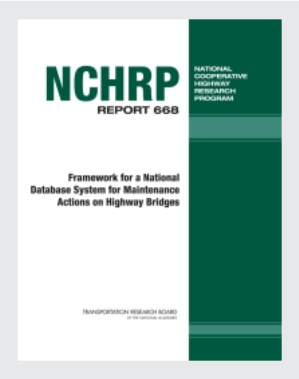

Framework for a National Database System for Maintenance Actions on Highway Bridges

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 668

Framework for a National Database System for Maintenance Actions on Highway Bridges

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TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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NCHRP Project 14-15 was performed by the Regents of the University of Colorado at Boulder. Dr. George Hearn was the Principal Investigator and the author of this report. Mr. Paul D. Thompson, Mr. Walter Mystkowski, and Mr. William Hyman (formerly with Applied Research Associates) were consultants on this project.

Essential contributions were made by several departments of transportation (DOTs) including Alabama, California, Colorado, Michigan, Minnesota, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Virginia, and Wisconsin. These DOTs generously provided data on their bridge maintenance work, bridge inventories, and bridge element-level conditions.

FOREWORD

By Amir N. Hanna
Staff Officer
Transportation Research Board

This report presents a potential framework for a National Bridge Maintenance Database (NBMD). This framework provides a uniform format for collecting, reporting, and storing information on bridge maintenance actions. Use of this framework will promote compatibility of maintenance data reported by different agencies and will provide an effective means for using these data in evaluating cost and performance of alternative maintenance applications or as a basis for cost-benefit analysis and evaluation of cost and deterioration models. The material contained in the report should be of immediate interest to state bridge and maintenance engineers and others concerned with the maintenance and management of bridges.

A variety of maintenance actions are performed by highway agencies to preserve highway bridges. Although similar maintenance actions are applied, practices for reporting maintenance methods, rates, bases of measurement, costs, performance, and other related factors differ among these agencies. There is no widely accepted system for uniformly recording data pertaining to maintenance actions. Without such a system, the reported data cannot be easily interpreted and used outside of individual agencies. Thus research was needed to develop a framework for a database system for collection, storage, and retrieval of related data. This database framework together with clear definitions of maintenance items will ensure proper interpretation of the data and facilitate their use by other highway agencies.

Under NCHRP Project 14-15, "Developing a National Database System for Maintenance Actions on Highway Bridges," the University of Colorado at Boulder worked with the objective of developing a framework for a national database system for the collection and archiving of bridge maintenance actions, materials, and methods, and their effectiveness.

The research included a review of the current practices relevant to reporting bridge maintenance programs and developing the framework for a data system for collecting, storing, and reporting information on the contexts, actions, and outcomes of bridge maintenance. The data system was developed as a set of 13 tables presenting bridge maintenance actions together with bridge inventory and condition data. Within the dataset, the outcomes of maintenance actions, reflected by changes in bridge condition, can be evaluated and studied to assess the effectiveness or costs of alternative maintenance applications or evaluate and develop cost and deterioration models. Also, to illustrate use of the framework, data were collected from 12 state departments of transportation (DOTs). These data resulted in complete datasets for 8 DOTs and partially complete datasets for the other 4 DOTs. In addition, to promote consistency in terminology related to bridge maintenance actions, the research compiled and presented a glossary of terms related to bridges and maintenance.

The agency's final report contains five appendices that provide information on bridge maintenance programs, the tables comprising the NBMD framework, a list of the element-level costs of maintenance actions, examples of the database framework use, and software to view and check the data tables. These appendices are not published herein but are available on the *NCHRP Report 668* summary webpage at http://www.trb.org/Publications/Blurbs/164203.aspx.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Framework for a National Database System for Maintenance Actions on Highway Bridges

A variety of maintenance actions are performed by DOTs to preserve highway bridges. DOTs employ similar maintenance actions but can have different practices for reporting maintenance accomplishments, costs, and performances. There is no single system in the United States for uniform recording and reporting of data on bridge maintenance. NCHRP Project 14-15 was conducted to provide a framework for a database system for uniform reporting of bridge maintenance actions and demonstrate the new system's capability with existing practices of U.S. DOTs. The database system, called the National Bridge Maintenance Database (NBMD), promotes sharing of data on bridge maintenance. The database allows DOTs to evaluate costs and performance of maintenance actions and execute cost-benefit analyses. The database system is intended to help DOTs manage bridge maintenance resources effectively.

NBMD provides a uniform, readable format for bridge maintenance, condition, and inventory data. NBMD presents maintenance actions, contexts of actions, and outcomes of actions. For bridge condition data and inventory data, NBMD conforms to the U.S. National Bridge Inventory (*35*), and the Pontis bridge management system.

U.S. state DOTs have various systems for recording bridge maintenance work, and often use separate systems for maintenance work by DOT crews and maintenance work by contract. NBMD offers a uniform, compatible format for reporting all bridge maintenance work.

NBMD is a system for the collection and archiving of bridge maintenance data. DOTs that contribute to NBMD will continue their current practices for recording crew work and contract work. NBMD is a recipient of data. NBMD collects outputs from existing DOT data systems and casts these outputs into standard format.

This report summarizes current practice in the United States in bridge maintenance work and bridge maintenance data systems, presents NBMD data tables and NBMD software utilities, reviews tasks in collection and use of bridge inventory, condition and maintenance data from US DOTs, applies NBMD data to the computation of element-level costs of maintenance, and proposes a plan for implementation of NBMD.

Project Deliverables

The deliverables of this project include the NBMD system's framework of data tables and standard formats, software utilities for standard tables, datasets formed with data collected from DOTs, computation of element-level maintenance costs, background information on bridge maintenance programs among US DOTs, a glossary of terms in bridge maintenance, and an implementation plan for NBMD. Each deliverable is briefly described in the following sections.

Background Information on DOT Bridge Maintenance Programs

Design of the NBMD system is guided by information on current practices in work execution and reporting of bridge maintenance programs among U.S. DOTs. Background information on bridge maintenance programs is presented in Chapter 1.

NBMD Data Tables and Standard Formats

NBMD is a data system for collection, storage, and reporting of information on the contexts, actions and outcomes of bridge maintenance. NBMD is a set of 13 tables presenting bridge maintenance actions together with bridge inventory and condition data. The database is presented in two formats that have identical structure and content. The first and primary format presents NBMD as a set of tab-delimited text files (called tab-text files in this report). The second format presents NBMD tables as a set of XML documents each conforming to a standard XSD schema.

NBMD presents histories of bridge maintenance work. NBMD tables are collected as datasets. Each dataset is a complete, self-contained body of bridge work, condition, and inventory data for a single DOT and a specific reporting period. Within each dataset, the outcomes of maintenance actions can be evaluated and studied as changes in bridge conditions.

NBMD datasets are stackable. Data from multiples years, residing in multiple, separate datasets can be merged into large datasets so that maintenance work and trends in conditions can be examined over time. Datasets can be combined from multiple DOTs so that large datasets can be assembled for nationwide studies, for regional studies, or to assemble larger populations of specific bridge types, bridge elements or maintenance actions. NBMD's internal identifiers for maintenance events and for bridges accommodate the merging of datasets without loss of unique identification of events, bridges, and elements.

NBMD data are readable. NBMD uses plain-language keywords to identify maintenance work, maintenance resources, bridge elements, and bridges. NBMD data headings are readable, also using plain language to identify the data that are reported.

NBMD indexing fields are concatenations of identifiers. All identifiers begin with a global ID for a dataset that indicates the DOT and the reporting year. To these, NBI structure numbers are appended to create bridge IDs, abbreviations for maintenance actions are appended to create event IDs, element numbers are appended to create element IDs, inspection dates are appended to create bridge inspection IDs, etc. NBMD identifiers include strings to denote inspections, bridge elements, or maintenance resources, as needed.

NBMD data tables include redundant entries. NBMD has tables that define maintenance actions, bridge elements and maintenance resources. Definition tables relate DOT data codes to NBMD plain language keywords. NBMD has tables that use NBMD keywords in presentation of bridge data. Data tables include both DOT identifiers and NBMD keywords, duplicating some information in definition tables. This is useful for stand-alone reading and use of NBMD tables.

Format and structure of NBMD data tables are presented in Chapter 2.

NBMD Software Utilities

The NBMD system includes four software utilities to access, create, and check NBMD datasets. These are the following:

- A viewer for datasets that presents simple summaries of data content; it also can merge datasets and compute element-level unit costs of maintenance.
- An application for generation of XML documents from tab-text NBMD tables.

- An application for viewing and editing of keyword fields in NBMD tables.
- An application to determine line counts for NBMD tables, to assist the NBMD viewer.

NBMD applications run under Windows operating systems. Applications are presented in Chapter 3. Tutorials in the use of software are provided.

Bridge Maintenance Data

In the course of this project, 12 U.S. state DOTs provided data on bridges and maintenance (Alabama, California, Colorado, Michigan, Minnesota, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Virginia, and Wisconsin.). Data from eight DOTs were used to create 15 complete NBMD datasets. Data from two DOTs spanned several years. From these data, multiple single-year datasets were created.

DOT data, its collection and preparation, are presented in Chapter 4.

Element-Level Costs of Maintenance Actions

NBMD data are used to compute unit costs for maintenance actions that improve conditions of bridge elements. Costs are computed when types of maintenance actions are compatible with observed improvements to conditions of elements. Element conditions are collected from element-level inspection reports. Improvements to conditions are computed as differences in element quantities in condition states before and after maintenance. Costs of actions are collected from DOT maintenance records, or summed from DOT resource records. Unit costs of element-level actions are computed as total costs divided by the quantities of elements improved. The computation yields unit costs together with initial and final condition states for elements. Element-level costs of maintenance actions are presented in Chapter 5.

Glossary of Terms in Bridge Maintenance

A glossary of terms related to bridges and maintenance is provided in Chapter 6.

Implementation Plan

NBMD becomes more useful and more valuable as its store of bridge maintenance data grows. The implementation plan is twofold: to provide for ongoing data collection and associated management of NBMD datasets, and; to develop applications for NBMD data that can be adopted by DOTs. Early tasks in NBMD implementation focus on expanding the number of datasets to include more state DOTs and, among DOTs already participating, more years of data. Later tasks address development and dissemination of evaluations of maintenance programs based on NBMD data.

It is proposed that NBMD be implemented through identification of a sponsoring agency, formation of a technical working group of DOTs, and selection of a contractor for NBMD system maintenance and development. The contractor will manage an internet web site for public access to NBMD datasets, software utilities, documentation, and bridge maintenance studies. The contractor will provide training materials for DOT users. The contractor will develop applications for data transfer between NBMD and other applications including Pontis and enterprise data systems at individual DOTs.

Specific tasks in implementation are:

1. Identify a supporting agency. Support for NBMD is needed to fund continuing collection of data, formation of NBMD datasets, and maintenance of NBMD internet services. NBMD might be supported by a research funding agency, a federal agency or a pool of state agencies.

2. Establish a technical working group (TWG) of DOTs that commit to participate in NBMD for a period of five years (or other fixed term). The working group will:
   a. Contribute to the NBMD data collection by making annual uploads of bridge maintenance, inventory and condition data for their bridge networks.
   b. Evaluate outputs from data analysis based on NBMD tables, such as the element-level unit costs.
   c. Assess, through active use among TWG members, the effectiveness of NBMD in evaluation and deployment of best practices for bridge maintenance.
   d. Recommend new applications for NBMD data; that is, pose questions of interest to their own DOT and other DOTs that can be answered or studied with NBMD data.
   e. Participate in focused development of data transfer procedures from DOTs' data systems to NBMD data tables.
3. Engage a contractor for NBMD to perform system maintenance and development. The contractor will do the following:
   a. Host the website for NBMD data.
   b. Prepare and deploy datasets collected from DOTs. Make regular updates to the catalog of datasets as DOTs on the TWG provide data.
   c. Develop and maintain training materials for DOT staff. Printed guides and web-based tutorials are likely to be sufficient for self-directed training of staff at US state DOTs.
   d. Develop applications for data collection and formatting at individual DOTs.
   e. Develop applications for use of NBMD data, focusing on stand-alone applications for specific computations and evaluations.
   f. Provide technical support to NBMD users.
   g. Respond to TWG members' requests for data reports and application development.
   h. Maintain the structures, formats and standard keywords for NBMD data tables.
   i. Make periodic (annual) reports of the status of the NBMD system, its data content, its applications, its file creation capabilities, and its products in element-level costs and other evaluations.
   j. Coordinate regular meetings of the technical working group.
4. Integrate NBMD with Pontis BMS in two key areas:
   a. NBMD records for maintenance work should offer automated reporting of completed maintenance work to Pontis.
   b. NBMD computation of element-level costs of maintenance should be generated as Pontis-compatible values, delivered from NBMD as a Pontis Data Interchange File, and sent to Pontis to update cost tables in the Pontis preservation model.
5. Integrate NBMD outputs with Pontis training by Providing demonstrations and training for use of NBMD data in the computation of unit costs for element-level actions required in Pontis.
6. Integrate NBMD with DOT enterprise software.
   a. Develop methods to collect bid tabulations from Trns*port to form NBMD data for maintenance events.
   b. Develop methods to collect crew work accomplishments and costs from SAP Plant Maintenance module.

Deployment at DOTs

NBMD establishes a framework for collaboration and sharing of data on bridge maintenance among interested DOTs. DOTs individually create NBMD-compatible data records and assemble NBMD data tables. The NBMD use of plain language keywords and plain-text files allows DOTs to create in-house procedures to transfer their bridge maintenance data to NBMD.

NBMD is a framework for data content rather than a set of procedures for evaluation. Methods of evaluation and parameters used in evaluations such as discount rate, cost basis, and inflation index are supplied by users of NBMD data. Costs may be direct costs, or a combination of direct costs and user costs, agency costs or other explicit or implicit costs. Inflation indexes may be obtained from the US Army Corps of Engineers, from RS Means, from the US Department of Commerce or other sources.

Appendices

Appendices A through E provide detailed information on the different aspects of the research. These appendices are not published herein but they are available on the *NCHRP Report 668* summary webpage at http://www.trb.org/Publications/Blurbs/164203.aspx.

CHAPTER 1

Background on Bridge Maintenance Programs at U.S. Departments of Transportation

The database system developed under this project is designed to be compatible with existing practices in bridge maintenance of U.S. Departments of Transportation (DOTs). To ensure compatibility, current practices in programs for bridge maintenance were reviewed. Common features in maintenance work activities and work reporting were noted. These common features became the basis in formation of a national database for bridge maintenance work. The review examined the type and scope of work activities in bridge maintenance. The review produced a glossary of terms in bridge maintenance.

Scope of Bridge Maintenance

Bridge maintenance can be defined in terms of policy statements, lists of actions, budget status and the capabilities of DOTs' maintenance data systems. DOTs recognize maintenance as distinct from new construction, replacement of structures, and major rehabilitation of structures. Replacement or modification of portions of bridges may be maintenance if projects are small and have a short duration. Larger projects are construction, rather than maintenance. Emergency work, usually in response to accidents or extreme events, is classified as maintenance and can entail significant, temporary modifications to bridges.

DOT Maintenance Actions

Most DOTs recognize bridge components as objects of maintenance actions. Maintenance actions at most DOTs distinguish construction materials (repair *steel* versus repair *concrete*) and types of work (*patch* beam versus *straighten* beam). Some DOTs recognize separate maintenance actions for different types or forms of bridge component.

Numbering systems for maintenance actions exist in three forms: as maintenance operation items used by maintenance management systems, as action items used by maintenance crews, and as pay items for contract maintenance. Some DOTs employ multiple numbering systems. Work by DOT crews may be reported in one numbering system for crew activity reports and in another numbering system for a maintenance management system.

At most DOTs, there is greater detail in data systems that record crew activities or contract pay items, and greater aggregation in management systems for maintenance programs. Both systems are useful. Detail in crew activities and pay items allows simple computation of costs. Aggregation into maintenance operations provides an overview of maintenance program scope and accomplishment.

Bridge Maintenance Scope and Definition

Definitions of bridge maintenance are collected from AASHTO (*1, 12*), published materials of state DOTs, and NCHRP reports. Bridge maintenance can be defined by at least the following four means:

1. **Policies:** Descriptive concepts of the kinds of work and outcomes that are maintenance.
2. **Actions:** Maintenance denoted by lists of maintenance crew actions and maintenance contract pay items.
3. **Budgets:** Maintenance identified by the source of funding and by U.S. federal participation, if any, in funding.
4. **Data:** Maintenance identified and perhaps limited by the capabilities of data systems used in maintenance operations.

Maintenance Defined By Policies

Policy-level definitions of maintenance are obtained from AASHTO, FHWA, and state transportation agencies.

AASHTO's guide (*13*) defines maintenance as any activity other than new construction. AASHTO's maintenance manual

(2) more narrowly defines maintenance as routine upkeep and relatively small repairs that keep bridges in good condition. Maintenance actions include routine cleaning and painting as well as repairs and replacements of components. FHWA (*33*) recognizes these same activities as maintenance.

NCHRP Report 131 on budgeting for highway maintenance (*30*) defines maintenance as actions that preserve assets in their as-constructed condition. This definition excludes improvements to existing structures as well as new construction. State DOTs often define maintenance in a similar, narrow sense. Maintenance preserves bridges and can restore bridges to original condition. New construction and betterments—actions that increase capacity or improve function of bridges—are often excluded.

California DOT maintenance manual (*22*) notes that, maintenance does not include reconstruction or improvements. Idaho DOT (*23*) considers improvements part of maintenance. Michigan DOT (*6*) notes that maintenance projects are of short duration and have little impact on traffic operations. Montana DOT notes that (*28*) maintenance preserves the originally intended use and function of bridges. Ohio DOT (*37*) notes that maintenance is intended to keep bridges in original condition. Oregon DOT (*20*) identifies preserving, repairing, and restoring as maintenance. Texas DOT (*21*) identifies maintenance in three categories: routine, preventive, and major. Texas' major maintenance includes bridge replacement and bridge reconstruction. Washington State DOT (*27*) identifies cleaning and minor repairs as normal maintenance.

Based on stated policies, cleaning and minor repairs are always maintenance. Repairs or replacements of components are often maintenance. Improvements achieved in small projects might be maintenance. Larger projects for improvement, bridge reconstruction, and bridge replacement are not maintenance. New construction is not maintenance.

Maintenance Defined by Lists of Actions

A review of maintenance actions presented by AASHTO and by state DOTs reveals seven common operations in bridge maintenance (Exhibit 1).

Most state DOTs identify maintenance actions in all operations shown in Exhibit 1 though terms vary among DOTs. Some DOTs identify *minor* repair and *major* repair rather than *repair* and *replace.* Some DOTS describe *betterments,* instead of *modify* actions. Modify actions, within maintenance programs, can include replacement of obsolete railings, extension to drain outlets, and relocation of bracing in truss portal frames. Some DOTs have separate categories for maintenance of movable spans, motion equipment, tunnels, or other structural assets.

Maintenance Defined by Budgets

Budgets in transportation departments identify funds for the maintenance division, contract maintenance, and equipment and materials used in maintenance tasks. The federal Highway Bridge Program (HBP) program has an impact here. Bridge replacement or major rehabilitation projects that are eligible for HBP funds are not maintenance. At the same time, projects that extend life of bridges are maintenance and can be HBP-eligible. Eligible maintenance projects usually entail repairs, element replacements, or minor modifications.

From the perspective of DOTs' budgets, cleaning and other routine upkeep are always maintenance. Repairs, component

Exhibit 1. Common operations in bridge maintenance.

- **Clean, Clear** actions include sweeping, flushing, removal of incompressibles, removal of vegetation, removal of material in channels, and all similar operations.
- **Seal, Paint, Coat** actions provide spot, partial, or complete application of fluid sealers, paints, coatings or preservatives.
- **Reset** actions include re-positioning, lubrication, and tightening (of bolts and rods).
- **Repair** actions return elements to better condition and perhaps to as-built condition. Patching is a repair action.
- **Replace** actions are replacement, in kind, of all or part of elements.
- **Modify** actions are repairs or replacements that alter elements.
- **Emergency** actions are executed in response to sudden acute problems that must be corrected to restore or continue traffic operations.

replacements, and minor modifications are usually maintenance and may be eligible for federal HBP funds. Bridge replacement and major rehabilitations are not maintenance.

Maintenance Defined by Data Systems

The capabilities of data systems can impose limits on the work that is tracked as maintenance. Maintenance data are the history of maintenance actions executed on bridges. Each bridge is presented to the maintenance database as an entity; as a complete set of descriptive and defining data. A bridge is presented as its National Bridge Inventory (NBI) record, its element-level model, its element-level condition data, etc. Maintenance actions are tied to individual bridges. The existence and immutability of each bridge and its make-up are essential attributes. Projects that replace bridges or greatly alter bridges are not maintenance, in this context, because they are not compatible with the basic organization of maintenance data.

Maintenance Categories

Maintenance programs consist of two broad categories: *cyclic* work and *singular* work. Cyclic work, which includes actions such as deck sweeping, is performed at set intervals. Singular work, such as repair, is performed in response to deficient conditions. The categories reveal two distinct origins of maintenance projects. Cyclic work is performed in response to DOT policy. Singular work is performed in response to inputs from bridge inspections and road surveys. A third category, *updating,* may be added. Updating is work to replace obsolete elements such as bridge railings, when the replacement is performed as part of the maintenance program. DOTs use various names for these categories of maintenance. Terminology is addressed in Chapter 6.

Contract Maintenance

Contracts for bridge maintenance work include *site* contracts that deliver a fixed schedule of repairs at a fixed set of bridges, *open-ended* contracts that provide specified maintenance actions, and *asset management* contracts that provide a level of service along a route (Table 1). Site contracts are construction contracts that deliver a set of repairs or treatments at bridges. Open-ended contracts offer a schedule of maintenance actions that district managers can direct to bridges. Asset management (AM) contracts place responsibility for both the identification of maintenance needs and the execution of work with the contractor. In AM contracts, DOTs make periodic inspections of assets to verify that the level of service is adequate.

In bid processes, site contracts entail bidding on a fixed schedule of items with fixed quantities. Open-ended contracts entail bidding on a fixed schedule of actions with estimated quantities; quantities are estimated for the first years' work in the contract based on known maintenance needs. Asset Management contracts entail bidding on a schedule of actions and

Table 1. Bridge maintenance contracting (*14*).

DOT	Contract	Note
Delaware	Open-end	3-year duration, Standard maintenance actions and costs, Maximum contract amount.
Florida	AM	Maintenance action executed when requested by DOT.
	Site	Bridge rehabilitation, Bridge replacement.
Michigan	Site	Capital scheduled maintenance, Capital preventive maintenance.
New York	Site	Larger maintenance projects.
	Job Order	An open-ended contract type using a construction task catalog of fixed prices. Suited to replacement-in-kind maintenance needs.
	Hybrid	Contracts that provide bid items, quantities and engineering design plans for one among a set of similar projects. Schedule of bid prices are applied to additional, similar projects as quantities and engineering design become available.
Oregon	Site	Small contracts are administered within districts. Larger projects go to OrDOT's central procurement.
Virginia	Open-end	District-wide contracts having 3-year duration and renewed each year. Contracts funded at $2MM annually. Contracts have 95 bid items for both ordinary and preventive maintenance, and a mix of federal-eligible and non-eligible actions.
	AM	Turnkey asset management (TAM) contracts are used for operations and minor repairs along interstate routes.
	Design	Consultant design services are available to VaDOT districts through three, open-ended, regional contracts.
Washington	Job Order	An open-ended contract type. Used for maintenance actions at ferry terminals.

Exhibit 2. Terms describing bridges.

Bridge: A structure carrying traffic over a span of greater than 20 feet, as defined in NBIS (Ref 42). Culverts, as defined in NBIS.

Component: One among the major regions or assemblies of a bridge. There are five NBIS components (deck, superstructure, substructure, channel, culvert), and six additional components that are objects of maintenance (joints, drains, railings, bearings, approaches, movable bridge).

Element: One among AASHTO's commonly recognized elements, or among additional elements defined by DOTs.

Device: A part that can be replaced as a unit, often without demolition of attached portions of the bridge.

estimated quantities intended to deliver a specified level of service along a route.

Summary on Bridge Maintenance Scope

Bridge maintenance can be defined in terms of policy statements, lists of actions, budget status, and the capabilities of maintenance data systems. U.S. DOTs recognize maintenance as distinct from new construction, replacement of structures, and major rehabilitation of structures. Cleaning, painting, and minor repairs are always maintenance. Replacement or modification of portions of bridges may be maintenance if projects are small and have a short duration. Large projects are construction, rather than maintenance. Emergency work, usually in response to accidents or extreme events, is classified as maintenance and can entail significant, temporary *modifications* of bridges.

Terms in Bridge Maintenance

This section reports a set of frequently used terms in bridge maintenance. Chapter 6 provides a glossary of terms collected from DOT maintenance manuals and guides.

Bridges are structures included in the National Bridge Inventory System (NBIS) (*35*). Bridges may include short spans and minor culverts. Bridge *components* include the five components that appear in the NBIS (deck, superstructure, substructure, channel, culvert) plus six components that are identified in maintenance work (joints, drains, railings, bearings, approaches, movable bridge). Bridge *elements* include AASHTO's commonly recognized bridge elements (*1*) plus additional elements defined by DOTs. Bridge *devices* are prefabricated parts such as railings or bearings that can be replaced as individual units (Exhibit 2).

An *Operation* is a kind of maintenance (Exhibit 3). An *Activity* is a general method for an operation. A maintenance *Event* is the accomplishment of one operation, on one bridge, at one time. A maintenance *Record* is the collection of data for one maintenance event. A maintenance *Item* is the identification, usually by a numerical code, of a maintenance action.

Costs of maintenance are computed from usages of resources. *Resources* include *Labor, Equipment,* and *Materials* for DOT crew work, and pay items and quantities for contract maintenance (Exhibit 4). Labor costs are sums of employee hours and labor rates. *Equipment* costs are sums of equipment usage and equipment rates. Material costs are sums of material quantities and unit costs. Contract costs are sums of *pay Item* quantities and bid prices. Maintenance *Accomplishments* are quantities of maintenance work completed. These may be expressed in units specific to maintenance operations, or as quantities of bridge elements that receive maintenance.

Exhibit 3. Terms describing maintenance work.

Operation: A type of maintenance work, being one among: Clean, Reset, Coat, Repair, Replace, Modify, Emergency.

Activity: A method of performance of an operation.

Event: The accomplishment of an operation at a specific structure, on specific dates, in specific quantities, incurring specific costs and delivering specific improvement.

Record: Data for one event, identifying the structure, the action, the date, the resources used, the action quantity accomplished, and the improvement to bridge condition.

Item: The identifying number of a maintenance action.

Exhibit 4. Terms related to maintenance cost.

Resource: Any measurable contributor to the cost of maintenance. Resources include labor, equipment, materials, and pay items.

Labor: As a resource, the set of employees and hours. As a cost, the sum of products of hours and rates.

Equipment: As a resource, the set of equipment types and usages. As a cost, the sum of products of equipment usages and rates.

Materials: As a resource, the set of material items and quantities. As a cost, the sum of products of material quantities and unit costs..

Pay Items: As a resource, the set of pay items and quantities. As a cost, the sum of products of pay items and bid prices.

Accomplishment: The quantity of maintenance work that is completed, expressed in action units, or bridge element units or both.

Outcome: Improvement to condition ratings or road survey data achieved by a maintenance event.

Maintenance *Outcomes* are the improvements to bridge conditions achieved by maintenance events.

Most DOTs recognize categories of maintenance. These are variously called *Scheduled/Response*, *Preventive/Routine*, or *Proactive/Reactive.* These terms have different and sometimes conflicting meanings for different DOTs. Exhibit 5 lists these terms as they are defined by AASHTO and by DOT sources.

Condition ratings are integer values indicating the presence and severity of defects at bridges (Exhibit 6). In practice in the United States, *ratings* usually denote the 9-to-0 scale used in the NBIS and applied to bridge components. *Condition States* are also integer values indicating the presence and severity of defects. *States* usually denote the 5-valued and 4-valued scales used for AASHTO's commonly recognized bridge elements. *Road Surveys* report presence of debris, graffiti, and other deficiencies in upkeep along routes and at bridges. Similar data may be called maintenance *assurance values,* maintenance *quality data,* or simply *field data.* Condition ratings and condition states are usually reported by bridge inspectors. Road survey data are reported by road maintenance crews.

Summary on Maintenance Terms

Selected terms describing bridge features, maintenance work, costs, and condition data are defined in this section. Most of these terms are familiar, and the definitions given here are com-

Exhibit 5. Terms describing maintenance categories.

AASHTO (*2*)	**Scheduled:** Work programmed at intervals. **Response:** Done as needed and as identified through the inspection process.
Alabama (*11*)	**Routine Limited Activities:** Quantities of work that can be established and firmly adhered to. Control is exercised on the basis of planned work units. Examples: Mowing, Bridge Inspection. **Routine Unlimited Activities:** High priority work performed when needed in the amounts required to minimize deficiencies.
Oregon (*20*)	**Proactive:** Activities planned in advance to reduce lifecycle costs; inspection, upkeep. **Proactive:** Activities planned in advance to forestall significant damage. Preservation or restoration activities. **Reactive:** Incident driven activities. Performed to correct or respond to immediate problems.
Texas (*21*)	**Preventive Maintenance:** Steel structure cleaning and repainting; installation of other coatings; installation of bridge deck protection; joint cleaning and sealing or replacement. **Routine Maintenance:** Repair of substructures, superstructures, decks, joints, approach slabs, and railing; spot painting; repair and operation of movable bridges; installation of temporary bridges; repair and installation of fender systems.

Exhibit 6. Terms describing field data.

Condition Rating: An integer value indicating presence and severity of defects in a bridge component.

Condition State: An integer value indicating presence and severity of defects in a bridge element.

Road Survey, Assurance Value, Quality Data, Field Data: Reports of presence and extent of debris graffiti or other upkeep deficiencies.

monly used. Three terms—Operation, Activity and Event—have a special role in the database developed in this project. A larger list of terms collected from DOT maintenance manuals is provided in Chapter 6.

Maintenance Actions

U.S. state DOTs perform similar maintenance work, but there are differences in the level of detail used to record maintenance accomplishments and to distinguish methods and products.

Sets of maintenance actions are collected from public documents including the following:

- **Manuals on maintenance policies and recommendations.** These provide descriptive information on maintenance actions but might not contain formal numbering and measurement units for actions.
- **Manuals for maintenance foremen and maintenance crews.** These usually report formal procedures for recording and reporting maintenance activities. Reporting includes crew size, crew activities, materials used, and equipment used. Often, measures of indirect activities such as traffic control, travel time, and preparation at the maintenance yard, are included.
- **Manuals for information systems.** These list the numbers (IDs) for maintenance actions. At some DOTs, different maintenance information systems are used by different department branches. The branch tracking costs might employ a management system that reports maintenance operations, with each operation covering many related actions. The maintenance crews may use a more detailed list of actions.

Details of information from AASHTO and from state DOTs are reported in the following section. A summary of categories of bridge maintenance work and maintenance actions reported by AASHTO and state DOTs are provided in several tables in Appendix A.

AASHTO Maintenance Manual

The AASHTO maintenance manual (*2*) identifies various bridge elements, discusses their common modes of deterioration, and presents actions for maintenance of these elements. The maintenance manual does not provide a formal list of maintenance actions, but maintenance actions are evident in the narrative.

AASHTO actions are presented for bridge deck, superstructure, substructure, joints, drains, curbs, railings, approach pavement, approach embankment, and channel. The following are the six maintenance operations:

- Clean, Clear;
- Seal, Paint, Coat;
- Reset;
- Patch;
- Repair; and
- Modify.

The AASHTO presentation includes several actions for each operation, taking into account different types of bridge elements, different methods of maintenance, and different repair products. The AASHTO actions include major operations. For decks, actions such as installation of cathodic protection, placement of concrete deck overlay, deck replacement, and asphaltic overlay with waterproofing membrane are included. For channels, AASHTO actions include construction of revetments, placement of channel liners, and construction of check dams.

Alabama DOT

The Alabama DOT (*11*) identifies basic maintenance operations as the following:

- Cleaning,
- Painting,
- Minor Repairs,
- Major Repairs,
- Moveable Span Maintenance,
- Tunnel Maintenance, and
- Other Structure Maintenance.

Alabama DOT uses two systems of numbering for maintenance actions. The Alabama maintenance management system uses six numbers (645–650) to identify operations. Alabama maintenance crews report their accomplishments as "B" codes—a set of 39 actions (*11*). The Alabama B codes recognize eleven components: Bridge, Movable Spans, Deck,

Joints, Curbs/Rails, Superstructure, Substructure, Slopes/Shores, Culverts, Navigation Lights, and Tunnels. For most components, the actions include cleaning, coating, minor repair and major repair.

California DOT

Bridge maintenance actions are reported in Chapter H of the California Maintenance Manual (*22*). California maintenance actions include cleaning, coating, repair, rehabilitation, and replacement of bridge components.

Colorado DOT

Colorado DOT employs two sets of maintenance actions. One set is coordinated with Colorado's implementation of the Pontis Bridge Management System (*32*). This set has 40 actions with identifying numbers between 351 and 399. The set recognizes eight bridge components (Bridge, Deck, Expansion Joints, Curbs/Rails, Superstructure, Bearings, Substructures, and Approaches). The actions include cleaning, painting, repositioning, lubricating, tightening and repairing. Activity 398 is used to identify miscellaneous work such as repair of utilities. Activity 399 is reserved for identifying deficiencies that require engineering design to accomplish a repair.

Separately, contract maintenance is organized as pay items. Annually, Colorado DOT tabulates average costs for pay items in maintenance contracts (*39*), as well as annual item data books (*17*). Contract actions include the full range of cleaning, painting, repairing and replacement actions.

Florida DOT

The Florida DOT maintenance management system (MMS) includes 14 actions. The actions identify the components. The components are Bridge, Deck, Drains, Railings, Superstructure, Substructure, Channel, Electrical Systems, and Mechanical Systems. Actions for each component include both maintenance and repair.

Georgia DOT

Georgia DOT lists 13 actions in its Bridge Information Management System (BIMS) (*5*). The components are Bridge, Decks, Curb/Rails, Joints, Superstructure, Substructure, Approach Slab, and Culverts. Most actions provide for major repair or replacement of components. One action, number 845, provides cleaning, routine maintenance and minor repair for most components.

Idaho DOT

The Idaho maintenance manual (*23*) describes, in text, a set of 52 actions. The actions address 10 components: Bridge, Decks, Joints, Bearings, Curb/Railing, Substructure, Approach Pavements, Channel, Culvert, Accessories, and Signs/Utilities. Under *Accessories* are actions for drainage systems, catwalks, sidewalks, cathodic protection systems, de-icing systems, fill stabilization, walls, and slope paving. Maintenance actions provide cleaning, clearing, painting, repairs, replacements, and modifications.

Illinois DOT

Illinois DOT lists 139 maintenance actions in the manual for the Illinois Highway Information System, ISIS (*16*). The components are: Bridge, Decks, Drains, Joints, Railings, Superstructure, Bearings, Substructure, Slopes, Approach Pavements, Channels, and Miscellaneous. Under *Miscellaneous* are actions for lighting, and movable bridges. Maintenance actions include cleaning, clearing, painting, sealing, patching, repairs, replacements, modifications and removal of structures.

Illinois actions are further defined by repair products. Painting is an example. ISIS has 26 codes identifying paint material and manner of application. Illinois records as many as four paint codes per bridge to identify the various paints used.

Maryland DOT

Maryland DOT (*4*) uses open-ended maintenance contracts within DOT regions to perform actions such as deck patching, clearing drains, debris removal, slope protection, and underdeck timber planking. Separate contracts for bridge painting include items for zone painting, overcoating, and complete removal and repainting.

Michigan DOT

Maintenance actions are collected from the Michigan DOT Bridge Capital Scheduled Maintenance Manual (CSM) (*6*). The CSM manual lists maintenance first as operations and then as specific actions within each operation. The operations are the following:

- Superstructure Washing;
- Vegetation Control;
- Drainage System Cleaning/Repair;
- Spot Painting;
- Joint Repair/Replacement;
- Concrete Coating/Sealing;
- Minor Concrete Patching and Repair;
- Concrete Crack Sealing;
- Approach Pavement Relief Joints; and
- Slope Paving Repair.

Within each operation, specific actions differ in repair method or material. The CSM manual addresses contract maintenance work and lists 51 maintenance pay items. Additional information, collected from Juntunen (*18*), indicates that zone painting, full painting and epoxy overlays for decks are also maintenance actions.

Montana DOT

The Montana DOT Maintenance Manual (*25*) identifies both state-force maintenance and contract maintenance. Maintenance and repair of structures are provided by a set of 13 actions that include cleaning, clearing (drains), debris removal, adjustment/tightening of parts, and repair of elements. Contract maintenance is used for maintenance overlays, crack sealing, and coatings. Montana DOT performs maintenance actions in response to visible deficiencies. Montana DOT employs a readable system for numbering of maintenance actions (as opposed to a simple index). Each action is identified by a four digit sequence composed of the following:

- A single digit for highway asset,
- A single digit for purpose of the action, and
- Two digits identifying a specific action.

Bridges are highway asset "4," and preventive maintenance is purpose "1." Actions for preventive maintenance of bridges are numbered "41XX," where "XX" are from a list of the specific activities.

New Hampshire lists bridge maintenance actions for deck, beams, trusses, joints, and rails.

New York State DOT

New York State DOT (*38*) identifies cyclic maintenance actions including deck washing, concrete sealing, bearing lubrication, bridge painting and deck overlays. Repairs, replacements, and modifications to reduce vulnerability are also maintenance, though not cyclic. New York associates some maintenance actions with specific construction materials or element types. In addition, maintenance actions are appropriate only for structures within a stated range of condition ratings.

North Carolina DOT

North Carolina DOT's program for preventive maintenance (*10*) includes bridge painting, joint repairs, and rehabilitation of decks.

Ohio DOT

Ohio DOT's bridge maintenance actions are collected from the on-line Bridge Maintenance Manual (*29*), the Transportation Management System (TMS) Foreman's Manual (*37*) and the Maintenance Administration Manual (*19*).

The on-line maintenance manual is an illustrated guide to maintenance and repair of bridges. The on-line manual recognizes eleven bridge components (Bridge, Deck, Drains, Joints, Railings, Sidewalks, Superstructure, Substructure, Approach, Channel, Culvert) and six operations (Clean, Coat, Reset, Repair, Replace, Modify). The on-line manual recognizes different bridge elements (by type of joint, type of bearing, etc.), different construction materials, and different repair products. Starting with eleven components and six maintenance operations, the multiplicity of elements, materials, and products yield a list of 300+ actions in bridge maintenance.

A formal list of 126 maintenance actions appears in Ohio's TMS Foreman's Manual (*37*). These actions are used in reporting crew work and accomplishments. These actions address the maintenance programs for bridges, roadways, and facilities. There are 43 actions related to bridges and culverts. These actions recognize the same components and basic actions found in the on-line maintenance manual.

Oklahoma DOT

Oklahoma DOT's (*31*) actions for bridge maintenance include painting, sealing, and repairs to decks, superstructure, and substructure. Repair methods include use of synthetic fiber wraps for reconstruction of concrete elements, and the rebuilding of steel beams by cutting out deteriorated portions (ends of beams, often) and welding in a matched section of steel.

Oregon DOT

Oregon DOT employs two numbering systems for maintenance actions (*20*). A set of nine actions is used in the MMS. These MMS actions recognize three structures (Culvert, Bridge, Movable Bridge) and four operations (Clean, Coat, Maintain, Repair). A separate numbering system, called TEAMS, is used by DOT work crews to report production. There are 49 TEAMS actions for bridges. The TEAMS actions recognize nine components (Movable Bridge, Deck, Drains, Walks/Rails/Curbs, Superstructure, Substructure, Slope, Channel, Culvert); four construction materials (Concrete, Steel, Timber, Any); and a few bridge elements.

Pennsylvania DOT

Pennsylvania DOT lists bridge maintenance actions in its *Procedures and Standards for Bridge Maintenance* (*34*). The publication lists procedures that include operations for cleaning, resetting, repairing, replacing, and modifying. Often, separate procedures are listed for similar actions applied to different structure types or different construction materials.

Maintenance procedures recognize 12 components (Bridge, Deck, Drains, Joints, Railings, Sidewalks/Curbs/Parapets, Superstructure, Bearings, Substructure, Approach, Channel, Culvert). Actions provide cleaning, repositioning, tightening, coating, repairing, replacing, and modifying of components.

Actions are identified under two numbering systems: the Maintenance of Roadways Information System (MORIS) cost functions and the BMS activity numbers. MORIS lists 31 actions for bridge maintenance. The MORIS numbers

aggregate similar actions for different structure types or construction materials. There are 77 BMS activity numbers for bridge maintenance. The BMS activities recognize distinctions among elements, though a single BMS activity can correspond to more than one procedure.

An overview of Pennsylvania's bridge preservation program is provided by Rogers (*36*).

Texas DOT

Texas DOT's (*3, 21, 26*) maintenance actions recognize nine components (Bridge, Deck, Drains, Joints, Railings, Superstructure, Substructure, Approaches, Channel). The actions provide for cleaning, coating, repair, and replacement of components. Contract maintenance projects are organized as standard pay items.

Texas DOT (*8*) developed standard repair details for the guidance of maintenance personnel. The general goals of preventive maintenance are to keep joints clean and sealed, control drainage, clear debris from channels and maintain bearings.

Virginia

The Virginia Transportation Research Council (VTRC) identifies washing, sweeping, lubrication, joint sealing, overlays, vegetation control, and zone painting among preventive maintenance actions (*7*). Repairs, element replacements and modifications are also maintenance. Modifications include retrofit of fatigue-prone details and installation of cathodic protection systems. VTRC reports intervals and average costs for some actions in preventive maintenance.

Washington State DOT

Washington State DOT's maintenance program recognizes two classes of structures (*24*). Major structures are bridges on the state bridge list. Minor structures are drainage structures, retaining walls, noise barriers, etc. Area maintenance crews take actions to sweep decks, remove debris on components, and clear drains. Other repair works on bridges are the responsibility of the state Bridge Preservation Engineer.

Washington DOT provides detailed guidance for compliance with environmental regulations, especially for activities that can affect waters of the state. Programmatic permit guides are provided for the following:

- Bridge Maintenance Washing and Cleaning,
- Bridge and Ferry Terminal Deck Overlay Replacement,
- Bridge and Ferry Terminal Deck and Drain Cleaning,
- Bridge General Maintenance and Repair, and
- Bridge Paint-Prep Washing and Blasting.

Summary and Maintenance Actions—Existing Practice

Maintenance operations at most DOTs include cleaning, coating, and repairs. Many DOTs also include operations for replacement (usually of parts or portions of bridge components), for minor modifications, as well as actions for lubrication and other actions to reset devices on bridges. Maintenance actions at most DOTs are distinguished by construction material (repair *steel* versus repair *concrete*) or by type of work (*patch* beam versus *straighten* beam).

Most DOTs recognize bridge components as objects of maintenance actions, and most recognize more than the five NBIS components. Some DOTs recognize separate maintenance actions for different types or forms of bridge component. These are element-level distinctions, though CoRe elements are not often used directly.

Numbering systems for maintenance actions exist in three forms: as maintenance operation items used by maintenance management systems, as action items for maintenance crews, and as pay items for contract maintenance. Some DOTs employ more than one numbering system.

At most DOTs there is greater detail in recording crew activities and contract pay items, and greater aggregation in maintenance operations tracked by management systems. Both are needed. Detail in crew activities and pay items allows simple computation of costs. Aggregation into maintenance operations provides an overview of maintenance program scope and costs.

Bridge Maintenance Data—Existing Practice

Data in bridge maintenance programs identify and quantify: actions taken, usages of resources, and quantities of accomplishment. Direct uses of data include cost computations and computation of resources needed for unit accomplishment of maintenance actions. Reports are summaries of maintenance data for a type of action, a DOT region, a time period, or other organizing basis. Evaluations are comparisons of cost and benefits in various guises: cost for maintenance quantity, cost for maintenance quality, comparative costs of repair products, comparative productivity of different equipment or crew size, etc. Programmatic evaluations are needed for Governmental Accounting Standards Board (GASB) reporting and life-cycle cost computations. Maintenance management, finally, is the intelligent application of reports and evaluations to estimation of future needs and planning.

Users of maintenance data include maintenance crews, foremen, and regional superintendents, all working with information on resource needs and production rates for maintenance actions. DOT maintenance directors use reports

of maintenance data to justify budget requests and report achievements of maintenance programs. Bridge engineers use maintenance data in the evaluation of products and methods.

Maintenance Data

Data are considered in two sets: data on usage of resources and data on conditions of bridges. Each has two subsets. For resources, there are data on resources used in work by DOT crews, and there are data on pay items and quantities for contract maintenance. For conditions, there are data from bridge inspections and data from surveys by road crews.

Data on Resources

Data on resources include all labor, equipment, and material needed to accomplish a maintenance task (*30*). This concept is evident in some state DOT policy statements (Table 2) and in the forms used for reporting crew maintenance work and contract maintenance.

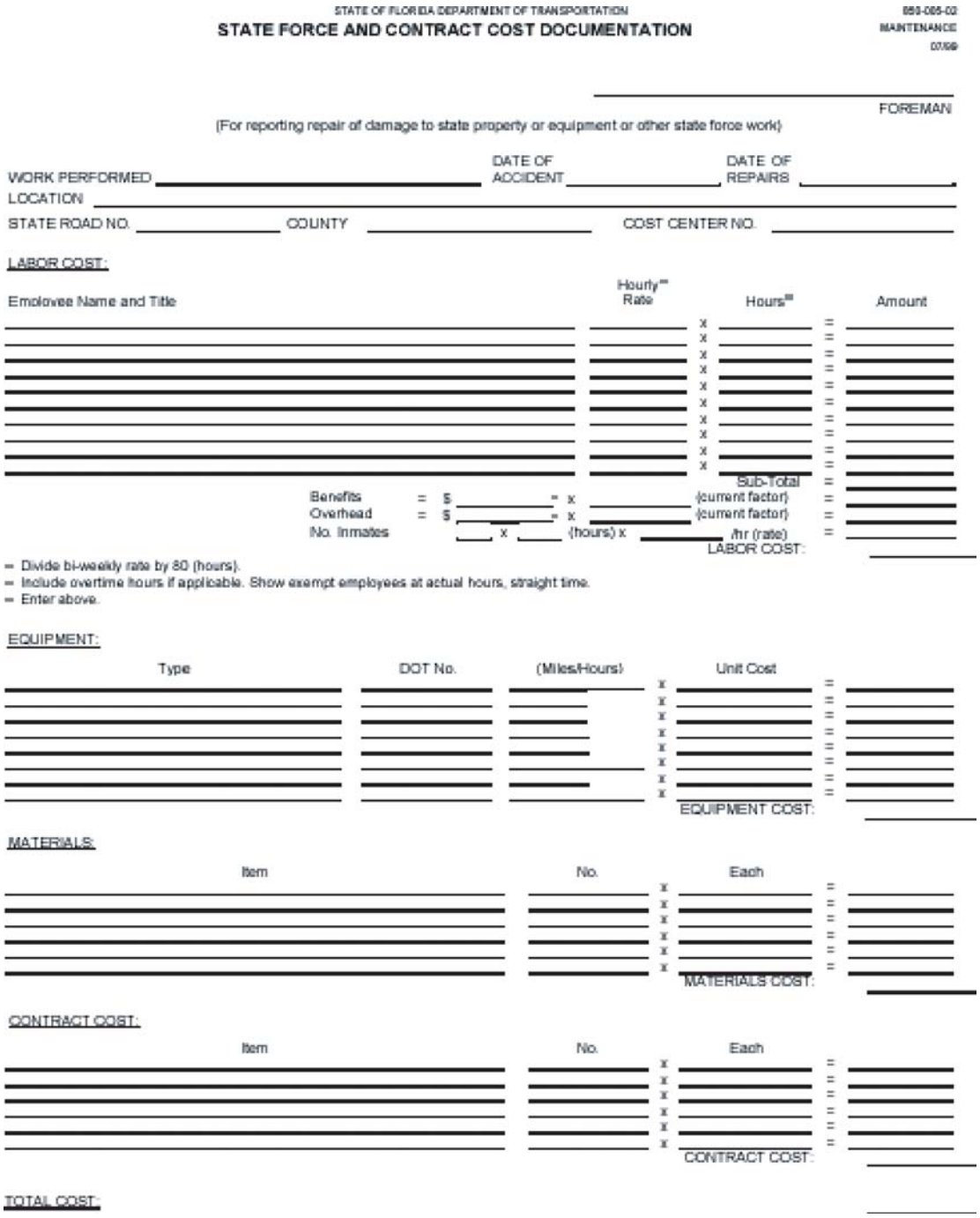
Maintenance by DOT Crews

A primary source of data for work by DOT crews is the crew card (also called day card, daily work report, daily time card, etc.). Crew cards provide information on resources and accomplishments. Examples are found in the Ohio DOT's *Transportation Management System's Foreman's Manual* (*37*) and the Alabama DOT's *Field Operation's Manual* (*11*) (Figure 1). Typical content of crew cards includes the following:

- Work Administration
  - Maintenance unit number and name
  - Job number or index to maintenance program plan
  - Date(s)
  - Crew Leader name or ID
- Work performed
  - Action Number and name
  - Activity Numbers and names
- Exact location where the work was performed
  - Bridge ID
  - *Optional:* Location on a bridge identified by span, lane, beam line, etc.

Table 2. Policies on maintenance costs.

DOT	Policy
Ohio (*37*)	It is intended that all work effort, inclusive of layout, mobilization, final clean up, etc., that contributes directly to achieve the accomplishment of the item be charged to the item's Program Activity Code. (All work is part of the activity, and not a separate item or cost. This will lead to different apparent costs when traffic control is provided for a single activity and when traffic control allows several activities to occur together.)
Ohio (*19*)	It is imperative that ODOT capture the cost of using in-house resources to perform the work necessary to reach its goals. This information will be used in various ways including the following: • As a tool to assist managers in allocating resources based on projected workloads. • To compare costs of performing similar activities between districts, determine desired performance thresholds, and identify best practices of those business areas that perform within the cost thresholds. • To accurately compare in-house costs to costs of outsourcing. • To calculate overhead rates for the Department, District, County and Garage. • To refine allocation methods relating to overhead rates as the process becomes more defined. • To monitor accountability and accuracy of the data in TMS through Quality Assurance Reviews.
Texas (*21*)	Provide data on work load and cost of maintenance activities to support budgeting and planning efforts; Provide a tool for analyzing maintenance activities so that production efficiency can be improved; Help identify sections of highway which qualify for rehabilitation; Document the work accomplished in order to support the department's budget requests to the legislature; and Provide data to compare costs of maintenance activities performed under contract with those performed by state forces.



STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

STATE FORCE AND CONTRACT COST DOCUMENTATION

850-065-02
MAINTENANCE
07/99

FOREMAN

(For reporting repair of damage to state property or equipment or other state force work)

WORK PERFORMED _____ DATE OF ACCIDENT _____ DATE OF REPAIRS _____

LOCATION _____

STATE ROAD NO. _____ COUNTY _____ COST CENTER NO. _____

LABOR COST:

Employee Name and Title	Hourly** Rate		Hours**		Amount
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
			Sub-Total	=	
Benefits = $ _____ = x			(current factor)	=	
Overhead = $ _____ = x			(current factor)	=	
No. Inmates ____ x ____ (hours) x			/hr (rate)	=	
			LABOR COST:		

= Divide bi-weekly rate by 80 (hours).
= Include overtime hours if applicable. Show exempt employees at actual hours, straight time.
= Enter above.

EQUIPMENT:

Type	DOT No.	(Miles/Hours)		Unit Cost		
			x		=	
			x		=	
			x		=	
			x		=	
			x		=	
			x		=	
			x		=	
			x		=	
				EQUIPMENT COST:		

MATERIALS:

Item	No.		Each		
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
			MATERIALS COST:		

CONTRACT COST:

Item	No.		Each		
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
			CONTRACT COST:		

TOTAL COST: _____

Figure 1. Work reporting form—Florida DOT.

- Labor Usage
  - Crew Size
  - Employee names or IDs
  - Number of hours worked by each employee on each activity
- Equipment Usage
  - Equipment Type(s) and ID(s)
  - Miles or hours used for each type of equipment
  - Miles or hours used for each activity
- Material Usage
  - Material Item Number(s)
  - Quantities of materials
- Work Accomplishment
  - Work unit
  - Number of units accomplished

Crew cards identify the maintenance yard, date of work, and crew leader. The crew card may include a job or authorization

number that places this work within the maintenance program plan. The work itself is identified by an action number or description. The location of work is shown, at least as bridge ID, and possibly as a span, lane, beam line, etc., on the bridge.

Labor usage is recorded as employees and hours. Equipment IDs and usage are shown. Material item numbers and material quantities are shown. Work accomplishment is shown.

Labor usage for indirect activities on crew cards can include yard preparation, travel time, mobilization, traffic control, work interruptions, and clean-up. Some DOTs use standard codes to identify such activities. There are other indirect activities such as administration, inspections, equipment transfer (between yards), and material stockpiling, that are not recorded on crew cards.

Crew cards often record work order numbers. The bridge ID, job authorization number, and maintenance action are entered in advance by maintenance administrators. A crew leader receives the card, executes the action, records usages of labor, equipment and materials, and returns the completed card to maintenance administration.

Usually the information on a crew card can be tied to a specific bridge. However, there are exceptions when a crew performs multiple activities on a single bridge or the same activity on multiple bridges. There is a related issue: all the work performed on a particular bridge might not be recorded on one daily work report if either multiple days or multiple crews are used.

Some DOTs have implemented MMS that are driven by work orders. In principle, a work order is issued for each deficiency on a bridge, and when the work is completed, the work order is closed out.

The Florida work reporting form (Figure 1) includes both field data and office data. Identification of crew members, equipment, materials, and quantities are field data. Crew pay rates, equipment rates, and material unit costs are office data. The extended costs are office computations (Table 3).

Contract Maintenance

Resources used in contract maintenance are reported as pay items and quantities. A single pay item may combine labor, equipment, and material costs. Reports (billings) from contracts may provide the following:

- Pay items and quantities for a single maintenance action at one bridge,
- Pay items and quantities for the same action at more than one bridge,
- Pay items and quantities for multiple maintenance actions at one bridge, and
- Pay items and quantities for a project that includes both maintenance and non-maintenance actions.

To record resources expended for each maintenance action at each bridge, it may be necessary to allocate pay items among several actions and several bridges. Further allocation may be needed to identify resources for direct and indirect activities.

Condition Data

Maintenance can improve conditions of bridges. Measures of improvement can be used in evaluations of effectiveness of maintenance actions. For bridges, condition data are available as CoRe element condition reports, as National Bridge Inventory (NBI) condition ratings and as road survey values.

CoRe element condition reports list element quantities in condition states (*1*). For many elements, more than one condition state may be reported. Condition states indicate defects. The response, naturally, is repair or replacement. CoRe condition states are defined separately for separate elements. CoRe language is specific, and is intended to foster simple, consistent assignment of conditions states for observed conditions. A condition state may name more than one defect or visible indicator of condition. The CoRe report of condition states does not identify which defect is present. As a result, a condition state can correspond to several maintenance actions that might be needed, but the condition state does not indicate a specific maintenance action (Table 4).

NBI condition ratings are more general (*35*). Three ratings, one each for deck, superstructure and substructure share a common set of definitions. The naming of multiple defects is absent. Both extremes of the NBI rating scale are infrequently used. Rating 0 for failed bridges is not frequently needed. Rating 9 for new or near-new bridges is rarely used. NBI condition ratings indicate the need for a maintenance operation, but not a specific maintenance action (Table 5).

Channels and culverts have separate definitions of NBI condition ratings (see Tables 6 and 7).

Table 3. Field data and office data.

Field Data	Office Data	Office Computation
Employee names, job titles, and hours	Employee hourly rates	Labor cost
Equipment types, IDs, and usage	Equipment rates	Equipment cost
Material types, items and quantities	Material unit costs	Material cost

Table 4. Maintenance actions for CoRe condition states.

	Bridge Element		
Condition State	**Concrete Deck**	**Steel Beam**	**Concrete Substructure**
1	Clean, Seal surface	Clean	Clean
2	Patch, Seal cracks, Seal surface	Spot paint	Patch, Seal cracks, Seal surface
3	Patch	Spot paint, Full paint	Patch
4	Patch, Replace Portion, Modify protection	Full paint, Repair,	Patch, Replace Portion, Modify protection
5	Patch, Modify protection, Replace Entire	Repair, Replace	Patch, Modify protection, Replace Entire

Table 5. NBI and maintenance operations: deck, superstructure, and substructure.

Code	Description	Operation
N	Not applicable	
9	Excellent condition	Clean
8	Very good condition	Clean
7	Good condition	Reset
6	Satisfactory condition	Reset, Coat
5	Fair condition	Repair, Coat
4	Poor condition	Replace, Modify
3	Serious condition	Modify, Emergency
2	Critical condition	Emergency
1	"Imminent" failure condition	
0	Failed condition	

Condition information is also available from road surveys. These data are variously called quality survey data, level-of-service data, assurance data, or simply field data. Road surveys report debris, sand/grit, problem vegetation, graffiti, and other conditions that can contribute to deterioration. Maintenance can be cleaning, clearing, spot painting, and resetting.

Reports

Some DOTs develop *Performance Standards* (*30*) for maintenance actions. Each maintenance action has its own performance standard, and each performance standard indicates the resources needed to complete a unit accomplishment of the action. Performance standards are useful in planning and scheduling maintenance work, and typically include the following:

- Crew size/Labor requirements;
- Kinds and number of equipment used;
- Suggested procedures;
- Material quantities;
- Average daily accomplishment; and
- Authorizations, permitting and scheduling constraints.

Maintenance data provide the average values for required labor, equipment and materials, and the average values of accomplishment using these resources. An example performance standard is taken from Pennsylvania DOT is provided in Figure 2.

Table 6. NBI and maintenance operations: channel.

Code	Description	Operation
N	Not applicable.	
9	No noticeable or noteworthy deficiencies.	
8	Banks are protected or well vegetated.	
7	Bank protection is in need of minor repairs.	Clear, Reset
6	Bank is beginning to slump.	Clear, Reset
5	Bank protection is being eroded.	Clear, Repair
4	Bank and embankment protection is severely undermined.	Replace
3	Bank protection has failed.	Replace, Modify
2	The bridge is near a state of collapse.	Modify, Emergency
1	Bridge closed because of channel failure.	
0	Bridge closed because of channel failure.	

Table 7. NBI and maintenance operations: culvert.

Code	Description	Operation
N	Not applicable. Use if structure is not a culvert.	
9	No deficiencies.	
8	No noticeable or noteworthy deficiencies.	
7	Insignificant damage not requiring corrective action.	
6	Deterioration or initial disintegration.	Repair
5	Moderate to major deterioration or disintegration.	Repair
4	Considerable settlement or misalignment.	Repair, Replace
3	Severe movement or differential settlement of the segments.	Replace
2	Corrective action required to maintain traffic.	Emergency
1	Bridge closed. Corrective action may put back in light service.	
0	Bridge closed. Replacement necessary.	

Summary of Maintenance Data and Uses

Maintenance data include information on resources which are used to compute costs and information on bridge conditions which are used to quantify improvements. Using these data, various evaluations can be made to present the cost and effectiveness of maintenance actions or the scope and accomplishments of maintenance programs. Performance standards are derived from maintenance data.

Maintenance Management Systems

MMSs use maintenance data, reports, and evaluations to support decisions in maintenance programs. Management functions build upon basic reports and evaluations. Aspects of maintenance management are reviewed here.

Maintenance Management Modules

AASHTO guidelines (*13*) identify six modules for MMS: Planning, Programming, Resources, Scheduling, Monitoring, and Administration. For MMS, each module combines diverse inputs on conditions of structures, maintenance actions, financial resources, physical resources, public input/perceptions, DOT policies, and DOT goals.

Planning. MMS planning proceeds from maintenance needs and feasible actions. MMS may automate the identification of some maintenance needs based on the comparisons of current conditions of structures with target values for conditions. Other needs may be based on a desired interval (for cleaning, etc.) without specific reliance on condition data.

Programming. MMS composes work programs based on maintenance needs, priorities among needs, and constraints imposed by available resources. Priorities may be based on condition data available from a BMS database. BMS optimization routines can be primary sources in formation of maintenance programs.

Resource Management. MMS evaluates needs in funding, labor, equipment, and materials as the aggregate of needs

MORIS 711-7431-01, BMS Activity: A743101, Clean/Flush Deck
Unit of measurement: Each Bridge
ACTIVITY REQUIREMENTS

LABOR		EQUIPMENT		MATERIAL	
Number	Classification	Number	Type	Amount	Description
1	Foreman	1	Sweeper		Water
2	Crew members	1	Water tank, compressor, hoses		
1	Equipment operator	1	Front end loader		
PRODUCTION UNITS / HR		PLANNING UNITS		PERFORMANCE STANDARD	
Bridges / HR		3 Bridges / Day		8 MH / Bridge	

Figure 2. Performance standard: Pennsylvania DOT (34).

for all actions in the current maintenance program. Needs in each category are also broken down by DOT region, so that appropriate distribution of resources can be achieved.

Scheduling. MMS schedules individual maintenance actions based on needs, on available crews and equipment, and (often) with consideration of impacts on network traffic operations.

Monitoring and Evaluation. MMS tracks work accomplishment, resources used, productivity, costs, and improvements to conditions.

Maintenance Support and Administration. MMS assists in coordination of maintenance events with regulatory agencies, public-interest programs, safety programs and resource management. MMS embodies, as a set of logical rules, knowledge of the restrictions imposed by statute or regulation, and of stakeholders in activities that are in line with or in support of the maintenance program. Maintenance data contribute to the operation of all six modules. Some of these contributions are indicated in Table 8.

Commercial Maintenance Management Systems

For reasons of financial accountability, DOTs employ some means for recording the dates, locations, maintenance activities, resource utilization, and accomplishment for work performed by DOT crews. These data are normally entered into highway maintenance management systems (HMMS).

There are several commercial HMMS available to DOTs. There is not much uniformity among commercial systems. The number of activities defined in these systems range from roughly 30 to 80 activities. DOTs with HMMS distinguish between activities for planning purposes and for recording work accomplishments. HMMS originally provided for recording short lists of maintenance activities, but evolved to record activities plus work methods, in effect multiplying the number of distinct maintenance actions that HMMS could track.

There are a number of vendors of commercial off-the-shelf software for management of plant maintenance. These systems are intended for maintenance of equipment, vehicles, and facilities, but can be applied to bridges. One drawback to use in bridge maintenance is the lack of location referencing capabilities. Plant maintenance systems are adapted to ID numbers. Bridge maintenance requires both bridge ID and bridge linear referencing data. However, toll authorities have found the software practical because of the need to maintain their toll facilities, and their bridge networks are much smaller and fundamentally different than state highway networks. Collectively, the major vendors have an installed base of tens of thousands of plant maintenance management systems in various commercial, government and quasi-government entities including toll authorities.

Summary on Bridge Maintenance Programs in the United States

U.S. DOTs have programs for maintenance of bridges that are similar in the physical activities performed, but different in the identification and reporting of actions. Each DOT rec-

Table 8. MMS and contributing maintenance data.

MMS Module	Maintenance Actions	Condition Data	Resource Data
Planning	Catalog of feasible actions for element and condition	Condition of element shows need for maintenance	
Programming	Selection of a feasible action	Condition report may indicate quantity of element needing maintenance	Resources requirements estimated from performance standard
Resource management			Performance standard indicates materials needs
Scheduling	Standard action may include a recommendation for scheduling		Performance standard indicates crew type, and equipment type
Monitoring and Evaluation		New condition data, after maintenance, indicates level of improvement	Actual usages of resources are reported
Support & Administration	Standard action may require permits	Network conditions	Reports of usage of resources contribute to budgeting process.

ognizes a boundary between actions that are maintenance and actions that are (re)construction, but different DOTs do not recognize quite the same boundary. Each DOT identifies the resource amounts and resource costs used in bridge maintenance, but various DOTs employ differing identifications and measurement bases for resources. Condition data for bridge components (NBI ratings) and bridge elements (CoRe condition states) are similar among U.S. DOTs. Some DOTs define additional bridge elements.

Current practices in bridge maintenance programs have implications for a national database system for bridge maintenance data. A national system must resolve the different numbering systems for maintenance actions used by DOTs. A national system must accommodate all kinds of work that DOTs identify as bridge maintenance. A national system must accept the different approaches to identification and measurement of resources used by DOTs. A national system must accommodate additional condition data reported by some DOTs.

CHAPTER 2

National Bridge Maintenance Database

The National Bridge Maintenance Database (NBMD) is a collection of self-contained sets of data on bridge inventory, conditions, and maintenance work. Each dataset is established for one state DOT and for a fixed reporting period, usually one year. Data are collected from records of the U.S. NBI, from Pontis bridge databases of state DOTs, from DOT maintenance management systems, from maintenance work reporting systems and from contract reporting systems. NBMD offers a uniform, consistent format and structure for data on bridge maintenance work, on the context of bridge maintenance work, and on the outcomes of bridge maintenance work.

The NBMD data system is a set of standard data tables, standard headings for data fields, standard keywords for indexing fields, and standard methods for the creation of unique identifiers for bridges, bridge elements, maintenance actions and maintenance resources. NBMD is instantiated as a set of plain text data files, and a set of XML documents each supported by an XML schema.

Three concepts are applied to NBMD design. First, bridge maintenance data are collected into self-contained datasets that bundle all related maintenance, condition, and inventory data. Second, data are presented in plain language keywords so that information is easily understood without recourse to coding guides or lookup tables. Data headings, too, are presented in plain language. Third, NBMD datasets are stackable. Unique IDs for bridges, elements, actions, and resources are established for each dataset and remain unique when datasets are merged. Merging allows for aggregations of large numbers of data records when data analysis and statistical evaluations require it.

A Database for Bridge Maintenance

NBMD is an archive of maintenance events. An event is the execution of one maintenance operation at one bridge at one time. Each record in the database is a single event, and each record contains complete information on the work performed. The data include the following:

1. Structure,
2. Operation,
3. Dates,
4. Resources, and
5. Outcomes.

The Structure. NBMD stores selected fields from NBI records and Pontis bridge databases. These include NBI and Pontis condition data together with data on structure type, route, milepost, custodian, structural size, age, construction materials, and administrative authority.

The Operation. Maintenance work is identified using NBMD standard keywords for components and operations.

The Dates. The date(s) of completion of the maintenance event are recorded.

The Resources. Resources include usage of labor, materials, and equipment for DOT work, or pay items and quantities for contract maintenance. Specific repair products and manufacturers can be stored. Resource data are used to compute total costs and unit costs for actions.

The Outcomes. Outcomes include maintenance production and changes to conditions. Production may be expressed in units for the maintenance action and as the quantity of bridge element that is improved. Conditions are new values of bridge condition ratings achieved as a result of this maintenance event.

Standard Data for Highway Bridge Maintenance

Standard Bridge Components

NBMD uses 14 standard bridge components (Table 9). Five components are named in the NBIS (Deck, Superstructure,

Table 9. Standard bridge components.

Component	Description
Approaches/ Embankments	Approach slab and pavement, slopes, slope protection (other than channel banks), embankments.
Bearings	Bearing devices, both fixed and expansion.
Bridge	All bridges on the state's list, also a catch-all component for maintenance work not reported under other components.
Channel	Watercourse, flow restrictors/deflectors, banks, and bank protection.
Culvert	All types and sizes of culverts maintained by structures maintenance program.
Deck	The structural deck, wearing surface, waterproofing membrane, if any.
Drains	Scuppers, grates, pipes, outlets, features for over-the-edge drainage.
Joints	All joints in the deck, all maintainable (sealable) joints in superstructure and substructure components.
Mechanical /Electrical	Electrical or mechanical systems on bridges, includes all mechanical and electrical equipment for movable spans, all gates, lights and delineators for traffic.
Movable span	The operable parts and systems of a movable bridge. Includes deck and superstructure of movable span.
nonBridge	Other structural assets.
Rails/Walks	All deck accessories for directing/restricting vehicles and pedestrians. All sidewalks and medians.
Substructure	Piers, abutments, and their foundations. Wing walls.
Superstructure	Stringers, floorbeams, girders, truss members, arch members, etc.

Substructure, Channel, Culvert). Seven more components are used by many DOTs as objects of maintenance actions (Joints, Drains, Railings, Bearings, Approaches, Movable Bridge, Electrical & Mechanical Systems). A twelfth component, Bridge, is used when actions are applied to an entire structure, or a specific component is not reported. The thirteenth component, nonBridge, is used for other assets.

Standard Maintenance Operations

NBMD uses eight standard maintenance operations: Clean, Reset, Coat, Repair, Replace, Modify, Emergency, and nonMaintenance (Table 10). Note that a Replace operation refers to the replacement of a part or portion of the bridge. Complete replacement of a bridge is not maintenance. In a

Table 10. Standard maintenance operations.

Operation	Description
Clean/clear	Sweeping, washing, debris removal, graffiti removal, clearing scuppers, clean-out drain lines.
Reset	Renew consumable elements such as lights, removable joint seals; Tighten bolts or rods, Lubricate bearings or other moving parts; Minor re-alignment of railings, repositioning of bearings.
Coat	All surface applications of paint, waterproofing, galvanic coatings, chemical preservatives, crack sealing materials.
Repair	Restoring damaged or deteriorated elements. Patching, welding, reinforcing, etc.
Replace	In-kind replacement of damaged or deteriorated elements.
Modify	Repair or replacement actions that yield changes to elements. These may be improvements to function as when drains are extended, changes in function as when relief joints are installed in rigid pavements, changes to vulnerability as by seismic retrofit, changes to strength by post-tensioning, jacketing, installation of scab plates, changes to clearances as by re-positioning of bracing in truss portals, or installation of a system for corrosion protection when none was present before.
Emergency	All repairs, replacements, and modifications completed as an immediate response to a sudden condition or event.
nonMaintenance	Operations, inspections.

similar way, Modify operations include minor modifications, and exclude larger projects such as bridge rehabilitation.

Maintenance activities are generic methods for maintenance operations. Activities are modifiers to operations, providing more specific reports of maintenance work. Each operation has its own set of activities. Actions are reported in a hierarchy of fields such as the following:

Component → Operation → Activity → Mode

NBMD employs standard keywords for components and operations and allows descriptive keywords for activities and modes. Actions must be reported by component, should be reported by operation, may be reported by activity, and might be reported by mode. This hierarchy admits both general (component only) and detailed (all four descriptors) reporting of maintenance actions.

Notes on Maintenance Operations

Reset versus Repair/Replace. The replacement of consumable parts is a Reset operation. Parts such as light bulbs, fan belts, gaskets, and rubber joint elements are replaced as needed or on a set schedule. Repairs are made in response to deterioration or damage and entail parts that are not consumable. The designation of these activities as Repair or Replace correctly identifies the significance of the operation within the maintenance program, and correlates with costs since consumable elements are designed for replacement and other parts might not be.

Modify versus Repair/Replace. Modify operations are repairs or replacements that change (usually improve) bridges. Improvements may include: greater clearances, greater resistance to fatigue, greater safety for traffic, greater resistance to high water flow, etc. Modify operations may be in response to obsolete features, as when railings are upgraded, or in response to damage or deterioration.

Maintenance Activities

Activities are descriptive keywords for NBMD bridge maintenance operations. Examples of Activities for maintenance operations are presented in the following sections.

Activities for Clean/Clear Operations. The Clean/Clear operation includes washing of structures, and removal of detritus, drift, and vegetation. Activities for Clean/Clear operations are described in Table 11.

Activities for Reset Operations. The Reset operation provides expected maintenance for consumable parts or parts needing periodic lubrication or adjustment. Activities for reset operations are described in Table 12.

Activities for Coat/Paint Operations. The Coat/Paint operation includes all application, maintenance and renewal of surface-applied sealers, paints and chemical treatments. Activities for Coat/Paint operations are described in Table 13.

Activities for Repair Operations. The Repair operation restores original condition or functionality of bridge components after deterioration or damage. Repair does not include substantial replacement of components and does not include improvements to components beyond their original capacity or function. Activities for repair operations are described in Table 14.

Table 11. Activities for clean/clear operations.

Activity	Description
Wash	The use of water at moderate pressure to clean bridge components.
Zone Wash	Washing of selected portions of components, usually those portions exposed to salt water, salt spray, or standing water. These can include parapets facing traffic, gutters in decks, and areas below open joints. Any selective washing of portions of structures.
Sweep	Dry removal of sand, grit, or other minor detritus on bridge components.
Flush	The use of water at higher flow rate and/or pressure to clear more substantial size or amounts of detritus on bridge components.
Unclog and Cleanouts	Maintenance of scuppers, troughs, pipes, and other drainage elements. Methods entail opening grates and cleanouts, removal of waste material, flushing as needed and reassembly of parts.
Graffiti	Removal or covering (masking) of unauthorized markings on bridges.
Vegetation	Trimming and/or removal of brush, trees, etc., on slopes, approach embankments, channel banks and within channels.
Debris & Drift	Removal of (loose) material on substructures, at foundations, on channel banks and within channels. This activity does not include channel dredging.

Table 12. Activities for reset operations.

Activity	Description
Consumables	Replacing light bulbs, rubber joint elements, pavement reflectors, etc.
Tighten	Checking and tightening of bolts, anchors, rods and other threaded parts. *Tighten* also includes replacement of missing fasteners in otherwise complete connections.
Caulk	Removal and replacement of caulk in railings, fixed joints and construction joints.
Lubricate	Inspection and lubrication of bearings, expansion joints, railing joints and other moving or sliding parts.
Reposition	Inspection and re-centering or re-alignment of bearings, joints, and other parts needing periodic adjustment.
Gates and Signals	Inspection and servicing of traffic control systems, especially for movable bridges.
Mechanical Equipment	Inspection and servicing of mechanical parts of motion equipment for movable spans. Mechanical Equipment includes consumables (filters, belts, etc), lubrication, and adjustment of machinery.
Electrical Equipment	Inspection and servicing of electrical parts of motion equipment for movable spans. Electrical Equipment includes consumables (fuses, switches), and adjustment of equipment.

Table 13. Activities for coat/paint operations.

Activity	Description
Paint	Application of paint on bridge components, usually to an entire component.
Spot Paint	Application of paint on selected areas of components that may include: areas of deteriorated paint, areas of special exposure (splash zones), damaged areas (as by collision), etc.
Seal Surface	Application of water-repelling or other surface treatments, usually to concrete or asphalt surfaces.
Seal Cracks	Use of epoxy, high-weight methyl-methacrylate or other pourable materials to fill existing cracks. Usually applied to concrete surfaces, but can be crack sealing in asphalt surfaces and crack sealing in timber elements.
Chemical Treatments	Surface application of preservatives for timber components. Surface application of herbicides or pesticides on slopes as part of bridge maintenance.
Surface Preparation	Preparation of surfaces for coating or painting if separate tracking of preparation cost is desired. Otherwise, surface preparation is part of a coating or painting action.

Table 14. Activities for repair operations.

Activity	Description
Patch	Repairs to concrete components, concrete surfaces, or asphalt surfaces by filling with cementitious or bituminous material
Re-attach/ Re-anchor	Work to restore lost or weakened anchors for railings, joints, bearings, or other components.
Straighten	For metal components, the use of bending or heat to restore proper shape.
Jack/Align	For pavements or substructures, the use of jacking and filling to mitigate tilting or settlement.
Reinforce/Strengthen	Application of welds, scab plates, concrete jackets, cables, post-tensioning, etc., to restore strength to weakened structural components.
Dredge/Grade	Earth moving activities to repair shifted or scoured slopes and banks, or to re-establish channel depth and profile.

Table 15. Activities for replace operations.

Activity	Description
Individual	Replacement of an individual unit of a component made up of a collection of units, such as replacement of individual bearings, individual joints, individual beams, individual piers.
Section	Replacement of a portion of a continuous component, such as a bridge deck, that is not a collection of similar units.
Complete	Replacement of an entire component. Complete replacement of a collection of elements. Complete replacement of a continuous component.
Span	Complete replacement of a component within one span of a multispan bridge.

Activities for Replace Operations. The Replace operation provides in-kind replacement of bridge components in whole or in part. Activities for Replace operations are described in Table 15.

Activities for Modify Operations. The Modify operation provides improvements to components. Improvements may mitigate observed problems in performance of components, may reduce vulnerability of components, or may deliver compliance with higher or newer standards, especially where standards can be met within a maintenance project rather than a rehabilitation project. Activities for Modify operations are described in Table 16.

Activities for Emergency Operations. Emergency activities are performed in response to extreme events and/or sudden damage to structures. Activities for Emergency operations are described in Table 17.

Operations, Activities, and Bridge Components

Activities, more so than operations, may target specific components or construction materials. Frequent combinations of activities with bridge components are discussed in this section.

Clean/Clear Operations. Among the activities for Clean/Clear operations: *Wash* applies to structural elements, but not

Table 16. Activities for modify operations.

Activity	Description
Geometry	Modifications to clearances including internal clearances of thru-trusses and thru-arches.
Protection	Addition of protection system that is new to the component, including corrosion protection, fenders, channel modifications.
Vulnerability	Modifications that reduce vulnerability to fatigue, seismic loads, sudden fracture, etc.
Strength/Capacity	Modifications that increase load rating of bridges, flood/flow capacity of channels, flow capacity of drains, motion capacity of expansion joints or bearings, etc.
Function	Modifications that alter load paths or expansion regimes. These may be: helper bents, conversion to integral abutments, relief joints in approach pavements, etc.
Assembly	Modifications that provide a newer device, such as a joint, bearing, or railing in place of an older, obsolete device.

Table 17. Activities for emergency operations.

Activity	Description
Post	Investigations and repairs leading to load restrictions on structures.
Shore	Installation of temporary supports for decks or superstructures. Construction of "diapers" to catch loose materials.
Closure, Partial	Activities to exclude traffic from some portion of a structure, such as closures at weakened or blocked traffic lanes.
Closure, Full	Complete closure of a structure.
Detour	Activities needed to establish alternate routes around restricted or closed structures.
Temporary Bridge	Deployment and maintenance of temporary bridges.

Table 18. Clean/clear—frequent uses of activities.

Clean/Clear	Bridge Components
Wash	All except earth slopes and banks.
Zone wash	All except earth slopes and banks.
Sweep	Decks, Joints, Approach pavement, Substructures.
Flush	All except earth slopes and banks.
Unclog /cleanouts	Drains.
Graffiti	Superstructure, Substructure, Parapets/Sidewalks, Culverts.
Vegetation /trees	Earth slopes and banks.
Debris /Drift	Substructures, Channels, Culverts.

earth slopes and banks; *Sweep* applies to horizontal surfaces, but not vertical ones; *Unclog* applies to drains but not to open surfaces; *Vegetation* control applies to earth slopes and banks, but not to structural components. A list of likely applications of Clean/Clear activities to bridge components is shown in Table 18.

Reset Operations. Among the activities for Reset operations: *Consumables* maintenance applies to light bulbs, rubber parts of joints, but not other bridge components; *Tighten* applies to threaded parts; *Caulk* applies to fixed, closed joints in components, but not other joints; *Lubricate* applies to moving joints, bearings and rails, but not other parts; *Gates/Signals* applies to traffic control on movable bridges, but not other traffic control; *Equipment* maintenance applies to motion equipment for movable bridges, but not other equipment. A list of likely applications of reset activities with bridge components is shown in Table 19.

Coat/Paint Operations. Among the activities for Coat/Paint operations: *Paint* applies to structural components, but not earth slopes and banks; *Sealing* applies to concrete and bituminous surfaces usually; *Chemical Treatments* apply to timber elements, and to control of vegetation. A list of likely applications of *coat/paint* actions with bridge components is shown in Table 20.

Repair Operations. Among the activities for Repair operations: *Patch* applies to concrete structural components and bituminous wearing surfaces; *Re-attach* applies to anchors for

Table 19. Reset—frequent uses of activities.

Reset	Bridge Components
Consumables	Bridge (lights), Joint seals.
Tighten	All components having bolts or rods.
Caulk	All except Embankment, Channel.
Lubricate	Bearings, Railings (at joints).
Reposition	Bearings, Railings, Channel (protection), Movable Span.
Gates and signals	Movable span.
Mechanical equipment	Movable span.
Electrical equipment	Movable span.

Table 20. Coat/paint—frequent uses of activities.

Coat/Paint	Bridge Components
Paint	All except Embankments, Channels.
Spot paint	All except Embankments, Channels.
Seal surface	Concrete or Bituminous elements of Deck, Wearing surface, Parapets/Railings/Sidewalks, Superstructure, Substructure, Embankment (protection), Culvert, Movable Span.
Seal cracks	Concrete or Bituminous elements of Deck, Wearing surface, Parapets/Railings/Sidewalks, Superstructure, Substructure, Embankment (protection), Culvert, Movable Span.
Chemical treatment	Preservatives for Timber Deck, Railings, Superstructure, Substructure, Culverts and Movable Spans. Herbicides/Pesticides for earth slopes and banks.
Surface prep	All structural components.

Table 21. Repair—frequent uses of activities.

Repair	Bridge Components
Patch	All concrete or bituminous Deck/Wearing course, Parapets/Railings/Sidewalks, Superstructure, Substructure Approach/Embankment (protection), Channel (protection), Culvert, Movable Span.
Re-attach/ re-anchor	Deck (grate), Joints (armor), Joint (seal), Drains, Parapets/Railings/Sidewalks, Superstructure, Bearings, Substructure, Channel (protection), Culvert (metal), Movable Span.
Straighten	Parapets/Railings (metal), Superstructure (metal members), Substructure (metal elements), Culvert (metal), Movable Span.
Jack/Align	Approach slabs (mudjack), Substructures, Culverts.
Reinforce/ Strengthen	Deck (structural), Parapets/Railings/Sidewalks, Superstructure, Substructure, Culvert, Movable Span.
Dredge/ Grade	Approach/Embankment, Channel.

joint, bearings, railings, etc.; *Straighten* applies to metal elements; *Jack* applies to components that have tilted or settled; *strengthen* applies to structural components; *Dredge/Grade* applies to earth slopes, banks, and channels. A list of likely applications of Repair activities with bridge components is shown in Table 21.

Replace Operations. Among the activities for Replace operations: *Individual* applies to items such as joints, bearings, railing sections and beams where the component is a collection of similar elements; *Section* applies to decks, wearing surfaces, and other components that are continuous; *Complete* is full in-kind replacement of a component; *span* is complete replacement of a component in one span of a multi-span bridge. A list of likely applications of Replace activities with bridge components is shown in Table 22.

Table 22. Replace—frequent uses of activities.

Replace	Bridge Components
Individual	Unit, all components.
Section	All components
Complete	All components
Span	All components

Modify Operations. Among the activities for Modify operations: *Geometry* applies to improvements to clearances; *protection* applies to new protection of structural components against corrosion, or channels against scour; *Vulnerability* applies to the potential for sudden failure of structural components; *strength* applies to increases in load rating for structural components, and increases in motion or flow capacity for joints, drains, bearings and channels; *Function* applies to changes in load path or movement regime; *Assembly* applies to upgrades of joints, bearings, railings and other devices. A list of the frequent uses of Modify activities with bridge components is shown in Table 23.

Emergency Operations. Among the activities for Emergency operations, *Post* applies to structural components; *Shore* applies to any component needing additional support; *Closure* applies to bridges and culverts; *Detour* applies to bridges

Table 23. Modify—frequent uses of activities.

Modify	Bridge Components
Geometry	Bridge, Superstructure, Parapets/Railings/Sidewalks, Culvert, Movable Span.
Protection	Bridge, Deck, Parapets/Railings/Sidewalks, Superstructure, Substructure, Approach/Embankment, Culvert, Channel, Movable Span.
Vulnerability	Bridge, Parapets/Railings/Sidewalks, Superstructure, Substructure, Culvert, Channel, Movable Span.
Strength/ capacity	Bridge, Deck, Parapets/Railings/Sidewalks, Superstructure, Substructure, Culvert, Movable Span.
Function	Bridge, Deck, Joints, Drains, Parapets/Railings/Sidewalks, Superstructure, Bearings, Substructure, Movable Span.
Assembly	Bridge, Parapets/Railings/Sidewalks, Movable Span.

Table 24. Emergency—frequent uses of activities.

Emergency	Bridge Components
Post	Bridge, Deck, Superstructure, Substructure, Culvert, Movable Span.
Shore	Bridge, Deck, Joints, Drains, Parapets/Railings/Sidewalks, Superstructure, Bearings, Substructure, Approach/Embankment, Channel (bank), Culvert, Movable Span.
Closure, partial	Bridge, Culvert, Movable Span.
Closure, full	Bridge, Culvert, Movable Span.
Detour	Bridge, Culvert, Movable Span.
Temporary bridge	Bridge, Culvert, Movable Span.

and culverts; *Temporary* applies to bridges and culverts. A list of likely applications of Emergency activities with bridge components is shown in Table 24.

NBMD Database

NBMD is a modular self-contained historical record of maintenance work at bridges. NBMD is a ledger of bridges, bridge conditions, work performed, resources expended, and costs. NBMD is a collection of datasets of identical structure (Figure 3). All information on maintenance actions, their costs, the bridges affected, and the outcomes are contained in a dataset. Each dataset contains information from a single DOT and a fixed reporting period.

Each NBMD database is a collection of 13 tables (Figure 4). Of these, two tables contain maintenance work data (Production and Resources), two tables contain inventory data (Structure and Roadway), three tables contain bridge inspection information (Inspection_Cross_Reference, Element_Inspection, and Inspection_Event), three tables define the correspondences between NBMD data entries and DOT data entries (Activity_Definition, Element_Definition, and Resource_Definition), one table identifies data sources (Contact), one table lists element-level unit costs of maintenance (Element_Unit_Cost) and one table provides file size information used by NBMD software applications (Size). The tables are linked through global identifiers for bridges, maintenance events, and definitions for actions, bridge elements, and resources.

Maintenance production is recorded as Events. An event is defined as a set of work activities conducted at the same time on a single structure. Each event provides a specific maintenance

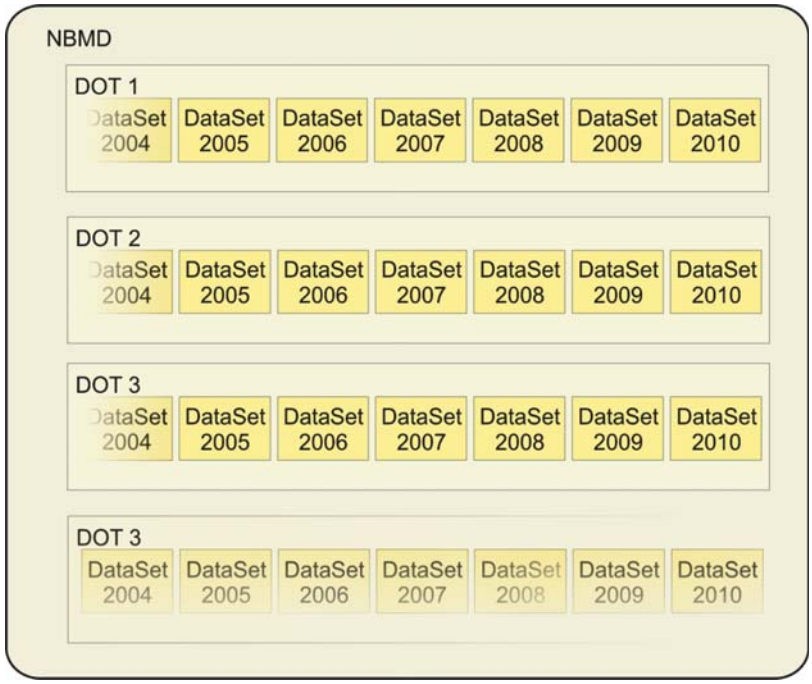


Figure 3. National bridge maintenance database.

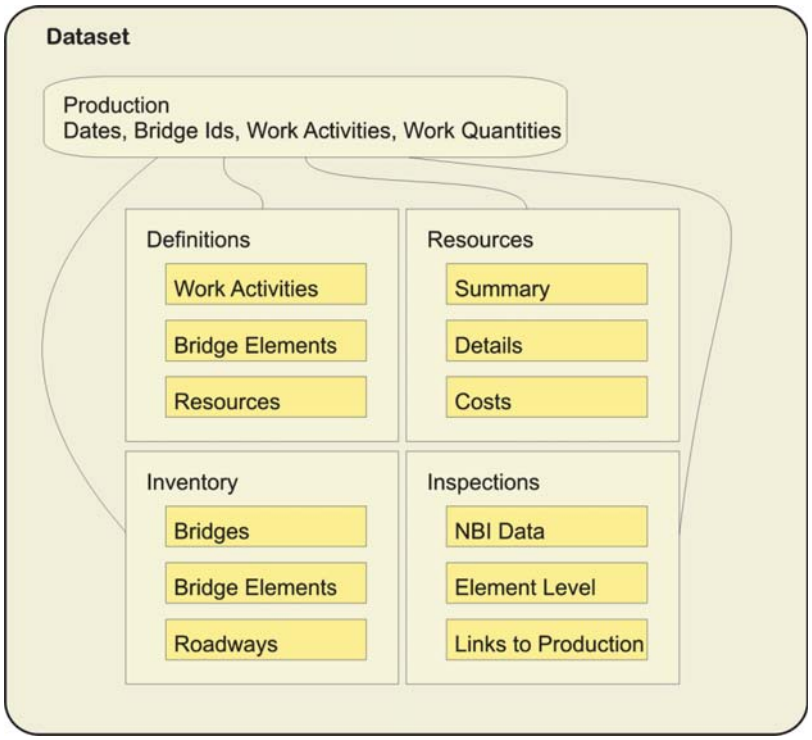


Figure 4. NBMD dataset organization.

Operation and one bridge Component. Each event is associated with bridge inspections before and after the event. Inventory data are recorded for the structure and the roadway. A Resource is a quantity of labor, material, equipment, or contract pay item applied in the accomplishment of an action.

NBMD Data Sources

NBMD contains data adequate for computation of total costs and unit costs, generation of reports of maintenance accomplishments, creation of performance standards, and evaluations of maintenance actions. NBMD preserves the history of maintenance events so that long-term performance of actions can be examined, life-cycle costs can be computed, and the evolution of maintenance programs can be tracked. Data include the following:

- Crew card data in all headings: Work Administration, Work Performed, Location, Labor usage, Equipment Usage, Material Usage, Work Production.
- Quantities of affected bridge component or element.
- Bridge conditions before and after the maintenance event.
- Total cost and unit costs of maintenance.

While data from crew cards and contract tabulations are routinely available, other data may not be. The field collection of element-level maintenance quantities is not usual. The immediate or at least near-term re-evaluation of element conditions after maintenance is not usual. In response, NBMD identifies and stores bridge condition data from inspections that occur before and after maintenance events.

NBMD collects data from existing sources at DOTs including NBI files, Pontis bridge databases, maintenance managements systems, and reporting systems for labor, materials, and equipment. NBMD identifies appropriate data fields in DOT sources. NBMD moves unmodified DOT data to appropriate storage areas in NBMD data tables and augments DOT data with NBMD keywords. The NBMD keywords provide the uniform reporting and retrieval features that make any DOT's data useful to all DOTs. The paths of DOT data into NBMD datasets, and the potential for sharing of NBMD datasets through internet sites is shown in Figure 5.

Data Integrity

NBMD is a long-term repository of bridge maintenance data. For this reason, datasets are self-contained. Datasets are complete with all bridge inventory and condition data and all maintenance action, accomplishment, resource and cost data. Changes over time to bridges (as by modification or replacement), inventory and condition data (by new coding formats), or maintenance data (by introduction of new methods or materials) will not affect the historical record and will not limit the future ability to retrieve and understand the historical record.

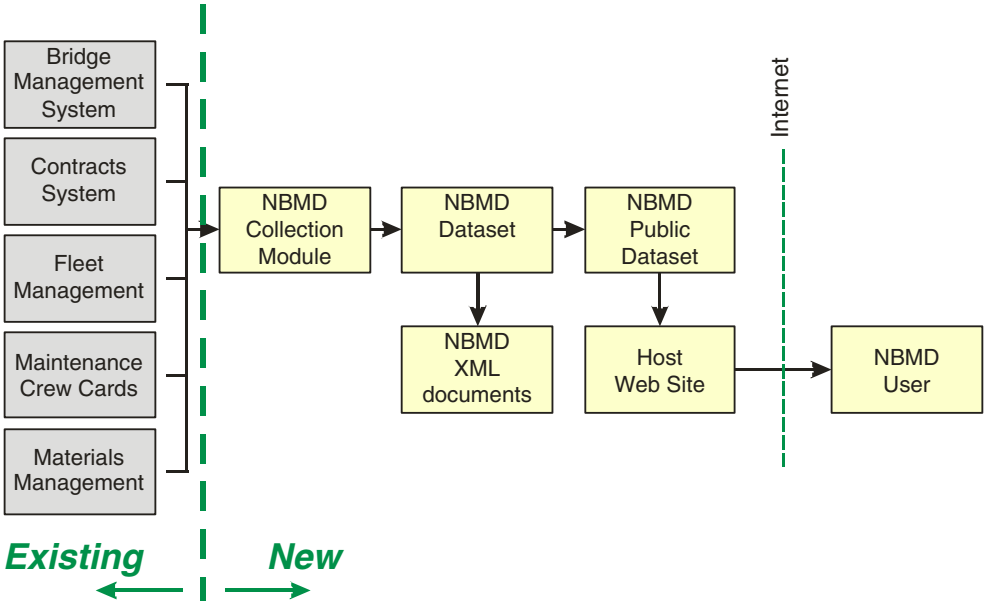


Figure 5. Path for maintenance data.

NBMD Tables

There are 13 data tables in NBMD datasets. These are listed in Table 25.

NBMD datasets are temporal. Each dataset contains complete data for bridges and maintenance work for a defined reporting period. Reporting periods can be a calendar year, a fiscal year, an inspection biennium, or other convenient reporting period. NBMD anticipates that one bridge will have one maintenance event of a given work-type within one reporting period. One bridge may have more than one event, entailing different work-types, within one reporting period.

Table 25. NBMD data tables.

NBMD Table	Description
Activity_Definition_Table	Mapping of DOT actions to NBMD descriptors.
Contact_Table	Contact information for agency providing bridge maintenance, condition and inventory data.
Element_Definition_Table	Mapping of DOT bridge elements to NBMD descriptors.
Element_Inspection_Table	Element-level condition data adapted from Pontis' eleminsp table.
Element_Unit_Cost_Table	Unit costs of maintenance actions generated by NBMD viewer utility.
Inspection_Cross_Reference_Table	List of NBI and element-level inspections before and after maintenance events.
Inspection_Event_Table	NBI condition and appraisal ratings collected from Pontis' inspevnt table or from NBI files.
NBMD_Size	Line counts for NBMD data tables. Generated by NBMD_Size utility.
Production_Table	Maintenance work activities, production (accomplishment), and costs.
Resource_Definition_Table	Mapping of DOT equipment, labor, and material IDs to NBMD descriptors.
Resource_Table	Equipment, labor and material types, quantities, and costs for maintenance events.
Roadway_Table	Route inventory data, mostly NBI fields, collected from Pontis' roadway table or from NBI files.
Structure_Table	Bridge inventory data, mostly NBI fields, collected from Pontis' bridge table or from NBI files.

Table 26. Global identifiers for NBMD.

Data Field	Description
Dataset	**DOT{Year** Global identifier attached to all records in a set of bridge work, condition, and inventory data.
NBMD_Bridge_ID	**Dataset{Structure_Number** Global identifier for each structure. The structure_number is the NBI data, usually, but can be the Pontis bridge key (brkey). The NBMD ID is unique for the structure, the DOT, and the reporting period.
NBMD_Event_ID	**NBMD_Bridge_ID{COAM** Global identifier for a maintenance event. *COAM* is a concatenation of abbreviations for bridge component, operation, activity and mode.
NBMD_Elemkey	**Dataset{Elem{DOT_Elemkey** Global identifier for bridge elements. The static string "Elem" marks this as an element ID.
NBMD_Inspection_ID	**NBMD_Bridge_ID{Insp{Inspection_Date** Global identifier for a bridge inspection. The static string "Insp" marks this as an inspection ID.
Resource_ID	**Dataset{Res{Cat{DOT_Resource_ID** Global identifier for resources used in maintenance events. *Cat* strings are abbreviations for resource categories. The static string "Res" marks this as a resource ID.

NBMD Identifiers

NBMD generates global identifiers for maintenance events, bridges, bridge elements, and maintenance resources (Table 26). Global identifiers link events, bridges, etc., across tables in a dataset, and allow datasets to be merged without loss of identity of events, bridges, etc. Identifiers are built up as combinations of existing IDs that are unique within DOTs' bridge populations and NBMD dataset labels that tie records to particular DOTs and reporting periods.

NBMD Naming Conventions

NBMD employs conventions for simple, predictable formation of NBMD identifiers (Table 27). The Dataset identifier is formed with abbreviations for bridge owners plus reporting years. Bridge IDs are formed with Dataset identifiers plus DOTs' own structure ID. DOT structure IDs can be the NBI structure numbers or Pontis brkeys. Either is unique within one DOT. Combined with the dataset ID, the resulting NBMD bridge ID is unique among all bridge owners and all reporting periods.

By similar steps, identifiers are formed for bridge elements and maintenance resources. Identifiers for maintenance events combine the NBMD bridge ID and abbreviations for maintenance components and operations. Since NBMD bridge IDs include dataset identifiers, the resulting event IDs indicate bridge owners, reporting periods, bridges, and maintenance actions.

The parts of each identifier are separated by left brackets. This allows parsing of identifiers in software applications.

Note that DOTs are identified as state postal codes followed by the string "DOT." For many states, the NBMD identifier differs from the state's own abbreviation for their transportation department.

COAM String

Abbreviations for maintenance Component and Operation are part of maintenance event IDs. The abbreviations are shown in Table 28.

Resource IDs for equipment and materials are formed from the dataset identifier, a static string "Res" and DOTs' identifying number. Labor resources are identified as dataset, Res, and abbreviations of labor job titles. Abbreviations for Tennessee DOT job titles are shown in Table 29.

NBMD Keywords

NBMD employs plain-language keywords to identify maintenance actions, maintenance resources and bridge elements. This makes NBMD tables readable and allows for the introduction of additional keywords as needed without revision of older data records. Additional keywords will likely be needed in the future for new bridge components, new construction materials, new maintenance materials, and new maintenance actions.

NBMD keywords are either *standard* keywords or *descriptive* keywords. Standard keywords are proposed in this project, and are intended to provide simple, definite description of bridge elements, maintenance actions, and maintenance

Table 27. NBMD dataset identifier—examples.

NBMD Identifier	Formation	Example	Note
Dataset	DOT{Year	CaDOT{2006	California data for fiscal year 2006
Action_ID	Dataset{Act{DOT_ID	CaDOT{2006{Act{H30060	California deck overlay action, 2006 report
Bridge_ID	Dataset{Bridge_ID	MiDOT{2005{82182072000R010	Michigan bridge ID, 2005 reporting period
Element_ID	Dataset{Elem{DOT_ID	PaDOT{2008{Elem{48	Pennsylvania concrete slab element in 2008 report
Event_ID	Bridge_ID{COAM string	TnDOT{2007{16I002400141{Drn{Rpr	Repairs to drains in 2007 for Tennessee structure
Inspection_ID	Bridge_ID{Insp{Date	OrDOT{2006{S8837A064 01072{Insp{2005/03/07	Oregon inspection in 2005 related to maintenance work in 2006.
Resource_ID	Dataset{Res{DOT_ID	TnDOT{2007{Res{EQA127	Tennessee equipment resource in 2007 report
		TnDOT{2007{Res{HMW3	Tennessee Highway Maintenance Worker in 2007 report

resources. Standard keywords may evolve over time, but may be regulated by an NBMD users' group.

Descriptive keywords provide additional information on bridge elements, maintenance actions, or maintenance resources. These, too, work best when all users (all DOTs) employ a common set of keywords. But descriptive keywords are not regulated. Descriptive keywords can be specific to individual DOTs. Descriptive keywords provide positive identification of specific elements, actions, or materials at a DOT.

Table 28. NBMD abbreviations for COAM strings.

Components	Abbr.	Operations	Abbr.
Approach/Embankment	ApEm	Clean	Cln
Bearing	Brg	Coat	Cot
Bridge	Brd	Reset	Rst
Channel	Chn	Repair	Rpr
Culvert	Cul	Replace	Rpl
Deck	Dk	Modify	Mod
Drain	Drn	Emergency	Emg
Joint	Jt	nonMaintenance	nMnt
Mech/Elec	MeEl		
MovableSpan	Mov		
nonBridge	nBrd		
Rail/Walk	RWk		
Substructure	Sub		
Superstructure	Sup		

Standard keywords and descriptive keywords are used in separate data fields in NBMD.

Maintenance Actions

Bridge maintenance actions are described by four keyword fields. The first two, Component and Operation, are NBMD standard keywords. The second two, Activity and Mode, are descriptive (Table 30).

Table 31 lists the standard keywords for Component and Operation. Among the Component keywords, *Mech/Elec* is for mechanical and electrical systems of movable bridges, and

Table 29. Abbreviations for job titles—Tennessee DOT.

Job Title	Abbreviation
County Supervisor	CySpv
Assist County Supervisor	AsCySpv
Floating Crew Supervisor 2	FlCwSpv2
Floating Crew Supervisor 1	FlCwSpv1
Highway Maintenance Worker 3	HMW3
Highway Maintenance Worker 2	HMW2
Highway Maintenance Worker 1	HMW1
Carpenter 2	Cpt2
Carpenter 1	Cpt1
Other	Oth

Table 30. NBMD descriptors for maintenance actions.

	Keyword Field	Type	Description
Maintenance Actions	Component	Standard	Name of the structural component.
	Operation		The category of maintenance work.
	Activity	Descriptive	Type of work within the category.
	Mode		Further description of the work; may identify a material type.

nonBridge identifies assets other than bridges and culverts, such as tunnels, retaining walls, sign bridges, and other structural assets that are reported in a DOT's maintenance data system. Among Operation keywords, *nonMaintenance* indicates inspection, operation (of movable spans), complaint investigation, and other activities that may be performed by DOT crews and appear in maintenance data systems.

Standard keywords are exclusive. No component keyword appears in the operation list, and no operation keyword appears in the component list. Keywords used in activity and mode should also be exclusive; keywords in each field should be used only in that field.

NBMD maintenance actions are identified at least by a component keyword, and may be identified by a component plus any among the operation, activity, and mode keywords.

Bridge Elements

Bridge elements are described with five NBMD keyword fields: Component, Material, Form, Part, and Protection. Component and Material are standard keywords. Part, Form, and Protection are descriptive. Table 32 lists the standard keywords for Component and Material, and the keywords for Part, Form, and Protection that appear in the current NBMD datasets. The Component keywords for bridge elements are identical to the Component keywords for maintenance actions.

Table 31. NBMD standard keywords for maintenance actions.

Component Keywords	Operation Keywords
Approach/Embankment	Clean
Bearing	Coat
Bridge	Emergency
Channel	Modify
Culvert	Repair
Deck	Replace
Drain	Reset
Joint	nonMaintenance
Mech/Elec	
Movable Span	
nonBridge	
Rail/Walk	
Substructure	
Superstructure	

NBMD Resources

Resources used in maintenance are described by a standard keyword for resource Category. Standard categories are: Equipment, Labor, Material, and Other. Three descriptive keywords may be used. These are resource Group, Keyword_A, and Keyword_B. These keywords describe the type and capacity of equipment, the grade and title or labor, and the kind and grade of materials. Two more resources keywords, *Manufacturer* and *Product,* are used only for materials and identify specific products used in maintenance actions.

NBMD Tables and Data Fields

NBMD tables and data fields are presented in this section. Tables are presented in alphabetical order.

Activity_Definition_Table

The NBMD Activity_Definition_Table (Table 33) relates the codes and titles for DOT maintenance actions to the NBMD keywords for Component, Operation, Activity, and Mode. DOTs' units of measurement for actions are reported. The NBMD dataset ID is present, linking each maintenance action to a specific DOT and reporting period.

Activity definition tables are formed for each dataset by collecting all unique DOT actions and assigning appropriate NBMD keywords to them. Within a single DOT, the IDs for maintenance actions may persist over many years, and so activity definition tables for different reporting years may have many identical entries. Examples of activity definition tables are provided in Appendix B.

Contact_Table

The NBMD Contact_Table (Table 34) identifies datasets, their DOT sources, and staff contacts at DOTs. Each NBMD dataset has one or more contacts. These are one or more personnel at a single DOT or other bridge owners' agency.

Table 32. NBMD element standard keywords.

Component	Material	Part	Form	Protection
Approach/Embankment	Asphalt	Abandoned	Bottom Chord	AC Overlay
Bearing	Concrete	Abutment	Box	AC Overlay - Protected
Bridge	Elastomeric	Arch	Concrete-filled	Cathodic
Channel	Metal	Assembly	Deck Crack	Coated
Culvert	PS	Beam	Disk	Coated Bars
Deck	Concrete	Cable	Drilled	Painted
Joint	Steel	Cap	Fatigue	Rigid Overlay
nonBridge	Timber	Column	Impact	Thin Overlay
Rail/Walk		Compression	Modular	Bituminous overlay
Substructure		Corrugated	Open	Bituminous overlay, coated bars
Superstructure		Deck Truss	Pack Rust	Concrete encased
		Electrical/Mechanical Sys	Pot	Galvanized
		Enclosed	Scour	Bituminous overlay, Membrane, coated bars
		Expansion	Section loss	Rigid overlay, coated bars
		Fender	Settlement	
		Finger	Shell	
		Fixed	Soffit	
		Flag	Strip seal	
		Flume	Wall	
		Footing	Portal	
		Footing seal	Roadway	
		Frame	Wearing Surface	
		Grid	Damage	
		Movable	Incident	
		Paint	Compression	
		Ped/Bike		
		Pier		
		Pile		
		Pile Cap		
		Pin/Hanger		
		Plate		
		Plug		
		Pourable		
		Private		
		Railing		
		Railing with Sidewalk		
		Railroad		
		Seal		
		Sign		
		Slab		
		Slope Protection		
		Stringer		
		Thru Truss		
		Tunnel		
		Cap/Footing		
		Headwall		
		Sidewalk		
		Trough		

Table 33. NBMD Activity_Definition_Table.

Data Field	Description
Dataset	Global identifier
Action_ID	*Dataset*{Act{*DOT_Action_ID* NBMD identifier for this DOT action and dataset. The static string 'Act' marks this as an action ID.
DOT_Action_ID	DOT's code for maintenance activity
DOT_Action_Description	DOT's title for work activity
DOT_Unit	DOT's reporting unit for this work activity
NBMD_Component	NBMD standard keyword for bridge component
NBMD_Operation	NBMD standard keyword for maintenance operation
NBMD_Activity	Descriptive keyword for maintenance action
NBMD_Mode	Descriptive keyword for maintenance action
NBMD_Unit	NBMD unit of measure, if different from DOT unit
NBMD_CoamString	Standard abbreviations for bridge component and maintenance operation

Element_Definition_Table

NBMD Element_Definition_Tables relate DOT IDs and titles for bridge elements to NBMD keywords for bridge elements. Element_Definition_Tables list the units of measurement for elements. Element_Definition_Tables (Table 35) are developed partly from Pontis elemdefs tables, and partly from element coding guides published by DOTs. Pontis elemdefs tables are collected as Pontis Data Interchange (PDI) files. PDI files are converted to tab-text files with column headings using an application developed in this project (see Appendix E).

Similar to DOT maintenance activities and their definitions, the set of bridge elements at a DOT continues with few changes from year to year. NBMD datasets from a single DOT will have similar Element_Definition_Tables with many identical records.

Element_Inspection_Table

NBMD's Element_Inspection_Tables are adaptations of Pontis eleminsp tables. Element_Inspection_Tables are formed with selected Pontis data fields obtained from PDI files, iden-

Table 34. NBMD Contact_Table.

Data Field	Description
Dataset	Global identifier
Contact_ID	*DataSet*{Con{*Seq* Unique identifier for this contact record. The static string 'Con' marks this as a contract ID. The Seq (sequence) is 1, 2, 3 … as needed for the contacts contributing to this dataset.
Type	General type of bridge information; one among maintenance, inventory, or condition data.
Last_Name	Last name of staff contact
First_Name	First name of staff contact
Initial	Middle initial(s) of staff contact
Agency	Name of transportation department, or other bridge owner
Office / Branch	Office within transportation department
Title	Staff contact's job title
Address_1	Postal address
Address_2	
City	Staff contact information
State	
Zip	
telephone	
cell_phone	
email	
website	

Table 35. Element Definition Table.

Data Field	Note
Dataset	Global Identifier
NBMD_Elemkey	*Dataset*{Elem{*DOT_Elemkey* Global identifier for bridge element, tied to dataset
DOT_Elemkey	From Pontis (usually), the numeric ID for an element
elemshort	From Pontis, short name for bridge element
elemlong	From Pontis, long name for bridge element
DOT_Unit	Unit of measurement for bridge element
Statecnt	Number of condition states for bridge element
Component	NBMD keyword for bridge component
Material	NBMD keyword for element material
Part	NBMD keyword for specific part of bridge component indicated by this element
Form	NBMD keyword for form of element (such as *open* beam versus *box* beam)
Protection	NBMD keyword for paint, membrane, coated rebar or other feature offering protection to the bridge element

tifiers for NBMD bridges, inspections, and elements and augmented by elements' units of measurement (Table 36).

Element_Unit_Cost_Table

NBMD's Element_Unit_Cost_Tables are generated from data in Production_Tables and Element_Inspection_Tables. Element_Unit_Cost_Tables are generated after other tables in a dataset have been formed from DOT inputs (Table 37).

Element_Unit_Cost_Table reports the costs and improvements to one element at one bridge due to one maintenance event, and the median costs for unique pairs of bridge elements and maintenance actions. A single maintenance event may improve several elements. The resulting table will contain as many records as improved elements. A single bridge and element may be improved by different maintenance events (events may differ by maintenance Operation). The resulting table will contain as many records as maintenance events.

Table 36. NBMD Element_Inspection_Table.

Data Field	Description
DataSet	Global Identifier
NBMD_Bridge_ID	Global Identifier
NBMD_Inspection_ID	*NBMD_Bridge_ID*{Insp{Inspection_Date Global Identifier
Structure_Unit	From Pontis
NBMD_Elemkey	Global Identifier
DOT_Element_Key	From Pontis, numeric ID of bridge element
Environment_Key	From Pontis
Element_Total_Quantity	From Pontis
Element_Quantity_Unit	From NBMD Element_Definition_Table
Quantity_State_1	From Pontis, element-level condition report of element quantities.
Quantity_State_2	
Quantity_State_3	
Quantity_State_4	
Quantity_State_5	
Percentage_State_1	From Pontis, element-level condition report of element percentages.
Percentage_State_2	
Percentage_State_3	
Percentage_State_4	
Percentage_State_5	
Element_Scale_Factor	From Pontis
brkey	From Pontis
inspkey	From Pontis
Notes	From Pontis

Table 37. Element_Unit_Cost_Table.

Data Field	Description
Dataset	NBMD global identifier
NBMD_Event_ID	NBMD global identifier
NBMD_Bridge_ID	NBMD global identifier
Action_Component	Bridge component identified in event record
Action_Operation	Maintenance operation identified in event record
Event_Total_Cost	Event total cost allocated to this element
NBMD_Prior_Insp	Inspection ID, inspection before maintenance event
NBMD_Post_Insp	Inspection ID, inspection after maintenance event
NBMD_Element_ID	NBMD global identifier
Element_long	Long name of element
Element_Unit	Unit of measurement for element
Prior_Total_Quantity	Element total quantity prior to maintenance event
Post_Total_Quantity	Element total quantity after maintenance event
Element_Component	NBMD keyword for element component
Element_Material	NBMD keyword for element material
Element_Form	NBMD keyword for element form
Element_Part	NBMD keyword for element part
Element_Protection	NBMD keyword for element protection
Improvement_Quantity	Quantity of element moved to better condition state
Prior_State	Element condition before maintenance; best condition state among states that lose quantity after maintenance
Post_State	Element condition after maintenance; worst condition state among states that gain quantity after maintenance
Inventory_Change	Change in total quantity of element due to maintenance
Cost_Type	Cost of single event, or median cost of similar events
Element_Unit_Cost	Event cost divided by improved quantity of element
Element_Unit_Cost_Unit	Units of measurement for unit cost
Cost_Status	One among Single element, Multiple elements, Multiple components

Element_Unit_Cost_Tables contain the maintenance events that improve element conditions as revealed in element-level inspection reports, provided that event Components agree with element Components. The Cost_Status field indicates whether total costs of one maintenance event are distributed to one bridge element, to multiple elements, or to multiple bridge components. The computation of element-level unit costs is discussed in Chapter 5.

Inspection_Cross_Reference_Table

NBMD Inspection_Cross_Reference_Tables link each maintenance event to three NBI safety inspections and three element-level inspections (Table 38). These are: inspections nearest in date to maintenance events, inspections one cycle prior to events, and inspections one cycle after. Together, these three inspections can reveal the changes (improve-

Table 38. NBMD Inspection_Cross_Reference_Table.

Data Field	Description
NBMD_Bridge_ID	Global Identifier
NBMD_Event_ID	Global Identifier
NBMD_Inspection_ID	Global Identifier
Inspection_Type	NBMD standard keyword: Element or *NBI*
Inspection_Order	NBMD standard keyword. Inspections are Prior, Middle or Post, meaning prior to maintenance, nearest to maintenance, or after maintenance
Inspection_Date	Date of inspection presented as YYYY/MM/DD
brkey	From Pontis, key to bridge record
inspkey	From Pontis, key to inspection record

Table 39. NBMD Inspection_Event_Table.

Data Field	Description
DataSet	Global Identifier
NBMD_Bridge_ID	Global Identifier
NBMD_Inspection_ID	Global Identifier
brkey	From Pontis, bridge key
inspkey	From Pontis, inspection key
Inspection_Date	Date of inspection, YYYY/MM/DD
NBI_Done	Yes / No indicated as 1/0, from Pontis
Element_Level_Done	Yes / No indicated as 1/0, from Pontis
Element_Inspection_Date	Date of inspection presented as YYYY/MM/DD
UW_Required	1/0 indicator that underwater inspection is required
UW_Done	1/0 indicator that underwater inspection was performed
FC_Required	1/0 indicator that fracture critical member inspection is required
FC_Done	1/0 indicator that fracture critical member inspection was performed
Special_Required	1/0 indicator that special or other inspection is required
Special_Done	1/0 indicator that special or other inspection was performed
Appraisal_Date	Date of NBI appraisals
Rail_NBI_36A	NBI item 36 for traffic safety features
Rail_Transition_NBI_36B	
Approach_Rail_NBI_36C	
Approach_Rail_End_NBI_36D	
Open_Posted_Closed_NBI_41	NBI item 41 for structure open, posted or closed.
Deck_Geometry_NBI_68	NBI item 68 Deck geometry
Underclearance_NBI_69	NBI item 69 Underclearances
Waterway_Adequacy_NBI_71	NBI item 71 Waterway adequacy
Pier_Protection_NBI_111	NBI item 111 Pier or abutment protection
Scour_Critical_NBI_113	NBI item 113 Scour Critical Bridges
Approach_Alignment_NBI_72	NBI item 27 Approach roadway alignment
Deck_Rating_NBI_58	NBI item 58 Deck condition rating
Superstructure_Rating_NBI_59	NBI item 59 Superstructure condition rating
Substructure_Rating_NBI_60	NBI item 60 Substructure condition rating
Channel_Rating_NBI_61	NBI item 61 Channel and channel protection
Culvert_Rating_NBI_62	NBI item 62 Culvert condition
Structural_Evaluation_NBI_67	NBI item 67 Structural evaluation
NBI_Status	NBI status
NBI_Sufficiency_Rating	NBI sufficiency rating
NBI_Sufficient_Prefix	NBI position 428
Notes	From Pontis

ments) to bridge element conditions as a result of maintenance events.

Inspection_Cross_Reference_Tables are generated from Pontis *inspevnt* tables and NBMD Production_Tables using an NBMD software utility called Inspection Cross (see Appendix E).

Inspection_Event_Table

NBMD's Inspection_Event_Tables contain NBI condition and appraisal ratings (Table 39). Inspection_Event_Tables can be generated from Pontis' *inspevnt* table or from FHWA files of NBI data.

NBMD_Size

NBMD's Size_Tables are used by the NBMD viewer application to establish the sizes of arrays when data tables are loaded (Table 40). Size_Tables list files included in the dataset and the number of lines in each file. Size_Tables are created

Table 40. NBMD Size_Table.

Data Field	Description
File path and name	Tab-text file of NBMD data
File lines	Count of lines in NBMD tab-text file

by a software utility, NBMD_Size, after all other tables in a dataset have been assembled. Size_Tables must be updated by the software application if any tables in a dataset are modified.

Production_Table

NBMD Production_Tables report the production (accomplishments) of maintenance actions at bridges (Table 41). Each record identifies a bridge, an NBMD maintenance component and operation, the unit of measurement, the production amount, total cost, and unit cost. Records also include DOTs' identifying codes and titles for actions, DOT reference numbers such as contract number, crew number, work order or other identifying number.

NBMD Production_Tables provide total cost for each NBMD action at each bridge. Most production records combine multiple work reports of DOTs. Each NBMD production record can be the sum of more than one DOT work order, or DOT maintenance action, if these orders and actions contribute to a single NBMD action at a single bridge. As a result, DOT work order numbers may be absent from an NBMD production record, if multiple work orders contribute. DOT action ID may be absent from an NBMD production record, if multiple actions contribute. DOT units of measurement may be absent if the contributing DOT records have differing units.

Resource_Definition_Table

NBMD Resource_Definition_Tables relate DOT identifiers for equipment, material and labor to NBMD resources categories (Table 42). Categories are standard keywords. Other keywords are descriptive. For materials, the table can track manufacturer and product names.

Resource_Table

NBMD Resource_Tables identify the resources used in maintenance events, together with resource quantities and costs (Table 43). Records identify maintenance events and resources. Each record may combine several DOT records for resource use.

Roadway_Table

NBMD Roadway_Tables contains NBI inventory data for routes on and under bridges (Table 44). Roadway_Tables contain records needed for the maintenance events in a dataset.

Table 41. NBMD Production_Table.

Data Field	Description
Dataset	Global identifier
NBMD_Bridge_ID	Global identifier
NBMD_Event_ID	Global identifier. Concatenation of NBMD_Bridge_ID and abbreviations for component and operation
NBMD_DOT_Event_ID	Concatenation of NBMD_Bridge_ID and DOT activity code, if available.
DOT_Bridge_ID	*Structure_Number* from NBI records, or bridge key (brkey) from a DOTs' Pontis bridge database.
Start_Date	Earliest record for this maintenance event, shown as YYYY/MM/DD
End_Date	Latest record for this maintenance event, shown as YYYY/MM/DD.
DOT_Activity_ID	DOTs' identifying code for maintenance activity
DOT_Activity_Title	DOTs' title for maintenance activity
DOT_RefA	DOTs' reference number such as work order, contract number, crew number or other identifying code useful for retrieval of internal DOT records
DOT_RefB	Additional DOT reference number
NBMD_Component	NBMD standard keyword
NBMD_Operation	NBMD standard keyword
NBMD_Activity	NBMD descriptive keyword
NBMD_Mode	NBMD descriptive keyword
NBMD_CoamString	Abbreviations for component and operation
DOT_Production	Quantity of work accomplished
DOT_Production_Unit	Measurement unit for work
DOT_Unit_Cost	Total cost divided by work quantity
DOT_Unit_Cost_Unit	Measurement unit for unit cost
DOT_Total_Cost	Cost reported by DOT, summed from multiple work records or resource records
Cost_Unit	Monetary unit for total cost
Notes	

Table 42. NBMD Resource_Definition_Table.

Data Field	Description
Dataset	Global identifier
Resource_ID	Global identifier
DOT_Resource_ID	DOT's identifying code for resource
DOT_Resource_Description	DOT's title for resource.
DOT_Unit	Unit of measurement for use or cost of resource
NBMD_Resource_Category	NBMD standard keyword (labor, equipment, material, other)
NBMD_Resource_Group	NBMD descriptive keyword
NBMD_Resource_KeywordA	NBMD descriptive keyword
NBMD_Resource_KeywordB	NBMD descriptive keyword
NBMD_Resource_Manufacturer	Name of manufacturer, for materials
NBMD_Resource_Product	Name of product, for materials
NBMD_Unit	Unit of measurement for NBMD
NBMD_Unit_Cost	Unit cost of resource in DOT units
notes	Notes on resource record

Table 43. NBMD Resource_Table.

Data Field	Description
Dataset	Global identifier
Resource_ID	Global identifier
NBMD_Bridge_ID	Global identifier
NBMD_Event_ID	Global identifier
NBMD_DOT_Event_ID	Concatenation of *NBMD_Bridge_ID* and DOT activity code, if available
DOT_Bridge_ID	*Structure_Number* from NBI records, or bridge key (brkey) from Pontis bridge database
Start_Date	Earliest resource record for this maintenance event
End_Date	Latest resource record for this maintenance event
DOT_Activity_ID	DOT's identifying code for maintenance activity
DOT_Activity_Title	DOT's title for maintenance activity
DOT_RefA	DOT's reference number such as work order, contract number, crew number or other identifying code useful for retrieval of internal DOT records on bridge maintenance work
DOT_RefB	Additional DOT reference number
DOT_Resource_ID	DOT's identifying code for resource
DOT_Resource_Description	DOT's title for resource
DOT_Resource_Category	DOT's category for resource
DOT_Resource_Quantity	Use of resource in hours, miles, mass, volume, etc.
DOT_Quantity_Unit	Unit for measurement of resource use
DOT_Unit_Cost	Unit cost of resource
DOT_Unit_Cost_Unit	Units for unit cost
DOT_Total_Cost	Total cost for this resource in this event
DOT_Total_Cost_Unit	Units for total cost
NBMD_Resource_Category	NBMD standard keyword
NBMD_Resource_Group	NBMD standard keyword
NBMD_Resource_Keyworda	NBMD descriptive keyword
NBMD_Resource_Keywordb	NBMD descriptive keyword
NBMD_Resource_Manufacturer	Name of manufacturer, for materials
NBMD_Resource_Product	Name of product, for materials
NBMD_Unit	Unit for NBMD measurement of resource, if different from DOT
NBMD_Unit_Cost	Unit cost of resource in NBMD units of measurement
notes	Notes on use of resource

Table 44. NBMD Roadway Table.

Data Field	Description
Dataset	Global identifier
NBMD_Bridge_ID	Global identifier
NBMD_Road_ID	Global identifier
Record_Type	NBI item 5A Record Type
Kind_Highway	From Pontis roadway table
Level_Service	NBI item 5C Designated level of service
Route_Prefix	NBI item 5B Route signing prefix
Route_Number	NBI item 5D Route number
Direction_Suffix	NBI item 5E Directional suffix
Roadway_Name	From Pontis roadway table
Kilometer_Post	NBI item 11 Kilometerpoint
Lanes_On	NBI item 28A Lanes on the structure
Lanes_Under	NBI item 28B Lanes under the structure
Functional_Class	NBI item 26 Functional classification of inventory route
ADT	NBI item 29 Average daily traffic
Year_ADT	NBI item 30 Year of average daily traffic
Direction_Traffic	NBI item 102 Direction of traffic
ADT_Pct	NBI item 109 Average daily truck traffic, percentage
Road_Speed	From Pontis roadway table
Roadway_Width	NBI item 51 Bridge roadway width curb-to-curb
Approach_Width	NBI item 32 Approach roadway width

In any one reporting period, maintenance events affect a subset of bridges in a DOT's network. These bridges are included in Roadway_Tables. Roadway_Tables can be formed from NBI text files or from Pontis roadway tables.

Structure_Table

NBMD Structure_Tables contain NBI inventory data including bridge owner, year built, design type and material types (Table 45). In a single dataset, Structure_Table contain records only for bridges having maintenance events. Structure_Tables can be formed from NBI text files or from the Pontis' bridge table.

File Formats for NBMD Tables

NBMD tables are presented as tab-delimited text (tab-text) files and as XML documents.

Tab-Text Files

Tab-text files are convenient for the assembly of NBMD tables. NBMD collects data from many DOT sources, and must incorporate information from databases, from spreadsheets, and from other text files. In this context, text files are the simplest intermediary files for collection and assembly of NBMD data. Tab-text files of NBMD tables all have similar layout. The first line contains headings for all data fields. The second line and all following lines are data records. All lines contain the same number of columns, set off by tab characters.

An example tab-text file, a list of bridge maintenance actions in data collected from Tennessee DOT, is shown in Figure 6.

Tab-text files can be opened in MS Excel by "drag-drop" operations. This allows quick views of NBMD data. Tab-text data entries are sometimes altered in Excel (date fields, and any field containing "/" can be misread by Excel). Saving NBMD tables from Excel is not recommended.

XML Documents

NBMD data tables are presented as XML documents conforming to XSD schemas prepared in this project. XML documents are self-defining sets of data fields and data values. XML documents offer definite and unaltered input of data tables to applications such as MS Excel and MS Access. Templates can be created to display XML documents in web browsers.

A portion of the XML document for Oregon's Inspection_Cross_Reference_Table is shown in Figure 7. File structure is repetitive. Each data field is identified by name within "< >" brackets Next the data entry appears. Last, the data field is terminated by </ > brackets. Each complete data record is enclosed by <Inspection_Cross_Reference>· · ·</Inspection_Cross_Reference> tokens. The XML document continues with similar structure for all records in the table.

Table 45. NBMD Structure_Table.

Data Field	Description
Dataset_ID	Global identifier
NBMD_Bridge_ID	Global identifier
brkey	From Pontis, bridge key
bridge_id	From Pontis, usually a short form of the NBI structure number
Structure_Number	NBI item 8 Structure number
Structure_Name	From Pontis
Features_Intersected	NBI item 6A Features intersected
District	NBI item 2 Highway agency district
County	NBI item 3 County (parish) code
Facility	NBI item 7 Facility carried by structure
Location	NBI item 9 Location
Custodian	NBI item 21 Maintenance responsibility
Owner	NBI item 22 Owner
Admin_Area	From Pontis
State_Code	NBI item 1 State code
Year_Built	NBI item 27 Year built
Year_Reconstructed	NBI item 106 Year reconstructed
Historical_Significance	NBI item 37 Historical significance
Design_Load	NBI item 31 Design load
Type_Service_Bridge	NBI item 42A Type of service on bridge
Type_Service_Under	NBI item 42B Type of service under bridge
Number_Spans_Main	NBI item 45 Number of spans in main unit
Number_Approach_Spans	NBI item 46 Number of approach spans
Length_Maximum_Span	NBI item 48 Length of maximum span
Structure_Length	NBI item 49 Structure length
Deck_area	From Pontis
Bridge_Median	NBI item 33 Bridge median
Skew	NBI item 34 Skew
Material_Type_Main	NBI item 43A Structure type main, kind of material/design
Design_Type_Main	NBI item 43B Structure type main, type of design/construction
Material_Type_Approach	NBI item 44A Structure type approach, kind of material/design
Design_Type_Approach	NBI item 44B Structure type approach, type of design/construction
Deck_Structure_Type	NBI item 107 Deck structure type
Type_Membrane	NBI item 108B Type of membrane
Type_Wearing_Surface	NBI item 108A Type off wearing surface
Deck_Protection	NBI item 108C Deck protection
Deck_Width	NBI item 52 Deck width, out-to-out
Left_Walk_Width	NBI item 50A Left curb/sidewalk width
Right_Walk_Width	NBI item 50 Right curb/sidewalk width
Notes	

XML documents conform to schema defined for each NBMD table, and stored in "XSD" files. Schema files list the data fields that belong in each table together with information on types of data entries and the number of data entries required and allowed. The XSD file for the Inspection_Cross_Reference_Table is shown in Figure 8.

The full set of XML schema files is available in the *xsd* directory of the NBMD system distribution.

Dataset	Action_ID	DOT_Action_ID	DOT_Action_Description	DOT_Unit	NBMD_Component	NBMD_Operation	NBMD_Activity
TnDOT{2007	TnDOT{2007{Act{400	400	SPECIAL PROJECTS	each	Bridge		
TnDOT{2007	TnDOT{2007{Act{477	477	TRAFFIC CONTROL	each	Bridge	nonMaintenance	
TnDOT{2007	TnDOT{2007{Act{450	450	STRUCTURE CLEANING	each	Bridge	Clean	
TnDOT{2007	TnDOT{2007{Act{454	454	MAJ STRUCTURE REPAIR	each	Bridge	Repair	Major
TnDOT{2007	TnDOT{2007{Act{402	402	CRACK REPAIR	each	Bridge	Repair	Crack
TnDOT{2007	TnDOT{2007{Act{451	451	MINOR STRUCTURE REPAIR	each	Bridge	Repair	Minor
TnDOT{2007	TnDOT{2007{Act{412	412	JOINT REPAIR	each	Joint	Repair	
TnDOT{2007	TnDOT{2007{Act{433	433	REPAIR DRAIN STRCT - EACH	each	Drain	Repair	
TnDOT{2007	TnDOT{2007{Act{401	401	MANUAL SPOT PATCHING	each	Bridge	Repair	Patch
TnDOT{2007	TnDOT{2007{Act{438	438	MANUAL BRUSH CONTROL	each	Bridge	Clean	Brush
TnDOT{2007	TnDOT{2007{Act{447	447	MANUAL SWEEPING	each	Bridge	Clean	Sweep
TnDOT{2007	TnDOT{2007{Act{405	405	MILLING	each	Bridge	Repair	
TnDOT{2007	TnDOT{2007{Act{475	475	GUARDRAIL + BARRIER WALL	each	Rail/Walk	Repair	
TnDOT{2007	TnDOT{2007{Act{461	461	DE-ICING (SALT)	each	Bridge	nonMaintenance	
TnDOT{2007	TnDOT{2007{Act{463	463	ANTI-ICING (SALT BRINE)	each	Bridge	nonMaintenance	
TnDOT{2007	TnDOT{2007{Act{446	446	MECHANICAL SWEEPING	each	Bridge	Clean	Sweep
TnDOT{2007	TnDOT{2007{Act{442	442	EROSION CONTROL	each	Bridge	Repair	Erosion

Figure 6. Example of a tab-delimited text file.

```
...
<Inspection_Cross_Reference>
        <DataSet> OrDOT{2006 </DataSet>
        <NBMD_Bridge_ID> OrDOT{2006{S8837A064 01072 </NBMD_Bridge_ID>
        <NBMD_Event_ID> OrDOT{2006{S8837A064 01072{nBrd{ </NBMD_Event_ID>
        <NBMD_Inspection_ID> OrDOT{2006{S8837A064 01072{Insp{0 </NBMD_Inspection_ID>
        <Inspection_Type> NBI </Inspection_Type>
        <Inspection_Order> Middle </Inspection_Order>
        <Inspection_Date> 0 </Inspection_Date>
        <brkey> S8837A064 01072 </brkey>
        <inspkey> -1 </inspkey>
</Inspection_Cross_Reference>
<Inspection_Cross_Reference>
        <DataSet> OrDOT{2006 </DataSet>
        <NBMD_Bridge_ID> OrDOT{2006{S8837A064 01072 </NBMD_Bridge_ID>
        <NBMD_Event_ID> OrDOT{2006{S8837A064 01072{nBrd{ </NBMD_Event_ID>
        <NBMD_Inspection_ID> OrDOT{2006{S8837A064 01072{Insp{0 </NBMD_Inspection_ID>
        <Inspection_Type> NBI </Inspection_Type>
        <Inspection_Order> Post </Inspection_Order>
        <Inspection_Date> 0 </Inspection_Date>
        <brkey> S8837A064 01072 </brkey>
        <inspkey> -1 </inspkey>
</Inspection_Cross_Reference>
...
```

Figure 7. XML document (sample).

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified">
<xs:element name="dataroot">
        <xs:complexType>
                <xs:sequence>
                        <xs:element ref="Inspection_Cross_Reference" minOccurs="0"
                maxOccurs="unbounded"/>
                </xs:sequence>
        </xs:complexType>
</xs:element>

<xs:element name="Inspection_Cross_Reference">
        <xs:annotation>
                <xs:documentation>
NCHRP Project 14-15
NBMD Inspection Cross Reference Table
2009 G. Hearn
TABLE Inspection_Cross_Reference_Table.xml
                </xs:documentation>
        </xs:annotation>
        <xs:complexType>
                <xs:sequence>
                        <xs:element name="DataSet" type="xs:string"/>
                        <xs:element name="NBMD_Bridge_ID" type="xs:string"/>
                        <xs:element name="NBMD_Event_ID" type="xs:string"/>
                        <xs:element name="NBMD_Inspection_ID" type="xs:string"/>
                        <xs:element name="Inspection_Type" type="xs:string"/>
                        <xs:element name="Inspection_Order" type="xs:string"/>
                        <xs:element name="Inspection_Date" type="xs:string"/>
                        <xs:element name="brkey" type="xs:string"/>
                        <xs:element name="inspkey" type="xs:string"/>
                </xs:sequence>
        </xs:complexType>
</xs:element>
</xs:schema>
```

Figure 8. XML schema for Inspection_Cross_Reference_Table.

CHAPTER 3

NBMD Software Applications

The NBMD data system includes a formal organization for directories that contain data, software applications, and XSD schema files. In this chapter, the organization of directories and the use of software applications are presented as instructions and tutorials.

Directory Structure

The full implementation of the NBMD system includes tab-text data files, XML documents, XSD schemas, and applications for basic viewing and checking of NBMD data tables and for generation of XML documents from NBMD tab-text data tables.

The NBMD applications require a specific arrangement of directories and files. The directory tree is shown in Figure 9.

The *NBMD* directory contains directories for applications, *xsd* schemas, and NBMD datasets. The *apps* directory contains executable files for the *NBMD* viewer, keyword checker, file sizer, and XML generator. The *Data* directory contains datasets. The *xsd* directory contains the definition files for schema for NBMD tables. For installation on users' computers, it may be convenient to create the NBMD root directory as a subdirectory to *Documents.* For installation from the distribution disk, drag the NBMD directory into *Documents* (*My Documents* on Windows XP), or into another directory of choice.

NBMD Directory

The *NBMD* directory is the root directory for all NBMD files. It may be convenient for the NBMD directory to contain shortcuts to NBMD applications. The user must create shortcuts, if desired. Steps to create shortcuts are presented in the following sections.

apps Directory

The *apps* directory contains executable files and icons for four applications: NBMD, NBMD_XML, Keywords, and NBMD_Size.

Shortcuts to Applications

To create shortcuts to NBMD applications, do the following:

Open two Explorer windows, and set one to the *NBMD* directory and the second to the *apps* directory. The computer desktop will look like Figure 10.

To create a shortcut for the *NBMD* viewer application, in the *apps* directory select *NBMD.exe* with the mouse, hold down right-click, and drag into the *NBMD* directory. Release the mouse. In the small context menu select "Create Shortcuts Here." There is now a shortcut to the viewer in NBMD.

Repeat the steps to create shortcuts for Keywords.exe and for NBMD_XML.exe. Once complete, the contents of the *NBMD* directory will look like Figure 11.

Data Directory

The *Data* directory contains datasets, with each set in its own subdirectory. A typical set of subdirectories is shown in Figure 12. Each subdirectory contains the TXT files and XML documents for a single set of bridge maintenance data.

As additional datasets are developed, they are added as subdirectories to the *Data* directory.

NBMD Applications

The NBMD system includes software applications to view and check text files of NBMD tables, an application to create XML documents from NBMD text files, and an application to generate the NBMD_Size_Table that is used by the NBMD viewer. The applications function under Windows XP and Windows Vista operating systems.

NBMD Viewer Application

The NBMD viewer, called simply *NBMD,* is the main application for cursory investigation of the contents of NBMD datasets. The NBMD viewer also computes element-level

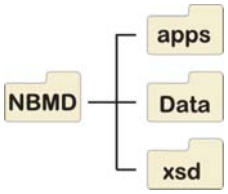


Figure 9. NBMD directory tree.

costs of maintenance actions. With the NBMD viewer, users can determine whether (and which) datasets have useful information.

Running *NBMD*

To run NBMD, double click on *NBMD.exe* in the *apps* directory, or double-click on the *NBMD* shortcut in the *NBMD* directory (if shortcuts have been created). The opening screen appears (Figure 13).

The NBMD viewer provides tabbed interface for access to datasets and to tables within datasets. There are eight tabs (Table 46).

A startup, only the *Datasets* and *About* tabs are active. Other tabs remain disabled until bridge maintenance data are loaded.

The *Datasets* tab has three buttons (Table 47).

Loading Bridge Maintenance Data

To load bridge management data, click the *Data Directory* button, and use the browser window to select the *Data* directory. When the selection is made, the screen will look like Figure 14.

Click *OK,* and available datasets will be listed in the upper box of the application (Figure 15).

The available datasets appear in a checkbox list. The *NBMD* application can load one or more datasets. Check the datasets to retrieve. Here, the dataset for California DOT will be loaded. Check the box, and click the *Load Sets* button (Figure 16).

Datasets may take several minutes to load. Larger sets and the selection of multiple sets require longer times for loading. The progress bar at the bottom of the tab will advance several times as various loading and computing steps are executed. When the work is complete, the progress bar is filled, and val-

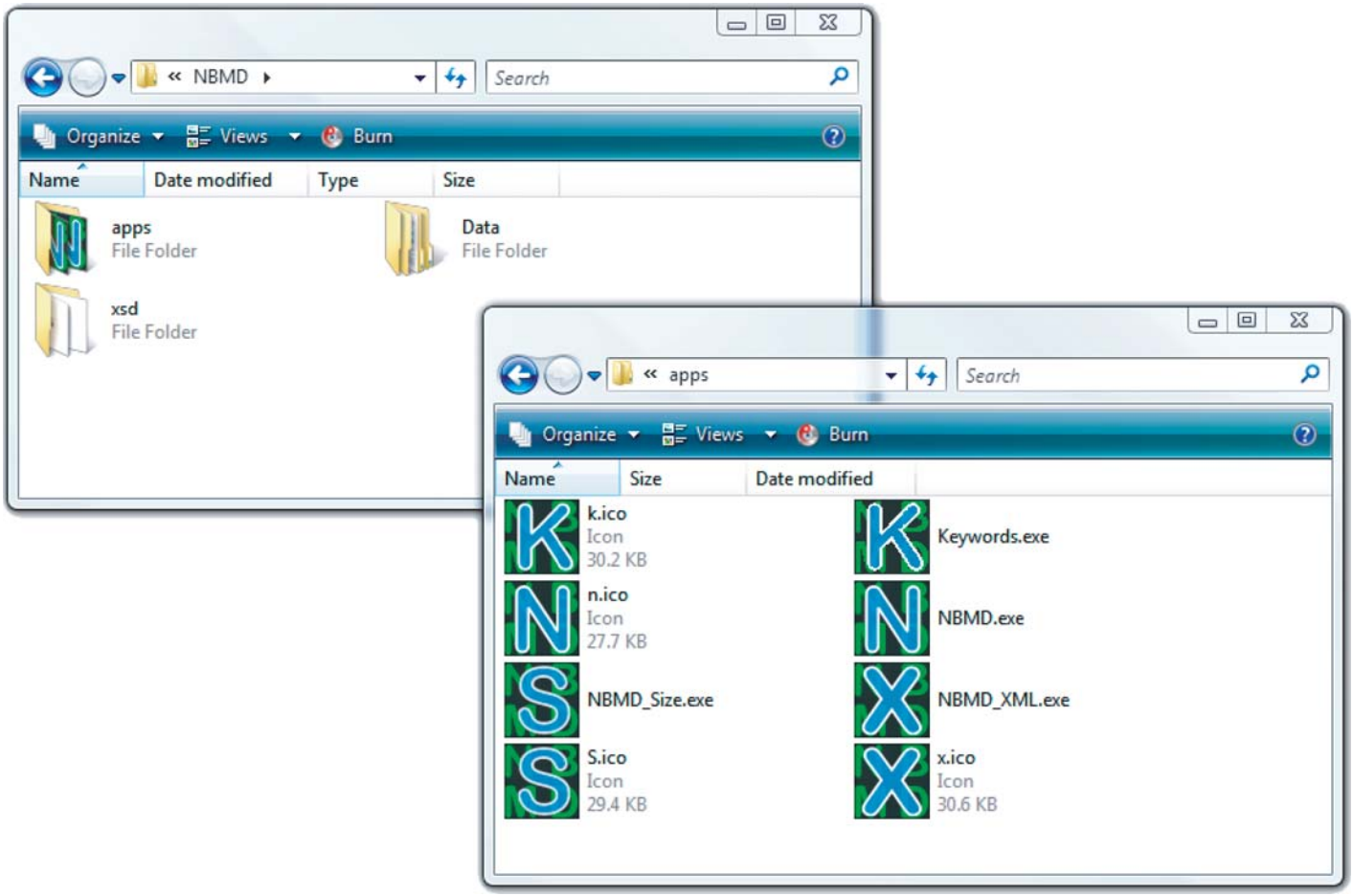


Figure 10. Making shortcuts.

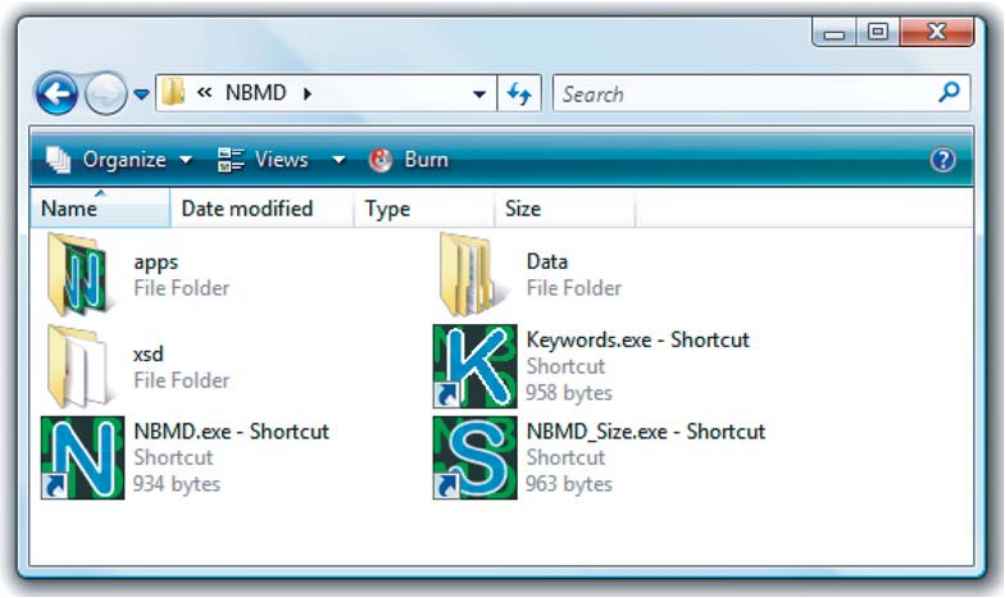


Figure 11. Shortcuts for NBMD applications.

ues of file lengths for production, bridges, elements, and resources are displayed (Figure 17).

The other tabs (Actions, Elements, Bridges, Resources, Action Costs and Element Costs) are now active. Their functions are similar.

Click on the *Actions* tab to open it. There is a computation task; its execution is indicated by the progress bar. At completion, the tab lists the earliest and latest dates in the set of bridge maintenance data; five selection boxes, each set to *Any;* and three buttons (Figure 18).

The upper four selection boxes operate with NBMD keywords for maintenance actions. The lower, fifth selection box operates with DOTs' codes and titles for maintenance actions. The *Actions* tab provides counts of the number of events, number of bridges, and aggregate cost of maintenance actions for selected maintenance actions.

The *Run* button produces a summary. Click on *Run* (with all selection boxes set to *Any*), and find that the California DOT dataset contains 1,578 events on 1,153 bridges with an aggregate cost of more than $15MM (MM is one million) (Figure 19).

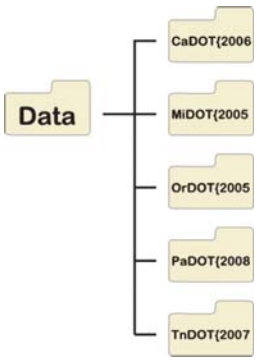


Figure 12. Data and datasets.

The *Filter* button checks which keywords occur together in bridge maintenance records. The *Clear* button resets all selection boxes to *Any*. This is useful after filtering on keywords to get subsets of maintenance actions.

Hit the *Clear* button, and then explore the selection boxes (but don't select anything just yet. Leave all boxes set to *Any*). Each selection box lists unique entries for a data field. Each selection box lists only those entries that are present in the dataset (Figure 20).

Look at the *Activity* selection box. There are 14 activities listed, if all other boxes are set to *Any*. Go to the *Component* selection box. Select *Deck,* and then press the *Filter* button. Now look at the *Activity* box again; there are only six activities. These activities occur for *Deck* components (Figure 21).

Press *Run* and find that the California dataset contains deck work in 278 maintenance events on 262 bridges with the aggregate cost just under $12MM. In the *Activity* selection box, select *Overlay* (keep *Deck* as the selected component). Press *Run* and find that California data contains deck overlays in one event on one bridge costing $3.4k.

To perform *Filter* operations, press the *Clear* button, select an entry in any of the five selection boxes, and press *Filter*. The selected entry remains, and all other selection boxes are adjusted to the subset of entries that occur with the first selection. To *Filter* on two or more selection boxes, perform sequential *Filter* operations. That is, make a first selection, press *Filter*. Make the next selection (in a different selection box) and press *Filter*. The remaining selection boxes are updated for the combination of the first two selections.

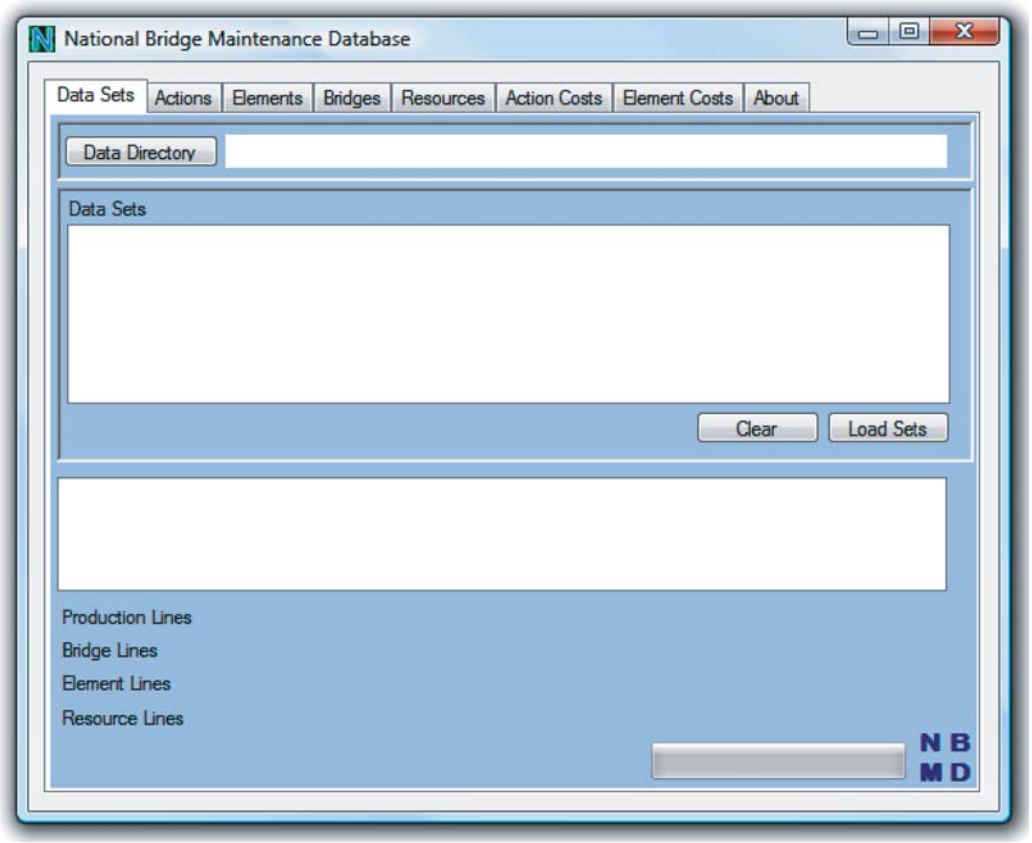


Figure 13. NBMD viewer application.

Table 46. NBMD viewer tabs.

Tab	Description
Datasets	Selection and loading of one or more NBMD datasets
Actions	Summary of maintenance action records in a dataset
Elements	Summary of bridge element records in a dataset
Bridges	Summary of bridge records in a dataset
Resources	Summary of resource records in a dataset
Action Costs	Summary of costs of maintenance actions
Element Costs	Summary of costs of element-level actions, and output of element cost table
About	Information on NCHRP Project 14-15

Table 47. Buttons on datasets tab.

Button	Description
Data Directory	Navigate to the Data directory
Load Sets	Build data tables for selected datasets
Clear	Clear current data tables, if any, and allow selection of other datasets.

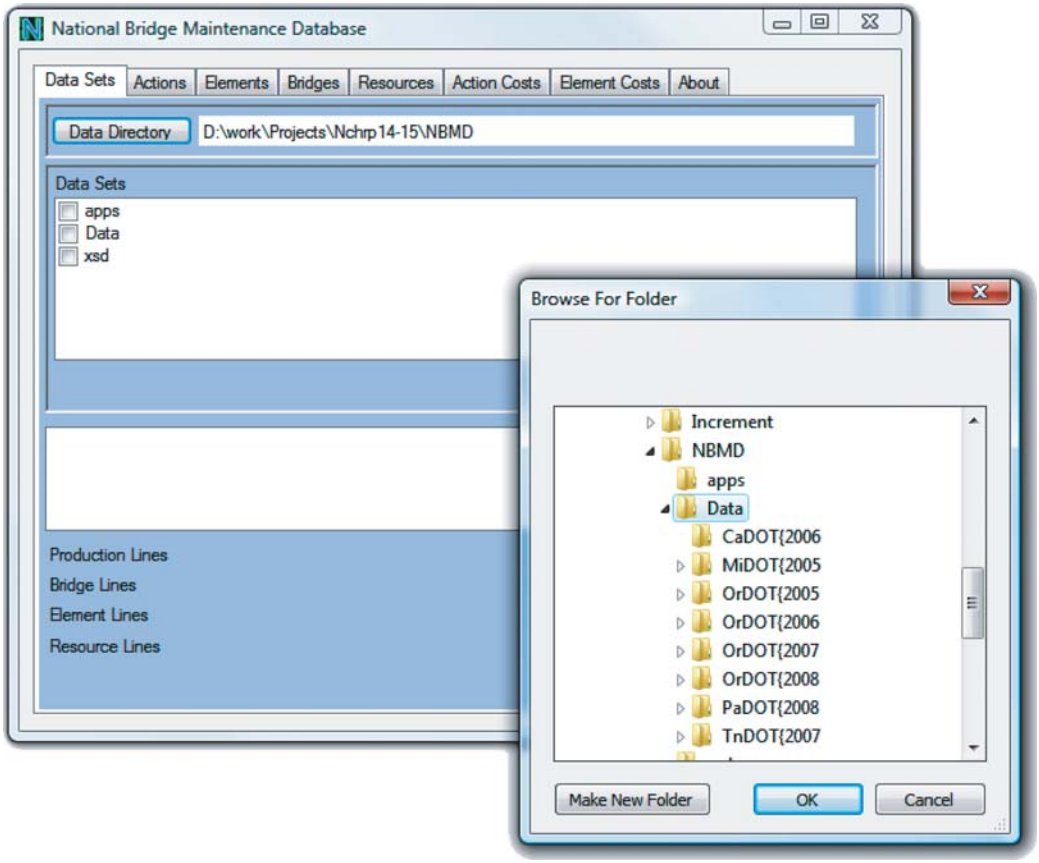


Figure 14. Data directory selection.

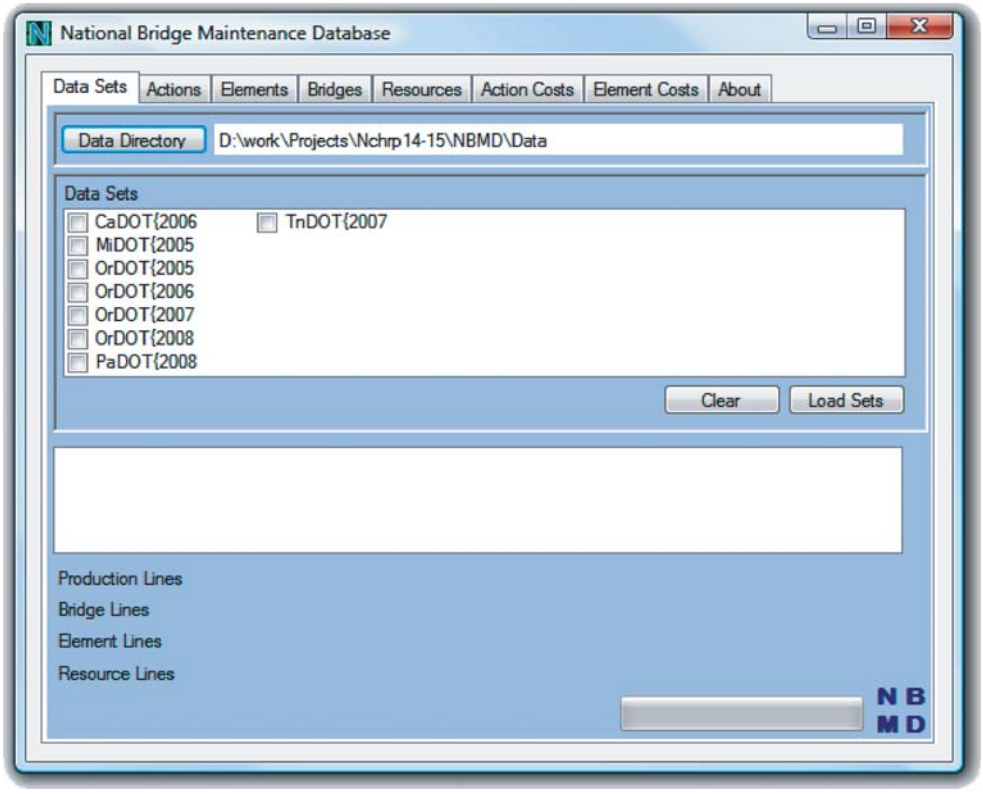


Figure 15. List of datasets.

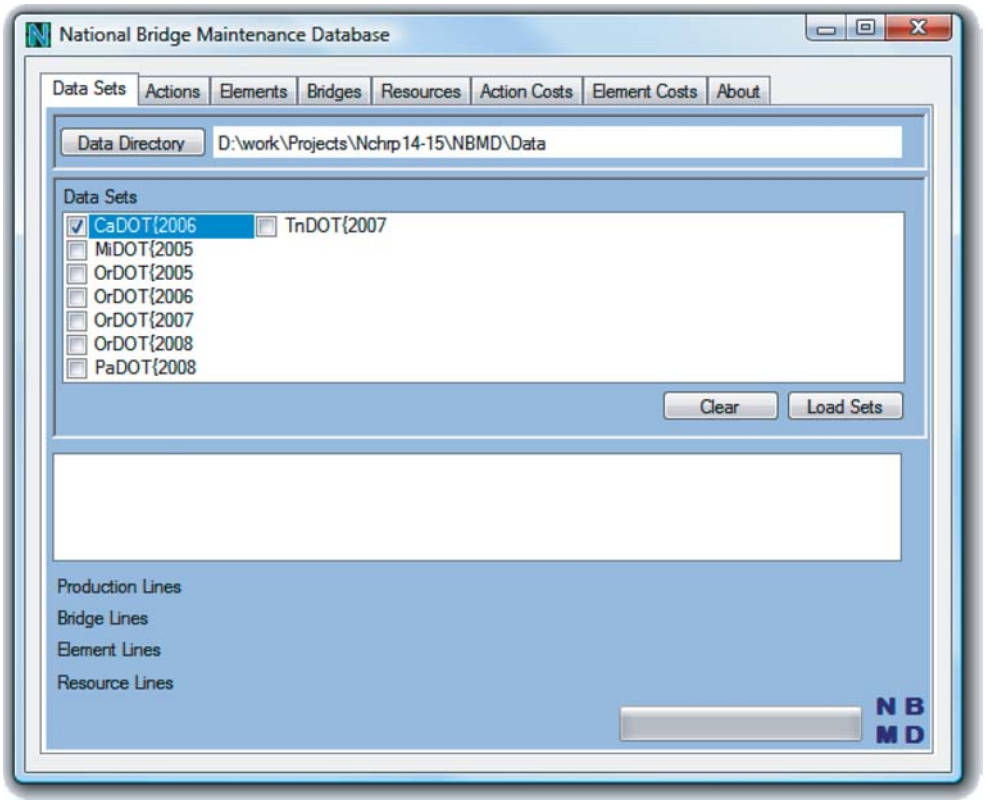


Figure 16. Dataset selection.

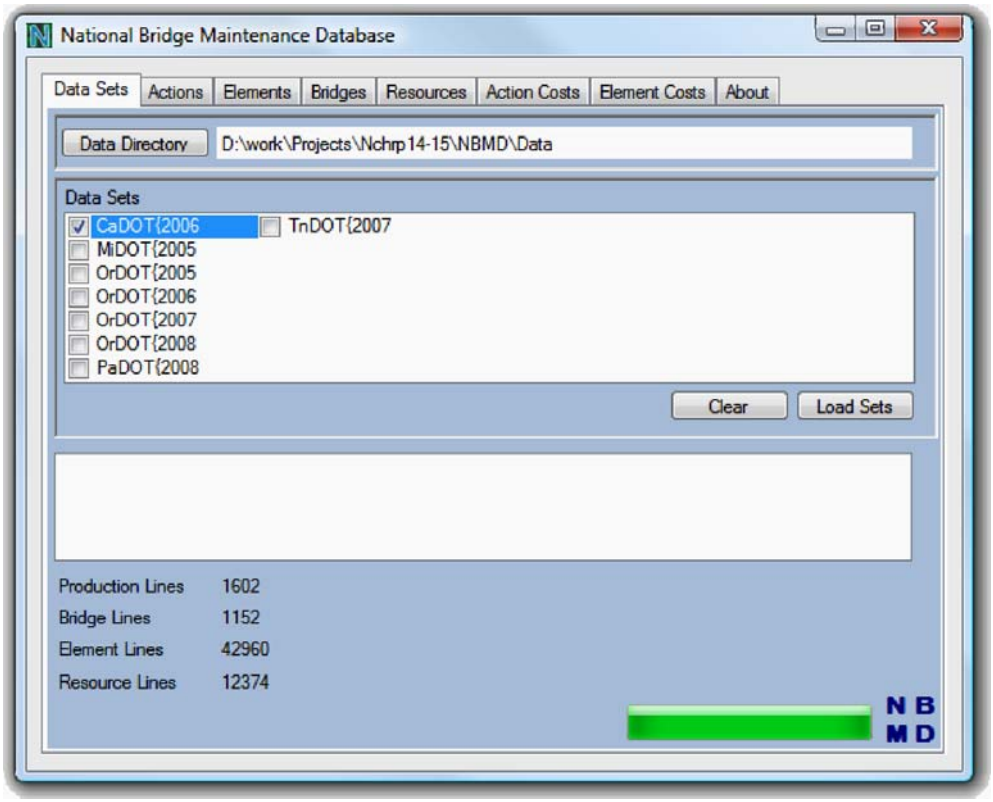


Figure 17. Datasets loaded.

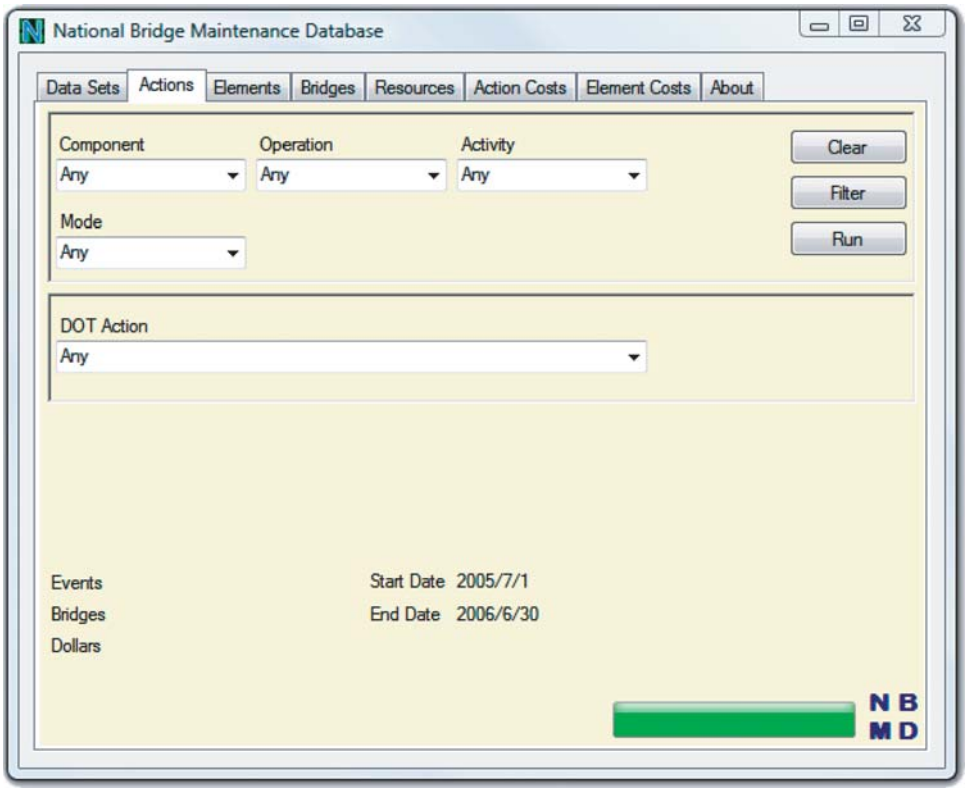


Figure 18. Actions tab.

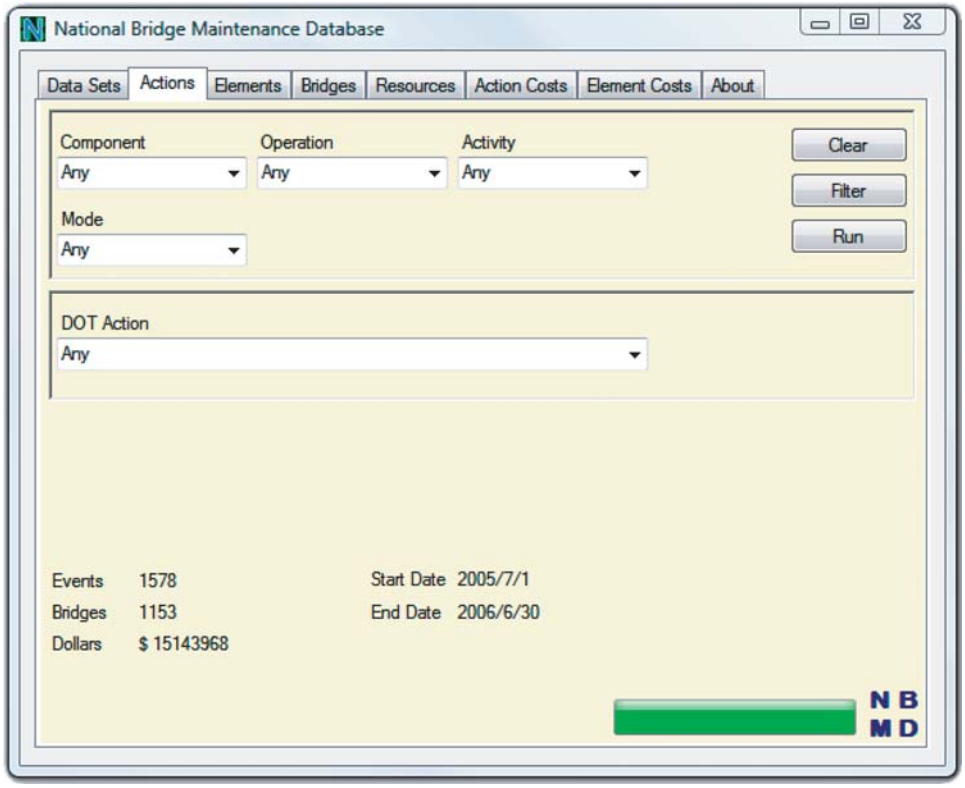


Figure 19. California action counts.

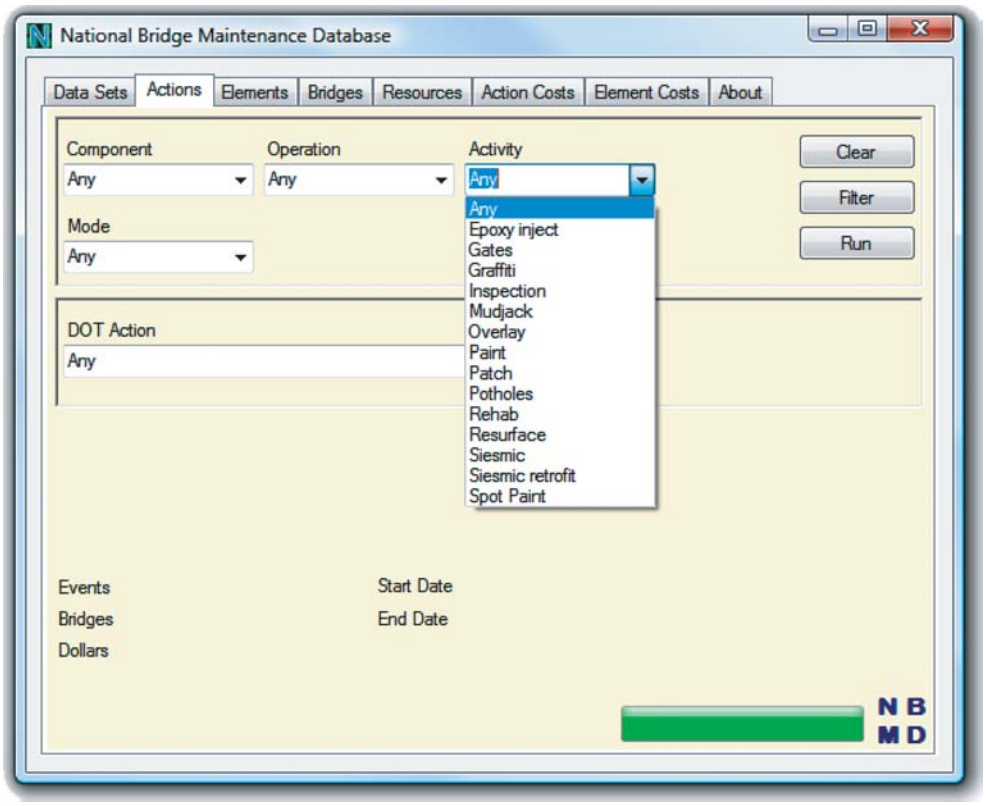


Figure 20. Activity selection box.

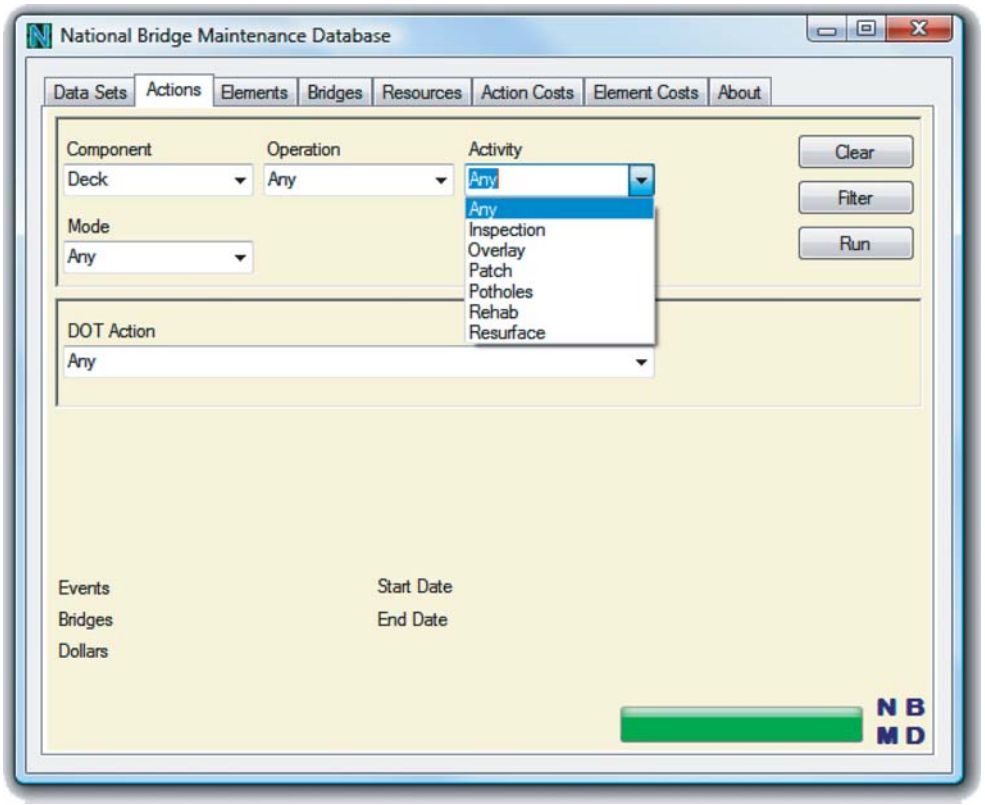


Figure 21. Activities for deck component.

Tabs for Elements, Bridges, Resources and Action Costs

The tabs for *Elements, Bridges, Resources* and *Action Costs* have functions, selection boxes and buttons similar to the *Actions* tab. Each tab accesses a different aspect of NBMD data.

Elements Tab

The *Elements* tab provides summary reports of elements, bridges, and element quantities in a bridge maintenance dataset. Selection boxes are provided for NBMD element keywords for component, material, type, part and protection, and also for DOTs' designations of bridge elements. Selections and filtering for elements operates as for *Actions.* The *Run* button provides a computation of the number of element-level inspections that include the selected element(s), the count of bridges that include selected element(s), and the approximate aggregate quantities of elements. If a *Run* includes elements with different units of measurement, totals in each unit are reported.

Using the California dataset, open the *Elements* tab, allow the initial computation to complete (watch the progress bar), and then press the *Run* button. The computation of element counts and quantities is slow, but after a short wait, the tab indicates that California data includes around 4,200 element-level inspections at 1,150 bridges addressing bridge elements of 846,000 square meters, 400,000 linear meters, and 42,000 single elements. This is an indication of the scope of information available in this dataset (Figure 22).

Use *Clear* to reset boxes to *Any*. Now select the *Joint* component and then filter; next select *Compression* form. Press *Run* and find that the California dataset has 1200 inspections of 380 bridges having 34,000 meters of compression joints (Figure 23). For joints, or for other elements, the filtering and reporting facility indicates how much information is available in a dataset. From such indications, users decide whether a further and more detailed investigation of these data would be useful.

Bridges Tab

The *Bridges* tab shows counts of bridges selected on the basis of Owner, Material Type, Design Type, Functional Class, ADT, and percentage ADTT. The *Filter* and *Run* functions are similar to other tabs. Using the *Bridge* tab, find that California dataset contains 161 prestressed concrete continuous bridges (Figure 24).

Resources Tab

The *Resources* Tab filters and reports resources used in bridge maintenance actions. *Filter* and *Run* functions are sim-

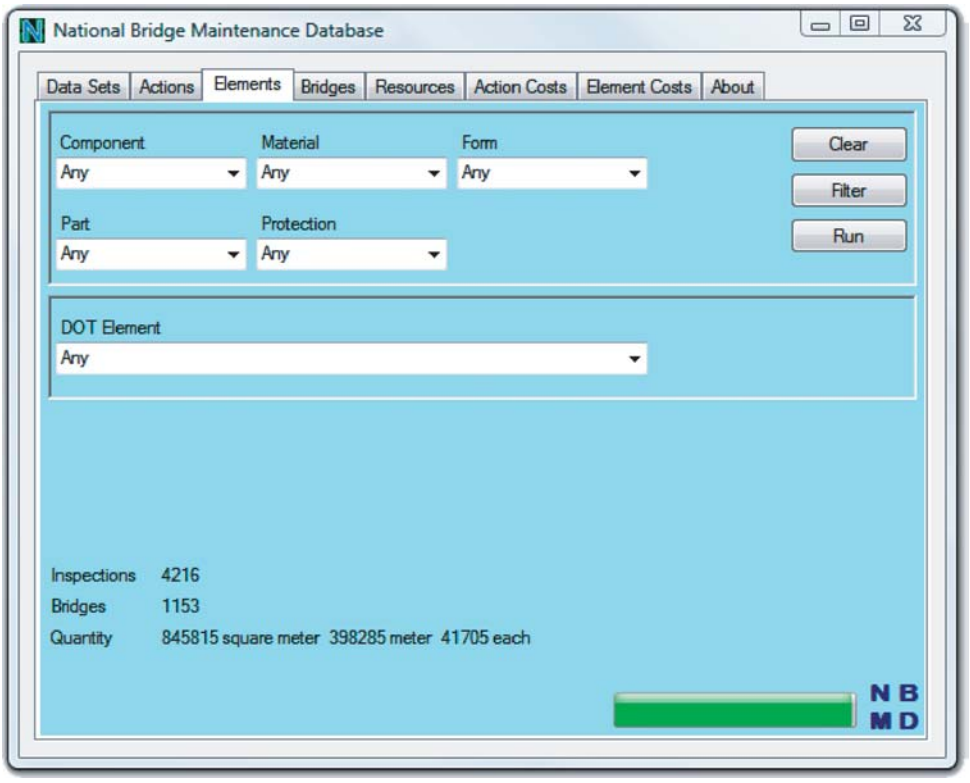


Figure 22. Elements tab.

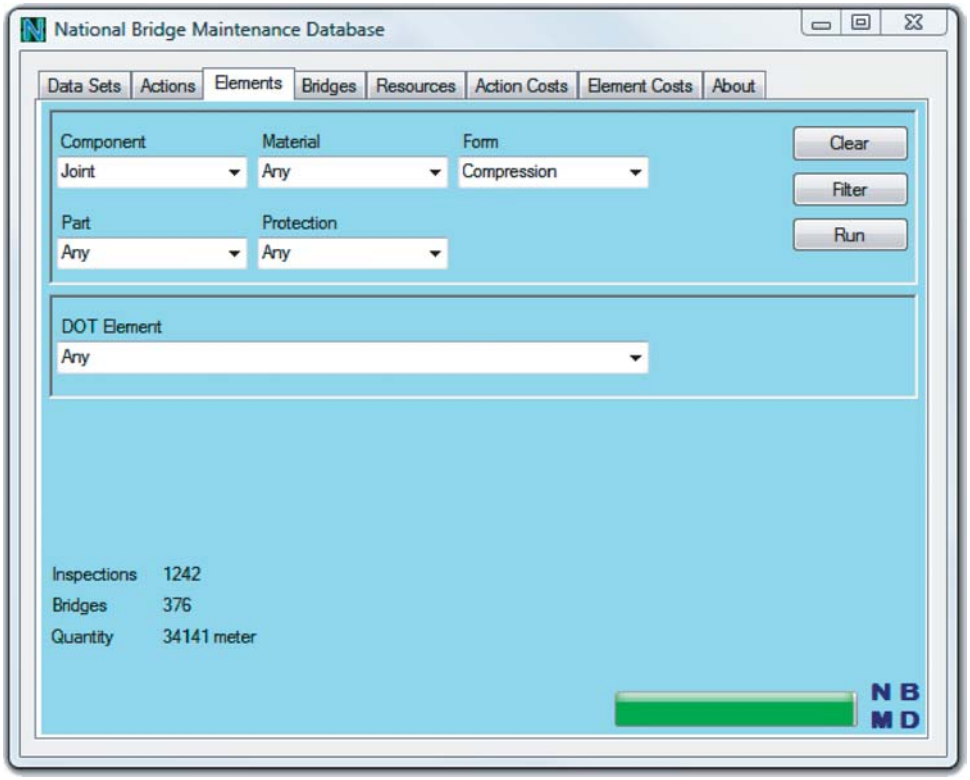


Figure 23. California compression joints.

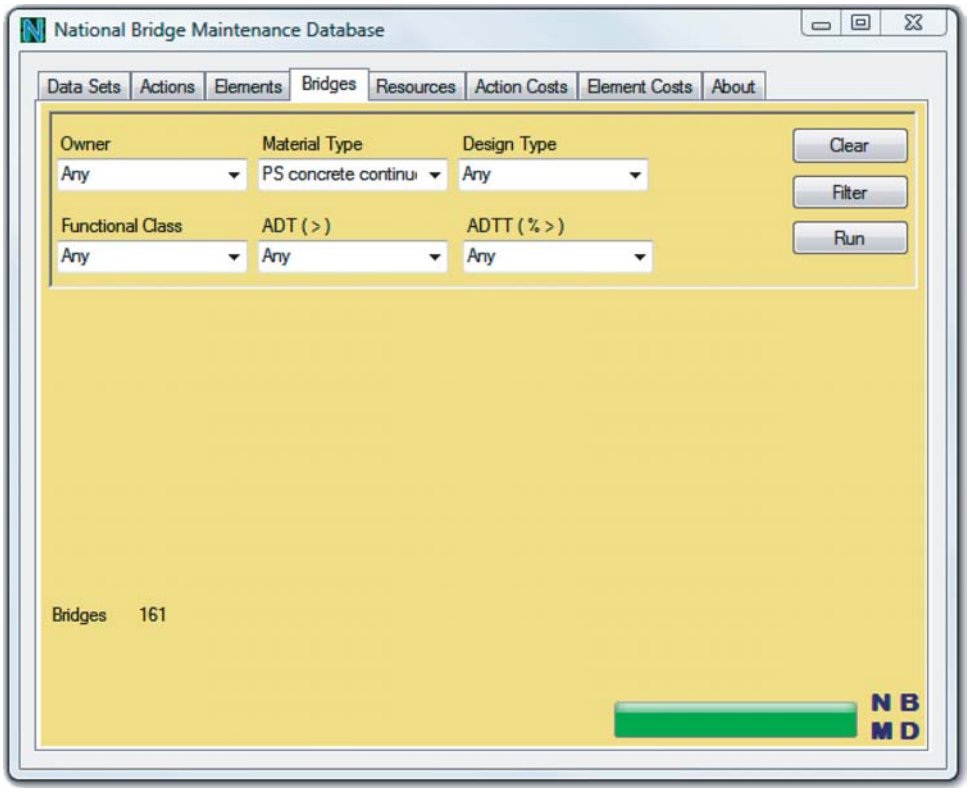


Figure 24. Bridges tab.

ilar to other tabs. An initial *Run* on the resources shows that the California dataset contains resources records for 1,575 events at 1,151 bridges with aggregate cost of nearly $21MM. Note that the cost reported for resources is greater than the cost of maintenance actions. This indicates that some DOT resource records are not matched to DOT action records.

Set the resource category to *Equipment* and find that California dataset contains records of equipment usage for 1,134 bridges in 1,545 events costing about $2MM (Figure 25).

Resources can be filtered and reported for selections of Manufacturer and Product. In the Manufacturer box, select *Meadows,* then *Filter,* and in the Product box, select *Speed Crete.* Now select *Run* and find that California used Speed Crete in 79 maintenance events on 76 bridges at a cost of $12,965 (Figure 26).

Action Costs Tab

The *Action Costs* tab reports costs of actions listed in the NBMD Production_Table. The *Filter* and *Run* functions are similar to other tables. An initial *Run* with all selection boxes set to *Any* yields median unit costs of $648 for actions with no units, $292 for actions with *each* units, and $4.23 for actions per square foot. The values have little meaning, since these are median values for all California maintenance actions combined.

Select *Bearing* as the component, then *Filter,* then select 'BMS Bearings—Clean' as the DOT action, then *Run,* and find that among seven events at seven bridges, the median cost for cleaning bearings is $450 each (Figure 27).

Element Costs Tab

The *Element Costs* tab reports costs for actions that improve conditions of bridge elements. The method for computation of element-level costs is presented in Chapter 5. The tab in the NBMD viewer allows selection, filtering, and reporting functions equivalent to the functions of other tabs. The tab reports median values of element-level costs of improvement actions.

Select *Joint* as the component and then select *Filter.* In the *Form* box, notice that *Modular, Open,* and *Strip Seal* joints are listed. In the *Operation* box, notice that *Modify, Repair,* and *Replace* are listed (along with *Coat* and *nonMaintenance*). In the Operation box, select *Repair,* then select *Run,* and find that the median cost for joint repair is $61 per meter. In the *Form* box, select *Modular,* then select *Run,* and find that the median cost for modular joint repair is $507 per meter (Figure 28). Change the selection in the *Form* box and then select *Run* to find that for open joints the median repair cost is $8.51 per meter, and for strip seals the median repair cost is $268 per meter.

The *Write Costs* button creates a tab-text file of all element-level costs, and a list of median values of element-level costs. Press the *Write Costs* button to open a file dialog box (Figure 29). Select a directory and filename for the output file of

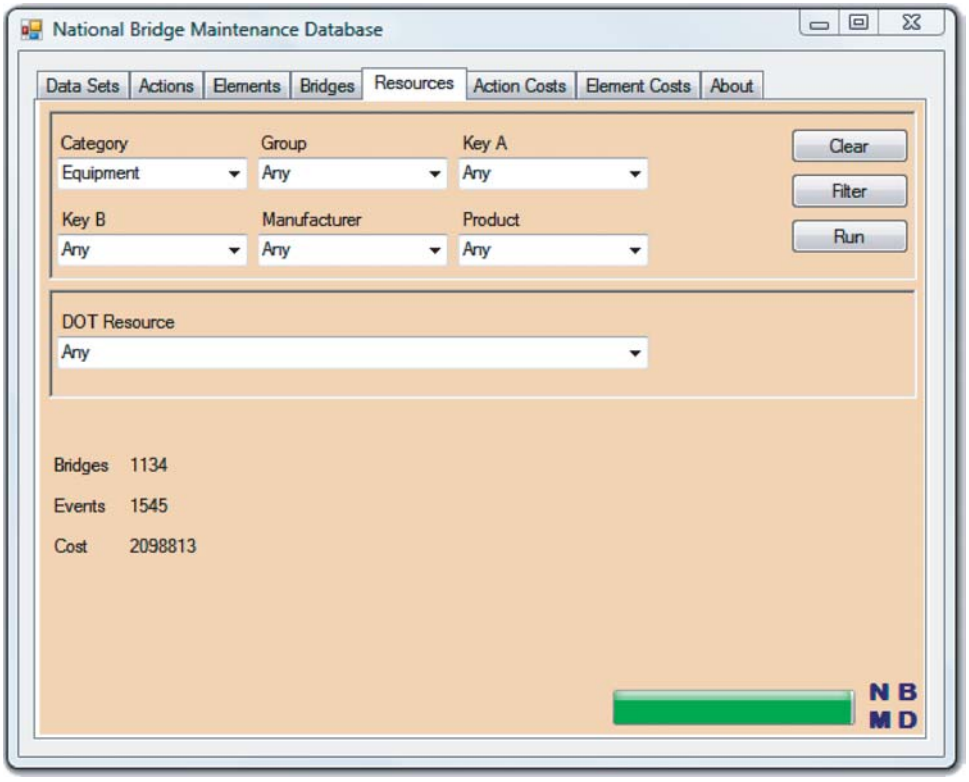


Figure 25. Resources tab.

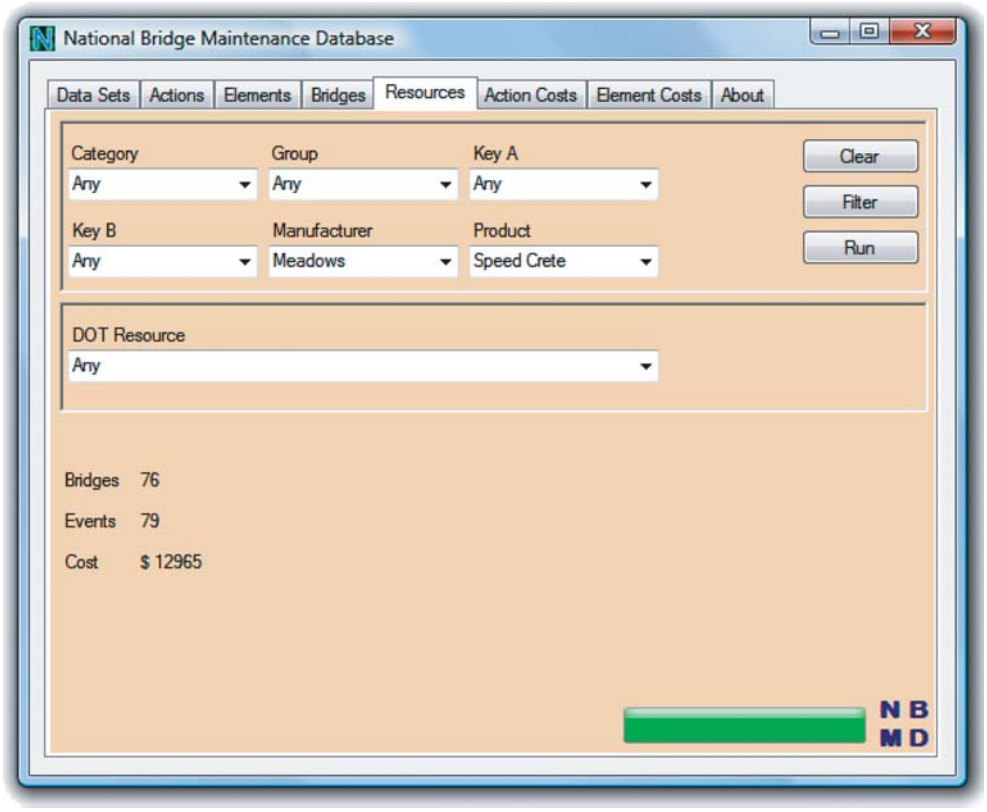


Figure 26. Material manufacturer and product.

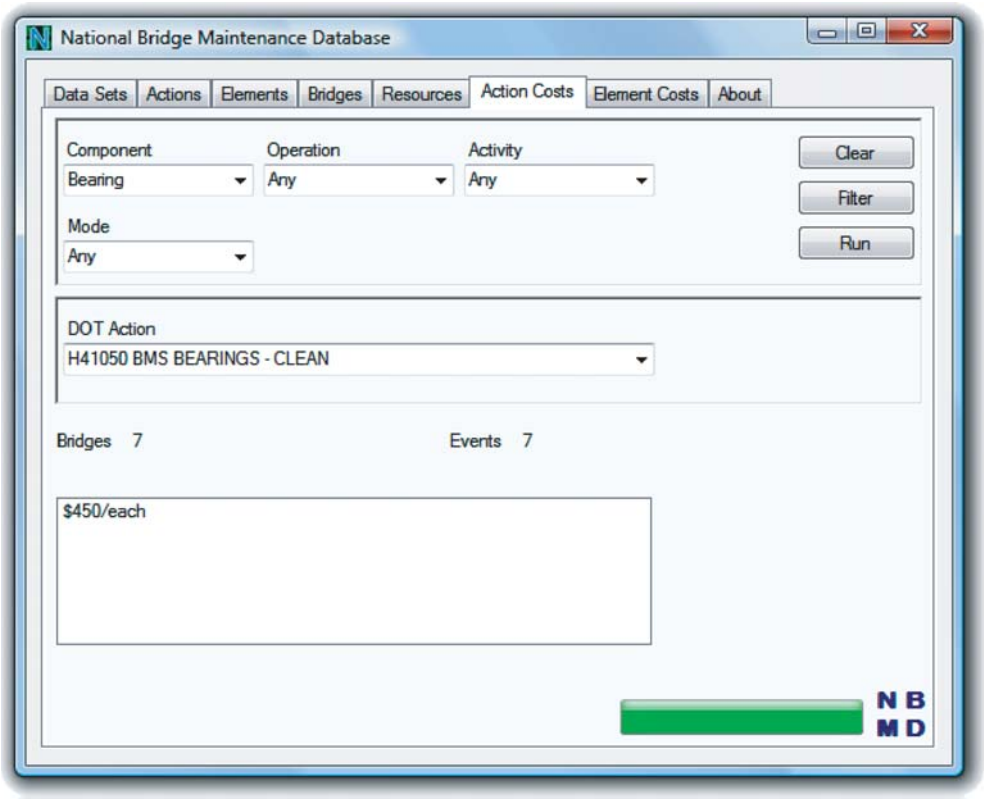


Figure 27. Action costs tab.

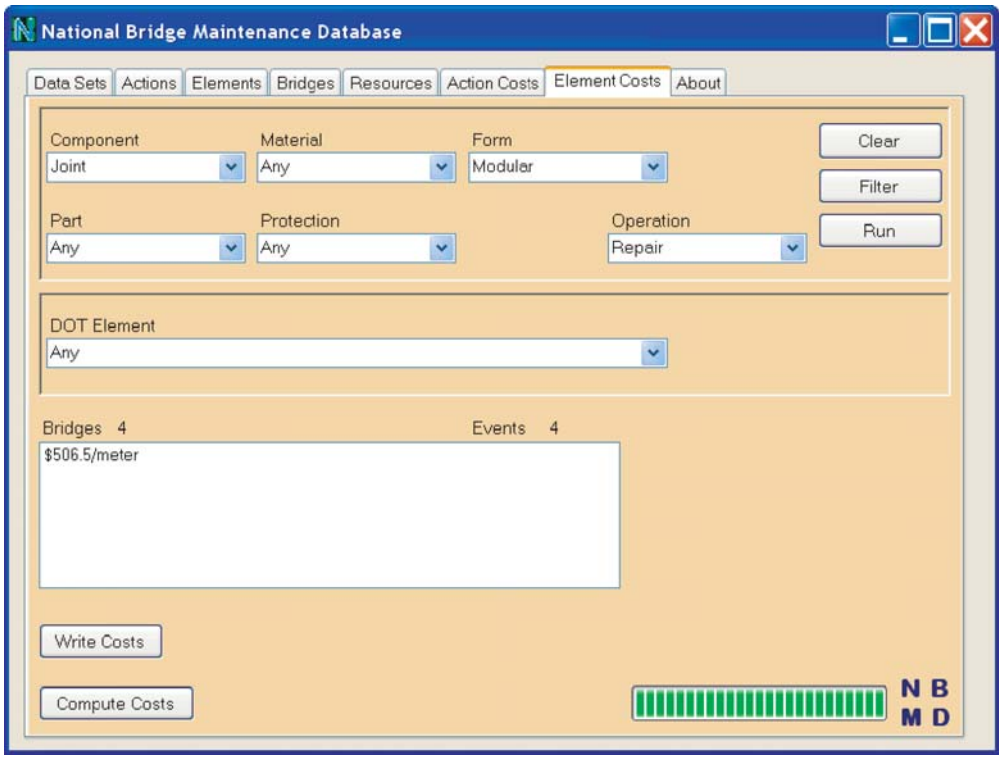


Figure 28. Element costs tab.

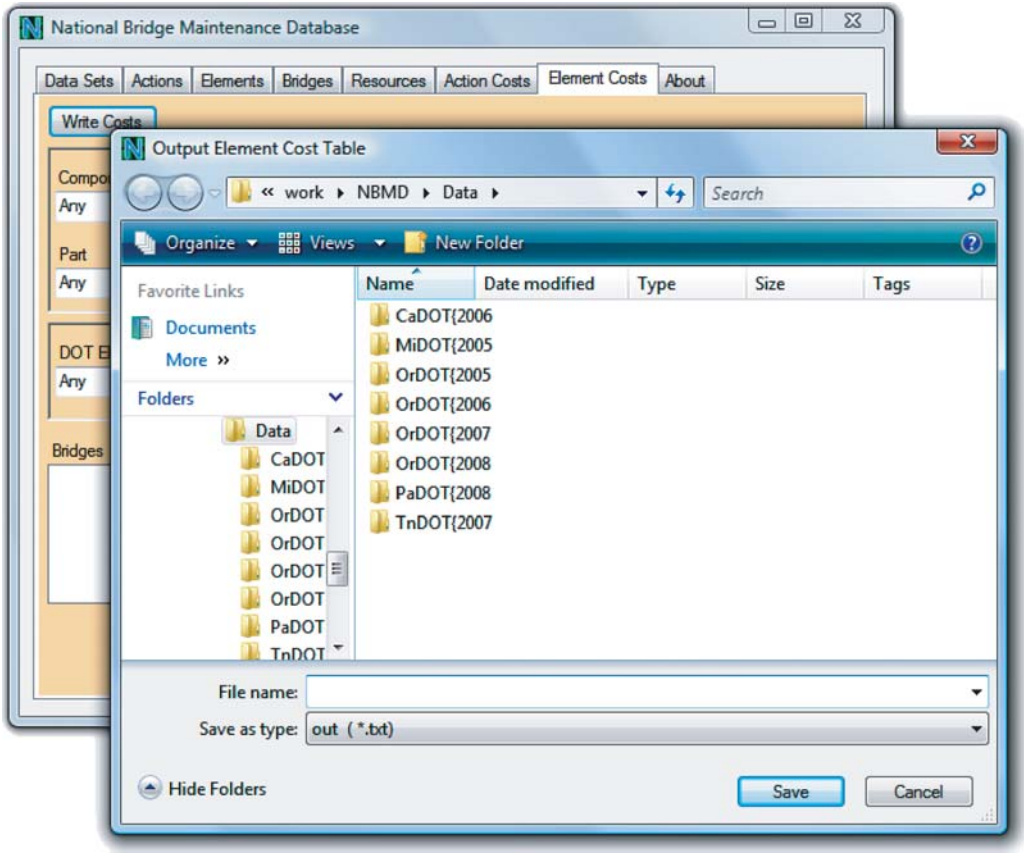


Figure 29. Element-level cost file.

element costs, and click *Save.* The operation is complete when the output file name is listed next to the *Write Costs* button. The saved file can be opened in a text editor, or in most office applications. Spreadsheets are useful for review and analysis of unit costs reported in this output file. Note that the *Write Costs* operation reports all element-level costs. Filtering operations, provided by selection boxes, are not recognized.

New values of unit costs and median unit costs are computed using the *Compute Costs* button. Costs have been computed for all datasets submitted for project, so this function isn't needed right now. The *Compute Costs* function is needed for new datasets, or to obtain median costs for merged datasets. The computation is slow.

About Tab

The *About* tab lists basic information about NCHRP Project 14-15—the project in which the NBMD framework was developed. There are no functions on this tab.

NBMD_XML Application

The NBMD_XML application creates XML documents from tab-text NBMD data tables. The anticipated use is that DOTs create text versions of NBMD tables first from their own spreadsheets and data systems, and then NBMD text tables are converted to XML documents if XML files are needed for porting to other database systems or other XML-based uses.

The NBMD_XML application requires two inputs: a standard NBMD tab-text table, and an XSD schema file. Schema files are provided for all standard NBMD tables.

To run the application, double-click the *X* shortcut in the NBMD root directory (Figure 30).

The NBMD_XML application has a single window, input buttons for *Schema* and *Data* (the NBMD tab-text table), and an output line for the completed XML document. The NBMD_XML application creates two outputs; one is an XML document and the other is a re-creation of the input text table. NBMD_XML does not overwrite existing files. Instead, newly created files are identified by the string *XmlBurp* at the end of the file name.

To create an XML document for California's production table, first load the XSD file. Press the *Schema* button, and navigate to the *xsd* directory under the root NBMD directory. A list of XSD files appears in the dialog box. Select *Production.xsd* and click *Open* (Figure 31).

The NBMD_XML application now displays the path and name of the schema at the top, and the data fields that will

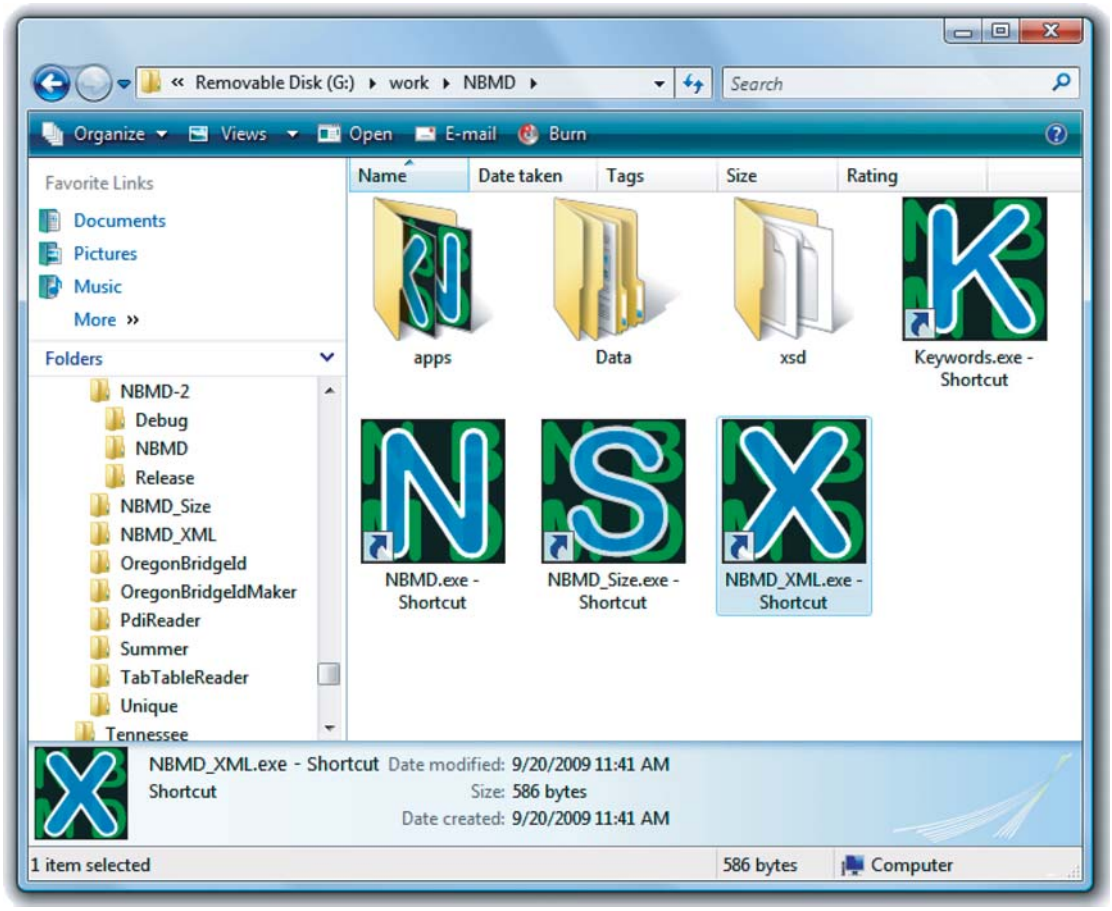


Figure 30. NBMD XML application.

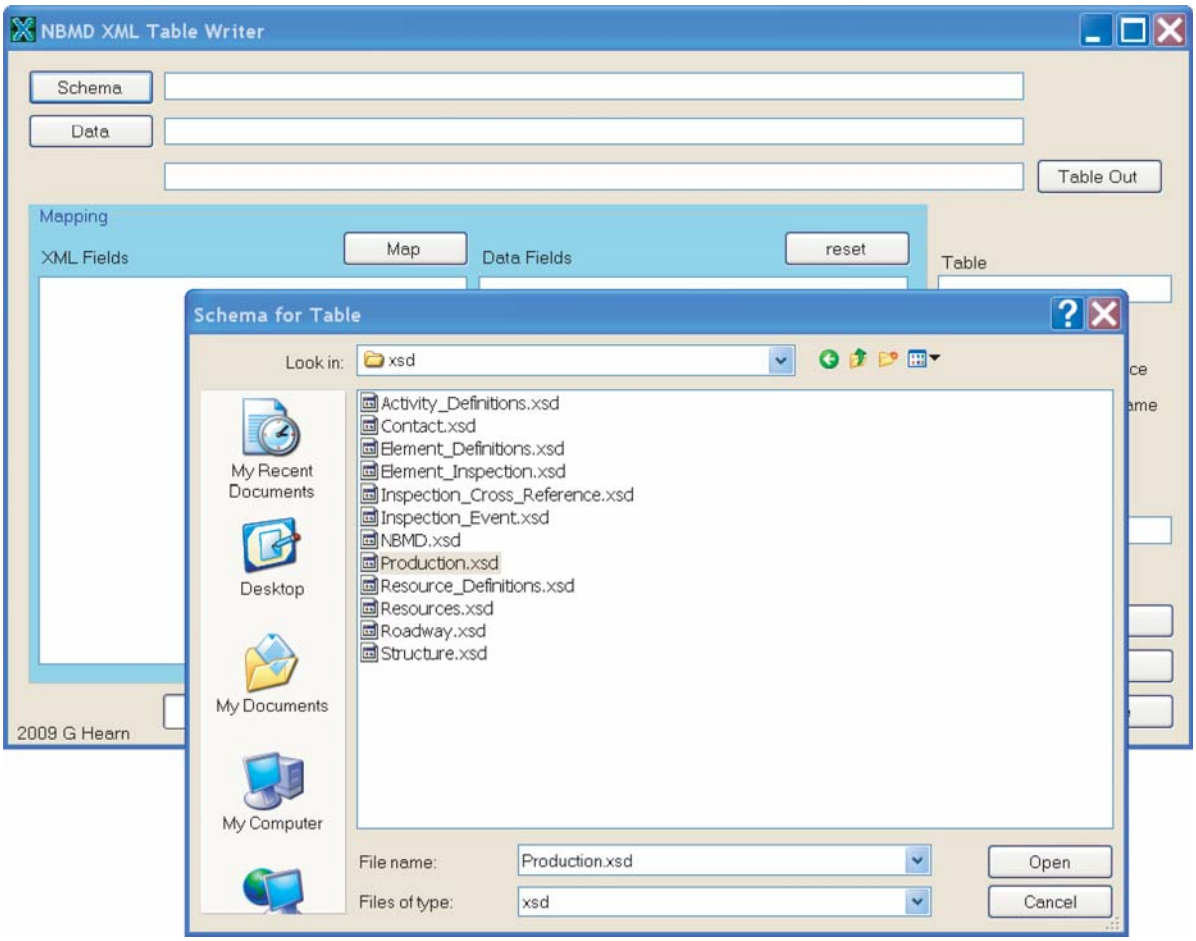


Figure 31. XML schema file.

be included in the XML document in the left-side listbox (Figure 32). There is also a default file name for the output XML document, as well as a default table name. The table name appears internally in the XML document as the main record name.

Press the *Data* button, and navigate to the California 2006 dataset. Select the Production_Table.txt file and press *Open* (Figure 33).

Once the data file is open, notice three changes in the NBMD_XML window:

1. The output file points to the directory that contains the input txt file. This is generally where the XML document should go. To select a different directory, press *Table Out,* navigate to the directory of your choice and provide an output filename.
2. The data fields available in the txt file are listed in the right-side listbox of the application.
3. The XML data fields have been mapped to corresponding txt data fields.

Mapping Data Fields

In the left-side listbox notice the following construction:

Dataset::Dataset

The construction indicates

XML_Data_Field::Text_Data_Field

The *Dataset* fields in the XML document will be obtained, record by record, from the *Dataset* fields in the text file. The *NBMD_XML* application takes field names from the XSD schema, compares these to column headings in the tab-text file, identifies matching fields, and reports the mappings. Usually, this process is automatic.

Mapping can be changed by users. In the left-side listbox, select DOT_Activity_ID, and press reset. Note that its prior mapping is removed. Select Data_Activity_ID in the left-side listbox, and NBMD_Component in the right-side listbox (Figure 34).

Press *Map*. Now the XML field for DOT_Activity_ID will be filled with entries from the NBMD_Component field. Now

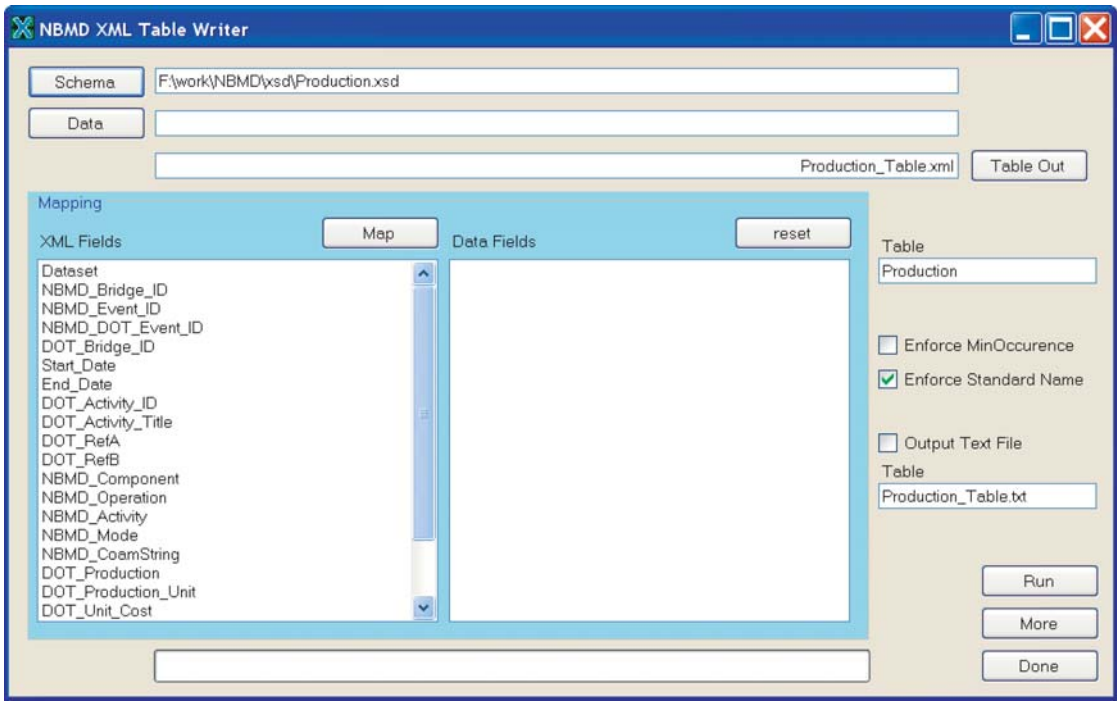


Figure 32. XML data fields.

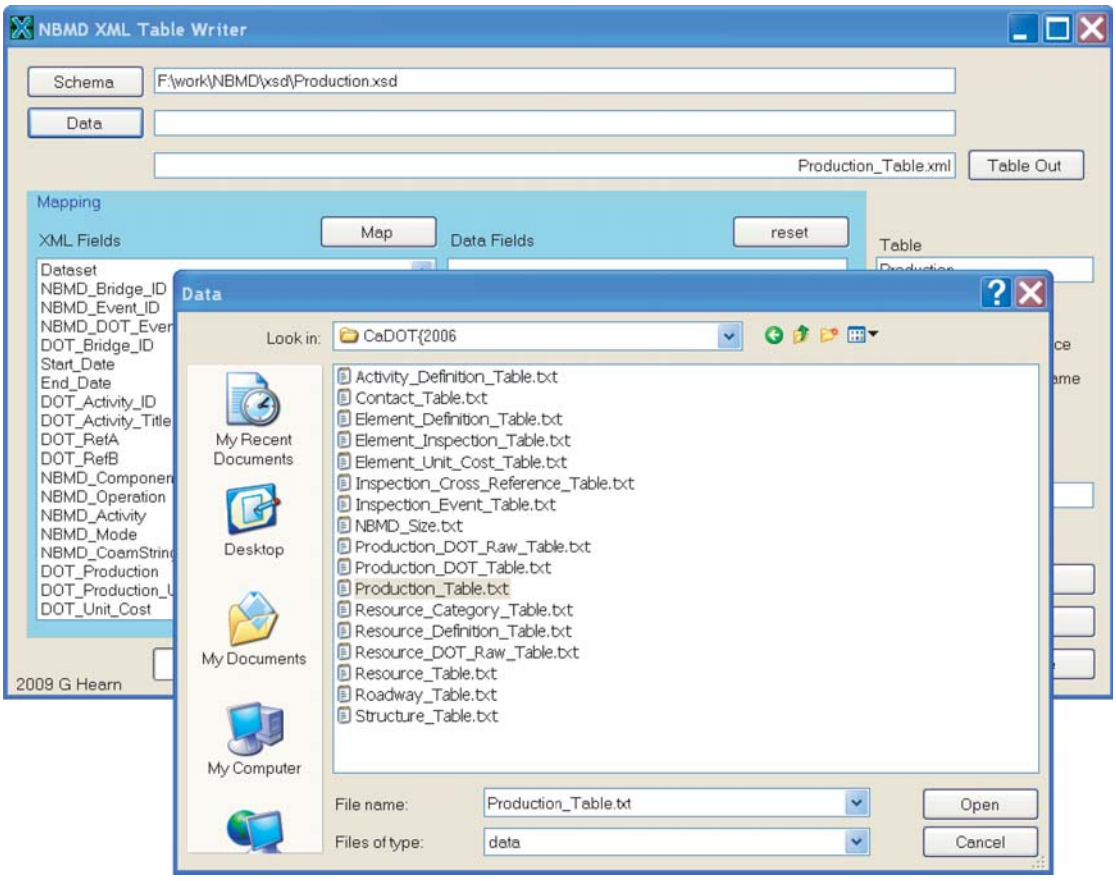


Figure 33. Tab-text table.

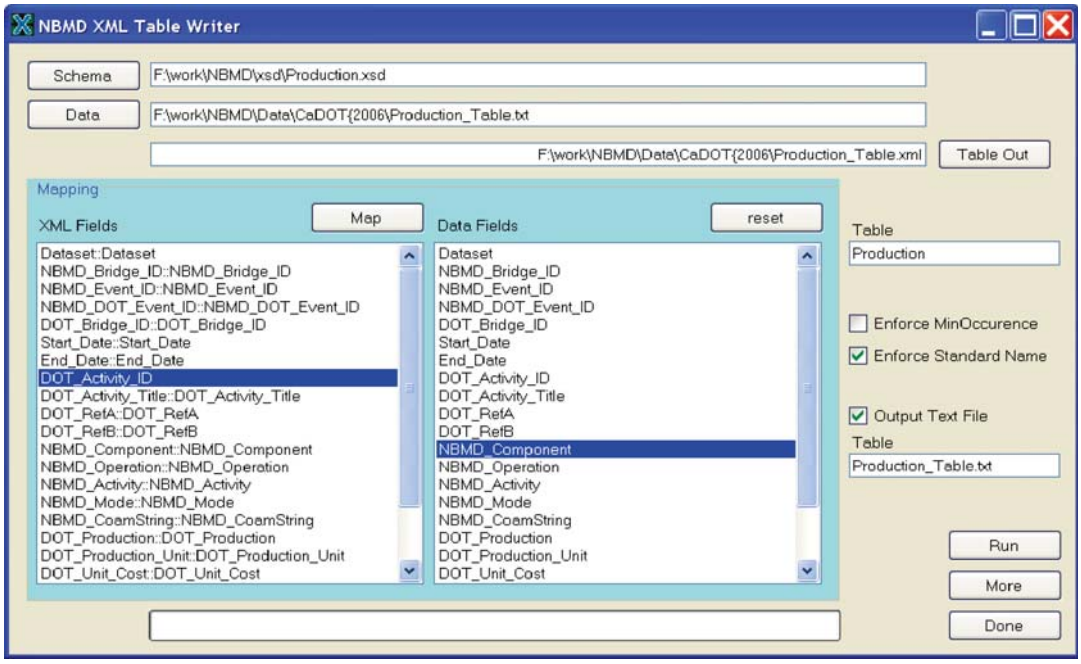


Figure 34. Mapping data fields.

restore the correct mapping. Select DOT_Activity_ID in the left-side listbox. Press reset. Select DOT_Activity_ID in box left- and right-side list boxes. Press *Map*.

To create the XML document, press *Run*. After a pause, the output file name vanishes. This indicates that the operation is complete. At this point, to exit the application, press *Done*. To create additional XML documents, press *More,* and then select schema files and text files as needed.

NBMD_Size Application

The NBMD_Size application examines NBMD text files, counts the lines in each file, and reports these counts. The reports are stored in each dataset directory. The reports are used by the NBMD viewer to create data arrays.

NBMD_Size is run for each new dataset that is deployed, and must be run if data text files are altered or updated. NBMD_Size performs a single task and offers few choices to users.

To run NBMD_Size, double click on its shortcut in the NBMD root directory. The application window offers three buttons (Figure 35). *Data Directory* is used to navigate to NBMD datasets. *Process* performs the NBMD_Size operation. *Done* exits the application.

Press *Data Directory* and navigate to the *Data* directory below the NBMD root directory. Press OK in the folder browser. The NBMD_Size window now contains the list of datasets (Figure 36).

Notice that all datasets are checked. That means that all datasets will be processed. It is necessary to process datasets

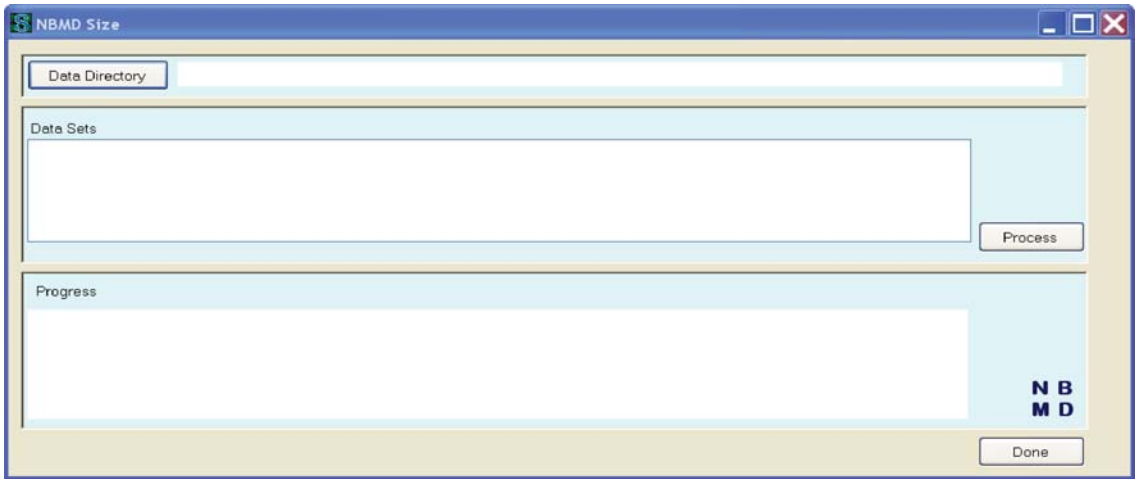


Figure 35. NBMD_Size.

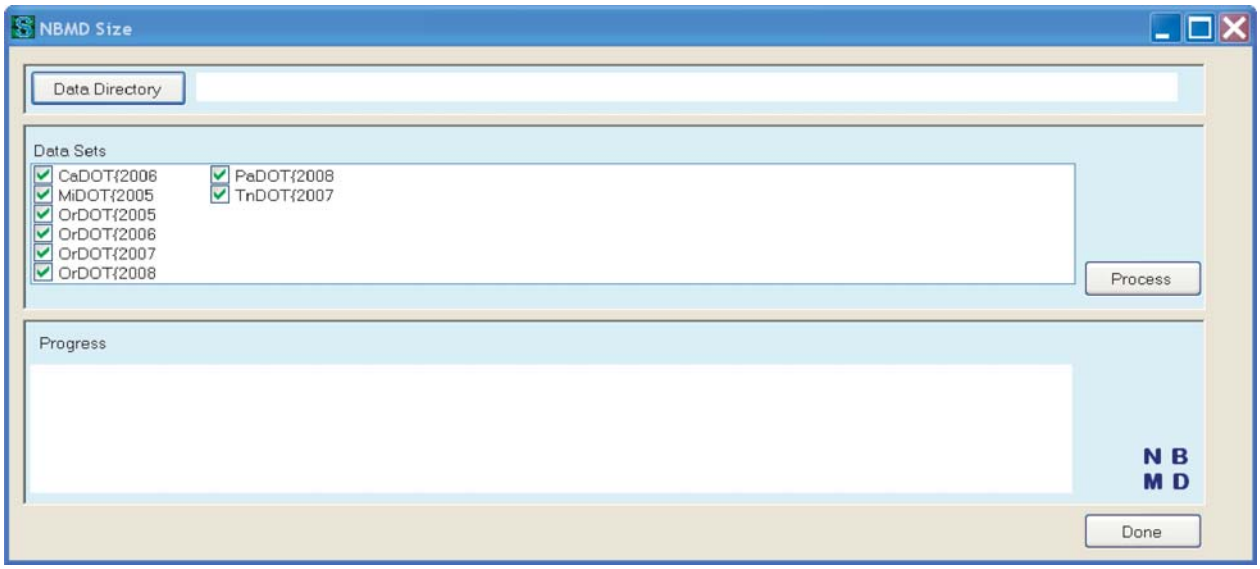


Figure 36. Datasets to process.

that have been altered or updated. It is OK to process all sets. Leave all sets checked and press *Process.* After a pause, the checks all vanish. This indicates that the application is complete (Figure 37). Press *Done* to exit.

NBMD Keywords Application

The *Keywords* application provides checking and updates of data fields for keywords and units in NBMD text tables. The *Keywords* application compares content in data files to standard keywords, and notes the nonstandard entries, if any. *Keywords* can replace nonstandard keywords based on user selections among standard keywords, or based on new keywords added by users. *Keywords* is intended for use on newly-formed NBMD data tables. Once data tables are validated, further review in *Keywords* is not necessary.

To start the application, double-click on the *Keywords* shortcut in the NBMD root directory (Figure 38).

The application window takes an input file of Keywords and an NBMD tab-text table (Figure 39). Once both are loaded, the list boxes fill with data fields of the data table. The application displays five data fields at a time. Additional fields, deeper into the data table, are accessed using the *Advance* button.

Press *Keywords,* and navigate to the *xsd* directory. The text file of standard keywords, called *KeywordList.txt,* is kept there. In the file dialog, select *KeywordList.txt* and press *Open.*

Next press the *Table In* button and navigate to the California 2006 dataset. Select the *Production_Table.txt* and press *Open* (Figure 40).

The *Keywords* application searches for NBMD keywords for Component, Operation, Material, Form, Part and Protection.

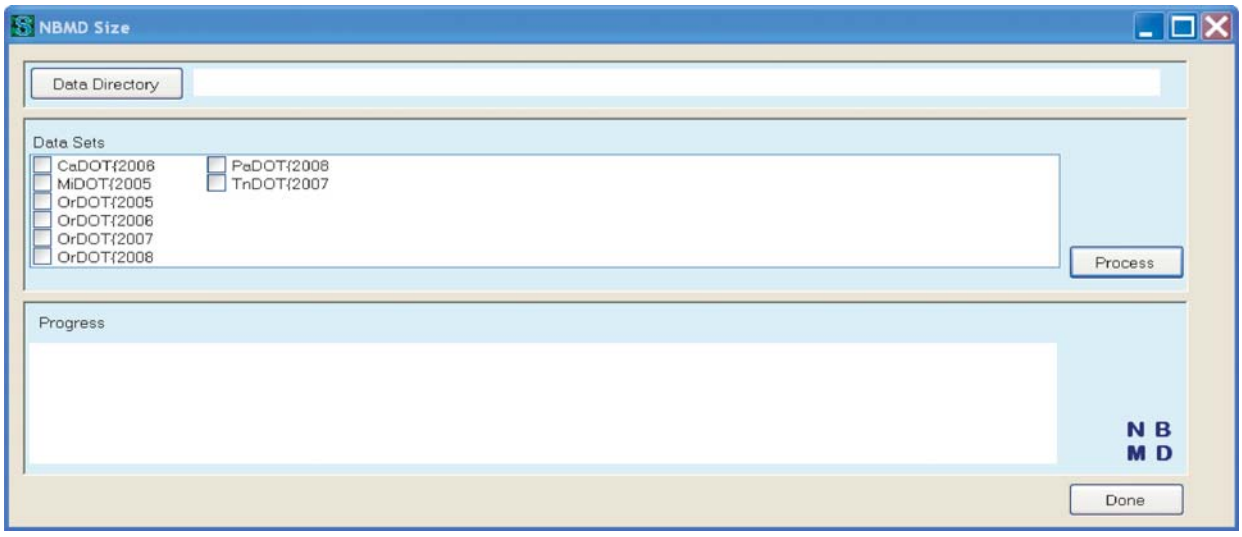


Figure 37. Dataset processing complete.

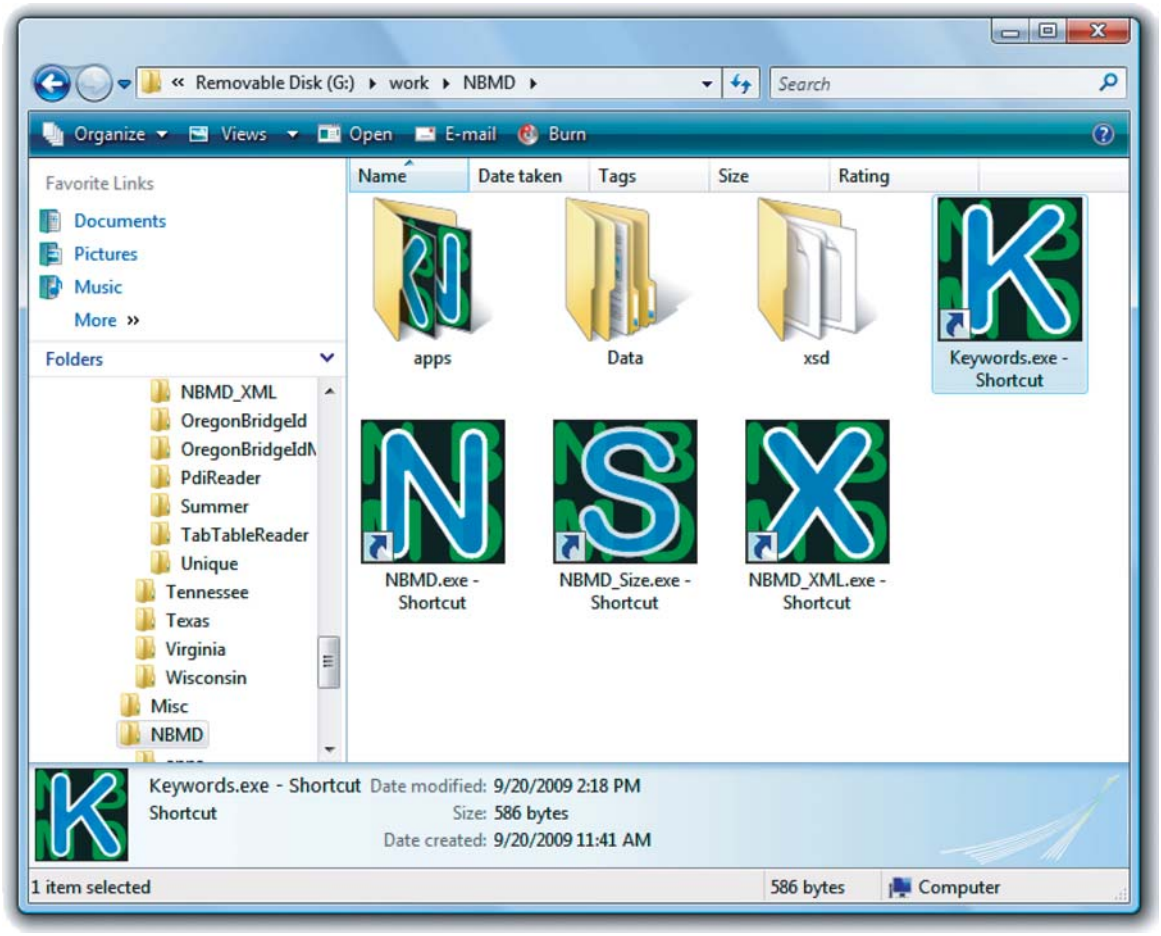


Figure 38. Keywords application.

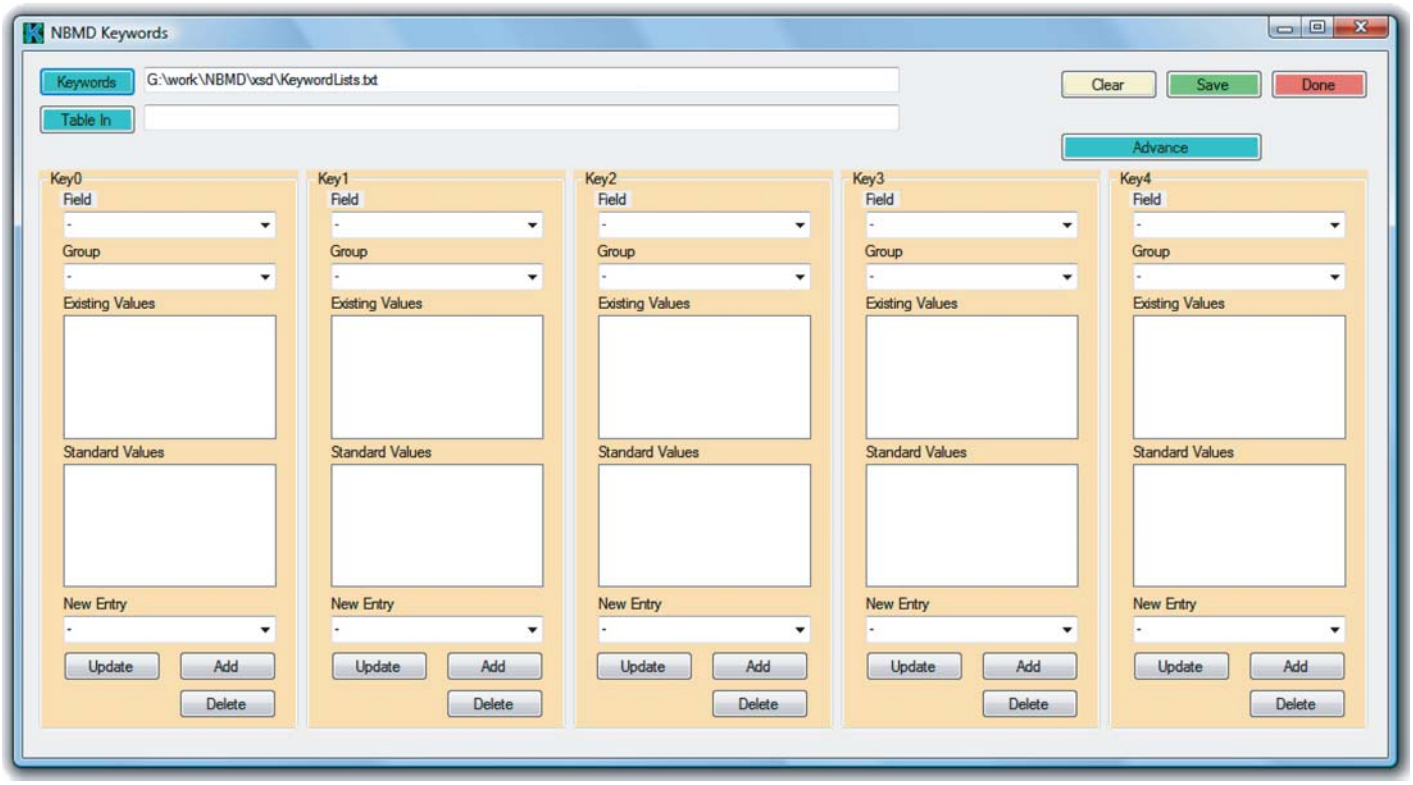


Figure 39. Keywords application window.

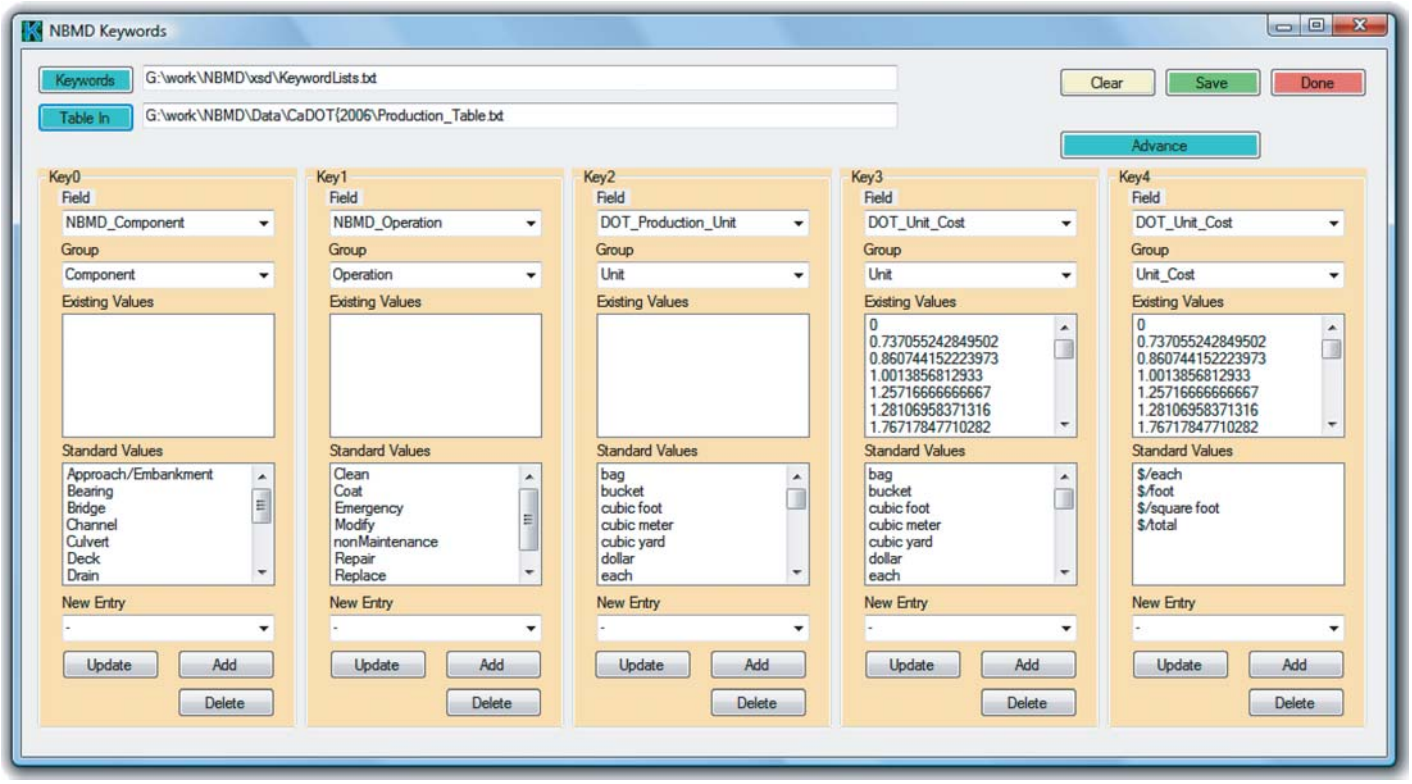


Figure 40. Keyword fields for Production_Table.

The application also searches for all data fields that include units. When a keyword field or a unit-related field is detected, the application loads the standard keywords, scans the data table for entries that differ from standards, and displays the results.

In the initial loading of this *Production_Table,* the application found the fields for component and operation, production units, and unit costs. The standard values of keywords and of units are displayed for each data field in the lower list boxes. The upper list boxes display data entries that differ from standard keywords and units. Among components, operations and production units, all entries are standard, and so no entries appear in the upper list boxes. For the unit cost field, the cost values do not (and are not supposed to) match either units or cost standard entries, so entries appear in upper boxes. No changes will be made to the unit cost quantities displayed.

Additional NBMD Software

Software utilities Assembly, Build, Inspection_Cross_Reference, NBI Reader, and PDI Reader are used for preparation of NBMD data tables. Descriptions of these utilities are provided in Appendix E.

CHAPTER 4

Data Sources for NBMD

NBMD collects data on bridge inventory, bridge conditions and bridge maintenance work. Sources for bridge inventory and condition data are standardized both by regulation and by common use of the Pontis bridge management system. Maintenance data formats, field names and content vary among U.S. state DOTs.

Bridge Inventory Data

Bridge inventory data are standardized as the content and format of the NBI Standards. Inventory data are available from the U.S. FHWA website and also from the *bridge* and *roadway* tables of the Pontis bridge database. The data sources, NBI and Pontis, are equally convenient for collection of bridge inventory data.

Bridge Condition Data

Bridge condition data, like inventory data, are standardized. The NBI record contains condition ratings for deck, superstructure, substructure, channel and culvert, as well as appraisal ratings for bridge geometry, alignment, and railings.

Many DOTs collect element-level condition data compatible with the Pontis bridge management system. State DOTs modify or add some bridge elements, and may modify condition states. The general format, though, is uniform among DOTs.

Bridge Maintenance Data

Bridge maintenance data are not standardized. There has been no federal regulation and no national-level development of systems for bridge maintenance identification, recording, and reporting. There is no dominant software package for reporting maintenance activities and accomplishments.

DOTs perform bridge maintenance with DOT crews and with contractors. Often, crews perform maintenance of lesser cost or duration. Larger projects and longer durations are executed through contracts. The two types of work use different data reporting systems.

Crew work is reported though systems that are variously identified as crew-card, day-card, or work order systems. The usual record is a report for crew activities for one day. The record, typically, will contain a bridge ID, a date, a work activity, and some information on costs. Costs may be presented as itemized lists of the equipment, materials, and personnel used at the project, or only the hours for labor, or only as overall costs. Expenditures are reported. Production, often, is not. These are systems adapted to accounting for DOT budgets for labor, materials, fleet equipment, etc.

Contract work presents a different type of data record. Data for contracts are presented as sets of bid items. Potentially, this is a great level of detail in work, and precise information on costs. Moreover, direct costs for materials and installations can be separated from indirect costs for mobilization and traffic control. A common limitation is that contracts cover all site, pavement, and bridge work required for an overall project; bridge repairs are one part of a larger project. As a result, the identification of the bridge work among a complete list of bid items, and the allocations of some quantities within bid items that provide for both bridge work and pavement work, is not apparent from the public records. That is, the list of bid items does not offer sufficient information to isolate bridge work quantities and costs.

Bridge staff at DOTs tracks contract maintenance on bridges. Many DOTs keep spreadsheets that list bridges, the contracts that deliver work on bridges, and the cost allocations to bridge work. In addition, the type of work, and year of work are recorded. NCHRP Project 14-15 uses the bridge work spreadsheet provided by Michigan DOT in preparation of the Michigan dataset for NBMD.

Table 48. NBMD data collection formats.

DOT	Inventory	Condition	Maintenance
Alabama	Spreadsheet from ABIMS	Spreadsheet from ABIMS	Tab-text files from ABIMS
California	Pontis tables as MS Access	Pontis tables as MS Access	Spreadsheet from IMMS
Colorado	NBI files	Pontis bridge database	Spreadsheet from LOS system
Michigan	Pontis bridge database	Pontis bridge database	Spreadsheet from Bridge Operations Unit
Ohio	NBI files	NBI files	Spreadsheet from TMS
Oregon	Pontis PDI files	Pontis PDI files	Spreadsheet from MMS
Pennsylvania	Spreadsheet from BMS2	Spreadsheet from BMS2	Spreadsheet from BMS2
Tennessee	Pontis PDI files	Pontis PDI files	Spreadsheet from MMS

ABIMS = Alabama Bridge Information Management System
IMMS = Integrated Maintenance Management System
LOS = Level of Service management system
TMS = Transportation Management System
PDI = Pontis Data Interchange
BMS2 - PaDOT's BMS2 has modules for bridge inspection data, bridge work recommendations, and work completion.

Data Collection

Collection of data from U.S. DOTs produced complete datasets from eight DOTs, and incomplete datasets from four other DOTs. Datasets from Alabama, Colorado and Ohio DOTs were collected in 2007, and these are formatted for an earlier version of NBMD data tables. These three sets have not yet been updated to the newer format developed in 2009. Datasets from California, Michigan, Oregon, Pennsylvania and Tennessee are in the newer format. Datasets from Minnesota, Wisconsin, and Virginia lack maintenance data.

Data sources include NBI files, Pontis BMS tables in various formats, spreadsheets of maintenance work, and tab-text files of maintenance work (Table 48). The counts of bridges, maintenance events and inspections are shown in Table 49.

Table 49. Counts of bridges, maintenance events, and inspections.

DOT	Bridges	Events	Inspections
Alabama	2915	4851	5800
California	1152	1578	4218
Colorado	3522	7034	8800
Michigan	434	444	1511
Ohio	2187	2462	4400
Oregon	1322	2475	3815
Pennsylvania	9100	12057	930
Tennessee	550	626	1857

Inspections = Counts of NBI inspections plus element-level inspections
Colorado data include years 2000 to 2007
Oregon data include years 2005 to 2008

Instances of DOT Maintenance Data

NBMD data tables for maintenance production and maintenance resources are created by identifying the correspondences between DOT data fields and NBMD data fields, and then transferring data from DOT tables to NBMD tables. DOT data headings for maintenance records and their correspondence to NBMD data fields are reported are provided in the following sections.

Alabama DOT Maintenance Data

Alabama bridge maintenance work is collected from the Alabama Bridge Information Management System (ABIMS) in reports for work by DOT crews on state-owned bridges (ABIMS report BI-10), for contract work on state-owned bridges work (ABIMS report BI-12) and for work performed on non-state bridges (ABIMS report BI-11). The contents of the reports are similar. The relation of Alabama data fields to NBMD data fields is shown in Table 50.

California DOT Maintenance Data

California maintenance data are collected in two spreadsheets: a *Production* spreadsheet and an *Expense* spreadsheet. Data fields in California's *Production* spreadsheet are mapped to NBMD *Production_Table* (Table 51). Data fields in California's *Expense* spreadsheet are mapped to NBMD *Resource_Table* in Table 52.

Table 50. Alabama DOT maintenance data.

Alabama Data Field	BI report	Note	NBMD Field Production_Table	NBMD Field Resource_Table
BIN	10,11,12	Bridge identification number	NBMD_Bridge_ID	NBMD_Bridge_ID
Year	10,11,12		Start_Date	Start_Date
Month	10,11,12			
Day	10,11,12			
Card Number	10,11	ID for work report	DOT_RefA	DOT_RefA
Activity	10,11	'B' code for maintenance work	DOT_Activity_ID	DOT_Activity_ID
Responsible	11	Maintenance responsibility		
Crew Size	10			
Labor	10	Identifies DOT personnel hours and convict hours		DOT_Resource_Quantity DOT_Resource_Category
	11	I = in-house, C = contract		
Accomplishment	10,11,12	Work production	DOT_Production	
Amount	10,11,12	Cost in dollars	DOT_Total_Cost	DOT_Total_Cost
Complete	10,11,12	Y/N		

Table 51. California DOT maintenance production spreadsheet.

California Data Field	Note	NBMD Field Production_Table
DIST	California DOT district	
WORKDATE	Date of report	Start_Date
ACTIVITY	Work action listed in California's 'H' series	DOT_Activity_ID
ACTIVITY DESCRIPTION	Title of work action	DOT_Activity_Title
WO#	Work Order Number	DOT_RefA
UNITID	Bridge ID	DOT_Bridge_ID
PROD. UNIT	Quantity produced (Accomplished)	DOT_Production
PROD. U.O.M.	Unit of measurement	DOT_Production_Unit

Table 52. California DOT maintenance expense spreadsheet.

California Data Field	Note	NBMD Field Resource_Table
DIST	California DOT district	
WORKDATE	Date of report	Start_Date
ACTIVITY	Work action listed in California's 'H' series	DOT_Activity_ID
ACTIVITY DESCRIPTION	Title of work action	DOT_Activity_Title
WORK ORDER #	Work Order Number	DOT_RefA
UNITID	Bridge ID	DOT_Bridge_ID
COST TYPE*	Token identifying equipment, labor material or other	NBMD_Resource_Category
IDCLASS	Identifying number for resource	DOT_Resource_ID
DESCRIPTION	Title for resource	DOT_Resource_Description
HOURS	Hours of usage	DOT_Resource_Quantity
TOTAL $'s	Total Cost	DOT_Total_Cost

Colorado DOT Maintenance Data

Maintenance data from Colorado DOT are presented in spreadsheets that list work activity codes and costs (Table 53). The spreadsheet is an output from Colorado's Level of Service Maintenance Management System (*15*).

Michigan DOT Maintenance Data

Michigan maintenance data are collected in a spreadsheet listing bridge contracts, work types, and allocated costs (Table 54). The spreadsheet is kept by Michigan's central bridge operations unit.

Ohio DOT Maintenance Data

Ohio DOT data are reported in a spreadsheet that contains accomplishments and resources (Table 55).

Oregon DOT Maintenance Data

Oregon DOTs crew maintenance accomplishments are reported in a spreadsheet (Table 56) obtained as output from Oregon's maintenance management system.

Pennsylvania DOT Maintenance Data

Maintenance work from Pennsylvania DOT is presented in a spreadsheet that is output from PaDOT's bridge management system (*7*). The PaDOT fields for maintenance work and the correspondence of PaDOT fields to NBMD data fields are shown in Table 57.

Tennessee DOT Maintenance Data

Tennessee DOT maintenance data are reported in three spreadsheets: Maintenance labor, maintenance equipment,

Table 53. Colorado DOT maintenance data.

Colorado Data Field	Note	NBMD Field *Production Table*	NBMD Field *Resource_Table*
Record ID			
Green Sheet	DOT unique identifier for the work record	DOT_RefA	DOT_RefA
Work Date	Date of work	Start_Date	Start_Date
Change Date	Date of data entry or revision		
Maintenance Section	DOT section		
Maintenance Patrol	DOT crew number		
Supervisor	DOT ID		
Structure ID	Bridge ID	DOT_Bridge_ID	DOT_Bridge_ID
Site			
Frontage			
Route	Route number		
Begin Reference Point	Linear reference		
End Reference Point	Linear reference		
Action Number	Maintenance activity number	DOT_Activity_ID	DOT_Activity_ID
Group Number			
Action Description	Maintenance activity title	DOT_Activity_Title	DOT_Activity_Title
Work Accomplished	Production	DOT_Production	
Unit	Unit of production	DOT_Production_Unit	
Crew Size	Number or personnel		DOT_Resource_Quantity, DOT_Quantity_Unit
Regular Hours	Crew hours		
Crew Notes		Notes	Notes

Table 54. Michigan DOT maintenance data.

Michigan Data Field	Note	NBMD Production_Table
district	DOT district	
brkey	Structure number	DOT_Bridge_ID
strc_num	Short ID for bridge	DOT_RefB
facility	Route carried	
featint	Route intersected	
job_id	Contract ID	DOT_RefA
let_date	Contract letting	Start_Date
Year	Contract let year	
strc_wk_desc	Text description	DOT_Activity_Title
rel_const_cost	Cost of bridge work	DOT_Total_Cost

Table 55. Ohio maintenance data.

Ohio Data Field	Note	NBMD Production_Table	NBMD Resource_Table
Dist.	DOT District		
County	Alpha abbreviation		
Program Activity	Programmed activity code	DOT_Activity_ID	DOT_Activity_ID
SFN	Structure File Number	DOT_Bridge_ID	DOT_Bridge_ID
Route			
SLM	Linear reference		
Old Bridge #			
Bridge Suffix	R/L		
Record Type	LB - labor		DOT_Resource_Category
Transaction Date		Start_Date	Start_Date
Equipment Number			DOT_Resource_ID
Material Code			
Resource Description			DOT_Resource_Description
Resource Quantity			DOT_Resource_Quantity
Resource UM			DOT_Quantity_Unit
Employee Number			DOT_Resource_ID
Employee Name			
Job Classification			
Hours			DOT_Resource_Quantity
Labor UM	RG – regular, OT - overtime		
Work Accompl.	Work accomplished	DOT_Production	
WA UM	Work unit of measurement	DOT_Production_Unit	

Table 56. Oregon DOT maintenance data.

Oregon Data Field	Note	NBMD Production_Table	NBMD Resource_Table
Chrge Unit	DOT crew ID		
Activity	Activity ID	DOT_Activity_ID	DOT_Activity_ID
Activity Description	Title	DOT_Activity_Title	DOT_Activity_Title
Transaction Amount	Cost	DOT_Total_Cost	DOT_Total_Cost
Fiscal Year		Start_Date	Start_Date
EA/SJ	Subjob ID	DOT_RefA	DOT_RefA
EA Description	Linear reference	DOT_RefB	DOT_RefB
Transaction Qty	Resource quantity		DOT_Resource_Quantity
Trans Code	Resource ID		DOT_Resource_ID
Trans Code Description	Resource title		DOT_Resource_Description

Table 57. Pennsylvania DOT maintenance data.

Pennsylvania Data Field	Note	NBMD Field Production_Table
5A03 BRKEY	BMS bridge key	
5A01 Structure ID	Structure Number	DOT_Bridge_ID
IM02 Element	(not used in PaDOT{2008 dataset)	
IM01 Scope	One of Bridge, Element, Flexaction	
IM03 Action Code	A743101	DOT_Activity_ID
IM03 Action Description	CLEAN/FLUSH DK	DOT_Activity_Title
IM07 Status of Work Candidate	Work is planned, scheduled or completed	
IM11 Work Assignment	Agency or Contractor	
IM14 Date Completed	Date presented as MM/DD/YYYY	End_Date
IM18 Quantity	Quantity completed	DOT_Production
IM19 Cost	Cost of work	DOT_Total_Cost
3A02 Candidate ID	DOT internal reference	DOT_RefA
3A12 Assigned Indicator	Yes / No	

and maintenance materials. The labor spreadsheet reports work production along with labor job titles, labor hours, and labor cost. The equipment spreadsheet reports fleet IDs, hours of use and costs. The materials spreadsheet reports material IDs, units of measurement, usage and costs. The relation of these fields to NBMD data tables are shown in Table 58 for TnDOT's labor spreadsheet, in Table 59 for the equipment spreadsheet and in Table 60 for the materials spreadsheet.

Applications of NBMD Data

NBMD data are used to compute element-level unit costs of maintenance actions. Demonstrations of use of NBMD were prepared with data from DOTs in Alabama, Colorado and Ohio; these are presented in Appendix D. Subsequently, changes were made to NBMD tables to improve their performance such that some initial details on data table contents and data field names have become obsolete.

Table 58. Tennessee DOT labor spreadsheet.

Tennessee Data Field	Note	NBMD Production_Table	NBMD Resource_Table
Work Date			
Bridge ID		NBMD_Bridge_ID	NBMD_Bridge_ID
Actvity #		DOT_Activity_ID	DOT_Activity_ID
Activity Description		DOT_Activity_Title	DOT_Activity_Title
Reported Accomplishment	Quantity and units	DOT_Production DOT_Production_Unit	
County Supervisor	Hours by job title		DOT_Resource_Description DOT_Resource_Quantity
Assist County Supervisor			
Floating Crew Supervisor 2			
Floating Crew Supervisor 1			
Highway Maintenance Worker 3			
Highway Maintenance Worker 2			
Highway Maintenance Worker 1			
Carpenter 2			
Carpenter 1			
Other			
Cost $		DOT_Total_Cost	DOT_Total_Cost

Table 59. Tennessee DOT equipment spreadsheet.

Tennessee Data Field	Note	NBMD Production_Table	NBMD Resource_Table
Work Date		Start_Date	Start_Date
Bridge ID		DOT_Bridge_ID	DOT_Bridge_ID
Activity #		DOT_Activity_ID	DOT_Activity_ID
Activity Description		DOT_Activity_Title	DOT_Activity_Title
Equip Tag #			DOT_Resource_ID
Equipment Description			DOT_Resource_Description
Tied-Up Time (Hrs)			DOT_Resource_Quantity
Cost ($)		DOT_Total_Cost	DOT_Total_Cost

Table 60. Tennessee DOT materials spreadsheet.

Tennessee Data Field	Note	NBMD Production_Table	NBMD Resource_Table
Work Date		Start_Date	Start_Date
Bridge ID		DOT_Bridge_ID	DOT_Bridge_ID
Activity #		DOT_Activity_ID	DOT_Activity_ID
Activity Description		DOT_Activity_Title	DOT_Activity_Title
Material #			DOT_Resource_ID
Material Description			DOT_Resource_Description
QTY			DOT_Resource_Quantity
UOM	Unit of measurement		DOT_Quantity_Unit
Cost ($)		DOT_Total_Cost	DOT_Total_Cost

CHAPTER 5

Element-Level Costs of Maintenance Actions

Basic Computation

The NBMD system in its NBMD viewer application computes costs of maintenance actions that improve conditions of bridge elements. These costs can be related to costs of Pontis actions. The NBMD implementation is valid for any condition reporting system that yields element quantities in condition states.

The unit costs of actions that improve bridge elements are

$$Unit_{Cost_{element}} = \frac{Allocated_{Cost_{element}}}{Improved_{Quantity_{element}}} \quad \text{(Eq. 1)}$$

Allocated costs and improved quantities of elements are determined by analysis of NBMD production data and associated NBMD element-level inspection data. The process has three steps:

1. Identify a maintenance event and collect element-level condition data.
2. Identify elements that are the appropriate bridge component and that show improvement to conditions after the maintenance event.
3. Allocate maintenance costs to elements.

Maintenance Events and Element Condition Data

For each maintenance event, element-level inspections before and after the event are identified in an NBMD Inspection_Cross_Reference_Table. Inspection IDs are obtained from the cross reference table and element quantities are collected into arrays. These are the element quantities for the single bridge (or culvert) in the maintenance event. Changes to element quantities, Δq_i, are computed for each condition state.

$$\Delta q_i = q_{i,post} - q_{i,prior} \quad \text{(Eq. 2)}$$

where

- Δq_i Change in element quantity in condition state i
- $q_{i,post}$ Element quantity in condition state i after the maintenance event
- $q_{i,prior}$ Element quantity in condition state i prior to the maintenance event

Values Δq_i are computed for every element of the bridge. Maintenance events that improve element conditions produce positive changes to element quantities in better condition states and negative changes to quantities in poorer condition states. Improvements will be observed for some but usually not all elements of the bridge. The total quantity (inventory) of each element is computed too, since maintenance events may alter element quantities or introduce new elements to bridges.

Identifying Elements

Elements are included in a cost computation if element component agrees with the component of maintenance actions and if elements show improvement.

Element Component and Maintenance Component

All bridge elements and some maintenance actions are associated with specific components of bridges. Elements are kept in the cost computation if their component matches the action component. Some components, such as Substructure, can admit several elements at the same bridge. One component, *Bridge,* admits all elements.

Table 61. Condition report for reinforced concrete abutment.

	Condition State			
	1	2	3	4
Reinforced Concrete Abutment	40%	20%	40%	0%

Element Improvement

The quantity of element that is improved is computed as the sum of gains in element quantities in better condition states. The improved quantity is computed as

$$Improved_{Quantity_{element}} = \sum_{i=1}^{j} \Delta q_i \qquad \text{while } \Delta q_i \geq 0 \qquad \text{(Eq. 3)}$$

Equation 3 computes improvement quantity as the sum of non-negative quantity changes in better condition states. The sum terminates before the first negative quantity changes. The transition in conditions is obtained as well. The best condition state with a negative quantity change is the prior condition for the element, the worst condition state with a positive quantity change is the post condition of the element.

An example for operation of Equation 3 is provided. Consider that a reinforced concrete abutment that has minor deterioration for 20% of its width and defects for 40% of its width. The condition report for this element is shown in Table 61.

A repair action is performed on the worst defects at the abutment. The result is that sections that had been in condition state 3 are improved to condition state 1. The condition report, after repair, is shown in Table 62.

Differences in element quantities are computed using Equation 2. Results are shown in Table 63.

Operation of Equation 3 yields an element improvement quantity equal to 40% of the element quantity. The summation includes condition states 1 and 2, but not state 3 since its change is a loss (removal, actually) of element quantity due to the effects of repair action.

Elements that show positive values of improved quantity are kept in the cost computation. Elements that do not show improvement are eliminated.

Cost Allocation

After obtaining the short list of elements that are the right bridge component and that show improvement, the total cost of the maintenance event is allocated equally to all elements.

$$Allocated_{Cost_{element}} = \frac{Event_{Total_{Cost}}}{Element_{Count}} \qquad \text{(Eq. 4)}$$

Where

$Element_{Count}$ is the number of elements in the short list

Now the unit costs for actions and elements are computed using Equation 1.

Table 62. Condition report for reinforced concrete abutment, after repair.

	Condition State			
	1	2	3	4
Reinforced Concrete Abutment	80%	20%	0%	0%

Table 63. Condition differences for reinforced concrete abutment.

	Δq			
	1	2	3	4
Reinforced Concrete Abutment	+40%	0%	-40%	0%

Element_Unit_Cost_Table

Element unit costs are reported in a table that is generated by the *NBMD* viewer application. The element unit cost table is a derived table. Its entries are collected or computed from other NBMD tables. Data fields in the unit costs table are listed in Chapter 2.

The element unit cost table contains a record for each element in each maintenance event. Records list maintenance events, components and operations for maintenance actions, inspections before and after maintenance, element identifications and units, allocated costs, inventory changes, improved quantities, and unit costs.

List of Element Unit Costs

Element-level costs are computed from data collected from the California DOT, Michigan DOT, Oregon DOT, and Tennessee DOT. Data from the Pennsylvania DOT do not have sufficient number of element-level inspections to evaluate improvement quantities for elements. The complete list of element-level unit costs of actions is presented in Appendix C. The list presents median unit costs by DOT in the order of element numbers. For each element, a matrix of costs is presented that indicates the condition state before maintenance, the condition state after maintenance, the unit cost, and the maintenance operation.

Comparison

Element-level maintenance costs are compared for bare concrete deck in Figure 41. The operations include Main-

California 12 Concrete Deck - Bare / square meter		Condition After		
		1	2	3
Condition Before	1			
	2	$ 0.30 Maint $ 106 Coat $ 1.70 Repair		
	3		$ 1.20 Repair	
	4		$ 0.82 Repair	
	5			

Michigan 12 Concrete Deck- Black Bars /square meter		Condition After		
		1	2	3
Condition Before	1			
	2	$ 11.41 Coat $ 12.81 Repair		
	3	$ 8.51 Coat $ 19.15 Repair	$ 6.94 Repair	
	4		$ 18.85 Repair	$ 52.15 Repair
	5	$ 67.08 Repair		

Oregon 12 Concrete Deck - Bare / square meter		Condition After		
		1	2	3
Condition Before	1			
	2	$ 0.07 Maint		
	3		$ 0.14 Repair	
	4		$ 0.02 Maint	
	5			

Tennessee 12 Concrete Deck - Bare / square meter		Condition After		
		1	2	3
Condition Before	1			
	2			
	3		$ 0.32 Repair	
	4			
	5			

Figure 41. Element-level costs for concrete deck.

tenance (unspecified action), Coating, and Repair. All costs are per square meter of deck. Costs are similar for California, Oregon and Tennessee, but differ strongly for Michigan. Michigan costs are taken from maintenance contract data. Costs from the other three DOTs are crew costs.

Estimates of Pontis costs for deck repairs are collected from Delaware and Louisiana and shown in Figure 42. Cost estimates from Delaware and Louisiana were collected in the 2009 domestic scan on bridge management decision-making (NCHRP Project 20-68A, Scan 07-05). The computed costs for California, Oregon, and Tennessee are in the same range of values as the estimated costs for Delaware and Louisiana.

Other comparisons may be made among DOTs for unit costs for maintenance of similar bridge elements. Some general trends are apparent. Costs for replacement are often higher than costs of repairs. Costs for repairs increase for elements in poorer condition states. However, unit costs vary considerably among DOTs and among condition states.

Condition State	% of Deck	Delaware Cost / square meter	Louisiana Cost / square meter
2	1	$ 2.01	$ 0.90
3	6	$12.08	$ 5.40
4	17	$ 34.23	$ 15.31
5	25	$ 50.34	-

Figure 42. Estimated costs of Pontis actions.

CHAPTER 6

Glossary of Terms in Highway Bridge Maintenance

Activity Guideline: An activity guideline defines each activity and identifies the activity's specific "unit of measure." The guideline also outlines the recommended process for performing the activity along with instructions for reporting its location. Other helpful instructions for reporting may also be included in the guideline (Ohio) (*19*).

Activity Numbers: Code numbers given to an activity. The last two digits in the 4 digit program activity number (Ohio) (*37*).

Annual Work Program (AWP): An annual work program is an estimate and a goal for the quantity of work to be completed for each maintenance activity in the program year. The AWP drives both budget and resource needs (AASHTO) (*13*).

Anti-Icing: The early application of temperature suppressant chemicals to prevent snow and ice accumulation or prevent a hard bond of snow and ice to the pavement. This is preventative in nature (Montana) (*25*).

Approved Annual Budget: The approved estimated cost to perform the maintenance work load for the highway system (Ohio) (*37*).

Appurtenances: Anything that pertains. Referencing roadway systems, appurtenances refer to all things associated with the roadway (Ohio) (*19*).

Asset Inventory: An asset inventory is a physical count of assets. The count may be by coordinates, milepoints, road section, geographical area, road network, maintenance section, or other convenient method of sorting and reporting the amount of assets in the road system (AASHTO) (*13*).

Asset Management System (AMS): An AMS is a business method in which organizational structure, business processes, and technologies are integrated as a total approach for maintaining infrastructure. Effectively implemented, AMS seeks to minimize the overall lifecycle cost of assets and maximize maintenance levels of service (AASHTO) (*13*).

Asset: An asset is a physical item of roadway infrastructure that has value. Assets are sometimes referred to as roadway "furniture" or "features." An asset may be a single item, such as a sign, or a linear item such as a road or guardrail section. An asset may also be a spatial item such as a rest area or mowable acreage (AASHTO) (*13*).

Atomic Data: Data items containing the lowest level of detail. For example, in a daily maintenance activity report, the individual equipment used would be atomic data, while rollups like summary totals from equipment rental invoices are aggregate data (see also aggregate data) (FHWA) (*9*).

Bank full width: Synonymous with floodplain and means the flat landscape feature immediately adjacent to most stream and river channels that begins at the edge of the bank full channel and receives over bank flow during most years (Montana) (*25*).

Berm: The paved or aggregate area just beyond the edgeline stripes (Ohio) (*37*).

Best Management Practice (BMP): Physical, structural, and/or managerial practices that, when used singly or in combination, reduce water quality and aquatic habitat impacts of maintenance activities (Montana) (*25*).

Betterment: Replacement of bridge rails and floors to a higher standard. Widening of bridges 100 ft or less between abutments. Extensions or new installation of walls involving 80 cubic yards or less of structural material. Replacement of walls to higher standard (AASHTO) (*2*).

Betterment work is work that adds a new roadway feature, expands or improves an existing roadway feature, or improves the existing roadway section (e.g., removing a bank to improve sight distance) (Ohio) (*19, 37*).

Bridge Inventory and Appraisal Code Sheets: Federal legislation has mandatory requirements that particular specified data be collected and maintained for all bridges on the public highway and street systems in Ohio. The BR-87 and BR-87A forms provide for a collection of bridge data to be used for producing various analytical and statistical

reports, which aid in the design, planning, programming, and financing of bridge maintenance and construction. The Office of Structural Engineering publishes a Bridge Inventory and Appraisal Guide. The Bridge Inventory and Appraisal Coding Guide was prepared through the joint efforts of the Office of Structural Engineering and Office of Application Services to establish policies and procedures for the creation and maintenance of a Bridge Management System (Ohio) (*19*).

Bridge Management System (BMS): BMS provides a collection of bridge data to be used for producing various analytical and statistical reports, which aid in the design, planning, programming, and financing of bridge maintenance and construction in Ohio (Ohio) (*23*).

Bridge: This term is used in a name when the function of the structure is to carry traffic over a watercourse such as a bay, canyon, river, creek, wash, or slough (California) (*22*).

All structures having an opening measured along the center of the roadway of more than 6.1 m (20 feet) between abutments or spring lines of arches or extreme ends of openings for multiple boxes. It may also include multiple pipes where the distance between the openings is less than half the smallest pipe's opening (Idaho) (*23*).

Budget Analysis: Budget analysis is a business process used to determine budget needs. In modern maintenance management practice, budget analysis allows decision makers to tie budget needs to outcomes and LOS. What if and impact scenarios can be analyzed to determine expected outcomes from various funding levels (AASHTO) (*13*).

Channel Migration Zone (CMZ): CMZ is synonymous with a 100-year floodplain and means the lateral extent of likely movement along a stream reach with evidence of active steam channel movement over the past 100 years (Montana) (*25*).

Chip Seal: A chip seal consists of liquid asphalt covered with an approved cover coat material (Idaho) (*23*).

Clear Zone: A roadside area, cleared of obstructions, designed to allow for vehicular recovery. Design area is determined by traffic speed, actual daily traffic, and horizontal curvature, and embankment slope (1996 AASHTO Roadside Design Guide) (Montana) (*25*).

Condition Assessment: Condition assessment is a physical inspection and rating of roadway assets to determine the condition of individual assets, roadway sections, or overall road networks (AASHTO) (*13*).

Consent Ordinance: The Director of Transportation needs to obtain a consent ordinance from villages to maintain the traveled portion of the roadway system within village limits, provide centerline and lane line markings, install and maintain regulatory and warning signs, and remove snow and ice (Ohio) (*19*).

Construction and Reconstruction: On structures having a span of 20′ or less, complete reconstruction to a higher standard. Complete re-construction or additions to bridges of more than 10′ span. Widening of bridges over 100′ long. Extensions or new installations of walls involving over 80 cubic yards of structural material (AASHTO) (*2*).

Construction and Materials Specifications (Spec Book): Contains detailed provisions, which, together with the Plans and the Proposal, constitute the Contract for the performance of required work. It is the official legal and technical document by which ODOT bids and constructs highway projects (Ohio) (*19*).

Construction Inspection Manual of Procedures (MOP): This manual provides construction personnel with information to perform accurate inspections of the various department construction work items (Ohio) (*19*).

Construction Management System (CMS): CMS is construction management system software created for ODOT's use statewide to track and monitor construction projects (Ohio) (*19*).

Continuous Location: A designation used to record certain roadway inventory features that occur continuously over a considerable length of highway, such as surface type, slope maintenance, etc. (Ohio) (*37*).

County Work Plan (CWP): The District, County, and Roadway Services County Work Plans identify the current conditions, 3 Year District Maintenance OPI Goals, Preventive Maintenance Goals, available resources, level of effort, projected conditions, costs, and narrative summary for the highway system in each District and respective Counties. Each CWP consists of an Available Resources, Maintenance OPI, Pavement Engineering, and Preventive Maintenance Category (Ohio) (*19*).

County Work Plan Summary: Annually, a complete CWP report will be published to summarize the State conditions, goals, resources proposed, and projected conditions (Ohio) (*19*).

Crack sealing: Crack sealing of flexible pavements is a routine maintenance activity that basically involves cleaning and filling cracks with a liquid sealant (Idaho) (*23*).

Crew Hours: The time in hours spent by a crew as a group working on an activity (Ohio) (*37*).

Critical Areas: The following areas and ecosystem: (a) Wetlands, (b) areas with a critical recharging effect on aquifers used for potable water, (c) fish and wildlife habitat conservation areas, (d) frequently flooded areas, and (e) geologically hazardous areas (Montana) (*25*).

Culverts: Metal pipe, timber, concrete culverts and other structures with less than 3 m (10 feet) of clear span measured normal to center line of feature intersected (Idaho) (*25*).

Customer Input: Customer input is documented data and information is systematically obtained from customers related to opinions, needs, expectations, and perceptions (AASHTO) (*13*).

Customer Service: Customer service is a systematic business process for responding to transportation customer needs and expectations. Customer service involves obtaining customer input on performance targets and budgets, effectively handling customer requests, and getting feedback from customers on performance (AASHTO) (*13*).

Customer: Customers are any individuals or groups who are served by or have a stake in the transportation system. They include the traveling public, taxpayer, public entity, public official, or internal entities. In modern maintenance management practices, customer input is the driving force for setting performance targets and measuring results (AASHTO) (*13*).

Danger Tree: Trees or snags, on or near the highway, that are found to be weakened, unsound, undermined, leaning, or exposed so they may fall across the highway. When permission to remove the trees cannot be obtained, it is necessary to trim and do whatever else is reasonable to alleviate the hazard (Montana) (*25*).

De-Icing: The application of temperature suppressant chemicals to remove accumulated snow and ice. This is considered reactive in nature and requires more chemicals (Montana) (*25*).

Ditch: A drainage feature that is a constructed conveyance system that collects, conveys, channels, holds, inhibits, or diverts the movement of storm water or ground water from the MDT facility and adjacent properties. It is not a channelized stream, or fish bearing stream (Montana) (*25*).

Emergency: An emergency consists of circumstances creating a substantial risk of loss, damage, interruption of services or threat to public health or safety that could not have been reasonably foreseen. An emergency is a situation involving an act of God, disasters, casualties, national defense, or security measures, etc., and includes response activities that must be taken to prevent the imminent loss of human life or property (Montana) (*25*).

Emergency Disaster Management: activities required to alleviate an emergency condition. Work activities are the same or similar to routine maintenance activities except that they are greater in magnitude and scope depending on the nature and intensity of the emergency. This work is not budgeted and/or scheduled and creates an immediate threat to life, the public, property, or environmental degradation. This includes work accomplished on a damaged highway facility/element that has substantially retained the intended functionality of its original design. It does not include construction of new roadway elements. Examples include: erection, dismantling, and maintenance of a Bailey bridge; establishment of detours and temporary minor structures; emergency traffic control; any work needed to protect and maintain the area affected by the emergency (Montana) (*25*).

Equipment Management System (EMS): A computerized equipment and materials inventory information system. EMS reports an audit trail comparing stock used with work orders. This audit report ensures that all stock items are charged out to the correct piece of equipment (Ohio) (*19*).

Equivalent Single Axle Loads (ESALs): Bridges and other structures on the state highway system are rated for capacity, usually gross and axle weight. Bridges determined to be unsafe for legal weight vehicles have signs posted that specify reduced weight limits. Stronger structures have ratings of 100 percent (maximum legal weight) and up to 150 percent (maximum permittable weight). Any single axle with a spacing of less than 16 feet between an adjacent axle is 20,000 pounds (Ohio) (*19*).

Exception Report: An output report that shows information which deviates greatly from standards (Ohio) (*37*).

Facility: The building and grounds owned and operated by ODOT (Ohio) (*37*).

Features Inventory: A list of the maintainable physical features of the highway system. For example, lane miles of pavement, lengths of ditches, fences, and guardrail and locations of culverts. The inventory also includes features that influence the work load such as ADT (Average Daily Traffic), climate, terrain, highway types, and classifications (Ohio) (*37*).

Federal Highway Administration (FHWA): FHWA is a part of the U.S. Department of Transportation and is headquartered in Washington, D.C., with field offices across the United States (Ohio) (*19*).

Forbs: A general name for any herbaceous plant, other than grass, which is found in grasslands or woodlands (Montana) (*25*).

Foreman's Manual: ODOT has compiled the TMS Foreman's Manual to aid the county and district work forces in effectively maintaining the ODOT highway system and in accurately reporting and tracking work effort and cost accounting data (Ohio) (*19*).

Geographic Information System (GIS). This is a spatial referencing system for integrating data by location using geo-coordinate referencing (AASHTO) (*13*).

Global Positioning System (GPS): A satellite-enabled technology for location referencing by x, y, and z coordinates (AASHTO) (16).

Grade Separation: A structure carrying traffic of one highway over another highway (Idaho) (*23*).

Highway Bridge Replacement Rehabilitation Program (HBRRP): Federal Highway Act which funds, regulates, and prioritizes the improvement of the nation's bridges. Only those bridges classified as "structurally deficient or functionally obsolete" and having a sufficiency rating of 80.0 or less are eligible for funding under this program (Illinois) (*16*).

Highway Maintenance Program: A highway maintenance program involves the systematic process of planning, implementing, measuring, and making improvements with highway maintenance. Decisions are based on the cost-effective use of limited resources to improve efficiency and protect the investment in the State's existing transportation infrastructure (Ohio) (*19*).

History: Any data base item where all past values for that item are stored on the data base. Inspection items are examples of items where history is retained by inspection date. Average Daily Traffic (Item 29) is an example of an item where history is not retained, since past changes in traffic volumes are not retained in the computer system (Illinois) (*16*).

Illinois Geographic Information System (IGIS): The computer system that allows a graphical display of various elements contained in IHIS (Illinois) (*16*).

Illinois Highway Information System (IHIS): The master database resulting from the combining of the individual IRIS, IRRIS, ISIS, and IGIS data bases (Illinois) (*16*).

Illinois Railroad Information System (IRRIS): The computer system and database which accommodates the entry and retrieval of pertinent information in relation to the public at grade and grade separation rail crossings (Illinois) (*16*).

Illinois Roadway Information System (IRIS): The computer system and database which accommodates the entry and retrieval of pertinent information in relation to all highways open to public travel (Illinois) (*16*).

Illinois Structure Information System (ISIS): The computer system and database which accommodates the entry and retrieval of inventory and inspection data for all structures open to public travel. The state system bridge inspections are transferred overnight from the MMIS data base (Illinois) (*16*).

Inventory Milepost: A specific location, identified by the milepost system, on the highway system (Ohio) (*37*).

Inventory Route or Key Route: Technically, the two terms pertain to the same section of highway. "Inventory Route" (also called Marked or Unmarked Route) refers to the highway identified in Items 5A-5E of the NBI record, and whose highway designation terminology can be most familiar to the traveling public. "Key Route" is defined in Items 1A-1H and is used by IDOT to uniquely identify roadway that typically can cross county and township borders, sometimes starting at one end of the state and continuing to the opposite end. Key route may be viewed as the most basic unit of identification for the Illinois highway system. Example: For an identified section of highway, there may be many Inventory Route designations assigned to the section, but only one key route designation. Key Route data is recorded for the highway(s) on and under the structure. Inventory Route Data is computer generated from the Key Route information and stored in the ISIS database. The Illinois Structure Information System will accommodate the entry of an unlimited number of routes per structure. Individual data items located on Key Route computer screens are therefore recorded individually for each route (Illinois) (*16*).

Lane Mile Agreements: An agreement between ODOT and a municipality designed to accomplish agency goals. Refer to all parts of §5521 of the Ohio Revised Code for authority and requirements for municipal and county cooperation (Ohio) (*19*).

Longitudinal Striping: The painting of centerlines, edge lines, or roadway lane lines that extend lengthwise on the roadway to provide adequate traffic control (Ohio) (*19*).

Maintenance and Repair Form 502, the Daily Work Report: The 502 form is ODOT's source document for recording details of work activities. The crew leader completes the information on the Daily Work Report by verifying the exact location where the work was performed, the number of hours worked by each employee on each activity, the miles or hours of usage for each piece of equipment on each activity, the quantity and type of material used on each activity, and the number of production units accomplished on each activity that day (Ohio) (*19*).

Maintenance: The upkeep of a highway (which includes all of its elements) in or as close as possible to its original constructed condition, or its subsequently improved condition (Ohio) (*19*).

Maintenance Activity: Any work task related to operations and maintenance. A maintenance activity may be any physical work performed on the transportation assets, or may be an administrative, support, engineering, or customer service activity. Maintenance activities are usually assigned an activity code for work reporting and tracking (AASHTO) (*13*).

A maintenance activity is a small group of associated tasks and subtasks necessary to correct a highway maintenance problem, to accomplish a betterment, or to produce a material. An activity can also describe an indirect related task such as yard work, supervision, etc. (Ohio) (*19*).

Maintenance Activity Guideline: A maintenance activity guideline is a general guide specifying how maintenance activities should be performed to achieve maximum productivity and work quality. The guideline specifies resource needs, production planning rates, scheduling criteria, and high-level work methods (AASHTO) (*13*).

Maintenance Administration Manual: The Maintenance Administration Manual is a compilation of procedures, protocol, and directives regarding ODOT's maintenance activities. The Office of Maintenance Administration has gathered, reviewed, and updated the information and produced the manual as a reference tool for the district and county work forces. The manual contains years of

experience, research, and education and is intended to be a living document that will be updated as technology and research evolve (Ohio) (*19*).

Maintenance Index: The Maintenance Index is part of the overall Organizational Performance Index, which is the scoring system index by which maintenance efforts and system conditions are compared to ODOT goals (Ohio) (*19*).

Maintenance Level of Service (LOS): Maintenance levels of service measure the condition of individual assets as well as the overall condition of the roadway. LOS measures are generally specified in customer service terms related to safety, preservation, convenience, aesthetics, comfort, and mobility. Some states also measure LOS in terms of environmental impacts or legislative mandates (AASHTO) (*13*).

Maintenance Management (MM): The actions associated with organizing, administering, and supervising highway maintenance activities, customer services, and infrastructure preservation (AASHTO) (*13*).

Maintenance Management Information System (MMIS): The computer system and database that accommodate the entry of state bridge inspections. This system also contains numerous other state-maintained data information and functions (Illinois) (*16*).

Maintenance Management System (MMS): Similar to an asset management system, a modern MMS integrates organization structure, business processes, and technology to provide a systematic approach for planning and executing an efficient customer-oriented and performance-based maintenance program (AASHTO) (*13*).

A specialized budget and accounting system for managers. The MMS is used for work planning, scheduling, performance evaluation, budgeting, and expenditure control of maintenance activities (Montana) (*25*).

Maintenance Program Activity Code: The Transportation Management System uses program activity codes (PGAC) to group associated tasks and sub-tasks necessary to maintain our highway system. Examples of these PGAC codes are pothole patching, snow and ice control, pavement markings, and facility maintenance (Ohio) (*19*).

Maintenance Quality Assessment: Maintenance quality assessment is a process of physically inspecting and rating the condition of the roadway assets and maintenance services. The quality assessment employs the same measures used to set performance targets. The data from the maintenance quality assessment is used to assess outcomes, actual performance, and maintenance LOS (AASHTO) (*13*).

Maintenance Quality Assurance Review: It is ODOT's policy to use a Quality Assurance Review (QAR) process to ensure organizational units within ODOT adhere to all laws, regulations, policies, and standard operating procedures in carrying out ODOT's day-to-day business. Responsibility for conducting QARs is vested in Central Office Divisions and Offices (Ohio) (*19*).

Maintenance Quality Survey (MQS): The purpose of the maintenance quality survey is to develop numerical data for rating the performance of the highway maintenance activity. The procedures vary for the different highway elements. This is necessary because certain conditions occur with a greater frequency than others (Ohio) (*19*).

Major Defects: Some defects are considered major because they involve individual members that affect structural stability of an entire span thus requiring underpinning of the span or supplementing of the member before removal. Other defects are included in this group because the measures needed to correct defects are numerous and varied requiring structural or other technical advice or the defect may cause equipment failure (California) (*22*).

Major Maintenance: Bridge rehabilitation, reconstruction, or replacement. Replacement of structures only as a result of major disaster when no other funds or programs are available (Texas) (*21*).

Microsurfacing: Microsurfacing is a polymer-modified cold paving slurry seal system (Idaho) (*28*).

Milepost Marker: A sign identifying a specific location on the highway system (Ohio) (*44*).

Minor Defects: Minor defects are those which can be corrected with little or no risk of structure collapse or rendering of damage to adjacent or related members while making repairs or replacements (California) (*22*).

MQS Manual: The maintenance quality survey manual describes highway conditions, which are referred to as "Recordable Conditions." The recordable conditions are not necessarily maintenance deficiencies. The entire highway system will be surveyed over a 12-month (four quarters) time frame (Ohio) (*19*).

MQS Teams: Two (two person) Central Office teams survey approximately one fourth of each County in the State every 3 months for recordable maintenance conditions and deficiencies. The entire County (every centerline mile) is surveyed once over a 12-month time frame (Ohio) (*19*).

Multi-Year Work Plan: Ellis, the ODOT's Web-based project management system, contains the contracted portion of ODOT's long-term plan for maintaining ODOT's assets. The District Multi-Year Work Plans are a subset of this long-term plan. The goal of the District Multi-Year Work Plan is to develop a fiscally constrained work program that assures safe, reliable, efficient, and accessible, travel conditions, while maintaining bridge and pavement assets at agreed upon performance levels (Ohio) (*19*).

National Bridge Inspection Program (NBIP): The program developed by the Federal Highway Administration (FHWA) as a result of the Federal-Aid Highway Act of 1968, which requires the inventory and inspection of the nation's bridges (Illinois) (*16*).

National Bridge Inspection Standards (NBIS): The federal regulations establishing requirements for inspection procedures, frequency of inspections, qualification of personnel, inspection reports, and preparation and maintenance of a state bridge inventory (Illinois) (*16*).

Office of Maintenance Administration: The Office of Maintenance Administration is a section of Central Office Highway Operations that cooperates with local governments to provide necessary resources to restore roadways to normal conditions during times of disaster. It provides technical assistance in highway maintenance and construction engineering matters internally and externally of ODOT. Services offered include: Maintenance Quality Surveys, Maintenance Quality Assurance, Maintenance Efficiency Analysis, Transportation management System, Winter Maintenance Coordination, and Maintenance Policy Development and Implementation (Ohio) (*19*).

Office of Pavement Engineering: The Pavement Engineering section is part of Central Office Planning. This section provides the Districts with standards, policy, procedures, data, and research to allow them to provide smooth, quiet, cost effective pavements for the traveling public at a minimum of inconvenience (Ohio) (*19*).

Office Of Structural Engineering: Structural Engineering is a section of Central Office Highway Operations and provides ODOT districts with standards, policy, procedures, training, design resources, data, and research to allow them to continually monitor and improve the quality of ODOT's bridge inventory. This support will enable them to provide safe, cost effective, durable and smooth riding bridges for the public, along with providing bridges that meet the needs of Ohio's growing economy (Ohio) (*19*).

Office Of Traffic Engineering: Traffic Engineering is a section of Central Office Highway Operations and provides technical assistance and consultation on traffic engineering matters. It coordinates ODOT's safety improvement program, which make funds available to local governments for safety improvements at high accident locations. The office provides time lapse photography services in order to film hazardous locations and traffic operational problems, for further analysis. It develops, prepares, and distributes the Ohio Manual of Uniform Traffic Control Devices and a traffic application standards manual to ensure consistent application and design of traffic control devices. It also provides review and consultation to local governments regarding traffic control devices and highway lighting design and application (Ohio) (*19*).

Operation and Maintenance (O&M): Operations and maintenance encompasses all of the activities and services required to maintain infrastructure assets and provide services to the traveling public. O&M can generally be viewed as any activity other than new construction, roadway capacity improvements, expansion, or major rehabilitation (AASHTO) (*13*).

Organization Unit: An organization unit is a defined unit within the agency or department that has specified maintenance responsibilities. An organization unit may be a county, a maintenance section, district, region, or statewide unit (AASHTO) (*13*).

Organizational Performance Index (OPI): The OPI provides monthly information based on key performance areas for Plans, Highway Management, Construction Management, Maintenance, Highway System Conditions, Snow and Ice, Human Resources, Finance, Contracts, Equipment, and Facilities (Ohio) (*19*).

Outcomes: Outcomes are similar to levels of service and specify the overall results achieved from the maintenance program (AASHTO) (*13*).

Overcrossing: This term is used in the name of a structure which carries State highway traffic and provides for passage of a city street, county road or other facility other than a railroad or another State highway, under the State highway (California) (*22*).

Overhead: This term is used in a name when the function of the structure is to carry a State highway over a railroad (California) (*22*).

Overpass: A grade separation where the subject highway passes over the intersecting facility (Idaho) (*23*).

Pavement: The paved area between the edgeline stripes (Ohio) (*37*).

Pavement Condition Rating (PCR): A numerical rating of pavement distresses on a 0 to 100 scale based on visual inspection. A PCR of 100 signifies a perfect pavement with no distress (Ohio) (*19*).

Pavement Management System (PMS): The intent of the pavement management program is to select, design, and construct pavement management treatments in an expedited fashion to extend pavement life and maintain the pavement surface at the highest possible level of serviceability. The PMS can be accessed by General Query Language (GQL), which can be used to provide a first cut list of candidate projects for all of the pavement management treatments (Ohio) (*19*).

Performance Measure: A performance measure is used to rate asset condition or maintenance performance. Sample measures include height of grass, number of potholes per lane mile, and percent of signs below standard (AASHTO) (*13*).

Performance Target: A performance target is a goal or objective for the condition of assets or the road system. A performance target is usually a numerical rating, such as "pavement drop-off less than x inches." Performance targets vary by level of service (AASHTO) (*13*).

Performance-Based Budget: A performance-based budget is based on the annual work program. For the budget to be

performance-based, the annual work program must be linked to specified performance targets, level of service, or expected outcomes (AASHTO) (*13*).

Physical Maintenance: Cleaning, painting, and repairing. Replacements (using approximately same design) of rails, floors, stringers, or beams. Replacement of walls in kind. Repair of drawbridges and ferries (AASHTO) (*2*).

Present Serviceability Index (PSI): The PSI is a measure of pavement surface roughness or riding comfort. It is measured on a scale between 0 and 5, with 5 being a perfectly smooth ride (Ohio) (*19*).

Preventative Maintenance Category: The County Work Plan has a Preventive Maintenance category. The category requires specific maintenance with specific cycles for each identified maintenance activity. The activities encompass traffic control, vegetation management, surface cleaning, underdrain cleaning, and bridge preventive maintenance (Ohio) (*19*).

Preventive Maintenance: PM is a planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, extends the service life, and maintains or improves the functional condition of the system without substantially increasing structural capacity (Ohio) (*19*).

Steel structure cleaning and repainting or the installation of other coatings; installation of bridge deck protection; joint cleaning and sealing or replacement (Texas) (*21*).

Pre-wetting: The controlled application of temperature suppressant chemicals to "burn" or "stick" abrasives to snow and ice pack (Montana) (*25*).

Productivity: For each activity, the number of work units produced per person hour. Also, expressed as the number of work units produced by a standard size crew per day (Ohio) (*37*).

Program Activity Code (PGAC): The transportation management system uses PGACs to group associated tasks and sub-tasks necessary to maintain our highway system. Examples of these PGACs are pothole patching, snow and ice control, pavement markings, and facility maintenance. The detail labor, materials, equipment use, and actual costs associated with these three components will generate a work accomplishment and a performance measurement for each PGAC (Ohio) (*19*).

Pumping Plant: This term is used in the name of a facility that is assigned a bridge number because it is an intricate facility of structural, mechanical, and electrical combination for the purpose of preventing inundation of the highway (California) (*22*).

Quality Level: The specified level to which elements of the highway will be maintained (Ohio) (*44*).

Quality Standards: Guide line showing the level of maintenance to be attained for each activity (Ohio) (*44*).

Quantity Standards: For each activity the estimated number of work units per inventory unit that must be performed each year to maintain Quality Standards (Ohio) (*44*).

Reactive Maintenance: Reactive maintenance involves activities undertaken to correct defects and extend the life of the asset until a proper rehabilitation or reconstruction project may be undertaken. Reactive maintenance is frequently performed on a failing asset. It is a stopgap measure that keeps the asset at an acceptable serviceability, and is seldom cost-effective (Ohio) (*19*).

Resources: Labor, equipment, and material available, needed or used to perform an activity (Ohio) (*37*)

Riparian Area: The 300-foot (91.4 meter) slope distance from either side of the Channel Migration Zone (CMZ), or bankfull width, whichever is greater (Montana) (*30*).

Roadway: The area between the Right-of-Way limits including pavement, berm, shoulder, ditches, etc., (Ohio) (*37*).

Routine Maintenance: Budgeted work, performed routinely on a scheduled basis. It is intended to maintain the highway facility/element so that it substantially retains its original intended use and function. Examples include: sweeping and debris removal; cleaning ditches, culverts and catch basins; correcting moderate slides and slope failures; vegetation management and litter pickup; routine bridge maintenance; rest area operation and maintenance; pavement patching, crack sealing and routine surface treatment; restoration/replacement of traffic control devices; maintaining access control; drainage restoration; placing riprap; snow and ice removal; traffic control (Montana) (*25*).

(1) the maintenance which keeps a highway including all of its elements in or as close as possible to its original constructed condition or its subsequently improved condition and (2) those traffic services and operations which provide safe, convenient, and economic highway transportation for the public (Ohio) (*37*).

Repair of substructures, superstructures, decks, joints, approach slabs and railing; spot painting; repair and operation of movable bridges; installation of temporary bridges; repair and installation of fender systems (Texas) (*21*).

Sensitive (Critical) Areas: Sections of highways or highway features, the maintenance of which would detrimentally impact (directly or indirectly) fisheries or other aquatic species or habitat. Sensitive areas include: spawning streams and those inhabited by federally listed sensitive aquatic species, especially trout and other listed or candidate fish; those impaired water segments listed on Department of Environmental Quality's 1996 "Section 303(d) List" for Total Maximum Daily Load (TMDL) Plan development and restoration; those receiving direct runoff from treated roads and highways where there would be less than 100:1 dilution; those where a large volume of

highway runoff can directly reach small, poorly flushed ponds, lakes and wetlands; those where receiving water temperatures have warmed by the time highway runoff arrives; those areas where shallow ground water is overlain by coarse and permeable soils; facilities that allow surface water access to underground aquifers (Montana) (*25*).

Separation: This term is used in the name of a structure which carries traffic of one State highway over another State highway (California) (*27*).

Short Spans: All structures 6.1 m (20 feet) or less, as defined under "Bridges." Structures with a clear span of less than 3 m (10 feet), measured normal to center line of features intersected are not included in the inspection program (Idaho) (*23*).

Shoulder: The area between the berm and foreslope or edgeline and foreslope (Ohio) (*37*).

Slurry Seal: A slurry seal is a mixture of asphalt emulsion, well-graded fine aggregate (sand), and mineral filler mixed with water to produce slurry consistency (Idaho) (*23*).

Spot Locations: The exact location of certain roadway features such as bridges, culverts, rest areas, intersections, etc., as opposed to continuous locations. Spot locations are measured to the nearest 1/100th of a mile (Ohio) (*37*).

Structural Deduct (SD): Contained within the pavement condition rating process. It indicates those distresses which may be related to the structural integrity of the pavement (Ohio) (*19*).

Structure Information Management System (SIMS): A version of the ISIS database information in a PC Microsoft Access database format. Information is copied nightly from the ISIS database to the SIMS Access database where users can view data and generate reports (Illinois) (*16*).

Swath Mile: A 5-feet wide mowing cut, 1 mile long (Ohio) (*37*).

Thalweg (Montana Ref 30): the line extending down a channel that follows the lowest elevation of the bed.

Traffic Services. (AASHTO Ref 2) Operation of ferries, including cost of power, operators, and periodic replacements. That part of operation of drawbridges charged to highway traffic.

Transportation Management System (TMS)—The TMS is a work order driven computer program that tracks work accomplishments and actual costs for labor, equipment, and materials used by our workforce. The purpose of the TMS is to have current data available for ODOT managers to analyze and utilize in decision-making (Ohio) (*19*).

Tube. This term describes an underwater roadway facility constructed by lowering a prefabricated section in an excavated trench (California) (*22*).

Tunnel. This term refers to a roadway section through a mass of earth. Some undercrossings and separations are also tunnels (California) (*22*).

Underpass: This term is used in a name when the function of the structure is to carry a railroad and provides for passage of a State highway under the railroad (California) (*22*).

A grade separation where the subject highway passes under the intersecting facility (Idaho) (*23*).

Unit Cost: The total cost of labor, equipment and material needed to perform a unit of work, e.g., $/cubic yard, $/lane mile (Ohio) (*37*).

Unit of Work: The unit of measure used to describe the quantity of work performed for each activity, e.g., cubic yards, linear feet, person hours, etc. Also called unit of accomplishment (Ohio) (*37*).

Unscheduled Maintenance: Unanticipated activities that occur due to the unusual weather condition, vandalism, accident, etc. Work activities are conducted similar to routine maintenance activities except that work is unanticipated and poses imminent danger to the existing structures or traveling public. In cases of imminent danger, work will be only to repair existing structures, move obstructions, restore banks, protect property, or protect fish resources, to the serviceable function of its original design. It does not include construction of new roadway elements. Examples include: stream bank protection; bridge maintenance such as debris removal, scour abatement (approaches, abutments and piers); repair slides and slope failures; repair of culverts (Montana) (*25*).

Viaduct: This term is used in the name of a structure of any length, which carries State highway traffic along a steep side hill. It also is used as a compromise name for a long structure crossing over several facilities of approximately the same importance, any one of which alone would require a name category of Bridge, Overhead, Undercrossing, or Separation (California) (*22*).

Workload: The amount of work required to maintain the highway to a specified level. Workload applies to a given activity for a specific time period (Ohio) (*37*).

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APPENDICES A THROUGH E

Appendices A through E provide detailed information on the different aspects of the research. These appendices are not published herein, but they are available on the *NCHRP Report 668* summary webpage at http://www.trb.org/Publications/Blurbs/164203.aspx.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation