495 - Uncoat High Mast L.	2 - Surf Rust	1 - Clean and paint	500 (EA)
Set by the panel at 10% of replace paint system.			
495 - Uncoat High Mast L.	3 - Minor Loss	1 - Clean and paint	500 (EA)
Set by the panel at 10% of replace paint system.			
496 - Painted High Mast L.	3 - Surf Rust	1 - Spot Paint	500 (EA)
Set by the panel at 10% of replace paint system.			
496 - Painted High Mast L.	4 - Surf Pits	1 - Spot Paint	500 (EA)
Set by the panel at 10% of replace paint system.			
497 - Galvan. High Mast L.	3 - Surf Rust	1 - Spot Paint	500 (EA)
Set by the panel at 10% of replace paint system.			

497 - Galvan. High Mast L.	4 - Surf Pits	1 - Spot paint	500 (EA)
Set by the panel at 10% of replace paint system.			
550 - Hopkins Frame	3 - Surf Rust	1 - Spot paint	500 (EA)
Set by the panel at 10% of replace paint system.			
550 - Hopkins Frame	4 - Surf Pits	1 - Spot paint	500 (EA)
Set by the panel at 10% of replace paint system.			
561 - Live Load Shoes	2 - Min Deter	1 - Clean and paint	500 (EA)
Set by the panel at 10% of replace paint system of similar elements.			
562 - Counterweight Suppor	3 - Surf Rust	1 - Spot paint	500 (EA)
Set by the panel at 10% of replace paint system.			
562 - Counterweight Suppor	4 - Surf Pits	1 - Spot paint	500 (EA)
Set by the panel at 10% of replace paint system.			
563 - Acc Ladd & Plat	3 - Surf Rust	1 - Spot paint	250 (EA)
Set by the panel at 10% of replace paint system.			
563 - Acc Ladd & Plat	4 - Surf Pits	1 - Spot paint	250 (EA)
Set by the panel at 10% of replace paint system.			

303 - Clean rebar and patch

MMS costs were found to be too low, so the panel relied on anecdotal project evidence and expert judgment. These costs were on average one-third lower than the Clemson costs.

Element	State	Action	Final Cost
104 - P/S Conc Box Girder	3 - Delams/spalls	1 - Clean steel & patch	1000 (LF)
MMS data indicate action subcategory average of $42/lf. Estimated based on anecdotal project evidence and judgment.			
105 - R/Conc Box Girder	3 - Delams/spalls	1 - Clean rebar & patch,	1000 (LF)
Based on anecdotal project evidence and judgment.			
109 - P/S Conc Open Girder	3 - Delams/spalls	1 - Clean steel & patch,	200 (LF)
MMS data indicate action subcategory average of $42/lf, and a specific element average of $47/lf. Estimated based on anecdotal project evidence and judgment.			
110 - R/Conc Open Girder	3 - Delams/spalls	1 - Clean rebar & patch,	200 (LF)
MMS data indicate action subcategory average of $42/lf, and a specific element cost of $95/lf. Estimated based on anecdotal project evidence and judgment.			
116 - R/Conc Stringer	3 - Delams/spalls	1 - Clean rebar & patch,	200 (LF)
Based on anecdotal project evidence and judgment.			
143 - P/S Conc Arch	3 - Delams/spalls	1 - Clean steel & patch,	200 (LF)
Based on anecdotal project evidence and judgment.			
144 - R/Conc Arch	3 - Delams/spalls	1 - Clean rebar & patch,	200 (LF)
Based on anecdotal project evidence and judgment.			
155 - R/Conc Floor Beam	3 - Delams/spalls	1 - Clean rebar & patch,	200 (LF)
Based on anecdotal project evidence and judgment.			
204 - P/S Conc Column	3 - Delams/spalls	1 - Clean steel & patch	500 (EA)
Relevant MMS data available but in Man-hours unit. Estimated based on anecdotal project evidence and judgment.			
205 - R/Conc Column	3 - Delams/spalls	1 - Clean rebar & patch,	500 (EA)
Relevant MMS data available but in Man-hours unit. Estimated based on anecdotal project evidence and judgment.			
210 - R/Conc Pier Wall	3 - Delams/spalls	1 - Clean rebar & patch,	350 (LF)
MMS data indicate action subcategory average of $42/lf, and a specific element average of $43/lf. Estimated based on anecdotal project evidence and judgment.			
215 - R/Conc Abutment	3 - Delams/spalls	1 - Clean rebar & patch,	150 (LF)
MMS data indicate action subcategory average of $42/lf, and a specific element average of $23/lf. Estimated based on anecdotal project evidence and judgment.			
220 - R/C Sub Pile Cap/Ftg	3 - Delams/spalls	1 - Clean rebar & patch,	500 (EA)
Relevant MMS data available but in Man-hours unit. Estimated based on anecdotal project evidence and judgment.			
233 - P/S Conc Cap	3 - Delams,spalls	1 - Clean steel & patch,	200 (LF)
MMS data indicate action subcategory average of $42/lf. Estimated based on anecdotal project evidence and judgment.			
234 - R/Conc Cap	3 - Delams/spalls	1 - Clean rebar & patch,	200 (LF)
MMS data indicate action subcategory average of $42/lf, and a specific element average of $32/lf. Estimated based on anecdotal project evidence and judgment.			
299 - Pile Jacket/Cath Pro	3 - Mod Deter	1 - Clean and patch	500 (EA)
Based on anecdotal project evidence and judgment.			
331 - Conc Bridge Railing	3 - Delam/spalls pres	1 - Clean rebar & patch,	200 (LF)
MMS data indicate action subcategory average of $42/lf, and a specific element average of $41/lf. Estimated based on anecdotal project evidence and judgment.			
394 - R/Conc Abut Slope Pr	3 - Exposed Stl	1 - Clean and patch	100 (SF)
MMS data indicate action subcategory average of $33/sf. Estimated based on anecdotal project evidence and judgment.			

311 - Repair joint

Evidence in the Clemson study and MMS indicated that compression joints should be more expensive than strip seals, but the panel discussed this and felt that strip seals should cost more. They used a number consistent with Akbar for compression joint seals but increased the cost of strip seals.

Element	State	Action	Final Cost
300 - Strip Seal Exp Joint	2 - Minor leakage	1 - Patch/reset/clean jo	61 (LF)
Based on anecdotal project evidence and judgment. This number is higher than any of the available data sources (MMS $27/lf; Akbar $21/lf; DCP $37/lf).			
302 - Compressn Joint Seal	2 - Minor deterioration	1 - Patch/rem/reseal/cln	30 (LF)
Based on anecdotal project evidence and judgment. This number is consistent with Akbar ($21/lf) and slightly lower than DCP ($37/lf). It is about half as much as the Clemson study (64/lf).			

331 - Repair/lubricate machinery

Survey

Element	State	Action	Final Cost
540 - Open Gearing	2 - Min Deter	1 - Clean and lubricate	5620 (EA)
Relevant data available in MMS but in Man-hours unit. DCP data average is $102/ea. Survey used (modification of results for action subcat 231).			
541 - Speed Reducers	2 - Min Deter	1 - Clean and lubricate	8120 (EA)
Survey used (modification of results for action subcat 231).			
542 - Shafts	2 - Min Deter	1 - Clean and lubricate	420 (EA)
Survey used (modification of results for action subcat 231).			
543 - Shaft Brgs and Coupl	2 - Min Deter	1 - Clean and lubricate	330 (EA)
Survey used (modification of results for action subcat 231).			
544 - Brakes	2 - Min Deter	1 - Clean/Lubricate/Oil	450 (EA)
Survey used (modification of results for action subcat 231).			
561 - Live Load Shoes	2 - Min Deter	2 - Realign and/or shim	1500 (EA)
Survey used (modification of results for action subcat 231).			
565 - Trun/Str and Cur Trk	2 - Min Deter	1 - Clean and lubricate	650 (EA)
Survey used (modification of results for action subcat 231).			
570 - Transformers	2 - Min Deter	1 - Clean and lubricate	150 (EA)
Survey used (modification of results for action subcat 231).			

400 - Wash structure

Three different approaches were chosen depending on the units of measurement.

Element	State	Action	Final Cost
28 - Steel Deck/Open Grid	2 - Minor deterioration	1 - Surface clean	0.5 (SF)
DCP had 37 cents per sq.ft. while Clemson had 50 cents. The panel felt that 50 cents was closer to typical for planning purposes.			
29 - Steel Deck/Conc Grid	2 - Minor deterioration	1 - Surface clean	0.5 (SF)
The panel felt that this should be the same as element #28			
102 - Paint Stl Box Girder	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
102 - Paint Stl Box Girder	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
107 - Paint Stl Opn Girder	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
107 - Paint Stl Opn Girder	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
113 - Paint Stl Stringer	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
113 - Paint Stl Stringer	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
121 - P/Stl Thru Truss/Bot	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
121 - P/Stl Thru Truss/Bot	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
126 - P/Stl Thru Truss/Top	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
126 - P/Stl Thru Truss/Top	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
131 - Paint Stl Deck Truss	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
131 - Paint Stl Deck Truss	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
141 - Paint Stl Arch	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
141 - Paint Stl Arch	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
152 - Paint Stl Floor Beam	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
152 - Paint Stl Floor Beam	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
161 - Paint Stl Pin/Hanger	1 - No corrosion	1 - Surface clean	200 (EA)
Akbar data indicate action subcategory average of $3200/ea. Estimated based on an analysis of typical crew sizes and costs			
161 - Paint Stl Pin/Hanger	2 - Paint distress	1 - Surface clean	200 (EA)
Estimated based on an analysis of typical crew sizes and costs			
202 - Paint Stl Column	1 - No corrosion	1 - Surface clean	200 (EA)
Estimated based on an analysis of typical crew sizes and costs			
202 - Paint Stl Column	2 - Paint distress	1 - Surface clean	200 (EA)
Estimated based on an analysis of typical crew sizes and costs			
231 - Paint Stl Cap	1 - No corrosion	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
231 - Paint Stl Cap	2 - Paint distress	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
397 - Drain. Syst Metal	1 - Excellent	1 - Surface clean	200 (EA)

Akbar data indicate action subcategory average of $3200/ea. Estimated based on an analysis of typical crew sizes and costs

397 - Drain. Syst Metal	2 - Paint dist	1 - Surface Clean	200 (EA)
Estimated based on an analysis of typical crew sizes and costs			
398 - Drain. Syst Other	2 - Min Deter	1 - Surface clean	200 (EA)
Estimated based on an analysis of typical crew sizes and costs			
398 - Drain. Syst Other	3 - Mod Deter	1 - Surface clean	200 (EA)
Estimated based on an analysis of typical crew sizes and costs			
487 - Sign Member Horiz	2 - Paint Dist	1 - Surface clean	10 (LF)
Slightly reduced from MMS.			
488 - Sign Member Vertical	1 - Excellent	1 - Surface Clean	10 (LF)
Slightly reduced from MMS.			
488 - Sign Member Vertical	2 - Paint Dist	1 - Surface Clean	10 (LF)
Slightly reduced from MMS.			
496 - Painted High Mast L.	1 - Excellent	1 - Surface clean	200 (EA)
Akbar data indicate action subcategory average of $3200/ea. Estimated based on an analysis of typical crew sizes and costs			
496 - Painted High Mast L.	2 - Paint Dist	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
497 - Galvan. High Mast L.	1 - Excellent	1 - Surface Clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
497 - Galvan. High Mast L.	2 - Paint Dist	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
550 - Hopkins Frame	1 - Excellent	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
550 - Hopkins Frame	2 - Paint Dist	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
562 - Counterweight Suppor	1 - Excellent	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
562 - Counterweight Suppor	2 - Paint Dist	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
563 - Acc Ladd & Plat	1 - Excellent	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			
563 - Acc Ladd & Plat	2 - Paint Dist	1 - Surface clean	200 (EA)
Based on an analysis of typical crew sizes and costs			

401 - Repair potholes

These costs are not available from any existing source so are based on a discussion of anecdotal project evidence.

Element	State	Action	Final Cost
12 - Bare Concrete Deck	1 - No damage	2 - Miscellaneous Maint	2 (SF)
MMS data indicate action subcategory average of $24/sf, and a specific element average of $26/sf. Estimated based on anecdotal project evidence and judgment.			
12 - Bare Concrete Deck	2 - Distress <= 2%	1 - Repair spalled/delam	5 (SF)
Based on anecdotal project evidence			
12 - Bare Concrete Deck	3 - 2 to 10 % distress	1 - Repair spalled areas	10 (SF)
Based on anecdotal project evidence			
12 - Bare Concrete Deck	4 - 10 to 25% distress	1 - Repair spalled areas	20 (SF)
Based on anecdotal project evidence			
13 - Unp Conc Deck/AC Ovl	1 - No damage	1 - Miscellaneous Maint	2 (SF)
MMS data indicate a specific element average of $24/sf. Estimated based on anecdotal project evidence and judgment.			
28 - Steel Deck/Open Grid	1 - No corrosion	1 - Miscellaneous Maint	4 (SF)
MMS data indicate a specific element average of $28/sf. Estimated based on anecdotal project evidence and judgment.			
29 - Steel Deck/Conc Grid	1 - No corrosion	1 - Miscellaneous Maint	4 (SF)
MMS data indicate a specific element average of $32/sf. Estimated based on anecdotal project evidence and judgment.			
31 - Timber Deck	1 - No decay	1 - Miscellaneous Maint	2 (SF)
Based on anecdotal project evidence			
32 - Timber Deck/AC Ovly	1 - No deterioration	1 - Miscellaneous Maint	2 (SF)
Based on anecdotal project evidence			
32 - Timber Deck/AC Ovly	2 - Minor deterioration	1 - Repair potholes	4 (SF)
Based on anecdotal project evidence			
38 - Bare Concrete Slab	1 - No damage	2 - Miscellaneous Maint	2 (SF)
MMS data indicate a specific element average of $11/sf. Estimated based on anecdotal project evidence and judgment.			
38 - Bare Concrete Slab	2 - Distress <=2%	1 - Repair spalled/delam	5 (SF)
Based on anecdotal project evidence			
38 - Bare Concrete Slab	3 - 2-10% distress	1 - Repair spalled areas	10 (SF)
Based on anecdotal project evidence			
38 - Bare Concrete Slab	4 - 10-25% distress	1 - Repair spalled areas	20 (SF)
Based on anecdotal project evidence			
39 - Unp Conc Slab/AC Ovl	1 - No damage	1 - Miscellaneous Maint	2 (SF)
MMS data indicate a specific element average of $30/sf. Estimated based on anecdotal project evidence and judgment.			
54 - Timber Slab	1 - No decay	1 - Miscellaneous Maint	5 (SF)
Based on anecdotal project evidence			
55 - Timber Slab/AC Ovly	1 - No deterioration	1 - Miscellaneous Maint	10 (SF)
Based on anecdotal project evidence			
55 - Timber Slab/AC Ovly	2 - Minor deterioration	1 - Repair potholes	20 (SF)
Based on anecdotal project evidence			
98 - Conc Deck on PC Pane	2 - Distress under 2 %	1 - Spalls & Delams	5 (SF)
MMS data indicate a specific element average of $15/sf. Estimated based on anecdotal project evidence and judgment.			
98 - Conc Deck on PC Pane	3 - 2-10 % Distress	1 - Spalls & Delams	10 (SF)
Based on anecdotal project evidence			
98 - Conc Deck on PC Pane	4 - 10-25 % Distress	1 - Spalls & Delams	20 (SF)
Based on anecdotal project evidence			
99 - PS Conc Slab	2 - Dist <2%	1 - Repair	5 (SF)

MMS data indicate a specific element average of $23/sf. Estimated based on anecdotal project evidence and judgment.

99 - PS Conc Slab	3 - Dist 2-10%	1 - Repair Spl/Delam	10 (SF)
Based on anecdotal project evidence			
99 - PS Conc Slab	4 - Dist 10-25%	1 - Repair Spl/Delam	22 (SF)
Based on anecdotal project evidence			

402 - Restore top coat

These costs are not available from any existing source so are based on a discussion of anecdotal project evidence.

Element	State	Action	Final Cost
28 - Steel Deck/Open Grid Based on anecdotal project evidence	3 - Rust formation	1 - Surface clean+restor	1 (SF)
29 - Steel Deck/Conc Grid Based on anecdotal project evidence	3 - Rust formation	1 - Surface clean+restor	1 (SF)
101 - Unpnt Stl Box Girder MMS data indicate action subcategory average of $3/lf. Estimated based on anecdotal project evidence and judgment.	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
102 - Paint Stl Box Girder Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
106 - Unpnt Stl Opn Girder Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
107 - Paint Stl Opn Girder Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
112 - Unpnt Stl Stringer Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
113 - Paint Stl Stringer Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
120 - U/Stl Thru Truss/Bot Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
121 - P/Stl Thru Truss/Bot Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
125 - U/Stl Thru Truss/Top Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
126 - P/Stl Thru Truss/Top Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
131 - Paint Stl Deck Truss Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
140 - Unpnt Stl Arch Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
141 - Paint Stl Arch Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
146 - Misc Cable Uncoated Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	5000 (EA)
147 - Misc Cable Coated Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	5000 (EA)
147 - Misc Cable Coated Based on anecdotal project evidence	2 - Surface rust forming	1 - Clean & Restore Coat	7500 (EA)
147 - Misc Cable Coated Based on anecdotal project evidence	3 - Rust prevalent	1 - Clean & Restore Coat	10000 (EA)
151 - Unpnt Stl Floor Beam Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
152 - Paint Stl Floor Beam Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
161 - Paint Stl Pin/Hanger Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (EA)
201 - Unpnt Stl Column Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	500 (EA)
202 - Paint Stl Column Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	500 (EA)
230 - Unpnt Stl Cap	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)

Based on anecdotal project evidence			
231 - Paint Stl Cap Based on anecdotal project evidence	1 - No corrosion	2 - Miscellaneous Maint	25 (LF)
240 - Metal Culvert Based on anecdotal project evidence	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
298 - Pile Jacket Bare Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	500 (EA)
299 - Pile Jacket/Cath Pro Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	500 (EA)
330 - Metal Rail Uncoated Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
330 - Metal Rail Uncoated Based on anecdotal project evidence	2 - Rust formation	1 - Clean and Coat	25 (LF)
330 - Metal Rail Uncoated Based on anecdotal project evidence	3 - Active corrosion	1 - Clean and Coat	25 (LF)
334 - Metal Rail Coated Based on anecdotal project evidence	1 - No corrosion	1 - Miscellaneous Maint	25 (LF)
386 - Fender/Dolphin Uncoa Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	25 (LF)
393 - Blkhd Sewl Metal Unc Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	25 (SF)
395 - Timber Abut Slope Pr Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	25 (SF)
397 - Drain. Syst Metal Based on anecdotal project evidence	1 - Excellent	2 - Miscellaneous Maint	500 (EA)
474 - Walls Uncoated Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	25 (LF)
487 - Sign Member Horiz Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	25 (LF)
488 - Sign Member Vertical Based on anecdotal project evidence	1 - Excellent	2 - Miscellaneous Maint	25 (LF)
488 - Sign Member Vertical Based on anecdotal project evidence	2 - Paint Dist	2 - Clean and restore	60 (LF)
495 - Uncoat High Mast L. Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	500 (EA)
496 - Painted High Mast L. Based on anecdotal project evidence	1 - Excellent	2 - Miscellaneous Maint	500 (EA)
496 - Painted High Mast L. Based on anecdotal project evidence	2 - Paint Dist	2 - Clean and restore	6000 (EA)
497 - Galvan. High Mast L. Based on anecdotal project evidence	1 - Excellent	2 - Miscellaneous Maint	500 (EA)
497 - Galvan. High Mast L. Based on anecdotal project evidence	2 - Paint Dist	2 - Clean and restore	6000 (EA)
498 - Other High Mast L.P. Based on anecdotal project evidence	1 - Excellent	1 - Miscellaneous Maint	500 (EA)
550 - Hopkins Frame Survey	2 - Paint Dist	2 - Clean and restore	5000 (EA)
562 - Counterweight Suppor Survey	2 - Paint Dist	2 - Clean and restore	5000 (EA)
563 - Acc Ladd & Plat Survey	2 - Paint Dist	2 - Clean and restore	1000 (EA)

403 - Patch minor spalls

For elements measured in linear feet, the panel reviewed MMS and DCP data and decided to use MMS for condition state 1 and DCP for condition state 2, rounding the costs upward. Square-foot and each-based elements were based on anecdotal project evidence.

Element	State	Action	Final Cost
98 - Conc Deck on PC Pane	1 - No Damage	2 - Miscellaneous Maint	2 (SF)
Based on anecdotal project evidence and judgment. This number is lower than any of the available data sources (MMS $50/sf; Akbar $42/sf; DCP $31/sf).			
99 - PS Conc Slab	1 - No Damage	1 - Miscellaneous Maint	2 (SF)
Based on anecdotal project evidence			
104 - P/S Conc Box Girder	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
Based on MMS.			
104 - P/S Conc Box Girder	2 - Minor cracks/spalls	1 - Seal cracks minor pa	40 (LF)
Based on DCP.			
105 - R/Conc Box Girder	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS and DCP.			
105 - R/Conc Box Girder	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
109 - P/S Conc Open Girder	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS and DCP.			
109 - P/S Conc Open Girder	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
110 - R/Conc Open Girder	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
Based on MMS.			
110 - R/Conc Open Girder	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
116 - R/Conc Stringer	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS and DCP.			
116 - R/Conc Stringer	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
143 - P/S Conc Arch	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS and DCP.			
143 - P/S Conc Arch	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
144 - R/Conc Arch	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
Based on MMS.			
144 - R/Conc Arch	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
155 - R/Conc Floor Beam	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS and DCP.			
155 - R/Conc Floor Beam	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
204 - P/S Conc Column	1 - No deterioration	1 - Miscellaneous Maint	500 (EA)
Relevant data in MMS, Akbar, and DCP but in units of Man-hours and SF. Estimated based on anecdotal project evidence			
204 - P/S Conc Column	2 - Minor cracks/spalls	1 - Seal cracks minor pa	250 (EA)
Based on anecdotal project evidence			
205 - R/Conc Column	1 - No deterioration	1 - Miscellaneous Maint	500 (EA)
Based on anecdotal project evidence			
205 - R/Conc Column	2 - Minor cracks/spalls	1 - Seal cracks minor pa	250 (EA)
Based on anecdotal project evidence			
207 - P/S Conc Holl Pile	1 - Excellent	1 - Miscellaneous Maint	500 (EA)
Based on anecdotal project evidence			
207 - P/S Conc Holl Pile	2 - Min Ck/Spl	1 - Seal and patch	250 (EA)

Based on anecdotal project evidence			
207 - P/S Conc Holl Pile	3 - Exposed Stl	1 - Clean and Patch	300 (EA)
Based on anecdotal project evidence			
210 - R/Conc Pier Wall	1 - No deterioration	1 - Miscellaneous Maint	30 (LF)
Based on MMS.			
210 - R/Conc Pier Wall	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
215 - R/Conc Abutment	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS.			
215 - R/Conc Abutment	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on Akbar.			
220 - R/C Sub Pile Cap/Ftg	1 - No deterioration	1 - Miscellaneous Maint	500 (EA)
Based on anecdotal project evidence			
220 - R/C Sub Pile Cap/Ftg	2 - Minor cracks/spalls	1 - Seal cracks minor pa	250 (EA)
Based on anecdotal project evidence			
233 - P/S Conc Cap	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS.			
233 - P/S Conc Cap	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on DCP and Akbar.			
234 - R/Conc Cap	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS.			
234 - R/Conc Cap	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on DCP and Akbar.			
241 - Concrete Culvert	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
Based on MMS.			
298 - Pile Jacket Bare	2 - Min Ck/Spl	1 - Seal and patch	200 (EA)
Relevant data in MMS, Akbar, and DCP but in units of Man-hours and SF. Estimated based on anecdotal project evidence			
298 - Pile Jacket Bare	3 - Mod Deter	1 - Clean and patch	300 (EA)
Based on anecdotal project evidence			
299 - Pile Jacket/Cath Pro	2 - Min Ck/Spl	1 - Seal and patch	200 (EA)
Based on anecdotal project evidence			
331 - Conc Bridge Railing	1 - No deterioration	1 - Miscellaneous Maint	35 (LF)
Based on MMS.			
331 - Conc Bridge Railing	2 - Minor cracks/spalls	1 - Seal cracks minor pa	45 (LF)
Based on DCP and Akbar.			
387 - P/S Fender/Dolphin	1 - Excellent	1 - Miscellaneous Maint	35 (LF)
Based on MMS.			
387 - P/S Fender/Dolphin	2 - Min Ck/Stl	1 - Seal and patch	45 (LF)
Based on DCP and Akbar.			
387 - P/S Fender/Dolphin	3 - Exposed Stl	1 - Clean and patch	50 (LF)
Based on anecdotal project evidence			
388 - R/Conc Fender/Dolphi	1 - Excellent	1 - Miscellaneous Maint	25 (LF)
Based on MMS.			
388 - R/Conc Fender/Dolphi	2 - Min Ck/Spl	1 - Seal and patch	40 (LF)
Based on DCP.			
388 - R/Conc Fender/Dolphi	3 - Exposed Stl	1 - Clean and patch	50 (LF)
Based on anecdotal project evidence			
394 - R/Conc Abut Slope Pr	1 - Excellent	1 - Miscellaneous Maint	25 (SF)
MMS data indicate a specific element average of $52/sf. Estimated based on anecdotal project evidence			
394 - R/Conc Abut Slope Pr	2 - Min Ck/Spl	1 - Seal and patch	55 (SF)
MMS data indicate a specific element average of $52/sf.			
475 - R/Conc Walls	1 - Excellent	1 - Miscellaneous Maint	35 (LF)

Based on MMS.			
475 - R/Conc Walls	2 - Min Ck/Spl	1 - Seal and patch	40 (LF)
Based on DCP and Akbar.			
475 - R/Conc Walls	3 - Exposed Stl	1 - Clean and patch	50 (LF)
Based on anecdotal project evidence.			
489 - Sign Foundation	1 - Excellent	1 - Miscellaneous Maint	100 (EA)
Based on anecdotal project evidence.			
489 - Sign Foundation	2 - Min Ck/Spl	1 - Seal and patch	200 (EA)
Based on anecdotal project evidence.			
489 - Sign Foundation	3 - Exposed Stl	1 - Clean and patch	300 (EA)
Based on anecdotal project evidence.			
499 - H. M. L. P. Found.	1 - Excellent	1 - Miscellaneous Maint	100 (EA)
Based on anecdotal project evidence.			
499 - H. M. L. P. Found.	2 - Min Ck/Spl	1 - Seal and patch	200 (EA)
Based on anecdotal project evidence.			
499 - H. M. L. P. Found.	3 - Exposed Stl	1 - Clean and patch	300 (EA)
Based on anecdotal project evidence.			
564 - Counterweight	2 - Min Ck/Spl	1 - Seal and patch	(EA)
Relevant data in MMS, Akbar, and DCP but in units of Man-hours and SF. Estimated based on survey.			
564 - Counterweight	3 - Exposed Stl	1 - Clean and patch	(EA)
Survey			

404 - Maintain timber

No data were available for these activities, so unit costs were based on expert judgment.

Element	State	Action	Final Cost
111 - Timber Open Girder Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	25 (LF)
117 - Timber Stringer Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	25 (LF)
135 - Timber Truss/Arch Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	25 (LF)
156 - Timber Floor Beam Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	25 (LF)
206 - Timber Column Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	100 (EA)
216 - Timber Abutment Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	25 (LF)
235 - Timber Cap Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	25 (LF)
332 - Timb Bridge Railing Based on expert judgment.	1 - No decay	1 - Miscellaneous Maint	25 (LF)
389 - Timber Fender/Dolphi Based on expert judgment.	1 - Excellent	1 - Miscellaneous Maint	25 (LF)
476 - Timber Walls Based on expert judgment.	1 - Excellent	1 - Miscellaneous Maint	25 (LF)

405 - Maintain masonry

No data were available for these activities, so unit costs were based on expert judgment.

Element	State	Action	Final Cost
211 - Other Mtl Pier Wall Based on expert judgment.	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
217 - Other Mtl Abutment Based on expert judgment.	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
243 - Misc Culvert Based on expert judgment.	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
333 - Other Bridge Railing Based on expert judgment.	1 - No deterioration	1 - Miscellaneous Maint	25 (LF)
390 - Other Fender/Dolphin Based on expert judgment.	1 - Excellent	1 - Miscellaneous Maint	25 (LF)
396 - Other Abut Slope Pro Based on expert judgment.	1 - Excellent	1 - Miscellaneous Maint	25 (SF)
398 - Drain. Syst Other Based on expert judgment.	1 - Excellent	1 - Miscellaneous Maint	100 (EA)
477 - Other Walls Based on expert judgment.	1 - Excellent	1 - Miscellaneous Maint	25 (LF)

406 - Maintain MSE

No data were available for these activities, so unit costs were based on expert judgment.

Element	State	Action	Final Cost
478 - MSE Walls	1 - Excellent	1 - Miscellaneous Maint	25 (LF)

Based on expert judgment.

411 - Maintain joint

Average costs from MMS were reasonable.

Element	State	Action	Final Cost
300 - Strip Seal Exp Joint Based on MMS.	1 - No leakage	1 - Miscellaneous Maint	4 (LF)
301 - Pourable Joint Seal Based on MMS.	1 - No deterioration	1 - Miscellaneous Maint	4 (LF)
302 - Compressn Joint Seal Based on MMS.	1 - No deterioration	1 - Miscellaneous Maint	4 (LF)
303 - Assembly Joint/Seal Based on MMS.	1 - No deterioration	1 - Miscellaneous Maint	4 (LF)
304 - Open Expansion Joint Based on MMS.	1 - No deterioration	1 - Miscellaneous Maint	4 (LF)
399 - Other Expansion Join Based on MMS.	1 - Excellent	1 - Miscellaneous Maint	4 (LF)

413 - Maintain bearing

MMS costs are in man-hours, so anecdotal project experience was used.

Element	State	Action	Final Cost
310 - Elastomeric Bearing	1 - No deterioration	1 - Miscellaneous Maint	100 (EA)
Relevant data in MMS but in units of Man-hours. Estimated based on anecdotal project evidence.			
311 - Moveable Bearing	1 - No deterioration	1 - Miscellaneous Maint	100 (EA)
Based on anecdotal project evidence.			
312 - Enclosed Bearing	1 - No deterioration	1 - Miscellaneous Maint	100 (EA)
Based on anecdotal project evidence.			
313 - Fixed Bearing	1 - No deterioration	1 - Miscellaneous Maint	100 (EA)
Based on anecdotal project evidence.			
314 - Pot Bearing	1 - No deterioration	1 - Miscellaneous Maint	100 (EA)
Based on anecdotal project evidence.			

422 - Maintain channel

MMS costs are in man-hours, so anecdotal project experience was used.

Element	State	Action	Final Cost
290 - Channel	1 - Excellent	1 - Miscellaneous Maint	500 (EA)

Relevant data in MMS, Akbar, and DCP but in units of Man-hours, SF, and HA respectively. Estimated based on anecdotal project evidence.

423 - Maintain drainage system

MMS costs are in man-hours, so anecdotal project experience was used.

Element	State	Action	Final Cost
397 - Drain. Syst Metal Based on anecdotal project evidence.	2 - Paint dist	2 - Flush drainage syst	500 (EA)
397 - Drain. Syst Metal Based on anecdotal project evidence.	3 - Surf Rust	2 - Flush drainage syst	500 (EA)
397 - Drain. Syst Metal Based on anecdotal project evidence.	4 - Surf Pits	2 - Flush drainage syst	500 (EA)
398 - Drain. Syst Other Based on anecdotal project evidence.	2 - Min Deter	2 - Flush drainage syst	500 (EA)
398 - Drain. Syst Other Based on anecdotal project evidence.	3 - Mod Deter	2 - Flush drainage syst	500 (EA)

431 - Maintain machinery

Survey

Element	State	Action	Final Cost	
540 - Open Gearing	1 - Excellent	1 - Miscellaneous Maint	2810	(EA)
Relevant data in MMS but in units of Man-hours. DCP indicates average of $280/ea. Estimated based on survey (modification of results for action subcats 231 and 331).				
541 - Speed Reducers	1 - Excellent	1 - Miscellaneous Maint	4060	(EA)
Survey (modification of results for action subcats 231 and 331).				
542 - Shafts	1 - Excellent	1 - Miscellaneous Maint	210	(EA)
Survey (modification of results for action subcats 231 and 331).				
543 - Shaft Brgs and Coupl	1 - Excellent	1 - Miscellaneous Maint	170	(EA)
Survey (modification of results for action subcats 231 and 331).				
544 - Brakes	1 - Excellent	1 - Miscellaneous Maint	225	(EA)
Survey (modification of results for action subcats 231 and 331).				
545 - Emergency Drive	1 - Excellent	1 - Miscellaneous Maint	460	(EA)
Survey (modification of results for action subcats 231 and 331).				
545 - Emergency Drive	2 - Min Deter	1 - Service System	460	(EA)
Survey (modification of results for action subcats 231 and 331).				
546 - Span Drive Motors	1 - Excellent	1 - Miscellaneous Maint	710	(EA)
Survey (modification of results for action subcats 231 and 331).				
546 - Span Drive Motors	2 - Min Deter	1 - Maintain and/or Serv	710	(EA)
Survey (modification of results for action subcats 231 and 331).				
547 - Hydraulic Power Unit	1 - Excellent	1 - Miscellaneous Maint	1370	(EA)
Survey (modification of results for action subcats 231 and 331).				
547 - Hydraulic Power Unit	2 - Min Deter	1 - Maintain and/or serv	1370	(EA)
Survey (modification of results for action subcats 231 and 331).				
548 - Hydraulic Piping Sys	1 - Excellent	1 - Miscellaneous Maint	330	(EA)
Survey (modification of results for action subcats 231 and 331).				
548 - Hydraulic Piping Sys	2 - Min Deter	1 - Perform maintenance	330	(EA)
Survey (modification of results for action subcats 231 and 331).				
549 - Hydraulic Cylinders	1 - Excellent	1 - Miscellaneous Maint	750	(EA)
Survey (modification of results for action subcats 231 and 331).				
549 - Hydraulic Cylinders	2 - Min Deter	1 - Maintain and service	750	(EA)
Survey (modification of results for action subcats 231 and 331).				
550 - Hopkins Frame	1 - Excellent	2 - Miscellaneous Maint	1400	(EA)
Survey (modification of results for action subcats 231 and 331).				
560 - Locks	1 - Excellent	1 - Miscellaneous Maint	1370	(EA)
Survey (modification of results for action subcats 231 and 331).				
560 - Locks	2 - Min Deter	1 - Perform maintenance	1370	(EA)
Survey (modification of results for action subcats 231 and 331).				
561 - Live Load Shoes	1 - Excellent	1 - Miscellaneous Maint	750	(EA)
Survey (modification of results for action subcats 231 and 331).				
562 - Counterweight Suppor	1 - Excellent	2 - Miscellaneous Maint	400	(EA)
Survey (modification of results for action subcats 231 and 331).				
563 - Acc Ladd & Plat	1 - Excellent	2 - Miscellaneous Maint	450	(EA)
Survey (modification of results for action subcats 231 and 331).				
564 - Counterweight	1 - Excellent	1 - Miscellaneous Maint		(EA)
Survey (modification of results for action subcats 231 and 331).				
565 - Trun/Str and Cur Trk	1 - Excellent	1 - Miscellaneous Maint	325	(EA)
Survey (modification of results for action subcats 231 and 331).				
570 - Transformers	1 - Excellent	1 - Miscellaneous Maint	80	(EA)
Survey (modification of results for action subcats 231 and 331).				
571 - Submarine Cable	1 - Excellent	1 - Miscellaneous Maint	290	each

Survey (modification of results for action subcats 231 and 331).

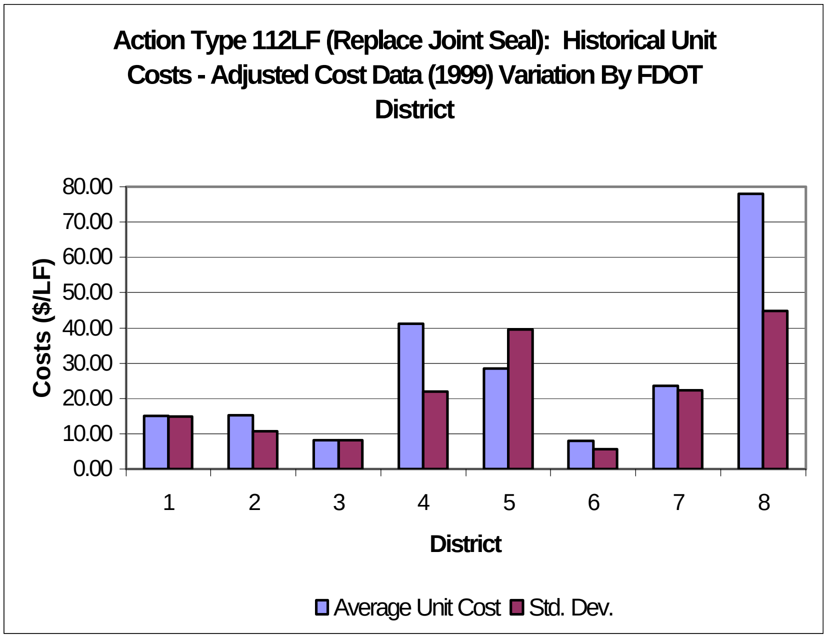
572 - Conduit & Junc. Box	1 - Excellent	1 - Miscellaneous Maint	100 (EA)
Survey (modification of results for action subcats 231 and 331).			
573 - PLCs	1 - Excellent	1 - Miscellaneous Maint	6330 (EA)
Survey (modification of results for action subcats 231 and 331).			
573 - PLCs	2 - Min Deter	1 - Clean and maintain	6330 (EA)
Survey (modification of results for action subcats 231 and 331).			
574 - Control Console	1 - Excellent	1 - Miscellaneous Maint	5080 (EA)
Survey (modification of results for action subcats 231 and 331).			
574 - Control Console	2 - Min Deter	1 - Clean and maintain	5080 (EA)
Survey (modification of results for action subcats 231 and 331).			
580 - Navigational Lights	1 - Excellent	1 - Miscellaneous Maint	490 (EA)
Survey (modification of results for action subcats 231 and 331).			
580 - Navigational Lights	2 - Min Deter	1 - Clean and maintain	490 (EA)
Survey (modification of results for action subcats 231 and 331).			
581 - Operator Facilities	1 - Excellent	1 - Perform maintenance	2170 (EA)
Survey (modification of results for action subcats 231 and 331).			
582 - Lift Bridge Spec. Eq	1 - Excellent	1 - Perform maintenance	6250 (EA)
Survey (modification of results for action subcats 231 and 331).			
582 - Lift Bridge Spec. Eq	2 - Mod Deter	1 - Perform maintenance	6250 (EA)
Survey (modification of results for action subcats 231 and 331).			
583 - Swing Bridge Spec. E	1 - Excellent	1 - Perform maintenance	6250 (EA)
Survey (modification of results for action subcats 231 and 331).			
583 - Swing Bridge Spec. E	2 - Mod Deter	1 - Perform maintenance	6250 (EA)
Survey (modification of results for action subcats 231 and 331).			
590 - Resistance Barriers	1 - Excellent	1 - Perform maintenance	130 (EA)
Survey (modification of results for action subcats 231 and 331).			
590 - Resistance Barriers	2 - Mod Deter	1 - Perform maintenance	130 (EA)
Survey (modification of results for action subcats 231 and 331).			
591 - Warning Gates	1 - Excellent	1 - Perform maintenance	330 (EA)
Survey (modification of results for action subcats 231 and 331).			
591 - Warning Gates	2 - Mod Deter	1 - Perform maintenance	330 (EA)
Survey (modification of results for action subcats 231 and 331).			
592 - Traffic Signals	1 - Excellent	1 - Perform maintenance	290 (EA)
Survey (modification of results for action subcats 231 and 331).			
592 - Traffic Signals	2 - Mod Deter	1 - Perform maintenance	290 (EA)
Survey (modification of results for action subcats 231 and 331).			

446 - Maintain approach slab

Anecdotal project experience was used.

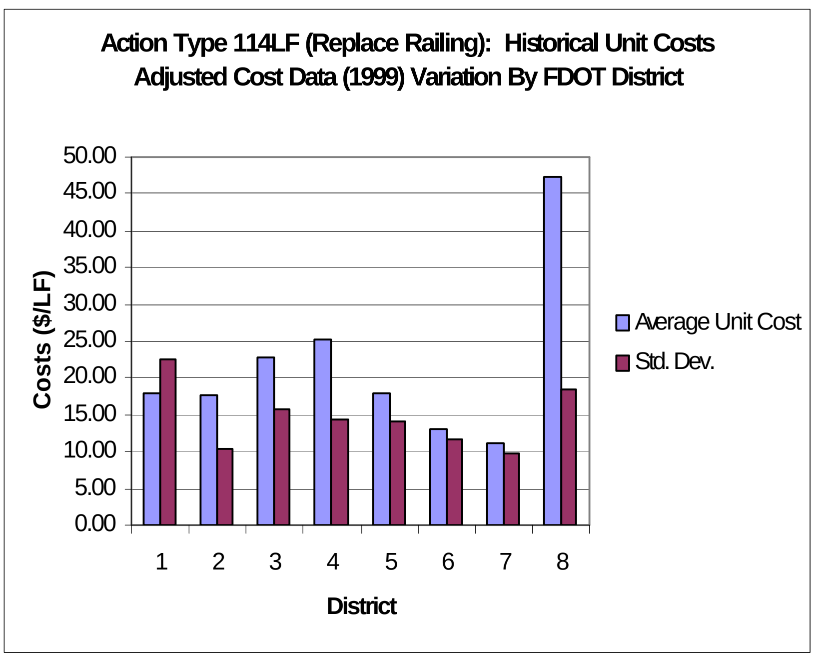
Element	State	Action	Final Cost
320 - P/S Conc Appr Slab	1 - No deterioration	1 - Miscellaneous Maint	200 (EA)
Relevant data in MMS and Akbar but in units of SF and SY respectively. Estimated based on anecdotal project evidence.			
321 - R/Conc Approach Slab	1 - No deterioration	1 - Miscellaneous Maint	200 (EA)
Based on anecdotal project evidence.			

Appendix B. Estimate of District Location Factors.



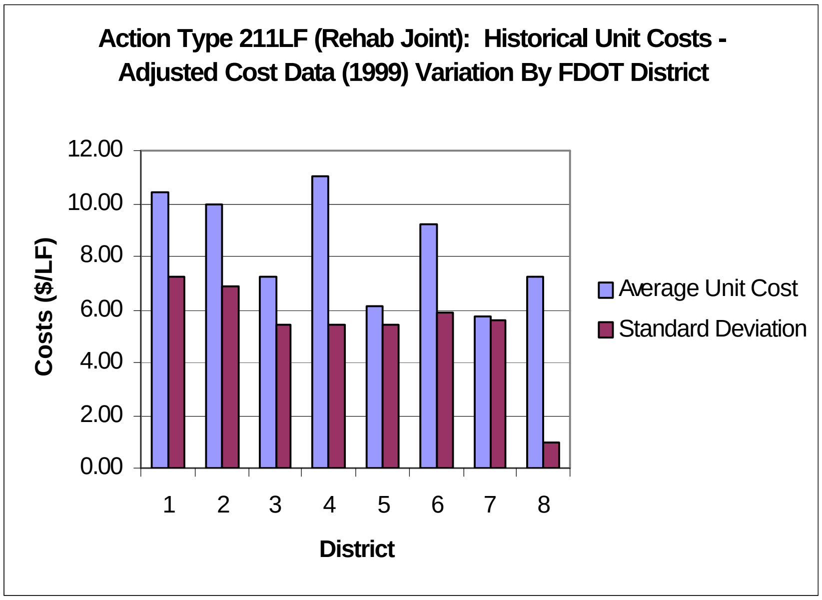
District	Location Factor
1	1.85
2	1.86
3	1.00
4	5.06
5	3.49
6	0.98
7	2.89
8	9.57

Figure B.1 Variation By District: Subcategory-Unit 112LF (Replace Joint Seal)



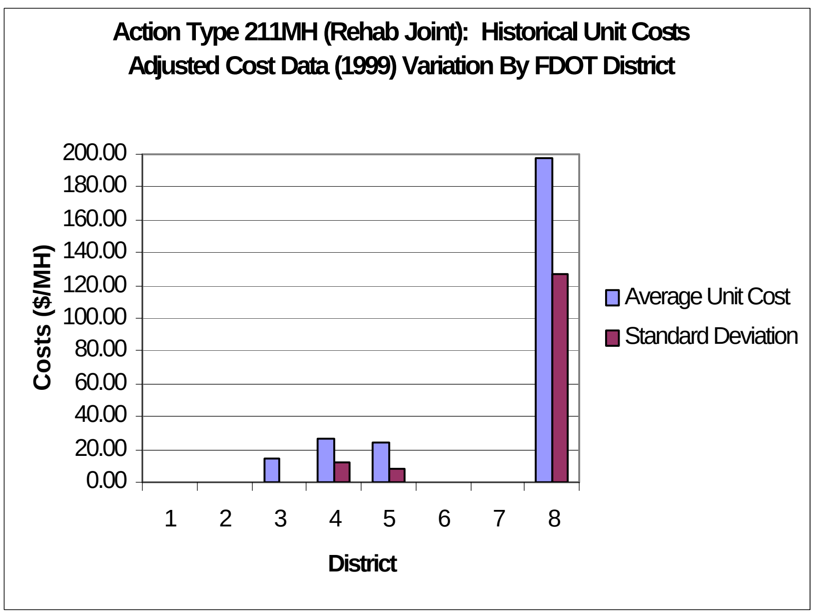
District	Location Factor
1	0.79
2	0.77
3	1.00
4	1.11
5	0.79
6	0.57
7	0.49
8	2.07

Figure B.2 Variation By District: Subcategory-Unit 114LF (Replace Railing)



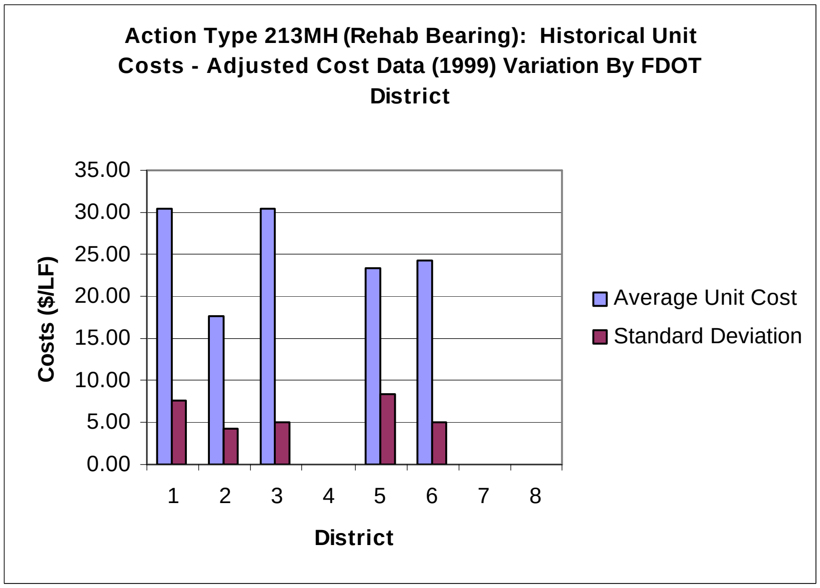
District	Location Factor
1	1.43
2	1.37
3	1.00
4	1.51
5	0.84
6	1.27
7	0.79
8	1.00

Figure B.3. Variation By District: Subcategory-Unit 211LF (Rehab Joint)



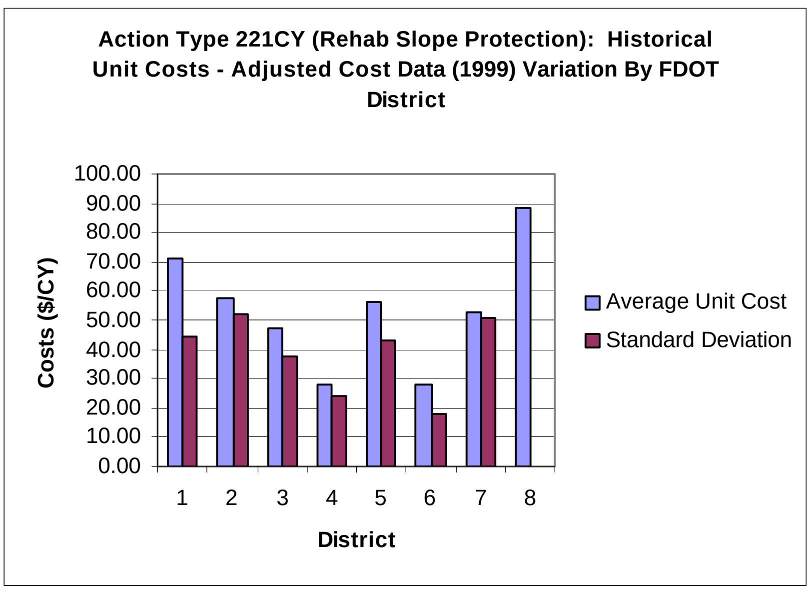
District	Location Factor
1	0.00
2	0.00
3	1.00
4	1.80
5	1.64
6	0.00
7	0.00
8	13.43

Figure B.4. Variation By District: Subcategory-Unit 211MH (Rehab Joint)



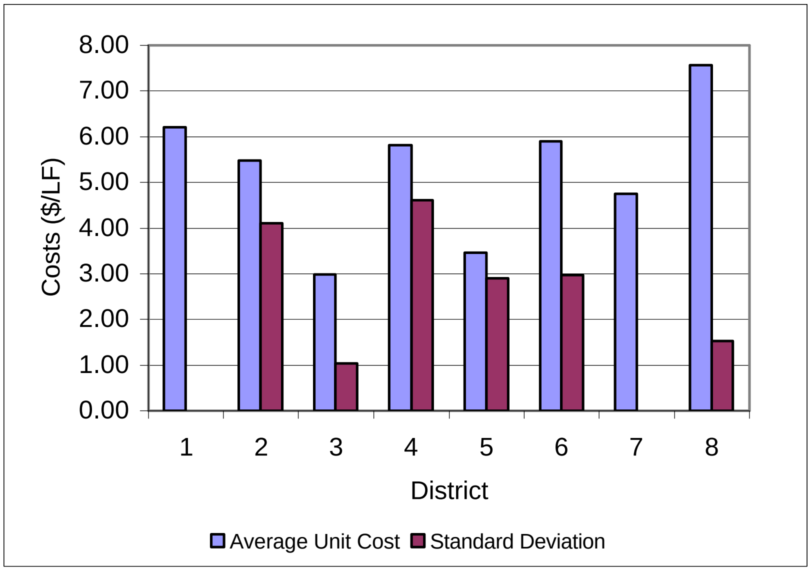
District	Location Factor
1	1.00
2	0.58
3	1.00
4	0.00
5	0.76
6	0.80
7	0.00
8	0.00

Figure B.5. Variation By District: Subcategory-Unit 213 MH (Rehab Bearing)



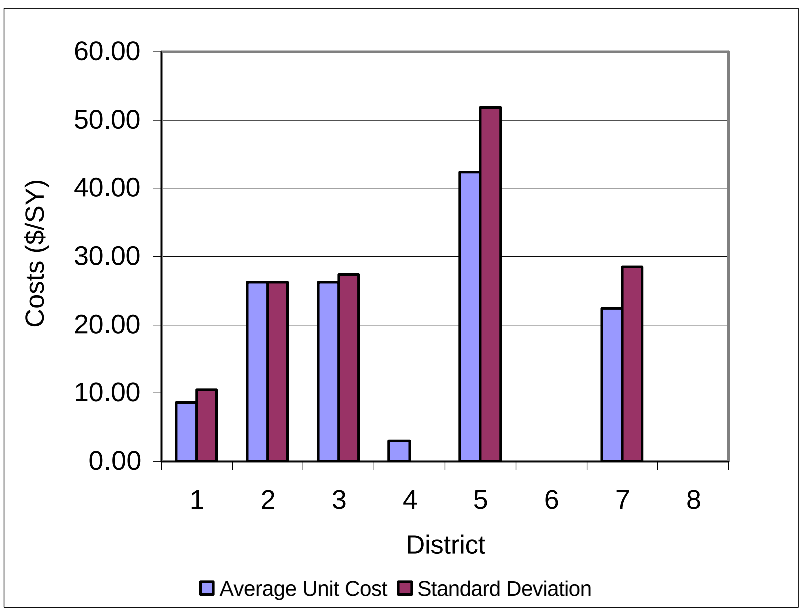
District	Location Factor
1	1.49
2	1.21
3	1.00
4	0.59
5	1.18
6	0.59
7	1.10
8	1.85

Figure B.6. Variation By District: Subcategory-Unit 221 CY (Rehab Slope Protection)



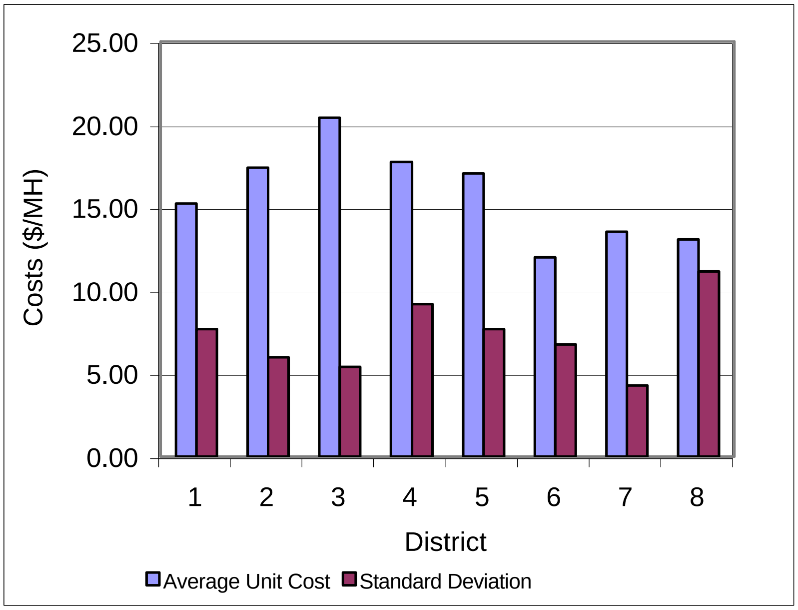
District	Location Factor
1	2.08
2	1.84
3	1.00
4	1.95
5	1.16
6	1.98
7	1.59
8	2.54

Figure B.7. Variation By District: Subcategory-Unit 221LF (Rehab Slope Protection)



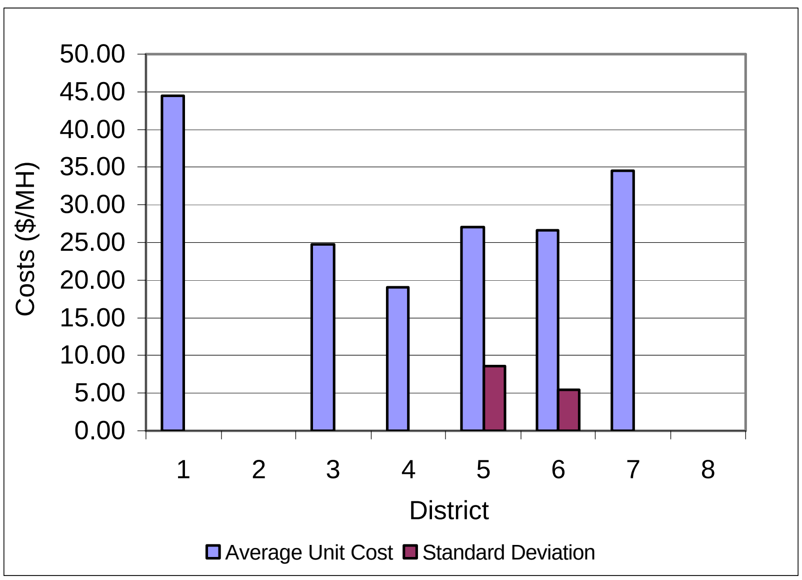
District	Location Factor
1	0.33
2	1.00
3	1.00
4	0.11
5	1.61
6	0.00
7	0.85
8	0.00

Figure B.8. Variation By District: Subcategory-Unit 221MH (Rehab Slope Protection)



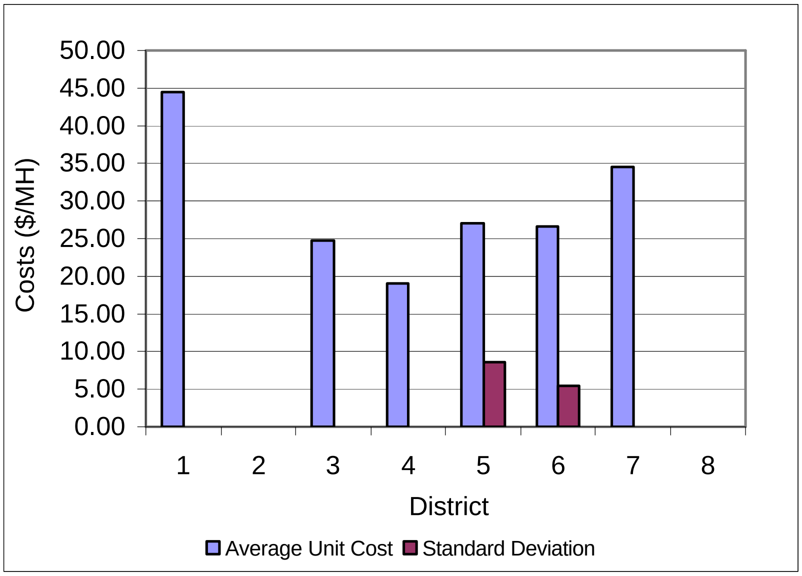
District	Location Factor
1	0.75
2	0.85
3	1.00
4	0.87
5	0.84
6	0.59
7	0.66
8	0.64

Figure B.9 Variation By District: Subcategory-Unit 221SY (Rehab Slope Protection)



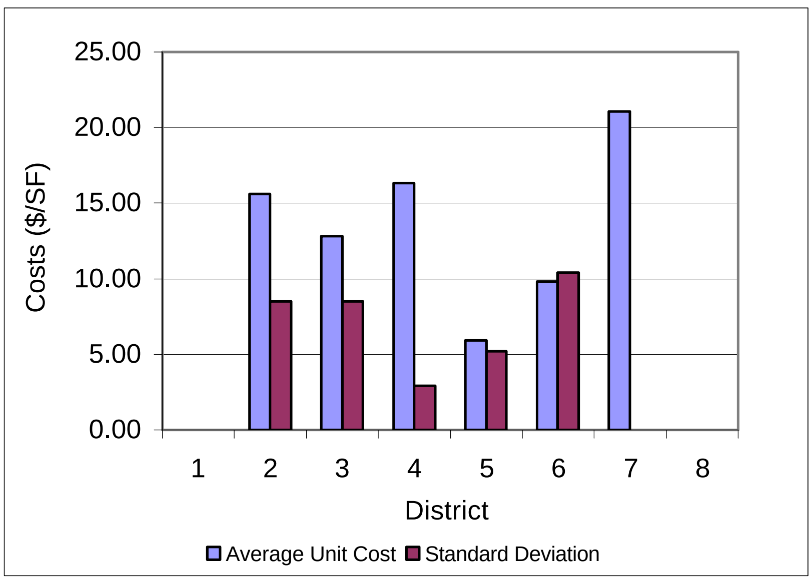
District	Location Factor
1	1.80
2	0.00
3	1.00
4	0.77
5	1.09
6	1.07
7	1.39
8	0.00

Figure B.10. Variation By District: Subcategory-Unit 222MH (Rehab Channel)



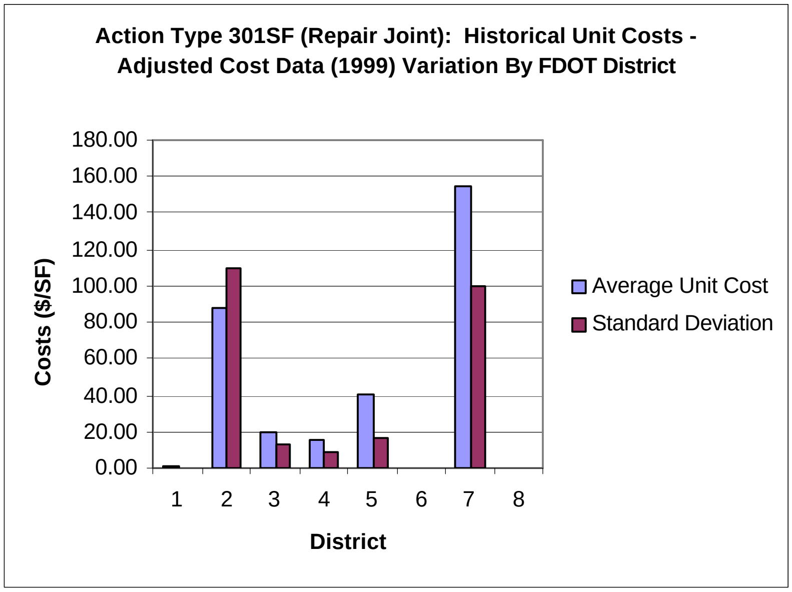
District	Location Factor
1	1.80
2	0.00
3	1.00
4	0.77
5	1.09
6	1.07
7	1.39
8	0.00

Figure B.11. Variation By District: Subcategory-Unit 231MH (Rehab Machinery)



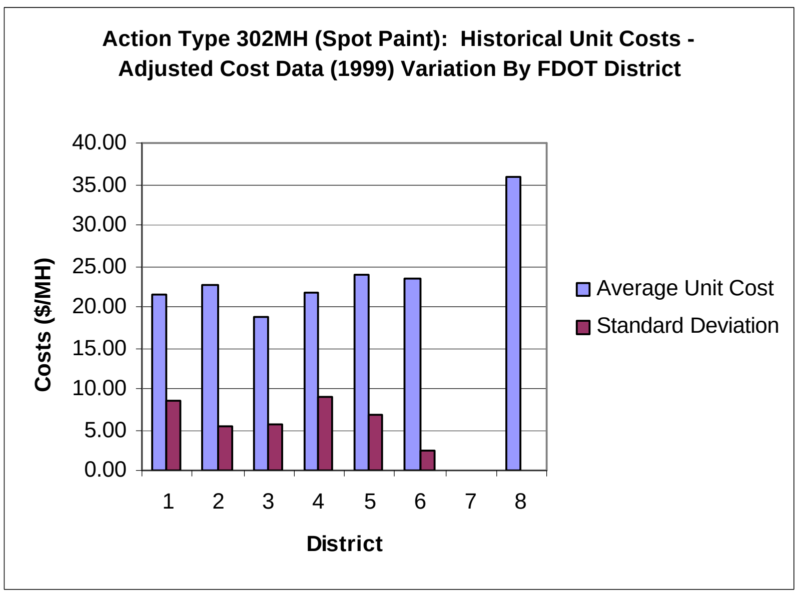
District	Location Factor
1	0.00
2	1.22
3	1.00
4	1.28
5	0.46
6	0.77
7	1.65
8	0.00

Figure B.12. Variation By District: Subcategory-Unit 246SF (Mudjacking)



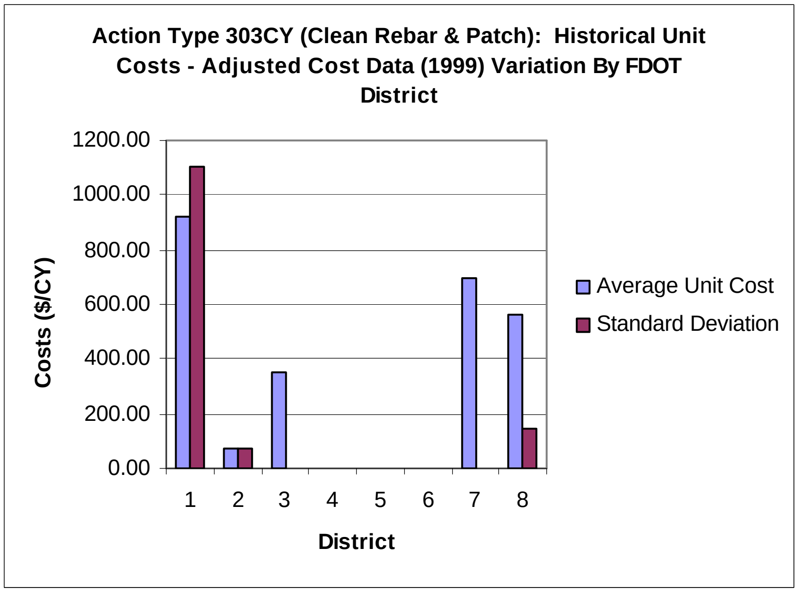
District	Location Factor
1	0.06
2	4.43
3	1.00
4	0.76
5	2.02
6	0.00
7	7.77
8	0.00

Figure B.13. Variation By District: Subcategory-Unit 301SF (Repair Joint)



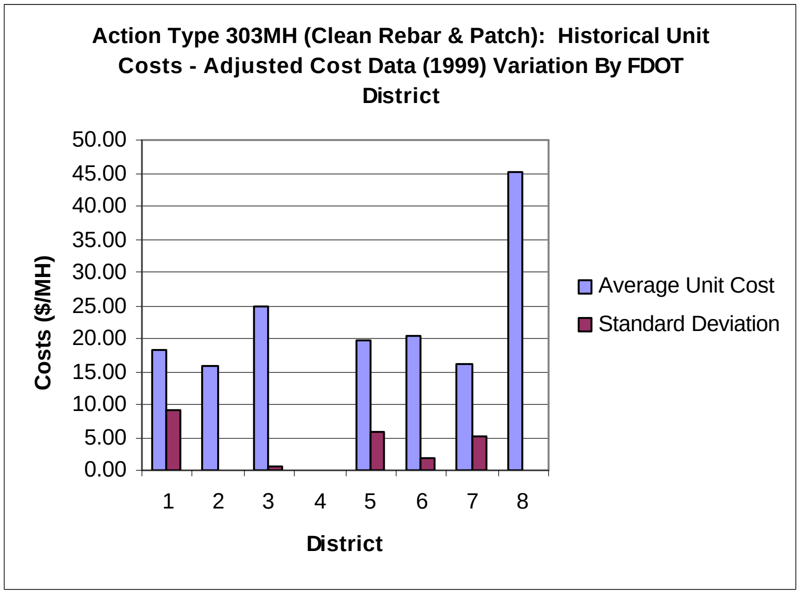
District	Location Factor
1	1.14
2	1.21
3	1.00
4	1.16
5	1.27
6	1.24
7	0.00
8	1.91

Figure B.14. Variation By District: Subcategory-Unit 302MH (Spot Paint)



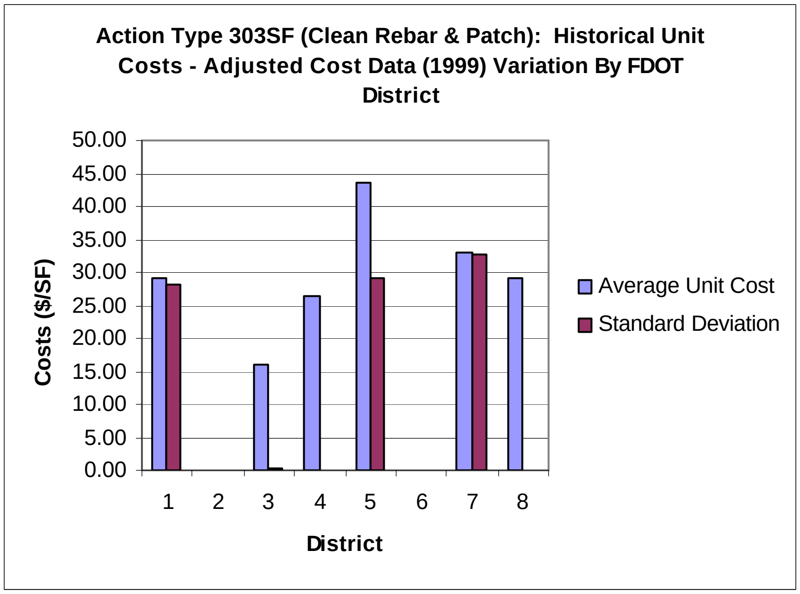
District	Location Factor
1	2.63
2	0.21
3	1.00
4	0.00
5	0.00
6	0.00
7	1.99
8	1.60

Figure B.15. Variation By District: Subcategory-Unit 303CY (Clean Rebar and Patch)



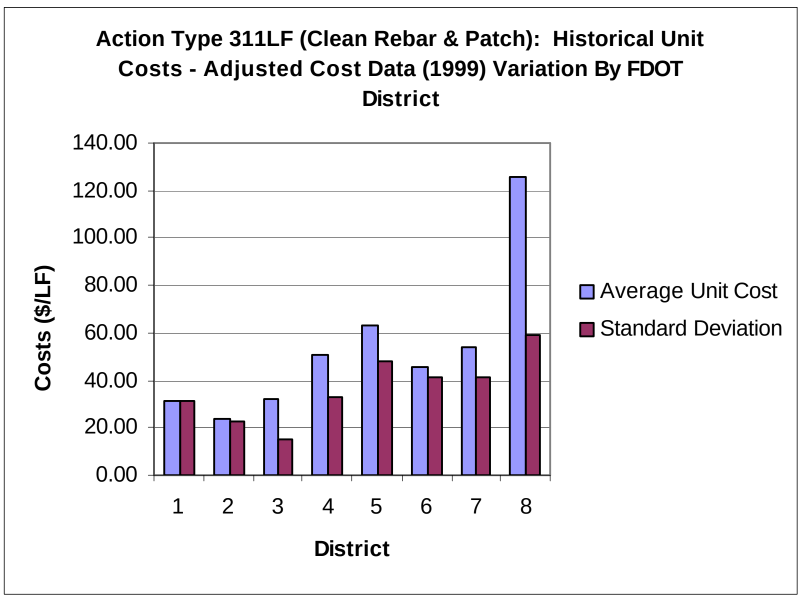
District	Location Factor
1	0.73
2	0.63
3	1.00
4	0.00
5	0.79
6	0.81
7	0.65
8	1.82

Figure B.16. Variation By District: Subcategory-Unit 303MH (Clean Rebar and Patch)



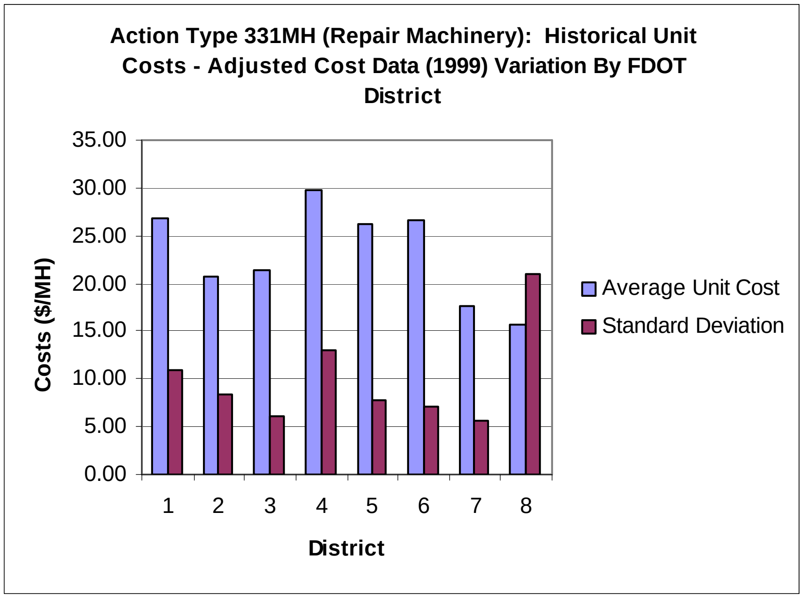
District	Location Factor
1	1.81
2	0.00
3	1.00
4	1.64
5	2.71
6	0.00
7	2.05
8	1.80

Figure B.17. Variation By District: Subcategory-Unit 303SF (Clean Rebar and Patch)



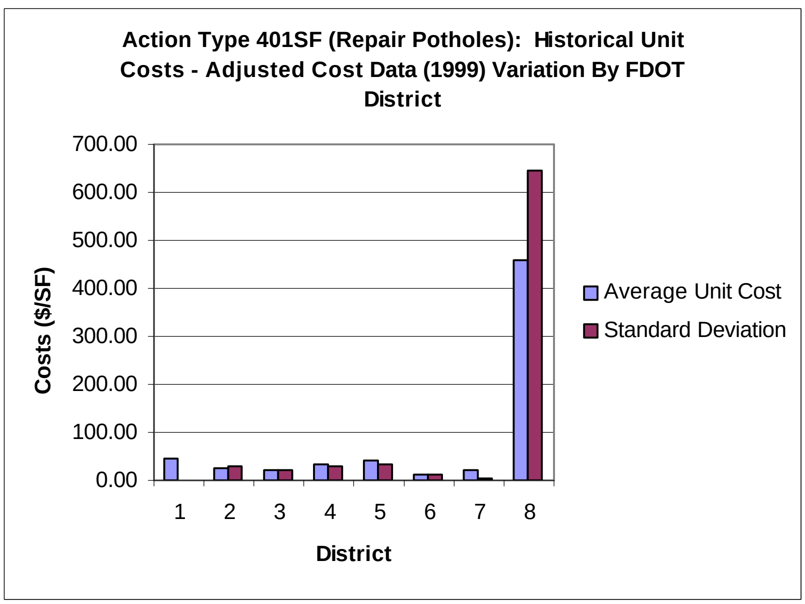
District	Location Factor
1	0.97
2	0.74
3	1.00
4	1.60
5	2.01
6	1.43
7	1.70
8	3.97

Figure B.18. Variation By District: Subcategory-Unit 311LF (Repair Joint)



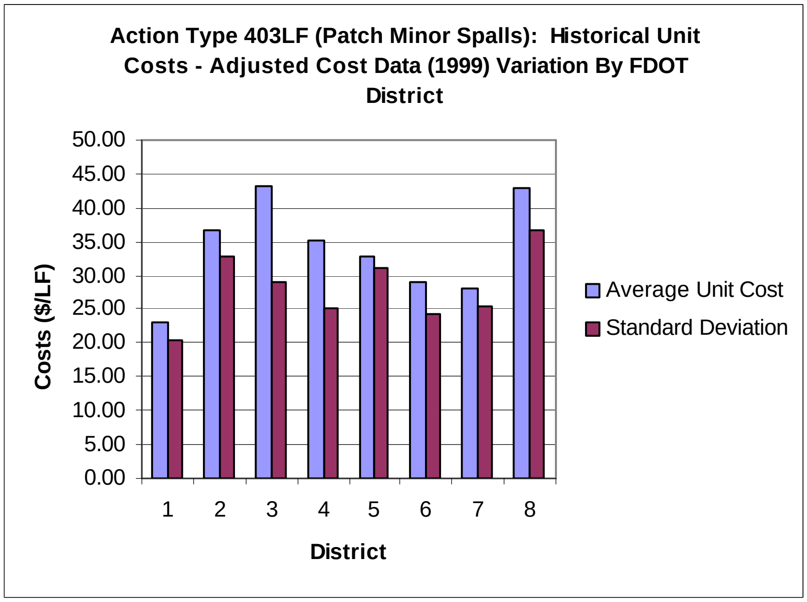
District	Location Factor
1	1.25
2	0.97
3	1.00
4	1.39
5	1.22
6	1.24
7	0.83
8	0.73

Figure B.19. Variation By District: Subcategory-Unit 331MH (Repair Machinery)



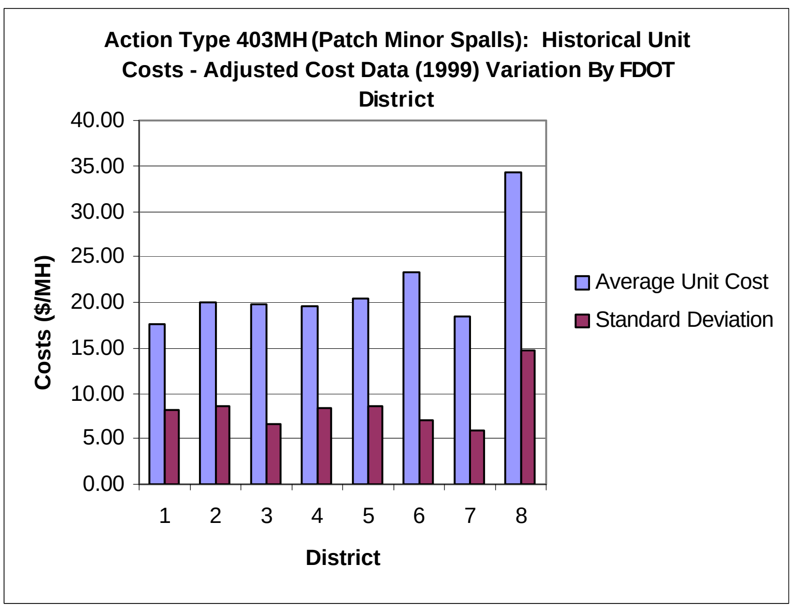
District	Location Factor
1	2.11
2	1.15
3	1.00
4	1.49
5	1.85
6	0.59
7	0.95
8	20.75

Figure B.20. Variation By District: Subcategory-Unit 401SF (Repair Potholes)



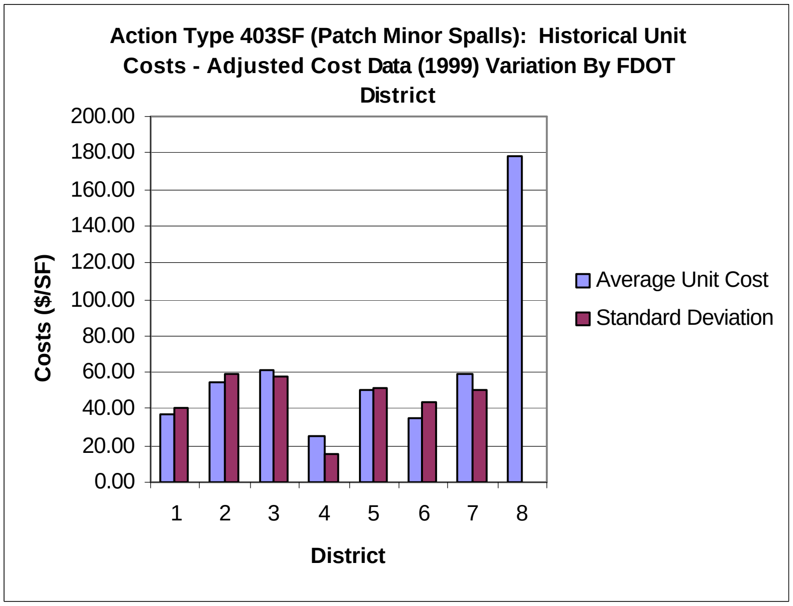
District	Location Factor
1	0.54
2	0.85
3	1.00
4	0.81
5	0.76
6	0.68
7	0.65
8	0.99

Figure B.21. Variation By District: Subcategory-Unit 403LF (Patch Minor Spalls)



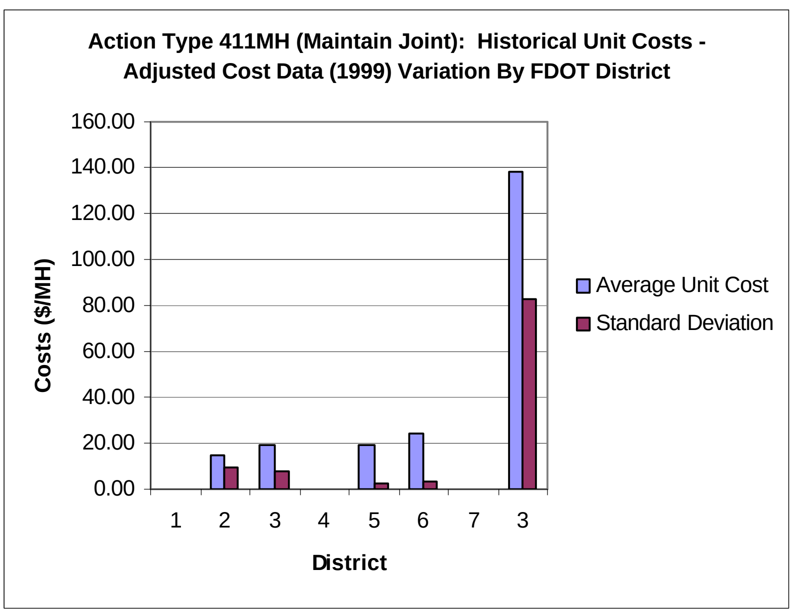
District	Location Factor
1	0.89
2	1.02
3	1.00
4	0.99
5	1.04
6	1.18
7	0.93
8	1.74

Figure B.22. Variation By District: Subcategory-Unit 403MH (Patch Minor Spalls)



District	Location Factor
1	0.61
2	0.90
3	1.00
4	0.42
5	0.84
6	0.57
7	0.97
8	2.93

Figure B.23. Variation By District: Subcategory-Unit 403SF (Patch Minor Spalls)



District	Location Factor
1	0.00
2	0.79
3	1.00
4	0.00
5	1.01
6	1.28
7	0.00
8	7.23

Figure B.24. Variation By District: Subcategory-Unit 411MH (Maintain Joint)

TABLE C1. AKBAR REFINED DATA SUMMARY

CONTRACT UNIT COSTS 1996 -- 1999 Akbar Data (ADJUSTED FOR INFLATION AND OUTLIERS)

ACTION_SUBCAT	ACT_SUBCAT-UNIT	UNIT	TOTAL QTY	TOTAL DOLLAR AMT.	UNIT PRICE AVERAGE	STD.DEV.	COEFF. OF VARIATION	NO. OF JOBS
112	**112LF**	**LF**	**42462**	**2,784,576.40**	**73.92**	**50.82**	**0.69**	**96**
114	114EA	EA	269	85,743.44	342.34	165.99	0.48	33
114	**114LF**	**LF**	**229500.6**	**3,187,757.85**	**28.78**	**29.03**	**1.01**	**73**
131	*131AS*	*AS*	*13*	*1,091,364.33*	*105,596.08*	*201,284.97*	*1.91*	*9*
131	**131EA**	**EA**	**786**	**2,499,138.28**	**40,551.21**	**58,782.59**	**1.45**	**29**
131	131LB	LB	35249931.9	38,679,395.59	3.00	2.73	0.91	115
131	131LF	LF	15433.24	1,201,276.75	104.55	120.36	1.15	13
131	131LS	LS	24	1,465,711.78	65,808.01	96,134.54	1.46	21
132	**132SF**	**SF**	**14380**	**466,774.70**	**44.05**	**20.56**	**0.47**	**3**
144	**144LF**	**LF**	**1208**	**161,090.79**	**131.54**	**55.38**	**0.42**	**5**
146	**146EA**	**EA**	**527**	**6,424,672.83**	**12,935.61**	**7,540.32**	**0.58**	**112**
204	**204LF**	**LF**	**16818**	**315,744.93**	**23.01**	**10.92**	**0.47**	**6**
213	**213EA**	**EA**	**41**	**53,222.46**	**3,453.31**	**4,031.12**	**1.17**	**2**
246	*246CY*	*CY*	*1470.85*	*497,637.98*	*406.08*	*108.44*	*0.27*	*18*
301	*301SY*	*SY*	*4756*	*206,672.35*	*43.46*			*1*
311	311CY	CY	1.13	14,167.34	12,537.47			1
311	**311LF**	**LF**	**614107**	**2,360,769.26**	**20.95**	**28.94**	**1.38**	**22**
400	**400EA**	**EA**	**149**	**547,540.04**	**3,193.50**	**2,811.77**	**0.88**	**4**
400	400LS	LS	32	202,454.93	7,861.15	8,158.98	1.04	16
400	*400SY*	*SY*	*7283*	*205,079.90*	*30.49*	*8.00*	*0.26*	*3*
401	401LF	LF	54567	244,742.26	25.65	29.47	1.15	11
401	*401SY*	*SY*	*721634.2*	*1,515,102.10*	*2.71*	*0.92*	*0.34*	*120*
403	403CF	CF	5651.65	1,490,440.37	696.78	985.61	1.41	18
403	403GA	GA	265	6,926.91	24.47	4.13	0.17	3
403	**403SF**	**SF**	**22961.6**	**249,288.97**	**41.47**	**32.40**	**0.78**	**7**
446	446LF	LF	3242	245,058.73	75.39	39.10	0.52	5
446	*446SF*	*SF*	*82233*	*350,143.12*	*5.61*	*2.39*	*0.43*	*11*
446	*446SY*	*SY*	*2418936.34*	*9,713,889.76*	*12.17*	*12.84*	*1.05*	*255*
							TOTALS	1012

311LF **DIRECT USE IN ACTION SUBCAT-UNIT**

400SY *INDIRECT USE IN ACTION SUBCAT-UNIT*

TABLE C2. DCP REFINED DATA SUMMARY						
CONTRACT UNIT COSTS 1993 -- 1999 DATA (ADJUSTED FOR INFLATION AND OUTLIERS)						
ACTION SUBCAT	**ACTION SUBCAT UNIT**	**UNIT**	**Avg. Unit Cost**	**STD. DEV.**	**C.V.**	**NO. OF DATA**
102	102LS	LS	115,186.89	223.25	0.00	2
102	*102M2*	*M2*	*73.33*	*46.19*	*0.63*	*3*
102	*102SF*	*SF*	*4.74*	*8.33*	*1.76*	*5*
111	**111LF**	**LF**	**281.61**			**1**
112	112CF	CF	541.00	186.84	0.35	5
112	112LF	LF	62.64	45.33	0.72	13
112	*112M1*	*M1*	*2,410.82*	*4,617.40*	*1.92*	*10*
112	112M3	M3	11,435.55			1
114	**114LF**	**LF**	**140.06**	**144.73**	**1.03**	**13**
114	*114M1*	*M1*	*176.82*	*114.33*	*0.65*	*3*
121	121CF	CF	20.43			1
121	121CY	CY	222.73	103.76	0.47	8
121	*121M2*	*M2*	*56.70*	*28.76*	*0.51*	*14*
121	121M3	M3	297.07	29.25	0.10	3
121	121MT	MT	74.22	19.30	0.26	6
121	*121SY*	*SY*	*86.33*	*23.51*	*0.27*	*14*
121	121TN	TN	183.17	112.21	0.61	10
123	**123EA**	**EA**	**596.64**	**378.33**	**0.63**	**6**
123	*123M1*	*M1*	*88.72*	*34.03*	*0.38*	*7*
131	*131AS*	*AS*	*411.73*	*353.08*	*0.86*	*36*
131	131CY	CY	16.02			1
131	**131EA**	**EA**	**161.32**	**225.28**	**1.40**	**824**
131	131KG	KG	20.00			1
131	131LB	LB	19.36			1
131	131LF	LF	3.09	3.25	1.05	41
131	131LO	LO	100.00			1
131	131LS	LS	1,131.81	1,589.26	1.40	11
131	131M1	M1	5.00	5.93	1.19	29
131	131PI	PI	1,006.33			1
132	132EA	EA	768.64	454.87	0.59	2
132	*132M2*	*M2*	*530.00*			*1*
141	141EA	EA	1,814.57			1
143	**143EA**	**EA**	**432.54**	**246.24**	**0.57**	**3**
143	*143LF*	*LF*	*3.93*			*1*
143	*143M1*	*M1*	*5.08*	*0.83*	*0.16*	*5*
143	143PI	PI	663.26			1
144	**144EA**	**EA**	**291.65**	**222.27**	**0.76**	**15**
144	*144M1*	*M1*	*127.00*	*31.11*	*0.24*	*2*
145	**145LF**	**LF**	**264.42**			**1**
146	146CY	CY	232.33	10.53	0.05	3
146	146M3	M3	492.00			1
146	*146SY*	*SY*	*55.73*	*10.83*	*0.19*	*2*
151	*151AS*	*AS*	*48,781.59*			*1*
151	**151EA**	**EA**	**739.89**	**794.82**	**1.07**	**180**
202	**202EA**	**EA**	**979.56**	**852.99**	**0.87**	**5**
203	203CF	CF	337.14	53.04	0.16	5
203	**203EA**	**EA**	**300.00**	**0.00**	**0.00**	**2**
203	**203LF**	**LF**	**682.14**	**101.30**	**0.15**	**2**
203	*203M1*	*M1*	*837.60*	*57.12*	*0.07*	*5*
203	203M3	M3	10,329.44	620.28	0.06	2
204	**204LF**	**LF**	**20.69**			**1**
204	*204M1*	*M1*	*65.00*	*0.00*	*0.00*	*2*
204	204M3	M3	2,152.02	838.85	0.39	4
204	204MB	MB	8,435.77	5,977.23	0.71	7
211	**211LF**	**LF**	**18.74**	**13.67**	**0.73**	**13**
211	*211M1*	*M1*	*55.63*	*89.72*	*1.61*	*4*
221	221CY	CY	49.99	52.33	1.05	5
221	*221M2*	*M2*	*3.42*	*2.92*	*0.85*	*3*
221	221M3	M3	11.41			1
221	*221SY*	*SY*	*28.97*	*10.00*	*0.35*	*11*

	TABLE C2. DCP REFINED DATA SUMMARY					
	CONTRACT UNIT COSTS 1993 -- 1999 DATA (ADJUSTED FOR INFLATION AND OUTLIERS)					
ACTION SUBCAT	**ACTION SUBCAT UNIT**	**UNIT**	**Avg. Unit Cost**	**STD. DEV.**	**C.V.**	**NO. OF DATA**
303	303CF	CF	529.79	462.38	0.87	20
303	303CY	CY	935.21	703.66	0.75	9
303	303M3	M3	3,281.81	6,490.07	1.98	11
311	**311LF**	**LF**	**36.60**	**12.49**	**0.34**	**4**
331	**331EA**	**EA**	**102.30**	**100.54**	**0.98**	**17**
331	331LO	LO	175.86	79.91	0.45	10
331	331LS	LS	1,745.45	1,208.60	0.69	10
331	331LU	LU	35.00	26.48	0.76	7
331	331PM	PM	13.83	11.89	0.86	3
400	*400M2*	*M2*	*2.05*	*1.31*	*0.64*	*10*
400	**400SF**	**SF**	**0.37**	**0.26**	**0.71**	**17**
403	**403LF**	**LF**	**36.70**	**6.16**	**0.17**	**7**
403	*403M1*	*M1*	*109.80*	*13.85*	*0.13*	*2*
403	**403SF**	**SF**	**30.73**	**38.31**	**1.25**	**13**
422	*422AC*	*AC*	*125.08*	*163.87*	*1.31*	*43*
422	422CY	CY	21.84			1
422	422EA	EA	386.36	1,084.83	2.81	83
422	*422HA*	*HA*	*212.56*	*322.93*	*1.52*	*22*
422	422KM	KM	660.68	1,284.82	1.94	8
422	422LF	LF	4.58	3.69	0.81	33
422	422M1	M1	9.63	5.20	0.54	12
422	*422M2*	*M2*	*0.40*			*1*
422	422PM	PM	168.48	162.70	0.97	12
423	423M2	M2	50.00			1
431	431AS	AS	216.80	262.44	1.21	5
431	**431EA**	**EA**	**272.97**	**199.86**	**0.73**	**4**
431	*431LO*	*LO*	*85.97*	*93.82*	*1.09*	*201*
446	446LF	LF	4.64	5.55	1.20	6
446	446M1	M1	14.96	2.86	0.19	3
446	446MT	MT	307.08	50.90	0.17	2
446	446TN	TN	918.56	87.07	0.09	2
					total	1941
	311LF	**DIRECT USE IN ACTION SUBCAT-UNIT**				
	400SY	*INDIRECT USE IN ACTION SUBCAT-UNIT*				

	TABLE C3. MMS REFINED DATA SUMMARY					
	MR&R UNIT COSTS 1993 -- 1999 DATA (ADJUSTED FOR INFLATION AND OUTLIERS)					
ACTION_SUBCAT	ACT_SUBCAT_UNIT	Units	99_Avg. Unit Cost	Std. Dev.	C.V.	No. of Data
101	101MH	MH	14.74			1
101	101SF	SF	117.09			1
102	102MH	MH	26.70			1
102	102SF	SF	20.91			1
111	111LF	LF	12.54	9.08	0.72	25
111	111SF	SF	6.90			1
111	111T	T	332.00			1
112	112LF	LF	21.50	30.64	1.43	164
112	112MH	MH	22.67	4.78	0.21	6
112	112SF	SF	530.84	749.08	1.41	2
113	113MH	MH	32.23	7.48	0.23	7
114	114LF	LF	18.46	13.84	0.75	130
114	114MH	MH	20.75	6.63	0.32	28
114	114SF	SF	11.13	6.13	0.55	3
121	121CY	CY	818.33			1
121	121MH	MH	64.48	40.20	0.62	21
123	123LF	LF	68.52	62.68	0.91	2
123	123MH	MH	18.00	4.24	0.24	8
123	123SF	SF	37.72			1
131	131MH	MH	20.99	5.50	0.26	60
131	131SF	SF	15.62			1
141	141MH	MH	29.64	17.90	0.60	2
144	144MH	MH	21.39	7.61	0.36	29
151	151EACH	EACH	40.81	57.35	1.41	3
151	151LF	LF	16.39			1
151	151MH	MH	26.07	12.55	0.48	31
151	151UNITS	UNITS	28.65	19.72	0.69	124
201	201MH	MH	24.94	17.48	0.70	3
201	201SF	SF	37.80	12.82	0.34	4
202	202CF	CF	138.83			1
202	202MH	MH	23.49	4.83	0.21	7
203	203MH	MH	22.36	2.12	0.09	2
204	204LF	LF	46.26	49.44	1.07	2
204	204MH	MH	24.35	17.23	0.71	13
211	211LF	LF	8.11	6.23	0.77	564
211	211MH	MH	150.19	133.10	0.89	123
211	211SF	SF	303.42	584.94	1.93	18
211	211T	T	107.27	146.70	1.37	2
213	213MH	MH	23.61	7.40	0.31	60
221	221A	A	892.14			1
221	221CF	CF	25.70	21.68	0.84	8
221	221CY	CY	48.02	42.84	0.89	128
221	221LF	LF	6.60	3.03	0.46	231
221	221MH	MH	68.90	94.68	1.37	821
221	221SF	SF	84.56	79.25	0.94	7
221	221SY	SY	23.75	26.85	1.13	86
221	221T	T	216.87	244.39	1.13	4
222	222CY	CY	105.88	83.10	0.78	200
222	222LF	LF	25.79	39.46	1.53	4
222	222MH	MH	16.91	7.27	0.43	377
222	222SF	SF	20.91	10.93	0.52	3
222	222SY	SY	12.93	14.66	1.13	95
223	223CY	CY	635.34	973.18	1.53	5
223	223LF	LF	20.00	19.19	0.96	18
223	223MH	MH	83.93	113.54	1.35	30
223	223SF	SF	28.02	31.24	1.11	13
223	223SY	SY	6.16			1
223	223T	T	286.07	114.86	0.40	2
231	231MH	MH	27.46	8.50	0.31	30

	TABLE C3. MMS REFINED DATA SUMMARY					
	MR&R UNIT COSTS 1993 -- 1999 DATA (ADJUSTED FOR INFLATION AND OUTLIERS)					
ACTION_SUBCAT	ACT_SUBCAT_UNIT	Units	99_Avg. Unit Cost	Std. Dev.	C.V.	No. of Data
246	246CF	CF	32.85	27.39	0.83	14
246	246CY	CY	79.09	67.28	0.85	5
246	246MH	MH	22.81	15.10	0.66	6
246	246SF	SF	12.91	7.62	0.59	24
246	246SY	SY	64.32	112.58	1.75	5
246	246T	T	185.18	116.43	0.63	43
301	301CY	CY	1,063.13			1
301	301MH	MH	22.66	4.11	0.18	13
301	301SF	SF	74.08	88.56	1.20	14
301	301T	T	206.53	113.43	0.55	12
302	302LF	LF	18.63	11.16	0.60	6
302	302MH	MH	22.30	6.23	0.28	131
302	302SF	SF	28.62	13.98	0.49	21
302	302UNITS	UNITS	11.95			1
303	303CY	CY	328.36	459.18	1.40	14
303	303LF	LF	42.24	45.83	1.08	29
303	303MH	MH	18.96	7.16	0.38	132
303	303SF	SF	33.10	28.16	0.85	41
303	303T	T	715.80			1
311	311LF	LF	52.49	48.30	0.92	261
311	311MH	MH	116.84	133.49	1.14	6
311	311SF	SF	25.88	34.43	1.33	8
331	331MH	MH	26.78	11.94	0.45	1023
331	331UNITS	UNITS	29.63	10.66	0.36	5
400	400CBM	CBM	175.89			1
400	400CY	CY	3,884.87			1
400	400LF	LF	11.31	14.16	1.25	3
400	400MH	MH	17.90	7.60	0.42	130
400	400SF	SF	5.04	5.53	1.10	115
400	400UNITS	UNITS	19.43			1
401	401CBM	CBM	111.81			1
401	401EACH	EACH	8.73	12.46	1.43	7
401	401LF	LF	8.23	4.78	0.58	48
401	401LM	LM	70.02	39.20	0.56	3
401	401MH	MH	21.20	9.93	0.47	28
401	401SF	SF	24.24	26.03	1.07	160
401	401T	T	219.59	162.13	0.74	27
402	402LF	LF	2.86	1.28	0.45	3
402	402MH	MH	20.99	6.96	0.33	26
402	402SF	SF	914.08			1
402	402UNITS	UNITS	23.95			1
403	403CY	CY	363.56	330.51	0.91	66
403	403LF	LF	32.11	28.32	0.88	336
403	403MH	MH	20.31	8.05	0.40	1413
403	403SF	SF	49.63	52.46	1.06	441
403	403T	T	4,249.96	5,578.41	1.31	2
411	411CY	CY	290.93			1
411	411LF	LF	3.89	2.91	0.75	72
411	411MH	MH	43.68	58.73	1.34	20
411	411SF	SF	8.15	9.59	1.18	54
413	413MH	MH	19.19	7.86	0.41	33
422	422A	A	255.42	259.98	1.02	48
422	422CBM	CBM	210.93			1
422	422CY	CY	172.18	138.83	0.81	8
422	422G	G	4.30	1.99	0.46	56
422	422LF	LF	3.27	2.29	0.70	18
422	422MH	MH	16.91	8.08	0.48	640
422	422SF	SF	31.40	28.56	0.91	6
422	422UNITS	UNITS	19.05			1

	TABLE C3. MMS REFINED DATA SUMMARY					
	MR&R UNIT COSTS 1993 -- 1999 DATA (ADJUSTED FOR INFLATION AND OUTLIERS)					
ACTION_SUBCAT	**ACT_SUBCAT_UNIT**	**Units**	**99_Avg. Unit Cost**	**Std. Dev.**	**C.V.**	**No. of Data**
423	423CBM	CBM	972.97	1,080.48	1.11	11
423	423CY	CY	179.11	140.17	0.78	3
423	423EM	EM	179.30			1
423	423LF	LF	8.73	6.49	0.74	11
423	*423MH*	*MH*	*19.00*	*8.14*	*0.43*	*64*
423	423SF	SF	9.94	9.59	0.96	413
431	*431MH*	*MH*	*19.94*	*3.78*	*0.19*	*30*
446	446CF	CF	14.44	13.75	0.95	2
446	446CY	CY	860.83			1
446	446LF	LF	8.43	6.38	0.76	54
446	*446MH*		*23.00*	*10.31*	*0.45*	*48*
446	*446SF*	*SF*	*22.47*	*28.04*	*1.25*	*250*
446	446T	T	385.63	349.86	0.91	20
					TOTALS	10014
	311LF	**DIRECT USE IN ACTION SUBCAT-UNIT**				
	331MH	*INDIRECT USE IN ACTION SUBCAT-UNIT*				
		C.V. above 1.00				

TABLE C.4 Action Subcategory-Unit 112LF (Replace Joint Seal) Model for Pontis Elements CES Data						
Groups	**Count**	**Average**	**CV**	**N****	**Error (d) in Mean Estimate***	**C.I.**
TYPE 1: EXPANSION JOINT SEAL (COMPRESSION ELAST)	20	41.95	0.54	80	10.01	$31.95 to $51.96
TYPE 2: EXPANSION JOINT SEAL (STRIP ELAST)	51	85.00	0.54	319	12.50	$72.50 to $97.51
TYPE 3: EXPANSION JOINT SEAL (MODULAR)	6	418.85	0.43	4987	144.14	$274.70 to $562.99
TYPE 4: ELASTIC PREFORMED JOINT SEAL	23	64.21	0.68	294	17.89	$46.32 to $82.10
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	711310.07	3	237103.36	71.5613	0.0000	2.6994
Within Groups	318076.00	96	3313.29			
Total	1029386.07	99				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.5 Action Subcategory-Unit 114LF (Replace Railing) Model for Pontis Elements CES Data						
Groups	**Count**	**Average**	**CV**	**N****	**Error (d) in Mean Estimate***	**C.I.**
TYPE 1: HANDRAIL CONC	32	53.29	0.54	126	9.91	$43.38 to $63.19
TYPE 2: HANDRAIL ALUMINUM (REMOVE & REINSTALL)	1	32.60	0.00	0	0.00	N/A
TYPE 3: GUARDRAIL (BRIDGE)	3	69.76	1.53	1753	120.86	$-51.10 to $190.61
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1218.78	2	609.39	0.4177	0.6620	3.2849
Within Groups	48149.65	33	1459.08			
Total	49368.43	35				

TABLE C.6 Action Subcategory-Unit 131EA (Replace Machinery) Model for Pontis Elements CES Data						
Groups	**Count**	**Average**	**CV**	**N****	**Error (d) in Mean Estimate***	**C.I.**
TYPE 1: MACHINERY & CASTINGS(F&I)	3	33822.57	0.84	125494459	32338.63	$1483.93 to $66161.20
TYPE 2: EMERGENCY GENERATOR	5	41701.27	0.30	23798500	10908.37	$30792.90 to $52609.64
TYPE 3: MACHINERY & CASTINGS(F&I)	3	120909.76	0.97	2098926970	132253.76	$-11344.01 to $253163.52
TYPE 4: LOGIC CONTROLLER	7	27998.64	0.71	61170793	14780.63	$13218.00 to $42779.27
TYPE 5: CONTROL CONSOLE(F&I)	9	93959.66	1.09	1625010962	67185.71	$26773.95 to $161145.36
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32078355889	4	8019588972	1.5136	0.2327	2.8167
Within Groups	1.1656E+11	22	5298203552			
Total	1.48639E+11	26				

TABLE C.7 Action Subcategory-Unit 131LS (Replace Machinery) Model for Pontis Elements CES Data						
Groups	**Count**	**Average**	**CV**	**N****	**Error (d) in Mean Estimate***	**C.I.**
TYPE 9: MACHINERY & CASTINGS	1	428655.88	0.00	0	0.00	$428655.88 to $428655.88
TYPE 11: MACHINERY & CASTINGS(F&I)	1	638735.90	0.00	0	0.00	$638735.90 to $638735.90
TYPE 10: NAVIGATION LIGHTS	11	31969.45	0.58	53601141	11037.24	$20932.20 to $43006.69
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4E+11	2	2E+11	642.265	0.000	4.103
Within Groups	3E+09	10	3E+08			
Total	5E+11	12				

TABLE C.8 Action Subcategory-Unit 403SF (Patch Minor Spalls) Model for Pontis Elements CES Data						
Groups	**Count**	**Average**	**CV**	**N****	**Error (d) in Mean Estimate***	**C.I.**
PATCHING PORTLAND CEMENT CONCRETE PAVEMENT	5	57.44	0.37	70	18.75	$38.69 to $76.20
CONC SURFACES CLEANING & SEALING	2	1.52	0.82	0	1.73	$-0.20 to $3.25
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4467.56	1	4467.56	12.1916	0.0174	6.6079
Within Groups	1832.22	5	366.44			
Total	6299.78	6				

TABLE C.9 Action Subcategory-Unit 112LF (Replace Joint Seal) Model for Pontis Elements DCP Data						
Groups	**Count**	**Average**	**C.V.**	**Required N****	**Error (d) in Mean Estimate***	**C.I.**
(A460 7 2) - EXPANSION JOINT SEAL (COMPRESSION ELAST)	6	55.22	1.20	674	52.98	$2.24 to $108.20
(A460 8101) - ELASTIC PREPRMD JOINT SEAL (PLYMRIC NOSING)	2	92.26	0.20	52	25.42	$66.84 to $117.68
(A460 20 4) - ELASTOMERIC STRUCTURAL JOINT SEAL REPLCMT	5	59.69	0.14	10	7.24	$52.45 to $66.93
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	2129.18	2	1064.59	0.4725	0.6367	4.1028
Within Groups	22533.03	10	2253.30			
Total	24662.21	12				
* 95% Confidence Level						
** Actual number of data points. Based on tolerance of +/- 5						

TABLE C.10 Action Subcategory-Unit 112M1 (Replace Joint Seal) Model for Pontis Elements DCP Data						
Groups	**Count**	**Average**	**CV**	**Required N****	**Error (d) in Mean Estimate***	**C.I.**
EXPANSION JOINT SEAL (STRIP ELASTOMERIC)	5	4588.52	1.31	5547630	5266.70	$-678.18 to $9855.22
ELASTIC PREFORMED JOINT SEAL	2	181.63	0.98	4869	246.71	$-65.08 to $428.34
ELASTOMERIC STRUCTURAL JOINT SEAL REPLACEMENT	3	267.45	0.27	775	80.35	$187.10 to $347.80
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	47432543.85	2	23716271.92	1.1493	0.3702	4.7374
Within Groups	144451117.1	7	20635873.87			
Total	191883660.9	9				
* 95% Confidence Level						
** Actual number of data points. Based on tolerance of +/- 5						

TABLE C.11 Action Subcategory-Unit 114LF (Replace Railing) Model for Pontis Elements DCP Data

Groups	Count	Average	C.V.	Required N**	Error (d) in Mean Estimate*	C.I.
CONC HANDRAIL	9	187.41	0.81	3532	99.05	$88.36 to $286.46
HANDRAIL ALUMINUM	3	38.89	0.71	118	31.33	$7.56 to $70.22
GUARDRAIL	1	17.37	0.00	0	0.00	N/A

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	65939.76806	2	32969.88403	1.7781	0.2184	4.1028
Within Groups	185421.45	10	18542.14454			
Total	251361.21	12				

* 95% Confidence Level

** Actual number of data points. Based on tolerance of +/- 5

TABLE C.12 Action Subcategory-Unit 121M2 (Replace Slope Protection) Model for Pontis Elements DCP Data						
Groups	**Count**	**Average**	**CV**	**Required N****	**Error (d) in Mean Estimate***	**C.I.**
DITCH PAVEMENT CONCRETE	9	72.20	1.23	1203	57.80	$14.40 to $130.00
SLOPE PAVEMENT CONCRETE	5	82.34	0.22	50	15.74	$66.60 to $98.08
RIPRAP FABRIC-FORMED CONCRETE	1	32.36	0	0	0.00	N/A
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	2093.14	2.00	1046.57	0.1965	0.8242	3.8853
Within Groups	63906.86	12.00	5325.57			
Total	66000.00	14.00				
* 95% Confidence Level						
** Actual number of data points. Based on tolerance of +/- 5						

TABLE C.13 Action Subcategory-Unit 121SY (Replace Slope Protection) Model for Pontis Elements DCP Data						
Groups	**Count**	**Average**	**CV**	**Required N****	**Error (d) in Mean Estimate***	**C.I.**
RIP-RAP (CONCRETE)	3	63.46	0.51	158	36.30	$27.16 to $99.76
CONC SLOPE PAVT	11	92.57	0.19	48	10.45	$82.12 to $103.02
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	1997.43	1	1997.429789	4.621	0.05267965	4.747
Within Groups	5187.19	12	432.27			
Total	7184.62	13				
* 95% Confidence Level						
** Actual number of data points. Based on tolerance of +/- 5						

TABLE C.14 Action Subcategory-Unit 123M1 (Replace Drainage System) Model for Pontis Elements DCP Data

Groups	Count	Average	CV	Required N**	Error (d) in Mean Estimate*	C.I.
UNDERDRAIN, TYPE I	1	80.93	0.00	0	0.00	N/A
UNDERDRAIN, TYPE V	2	132.72	0.05	6	8.83	$123.89 to $141.55
UNDERDRAIN OUTLET PIPE	4	68.68	0.31	70	20.92	$47.76 to $89.60

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5539.54	2	2769.77	7.8708	0.0411	6.9443
Within Groups	1407.62	4	351.91			
Total	6947.16	6				

* 95% Confidence Level

** Actual number of data points. Based on tolerance of +/- 5

TABLE C.15 Action Subcategory-Unit 131AS (Replace Machinery) Model for Pontis Elements DCP Data

Groups	Count	Average	CV	Required N**	Error (d) in Mean Estimate*	C.I.
LOOP ASSEMBLY	17	756.09	0.23	4666	82.83	$673.26 to $838.92
CNTRL ASSEM ACT SS F&I(D-4,1 PRE PLN)	1	13150.88	0.00	0	0.00	N/A
BALLAST ASSEMBLY	19	103.62	0.55	494	25.50	$78.12 to $129.12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	161719447	2	80859723.74	5056.80	8.4522E-43	3.27590044
Within Groups	543670	34	15990.30			
Total	162263118	36				

* 95% Confidence Level

** Actual number of data points. Based on tolerance of +/- 5

TABLE C.16 Action Subcategory-Unit 131EA (Replace Machinery) Model for Pontis Elements DCP Data						
Groups	Count	Average	CV	Required N**	Error (d) in Mean Estimate*	C.I.
CONTROLLER CABINET	1	500.00	0.00	0	0.00	N/A
PULL & JUNCTION BOXES	66	155.89	1.22	5573	45.94	$109.94 to $201.83
MAST ARM COMB,STD	19	248.59	1.05	10379	116.86	$131.72 to $365.45
DETECTOR PEDEST	1	150.00	0.00	0	0.00	N/A
LUMINAIRE & BRACKET ARM	83	201.16	0.02	6442	44.05	$157.11 to $245.21
LOAD CENTER	167	201.52	1.85	21303	56.47	$145.05 to $257.99
SURGE PROTECTOR	17	21.76	0.43	13	4.42	$17.35 to $26.18
REFRACTOR	44	46.62	0.74	182	10.18	$36.44 to $56.80
QUICK DISCONNECT PLUG	29	109.72	0.45	372	17.91	$91.81 to $127.63
FRANGIBLE BASE FOR LIGHT POLE	45	125.07	0.92	2051	33.76	$91.31 to $158.82
SYS CNTRL EQUIP	10	183.11	0.26	344	29.31	$153.81 to $212.42
SYS AUX	67	372.82	0.95	19471	85.24	$287.58 to $458.05
CLOSED CIRCUIT TV	18	806.90	1.85	343388	690.60	$116.30 to $1497.50
HIGH MAST PARTS	81	346.13	2.83	147414	213.30	$132.83 to $559.44
BALLAST	13	76.85	0.36	121	15.24	$61.61 to $92.09
LAMP	68	42.63	0.77	165	7.78	$34.85 to $50.41
LUMINAIRE STARTER BOARD	5	32.38	0.32	16	9.03	$23.35 to $41.42
GROUND ROD	9	28.93	0.34	15	6.40	$22.53 to $35.33
FUSE	19	9.66	0.57	5	2.47	$7.19 to $12.14
DUMMY SLUG	9	1.73	0.99	0	1.12	$0.61 to $2.85
FUSE HOLDER	37	16.11	0.40	6	2.07	$14.04 to $18.17
LOAD BREAK	10	220.51	0.90	6015	122.63	$97.87 to $343.14
TRANSFORMER	3	1748.93	0.78	286393	1544.87	$204.06 to $3293.80
VALVE BOX	1	1209.71	0.00	0	0.00	N/A
HIGH VOLTAGE PRIMARY LIGHTNING ARREST(	1	683.80	0.00	0	0.00	N/A
JUNCTION BOXES	1	3629.13	0.00	0	0.00	N/A
LOOP ASSEMBLY	1	967.77	0.00	0	0.00	N/A
MUSHROOM BOLT ASSY.W/DEFLECTOR	1	37.61	0.00	0	0.00	N/A
OIL SWITCH	1	228.71	0.00	0	0.00	N/A
SWITCH BOX	2	87.96	0.61	443	74.40	$13.56 to $162.35

TABLE C.16 Action Subcategory-Unit 131EA (Replace Machinery) Model for Pontis Elements DCP Data (Continued)

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38128382.12	29	1314771.80	6.6480	0.0000	1.4818
Within Groups	158016944.67	799	197768.39			
Total	196145326.79	828				

* 95% Confidence Level

** Actual number of data points. Based on tolerance of +/- 5

TABLE C.17 Action Subcategory-Unit 131LF (Replace Machinery) Model for Pontis Elements DCP Data

Groups	Count	Average	CV	Required N**	Error (d) in Mean Estimate*	C.I.
GROUNDING ELECTRODE	1	3.76	0.00	0	0.00	N/A
CONDUIT	20	6.27	1.12	8	3.09	$3.18 to $9.36
LOOP MATERIAL	1	4.41	0.00	0	0.00	N/A
SYS COMMUNICATIONS CARRIER	11	1.35	0.64	0	0.51	$0.84 to $1.86
CONDUCTORS	9	1.08	0.60	0	0.42	$0.66 to $1.50

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	254.39	4	63.60	2.46608	0.06178	2.62605
Within Groups	954.18	37	25.79			
Total	1208.57	41				

* 95% Confidence Level

** Actual number of data points. Based on tolerance of +/- 5

TABLE C.18 Action Subcategory-Unit 131LS (Replace Machinery) Model for Pontis Elements DCP Data						
Groups	**Count**	**Average**	**C.V.**	**Required N****	**Error (d) in Mean Estimate***	**C.I.**
NAVIGATION LIGHTS	6	5785.04	1.56	12464958	7206.06	$-1421.02 to $12991.10
SYS COMM	6	260.15	0.04	18	8.65	$251.50 to $268.80
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	91573100.55	1	91573100.55	2.2578	0.1638	4.9646
Within Groups	405591934.71	10	40559193.47			
Total	497165035.26	11				
* 95% Confidence Level						
** Actual number of data points. Based on tolerance of +/- 5						

TABLE C.19 Action Subcategory-Unit 131M1 (Replace Machinery) Model for Pontis Elements DCP Data						
Groups	**Count**	**Average**	**CV**	**Required N****	**Error (d) in Mean Estimate***	**C.I.**
CONDUCTOR	25	4.07	1.42	5	2.26	$1.81 to $6.33
GROUNDING	1	12.33	0.00	0	0.00	N/A
CONDUIT	2	37.34	0.88	166	45.52	$-8.19 to $82.86
LOOP MATERIAL	2	8.35	0.28	1	3.23	$5.12 to $11.58
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	2086.34	3	695.45	9.6102	0.0002	2.9752
Within Groups	1881.49	26	72.37			
Total	3967.83	29				
* 95% Confidence Level						
** Actual number of data points. Based on tolerance of +/- 5						

TABLE C.20 Action Subcategory-Unit 221SY (Rehab Slope Protection) Model for Pontis Elements DCP Data						
Groups	**Count**	**Average**	**CV**	**Required N****	**Error (d) in Mean Estimate***	**C.I.**
PLASTIC FILTER FABRIC	3	26.01	0.75	58	21.99	$4.02 to $48.00
CONC DITCH PAVT	8	30.08	0.18	5	3.78	$26.30 to $33.86
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	36.09	1	36.09	0.3371	0.5757	5.1174
Within Groups	963.56	9	107.06			
Total	999.65	10				
* 95% Confidence Level						
** Actual number of data points. Based on tolerance of +/- 5						

TABLE C.21 Action Subcategory-Unit 111LF (Replace Joint) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
301 - Pourable Joint Seal	11	15.45	0.71	18	6.47	$8.98 to $21.92
302 - Compression Joint Seal	14	14.08	0.77	18	5.67	$8.41 to $19.75
304 - Open Expansion Joint	5	9.57	0.17	0	1.45	$8.12 to $11.02
	30					
Overall Data:	30	13.83	0.72	15	3.55	$10.28 to $17.38
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	120.30	2	60.15	0.594	0.5589	3.354
Within Groups	2732.03	27	101.19			
Total	2852.33	29				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.22 Action Subcategory-Unit 112LF (Replace Joint Seal) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
301 - Pourable Joint Seal	74	13.29	1.55	65	4.68	$8.61 to $17.97
302 - Compression Joint Seal	94	30.98	1.20	211	7.50	$23.48 to $38.48
303 - Assembly Joint/Seal	9	14.38	0.82	21	7.71	$6.67 to $22.09
304 - Open Expansion Joint	7	9.79	0.77	9	5.56	$4.23 to $15.35
	184					
Overall Data:	184	22.25	1.39	147	4.47	$17.78 to $26.72
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19014.08	4	4753.52	5.339	0.00044	2.422
Within Groups	160269.45	180	890.39			
Total	179283.5286	184				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.23 Action Subcategory-Unit 114LF (Replace Railing) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
331 - Reinforced Conc Bridge Railing	75	19.93	0.69	29	3.13	$16.80 to $23.06
333 - Other Bridge Railing	61	16.73	0.78	26	3.27	$13.46 to $20.00
334 - Metal Bridge Railing - Coated	20	14.71	0.61	12	3.91	$10.80 to $18.62
	156					
Overall Data:	156	18.01	0.73	26	2.05	$15.96 to $20.06
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	595.23	2	297.61	1.7578	0.1759	3.0552
Within Groups	25904.43	153	169.3099795			
Total	26499.65	155				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.24 Action Subcategory-Unit 114MH (Replace Railing) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
201 - Unpainted Steel Column or Pile	2	21.27	0.26	5	7.68	$13.59 to $28.95
202 - Painted Steel Column or Pile	3	18.22	0.16	1	3.21	$15.01 to $21.43
204 - P/S Conc Column or Pile	13	17.16	0.19	2	1.79	$15.36 to $18.95
205 - Reinforced Conc Column or Pile	21	19.58	0.32	6	2.66	$16.92 to $22.25
206 - Timber Column or Pile	5	24.92	0.38	13	8.21	$16.71 to $33.14
210 - Reinforced Conc Pier Wall	9	18.10	0.18	2	2.14	$15.96 to $20.24
215 - Reinforced Conc Abutment	26	20.59	0.34	8	2.72	$17.87 to $23.31
220 - Pile Cap/Footing	21	20.51	0.28	5	2.48	$18.02 to $22.99
234 - Reinforced Conc Cap	28	20.33	0.34	7	2.55	$17.78 to $22.88
241 - Reinforced Concrete Culvert	1	32.20	0.00	0	0.00	N/A
298 - Pile Jacket without Cathodic Protection	3	22.54	0.10	1	2.65	$19.89 to $25.20
299 - Pile Jacket with Cathodic Protection	1	17.07	0.00	0	0.00	N/A
386 - Fender Dolphin System Metal Uncoated	2	23.46	0.10	1	3.39	$20.07 to $26.85
387 - Fender Dolphin System Prestressed Concret	12	17.41	0.21	2	2.03	$15.38 to $19.44
389 - Fender Dolphin System Timber	11	17.86	0.12	1	1.22	$16.63 to $19.08
393 - Bulkhead/Seawall Metal Uncoated	1	17.07	0.00	0	0.00	N/A
394 - Abutment Slope Protection Reinforced Conc	6	22.52	0.44	15	7.88	$14.64 to $30.40
396 - Abutment Slope Protection Other Material	22	20.02	0.29	5	2.44	$17.58 to $22.47
	187					
Overall Data:	203	19.91	0.30	5	0.82	$19.09 to $20.73
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	668.07	17.00	39.30	1.1072	0.3506	1.6835
Within Groups	5998.50	169.00	35.49			
Total	6666.56	186.00				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.25 Action Subcategory-Unit 121MH (Replace Slope Protection) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
394-Abutment Slope Protection Reinforced Concre	20	66.98	0.59	240	17.33	$49.66 to $84.31
396 - Abutment Slope Protection Other Material	4	39.48	0.79	149	30.56	$8.92 to $70.04
	24					
Overall Data:	24	62.40	0.63	235	15.64	$46.76 to $78.04
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2521.23	1	2521.23	1.7008	0.2057	4.3009
Within Groups	32612.80	22	1482.40			
Total	35134.03579	23				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.26 Action Subcategory-Unit 131MH (Replace Machinery) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
540 - Open Gearing	24	17.58	0.15	1	1.05	$16.53 to $18.63
541 -Speed Reducers	23	17.25	0.12	1	0.87	
542 - Shafts	24	17.58	0.15	1	1.05	$16.53 to $18.63
543 - Shaft Bearings and Shaft Couplings	24	17.58	0.15	1	1.05	$16.53 to $18.63
544 - Brakes	23	17.25	0.12	1	0.87	$16.38 to $18.11
545 - Emergency Drive and Back Up Power Syster	25	18.25	0.23	3	1.67	$16.58 to $19.93
546 - Span Drive Motors	18	17.79	0.14	1	1.16	$16.63 to $18.95
547 - Hydraulic Power Units	15	19.23	0.28	4	2.73	$16.50 to $21.95
548 - Hydraulic Piping System	15	19.23	0.28	4	2.73	$16.50 to $21.95
549 - Hydraulic Cylinders/Motors/Rotary Actuators	15	19.23	0.28	4	2.73	$16.50 to $21.95
550 - Hopkins Frame	5	18.79	0.09	0	1.52	$17.27 to $20.31
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	27	18.30	0.22	2	1.49	$16.81 to $19.79
561 - Live Load Shoes/Strike Plates/Buffer Cylinde	31	18.19	0.23	3	1.47	$16.72 to $19.65
562 - Counterweight Support	29	18.29	0.22	3	1.48	$16.80 to $19.77
563 - Access Ladder & Platforms	34	18.13	0.22	2	1.34	$16.79 to $19.47
564 - Counterweight	31	18.37	0.22	2	1.40	$16.98 to $19.77
565 - Trunnion/Straight and Curved Track	31	18.37	0.22	2	1.40	$16.98 to $19.77
570 - Transformers & Thyristors	13	17.52	0.11	1	1.04	$16.48 to $18.56
571 - Submarine Cable	24	18.31	0.23	3	1.67	$16.64 to $19.98
572 - Conduit & Junction Boxes	31	18.37	0.22	2	1.40	$16.98 to $19.77
573 - Programmable Logic Controllers	21	18.20	0.24	3	1.91	$16.29 to $20.11
574 - Control Console	27	18.13	0.22	2	1.51	$16.62 to $19.65
580 - Navigational Light System	30	18.15	0.21	2	1.37	$16.78 to $19.51
581 - Operator Facilities	30	18.15	0.21	2	1.37	$16.78 to $19.51
Lift Bridge Specific Equipment	4	18.87	0.24	3	4.52	$14.35 to $23.39
583 - Swing Bridge Specific Equipment	3	15.64	0.26	2	4.53	$11.11 to $20.17
590 - Resistance Barriers	4	17.38	0.13	1	2.19	$15.19 to $19.56
591 - Warning Gates	27	18.13	0.22	2	1.51	$16.62 to $19.65
592 - Traffic Signal	27	18.13	0.22	2	1.51	$16.62 to $19.65
	635					

TABLE C.26 Action Subcategory-Unit 131MH (Replace Machinery) Model for Pontis Elements MMS Data (Continued)						
Overall Data:	661	20.75	0.21	3	0.33	$20.42 to $21.08
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	151.92	28	5.43	0.3720	0.9989	1.4950
Within Groups	8837.9	606	14.58			
Total	8989.8	634				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.27 Action Subcategory-Unit 144MH (Replace Substructure) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
201 - Unpainted Steel Column or Pile	2	21.27	0.26	5	7.68	$13.59 to $28.95
202 - Painted Steel Column or Pile	3	18.22	0.16	1	3.21	$15.01 to $21.43
204 - P/S Conc Column or Pile	13	17.16	0.19	2	1.79	$15.36 to $18.95
205 - Reinforced Conc Column or Pile	21	19.58	0.32	6	2.66	$16.92 to $22.25
206 - Timber Column or Pile	5	24.92	0.38	13	8.21	$16.71 to $33.14
210 - Reinforced Conc Pier Wall	9	18.10	0.18	2	2.14	$15.96 to $20.24
215 - Reinforced Conc Abutment	26	20.59	0.34	8	2.72	$17.87 to $23.31
220 - Pile Cap/Footing	21	20.51	0.28	5	2.48	$18.02 to $22.99
234 - Reinforced Conc Cap	28	20.33	0.34	7	2.55	$17.78 to $22.88
241 - Reinforced Concrete Culvert	1	32.20	0.00	0	0.00	N/A
298 - Pile Jacket without Cathodic Protection	3	22.54	0.10	1	2.65	$19.89 to $25.20
299 - Pile Jacket with Cathodic Protection	1	17.07	0.00	0	0.00	N/A
386 - Fender Dolphin System Metal Uncoated	2	23.46	0.10	1	3.39	$20.07 to $26.85
387 - Fender Dolphin System Prestressed Concret	12	17.41	0.21	2	2.03	$15.38 to $19.44
389 - Fender Dolphin System Timber	11	17.86	0.12	1	1.22	$16.63 to $19.08
393 - Bulkhead/Seawall Metal Uncoated	1	17.07	0.00	0	0.00	N/A
394 - Abutment Slope Protection Reinforced Conc	6	22.52	0.44	15	7.88	$14.64 to $30.40
396 - Abutment Slope Protection Other Material	22	20.02	0.29	5	2.44	$17.58 to $22.47
	187					
Overall Data:	203	19.91	0.30	5	0.82	$19.09 to $20.74
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	668.07	17	39.30	1.1072	0.3506	1.6835
Within Groups	5998.50	169	35.49			
Total	6666.56	186				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

Table C.28 Action Subcategory-Unit 211LF (Rehab Joint) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
300 - Strip Seal Expansion Joint	12	6.00	0.76	3	2.59	$3.41 to $8.58
301 - Pourable Joint Seal	463	7.92	0.78	6	0.56	$7.35 to $8.48
302 - Compression Joint Seal	148	9.10	0.70	6	1.02	$8.08 to $10.12
303 - Assembly Joint/Seal (modular)	46	8.91	0.85	9	2.18	$6.72 to $11.09
304 - Open Expansion Joint	61	9.36	0.76	8	1.79	$7.57 to $11.15
	730					
Overall Data:	730	8.31	0.77	6	0.46	$7.84 to $8.77
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	311.65	4	77.91	1.9270	0.1041	2.3842
Within Groups	29312.17204	725	40.43			
Total	29623.81873	729				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

Table C.29 Action Subcategory-Unit 211MH (Rehab Joint) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
300 - Strip Seal Expansion Joint	55	169.38	0.72	2292	32.28	$137.10 to $201.65
301 - Pourable Joint Seal	43	85.38	1.29	1862	32.90	$52.48 to $118.28
302 - Compression Joint Seal	30	195.66	0.81	3820	56.42	$139.24 to $252.07
304 - Open Expansion Joint	5	22.92	0.81	54	16.36	$6.56 to $39.27
	133					
Overall Data:	133	142.64	0.94	2762	22.79	$119.86 to $165.43
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	336297.13	3	112099.04	7.1007	0.0002	2.6748
Within Groups	2036539.94	129	15787.13			
Total	2372837.08	132				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

Table C.30 Action Subcategory-Unit 213MH (Rehab Bearing) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
310 - Elastomeric Bearing	34	24.68	0.28	8	2.35	$22.34 to $27.03
311 - Moveable Bearing (roller, sliding, etc.)	39	23.43	0.36	11	2.62	$20.81 to $26.06
313 - Fixed Bearing	25	23.08	0.39	12	3.52	$19.56 to $26.60
	98					
Overall Data:	98	23.78	0.34	10	1.59	$22.19 to $25.36
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44.97	2	22.49	0.3443	0.7095884	3.0922
Within Groups	6204.07	95	65.31			
Total	6249.04	97				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

Table C.31 Action Subcategory-Unit 221SF (Rehab Slope Protection) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
394 - Abutment Slope Protection Reinforced Concrete	3	157.81	0.36	485	63.57	$94.24 to $221.37
396 - Abutment Slope Protection Other Material	3	38.78	0.86	170	37.59	$1.19 to $76.38
	6					
Overall Data:	6	98.30	0.78	915	61.74	$36.56 to $160.03
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21248.98	1	21248.98	9.9785	0.0342	7.7086
Within Groups	8517.90	4	2129.47			
Total	29766.88	5				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

Table C.32 Action Subcategory-Unit 221MH (Rehab Slope Protection) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
393 - Bulkhead/Seawall Metal Uncoated	16	13.77	0.46	6	3.12	$10.66 to $16.89
394 - Abutment Slope Protection Reinforced Concrete	422	89.89	1.22	1849	10.47	$79.42 to $100.36
396 - Abutment Slope Protection Other Material	378	68.71	1.35	1331	9.38	$59.33 to $78.09
	816					
Overall Data:	816	78.59	1.30	1601	7.00	$71.58 to $85.59
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	157995.59	2	78997.79	7.7080	0.0005	3.0068
Within Groups	8332226.359	813	10248.74			
Total	8490221.948	815				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

Table C.33 Action Subcategory-Unit 231MH (Rehab Machinery) Model for Pontis Elements MMS Data						
Treatments	**Count**	**Average**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
540 - Open Gearing	19	29.11	0.33	14	4.32	$24.79 to $33.43
541 - Speed Reducers	19	29.11	0.33	14	4.32	$24.79 to $33.43
542 - Shafts	20	29.05	0.32	13	4.10	$24.94 to $33.15
543 - Shaft Bearings and Shaft Couplings	20	29.05	0.32	13	4.10	$24.94 to $33.15
544 - Brakes	18	28.99	0.34	15	4.56	$24.43 to $33.55
545 - Emergency Drive and Back Up Power System	18	27.52	0.33	13	4.21	$23.31 to $31.73
546 - Span Drive Motors	19	29.11	0.33	14	4.32	$24.79 to $33.43
547 - Hydraulic Power Units	8	28.39	0.29	10	5.66	$22.74 to $34.05
548 - Hydraulic Piping System	8	28.39	0.29	10	5.66	$22.74 to $34.05
549 - Hydraulic Cylinders/Motors/Rotary Actuators	8	28.39	0.29	10	5.66	$22.74 to $34.05
550 - Hopkins Frame	7	32.20	0.41	27	9.81	$22.39 to $42.01
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	21	28.68	0.32	13	3.97	$24.71 to $32.65
561 - Live Load Shoes/Strike Plates/Buffer Cylinders	21	28.68	0.32	13	3.97	$24.71 to $32.65
562 - Counterweight Support	10	31.59	0.25	9	4.87	$26.72 to $36.46
563 - Access Ladder & Platforms	22	28.24	0.33	13	3.88	$24.36 to $32.12
564 - Counterweight	21	28.68	0.32	13	3.97	$24.71 to $32.65
565 - Trunnion/Straight and Curved Track	21	28.68	0.32	13	3.97	$24.71 to $32.65
570 - Transformers & Thyristors	19	28.88	0.33	14	4.34	$24.54 to $33.22
571 - Submarine Cable	20	28.55	0.33	14	4.16	$24.39 to $32.72
572 - Conduit & Junction Boxes	21	28.68	0.32	13	3.97	$24.71 to $32.65
573 - Programmable Logic Controllers	10	28.82	0.30	11	5.35	$23.46 to $34.17
574 - Control Console	20	28.55	0.33	14	4.16	$24.39 to $32.72
580 - Navigational Light System	22	28.24	0.33	13	3.88	$24.36 to $32.12
581 - Operator Facilities	21	28.68	0.32	13	3.97	$24.71 to $32.65
590 - Resistance Barriers	5	26.61	0.27	8	6.31	$20.29 to $32.92
591 - Warning Gates	21	28.68	0.32	13	3.97	$24.71 to $32.65
592 - Traffic Signal	20	28.55	0.33	14	4.16	$24.39 to $32.72
	459					
Overall Data:	459	28.76	0.32	13	0.83	$27.93 to $29.60

Table C.33 Action Subcategory-Unit 231MH (Rehab Machinery) Model for Pontis Elements MMS Data (Continued)						
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	243.66	26	9.37	0.1072	1.0000	1.5213
Within Groups	37777.22	432	87.45			
Total	38020.88	458				
* 95% Confidence Level						
** Required number of data points. Based on tolerance of +/- 5						

TABLE C.34 Action Subcategory-Unit 331MH (Repair/lubricate machinery) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Avg**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
540 - Open Gearing	563	25.94	116.44	10.79	0.42	18	0.89	$25.05 to $26.83
541 - Speed Reducers	548	26.38	127.71	11.30	0.43	20	0.95	$25.44 to $27.33
542 - Shafts	571	26.21	124.26	11.15	0.43	19	0.91	$25.30 to $27.13
543 - Shaft Bearings and Shaft Couplings	615	27.01	141.22	11.88	0.44	22	0.94	$26.07 to $27.95
544 - Brakes	555	26.31	126.42	11.24	0.43	19	0.94	$25.37 to $27.25
545 - Emergency Drive and Back Up Power System	546	25.62	107.98	10.39	0.41	17	0.87	$24.75 to $26.49
546 - Span Drive Motors	573	27.04	137.15	11.71	0.43	21	0.96	$26.08 to $28.00
547 - Hydraulic Power Units	269	25.83	151.17	12.29	0.48	23	1.47	$24.36 to $27.30
548 - Hydraulic Piping System	269	25.83	151.17	12.29	0.48	23	1.47	$24.36 to $27.30
549 - Hydraulic Cylinders/Motors/Rotary Actuators	267	25.85	152.23	12.34	0.48	23	1.48	$24.37 to $27.33
550 - Hopkins Frame	224	26.97	141.74	11.91	0.44	22	1.56	$25.41 to $28.53
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	716	26.82	141.57	11.90	0.44	22	0.87	$25.95 to $27.69
561- Live Load Shoes/Strike Plates/Buffer Cylinders	685	26.70	143.83	11.99	0.45	22	0.90	$25.80 to $27.60
562 - Counterweight Support	650	26.49	147.64	12.15	0.46	23	0.93	$25.55 to $27.42
563 - Access Ladder & Platforms	761	26.61	140.08	11.84	0.44	22	0.84	$25.77 to $27.45
564 - Counterweight	735	26.67	141.63	11.90	0.45	22	0.86	$25.81 to $27.53
565 - Trunnion/Straight and Curved Track	743	26.60	140.47	11.85	0.45	22	0.85	$25.74 to $27.45
570 - Transformers & Thyristors	482	27.85	148.89	12.20	0.44	23	1.09	$26.76 to $28.94
571 - Submarine Cable	595	27.19	148.35	12.18	0.45	23	0.98	$26.22 to $28.17
572 - Conduit & Junction Boxes	761	26.54	138.26	11.76	0.44	21	0.84	$25.70 to $27.38
573 - Programmable Logic Controllers	481	28.00	169.16	13.01	0.46	26	1.16	$26.84 to $29.16
574 - Control Console	687	26.81	143.50	11.98	0.45	22	0.90	$25.92 to $27.71
580 - Navigational Light System	760	26.43	135.63	11.65	0.44	21	0.83	$25.60 to $27.26
581 - Operator Facilities	716	26.57	140.13	11.84	0.45	22	0.87	$25.70 to $27.43

TABLE C.34 Action Subcategory-Unit 331MH (Repair/lubricate machinery) Model for Pontis Elements MMS Data (Continued)								
582 - Lift Bridge Specific Equipment	29	21.21	78.66	8.87	0.42	12	3.23	$17.98 to $24.44
583 - Swing Bridge Specific Equipment	9	23.93	59.55	7.72	0.32	9	5.04	$18.89 to $28.97
590 - Resistance Barriers	87	27.96	179.44	13.40	0.48	28	2.81	$25.15 to $30.78
591 - Warning Gates	717	26.85	143.14	11.96	0.45	22	0.88	$25.97 to $27.72
592 - Traffic Signal	715	26.85	143.54	11.98	0.45	22	0.88	$25.97 to $27.73
	15329							
Overall Data:	15329	26.64	139.54	11.81	0.44	21	0.19	$26.46 to $26.83
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								
No ANOVA Testing								

TABLE C.35 Action Subcategory-Unit 301SF (Repair Deck & Substrate) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
12 - Concrete Deck - Bare	10	82.97	9303.43	96.45	1.16	1430	59.78	$23.18 to $142.75
13 - Concrete Deck - Unprotected w/ AC Overlay	2	19.07	192.53	13.88	0.73	30	19.23	$0.00 to $38.30
28 - Steel Deck - Open Grid	2	25.16	34.46	5.87	0.23	5	8.14	$17.03 to $33.30
29 - Steel Deck - Concrete Filled Grid	1	29.32	0.00	0.00	0.00	0	0.00	N/A
98 - Concrete Deck on Precast Deck Panels	1	158.66	0.00	0.00	0.00	0	0.00	N/A
99 - Prestressed Concrete Slab (Sonovoid)	1	10.59	0.00	0.00	0.00	0	0.00	N/A
	17							
Overall Data:	17	65.69	6723.58	82.00	1.25	1033	38.98	$26.71 to $104.67
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	23619.36332	5	4723.87	0.6189	0.6886	3.2039		
Within Groups	83957.87215	11	7632.53					
Total	107577.24	16						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.36 Action Subcategory-Unit 302LF (Spot Paint) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
102 - Painted Steel Closed Web/Box Girder	1	35.03	0.00	0.00	0.00	0	0.00	N/A
107 - Painted Steel Open Girder/Beam	2	21.84	46.23	6.80	0.31	7	9.42	$12.42 to $31.27
113 - Painted Steel Stringer	1	17.04	0.00	0.00	0.00	0	0.00	N/A
152 - Painted Steel Floor Beam	2	21.84	46.23	6.80	0.31	7	9.42	$12.42 to $31.27
540 - Open Gearing	1	17.04	0.00	0.00	0.00	0	0.00	N/A
541 - Speed Reducers	1	17.04	0.00	0.00	0.00	0	0.00	N/A
542 - Shafts	1	17.04	0.00	0.00	0.00	0	0.00	N/A
543 - Shaft Bearings and Shaft Couplings	1	17.04	0.00	0.00	0.00	0	0.00	N/A
544 - Brakes	1	17.04	0.00	0.00	0.00	0	0.00	N/A
546 - Span Drive Motors	1	17.04	0.00	0.00	0.00	0	0.00	N/A
550 - Hopkins Frame	1	17.04	0.00	0.00	0.00	0	0.00	N/A
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	2	21.84	46.23	6.80	0.31	7	9.42	$12.42 to $31.27
561 - Live Load Shoes/Strike Plates/Buffer Cylinders	2	21.84	46.23	6.80	0.31	7	9.42	$12.42 to $31.27
562 - Counterweight Support	1	17.04	0.00	0.00	0.00	0	0.00	N/A
563 - Access Ladder & Platforms	1	17.04	0.00	0.00	0.00	0	0.00	N/A
565 - Trunnion/Straight and Curved Track	1	17.04	0.00	0.00	0.00	0	0.00	N/A
	20							
Overall Data:	20	19.86	28.11	5.30	0.27	4	2.32	$17.54 to $22.18
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	349.27	15	23.28	0.5037	0.8514	5.8578		
Within Groups	184.90	4	46.23					

TABLE C.36 Action Subcategory-Unit 302LF (Spot Paint) Model for Pontis Elements MMS Data (Continued)									
Total	534.17	19							
* 95% Confidence Level									
** Required number of data points. Based on tolerance of +/- 5									

TABLE C.37 Action Subcategory-Unit 302MH (Spot Paint) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
102 - Painted Steel Closed Web/Box Girder	1	16.37	0.00	0.00	0.00	0	0.00	N/A
107 - Painted Steel Open Girder/Beam	98	22.07	29.02	5.39	0.24	4	1.07	$21.00 to $23.14
113 - Painted Steel Stringer	53	23.79	28.32	5.32	0.22	4	1.43	$22.35 to $25.22
121 - Painted Steel Bottom Chord Thru Truss	14	24.20	40.80	6.39	0.26	6	3.35	$20.85 to $27.54
126 - Painted Steel Thru Truss (excl. bottom chord)	14	24.20	40.80	6.39	0.26	6	3.35	$20.85 to $27.54
131 - Painted Steel Deck Truss	5	24.02	12.25	3.50	0.15	2	3.07	$20.95 to $27.09
141 - Painted Steel Arch	1	28.67	0.00	0.00	0.00	0	0.00	N/A
152 - Painted Steel Floor Beam	55	23.70	27.46	5.24	0.22	4	1.38	$22.32 to $25.09
161 - Painted Steel Pin and/or Pin and Hanger Assembly	1	22.82	0.00	0.00	0.00	0	0.00	N/A
202 - Painted Steel Column or Pile	16	22.16	22.23	4.71	0.21	3	2.31	$19.85 to $24.47
231 - Painted Steel Cap	2	16.03	16.62	4.08	0.25	3	5.65	$10.38 to $21.68
397 - Drainage System Metal Coated	1	20.55	0.00	0.00	0.00	0	0.00	N/A
540 - Open Gearing	36	23.89	29.69	5.45	0.23	5	1.78	$22.11 to $25.67
541 - Speed Reducers	23	23.68	23.05	4.80	0.20	4	1.96	$21.71 to $25.64
542 - Shafts	36	23.89	29.69	5.45	0.23	5	1.78	$22.11 to $25.67
543 - Shaft Bearings and Shaft Couplings	37	23.88	28.87	5.37	0.22	4	1.73	$22.15 to $25.61
544 - Brakes	22	23.69	24.14	4.91	0.21	4	2.05	21.64 to $25.74
546 - Span Drive Motors	23	23.82	22.50	4.74	0.20	3	1.94	$21.88 to $25.76
550 - Hopkins Frame	3	26.37	29.97	5.47	0.21	5	6.20	$20.18 to $32.57
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	35	23.46	21.70	4.66	0.20	3	1.54	$21.91 to $25.00
561 - Live Load Shoes/Strike Plates/Buffer Cylinders	33	23.83	21.20	4.60	0.19	3	1.57	$22.26 to $25.40
562 - Counterweight Support	25	23.55	15.99	4.00	0.17	2	1.57	$21.98 to $25.12

TABLE C.37 Action Subcategory-Unit 302MH (Spot Paint) Model for Pontis Elements MMS Data (Continued)								
563 - Access Ladder & Platforms	50	23.53	27.17	5.21	0.22	4	1.44	$22.08 to $24.97
565 - Trunnion/Straight and Curved Track	34	23.56	22.11	4.70	0.20	3	1.58	$21.98 to $25.14
582 - Lift Bridge Specific Equipment	1	23.18	0.00	0.00	0.00	0	0.00	N/A
583 - Swing Bridge Specific Equipment	13	24.27	44.11	6.64	0.27	7	3.61	$20.66 to $27.88
	632							
Overall Data:	632	23.43	26.64	5.16		4	0.40	$23.03 to $23.83
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	502.59	25	20.10	0.7471	0.8093	1.5243		
Within Groups	16307.35653	606	26.91					
Total	16809.94262	631						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.38 Action Subcategory-Unit 302SF (Spot Paint) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
107 - Painted Steel Open Girder/Beam	15	30.45	178.29	13.35	0.44	27	6.76	$23.69 to $37.20
113 - Painted Steel Stringer	15	30.45	178.29	13.35	0.44	27	6.76	23.69 to $37.20
121 - Painted Steel Bottom Chord Thru Truss	2	41.26	412.03	20.30	0.49	63	28.13	$13.13 to $69.40
126 - Painted Steel Thru Truss (excl. bottom chord)	2	41.26	412.03	20.30	0.49	63	28.13	$13.13 to $69.40
131 - Painted Steel Deck Truss	1	29.14	0.00	0.00	0.00	0	0.00	N/A
152 - Painted Steel Floor Beam	15	30.45	178.29	13.35	0.44	27	6.76	$23.69 to $37.20
202 - Painted Steel Column or Pile	3	40.03	145.53	12.06	0.30	22	13.65	$26.38 to $53.68
540 - Open Gearing	9	27.56	145.83	12.08	0.44	22	7.89	$19.67 to $35.45
541 - Speed Reducers	8	28.74	152.46	12.35	0.43	23	8.56	$20.18 to $37.29
542 - Shafts	9	27.56	145.83	12.08	0.44	22	7.89	$19.67 to $35.45
543 - Shaft Bearings and Shaft Couplings	11	26.11	127.49	11.29	0.43	20	6.67	$19.44 to $32.78
544 - Brakes	9	27.56	145.83	12.08	0.44	22	7.89	$19.67 to $35.45
546 - Span Drive Motors	11	26.11	127.49	11.29	0.43	20	6.67	$19.44 to $32.78
550 - Hopkins Frame	5	33.01	184.32	13.58	0.41	28	11.90	$21.11 to $44.91
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	13	26.19	110.55	10.51	0.40	17	5.72	$20.48 to $31.91
561 - Live Load Shoes/Strike Plates/Buffer Cylinders	13	28.32	132.21	11.50	0.41	20	6.25	$22.07 to $34.57
562 - Counterweight Support	12	26.88	113.89	10.67	0.40	18	6.04	$20.84 to $32.92
563 - Access Ladder & Platforms	13	26.19	110.55	10.51	0.40	17	5.72	$20.48 to $31.91
565 - Trunnion/Straight and Curved Track	13	26.19	110.55	10.51	0.40	17	5.72	$20.48 to $31.91
	179							
Overall Data:	179	28.55	140.38	11.85	0.42	22	1.74	$26.81 to $30.28

TABLE C.38 Action Subcategory-Unit 302SF (Spot Paint) Model for Pontis Elements MMS Data (Continued)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1711.97	18	95.11	0.6538	0.8516	1.6687
Within Groups	23276.47519	160	145.48			
Total	24988.44217	178				

* 95% Confidence Level

** Required number of data points. Based on tolerance of +/- 5

TABLE C.39 Action Subcategory-Unit 303LF (Clean Rebar & Patch) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
109 - P/S Conc Open Girder/Beam	22	46.50	2437.01	49.37	1.06	374	20.63	$25.87 to $67.13
110 - Reinforced Conc Open Girder/Beam	1	94.64	0.00	0.00	0.00	0	0.00	N/A
204 - P/S Conc Column or Pile	11	32.53	1546.58	39.33	1.21	238	23.24	$9.28 to $55.77
205 - Reinforced Conc Column or Pile	19	46.96	2331.57	48.29	1.03	358	21.71	$25.25 to $68.67
210 - Reinforced Conc Pier Wall	1	23.21	0.00	0.00	0.00	0	0.00	N/A
215 - Reinforced Conc Abutment	27	42.87	2253.93	47.48	1.11	346	17.91	$24.96 to $60.78
220 - Pile Cap/Footing	10	34.79	2094.33	45.76	1.32	322	28.36	$6.43 to $63.16
234 - Reinforced Conc Cap	21	31.59	1339.95	36.61	1.16	206	15.66	$15.93 to $47.25
298 - Pile Jacket without Cathodic Protection	1	4.39	0.00	0.00	0.00	0	0.00	N/A
321 - Reinforced Conc Approach Slab w/ or w/o AC Ovly	28	42.38	2177.17	46.66	1.10	335	17.28	$25.09 to $59.66
331 - Reinforced Conc Bridge Railing	25	41.07	2098.46	45.81	1.12	322	17.96	$23.11 to $59.03
387 - Fender Dolphin System Prestressed Concrete	2	23.78	0.66	0.81	0.03	0	1.12	$22.66 to $24.91
394 - Abutment Slope Protection Reinforced Concrete	18	44.41	2342.89	48.40	1.09	360	22.36	$22.05 to $66.77
475 - Wingwall/Retaining Wall Reinforced Concrete	11	36.27	1099.25	33.15	0.91	169	19.59	$16.67 to $55.86
	197							
Overall Data:	197	40.73	1953.68	44.20	1.09	300	6.17	$34.55 to $46.90
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	10090.4627	13	776.19	0.3810	0.9745	1.7740		
Within Groups	372830.3803	183	2037.32					
Total	382920.843	196						

TABLE C.40 Action Subcategory-Unit 303MH (Clean Rebar & Patch) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
109 - P/S Conc Open Girder/Beam	68	19.00	36.63	6.05	0.32	6	1.44	$17.56 to $20.43
110 - Reinforced Conc Open Girder/Beam	7	18.75	9.37	3.06	0.16	1	2.27	$16.48 to $21.02
204 - P/S Conc Column or Pile	41	18.88	43.75	6.61	0.35	7	2.02	$16.86 to $20.91
205 - Reinforced Conc Column or Pile	64	18.42	35.96	6.00	0.33	6	1.47	$16.95 to $19.89
210 - Reinforced Conc Pier Wall	3	17.98	70.72	8.41	0.47	11	9.52	$8.46 to $27.49
215 - Reinforced Conc Abutment	90	18.82	42.61	6.53	0.35	7	1.35	$17.47 to $20.17
220 - Pile Cap/Footing	36	20.59	39.37	6.27	0.30	6	2.05	$18.54 to $22.64
233 - P/S Conc Cap	3	25.12	10.00	3.16	0.13	2	3.58	$21.54 to $28.70
234 - Reinforced Conc Cap	79	18.92	34.39	5.86	0.31	5	1.29	$17.63 to $20.22
241 - Reinforced Concrete Culvert	38	19.64	76.35	8.74	0.44	12	2.78	$16.86 to $22.42
298 - Pile Jacket without Cathodic Protection	4	11.20	95.13	9.75	0.87	15	9.56	$1.64 to $20.75
299 - Pile Jacket with Cathodic Protection	1	1.14	0.00	0.00	0.00	0	0.00	N/A
321 - Reinforced Conc Approach Slab w/ or w/o AC Ovly	85	18.81	40.79	6.39	0.34	6	1.36	$17.45 to $20.17
331 - Reinforced Conc Bridge Railing	71	19.00	47.48	6.89	0.36	7	1.60	$17.40 to $20.60
387 - Fender Dolphin System Prestressed Concrete	8	18.62	16.43	4.05	0.22	3	2.81	$15.82 to $21.43
394 - Abutment Slope Protection Reinforced Concrete	51	18.81	52.18	7.22	0.38	8	1.98	$16.83 to $20.80
475 - Wingwall/Retaining Wall Reinforced Concrete	66	18.47	57.86	7.61	0.41	9	1.84	$16.63 to $20.30
564 - Counterweight	2	18.11	5.20	2.28	0.13	1	3.16	$14.95 to $21.27
	717							
Overall Data:	717	18.88	44.30	6.66	0.35	7	0.49	$18.40 to $19.37

TABLE C.40 Action Subcategory-Unit 303MH (Clean Rebar & Patch) Model for Pontis Elements MMS Data (Continued)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	826.7376329	17	48.63	1.1004	0.3485	1.6374
Within Groups	30890.79378	699	44.19			
Total	31717.53141	716				

* 95% Confidence Level

** Required number of data points. Based on tolerance of +/- 5

TABLE C.41 Action Subcategory-Unit 311LF (Repair Joint) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
300 - Strip Seal Expansion Joint	10	26.90	176.86	13.30	0.49	27	8.24	$18.66 to $35.14
301 - Pourable Joint Seal	67	42.23	1672.36	40.89	0.97	257	9.79	$32.44 to $52.02
302 - Compression Joint Seal	202	56.90	2559.37	50.59	0.89	393	6.98	$49.92 to $63.88
303 - Assembly Joint/Seal (modular)	44	37.71	1119.25	33.46	0.89	172	9.89	$27.83 to $47.60
304 - Open Expansion Joint	19	46.67	1793.56	42.35	0.91	276	19.04	$27.62 to $65.71
399 - Other Expansion Joint	5	25.68	542.58	23.29	0.91	83	20.42	$5.26 to 446.10
	347							
Overall Data:	347	49.76	2132.29	46.18	0.93	328	4.86	$44.90 to $54.62
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	28788.79187	5	5757.76	2.7693	0.0181	2.2405		
Within Groups	708983.4526	341	2079.13036					
Total	737772.2445	346						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.42 Action Subcategory-Unit 400LF (Wash Structure) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
110 - Reinforced Conc Open Girder/Beam	1	3.90	0.00	0.00	0.00	0	0.00	N/A
398 - Drainage Sytem Other Material	3	11.31	200.38	14.16	1.25	31	16.02	$-4.71 to $27.32
	4							
Overall Data:	4	9.45	147.31	12.14	1.28	23	11.89	$2.44 to $21.35
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	41.15	1	41.15	0.2054	0.6948	18.5128		
Within Groups	400.76	2	200.38					
Total	441.92	3						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.43 Action Subcategory-Unit 400MH (Wash Structure) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
102 - Painted Steel Closed Web/Box Girder	3	19.53	0.97	0.98	0.05	0	1.11	$18.42 to $20.64
105 - Reinforced Concrete Closed Webs/Box Girder	1	13.55	0.00	0.00	0.00	0	0.00	N/A
107 - Painted Steel Open Girder/Beam	23	20.95	43.00	6.56	0.31	4	2.68	$18.27 to $23.63
109 - P/S Conc Open Girder/Beam	98	17.06	59.21	7.69	0.45	15	1.52	$15.54 to $18.58
110 - Reinforced Conc Open Girder/Beam	3	14.45	11.02	3.32	0.23	0	3.76	$10.69 to $18.21
113 - Painted Steel Stringer	4	23.13	15.09	3.88	0.17	1	3.81	$19.32 to $26.94
152 - Painted Steel Floor Beam	4	23.13	15.09	3.88	0.17	1	3.81	$19.32 to $26.95
398 - Drainage Sytem Other Material	75	19.93	44.40	6.66	0.33	12	1.51	$18.42 to $21.44
	211							
Overall Data:	211	18.72	51.54	7.18	0.38	8	0.97	$17.75 to $19.69
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	734.4	7	104.91	2.1107	0.0440	2.0549		
Within Groups	10089.9	203	49.70					
Total	10824.2	210						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.44 Action Subcategory-Unit 400SF (Wash Structure) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
104 - P/S Conc Closed Web/Box Girder	1	1.21	0.00	0.00	0.00	0	0.00	N/A
107 - Painted Steel Open Girder/Beam	25	5.68	39.43	6.28	1.11	6	2.46	$3.22 to $8.14
109 - P/S Conc Open Girder/Beam	79	4.51	27.59	5.25	1.16	4	1.16	$3.35 to $5.67
110 - Reinforced Conc Open Girder/Beam	7	4.20	39.42	6.28	1.49	6	4.65	
113 - Painted Steel Stringer	6	3.34	4.48	2.12	0.63	1	1.69	$1.65 to $5.03
121 - Painted Steel Bottom Chord Thru Truss	1	2.30	0.00	0.00	0.00	0	0.00	N/A
126 - Painted Steel Thru Truss (excl. bottom chord)	1	2.30	0.00	0.00	0.00	0	0.00	N/A
146 - Cable - Uncoated (not embedded in concrete)	1	1.21	0.00	0.00	0.00	0	0.00	N/A
147 - Cable - Coated (not embedded in concrete)	1	1.21	0.00	0.00	0.00	0	0.00	N/A
152 - Painted Steel Floor Beam	6	3.34	4.48	2.12	0.63	1	1.69	$1.65 to $5.03
398 - Drainage Sytem Other Material	69	4.82	24.14	4.91	1.02	4	1.16	$3.66 to $5.98
	197							
Overall Data:	197	4.61	26.12	5.11	1.11	4	0.71	$3.90 to $5.32
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	98	10	9.79	0.3628	0.9610	1.8819		
Within Groups	5021	186	26.99					
Total	5119	196						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.45 Action Subcategory-Unit 401MH (Reoair Potholes) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
12 - Concrete Deck - Bare	7	24.06	135.00	11.62	0.48	21	8.61	$15.45 to $32.67
13 - Concrete Deck - Unprotected w/ AC Overlay	13	19.64	116.94	10.81	0.55	18	5.88	$13.77 to $25.52
38 - Concrete Slab - Bare	1	20.44	0.00	0	0.00	0	0.00	N/A
39 - Concrete Slab - Unprotected w/ AC Overlay	4	21.82	115.18	10.73	0.49	18	10.52	$11.30 to $32.34
99 - Prestressed Concrete Slab (Sonovoid)	5	20.40	3.80	1.95	0.10	1	1.71	$18.69 to $22.11
	30							
Overall Data:	30	21.12	92.00	9.59	0.45	14	3.43	$17.69 to $24.55
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	94	4	23.48	0.2280	0.9201	2.7587		
Within Groups	2574	25	102.96					
Total	2668	29						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.46 Action Subcategory-Unit 401SF (Repair Potholes) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
12 - Concrete Deck - Bare	54	25.88	890.43	29.84	1.15	137	7.96	$17.92 to $33.84
13 - Concrete Deck - Unprotected w/ AC Overlay	55	24.20	652.67	25.55	1.06	100	6.75	$17.44 to $30.95
28 - Steel Deck - Open Grid	3	30.46	466.23	21.59	0.71	72	24.43	$6.02 to $54.89
29 - Steel Deck - Concrete Filled Grid	1	31.85	0.00	0.00	0.00	0	0.00	N/A
38 - Concrete Slab - Bare	10	10.45	164.86	12.84	1.23	25	7.96	$2.49 to $18.41
39 - Concrete Slab - Unprotected w/ AC Overlay	11	29.75	903.12	30.05	1.01	139	17.76	$11.99 to $47.51
98 - Concrete Deck on Precast Deck Panels	8	15.30	191.31	13.83	0.90	29	9.58	$5.71 to $24.88
99 - Prestressed Concrete Slab (Sonovoid)	21	22.62	490.07	22.14	0.98	75	9.47	$13.15 to $32.08
	163							
Overall Data:	163	23.81	668.18	25.85	1.09	103	3.97	$19.84 to $27.78
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	3220	7	460.04	0.6789	0.6897	2.0691		
Within Groups	105024	155	677.58					
Total	108245	162						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.47 Action Subcategory-Unit 402MH (Restore Top Coat) Model for Pontis Elements MMS Data								
Treatments	Count	Average	Variance	Std. dev.	C.V.	N**	Error (d) in Mean Estimate*	C. I.
102 - Painted Steel Closed Web/Box Girder	4	16.91	2.51	1.58	0.09	0	1.55	$15.36 to $18.46
107 - Painted Steel Open Girder/Beam	10	20.34	12.72	3.57	0.18	2	2.21	$18.13 to $22.55
113 - Painted Steel Stringer	2	22.14	6.80	2.61	0.12	1	3.61	$18.53 to $25.75
152 - Painted Steel Floor Beam	2	22.14	6.80	2.61	0.12	1	3.61	$18.53 to $25.76
540 - Open Gearing	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
541 - Speed Reducers	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
542 - Shafts	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
543 - Shaft Bearings and Shaft Couplings	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
544 - Brakes	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
546 - Span Drive Motors	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
550 - Hopkins Frame	2	36.92	30.80	5.55	0.15	5	7.69	$29.23 to $44.61
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
561 - Live Load Shoes/Strike Plates/Buffer Cylinders	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
562 - Counterweight Support	2	36.92	30.80	5.55	0.15	5	7.69	$29.23 to $44.61
563 - Access Ladder & Platforms	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
565 - Trunnion/Straight and Curved Track	3	32.61	71.19	8.44	0.26	11	9.55	$23.06 to $42.16
	52							
Overall Data:	52	28.57	74.05	8.61	0.30	11	2.34	$26.23 to $30.91
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	2156	15	143.71	3.1914	0.0022	1.9543		
Within Groups	1621	36	45.03					
Total	3777	51						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.48 Action Subcategory-Unit 403LF (Patch Minor Spalls) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
104 - P/S Conc Closed Web/Box Girder	3	21.49	10.44	3.23	0.15	2	3.66	$17.83 to $25.14
105 - Reinforced Concrete Closed Webs/Box Girder	1	4.22	0.00	0.00	0.00	0	0.00	N/A
109 - P/S Conc Open Girder/Beam	217	33.54	906.99	30.12	0.90	139	4.01	$29.53 to $37.55
110 - Reinforced Conc Open Girder/Beam	18	22.16	174.71	13.22	0.60	27	6.11	$16.06 to $28.27
144 - Reinforced Conc Arch	2	22.79	100.43	10.02	0.44	15	13.89	$8.90 to $36.68
155 - Reinforced Conc Floor Beam	1	8.82	0.00	0.00	0.00	0	0.00	N/A
204 - P/S Conc Column or Pile	123	27.64	501.77	22.40	0.81	77	3.96	$23.68 to $31.60
205 - Reinforced Conc Column or Pile	199	34.14	969.46	31.14	0.91	149	4.33	$29.82 to $38.47
207 - Hollow Core Pile	5	34.12	333.79	18.27	0.54	51	16.01	$18.11 to $50.14
210 - Reinforced Conc Pier Wall	26	28.67	474.26	21.78	0.76	73	8.37	$20.30 to $37.04
215 - Reinforced Conc Abutment	319	31.99	808.05	28.43	0.89	124	3.12	$28.87 to $35.11
220 - Pile Cap/Footing	106	30.18	636.89	25.24	0.84	98	4.80	$25.37 to $34.98
234 - Reinforced Conc Cap	264	31.29	796.75	28.23	0.90	122	3.40	$27.89 to $34.70
241 - Reinforced Concrete Culvert	1	96.48	0.00	0.00	0.00	0	0.00	N/A
298 - Pile Jacket without Cathodic Protection	12	30.01	766.62	27.69	0.92	118	15.67	$14.34 to $45.67
299 - Pile Jacket with Cathodic Protection	5	15.54	100.48	10.02	0.64	15	8.79	$6.76 to $24.33
321 - Reinforced Conc Approach Slab w/ or w/o AC Ovly	317	31.78	810.09	28.46	0.90	124	3.13	$28.65 to $34.91
331 - Reinforced Conc Bridge Railing	262	32.06	730.62	27.03	0.84	112	3.27	$28.79 to $35.33
387 - Fender Dolphin System Prestressed Concrete	18	34.54	1094.45	33.08	0.96	168	15.28	$19.26 to $49.83
394 - Abutment Slope Protection Reinforced Concrete	163	35.49	978.48	31.28	0.88	150	4.80	$30.69 to $40.30
475 - Wingwall/Retaining Wall Reinforced Concrete	89	32.28	951.75	30.85	0.96	146	6.41	$25.87 to $38.69
564 - Counterweight	4	30.79	1223.02	34.97	1.14	188	34.27	$-3.48 to $65.06
	2155							

TABLE C.48 Action Subcategory-Unit 403LF (Patch Minor Spalls) Model for Pontis Elements MMS Data (Continued)								
Overall Data:	2151	32.01	805.08	28.37	0.89	124	1.20	$30.82 to $33.21
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	15806	21	752.66	0.9340	0.5459	1.5607		
Within Groups	1718796	2133	805.81					
Total	1734602	2154						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.49 Action Subcategory-Unit 403MH (Patch Minor Spalls) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	C. I.
104 - P/S Conc Closed Web/Box Girder	9	22.69	53.34	7.30	0.32	8	4.77	$17.91 to $27.46
105 - Reinforced Concrete Closed Webs/Box Girder	2	30.46	532.54	23.08	0.76	82	31.98	$-1.52 to $62.44
109 - P/S Conc Open Girder/Beam	914	20.67	68.00	8.25	0.40	10	0.53	$20.14 to $21.21
110 - Reinforced Conc Open Girder/Beam	102	18.31	43.47	6.59	0.36	7	1.28	$17.03 to $19.59
115 - P/S Conc Stringer	1	6.80	0.00	0.00	0.00	0	0.00	N/A
116 - Reinforced Conc Stringer	1	49.81	0.00	0.00	0.00	0	0.00	N/A
144 - Reinforced Conc Arch	1	14.95	0.00	0.00	0.00	0	0.00	N/A
154 - P/S Conc Floor Beam	1	6.80	0.00	0.00	0.00	0	0.00	N/A
155 - Reinforced Conc Floor Beam	11	25.20	81.84	9.05	0.36	13	5.35	$19.85 to $30.54
204 - P/S Conc Column or Pile	398	20.78	65.78	8.11	0.39	10	0.80	$19.98 to $21.57
205 - Reinforced Conc Column or Pile	923	20.36	65.12	8.07	0.40	10	0.52	$19.84 to $20.88
207 - Hollow Core Pile	13	14.25	27.59	5.25	0.37	4	2.86	$11.40 to $17.11
210 - Reinforced Conc Pier Wall	84	20.15	37.56	6.13	0.30	6	1.31	$18.84 to $21.46
215 - Reinforced Conc Abutment	1283	20.31	64.61	8.04	0.40	10	0.44	$19.87 to $20.74
220 - Pile Cap/Footing	436	20.08	53.09	7.29	0.36	8	0.68	$19.40 to $20.77
233 - P/S Conc Cap	4	18.45	17.95	4.24	0.23	3	4.15	$14.30 to $22.60
234 - Reinforced Conc Cap	1166	20.39	63.52	7.97	0.39	10	0.46	$19.93 to $20.85
241 - Reinforced Concrete Culvert	68	17.80	54.36	7.37	0.41	8	1.75	$16.05 to $19.55
298 - Pile Jacket without Cathodic Protection	54	19.68	43.37	6.59	0.33	7	1.76	$17.92 to $21.44
299 - Pile Jacket with Cathodic Protection	9	21.81	18.19	4.26	0.20	3	2.79	$19.02 to $24.60
321 - Reinforced Conc Approach Slab w/ or w/o AC Ovly	1281	20.48	66.06	8.13	0.40	10	0.45	$20.03 to $20.92
331 - Reinforced Conc Bridge Railing	1050	20.50	63.98	8.00	0.39	10	0.48	$20.02 to $20.99
387 - Fender Dolphin System Prestressed Concrete	57	19.81	31.64	5.63	0.28	5	1.46	$18.35 to $21.27
388 - Fender Dolphin System Reinforced Concrete	4	29.77	8.06	2.84	0.10	1	2.78	$26.98 to $32.55

TABLE C.49 Action Subcategory-Unit 403MH (Patch Minor Spalls) Model for Pontis Elements MMS Data (Continued)

394 - Abutment Slope Protection Reinforced Concrete	723	20.27	71.93	8.48	0.42	11	0.62	$19.65 to $20.89
475 - Wingwall/Retaining Wall Reinforced Concrete	449	19.40	61.44	7.84	0.40	9	0.73	$18.68 to $20.13
564 - Counterweight	30	20.80	15.96	4.00	0.19	2	1.43	$19.37 to $22.23
	9074							
Overall Data:	9074	20.33	64.09	8.01	0.39	10	0.16	$20.16 to $20.49

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4221	26	162.33	2.5439	0.000025	1.4968
Within Groups	577301	9047	63.81			
Total	581522	9073				

* 95% Confidence Level

** Required number of data points. Based on tolerance of +/- 5

TABLE C.50 Action Subcategory-Unit 403SF (Patch Minor Spalls) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
104 - P/S Conc Closed Web/Box Girder	4	50.53	3372.48	58.07	1.15	518	56.91	$-6.38 to $107.44
109 - P/S Conc Open Girder/Beam	295	49.25	2347.80	48.45	0.98	361	5.53	$43.72 to $54.78
110 - Reinforced Conc Open Girder/Beam	25	60.86	3764.24	61.35	1.01	578	24.05	$36.81 to $84.91
115 - P/S Conc Stringer	1	2.52	0.00	0.00	0.00	0	0.00	N/A
144 - Reinforced Conc Arch	2	11.81	5.08	2.25	0.19	1	3.13	$8.68 to $14.93
154 - P/S Conc Floor Beam	1	2.52	0.00	0.00	0.00	0	0.00	N/A
155 - Reinforced Conc Floor Beam	2	18.28	175.64	13.25	0.73	27	18.37	$-0.09 to $36.65
204 - P/S Conc Column or Pile	163	50.04	2877.53	53.64	1.07	442	8.24	$41.81 to $58.28
205 - Reinforced Conc Column or Pile	269	47.94	2343.55	48.41	1.01	360	5.79	$42.16 to $53.73
207 - Hollow Core Pile	4	52.74	3286.71	57.33	1.09	505	56.18	$-3.44 to $108.93
210 - Reinforced Conc Pier Wall	31	39.75	1562.21	39.52	0.99	240	13.91	$25.84 to $53.67
215 - Reinforced Conc Abutment	419	50.78	2854.71	53.43	1.05	439	5.12	$45.67 to $55.90
220 - Pile Cap/Footing	135	43.74	2548.98	50.49	1.15	392	8.52	$35.22 to $52.25
234 - Reinforced Conc Cap	374	48.70	2787.92	52.80	1.08	428	5.35	$43.35 to $54.05
241 - Reinforced Concrete Culvert	4	20.67	19.15	4.38	0.21	3	4.29	$16.39 to $24.96
298 - Pile Jacket without Cathodic Protection	20	37.49	941.87	30.69	0.82	145	13.45	$24.04 to $50.94
299 - Pile Jacket with Cathodic Protection	3	61.40	2777.72	52.70	0.86	427	59.64	$1.76 to $121.04
321 - Reinforced Conc Approach Slab w/ or w/o AC Ovly	407	50.33	2846.32	53.35	1.06	437	5.18	$45.15 to $55.51
331 - Reinforced Conc Bridge Railing	370	49.32	2741.52	52.36	1.06	421	5.34	$43.99 to $54.66
387 - Fender Dolphin System Prestressed Concrete	18	35.48	1178.04	34.32	0.97	181	15.86	$19.63 to $51.34
388 - Fender Dolphin System Reinforced Concrete	3	64.83	7647.08	87.45	1.35	1175	98.96	$-34.12 to $163.79
394 - Abutment Slope Protection Reinforced Concrete	223	51.51	2548.80	50.49	0.98	392	6.63	$44.89 to $58.14
475 - Wingwall/Retaining Wall Reinforced Concrete	144	56.29	3325.25	57.66	1.02	511	9.42	$46.88 to $65.71
564 - Counterweight	10	27.25	439.11	20.95	0.77	67	12.99	$14.26 to $40.23

TABLE C.50 Action Subcategory-Unit 403SF (Patch Minor Spalls) Model for Pontis Elements MMS Data (Continued)

Overall Data:	2927	49.42	2677.08	51.74	1.05	411	1.87	$47.55 to $51.30
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	45210	23	1965.64	0.7327	0.8159	1.5330		
Within Groups	7787925	2903	2682.72					
Total	7833135	2926						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.51 Action Subcategory-Unit 431MH (Maintain Machinery) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
540 - Open Gearing	27	20.15	14.38	3.79	0.19	2	1.43	$18.72 to $21.58
541 - Speed Reducers	26	20.13	14.95	3.87	0.19	2	1.49	$18.64 to $21.62
542 - Shafts	27	20.15	14.38	3.79	0.19	2	1.43	$18.72 to $21.58
543 - Shaft Bearings and Shaft Couplings	27	20.15	14.38	3.79	0.19	2	1.43	$18.72 to $21.58
544 - Brakes	26	20.13	14.95	3.87	0.19	2	1.49	$18.64 to $21.62
545 - Emergency Drive and Back Up Power System	25	20.23	15.31	3.91	0.19	2	1.53	$18.69 to $21.76
546 - Span Drive Motors	19	20.25	17.60	4.19	0.21	3	1.89	$18.37 to $22.14
547 - Hydraulic Power Units	5	20.48	22.79	4.77	0.23	4	4.18	$16.30 to $24.67
548 - Hydraulic Piping System	5	20.48	22.79	4.77	0.23	4	4.18	$16.30 to $24.67
549 - Hydraulic Cylinders/Motors/Rotary Actuators	5	20.48	22.79	4.77	0.23	4	4.18	$16.30 to $24.67
550 - Hopkins Frame	8	17.64	6.33	2.52	0.14	1	1.74	$15.89 to $19.38
560 - Span Locks/Toe Locks/Heel Stops/Tail Locks	21	20.18	16.45	4.06	0.20	3	1.73	$18.45 to $21.92
561 - Live Load Shoes/Strike Plates/Buffer Cylinders	25	19.87	15.58	3.95	0.20	2	1.55	$18.32 to $21.42
562 - Counterweight Support	17	20.38	16.08	4.01	0.20	2	1.91	$18.47 to $22.29
563 - Access Ladder & Platforms	28	20.01	14.36	3.79	0.19	2	1.40	$18.61 to $21.42
564 - Counterweight	19	20.34	17.95	4.24	0.21	3	1.91	$18.44 to $22.25
565 - Trunnion/Straight and Curved Track	21	20.18	16.45	4.06	0.20	3	1.73	$18.45 to $21.92
570 - Transformers & Thyristors	13	20.69	13.28	3.64	0.18	2	1.98	$18.71 to $22.67
571 - Submarine Cable	14	21.26	19.21	4.38	0.21	3	2.30	$18.96 to $23.55
572 - Conduit & Junction Boxes	22	20.20	15.67	3.96	0.20	2	1.65	$18.55 to $21.86
573 - Programmable Logic Controllers	6	21.80	20.74	4.55	0.21	3	3.64	$18.15 to $25.44
574 - Control Console	18	20.34	18.48	4.30	0.21	3	1.99	$18.35 to $22.33
580 - Navigational Light System	22	20.20	15.67	3.96	0.20	2	1.65	$18.55 to $21.86
581 - Operator Facilities	20	20.26	17.18	4.15	0.20	3	1.82	$18.44 to $22.25
583 - Swing Bridge Specific Equipment	7	19.51	9.41	3.07	0.16	1	2.27	$17.23 to $21.78
590 - Resistance Barriers	1	19.24	0.00	0.00	0.00	0	0.00	N/A

TABLE C.51 Action Subcategory-Unit 431MH (Maintain Machinery) Model for Pontis Elements MMS Data (Continued)

591 - Warning Gates	19	20.25	17.60	4.19	0.21	3	1.89	$18.37 to $22.14
592 - Traffic Signal	19	20.25	17.60	4.19	0.21	3	1.89	$18.37 to $22.14
	492							
Overall Data:	492	20.20	15.21	3.90	0.19	2	0.34	$19.85 to $20.54

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	98	27	3.63	0.2282	0.999988	1.5098
Within Groups	7373	464	15.89			
Total	7470	491				

* 95% Confidence Level

** Required number of data points. Based on tolerance of +/- 5

TABLE C.52 Action Subcategory-Unit 446MH (Maintain Approach Slab) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
12 - Concrete Deck - Bare	26	25.05	118.28	10.88	0.43	18	4.18	$20.87 to $29.24
13 - Concrete Deck - Unprotected w/ AC Overlay	18	21.36	101.78	10.09	0.47	16	4.66	$16.70 to $26.02
28 - Steel Deck - Open Grid	1	25.34	0.00	0.00	0.00	0	0.00	N/A
38 - Concrete Slab - Bare	1	15.48	0.00	0.00	0.00	0	0.00	N/A
	46							
Overall Data:	46	23.41	108.89	10.43	0.45	17	3.02	$20.39 to $26.42
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	213	3	70.92	0.6355	0.5963	2.8271		
Within Groups	4687	42	111.60					
Total	4900	45						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

TABLE C.53 Action Subcategory-Unit 446SF (Maintain Approach Slab) Model for Pontis Elements MMS Data								
Treatments	**Count**	**Average**	**Variance**	**Std. dev.**	**C.V.**	**N****	**Error (d) in Mean Estimate***	**C. I.**
12 - Concrete Deck - Bare	142	23.31	762.82	27.62	1.18	117	4.54	$18.77 to $27.85
13 - Concrete Deck - Unprotected w/ AC Overlay	69	19.76	547.94	23.41	1.18	84	5.52	$14.23 to $25.28
28 - Steel Deck - Open Grid	3	36.58	3319.20	57.61	1.58	510	65.19	$-28.62 to $101.77
29 - Steel Deck - Concrete Filled Grid	2	4.23	14.00	3.74	0.88	2	5.19	$-0.95 to $9.42
38 - Concrete Slab - Bare	16	23.24	1152.09	33.94	1.46	177	16.63	$6.61 to $39.87
39 - Concrete Slab - Unprotected w/ AC Overlay	15	28.29	1274.11	35.69	1.26	196	18.06	$10.22 to $46.35
98 - Concrete Deck on Precast Deck Panels	3	45.54	4974.28	70.53	1.55	764	79.81	$-34.27 to $125.35
99 - Prestressed Concrete Slab (Sonovoid)	12	17.15	413.46	20.33	1.19	64	11.50	$5.65 to $28.66
	262							
Overall Data:	262	22.63	786.98	28.05	1.24	121	3.40	$19.24 to $26.03
ANOVA								
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*		
Between Groups	4316	7	616.62	0.7789	0.6055	2.0457		
Within Groups	201086	254	791.68					
Total	205402	261						
* 95% Confidence Level								
** Required number of data points. Based on tolerance of +/- 5								

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
101	12	Bare Concrete Deck	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	13	Unp Conc Deck/AC Ovl	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	14	P Conc Deck/AC Ovly	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	18	P Conc Deck/Thin Ovl	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	22	P Conc Deck/Rigid Ov	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	26	Conc Deck/Coatd Bars	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	27	Conc Deck/Cathodic	(SF)	5-Distress over 25%	2-Replace Deck					SF	117.09		1																
101	28	Steel Deck/Open Grid	(SF)	5-Advanced corrosion	2-Replace unit					SF	117.09		1																
101	29	Steel Deck/Conc Grid	(SF)	5-Advanced corrosion	2-Replace unit					SF	117.09		1																
101	30	Corrug/Orthotpc Deck	(SF)	5-Major section loss	2-Replace unit					SF	117.09		1																
101	31	Timber Deck	(SF)	3-Some strength loss	2-Replace deck					SF	117.09		1																
101	31	Timber Deck	(SF)	4-Major strength loss	1-Replace deck					SF	117.09		1																
101	32	Timber Deck/AC Ovly	(SF)	3-Some strength loss	2-Replace deck & surfa					SF	117.09		1																
101	32	Timber Deck/AC Ovly	(SF)	4-Major strength loss	1-Replace deck & surfa					SF	117.09		1																
101	38	Bare Concrete Slab	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	39	Unp Conc Slab/AC Ovl	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	40	P Conc Slab/AC Ovly	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	44	P Conc Slab/Thin Ovl	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	48	P Conc Slab/Rigid Ov	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	52	Conc Slab/Coatd Bars	(SF)	5-Distress over 25%	2-Replace deck					SF	117.09		1																
101	53	Conc Slab/Cathodic	(SF)	5-Distress over 25%	2-Replace Deck					SF	117.09		1																
101	54	Timber Slab	(SF)	3-Some strength loss	2-Replace deck					SF	117.09		1																
101	54	Timber Slab	(SF)	4-Major strength loss	1-Replace deck					SF	117.09		1																
101	55	Timber Slab/AC Ovly	(SF)	3-Some strength loss	2-Replace deck and sur					SF	117.09		1																
101	55	Timber Slab/AC Ovly	(SF)	4-Major strength loss	1-Replace deck and sur					SF	117.09		1																
101	98	Conc Deck on PC Pane	(SF)	5-Distress over 25 %	2-Replace Deck					SF	117.09		1																
101	99	PS Conc Slab	(SF)	5-Dist >25%	2-Replace unit					SF	117.09		1																
102	102	Paint Stl Box Girder	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	107	Paint Stl Opn Girder	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	113	Paint Stl Stringer	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	121	P/Stl Thru Truss/Bot	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	126	P/Stl Thru Truss/Top	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	131	Paint Stl Deck Truss	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	141	Paint Stl Arch	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	152	Paint Stl Floor Beam	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	161	Paint Stl Pin/Hanger	(EA)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	202	Paint Stl Column	(EA)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	231	Paint Stl Cap	(LF)	4-Active corrosion	2-Replace paint system																					SF	4.74	1.76	5
102	487	Sign Member Horiz	(LF)	4-Surf Pits	2-Replace paint system																					SF	4.74	1.76	5
102	488	Sign Member Vertical	(LF)	4-Surf Pits	2-Repaint																					SF	4.74	1.76	5
102	496	Painted High Mast L.	(EA)	4-Surf Pits	2-Repaint																					SF	4.74	1.76	5
102	497	Galvan. High Mast L.	(EA)	4-Surf Pits	2-Repaint																					SF	4.74	1.76	5
102	550	Hopkins Frame	(EA)	4-Surf Pits	2-Repaint																					SF	4.74	1.76	5
102	562	Counterweight Suppor	(EA)	4-Surf Pits	2-Repaint																					SF	4.74	1.76	5
102	563	Acc Ladd & Plat	(EA)	4-Surf Pits	2-Repaint																					SF	4.74	1.76	5
111	300	Strip Seal Exp Joint	(LF)	3-Major leakage	2-Replace joint					LF	12.54	0.72	25	**LF**	**85.00**	**0.536**	**51**	LF	73.92	0.69	96					LF	281.61		1
111	302	Compressn Joint Seal	(LF)	3-Major deterioration	2-Replace joint					LF	12.54	0.72	25	**LF**	**41.95**	**0.544**	**20**	LF	73.92	0.69	96					LF	281.61		1
111	303	Assembly Joint/Seal	(LF)	3-Advanced corrosion	2-Replace unit					LF	12.54	0.72	25	**LF**	**418.85**	**0.430**	**6**	LF	73.92	0.69	96					LF	281.61		1
111	304	Open Expansion Joint	(LF)	3-Advanced corrosion	2-Replace unit					LF	12.54	0.72	25	**LF**				LF	73.92	0.69	96					LF	281.61		1
111	399	Other Expansion Join	(LF)	3-Maj Deter	2-Replace unit					LF	12.54	0.72	25	**LF**	**64.21**	**0.682**	**23**	LF	73.92	0.69	96					LF	281.61		1
112	300	Strip Seal Exp Joint	(LF)	3-Major leakage	1-Replace gland and pa	**LF**	**87.64**	**N/A**	**1**	LF	22.60	1.38	185	**LF**	**85.00**	**0.536**	**51**	LF	73.92	0.69	96	**M1**	**4,588.52**	**1.31**	5	LF	62.64	0.72	13
112	301	Pourable Joint Seal	(LF)	2-Minor leakage	1-Clean joint and repl	**LF**	**13.29**	**1.55**	**74**	LF	22.60	1.38	185	**LF**				LF	73.92	0.69	96					LF	62.64	0.72	13
112	302	Compressn Joint Seal	(LF)	3-Major deterioration	1-Replace gland and/or	**LF**	**30.98**	**1.20**	**94**	LF	22.60	1.38	185	**LF**	**41.95**	**0.544**	**20**	LF	73.92	0.69	96	**LF**	**55.22**	**1.20**	6	LF	62.64	0.72	13
113	160	Unpnt Stl Pin/Hanger	(EA)	4-Major section loss	2-Replace unit					MH	32.23	0.23	7																
113	161	Paint Stl Pin/Hanger	(EA)	5-Section loss	2-Replace unit					MH	32.23	0.23	7																
113	310	Elastomeric Bearing	(EA)	3-Major deterioration	2-Replace unit and res					MH	32.23	0.23	7																
113	311	Moveable Bearing	(EA)	3-Advanced corrosion	2-Replace unit					MH	32.23	0.23	7																
113	312	Enclosed Bearing	(EA)	3-Bearing failures	2-Replace unit					MH	32.23	0.23	7																
113	313	Fixed Bearing	(EA)	3-Advanced corrosion	2-Replace unit					MH	32.23	0.23	7																
113	314	Pot Bearing	(EA)	3-Advanced corrosion	2-Replace unit					MH	32.23	0.23	7																
113	315	Disk Bearing	(EA)	3-Advanced corrosion	2-Replace unit					MH	32.23	0.23	7																
114	330	Metal Rail Uncoated	(LF)	3-Active corrosion	2-Replace unit					LF	18.46	0.75	130	**LF**	**32.60**	**N/A**	**1**	LF	28.78	1.01	73	**LF**	**38.89**	**0.71**	3	LF	140.06	1.03	13
114	330	Metal Rail Uncoated	(LF)	4-Section loss	2-Replace unit					LF	18.46	0.75	130	**LF**	**32.60**	**N/A**	**1**	LF	28.78	1.01	73	**LF**	**38.89**	**0.71**	3	LF	140.06	1.03	13
114	331	Conc Bridge Railing	(LF)	4-Analysis warranted	2-Replace unit	LF	19.93	0.69	75	LF	18.46	0.75	130	**LF**	**53.29**	**0.536**	**32**	LF	28.78	1.01	73	**LF**	**187.41**	**0.81**	9	LF	140.06	1.03	13
114	332	Timb Bridge Railing	(LF)	3-Some strength loss	1-Replace unit					LF	18.46	0.75	130	**LF**				LF	28.78	1.01	73					LF	140.06	1.03	13
114	333	Other Bridge Railing	(LF)	3-Major deterioration	2-Replace unit	LF	16.73	0.78	61	LF	18.46	0.75	130	**LF**	**69.76**	**1.531**	**3**	LF	28.78	1.01	73	**LF**	**17.37**	**N/A**	1	LF	140.06	1.03	13
114	334	Metal Rail Coated	(LF)	4-Active corrosion	2-Replace unit	LF	14.71	0.61	20	LF	18.46	0.75	130	**LF**	**32.60**	**N/A**	**1**	LF	28.78	1.01	73					LF	140.06	1.03	13
114	334	Metal Rail Coated	(LF)	5-Analysis warranted	2-Replace unit	LF	14.71	0.61	20	LF	18.46	0.75	130	**LF**	**32.60**	**N/A**	**1**	LF	28.78	1.01	73					LF	140.06	1.03	13
121	394	R/Conc Abut Slope Pr	(SF)	4-Adv Corros	2-Replace unit	MH	66.98	0.59	20	MH	64.48	0.62	24									**M2**	**82.34**	**0.22**	**5**	SY	86.33	0.27	14
121	395	Timber Abut Slope Pr	(SF)	3-Minor Loss	2-Replace unit					MH	64.48	0.62	24													SY	86.33	0.27	14
121	395	Timber Abut Slope Pr	(SF)	4-Adv Deter	2-Replace unit					MH	64.48	0.62	24													SY	86.33	0.27	14
121	396	Other Abut Slope Pro	(SF)	3-Mod Deter	2-Replace unit	MH	39.48	0.79	4	MH	64.48	0.62	24									**SY**	**63.46**	**0.51**	**3**	SY	86.33	0.27	14

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
121	396	Other Abut Slope Pro	(SF)	4-Maj Deter	2-Replace unit					MH	64.48	0.62	24									**SY**	**63.46**	**0.51**	**3**	SY	86.33	0.27	14
123	397	Drain. Syst Metal	(EA)	5-Sect Loss	2-Replace unit					MH	18.00	0.24														EA	596.64	0.63	6
123	398	Drain. Syst Other	(EA)	4-Maj Deter	2-Replace unit					MH	18.00	0.24														EA	596.64	0.63	6
131	540	Open Gearing	(EA)	3-Mod Deter	2-Replace unit	MH	17.58	0.15	24	MH	20.99	0.26	60	**LS**	**428,655.88**	**N/A**	**1**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	540	Open Gearing	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60	**LS**	**428,655.88**	**N/A**	**1**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	541	Speed Reducers	(EA)	3-Mod Deter	2-Replace unit	MH	17.25	0.12	23	MH	20.99	0.26	60	**LS**	**428,655.88**	**N/A**	**1**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	541	Speed Reducers	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60	**LS**	**428,655.88**	**N/A**	**1**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	542	Shafts	(EA)	3-Mod Deter	2-Replace unit	MH	17.58	0.15	24	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	542	Shafts	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	543	Shaft Brgs and Coupl	(EA)	3-Mod Deter	2-Replace unit	MH	17.58	0.15	24	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	543	Shaft Brgs and Coupl	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	544	Brakes	(EA)	3-Mod Deter	2-Replace unit	MH	17.25	0.12	23	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	544	Brakes	(EA)	4-Maj Deter	2-Replace unit	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	545	Emergency Drive	(EA)	3-Mod Deter	2-Replace System	MH	18.25	0.23	25	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	545	Emergency Drive	(EA)	4-Maj Deter	1-Replace System	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	546	Span Drive Motors	(EA)	3-Mod Deter	2-Replace unit	MH	17.79	0.14	18	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	546	Span Drive Motors	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	547	Hydraulic Power Unit	(EA)	3-Mod Deter	2-Replace unit	MH	19.23	0.28	15	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	547	Hydraulic Power Unit	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	548	Hydraulic Piping Sys	(EA)	3-Maj Deter	2-Replace unit	MH	19.23	0.28	15	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	549	Hydraulic Cylinders	(EA)	3-Mod Deter	2-Replace unit	MH	19.23	0.28	15	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	549	Hydraulic Cylinders	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	550	Hopkins Frame	(EA)	5-Sect Loss	2-Replace unit	MH	18.79	0.09	5	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	560	Locks	(EA)	3-Mod Deter	2-Replace unit	MH	18.30	0.22	27	MH	20.99	0.26	60	**EA**	**33,822.57**	**0.84**	**3**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	560	Locks	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60	**EA**	**33,822.57**	**0.84**	**3**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	561	Live Load Shoes	(EA)	3-Maj Deter	2-Replace unit	MH	18.19	0.23	31	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	562	Counterweight Suppor	(EA)	5-Sect Loss	2-Replace unit	MH	18.29	0.22	29	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	563	Acc Ladd & Plat	(EA)	5-Sect Loss	2-Replace unit	MH	18.13	0.22	34	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	564	Counterweight	(EA)	4-Adv Corros	2-Replace unit	MH	18.37	0.22	31	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	565	Trun/Str and Cur Trk	(EA)	3-Mod Deter	2-Replace unit	MH	18.37	0.22	31	MH	20.99	0.26	60	**EA**	**120,909.76**	**0.97**	**3**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	565	Trun/Str and Cur Trk	(EA)	4-Maj Deter	1-Replace unit	MH				MH	20.99	0.26	60	**EA**	**120,909.76**	**0.97**	**3**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	570	Transformers	(EA)	3-Maj Deter	2-Replace unit	MH	17.52	0.11	13	MH	20.99	0.26	60					EA	40,551.21	1.45	29	**EA**	**1,748.93**	**0.78**	**3**	EA	161.32	1.40	824
131	571	Submarine Cable	each	3-Maj Deter	2-Replace unit	MH	18.31	0.23	24	MH	20.99	0.26	60					EA	40,551.21	1.45	29	**EA**	**155.89**	**1.22**	**66**	EA	161.32	1.40	824
131	572	Conduit & Junc. Box	(EA)	3-Maj Deter	2-Replace unit	MH	18.37	0.22	31	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	573	PLCs	(EA)	3-Maj Deter	2-Replace unit	MH	18.20	0.24	21	MH	20.99	0.26	60	**EA**	**27,998.64**	**0.71**	**7**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	574	Control Console	(EA)	3-Maj Deter	2-Replace unit	MH	18.13	0.22	27	MH	20.99	0.26	60	**EA**	**93,959.66**	**1.09**	**9**	EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	580	Navigational Lights	(EA)	3-Maj Deter	2-Replace unit	MH	18.15	0.21	30	MH	20.99	0.26	60	**LS**	**31,969.45**	**0.58**	**11**	EA	40,551.21	1.45	29	**LS**	**5,785.04**	**1.56**	**6**	EA	161.32	1.40	824
131	581	Operator Facilities	(EA)	2-Mod Deter	2-Replace unit	MH	18.15	0.21	30	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	581	Operator Facilities	(EA)	3-Maj Deter	2-Replace unit	MH				MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	582	Lift Bridge Spec. Eq	(EA)	3-Maj Deter	2-Replace unit	MH	18.87	0.24	4	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	583	Swing Bridge Spec. E	(EA)	3-Maj Deter	2-Replace unit	MH	15.64	0.26	3	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	590	Resistance Barriers	(EA)	3-Maj Deter	2-Replace unit	MH	17.38	0.13	4	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	591	Warning Gates	(EA)	3-Maj Deter	2-Replace unit	MH	18.13	0.22	27	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
131	592	Traffic Signals	(EA)	3-Maj Deter	2-Replace unit	MH	18.13	0.22	27	MH	20.99	0.26	60					EA	40,551.21	1.45	29					EA	161.32	1.40	824
132	12	Bare Concrete Deck	(SF)	1-No damage	1-Add a protective sys									**SF**	**44.05**	0.47	**3**	SF	44.05	0.47	3					M2	530.00		1
132	12	Bare Concrete Deck	(SF)	2-Distress <= 2%	2-Add a protective sys									**SF**	**44.05**	0.47	**3**	SF	44.05	0.47	3					M2	530.00		1
132	12	Bare Concrete Deck	(SF)	3-2 to 10 % distress	2-Rep spall & add prot									**SF**	**44.05**	0.47	**3**	SF	44.05	0.47	3					M2	530.00		1
132	12	Bare Concrete Deck	(SF)	4-10 to 25% distress	2-Rep spall & add prot									**SF**	**44.05**	0.47	**3**	SF	44.05	0.47	3					M2	530.00		1
132	12	Bare Concrete Deck	(SF)	5-Distress over 25%	1-Repair spalled areas									**SF**	**44.05**	0.47	**3**	SF	44.05	0.47	3					M2	530.00		1
132	26	Conc Deck/Coatd Bars	(SF)	1-No damage	1-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	26	Conc Deck/Coatd Bars	(SF)	2-Distress <=2%	2-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	26	Conc Deck/Coatd Bars	(SF)	3-Distress 2-10%	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	26	Conc Deck/Coatd Bars	(SF)	4-10-25% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	26	Conc Deck/Coatd Bars	(SF)	5-Distress over 25%	1-Repair spalled areas													SF	44.05	0.47	3					M2	530.00		1
132	27	Conc Deck/Cathodic	(SF)	1-No damage	1-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	27	Conc Deck/Cathodic	(SF)	2-Distress <=2%	2-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	27	Conc Deck/Cathodic	(SF)	3-2 to 10% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	27	Conc Deck/Cathodic	(SF)	4-10-25% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	27	Conc Deck/Cathodic	(SF)	5-Distress over 25%	1-Repair spalled areas													SF	44.05	0.47	3					M2	530.00		1
132	38	Bare Concrete Slab	(SF)	1-No damage	1-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	38	Bare Concrete Slab	(SF)	2-Distress <=2%	2-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	38	Bare Concrete Slab	(SF)	3-2-10% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	38	Bare Concrete Slab	(SF)	4-10-25% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	38	Bare Concrete Slab	(SF)	5-Distress over 25%	1-Repair spalled areas													SF	44.05	0.47	3					M2	530.00		1
132	52	Conc Slab/Coatd Bars	(SF)	1-No damage	1-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	52	Conc Slab/Coatd Bars	(SF)	2-Distress under 2%	2-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	52	Conc Slab/Coatd Bars	(SF)	3-2-10% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	52	Conc Slab/Coatd Bars	(SF)	4-10-25% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	52	Conc Slab/Coatd Bars	(SF)	5-Distress over 25%	1-Repair spalled areas													SF	44.05	0.47	3					M2	530.00		1
132	53	Conc Slab/Cathodic	(SF)	1-No damage	1-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	53	Conc Slab/Cathodic	(SF)	2-Distress under 2%	2-Add a protective sys													SF	44.05	0.47	3					M2	530.00		1
132	53	Conc Slab/Cathodic	(SF)	3-2-10% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
132	53	Conc Slab/Cathodic	(SF)	4-10-25% distress	2-Rep spall & add prot													SF	44.05	0.47	3					M2	530.00		1
132	53	Conc Slab/Cathodic	(SF)	5-Distress over 25%	1-Repair spalls+overla													SF	44.05	0.47	3					M2	530.00		1
132	98	Conc Deck on PC Pane	(SF)	2-Distress under 2 %	2-Add Protect. Syst.													SF	44.05	0.47	3					M2	530.00		1
141	106	Unpnt Stl Opn Girder	(LF)	4-Major section loss	2-Replace unit					MH	29.64	0.60	2																
141	107	Paint Stl Opn Girder	(LF)	5-Section loss	2-Replace unit					MH	29.64	0.60	2																
141	109	P/S Conc Open Girder	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	110	R/Conc Open Girder	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	111	Timber Open Girder	(LF)	3-Some strength loss	2-Replace unit					MH	29.64	0.60	2																
141	111	Timber Open Girder	(LF)	4-Major strength loss	2-Replace unit					MH	29.64	0.60	2																
141	112	Unpnt Stl Stringer	(LF)	4-Major section loss	2-Replace unit					MH	29.64	0.60	2																
141	113	Paint Stl Stringer	(LF)	5-Section loss	2-Replace unit					MH	29.64	0.60	2																
141	115	P/S Conc Stringer	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	116	R/Conc Stringer	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	117	Timber Stringer	(LF)	3-Some strength loss	2-Replace unit					MH	29.64	0.60	2																
141	117	Timber Stringer	(LF)	4-Major strength loss	2-Replace unit					MH	29.64	0.60	2																
141	151	Unpnt Stl Floor Beam	(LF)	4-Major section loss	2-Replace unit					MH	29.64	0.60	2																
141	152	Paint Stl Floor Beam	(LF)	5-Section loss	2-Replace unit					MH	29.64	0.60	2																
141	154	P/S Conc Floor Beam	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	155	R/Conc Floor Beam	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	156	Timber Floor Beam	(LF)	3-Some strength loss	2-Replace unit					MH	29.64	0.60	2																
141	156	Timber Floor Beam	(LF)	4-Major strength loss	2-Replace unit					MH	29.64	0.60	2																
141	230	Unpnt Stl Cap	(LF)	4-Major section loss	2-Replace unit					MH	29.64	0.60	2																
141	231	Paint Stl Cap	(LF)	5-Section loss	2-Replace unit					MH	29.64	0.60	2																
141	233	P/S Conc Cap	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	234	R/Conc Cap	(LF)	4-Analysis warranted	2-Replace unit					MH	29.64	0.60	2																
141	235	Timber Cap	(LF)	3-Some strength loss	2-Replace unit					MH	29.64	0.60	2																
141	235	Timber Cap	(LF)	4-Major strength loss	2-Replace unit					MH	29.64	0.60	2																
142	101	Unpnt Stl Box Girder	(LF)	4-Major section loss	2-Replace unit																								
142	102	Paint Stl Box Girder	(LF)	5-Section loss	2-Replace unit																								
142	104	P/S Conc Box Girder	(LF)	4-Analysis warranted	2-Replace unit																								
142	105	R/Conc Box Girder	(LF)	4-Analysis warranted	2-Replace unit																								
142	120	U/Stl Thru Truss/Bot	(LF)	4-Major section loss	2-Replace unit																								
142	121	P/Stl Thru Truss/Bot	(LF)	5-Section loss	2-Replace unit																								
142	125	U/Stl Thru Truss/Top	(LF)	4-Major section loss	2-Replace unit																								
142	126	P/Stl Thru Truss/Top	(LF)	5-Section loss	2-Replace unit																								
142	130	Unpnt Stl Deck Truss	(LF)	4-Major section loss	2-Replace unit																								
142	131	Paint Stl Deck Truss	(LF)	5-Section loss	2-Replace unit																								
142	135	Timber Truss/Arch	(LF)	3-Some strength loss	2-Replace unit																								
142	135	Timber Truss/Arch	(LF)	4-Major strength loss	2-Replace unit																								
142	140	Unpnt Stl Arch	(LF)	4-Major section loss	2-Replace unit																								
142	141	Paint Stl Arch	(LF)	5-Section loss	2-Replace unit																								
142	143	P/S Conc Arch	(LF)	4-Analysis warranted	2-Replace unit																								
142	144	R/Conc Arch	(LF)	4-Analysis warranted	2-Replace unit																								
142	145	Other Arch	(LF)	4-Major deterioration	2-Replace unit																								
143	146	Misc Cable Uncoated	(EA)	4-Analysis warranted	2-Replace unit																					EA	432.54	0.57	3
143	147	Misc Cable Coated	(EA)	4-Active corrosion	2-Replace unit																					EA	432.54	0.57	3
143	147	Misc Cable Coated	(EA)	5-Analysis warranted	2-Replace unit																					EA	432.54	0.57	3
144	201	Unpnt Stl Column	(EA)	4-Major section loss	2-Replace unit	MH	21.27	0.26	2	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	202	Paint Stl Column	(EA)	5-Section loss	2-Replace unit	MH	18.22	0.16	3	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	204	P/S Conc Column	(EA)	4-Analysis warranted	2-Replace unit	MH	17.16	0.19	13	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	205	R/Conc Column	(EA)	4-Analysis warranted	2-Replace unit	MH	19.58	0.32	21	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	206	Timber Column	(EA)	3-Some strength loss	2-Replace unit	MH	24.92	0.38	5	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	206	Timber Column	(EA)	4-Major strength loss	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	207	P/S Conc Holl Pile	(EA)	4-Adv Corros	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	210	R/Conc Pier Wall	(LF)	4-Analysis warranted	2-Replace unit	MH	18.10	0.18	9	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	211	Other Mtl Pier Wall	(LF)	4-Major deterioration	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	215	R/Conc Abutment	(LF)	4-Analysis warranted	2-Replace unit	MH	20.59	0.34	26	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	216	Timber Abutment	(LF)	3-Some strength loss	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	216	Timber Abutment	(LF)	4-Major strength loss	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	217	Other Mtl Abutment	(LF)	4-Major deterioration	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	220	R/C Sub Pile Cap/Ftg	(EA)	4-Analysis warranted	2-Replace unit	MH	20.51	0.28	21	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	225	Unpnt Stl Submd Pile	(EA)	4-Major section loss	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	226	P/S Conc Submgd Pile	(EA)	4-Analysis warranted	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	227	R/C Submerged Pile	(EA)	4-Analysis warranted	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	228	Timb Submerged Pile	(EA)	3-Some strength loss	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	228	Timb Submerged Pile	(EA)	4-Major strength loss	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	229	P/S Conc Holl Sub Pi	(EA)	4-Adv Corros	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	298	Pile Jacket Bare	(EA)	4-Maj Deter	2-Replace unit	MH	22.54	0.10	3	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	299	Pile Jacket/Cath Pro	(EA)	4-Maj Deter	2-Replace unit	MH	17.07	N/A	1	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	386	Fender/Dolphin Uncoa	(LF)	4-Adv Corros	2-Replace unit	MH	23.46	0.10	2	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	387	P/S Fender/Dolphin	(LF)	4-Adv Corros	2-Replace unit	MH	17.41	0.21	12	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	388	R/Conc Fender/Dolphi	(LF)	4-Adv Corros	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15

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						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
144	389	Timber Fender/Dolphi	(LF)	4-Adv Deter	2-Replace unit	MH	17.86	0.12	11	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	390	Other Fender/Dolphin	(LF)	3-Mod Deter	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	390	Other Fender/Dolphin	(LF)	4-Maj Deter	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	393	Blkhd Sewl Metal Unc	(SF)	4-Adv Corros	2-Replace unit	MH	17.07	N/A	1	MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	474	Walls Uncoated	(LF)	4-Adv Corros	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	475	R/Conc Walls	(LF)	4-Adv Deter	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	476	Timber Walls	(LF)	3-Minor Loss	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	476	Timber Walls	(LF)	4-Adv Deter	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	477	Other Walls	(LF)	4-Maj Deter	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	478	MSE Walls	(LF)	4-Maj Deter	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
144	489	Sign Foundation	(EA)	4-Adv Corros	2-Replace unit					MH	21.39	0.36	29					LF	131.54	0.42	5					EA	291.65	0.76	15
145	240	Metal Culvert	(LF)	4-Major corrosion	2-Replace unit																					LF	264.42		1
145	241	Concrete Culvert	(LF)	4-Major deterioration	2-Replace unit																					LF	264.42		1
145	242	Timber Culvert	(LF)	4-Major deterioration	2-Replace unit																					LF	264.42		1
145	243	Misc Culvert	(LF)	4-Major deterioration	2-Replace unit																					LF	264.42		1
146	320	P/S Conc Appr Slab	(EA)	3-Major cracks/spalls	2-Replace unit													EA	12,935.61	0.58	112					SY	55.73	0.19	2
146	320	P/S Conc Appr Slab	(EA)	4-Broken/Unstable	1-Replace unit													EA	12,935.61	0.58	112					SY	55.73	0.19	2
146	321	R/Conc Approach Slab	(EA)	3-Major cracks/spalls	2-Replace unit													EA	12,935.61	0.58	112					SY	55.73	0.19	2
146	321	R/Conc Approach Slab	(EA)	4-Broken/Unstable	1-Replace unit													EA	12,935.61	0.58	112					SY	55.73	0.19	2
151	487	Sign Member Horiz	(LF)	5-Sect Loss	2-Replace unit					LF	16.39		1													EA	739.89	1.07	180
151	488	Sign Member Vertical	(LF)	5-Sect Loss	2-Replace unit					LF	16.39		1													EA	739.89	1.07	180
151	495	Uncoat High Mast L.	(EA)	4-Adv Corros	2-Replace unit					EA	40.81	1.41	3													EA	739.89	1.07	180
151	496	Painted High Mast L.	(EA)	5-Sect Loss	2-Replace unit					EA	40.81	1.41	3													EA	739.89	1.07	180
151	497	Galvan. High Mast L.	(EA)	5-Sect Loss	2-Replace unit					EA	40.81	1.41	3													EA	739.89	1.07	180
151	498	Other High Mast L.P.	(EA)	4-Maj Deter	2-Replace unit					EA	40.81	1.41	3													EA	739.89	1.07	180
151	499	H. M. L. P. Found.	(EA)	4-Adv Corros	2-Replace unit					EA	40.81	1.41	3													EA	739.89	1.07	180
201	13	Unp Conc Deck/AC Ovl	(SF)	3-2 to 10% distress	2-Replac substrate and					SF	37.80	0.34	4																
201	13	Unp Conc Deck/AC Ovl	(SF)	4-10-25% distress	2-Repair substrate and					SF	37.80	0.34	4																
201	13	Unp Conc Deck/AC Ovl	(SF)	5-Distress over 25%	1-Repair substrate and					SF	37.80	0.34	4																
201	14	P Conc Deck/AC Ovly	(SF)	3-2 to 10% distress	2-Replace overlay					SF	37.80	0.34	4																
201	14	P Conc Deck/AC Ovly	(SF)	4-10-25% distress	2-Replace overlay+prot					SF	37.80	0.34	4																
201	14	P Conc Deck/AC Ovly	(SF)	5-Distress over 25%	1-Replace overlay+prot					SF	37.80	0.34	4																
201	18	P Conc Deck/Thin Ovl	(SF)	4-10-25% distress	2-Replace overlay					SF	37.80	0.34	4																
201	18	P Conc Deck/Thin Ovl	(SF)	5-Distress over 25%	1-Replace overlay					SF	37.80	0.34	4																
201	22	P Conc Deck/Rigid Ov	(SF)	4-Distress 10-25%	2-Replace overlay					SF	37.80	0.34	4																
201	22	P Conc Deck/Rigid Ov	(SF)	5-Distress over 25%	1-Replace overlay					SF	37.80	0.34	4																
201	27	Conc Deck/Cathodic	(SF)	4-10-25% distress	1-Repair spalled areas					SF	37.80	0.34	4																
201	39	Unp Conc Slab/AC Ovl	(SF)	3-2-10% distress	2-Repair substrate & r					SF	37.80	0.34	4																
201	39	Unp Conc Slab/AC Ovl	(SF)	4-10-25% distress	2-Repair substrate and					SF	37.80	0.34	4																
201	39	Unp Conc Slab/AC Ovl	(SF)	5-Distress over 25%	1-Repair substrate and					SF	37.80	0.34	4																
201	40	P Conc Slab/AC Ovly	(SF)	3-2-10% distress	2-Replace overlay					SF	37.80	0.34	4																
201	40	P Conc Slab/AC Ovly	(SF)	4-10-25% distress	2-Replace overlay and					SF	37.80	0.34	4																
201	40	P Conc Slab/AC Ovly	(SF)	5-Distress over 25%	1-Replace overlay and					SF	37.80	0.34	4																
201	44	P Conc Slab/Thin Ovl	(SF)	4-10-25% distress	2-Replace overlay					SF	37.80	0.34	4																
201	44	P Conc Slab/Thin Ovl	(SF)	5-Distress over 25%	1-Replace overlay					SF	37.80	0.34	4																
201	48	P Conc Slab/Rigid Ov	(SF)	4-10-25% distress	2-Replace overlay					SF	37.80	0.34	4																
201	48	P Conc Slab/Rigid Ov	(SF)	5-Distress over 25%	1-Replace overlay					SF	37.80	0.34	4																
201	98	Conc Deck on PC Pane	(SF)	1-No Damage	1-Protective Coating					SF	37.80	0.34	4																
201	320	P/S Conc Appr Slab	(EA)	2-Minor cracks/spalls	2-Seal Cracks					SF	37.80	0.34	4																
201	320	P/S Conc Appr Slab	(EA)	3-Major cracks/spalls	1-Place overlay					SF	37.80	0.34	4																
201	321	R/Conc Approach Slab	(EA)	2-Cracks/spalls	2-Seal Cracks					SF	37.80	0.34	4																
201	321	R/Conc Approach Slab	(EA)	3-Major cracks/spalls	1-Place overlay					SF	37.80	0.34	4																
202	28	Steel Deck/Open Grid	(SF)	3-Rust formation	2-Rehab connectors					MH	23.49	0.21	7													EA	979.56	0.87	5
202	28	Steel Deck/Open Grid	(SF)	4-Moderate corrosion	2-Rehab connectors					MH	23.49	0.21	7													EA	979.56	0.87	5
202	28	Steel Deck/Open Grid	(SF)	5-Advanced corrosion	1-Rehab connectors+rep					MH	23.49	0.21	7													EA	979.56	0.87	5
202	29	Steel Deck/Conc Grid	(SF)	3-Rust formation	2-Rehab connectors+con					MH	23.49	0.21	7													EA	979.56	0.87	5
202	29	Steel Deck/Conc Grid	(SF)	4-Failed connectors	2-Rehab connectors+con					MH	23.49	0.21	7													EA	979.56	0.87	5
202	29	Steel Deck/Conc Grid	(SF)	5-Advanced corrosion	1-Rehab connectors+con					MH	23.49	0.21	7													EA	979.56	0.87	5
202	30	Corrug/Orthotpc Deck	(SF)	3-Rust formation	2-Repair potholes and					MH	23.49	0.21	7													EA	979.56	0.87	5
202	30	Corrug/Orthotpc Deck	(SF)	4-Moderate deteriorati	2-Replace paint system					MH	23.49	0.21	7													EA	979.56	0.87	5
202	30	Corrug/Orthotpc Deck	(SF)	5-Major section loss	1-Rehab/replace paint					MH	23.49	0.21	7													EA	979.56	0.87	5
202	101	Unpnt Stl Box Girder	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	102	Paint Stl Box Girder	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	106	Unpnt Stl Opn Girder	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	107	Paint Stl Opn Girder	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	112	Unpnt Stl Stringer	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	113	Paint Stl Stringer	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	120	U/Stl Thru Truss/Bot	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	121	P/Stl Thru Truss/Bot	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	125	U/Stl Thru Truss/Top	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	126	P/Stl Thru Truss/Top	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	130	Unpnt Stl Deck Truss	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
202	131	Paint Stl Deck Truss	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	140	Unpnt Stl Arch	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	141	Paint Stl Arch	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	151	Unpnt Stl Floor Beam	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	152	Paint Stl Floor Beam	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	160	Unpnt Stl Pin/Hanger	(EA)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	161	Paint Stl Pin/Hanger	(EA)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	201	Unpnt Stl Column	(EA)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	202	Paint Stl Column	(EA)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	225	Unpnt Stl Submd Pile	(EA)	4-Major section loss	1-Rehab Unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	230	Unpnt Stl Cap	(LF)	4-Major section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	231	Paint Stl Cap	(LF)	5-Section loss	1-Major rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	240	Metal Culvert	(LF)	2-Minor corrosion	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	240	Metal Culvert	(LF)	3-Moderate corrosion	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	240	Metal Culvert	(LF)	4-Major corrosion	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	298	Pile Jacket Bare	(EA)	4-Maj Deter	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	299	Pile Jacket/Cath Pro	(EA)	4-Maj Deter	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	330	Metal Rail Uncoated	(LF)	4-Section loss	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	334	Metal Rail Coated	(LF)	4-Active corrosion	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	334	Metal Rail Coated	(LF)	5-Analysis warranted	1-Rehab unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	386	Fender/Dolphin Uncoa	(LF)	4-Adv Corros	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	393	Blkhd Sewl Metal Unc	(SF)	4-Adv Corros	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	398	Drain. Syst Other	(EA)	4-Maj Deter	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	474	Walls Uncoated	(LF)	4-Adv Corros	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	487	Sign Member Horiz	(LF)	5-Sect Loss	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	488	Sign Member Vertical	(LF)	5-Sect Loss	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	495	Uncoat High Mast L.	(EA)	4-Adv Corros	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	496	Painted High Mast L.	(EA)	5-Sect Loss	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	497	Galvan. High Mast L.	(EA)	5-Sect Loss	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	498	Other High Mast L.P.	(EA)	2-Min Deter	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	498	Other High Mast L.P.	(EA)	3-Mod Deter	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
202	498	Other High Mast L.P.	(EA)	4-Maj Deter	1-Rehabilitate unit					MH	23.49	0.21	7													EA	979.56	0.87	5
203	104	P/S Conc Box Girder	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	105	R/Conc Box Girder	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	109	P/S Conc Open Girder	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	110	R/Conc Open Girder	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	115	P/S Conc Stringer	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	116	R/Conc Stringer	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	143	P/S Conc Arch	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	144	R/Conc Arch	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	154	P/S Conc Floor Beam	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	155	R/Conc Floor Beam	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	204	P/S Conc Column	(EA)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	205	R/Conc Column	(EA)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	207	P/S Conc Holl Pile	(EA)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	210	R/Conc Pier Wall	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	215	R/Conc Abutment	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	220	R/C Sub Pile Cap/Ftg	(EA)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	226	P/S Conc Submgd Pile	(EA)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	227	R/C Submerged Pile	(EA)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	229	P/S Conc Holl Sub Pi	(EA)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	233	P/S Conc Cap	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	234	R/Conc Cap	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	241	Concrete Culvert	(LF)	2-Minor deterioration	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	241	Concrete Culvert	(LF)	3-Moderate deteriorati	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	241	Concrete Culvert	(LF)	4-Major deterioration	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	331	Conc Bridge Railing	(LF)	4-Analysis warranted	1-Rehab unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	387	P/S Fender/Dolphin	(LF)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	388	R/Conc Fender/Dolphi	(LF)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	394	R/Conc Abut Slope Pr	(SF)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	475	R/Conc Walls	(LF)	4-Adv Deter	1-Rehabilitate unit					MH	22.36	0.09	2													LF	682.14	0.15	2
203	489	Sign Foundation	(EA)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	499	H. M. L. P. Found.	(EA)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													EA	300.00	0.00	2
203	564	Counterweight	(EA)	4-Adv Corros	1-Rehabilitate unit					MH	22.36	0.09	2													EA	300.00	0.00	2
204	31	Timber Deck	(SF)	2-Minor decay	1-Rehab and/or protect													LF	23.01	0.47	6					LF	20.69		1
204	31	Timber Deck	(SF)	3-Some strength loss	1-Rehab deck													LF	23.01	0.47	6					LF	20.69		1
204	32	Timber Deck/AC Ovly	(SF)	2-Minor deterioration	2-Rehab and/or protect													LF	23.01	0.47	6					LF	20.69		1
204	32	Timber Deck/AC Ovly	(SF)	3-Some strength loss	1-Rehab deck+repair/re													LF	23.01	0.47	6					LF	20.69		1
204	54	Timber Slab	(SF)	2-Minor decay	1-Rehab and/or protect													LF	23.01	0.47	6					LF	20.69		1
204	54	Timber Slab	(SF)	3-Some strength loss	1-Rehab deck													LF	23.01	0.47	6					LF	20.69		1
204	55	Timber Slab/AC Ovly	(SF)	2-Minor deterioration	2-Rehab and/or protect													LF	23.01	0.47	6					LF	20.69		1
204	55	Timber Slab/AC Ovly	(SF)	3-Some strength loss	1-Rehab deck and surfa													LF	23.01	0.47	6					LF	20.69		1

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
204	111	Timber Open Girder	(LF)	2-Minor decay	1-Rehab &/or protect u					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	111	Timber Open Girder	(LF)	3-Some strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	111	Timber Open Girder	(LF)	4-Major strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	117	Timber Stringer	(LF)	2-Minor decay	1-Rehab &/or protect u					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	117	Timber Stringer	(LF)	3-Some strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	117	Timber Stringer	(LF)	4-Major strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	135	Timber Truss/Arch	(LF)	2-Minor decay	1-Rehab &/or protect u					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	135	Timber Truss/Arch	(LF)	3-Some strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	135	Timber Truss/Arch	(LF)	4-Major strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	156	Timber Floor Beam	(LF)	2-Minor decay	1-Rehab &/or protect u					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	156	Timber Floor Beam	(LF)	3-Some strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	156	Timber Floor Beam	(LF)	4-Major strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	206	Timber Column	(EA)	2-Minor decay	1-Rehab &/or protect u					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	206	Timber Column	(EA)	3-Some strength loss	1-Rehab unit					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	206	Timber Column	(EA)	4-Major strength loss	1-Rehab unit					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	216	Timber Abutment	(LF)	2-Minor decay	1-Rehab &/or protect u					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	216	Timber Abutment	(LF)	3-Some strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	216	Timber Abutment	(LF)	4-Major strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	228	Timb Submerged Pile	(EA)	2-Minor decay	1-Rehab &/or protect u					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	228	Timb Submerged Pile	(EA)	3-Some strength loss	1-Rehab unit					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	228	Timb Submerged Pile	(EA)	4-Major strength loss	1-Rehab unit					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	235	Timber Cap	(LF)	2-Minor decay	1-Rehab &/or protect u					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	235	Timber Cap	(LF)	3-Some strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	235	Timber Cap	(LF)	4-Major strength loss	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	242	Timber Culvert	(LF)	2-Minor decay	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	242	Timber Culvert	(LF)	3-Moderate deteriorati	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	242	Timber Culvert	(LF)	4-Major deterioration	1-Rehab unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	332	Timb Bridge Railing	(LF)	2-Minor decay	1-Rehab and/or apply s					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	389	Timber Fender/Dolphi	(LF)	2-Min Defect	1-Rehab and/or protect					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	389	Timber Fender/Dolphi	(LF)	3-Minor Loss	1-Rehabilitate unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	389	Timber Fender/Dolphi	(LF)	3-Minor Loss	2-Replace unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	389	Timber Fender/Dolphi	(LF)	4-Adv Deter	1-Rehabilitate unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	395	Timber Abut Slope Pr	(SF)	2-Min Defect	1-Rehab and/or protect					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	395	Timber Abut Slope Pr	(SF)	3-Minor Loss	1-Rehabilitate unit					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	395	Timber Abut Slope Pr	(SF)	4-Adv Deter	1-Rehabilitate unit					MH	24.35	0.71	13					LF	23.01	0.47	6					LF	20.69		1
204	476	Timber Walls	(LF)	2-Min Defect	1-Rehab and/or Protect					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	476	Timber Walls	(LF)	3-Minor Loss	1-Rehabilitate unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
204	476	Timber Walls	(LF)	4-Adv Deter	1-Rehabilitate unit					LF	46.26	1.07	2					LF	23.01	0.47	6					LF	20.69		1
205	145	Other Arch	(LF)	2-Minor deterioration	1-Rehab unit																								
205	145	Other Arch	(LF)	3-Moderate deteriorati	1-Rehab unit																								
205	145	Other Arch	(LF)	4-Major deterioration	1-Rehab unit																								
205	211	Other Mtl Pier Wall	(LF)	2-Minor deterioration	1-Rehab unit																								
205	211	Other Mtl Pier Wall	(LF)	3-Moderate deteriorati	1-Rehab unit																								
205	211	Other Mtl Pier Wall	(LF)	4-Major deterioration	1-Rehab unit																								
205	217	Other Mtl Abutment	(LF)	2-Minor deterioration	1-Rehab unit																								
205	217	Other Mtl Abutment	(LF)	3-Moderate deteriorati	1-Rehab unit																								
205	217	Other Mtl Abutment	(LF)	4-Major deterioration	1-Rehab unit																								
205	243	Misc Culvert	(LF)	2-Minor deterioration	1-Rehab unit																								
205	243	Misc Culvert	(LF)	3-Moderate deteriorati	1-Rehab unit																								
205	243	Misc Culvert	(LF)	4-Major deterioration	1-Rehab unit																								
205	333	Other Bridge Railing	(LF)	2-Minor cracks/spalls	1-Rehab unit																								
205	333	Other Bridge Railing	(LF)	3-Major deterioration	1-Rehab unit																								
205	390	Other Fender/Dolphin	(LF)	2-Min Deter	1-Rehabilitate unit																								
205	390	Other Fender/Dolphin	(LF)	3-Mod Deter	1-Rehabilitate unit																								
205	390	Other Fender/Dolphin	(LF)	4-Maj Deter	1-Rehabilitate unit																								
205	477	Other Walls	(LF)	2-Min Deter	1-Rehabilitate unit																								
205	477	Other Walls	(LF)	3-Mod Deter	1-Rehabilitate unit																								
205	477	Other Walls	(LF)	4-Maj Deter	1-Rehabilitate unit																								
206	478	MSE Walls	(LF)	2-Min Deter	1-Rehabilitate unit																								
206	478	MSE Walls	(LF)	3-Mod Deter	1-Rehabilitate unit																								
206	478	MSE Walls	(LF)	4-Maj Deter	1-Rehabilitate unit																								
211	301	Pourable Joint Seal	(LF)	3-Leakage problems	1-Clean joint; patch s	LF	7.92	0.78	463	LF	8.11	0.77	564													LF	18.74	0.73	13
211	303	Assembly Joint/Seal	(LF)	2-Minor deterioration	1-Rehab unit	LF	8.91	0.85	46	LF	8.11	0.77	564													LF	18.74	0.73	13
211	303	Assembly Joint/Seal	(LF)	3-Advanced corrosion	1-Rehab unit	LF	8.91	0.85	46	LF	8.11	0.77	564													LF	18.74	0.73	13
211	304	Open Expansion Joint	(LF)	2-Minor deterioration	1-Rehab unit	LF	9.36	0.76	61	LF	8.11	0.77	564													LF	18.74	0.73	13
211	304	Open Expansion Joint	(LF)	3-Advanced corrosion	1-Rehab unit	LF	9.36	0.76	61	LF	8.11	0.77	564													LF	18.74	0.73	13
211	399	Other Expansion Join	(LF)	2-Min Deter	1-Rehabilitate unit					LF	8.11	0.77	564													LF	18.74	0.73	13
211	399	Other Expansion Join	(LF)	3-Maj Deter	1-Rehabilitate unit					LF	8.11	0.77	564													LF	18.74	0.73	13
213	310	Elastomeric Bearing	(EA)	2-Minor deterioration	1-Reset bearings	MH	24.68	0.28	34	MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	310	Elastomeric Bearing	(EA)	3-Major deterioration	1-Reset bearings	MH	24.68	0.28	34	MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	311	Moveable Bearing	(EA)	3-Advanced corrosion	1-Rehab supports	MH	23.43	0.36	39	MH	23.61	0.31	60					EA	3,453.31	1.17	2								

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
213	312	Enclosed Bearing	(EA)	2-Minor deterioration	1-Rehab unit					MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	312	Enclosed Bearing	(EA)	3-Bearing failures	1-Rehab unit					MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	313	Fixed Bearing	(EA)	2-Minor deterioration	1-Clean and paint or r	MH	23.08	0.39	25	MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	313	Fixed Bearing	(EA)	3-Advanced corrosion	1-Rehab supports or be	MH	23.08	0.39	25	MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	314	Pot Bearing	(EA)	2-Minor deterioration	1-Rehab supports or be					MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	314	Pot Bearing	(EA)	3-Advanced corrosion	1-Rehab bearing device					MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	315	Disk Bearing	(EA)	2-Minor deterioration	1-Rehab supports or be					MH	23.61	0.31	60					EA	3,453.31	1.17	2								
213	315	Disk Bearing	(EA)	3-Advanced corrosion	1-Rehab bearing device					MH	23.61	0.31	60					EA	3,453.31	1.17	2								
221	396	Other Abut Slope Pro	(SF)	2-Min Deter	1-Rehab and/or Protect					SF	84.56	0.94	7													SY	28.97	0.35	11
221	396	Other Abut Slope Pro	(SF)	3-Mod Deter	1-Rehabilitate unit	**SF**	**38.78**	**0.86**	**3**	SF	84.56	0.94	7													SY	28.97	0.35	11
221	396	Other Abut Slope Pro	(SF)	4-Maj Deter	1-Rehabilitate unit	**SF**	**38.78**	**0.86**	**3**	SF	84.56	0.94	7													SY	28.97	0.35	11
222	290	Channel	(EA)	2-Min Deter	1-Rep. Banks/Prot	MH	16.91	0.43	377	SY	12.93	1.13	95																
222	290	Channel	(EA)	3-Mod Deter	1-Rep. Banks/Prot	MH	16.91	0.43	377	SY	12.93	1.13	95																
222	290	Channel	(EA)	3-Mod Deter	2-Countermeasures	MH	16.91	0.43	377	SY	12.93	1.13	95																
222	290	Channel	(EA)	4-Maj Deter	1-Countermeasures	MH	16.91	0.43	377	SY	12.93	1.13	95																
223	397	Drain. Syst Metal	(EA)	5-Sect Loss	1-Rehabilitate unit					MH	83.93	1.35	30																
231	540	Open Gearing	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	29.11	0.33	19	MH	27.46	0.31	30																
231	541	Speed Reducers	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	29.11	0.33	19	MH	27.46	0.31	30																
231	542	Shafts	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	29.05	0.32	20	MH	27.46	0.31	30																
231	543	Shaft Brgs and Coupl	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	29.05	0.32	20	MH	27.46	0.31	30																
231	544	Brakes	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	28.99	0.34	18	MH	27.46	0.31	30																
231	544	Brakes	(EA)	4-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	545	Emergency Drive	(EA)	3-Mod Deter	1-Rehabilitate System	MH	27.52	0.33	18	MH	27.46	0.31	30																
231	546	Span Drive Motors	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	29.11	0.33	19	MH	27.46	0.31	30																
231	547	Hydraulic Power Unit	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	28.39	0.29	8	MH	27.46	0.31	30																
231	548	Hydraulic Piping Sys	(EA)	3-Maj Deter	1-Rehabilitate unit	MH	28.39	0.29	8	MH	27.46	0.31	30																
231	549	Hydraulic Cylinders	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	28.39	0.29	8	MH	27.46	0.31	30																
231	550	Hopkins Frame	(EA)	5-Sect Loss	1-Rehabilitate unit	MH	32.20	0.41	7	MH	27.46	0.31	30																
231	560	Locks	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	28.68	0.32	21	MH	27.46	0.31	30																
231	561	Live Load Shoes	(EA)	3-Maj Deter	1-Rehabilitate unit	MH	28.68	0.32	21	MH	27.46	0.31	30																
231	562	Counterweight Suppor	(EA)	5-Sect Loss	1-Rehabilitate unit	MH	31.59	0.25	10	MH	27.46	0.31	30																
231	563	Acc Ladd & Plat	(EA)	5-Sect Loss	1-Rehabilitate unit	MH	28.24	0.33	22	MH	27.46	0.31	30																
231	565	Trun/Str and Cur Trk	(EA)	3-Mod Deter	1-Rehabilitate unit	MH	28.68	0.32	21	MH	27.46	0.31	30																
231	570	Transformers	(EA)	3-Maj Deter	1-Rehabilitate unit	MH	28.88	0.33	19	MH	27.46	0.31	30																
231	571	Submarine Cable	each	2-Min Deter	1-Rehabilitate unit	MH	28.55	0.33	20	MH	27.46	0.31	30																
231	571	Submarine Cable	each	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	572	Conduit & Junc. Box	(EA)	2-Min Deter	1-Rehabilitate unit	MH	28.68	0.32	21	MH	27.46	0.31	30																
231	572	Conduit & Junc. Box	(EA)	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	573	PLCs	(EA)	3-Maj Deter	1-Rehabilitate unit	MH	28.82	0.30	10	MH	27.46	0.31	30																
231	574	Control Console	(EA)	3-Maj Deter	1-Rehabilitate unit	MH	28.55	0.33	20	MH	27.46	0.31	30																
231	580	Navigational Lights	(EA)	3-Maj Deter	1-Rehabilitate unit	MH	28.24	0.33	22	MH	27.46	0.31	30																
231	581	Operator Facilities	(EA)	2-Mod Deter	1-Rehabilitate unit	MH	28.68	0.32	21	MH	27.46	0.31	30																
231	581	Operator Facilities	(EA)	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	582	Lift Bridge Spec. Eq	(EA)	2-Mod Deter	2-Rehabilitate unit					MH	27.46	0.31	30																
231	582	Lift Bridge Spec. Eq	(EA)	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	583	Swing Bridge Spec. E	(EA)	2-Mod Deter	2-Rehabilitate unit					MH	27.46	0.31	30																
231	583	Swing Bridge Spec. E	(EA)	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	590	Resistance Barriers	(EA)	2-Mod Deter	2-Rehabilitate unit	MH	26.61	0.27	5	MH	27.46	0.31	30																
231	590	Resistance Barriers	(EA)	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	591	Warning Gates	(EA)	2-Mod Deter	2-Rehabilitate unit	MH	28.68	0.32	21	MH	27.46	0.31	30																
231	591	Warning Gates	(EA)	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
231	592	Traffic Signals	(EA)	2-Mod Deter	2-Rehabilitate unit	MH	28.55	0.33	20	MH	27.46	0.31	30																
231	592	Traffic Signals	(EA)	3-Maj Deter	1-Rehabilitate unit					MH	27.46	0.31	30																
243	146	Misc Cable Uncoated	(EA)	4-Analysis warranted	1-Rehab unit and coat																								
243	147	Misc Cable Coated	(EA)	4-Active corrosion	1-Rehab unit and repla																								
243	147	Misc Cable Coated	(EA)	5-Analysis warranted	1-Rehab unit and repla																								
246	320	P/S Conc Appr Slab	(EA)	2-Minor cracks/spalls	1-Perform mudjacking o					SF	12.91	0.59	24					CY	406.08	0.27	18								
246	321	R/Conc Approach Slab	(EA)	2-Cracks/spalls	1-Perform mudjacking o	SF	11.60	0.61	**21**	SF	12.91	0.59	24					CY	406.08	0.27	18								
301	13	Unp Conc Deck/AC Ovl	(SF)	2-Distress <= 2%	1-Repair potholes and	SF	19.07	0.73	2	SF	74.08	1.20	14					SY	43.46		1								
301	13	Unp Conc Deck/AC Ovl	(SF)	3-2 to 10% distress	1-Repair potholes and	SF	19.07	0.73	2	SF	74.08	1.20	14					SY	43.46		1								
301	13	Unp Conc Deck/AC Ovl	(SF)	4-10-25% distress	1-Repair potholes and	SF	19.07	0.73	2	SF	74.08	1.20	14					SY	43.46		1								
301	14	P Conc Deck/AC Ovly	(SF)	2-Distress <= 2%	1-Repair potholes					SF	74.08	1.20	14					SY	43.46		1								
301	14	P Conc Deck/AC Ovly	(SF)	3-2 to 10% distress	1-Repair potholes					SF	74.08	1.20	14					SY	43.46		1								
301	14	P Conc Deck/AC Ovly	(SF)	4-10-25% distress	1-Patch potholes					SF	74.08	1.20	14					SY	43.46		1								
301	39	Unp Conc Slab/AC Ovl	(SF)	2-Distress under 2%	1-Repair potholes and					SF	74.08	1.20	14					SY	43.46		1								
301	39	Unp Conc Slab/AC Ovl	(SF)	3-2-10% distress	1-Repair potholes and					SF	74.08	1.20	14					SY	43.46		1								
301	39	Unp Conc Slab/AC Ovl	(SF)	4-10-25% distress	1-Repair potholes and					SF	74.08	1.20	14					SY	43.46		1								
301	40	P Conc Slab/AC Ovly	(SF)	2-Distress under 2%	1-Repair potholes					SF	74.08	1.20	14					SY	43.46		1								
301	40	P Conc Slab/AC Ovly	(SF)	3-2-10% distress	1-Repair potholes					SF	74.08	1.20	14					SY	43.46		1								
301	40	P Conc Slab/AC Ovly	(SF)	4-10-25% distress	1-Patch potholes					SF	74.08	1.20	14					SY	43.46		1								
301	98	Conc Deck on PC Pane	(SF)	3-2-10 % Distress	2-Repair and Protect	SF	158.66	N/A	1	SF	74.08	1.20	14					SY	43.46		1								
301	98	Conc Deck on PC Pane	(SF)	4-10-25 % Distress	2-Repair & Protect	SF	158.66	N/A	1	SF	74.08	1.20	14					SY	43.46		1								

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
301	98	Conc Deck on PC Pane	(SF)	5-Distress over 25 %	1-Repair & Protect	SF	158.66	N/A	1	SF	74.08	1.20	14					SY	43.46		1								
301	99	PS Conc Slab	(SF)	3-Dist 2-10%	2-Repair and protect	SF	10.59	N/A	1	SF	74.08	1.20	14					SY	43.46		1								
301	99	PS Conc Slab	(SF)	4-Dist 10-25%	2-Repair and protect	SF	10.59	N/A	1	SF	74.08	1.20	14					SY	43.46		1								
301	99	PS Conc Slab	(SF)	5-Dist >25%	1-Repair and protect	SF	10.59	N/A	1	SF	74.08	1.20	14					SY	43.46		1								
302	28	Steel Deck/Open Grid	(SF)	4-Moderate corrosion	1-Spot blast, clean an					SF	28.62	0.49	6																
302	29	Steel Deck/Conc Grid	(SF)	4-Failed connectors	1-Spot blast, clean an					SF	28.62	0.49	6																
302	30	Corrug/Orthotpc Deck	(SF)	4-Moderate deteriorati	1-Spot blast,clean,pai					SF	28.62	0.49	6																
302	101	Unpnt Stl Box Girder	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	101	Unpnt Stl Box Girder	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	102	Paint Stl Box Girder	(LF)	2-Paint distress	2-Clean & paint	LF	35.03	N/A	1	LF	18.63	0.60	6																
302	102	Paint Stl Box Girder	(LF)	3-Rust formation	1-Spot blast, clean &	LF	35.03	N/A	1	LF	18.63	0.60	6																
302	102	Paint Stl Box Girder	(LF)	4-Active corrosion	1-Spot blast, clean &	LF	35.03	N/A	1	LF	18.63	0.60	6																
302	106	Unpnt Stl Opn Girder	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	106	Unpnt Stl Opn Girder	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	107	Paint Stl Opn Girder	(LF)	2-Paint distress	2-Surface clean and re	LF	21.84	0.31	2	LF	18.63	0.60	6																
302	107	Paint Stl Opn Girder	(LF)	3-Rust formation	1-Spot blast,clean & p	LF	21.84	0.31	2	LF	18.63	0.60	6																
302	107	Paint Stl Opn Girder	(LF)	4-Active corrosion	1-Spot blast, clean &	LF	21.84	0.31	2	LF	18.63	0.60	6																
302	112	Unpnt Stl Stringer	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	112	Unpnt Stl Stringer	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	113	Paint Stl Stringer	(LF)	2-Paint distress	2-Clean & paint	LF	17.04	N/A	1	LF	18.63	0.60	6																
302	113	Paint Stl Stringer	(LF)	3-Rust formation	1-Spot blast, clean &	LF	17.04	N/A	1	LF	18.63	0.60	6																
302	113	Paint Stl Stringer	(LF)	4-Active corrosion	1-Spot blast, clean &	LF	17.04	N/A	1	LF	18.63	0.60	6																
302	120	U/Stl Thru Truss/Bot	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	120	U/Stl Thru Truss/Bot	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	121	P/Stl Thru Truss/Bot	(LF)	2-Paint distress	2-Clean & paint					LF	18.63	0.60	6																
302	121	P/Stl Thru Truss/Bot	(LF)	3-Rust formation	1-Spot blast, clean &					LF	18.63	0.60	6																
302	121	P/Stl Thru Truss/Bot	(LF)	4-Active corrosion	1-Spot blast, clean &					LF	18.63	0.60	6																
302	125	U/Stl Thru Truss/Top	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	125	U/Stl Thru Truss/Top	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	126	P/Stl Thru Truss/Top	(LF)	2-Paint distress	2-Clean & paint					LF	18.63	0.60	6																
302	126	P/Stl Thru Truss/Top	(LF)	3-Rust formation	1-Spot blast, clean &					LF	18.63	0.60	6																
302	126	P/Stl Thru Truss/Top	(LF)	4-Active corrosion	1-Spot blast, clean &					LF	18.63	0.60	6																
302	130	Unpnt Stl Deck Truss	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	130	Unpnt Stl Deck Truss	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	131	Paint Stl Deck Truss	(LF)	2-Paint distress	2-Clean & paint					LF	18.63	0.60	6																
302	131	Paint Stl Deck Truss	(LF)	3-Rust formation	1-Spot blast, clean &					LF	18.63	0.60	6																
302	131	Paint Stl Deck Truss	(LF)	4-Active corrosion	1-Spot blast, clean &					LF	18.63	0.60	6																
302	140	Unpnt Stl Arch	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	140	Unpnt Stl Arch	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	141	Paint Stl Arch	(LF)	2-Paint distress	2-Clean & paint					LF	18.63	0.60	6																
302	141	Paint Stl Arch	(LF)	3-Rust formation	1-Spot blast, clean &					LF	18.63	0.60	6																
302	141	Paint Stl Arch	(LF)	4-Active corrosion	1-Spot blast, clean &					LF	18.63	0.60	6																
302	146	Misc Cable Uncoated	(EA)	2-Surface rust	1-Clean & coat					LF	18.63	0.60	6																
302	146	Misc Cable Uncoated	(EA)	3-Moderate deteriorati	1-Clean & coat					LF	18.63	0.60	6																
302	151	Unpnt Stl Floor Beam	(LF)	2-Minor corrosion	1-Clean & paint					LF	18.63	0.60	6																
302	151	Unpnt Stl Floor Beam	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	152	Paint Stl Floor Beam	(LF)	2-Paint distress	2-Clean & paint	LF	21.84	0.31	2	LF	18.63	0.60	6																
302	152	Paint Stl Floor Beam	(LF)	3-Rust formation	1-Spot blast, clean &	LF	21.84	0.31	2	LF	18.63	0.60	6																
302	152	Paint Stl Floor Beam	(LF)	4-Active corrosion	1-Spot blast, clean &	LF	21.84	0.31	2	LF	18.63	0.60	6																
302	160	Unpnt Stl Pin/Hanger	(EA)	2-Minor corrosion	1-Clean and paint					LF	18.63	0.60	6																
302	160	Unpnt Stl Pin/Hanger	(EA)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	161	Paint Stl Pin/Hanger	(EA)	2-Paint distress	2-Clean & paint	**MH**	**22.82**	**N/A**	**1**	LF	18.63	0.60	6																
302	161	Paint Stl Pin/Hanger	(EA)	3-Rust formation	1-Spot blast, clean an					LF	18.63	0.60	6																
302	161	Paint Stl Pin/Hanger	(EA)	4-Active corrosion	1-Spot blast, clean an					LF	18.63	0.60	6																
302	201	Unpnt Stl Column	(EA)	2-Rust formation	1-Clean & paint					LF	18.63	0.60	6																
302	201	Unpnt Stl Column	(EA)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	202	Paint Stl Column	(EA)	2-Paint distress	2-Clean & paint	**MH**	**22.16**	**0.21**	**16**	LF	18.63	0.60	6																
302	202	Paint Stl Column	(EA)	3-Rust formation	1-Spot blast, clean &					LF	18.63	0.60	6																
302	202	Paint Stl Column	(EA)	4-Active corrosion	1-Spot blast, clean &					LF	18.63	0.60	6																
302	225	Unpnt Stl Submd Pile	(EA)	2-Rust formation	1-Clean & paint					LF	18.63	0.60	6																
302	225	Unpnt Stl Submd Pile	(EA)	3-Surface pitting	1-Clean & paint					LF	18.63	0.60	6																
302	230	Unpnt Stl Cap	(LF)	2-Rust formation	1-Clean & paint					LF	18.63	0.60	6																
302	230	Unpnt Stl Cap	(LF)	3-Some section loss	1-Clean & paint					LF	18.63	0.60	6																
302	231	Paint Stl Cap	(LF)	2-Paint distress	2-Clean & paint					LF	18.63	0.60	6																
302	231	Paint Stl Cap	(LF)	3-Rust formation	1-Spot blast, clean &					LF	18.63	0.60	6																
302	231	Paint Stl Cap	(LF)	4-Active corrosion	1-Spot blast, clean &					LF	18.63	0.60	6																
302	311	Moveable Bearing	(EA)	2-Minor deterioration	1-Clean & paint					LF	18.63	0.60	6																
302	334	Metal Rail Coated	(LF)	2-Surface rust forming	1-Clean and Restore Co					LF	18.63	0.60	6																
302	334	Metal Rail Coated	(LF)	3-Rust prevalent	1-Clean and Restore Co					LF	18.63	0.60	6																
302	386	Fender/Dolphin Uncoa	(LF)	2-Surf Rust	1-Clean and paint					LF	18.63	0.60	6																
302	386	Fender/Dolphin Uncoa	(LF)	3-Minor Loss	1-Clean and paint					LF	18.63	0.60	6																
302	393	Blkhd Sewl Metal Unc	(SF)	2-Surf Rust	1-Clean and paint					SF	28.62	0.49	21																

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
302	393	Blkhd Sewl Metal Unc	(SF)	3-Minor Loss	1-Clean and paint					SF	28.62	0.49	21																
302	397	Drain. Syst Metal	(EA)	3-Surf Rust	1-Spot paint	**MH**	**20.55**	**N/A**	**1**	LF	18.63	0.60	6																
302	397	Drain. Syst Metal	(EA)	4-Surf Pits	1-Spot paint					LF	18.63	0.60	6																
302	474	Walls Uncoated	(LF)	2-Surf Rust	1-Clean and paint					LF	18.63	0.60	6																
302	474	Walls Uncoated	(LF)	3-Minor Loss	1-Clean and paint					LF	18.63	0.60	6																
302	487	Sign Member Horiz	(LF)	2-Paint Dist	2-Clean and paint					LF	18.63	0.60	6																
302	487	Sign Member Horiz	(LF)	3-Surf Rust	1-Spot paint					LF	18.63	0.60	6																
302	487	Sign Member Horiz	(LF)	4-Surf Pits	1-Clean and paint					LF	18.63	0.60	6																
302	488	Sign Member Vertical	(LF)	3-Surf Rust	1-Spot Paint					LF	18.63	0.60	6																
302	488	Sign Member Vertical	(LF)	4-Surf Pits	1-Spot Paint					LF	18.63	0.60	6																
302	495	Uncoat High Mast L.	(EA)	2-Surf Rust	1-Clean and paint					LF	18.63	0.60	6																
302	495	Uncoat High Mast L.	(EA)	3-Minor Loss	1-Clean and paint					LF	18.63	0.60	6																
302	496	Painted High Mast L.	(EA)	3-Surf Rust	1-Spot Paint					LF	18.63	0.60	6																
302	496	Painted High Mast L.	(EA)	4-Surf Pits	1-Spot Paint					LF	18.63	0.60	6																
302	497	Galvan. High Mast L.	(EA)	3-Surf Rust	1-Spot Paint					LF	18.63	0.60	6																
302	497	Galvan. High Mast L.	(EA)	4-Surf Pits	1-Spot paint					LF	18.63	0.60	6																
302	550	Hopkins Frame	(EA)	3-Surf Rust	1-Spot paint	**MH**	**26.37**	**0.21**	**3**	LF	18.63	0.60	6																
302	550	Hopkins Frame	(EA)	4-Surf Pits	1-Spot paint					LF	18.63	0.60	6																
302	561	Live Load Shoes	(EA)	2-Min Deter	1-Clean and paint	**MH**	**23.83**	**0.19**	**33**	LF	18.63	0.60	6																
302	562	Counterweight Suppor	(EA)	3-Surf Rust	1-Spot paint	**MH**	**23.55**	**0.17**	**25**	LF	18.63	0.60	6																
302	562	Counterweight Suppor	(EA)	4-Surf Pits	1-Spot paint					LF	18.63	0.60	6																
302	563	Acc Ladd & Plat	(EA)	3-Surf Rust	1-Spot paint	**MH**	**23.53**	**0.22**	**50**	LF	18.63	0.60	6																
302	563	Acc Ladd & Plat	(EA)	4-Surf Pits	1-Spot paint					LF	18.63	0.60	6																
303	104	P/S Conc Box Girder	(LF)	3-Delams/spalls	1-Clean steel & patch					LF	42.24	1.08	29																
303	105	R/Conc Box Girder	(LF)	3-Delams/spalls	1-Clean rebar & patch,					LF	42.24	1.08	29																
303	109	P/S Conc Open Girder	(LF)	3-Delams/spalls	1-Clean steel & patch,	**LF**	**46.50**	**1.06**	**22**	LF	42.24	1.08	29																
303	110	R/Conc Open Girder	(LF)	3-Delams/spalls	1-Clean rebar & patch,	**LF**	**94.64**	**N/A**	**1**	LF	42.24	1.08	29																
303	115	P/S Conc Stringer	(LF)	3-Delams/spalls	1-Clean steel & patch,					LF	42.24	1.08	29																
303	116	R/Conc Stringer	(LF)	3-Delams/spalls	1-Clean rebar & patch,					LF	42.24	1.08	29																
303	143	P/S Conc Arch	(LF)	3-Delams/spalls	1-Clean steel & patch,					LF	42.24	1.08	29																
303	144	R/Conc Arch	(LF)	3-Delams/spalls	1-Clean rebar & patch,					LF	42.24	1.08	29																
303	154	P/S Conc Floor Beam	(LF)	3-Delams/spalls	1-Clean steel and patc					LF	42.24	1.08	29																
303	155	R/Conc Floor Beam	(LF)	3-Delams/spalls	1-Clean rebar & patch,					LF	42.24	1.08	29																
303	204	P/S Conc Column	(EA)	3-Delams/spalls	1-Clean steel & patch	**MH**	**18.88**	**0.35**	**41**	LF	42.24	1.08	29																
303	205	R/Conc Column	(EA)	3-Delams/spalls	1-Clean rebar & patch,	**MH**	**18.42**	**0.33**	**64**	LF	42.24	1.08	29																
303	210	R/Conc Pier Wall	(LF)	3-Delams/spalls	1-Clean rebar & patch,	**LF**	**23.21**	**N/A**	**1**	LF	42.24	1.08	29																
303	215	R/Conc Abutment	(LF)	3-Delams/spalls	1-Clean rebar & patch,	**LF**	**42.87**	**1.11**	**27**	LF	42.24	1.08	29																
303	220	R/C Sub Pile Cap/Ftg	(EA)	3-Delams/spalls	1-Clean rebar & patch,	**MH**	**20.59**	**0.30**	**36**	LF	42.24	1.08	29																
303	226	P/S Conc Submgd Pile	(EA)	3-Delams/spalls	1-Clean steel & patch,					LF	42.24	1.08	29																
303	227	R/C Submerged Pile	(EA)	3-Delams/spalls	1-Clean rebar & patch,					LF	42.24	1.08	29																
303	229	P/S Conc Holl Sub Pi	(EA)	3-Exposed Stl	1-Clean and patch					LF	42.24	1.08	29																
303	233	P/S Conc Cap	(LF)	3-Delams,spalls	1-Clean steel & patch,	**MH**	**25.12**	**0.13**	**3**	LF	42.24	1.08	29																
303	234	R/Conc Cap	(LF)	3-Delams/spalls	1-Clean rebar & patch,	**LF**	**31.59**	**1.16**	**21**	LF	42.24	1.08	29																
303	299	Pile Jacket/Cath Pro	(EA)	3-Mod Deter	1-Clean and patch					LF	42.24	1.08	29																
303	331	Conc Bridge Railing	(LF)	3-Delam/spalls pres	1-Clean rebar & patch,	**LF**	**41.07**	**1.12**	**25**	LF	42.24	1.08	29																
303	394	R/Conc Abut Slope Pr	(SF)	3-Exposed Stl	1-Clean and patch	**LF**	**44.41**	**1.09**	**51**	SF	33.10	0.85	41																
311	300	Strip Seal Exp Joint	(LF)	2-Minor leakage	1-Patch/reset/clean jo	**LF**	**26.90**	**0.49**	**10**	LF	52.49	0.92	261					LF	20.95	1.38	22					LF	36.60	0.34	4
311	302	Compressn Joint Seal	(LF)	2-Minor deterioration	1-Patch/rem/reseal/cln	**LF**	**56.90**	**0.89**	**202**	LF	52.49	0.92	261					LF	20.95	1.38	22					LF	36.60	0.34	4
331	540	Open Gearing	(EA)	2-Min Deter	1-Clean and lubricate					MH	26.78	0.450	1023													EA	102.30	0.98	17
331	541	Speed Reducers	(EA)	2-Min Deter	1-Clean and lubricate					MH	26.78	0.450	1023													EA	102.30	0.98	17
331	542	Shafts	(EA)	2-Min Deter	1-Clean and lubricate					MH	26.78	0.450	1023													EA	102.30	0.98	17
331	543	Shaft Brgs and Coupl	(EA)	2-Min Deter	1-Clean and lubricate					MH	26.78	0.450	1023													EA	102.30	0.98	17
331	544	Brakes	(EA)	2-Min Deter	1-Clean/Lubricate/Oil					MH	26.78	0.450	1023													EA	102.30	0.98	17
331	561	Live Load Shoes	(EA)	2-Min Deter	2-Realign and/or shim					MH	26.78	0.450	1023													EA	102.30	0.98	17
331	565	Trun/Str and Cur Trk	(EA)	2-Min Deter	1-Clean and lubricate					MH	26.78	0.450	1023													EA	102.30	0.98	17
331	570	Transformers	(EA)	2-Min Deter	1-Clean and lubricate					MH	26.78	0.450	1023													EA	102.30	0.98	17
400	28	Steel Deck/Open Grid	(SF)	2-Minor deterioration	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	29	Steel Deck/Conc Grid	(SF)	2-Minor deterioration	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	102	Paint Stl Box Girder	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	102	Paint Stl Box Girder	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	107	Paint Stl Opn Girder	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	107	Paint Stl Opn Girder	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	113	Paint Stl Stringer	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	113	Paint Stl Stringer	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	121	P/Stl Thru Truss/Bot	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	121	P/Stl Thru Truss/Bot	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	126	P/Stl Thru Truss/Top	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	126	P/Stl Thru Truss/Top	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	131	Paint Stl Deck Truss	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	131	Paint Stl Deck Truss	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	141	Paint Stl Arch	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	141	Paint Stl Arch	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
400	152	Paint Stl Floor Beam	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	152	Paint Stl Floor Beam	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	161	Paint Stl Pin/Hanger	(EA)	1-No corrosion	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	161	Paint Stl Pin/Hanger	(EA)	2-Paint distress	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	202	Paint Stl Column	(EA)	1-No corrosion	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	202	Paint Stl Column	(EA)	2-Paint distress	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	231	Paint Stl Cap	(LF)	1-No corrosion	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	231	Paint Stl Cap	(LF)	2-Paint distress	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	397	Drain. Syst Metal	(EA)	1-Excellent	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	397	Drain. Syst Metal	(EA)	2-Paint dist	1-Surface Clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	398	Drain. Syst Other	(EA)	2-Min Deter	1-Surface clean	**MH**	**19.93**	**0.33**	**75**	SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	398	Drain. Syst Other	(EA)	3-Mod Deter	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	487	Sign Member Horiz	(LF)	2-Paint Dist	1-Surface clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	488	Sign Member Vertical	(LF)	1-Excellent	1-Surface Clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	488	Sign Member Vertical	(LF)	2-Paint Dist	1-Surface Clean					LF	11.31	1.25	3					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	496	Painted High Mast L.	(EA)	1-Excellent	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	496	Painted High Mast L.	(EA)	2-Paint Dist	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	497	Galvan. High Mast L.	(EA)	1-Excellent	1-Surface Clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	497	Galvan. High Mast L.	(EA)	2-Paint Dist	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	550	Hopkins Frame	(EA)	1-Excellent	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	550	Hopkins Frame	(EA)	2-Paint Dist	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	562	Counterweight Suppor	(EA)	1-Excellent	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	562	Counterweight Suppor	(EA)	2-Paint Dist	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	563	Acc Ladd & Plat	(EA)	1-Excellent	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
400	563	Acc Ladd & Plat	(EA)	2-Paint Dist	1-Surface clean					SF	5.04	1.10	115					EA	3,193.50	0.88	4					SF	0.37	0.71	17
401	12	Bare Concrete Deck	(SF)	1-No damage	2-Miscellaneous Maint	**SF**	**25.88**	**1.15**	**54**	SF	24.24	1.07	160					SY	2.71	0.34	120								
401	12	Bare Concrete Deck	(SF)	2-Distress <= 2%	1-Repair spalled/delam					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	12	Bare Concrete Deck	(SF)	3-2 to 10 % distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	12	Bare Concrete Deck	(SF)	4-10 to 25% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	13	Unp Conc Deck/AC Ovl	(SF)	1-No damage	1-Miscellaneous Maint	**SF**	**24.20**	**1.06**	**55**	SF	24.24	1.07	160					SY	2.71	0.34	120								
401	14	P Conc Deck/AC Ovly	(SF)	1-No damage	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	18	P Conc Deck/Thin Ovl	(SF)	2-Distress <= 2%	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	18	P Conc Deck/Thin Ovl	(SF)	3-2-10% distress	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	18	P Conc Deck/Thin Ovl	(SF)	4-10-25% distress	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	22	P Conc Deck/Rigid Ov	(SF)	2-Distress <= 2%	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	22	P Conc Deck/Rigid Ov	(SF)	3-Distress 2-10%	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	22	P Conc Deck/Rigid Ov	(SF)	4-Distress 10-25%	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	26	Conc Deck/Coatd Bars	(SF)	2-Distress <=2%	1-Patch spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	26	Conc Deck/Coatd Bars	(SF)	3-Distress 2-10%	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	26	Conc Deck/Coatd Bars	(SF)	4-10-25% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	27	Conc Deck/Cathodic	(SF)	2-Distress <=2%	1-Patch spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	27	Conc Deck/Cathodic	(SF)	3-2 to 10% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	28	Steel Deck/Open Grid	(SF)	1-No corrosion	1-Miscellaneous Maint	**SF**	**30.46**	**0.71**	**3**	SF	24.24	1.07	160					SY	2.71	0.34	120								
401	29	Steel Deck/Conc Grid	(SF)	1-No corrosion	1-Miscellaneous Maint	**SF**	**31.85**	**N/A**	**1**	SF	24.24	1.07	160					SY	2.71	0.34	120								
401	30	Corrug/Orthotpc Deck	(SF)	1-No deterioration	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	30	Corrug/Orthotpc Deck	(SF)	2-Minor deterioration	1-Seal cracks and/or r					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	31	Timber Deck	(SF)	1-No decay	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	32	Timber Deck/AC Ovly	(SF)	1-No deterioration	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	32	Timber Deck/AC Ovly	(SF)	2-Minor deterioration	1-Repair potholes					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	38	Bare Concrete Slab	(SF)	1-No damage	2-Miscellaneous Maint	**SF**	**10.45**	**1.23**	**10**	SF	24.24	1.07	160					SY	2.71	0.34	120								
401	38	Bare Concrete Slab	(SF)	2-Distress <=2%	1-Repair spalled/delam					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	38	Bare Concrete Slab	(SF)	3-2-10% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	38	Bare Concrete Slab	(SF)	4-10-25% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	39	Unp Conc Slab/AC Ovl	(SF)	1-No damage	1-Miscellaneous Maint	**SF**	**29.75**	**1.01**	**11**	SF	24.24	1.07	160					SY	2.71	0.34	120								
401	40	P Conc Slab/AC Ovly	(SF)	1-No damage	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	44	P Conc Slab/Thin Ovl	(SF)	1-No damage	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	44	P Conc Slab/Thin Ovl	(SF)	2-Distress under 2%	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	44	P Conc Slab/Thin Ovl	(SF)	3-2-10% distress	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	44	P Conc Slab/Thin Ovl	(SF)	4-10-25% distress	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	48	P Conc Slab/Rigid Ov	(SF)	2-Distress under 2%	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	48	P Conc Slab/Rigid Ov	(SF)	3-2-10% distress	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	48	P Conc Slab/Rigid Ov	(SF)	4-10-25% distress	1-Repair spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	52	Conc Slab/Coatd Bars	(SF)	2-Distress under 2%	1-Patch spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	52	Conc Slab/Coatd Bars	(SF)	3-2-10% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	52	Conc Slab/Coatd Bars	(SF)	4-10-25% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	53	Conc Slab/Cathodic	(SF)	2-Distress under 2%	1-Patch spalls/delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	53	Conc Slab/Cathodic	(SF)	3-2-10% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	53	Conc Slab/Cathodic	(SF)	4-10-25% distress	1-Repair spalled areas					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	54	Timber Slab	(SF)	1-No decay	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	55	Timber Slab/AC Ovly	(SF)	1-No deterioration	1-Miscellaneous Maint					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	55	Timber Slab/AC Ovly	(SF)	2-Minor deterioration	1-Repair potholes					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	98	Conc Deck on PC Pane	(SF)	2-Distress under 2 %	1-Spalls & Delams	**SF**	**15.30**	**0.90**	**8**	SF	24.24	1.07	160					SY	2.71	0.34	120								

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
401	98	Conc Deck on PC Pane	(SF)	3-2-10 % Distress	1-Spalls & Delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	98	Conc Deck on PC Pane	(SF)	4-10-25 % Distress	1-Spalls & Delams					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	99	PS Conc Slab	(SF)	2-Dist <2%	1-Repair	**SF**	**22.62**	**0.98**	**21**	SF	24.24	1.07	160					SY	2.71	0.34	120								
401	99	PS Conc Slab	(SF)	3-Dist 2-10%	1-Repair Spl/Delam					SF	24.24	1.07	160					SY	2.71	0.34	120								
401	99	PS Conc Slab	(SF)	4-Dist 10-25%	1-Repair Spl/Delam					SF	24.24	1.07	160					SY	2.71	0.34	120								
402	28	Steel Deck/Open Grid	(SF)	3-Rust formation	1-Surface clean+restor					SF	914.08		1																
402	29	Steel Deck/Conc Grid	(SF)	3-Rust formation	1-Surface clean+restor					SF	914.08		1																
402	30	Corrug/Orthotpc Deck	(SF)	3-Rust formation	1-Surface clean+restor					SF	914.08		1																
402	101	Unpnt Stl Box Girder	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	102	Paint Stl Box Girder	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	106	Unpnt Stl Opn Girder	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	107	Paint Stl Opn Girder	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	112	Unpnt Stl Stringer	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	113	Paint Stl Stringer	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	120	U/Stl Thru Truss/Bot	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	121	P/Stl Thru Truss/Bot	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	125	U/Stl Thru Truss/Top	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	126	P/Stl Thru Truss/Top	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	130	Unpnt Stl Deck Truss	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	131	Paint Stl Deck Truss	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	140	Unpnt Stl Arch	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	141	Paint Stl Arch	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	146	Misc Cable Uncoated	(EA)	1-No corrosion	1-Miscellaneous Maint					SF	914.08		1																
402	147	Misc Cable Coated	(EA)	1-No corrosion	1-Miscellaneous Maint					SF	914.08		1																
402	147	Misc Cable Coated	(EA)	2-Surface rust forming	1-Clean & Restore Coat					SF	914.08		1																
402	147	Misc Cable Coated	(EA)	3-Rust prevalent	1-Clean & Restore Coat					SF	914.08		1																
402	151	Unpnt Stl Floor Beam	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	152	Paint Stl Floor Beam	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	160	Unpnt Stl Pin/Hanger	(EA)	1-No corrosion	1-Miscellaneous Maint					SF	914.08		1																
402	161	Paint Stl Pin/Hanger	(EA)	1-No corrosion	2-Miscellaneous Maint					SF	914.08		1																
402	201	Unpnt Stl Column	(EA)	1-No corrosion	1-Miscellaneous Maint					SF	914.08		1																
402	202	Paint Stl Column	(EA)	1-No corrosion	2-Miscellaneous Maint					SF	914.08		1																
402	225	Unpnt Stl Submd Pile	(EA)	1-No corrosion	1-Miscellaneous Maint					SF	914.08		1																
402	230	Unpnt Stl Cap	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	231	Paint Stl Cap	(LF)	1-No corrosion	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	240	Metal Culvert	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	298	Pile Jacket Bare	(EA)	1-Excellent	1-Miscellaneous Maint					SF	914.08		1																
402	299	Pile Jacket/Cath Pro	(EA)	1-Excellent	1-Miscellaneous Maint					SF	914.08		1																
402	330	Metal Rail Uncoated	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	330	Metal Rail Uncoated	(LF)	2-Rust formation	1-Clean and Coat					LF	2.86	0.45	3																
402	330	Metal Rail Uncoated	(LF)	3-Active corrosion	1-Clean and Coat					LF	2.86	0.45	3																
402	334	Metal Rail Coated	(LF)	1-No corrosion	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	386	Fender/Dolphin Uncoa	(LF)	1-Excellent	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	393	Blkhd Sewl Metal Unc	(SF)	1-Excellent	1-Miscellaneous Maint					SF	914.08		1																
402	395	Timber Abut Slope Pr	(SF)	1-Excellent	1-Miscellaneous Maint					SF	914.08		1																
402	397	Drain. Syst Metal	(EA)	1-Excellent	2-Miscellaneous Maint					SF	914.08		1																
402	474	Walls Uncoated	(LF)	1-Excellent	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	487	Sign Member Horiz	(LF)	1-Excellent	1-Miscellaneous Maint					LF	2.86	0.45	3																
402	488	Sign Member Vertical	(LF)	1-Excellent	2-Miscellaneous Maint					LF	2.86	0.45	3																
402	488	Sign Member Vertical	(LF)	2-Paint Dist	2-Clean and restore					LF	2.86	0.45	3																
402	495	Uncoat High Mast L.	(EA)	1-Excellent	1-Miscellaneous Maint					SF	914.08		1																
402	496	Painted High Mast L.	(EA)	1-Excellent	2-Miscellaneous Maint					SF	914.08		1																
402	496	Painted High Mast L.	(EA)	2-Paint Dist	2-Clean and restore					SF	914.08		1																
402	497	Galvan. High Mast L.	(EA)	1-Excellent	2-Miscellaneous Maint					SF	914.08		1																
402	497	Galvan. High Mast L.	(EA)	2-Paint Dist	2-Clean and restore					SF	914.08		1																
402	498	Other High Mast L.P.	(EA)	1-Excellent	1-Miscellaneous Maint					SF	914.08		1																
402	550	Hopkins Frame	(EA)	2-Paint Dist	2-Clean and restore	**MH**	**36.92**	**0.15**	**2**	SF	914.08		1																
402	562	Counterweight Suppor	(EA)	2-Paint Dist	2-Clean and restore	**MH**	**36.92**	**0.15**	**2**	SF	914.08		1																
402	563	Acc Ladd & Plat	(EA)	2-Paint Dist	2-Clean and restore	**MH**	**32.61**	**0.26**	**3**	SF	914.08		1																
403	98	Conc Deck on PC Pane	(SF)	1-No Damage	2-Miscellaneous Maint					SF	49.63	1.06	441					SF	41.47	0.78	7					SF	30.73	1.25	13
403	99	PS Conc Slab	(SF)	1-No Damage	1-Miscellaneous Maint					SF	49.63	1.06	441					SF	41.47	0.78	7					SF	30.73	1.25	13
403	104	P/S Conc Box Girder	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**21.49**	**0.15**	**3**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	104	P/S Conc Box Girder	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	105	R/Conc Box Girder	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**4.22**	**N/A**	**1**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	105	R/Conc Box Girder	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	109	P/S Conc Open Girder	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**33.54**	**0.90**	**217**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	109	P/S Conc Open Girder	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	110	R/Conc Open Girder	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**22.16**	**0.60**	**18**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	110	R/Conc Open Girder	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	115	P/S Conc Stringer	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	115	P/S Conc Stringer	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	116	R/Conc Stringer	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (ANOVA)				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOVA)				AKBAR AS# GROUP UNIT COST				DCP ELEMENT UNIT COST (ANOVA)				DCP AS# GROUP UNIT COST			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	*AVG.*	*C.V.*	*# of Data*	MMS Unit	*AVG.*	*C.V.*	*# of Data*	Akbar Unit	*AVG.*	*C.V.*	*# of Data*	Akbar Unit	*AVG.*	*C.V.*	*# of Data*	DCP Unit	*AVG.*	*C.V.*	*# of Data*	DCP Unit	*AVG.*	*C.V.*	*# of Data*
403	116	R/Conc Stringer	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	143	P/S Conc Arch	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	143	P/S Conc Arch	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	144	R/Conc Arch	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**22.79**	**0.44**	**2**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	144	R/Conc Arch	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	154	P/S Conc Floor Beam	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	154	P/S Conc Floor Beam	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	155	R/Conc Floor Beam	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**8.82**	**N/A**	**1**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	155	R/Conc Floor Beam	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	204	P/S Conc Column	(EA)	1-No deterioration	1-Miscellaneous Maint	**MH**	**20.78**	**0.39**	**398**	SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	204	P/S Conc Column	(EA)	2-Minor cracks/spalls	1-Seal cracks minor pa					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	205	R/Conc Column	(EA)	1-No deterioration	1-Miscellaneous Maint	**MH**	**20.36**	**0.40**	**923**	SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	205	R/Conc Column	(EA)	2-Minor cracks/spalls	1-Seal cracks minor pa					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	207	P/S Conc Holl Pile	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**14.25**	**0.37**	**13**	SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	207	P/S Conc Holl Pile	(EA)	2-Min Ck/Spl	1-Seal and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	207	P/S Conc Holl Pile	(EA)	3-Exposed Stl	1-Clean and Patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	210	R/Conc Pier Wall	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**28.67**	**0.76**	**26**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	210	R/Conc Pier Wall	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	215	R/Conc Abutment	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**31.99**	**0.89**	**319**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	215	R/Conc Abutment	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	220	R/C Sub Pile Cap/Ftg	(EA)	1-No deterioration	1-Miscellaneous Maint	**EA**	**20.08**	**0.36**	**106**	SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	220	R/C Sub Pile Cap/Ftg	(EA)	2-Minor cracks/spalls	1-Seal cracks minor pa					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	226	P/S Conc Submgd Pile	(EA)	1-No deterioration	1-Miscellaneous Maint					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	226	P/S Conc Submgd Pile	(EA)	2-Minor cracks/spalls	1-Seal cracks minor pa					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	227	R/C Submerged Pile	(EA)	1-No deterioration	1-Miscellaneous Maint					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	227	R/C Submerged Pile	(EA)	2-Minor cracks/spalls	1-Seal cracks minor pa					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	229	P/S Conc Holl Sub Pi	(EA)	1-Excellent	1-Miscellaneous Maint					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	229	P/S Conc Holl Sub Pi	(EA)	2-Min Ck/Spl	1-Seal and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	233	P/S Conc Cap	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	233	P/S Conc Cap	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	234	R/Conc Cap	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**31.29**	**0.90**	**264**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	234	R/Conc Cap	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	241	Concrete Culvert	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**96.48**	**N/A**	**1**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	298	Pile Jacket Bare	(EA)	2-Min Ck/Spl	1-Seal and patch	**MH**	**19.68**	**0.33**	**54**	SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	298	Pile Jacket Bare	(EA)	3-Mod Deter	1-Clean and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	299	Pile Jacket/Cath Pro	(EA)	2-Min Ck/Spl	1-Seal and patch	**MH**	**21.81**	**0.20**	**9**	SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	331	Conc Bridge Railing	(LF)	1-No deterioration	1-Miscellaneous Maint	**LF**	**32.06**	**0.84**	**262**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	331	Conc Bridge Railing	(LF)	2-Minor cracks/spalls	1-Seal cracks minor pa					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	387	P/S Fender/Dolphin	(LF)	1-Excellent	1-Miscellaneous Maint	**LF**	**34.54**	**0.96**	**18**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	387	P/S Fender/Dolphin	(LF)	2-Min Ck/Stl	1-Seal and patch					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	387	P/S Fender/Dolphin	(LF)	3-Exposed Stl	1-Clean and patch					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	388	R/Conc Fender/Dolphi	(LF)	1-Excellent	1-Miscellaneous Maint					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	388	R/Conc Fender/Dolphi	(LF)	2-Min Ck/Spl	1-Seal and patch					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	388	R/Conc Fender/Dolphi	(LF)	3-Exposed Stl	1-Clean and patch					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	394	R/Conc Abut Slope Pr	(SF)	1-Excellent	1-Miscellaneous Maint	**SF**	**51.51**	**0.98**	**163**	SF	49.63	1.06	336					SF	41.47	0.78	7					SF	30.73	1.25	13
403	394	R/Conc Abut Slope Pr	(SF)	2-Min Ck/Spl	1-Seal and patch					SF	49.63	1.06	336					SF	41.47	0.78	7					SF	30.73	1.25	13
403	475	R/Conc Walls	(LF)	1-Excellent	1-Miscellaneous Maint	**LF**	**32.28**	**0.96**	**89**	LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	475	R/Conc Walls	(LF)	2-Min Ck/Spl	1-Seal and patch					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	475	R/Conc Walls	(LF)	3-Exposed Stl	1-Clean and patch					LF	32.11	0.88	336					SF	41.47	0.78	7					LF	36.70	0.17	7
403	489	Sign Foundation	(EA)	1-Excellent	1-Miscellaneous Maint					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	489	Sign Foundation	(EA)	2-Min Ck/Spl	1-Seal and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	489	Sign Foundation	(EA)	3-Exposed Stl	1-Clean and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	499	H. M. L. P. Found.	(EA)	1-Excellent	1-Miscellaneous Maint					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	499	H. M. L. P. Found.	(EA)	2-Min Ck/Spl	1-Seal and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	499	H. M. L. P. Found.	(EA)	3-Exposed Stl	1-Clean and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	564	Counterweight	(EA)	2-Min Ck/Spl	1-Seal and patch	**MH**	**20.80**	**0.19**	**30**	SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
403	564	Counterweight	(EA)	3-Exposed Stl	1-Clean and patch					SF	49.63	1.06	441					SF	41.47	0.78	7					LF	36.70	0.17	7
404	111	Timber Open Girder	(LF)	1-No decay	1-Miscellaneous Maint																								
404	117	Timber Stringer	(LF)	1-No decay	1-Miscellaneous Maint																								
404	135	Timber Truss/Arch	(LF)	1-No decay	1-Miscellaneous Maint																								
404	156	Timber Floor Beam	(LF)	1-No decay	1-Miscellaneous Maint																								
404	206	Timber Column	(EA)	1-No decay	1-Miscellaneous Maint																								
404	216	Timber Abutment	(LF)	1-No decay	1-Miscellaneous Maint																								
404	228	Timb Submerged Pile	(EA)	1-No decay	1-Miscellaneous Maint																								
404	235	Timber Cap	(LF)	1-No decay	1-Miscellaneous Maint																								
404	242	Timber Culvert	(LF)	1-Sound condition	1-Miscellaneous Maint																								
404	332	Timb Bridge Railing	(LF)	1-No decay	1-Miscellaneous Maint																								
404	389	Timber Fender/Dolphi	(LF)	1-Excellent	1-Miscellaneous Maint																								
404	476	Timber Walls	(LF)	1-Excellent	1-Miscellaneous Maint																								
405	145	Other Arch	(LF)	1-No deterioration	1-Miscellaneous Maint																								
405	211	Other Mtl Pier Wall	(LF)	1-No deterioration	1-Miscellaneous Maint																								
405	217	Other Mtl Abutment	(LF)	1-No deterioration	1-Miscellaneous Maint																								

Appendix D (Table D.1.)-- Summary of Detailed Analysis on FDOT Data (Basic Statistics and ANOVA); Bold indicate Different Means for Elements in Same Action Subcategory (AS) Group)

						MMS ELEMENT UNIT COST (AN				MMS AS# GROUP UNIT COST				AKBAR ELEMENT UNIT COST (ANOV				AKBAR AS# GROUP UNIT CO				DCP ELEMENT UNIT COST (ANO				DCP AS# GROUP UNIT C			
AS#	Elem#	Element	Units	Condition State	Action	MMS Unit	AVG.	C.V.	# of Data	MMS Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	Akbar Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data	DCP Unit	AVG.	C.V.	# of Data
405	243	Misc Culvert	(LF)	1-No deterioration	1-Miscellaneous Maint																								
405	333	Other Bridge Railing	(LF)	1-No deterioration	1-Miscellaneous Maint																								
405	390	Other Fender/Dolphin	(LF)	1-Excellent	1-Miscellaneous Maint																								
405	396	Other Abut Slope Pro	(SF)	1-Excellent	1-Miscellaneous Maint																								
405	398	Drain. Syst Other	(EA)	1-Excellent	1-Miscellaneous Maint																								
405	477	Other Walls	(LF)	1-Excellent	1-Miscellaneous Maint																								
406	478	MSE Walls	(LF)	1-Excellent	1-Miscellaneous Maint																								
411	300	Strip Seal Exp Joint	(LF)	1-No leakage	1-Miscellaneous Maint					LF	3.89	0.75	72																
411	301	Pourable Joint Seal	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	3.89	0.75	72																
411	302	Compressn Joint Seal	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	3.89	0.75	72																
411	303	Assembly Joint/Seal	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	3.89	0.75	72																
411	304	Open Expansion Joint	(LF)	1-No deterioration	1-Miscellaneous Maint					LF	3.89	0.75	72																
411	399	Other Expansion Join	(LF)	1-Excellent	1-Miscellaneous Maint					LF	3.89	0.75	72																
413	310	Elastomeric Bearing	(EA)	1-No deterioration	1-Miscellaneous Maint					MH	19.19	0.41	33																
413	311	Moveable Bearing	(EA)	1-No deterioration	1-Miscellaneous Maint					MH	19.19	0.41	33																
413	312	Enclosed Bearing	(EA)	1-No deterioration	1-Miscellaneous Maint					MH	19.19	0.41	33																
413	313	Fixed Bearing	(EA)	1-No deterioration	1-Miscellaneous Maint					MH	19.19	0.41	33																
413	314	Pot Bearing	(EA)	1-No deterioration	1-Miscellaneous Maint					MH	19.19	0.41	33																
413	315	Disk Bearing	(EA)	1-No deterioration	1-Miscellaneous Maint					MH	19.19	0.41	33																
422	290	Channel	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**16.00**	**0.51**	**453**	SF	31.40	0.91	6													HA	212.56	1.52	22
423	397	Drain. Syst Metal	(EA)	2-Paint dist	2-Flush drainage syst					MH	19.00	0.43	64																
423	397	Drain. Syst Metal	(EA)	3-Surf Rust	2-Flush drainage syst					MH	19.00	0.43	64																
423	397	Drain. Syst Metal	(EA)	4-Surf Pits	2-Flush drainage syst					MH	19.00	0.43	64																
423	398	Drain. Syst Other	(EA)	2-Min Deter	2-Flush drainage syst					MH	19.00	0.43	64																
423	398	Drain. Syst Other	(EA)	3-Mod Deter	2-Flush drainage syst					MH	19.00	0.43	64																
431	540	Open Gearing	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.15**	**0.19**	**27**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	541	Speed Reducers	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.13**	**0.19**	**26**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	542	Shafts	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.15**	**0.19**	**27**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	543	Shaft Brgs and Coupl	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.15**	**0.19**	**27**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	544	Brakes	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.13**	**0.19**	**26**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	545	Emergency Drive	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.23**	**0.19**	**25**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	545	Emergency Drive	(EA)	2-Min Deter	1-Service System					MH	19.94	0.19	30													EA	272.97	0.73	4
431	546	Span Drive Motors	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.25**	**0.21**	**19**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	546	Span Drive Motors	(EA)	2-Min Deter	1-Maintain and/or Serv					MH	19.94	0.19	30													EA	272.97	0.73	4
431	547	Hydraulic Power Unit	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.48**	**0.23**	**5**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	547	Hydraulic Power Unit	(EA)	2-Min Deter	1-Maintain and/or serv					MH	19.94	0.19	30													EA	272.97	0.73	4
431	548	Hydraulic Piping Sys	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.48**	**0.23**	**5**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	548	Hydraulic Piping Sys	(EA)	2-Min Deter	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
431	549	Hydraulic Cylinders	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.48**	**0.23**	**5**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	549	Hydraulic Cylinders	(EA)	2-Min Deter	1-Maintain and service					MH	19.94	0.19	30													EA	272.97	0.73	4
431	550	Hopkins Frame	(EA)	1-Excellent	2-Miscellaneous Maint	**MH**	**17.64**	**0.14**	**8**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	560	Locks	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.18**	**0.20**	**21**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	560	Locks	(EA)	2-Min Deter	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
431	561	Live Load Shoes	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**19.87**	**0.20**	**25**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	562	Counterweight Suppor	(EA)	1-Excellent	2-Miscellaneous Maint	**MH**	**20.38**	**0.20**	**17**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	563	Acc Ladd & Plat	(EA)	1-Excellent	2-Miscellaneous Maint	**MH**	**20.01**	**0.19**	**28**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	564	Counterweight	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.34**	**0.21**	**19**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	565	Trun/Str and Cur Trk	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.18**	**0.20**	**21**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	570	Transformers	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.69**	**0.18**	**13**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	571	Submarine Cable	each	1-Excellent	1-Miscellaneous Maint	**MH**	**21.26**	**0.21**	**14**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	572	Conduit & Junc. Box	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.20**	**0.20**	**22**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	573	PLCs	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**21.80**	**0.21**	**6**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	573	PLCs	(EA)	2-Min Deter	1-Clean and maintain					MH	19.94	0.19	30													EA	272.97	0.73	4
431	574	Control Console	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.34**	**0.21**	**18**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	574	Control Console	(EA)	2-Min Deter	1-Clean and maintain					MH	19.94	0.19	30													EA	272.97	0.73	4
431	580	Navigational Lights	(EA)	1-Excellent	1-Miscellaneous Maint	**MH**	**20.20**	**0.20**	**22**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	580	Navigational Lights	(EA)	2-Min Deter	1-Clean and maintain					MH	19.94	0.19	30													EA	272.97	0.73	4
431	581	Operator Facilities	(EA)	1-Excellent	1-Perform maintenance	**MH**	**20.26**	**0.20**	**20**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	582	Lift Bridge Spec. Eq	(EA)	1-Excellent	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
431	582	Lift Bridge Spec. Eq	(EA)	2-Mod Deter	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
431	583	Swing Bridge Spec. E	(EA)	1-Excellent	1-Perform maintenance	**MH**	**19.51**	**0.16**	**7**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	583	Swing Bridge Spec. E	(EA)	2-Mod Deter	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
431	590	Resistance Barriers	(EA)	1-Excellent	1-Perform maintenance	**MH**	**19.24**	**N/A**	**1**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	590	Resistance Barriers	(EA)	2-Mod Deter	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
431	591	Warning Gates	(EA)	1-Excellent	1-Perform maintenance	**MH**	**20.25**	**0.21**	**19**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	591	Warning Gates	(EA)	2-Mod Deter	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
431	592	Traffic Signals	(EA)	1-Excellent	1-Perform maintenance	**MH**	**20.25**	**0.21**	**19**	MH	19.94	0.19	30													EA	272.97	0.73	4
431	592	Traffic Signals	(EA)	2-Mod Deter	1-Perform maintenance					MH	19.94	0.19	30													EA	272.97	0.73	4
446	320	P/S Conc Appr Slab	(EA)	1-No deterioration	1-Miscellaneous Maint					SF	22.47	1.25	250					SY	12.17	1.05	255								
446	321	R/Conc Approach Slab	(EA)	1-No deterioration	1-Miscellaneous Maint					SF	22.47	1.25	250					SY	12.17	1.05	255								

Appendix E
Deterioration and Action Effectiveness Questionnaire

Instructions

This questionnaire asks a set of structured questions about each element appearing in the FDOT bridge inventory. We are asking each respondent to provide an educated estimate in answer to each of the following questions, by filling in the boxes in the questionnaire.

Please answer based on **your own personal experience** in observing the condition of bridge elements over the years. If you have no experience with an element, leave its page blank. For example, if you have not worked with moveable bridges, then leave all moveable bridge elements blank.

Often there will be several elements that have similar deterioration experience. If you believe that all of the answers for a given element will be the same as for an earlier element that you already filled in, then all you need to do is enter the earlier element's number in the topmost box on the page, leaving the rest blank.

Please assume that each element is in the **Severe** environment. Base your answers on **typical** behavior of the element, not best-case or worst-case. Consider only bridges on the **state system**, not local bridges.

The questionnaire shows element and condition state definitions, and the list of feasible actions, as given in the Pontis database used in the study. In some cases the Field Guide definitions may be slightly different, usually just a matter of grammar and spelling. In such cases, the **Field Guide** takes precedence.

Do nothing cases

The first line of each condition state is labeled DO NOTHING. In the **unshaded** box, please answer the following question:

> *If 100 typical units of this element are in this state today, after* ***how many years*** *will 50 units have deteriorated to the indicated (next-worse) condition state, with the remaining 50 units still in today's state, if no action is taken?*

Note that the inspection units for each element are indicated in parentheses after the element name at the top of the page.

For the final condition state of each element, the unshaded box is labeled "fail". For this box, the question should be interpreted as follows:

> *If 100 typical units of this element are in this state today, after* ***how many years*** *will 50 units have deteriorated to the point where they* ***no longer serve their intended function****, with the remaining 50 units still in today's state, if no action is taken?*

For primary elements such as girders, an element ceases to serve its intended function if the bridge must be load-posted. For secondary elements such as joints, the element ceases to serve its intended function when its failure causes damage to other elements. In all cases, "failure" should be interpreted as significantly worse condition than the worst defined condition state for that element.

Do something cases

The remaining boxes under each condition state are to indicate the likelihood of each condition state occurring **immediately** following a maintenance, repair, or rehabilitation action. Please answer the following question for each box:

> *If 100 typical units of this element are in this condition state today,* ***how many of them*** *(out of 100) will be in the indicated condition state immediately after the indicated action is taken?*

When answering this question, take into account typical experience with quality control, as well as the typical suitability of the action for that condition state. For example, if a concrete element is both cracked and spalled, and the action is "crack sealing," then only a portion of the deterioration will be addressed by the action, with the remaining portion (the spalls) unchanged.

If you believe that a certain condition state is highly unlikely, enter zero. For elements with fewer than 5 condition states, some of the cells may be shaded. Leave these blank. The sum of all your answers along any one row must be 100.

If a row is labeled "unitary," that means that the action is defined as being applied to the entire element on a bridge, regardless of how much is deteriorated. For example, deck overlays are unitary because decks are always overlaid all at once.

Other environments

At the bottom of each page, please indicate how you would expect the answers to your questions to differ in Moderate or Benign environments. For example, if you think decks will move from one state to the next only half as fast in a Benign environment as in a Severe environment, please indicate this in a note at the bottom of the page.

Also please indicate whether you think the do-something answers would vary by environment.

Thank you very much for your help!

Appendix F. Element-Level Summary of Deterioration Results

			Do Nothing		Do Something		Median Years Out of State				
#	Element	State Count	Average Coef of Variation	Response Rate	Average Coef of Variation	Response Rate	1	2	3	4	5
12	Concrete Deck - Bare	5	0.38	100%	0.17	100%	20.0	15.0	10.5	4.8	2.5
13	Concrete Deck - Unprotected w/ AC Overlay	5	0.45	95%	0.33	100%	9.3	6.3	4.3	2.8	2.3
28	Steel Deck - Open Grid	5	0.54	70%	0.51	72%	10.7	6.3	6.3	3.0	3.5
29	Steel Deck - Concrete Filled Grid	5	0.40	70%	0.45	72%	15.0	9.7	4.7	5.3	4.0
31	Timber Deck - Bare	4	0.00	19%	0.00	25%	10.0	10.0	5.0		
32	Timber Deck - w/ AC Overlay	4	0.00	19%	0.00	25%	5.0	3.0	12.0		
38	Concrete Slab - Bare	5	0.39	70%	0.22	75%	21.7	16.7	10.0	4.3	2.5
39	Concrete Slab - Unprotected w/ AC Overlay	5	0.40	70%	0.11	75%	7.3	4.3	3.3	2.3	2.5
54	Timber Slab	4	0.00	19%	0.00	25%	10.0	10.0	5.0		
55	Timber Slab - w/ AC Overlay	4	0.00	19%	0.00	25%	5.0	3.0	12.0		
98	Concrete Deck on Precast Deck Panels	5	0.45	95%	0.32	100%	18.3	13.0	8.8	4.0	2.3
99	Prestressed Concrete Slab (Sonovoid)	5	0.39	95%	0.51	97%	5.3	8.8	15.0	11.0	4.7
101	Unpainted Steel Closed Web/Box Girder	4		0%		0%					
102	Painted Steel Closed Web/Box Girder	5	0.46	95%	0.25	100%	10.3	5.8	7.5	5.5	3.7
104	P/S Conc Closed Web/Box Girder	4	0.57	69%	0.27	70%	15.3	19.0	12.7	4.0	
105	Reinforced Concrete Closed Webs/Box Girder	4	0.17	44%	0.27	50%	30.0	15.0	10.0	6.0	
106	Unpainted Steel Open Girder/Beam	4	0.00	25%	0.00	25%	25.0	20.0	10.0	5.0	
107	Painted Steel Open Girder/Beam	5	0.31	100%	0.09	100%	11.5	6.3	5.3	4.0	3.5
109	P/S Conc Open Girder/Beam	4	0.37	100%	0.07	100%	41.3	16.3	8.0	3.3	
110	Reinforced Conc Open Girder/Beam	4	0.35	94%	0.35	100%	22.3	18.8	8.8	5.0	
111	Timber Open Girder/Beam	4	0.00	19%	0.00	25%	5.0	15.0	5.0		
112	Unpainted Steel Stringer	4		0%		0%					
113	Painted Steel Stringer	5	0.34	95%	0.27	100%	10.3	7.5	6.5	4.0	3.0
116	Reinforced Conc Stringer	4	0.00	19%	0.00	25%	25.0	10.0	5.0		
117	Timber Stringer	4		0%		0%					
120	Unpainted Steel Bottom Chord Thru Truss	4		0%		0%					
121	Painted Steel Bottom Chord Thru Truss	5	0.06	45%	0.09	47%	11.0	5.0	4.5	4.5	4.0
125	Unpainted Steel Thru Truss (excl. bottom chord)	4		0%		0%					
126	Painted Steel Thru Truss (excl. bottom chord)	5	0.04	45%	0.09	47%	12.0	5.0	4.5	4.5	4.0
131	Painted Steel Deck Truss	5	0.04	45%	0.09	47%	12.0	5.0	4.5	4.5	4.0
135	Timber Truss/Arch	4		0%		0%					
140	Unpainted Steel Arch	4		0%		0%					
141	Painted Steel Arch	5	0.09	50%	0.08	50%	13.5	5.0	4.5	4.5	4.5
143	P/S Conc Arch	4		0%		0%					
144	Reinforced Conc Arch	4	0.17	44%	0.29	50%	30.0	10.0	7.5	5.0	
146	Cable - Uncoated (not embedded in concrete)	4		0%		0%					
147	Cable - Coated (not embedded in concrete)	5		0%		0%					
151	Unpainted Steel Floor Beam	4		0%		0%					
152	Painted Steel Floor Beam	5	0.27	75%	0.10	75%	13.3	6.3	4.3	3.7	3.3
155	Reinforced Conc Floor Beam	4	0.22	44%	0.25	50%	32.5	15.0	7.5	6.0	
156	Timber Floor Beam	4		0%		0%					
161	Painted Steel Pin and/or Pin and Hanger Assembly	5	0.00	25%	0.00	25%	10.0	4.0	3.0	5.0	6.0
201	Unpainted Steel Column or Pile	4		0%		0%					
202	Painted Steel Column or Pile	5	0.31	95%	0.26	100%	10.8	6.3	5.3	4.0	3.0
204	P/S Conc Column or Pile	4	0.30	100%	0.19	95%	22.5	8.0	3.8	2.3	
205	Reinforced Conc Column or Pile	4	0.19	100%	0.20	100%	27.5	14.0	9.0	4.5	
206	Timber Column or Pile	4	0.21	75%	0.28	75%	11.7	4.7	2.7	1.3	
207	Hollow Core Pile	4	0.21	75%	0.21	70%	23.3	5.7	3.3	2.3	
210	Reinforced Conc Pier Wall	4	0.44	100%	0.32	100%	26.3	12.8	9.0	6.0	
211	Other Material Pier Wall	4	0.00	25%	0.00	25%	10.0	5.0	5.0	5.0	
215	Reinforced Conc Abutment	4	0.35	100%	0.31	100%	32.5	14.5	10.8	7.8	
216	Timber Abutment	4	0.23	50%	0.19	50%	17.5	8.0	5.0	4.0	
217	Other Material Abutment	4	0.00	25%	0.00	25%	10.0	5.0	10.0	10.0	
220	Pile Cap/Footing	4	0.50	100%	0.32	100%	23.8	10.3	8.8	6.5	
230	Unpainted Steel Cap	4		0%		0%					
231	Painted Steel Cap	5	0.15	50%	0.13	39%	10.0	5.5	4.5	4.5	7.0
233	P/S Conc Cap	4	0.30	50%	0.18	45%	30.0	15.0	9.0	7.0	
234	Reinforced Conc Cap	4	0.26	100%	0.22	100%	31.3	17.5	11.3	6.5	
235	Timber Cap	4	0.23	50%	0.19	50%	17.5	8.0	5.0	4.0	

#	Element	State Count	Do Nothing: Average Coef of Variation	Do Nothing: Response Rate	Do Something: Average Coef of Variation	Do Something: Response Rate	Median Years Out of State: 1	2	3	4	5
240	Metal Culvert	4	0.32	50%	0.19	45%	20.0	7.5	5.0	3.5	
241	Reinforced Concrete Culvert	4	0.26	94%	0.29	90%	23.8	14.3	8.8	5.3	
243	Other Culvert	4		0%		0%					
290	Channel	4	0.37	69%	0.29	75%	13.3	13.3	8.3	4.5	
298	Pile Jacket without Cathodic Protection	4	0.30	75%	0.27	75%	7.3	7.0	5.0	4.3	
299	Pile Jacket with Cathodic Protection	4	0.61	50%	0.18	45%	8.5	5.0	3.5	3.5	
300	Strip Seal Expansion Joint	3	0.34	75%	0.13	75%	4.7	2.3	1.3		
301	Pourable Joint Seal	3	0.41	100%	0.33	100%	4.8	3.0	1.5		
302	Compression Joint Seal	3	0.36	100%	0.16	100%	4.8	2.5	1.8		
303	Assembly Joint/Seal (modular)	3	0.25	50%	0.14	50%	5.0	4.5	3.5		
304	Open Expansion Joint	3	0.38	75%	0.10	69%	15.0	7.7	3.7		
310	Elastomeric Bearing	3	0.14	100%	0.24	100%	32.5	16.3	10.0		
311	Moveable Bearing (roller, sliding, etc.)	3	0.42	100%	0.10	94%	15.0	11.3	9.3		
312	Enclosed/Concealed Bearing	3	0.00	25%	0.00	25%	15.0	10.0	6.0		
313	Fixed Bearing	3	0.20	100%	0.18	100%	18.8	12.5	6.8		
314	Pot Bearing	3	0.21	50%	0.19	50%	10.0	12.5	7.0		
320	P/S Concrete Approach Slab w/ or w-o/AC Ovly	4	0.00	25%	0.00	21%	20.0	10.0	10.0	10.0	
321	Reinforced Conc Approach Slab w/ or w/o AC Ovly	4	0.33	100%	0.15	92%	20.8	17.5	15.0	7.3	
330	Metal Bridge Railing - Uncoated	4	0.00	25%	0.00	17%	10.0	5.0	10.0	10.0	
331	Reinforced Conc Bridge Railing	4	0.33	100%	0.31	100%	23.8	20.0	15.0	9.8	
332	Timber Bridge Railing	3	0.00	25%	0.00	25%	10.0	15.0	5.0		
333	Other Bridge Railing	3	0.39	75%	0.11	69%	28.3	18.3	8.3		
334	Metal Bridge Railing - Coated	5	0.25	75%	0.03	75%	13.3	8.0	6.7	5.0	4.7
386	Fender Dolphin System Metal Uncoated	4		0%		0%					
387	Fender Dolphin System Prestressed Concrete	4	0.35	75%	0.23	70%	23.3	6.7	6.0	3.3	
388	Fender Dolphin System Reinforced Concrete	4	0.20	50%	0.11	45%	22.5	8.0	5.5	4.5	
389	Fender Dolphin System Timber	4	0.61	75%	0.25	63%	13.3	8.0	5.0	4.3	
390	Fender Dolphin System Other Material	4	0.00	25%	0.00	17%	15.0	10.0	10.0	5.0	
393	Bulkhead/Seawall Metal Uncoated	4		0%		0%					
394	Abutment Slope Protection Reinforced Concrete	4	0.30	94%	0.29	95%	16.3	11.3	10.3	4.7	
395	Abutment Slope Protection Timber	4		0%		0%					
396	Abutment Slope Protection Other Material	4	0.32	100%	0.16	92%	11.8	13.3	7.0	4.0	
397	Drainage System Metal Coated	5	0.61	75%	0.29	70%	11.0	8.7	5.3	5.0	4.3
398	Drainage Sytem Other Material	4	0.52	50%	0.14	46%	10.0	10.0	8.5	5.5	
399	Other Expansion Joint	3	0.00	25%	0.00	19%	10.0	10.0	5.0		
474	Wingwall/Retaining Wall Metal Uncoated	4	0.00	25%	0.00	20%	10.0	15.0	10.0	5.0	
475	Wingwall/Retaining Wall Reinforced Concrete	4	0.29	94%	0.27	90%	27.5	20.0	11.3	6.7	
476	Wingwall/Retaining Wall Timber	4	0.00	25%	0.00	17%	5.0	10.0	15.0	10.0	
477	Wingwall/Retaining Wall Other Material	4	0.00	25%	0.00	20%	10.0	15.0	15.0	10.0	
478	Mechanically Stabilized Earth Wall	4	0.48	25%	0.03	25%	10.0	27.5			
487	Overlane Sign Structure Horizontal Member Metal Co	5	0.37	50%	0.11	41%	15.0	10.0	10.0	6.5	5.5
488	Overlane Sign Structure Vertical Member Metal Coat	5	0.37	50%	0.09	39%	15.0	10.0	10.0	6.5	5.5
489	Overlane Sign Structure Foundation	4	0.23	50%	0.13	45%	37.5	22.5	17.5	7.5	
495	High Mast Light Poles Metal Uncoated	4	0.44	50%	0.18	45%	15.0	7.5	3.5	3.0	
496	High Mast Light Poles Metal Coated	5	0.00	25%	0.00	14%	15.0	10.0	10.0	5.0	5.0
497	High Mast Light Poles Galvanized	5	0.00	25%	0.00	14%	20.0	15.0	15.0	10.0	10.0
498	High Mast Light Poles Other Material	4	0.00	25%	0.00	20%	10.0	10.0	10.0	5.0	
499	High Mast Light Pole Foundations	4	0.32	50%	0.32	50%	30.0	20.0	12.5	5.0	
540	Open Gearing	4	0.58	75%	0.24	75%	3.7	9.0	5.3	3.7	
541	Speed Reducers	4	0.28	75%	0.20	75%	6.7	9.3	4.7	4.3	
542	Shafts	4	0.57	75%	0.27	75%	10.7	9.0	7.7	5.7	
543	Shaft Bearings and Shaft Couplings	4	0.34	75%	0.23	75%	4.0	4.7	4.0	3.0	
544	Brakes	4	0.46	75%	0.28	75%	4.3	3.7	2.7	2.7	
545	Emergency Drive and Back Up Power System	4	0.58	75%	0.08	70%	7.0	7.3	6.0	5.3	
546	Span Drive Motors	4	0.65	75%	0.18	70%	7.3	5.3	2.7	2.3	
547	Hydraulic Power Units	4	0.42	75%	0.34	70%	4.0	4.0	3.0	2.7	
548	Hydraulic Piping System	3	0.28	75%	0.30	75%	6.7	4.7	3.3		
549	Hydraulic Cylinders/Motors/Rotary Actuators	4	0.41	75%	0.28	70%	3.7	4.0	3.0	2.7	
550	Hopkins Frame	5	0.53	75%	0.45	75%	10.7	7.7	5.7	5.0	4.7
560	Span Locks/Toe Locks/Heel Stops/Tail Locks	4	0.50	75%	0.16	75%	2.0	2.3	3.3	2.3	
561	Live Load Shoes/Strike Plates/Buffer Cylinders	3	0.27	75%	0.28	75%	7.7	11.7	5.0		
562	Counterweight Support	5	0.47	75%	0.44	75%	10.7	9.0	8.0	5.0	3.0

#	Element	State Count	Do Nothing: Average Coef of Variation	Do Nothing: Response Rate	Do Something: Average Coef of Variation	Do Something: Response Rate	Median Years Out of State: 1	2	3	4	5
563	Access Ladder & Platforms	5	0.39	75%	0.43	75%	10.7	7.7	6.3	4.7	3.7
564	Counterweight	4	0.28	75%	0.37	75%	16.7	11.7	10.0	6.7	
565	Trunnion/Straight and Curved Track	4	0.65	75%	0.24	75%	10.3	9.3	7.3	5.3	
570	Transformers & Thyristors	3	0.68	75%	0.22	69%	8.7	5.0	2.3		
571	Submarine Cable	3	0.34	75%	0.24	75%	16.7	6.7	3.7		
572	Conduit & Junction Boxes	3	0.15	75%	0.25	50%	10.0	4.7	4.0		
573	Programmable Logic Controllers	3	0.76	75%	0.24	75%	7.0	7.3	5.3		
574	Control Console	3	0.78	75%	0.18	75%	7.0	4.7	5.3		
580	Navigational Light System	3	0.79	75%	0.24	75%	6.1	5.0	4.3		
581	Operator Facilities	3	0.20	75%	0.10	75%	16.7	13.3	8.3		
582	Lift Bridge Specific Equipment	3	0.00	25%	0.00	25%	3.0	5.0	4.0		
583	Swing Bridge Specific Equipment	3		0%		0%					
590	Resistance Barriers	3	0.56	75%	0.15	70%	6.3	5.0	3.0		
591	Warning Gates	3	0.33	75%	0.15	70%	4.7	4.0	3.0		
592	Traffic Signal	3	0.13	50%	0.15	45%	8.5	11.0	4.5		