Development of a User-Friendly Bridge Information System - Phase II:

Report 2: Public-Private Partnerships: Exploring the National Bridge Inventory with a Customized Bridge Information Software Application

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<td>The National Bridge Inventory (NBI) Database as maintained by the Federal Highway Administration contains detailed information on approximately 600,000 public highway bridges spanning a period of two decades. While the NBI Database constitutes the most comprehensive source of publicly available information on the condition of the nation's bridge infrastructure, the data is provided in the form of encoded alpha-numeric text files, and many users lack the means to process and decode this information. This paper describes an ongoing collaborative effort between the New Mexico Department of Transportation, the Federal Highway Administration and the private sector to develop a low cost, user friendly bridge information system that provides a simplified means to access detailed information in the NBI Database.</td>
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DEVELOPMENT OF A USER-FRIENDLY BRIDGE INFORMATION SYSTEM – PHASE II

Report 2: Public-Private Partnerships: Exploring the National Bridge Inventory with a Customized Bridge Information Software Application

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PREFACE

The research reported herein describes a software development project currently underway by the NMDOT Research Bureau. Phase I of the project was initiated in 2008 and served to develop a prototype bridge information system based on publicly available National Bridge Inventory source files. This prototype was completed in 2010, and in 2012 Phase II of the project was initiated with the objective of enhancing the program with additional functionality, including management of NBIS metrics as recently implemented by the Federal Highway Administration. In 2013 the NMDOT executed a professional services agreement with a private sector consultant to refine the software prototype and produce a commercial quality application. The work is ongoing at the time of this report, and this paper presents the aspect of the project related to the public private partnership.

NOTICE

The United States Government and the State of New Mexico do not endorse products or manufacturers. Trade or manufacturer’s names appear herein solely because they are considered essential to the object of this report. This information is available in alternative accessible formats. To obtain an alternative format, contact the NMDOT Research Bureau, 7500B Pan American Freeway NE, Albuquerque, NM 87109 (PO Box 94690, Albuquerque, NM 87199-4690) or by telephone (505) 841-9145.

DISCLAIMER

This report presents the results of research conducted by the author(s) and does not necessarily reflect the view of the New Mexico Department of Transportation. This report does not constitute a standard or specification.
ABSTRACT
The National Bridge Inventory (NBI) Database as maintained by the Federal Highway Administration contains detailed information on approximately 600,000 public highway bridges spanning a period of two decades. While the NBI Database constitutes the most comprehensive source of publicly available information on the condition of the nation’s bridge infrastructure, the data is provided in the form of encoded alpha-numeric text files, and many users lack the means to process and decode this information. This paper describes an ongoing collaborative effort between the New Mexico Department of Transportation, the Federal Highway Administration and the private sector to develop a low cost, user friendly bridge information system that provides a simplified means to access detailed information in the NBI Database.

ACKNOWLEDGEMENT
The authors gratefully acknowledge the support and technical assistance provided by the New Mexico Division of the Federal Highway Administration, without which this report would not have been possible.
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OVERVIEW
In 2010 the New Mexico Department of Transportation (NMDOT) completed work on a prototype of a bridge information system that uses the National Bridge Inventory (NBI) Database as its primary source of data. The developers used Rapid Application Development (RAD) tools to produce the initial software, and in 2012 the application was updated using the Microsoft .NET framework to leverage recent technological advances in software application development and to address comments and suggestions submitted by program evaluators. The application was updated during that time at the request of the New Mexico Division of Federal Highway Administration (FHWA) to include a module that provides data processing and reporting functions in support of recently implemented National Bridge Inspection Standards (NBIS) metrics. These activities are described in a series of technical papers co-authored by NMDOT research staff and presented at various national conferences, including "Development of a User-Friendly Software Application for Extracting Information from National Bridge Inventory Source Files" [1]. In 2012 the New Mexico Division of the FHWA requested that NMDOT initiate and administer a research and development project for the purpose of creating a professionally produced bridge information system capable of being widely deployed at minimal cost to end users. A broad range of potential users was identified, including federal, state and local government agencies, academic institutions and private sector interests. A primary project objective was to provide the means to access detailed NBI information by both technical and casual users through a simple to navigate user interface in which the bulk of data processing operations is performed “behind the scenes”, while offering a reasonably comprehensive set of data management and reporting tools customized for specific purposes, including management of NBIS metrics.

Following a period of problem statement development and evaluation of project objectives by federal and state subject matter experts, NMDOT issued an “Invitation to Propose” to the state’s institutions of higher education, inviting submission of proposals to perform the work. When no proposals were received, the work was assigned to a private sector consultant for which a statewide price agreement for software development services was currently active. In June 2013 the NMDOT executed a task order based professional services contract with Clover Leaf Solutions Inc., a software development services company based in Albuquerque, NM to produce a professional bridge information system in accordance with industry standard conventions for software development. A contract period of two years was established, and the work is ongoing at the time of this writing. The software uses publicly available National Bridge Inventory (NBI) Database files as its data source. The content and format of the NBI files used as the primary source of data in the application are described in Federal Report No. FHWA-PD-96-001, “Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation’s Bridges” (hereafter “NBI Coding Guide”) [2].

BACKGROUND
In April of each year, owner agencies are required to submit detailed information on the condition of each bridge under its jurisdiction to the Federal Highway Administration. This information is provided in the form of an alpha-numeric text file formatted in accordance with the NBI Coding Guide. These files are submitted by each state, Washington DC, and Puerto Rico on an annual basis, and collectively they comprise the NBI Database. Approximately one hundred (100) items of information are reported for each bridge in the inventory, including information related to age, structure and material types, load and condition ratings, posting status, maintenance responsibility, inspection frequency, geometric information including bridge length, width and clearances, improvement cost, and much more. These public data files are maintained by the Federal Highway Administration and annual records are available for each state through the FHWA website [7] beginning from 1992. The NBI Database constitutes a long term repository of current and historical information on the condition of the nation’s bridges of invaluable use to a
wide range of technical and casual users in academia, government and the private sector. Examples of the use of this information are charts illustrating the age of bridges in the inventory and the number of deficient bridges by program year as depicted in Figures 1 and 2.

![Age Distribution of U.S. Bridges](image1)

Figure 1. Distribution of U.S. Highway Bridges by Age. Source: 2011 National Bridge Inventory Database.

![Number of Structurally Deficient Bridges by NBI Program Year](image2)

Figure 2. Number of Structurally Deficient Bridges by NBI Program Year. Source: 1992 - 2011 NBI Database.

The wealth of information provided in the NBI Database presents an opportunity to perform comparative analysis and trend studies, and to identify potential preventive or remedial strategies as supported by the data. Typical examples of the use of the information as processed through the software application described herein include:

- Examination of the data by private sector providers of bridge deck overlay products to identify bridges with a history of progressive deterioration in the condition of the deck,
sorted by age, design and material types, condition ratings and functional classification of the roadway.

- Identification of load restricted or low clearance bridges for preliminary use in route planning.
- Development of a schedule of bridges due for inspection in a given program year or identification of bridges due for inspection during the prior year that were inspected late.
- Identification of bridges of historic significance.
- Identification of specific classes of bridges, e.g. bridges with unknown foundations.
- Examination of irregularities and errors in NBI data sources.
- Statistical analysis and trend studies using historical structure condition data.
- Location of bridges within a user-defined radius by latitude and longitude.
- Location of bridges by combinations of selection criteria including county, material and design types, route and milepost or feature intersected.

Figure 3 presents a representative map and report of scour critical bridges in California that illustrates a typical use of NBI data as processed through the software described herein.

<table>
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<tr>
<th>Bridge No.</th>
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Figure 3. Partial listing of scour critical bridges in California. Source: 2012 NBI Database

**National Bridge Inspection Standards**

Federal regulations governing requirements related to the management of public bridges are documented in 23 CFR 650, “National Bridge Inspection Standards” [3]. This regulation is broadly categorized into requirements pertaining to inspection frequency and procedures, qualifications of inspection personnel, and information management. In 2010 the Federal Highway Administration proposed the use of twenty three (23) metrics by which to evaluate states’ compliance with federal bridge inspection, management and reporting requirements. These metrics were implemented in 2011 as a means to promote consistency in the oversight of compliance with requirements by owner agencies and to encourage management of the bridge inventory among states using a uniform data driven, risk based approach. These metrics are consistent with the requirements as embodied in 23 CFR 650. Detailed discussion of these metrics is beyond the scope of this report and the subject is more thoroughly covered in a previous paper by the authors, “Assessing National Bridge Inspection Standards Metrics Using
The paper includes a detailed discussion of the FHWA’s program for implementing NBIS metrics, and describes a module to manage these metrics as incorporated into the bridge information system software under development at that time by NMDOT. This module is updated and refined in the software application described herein and includes the means to perform statistical studies on randomized lists of bridges that meet FHWA’s NBIS metric criteria and to produce various maps and reports in support of the data management requirements for these metrics as documented in the FHWA publication "Metrics for the Oversight of the National Bridge Inspection Program" [5].

SOFTWARE DEVELOPMENT
In June 2013 the NMDOT initiated a two year task order based on-call contract with a private sector software services company located in Albuquerque, NM, Clover Leaf Solutions, Inc., to provide technical services in support of the development of a bridge information system that uses publicly available NBI text files as its primary data source. The objective of the project is to develop a fully operational bridge information system of practical use to a broad range of public and private users in the most optimal software development environment. The parties ultimately selected C#, a member of the Microsoft Visual Studio family of programming languages, as the primary tool to perform the work, using SQL databases as the repository for processed NBI data. The software builds upon earlier prototypes developed by NMDOT and includes provisions to query the data on a state-specific basis, to review detailed information on individual bridges, and to produce a large number of standard and specialized reports and maps of bridges in various categories. The underlying databases provide the means for users to query the data and to produce a virtually unlimited number of custom reports not already available through the application.

Application Prototyping
An important feature in the administration of the software services contract is the provision of a software prototype produced by the NMDOT Research Bureau for use by the consultant during application development. In this case, subject matter experts with limited proficiency in software design and coding performed much of the prerequisite application development work. This includes preliminary literature reviews, identification of data sources, development of program elements including scaled maps and other graphical objects, identification and development of reports, database structure and design, and overall application design and function. Through preliminary development of the software using rapid application development (RAD) tools including, for example, Visual Basic for Applications (VBA), the client (NMDOT) was able to construct a working model of the final product for use by the consultant. This approach is expected to save a considerable amount of time and resources that would otherwise be consumed by more costly consultant services by the permitting the consultant, who is not a subject matter expert in bridge information and management, to concentrate available resources on efficient and robust software design in accordance with industry conventions. The application prototype includes code modules that lay out the basic structure for decoding and translating data, populating and querying databases, and producing customized maps and reports. Using this model, the consultant is then able to refine and optimize the code, to include various software improvements as suggested by users, and to build a progressively comprehensive library of reusable code modules and other elements for use in this and other applications.

The SABIS Bridge Information System
In response to suggestions by a representative from the Transportation Research Board in 2008 to make more effective use of available data sources, NMDOT initiated an in-house research, development and technology transfer (RD&T) project to use information stored in the New Mexico NBI Database. The initial goal was to provide a simplified means to use the NBI Database to access information of use to NMDOT staff. This resulted in the development of a
prototype software application, code-named SABIS, an acronym for Simplified Access Bridge Information System.

While the original application used the data from the New Mexico NBI for use by NMDOT staff, it soon became apparent that the information was of interest to other users representing a wide range of public and private sector interests. The application was subsequently expanded to include all of the states and to include enhanced reporting functions. This work was completed in 2010 and is described in a technical paper, “Development of a User-Friendly Application for Extracting Information from National Bridge Inventory Source Files” [1], co-authored by staff in the NMDOT’s Research Bureau. The application was redesigned and re-coded by NMDOT in 2012 to incorporate improvements and to optimize the program for use on ultra portable workstations running the Windows 7 and later operating systems.

Comparison with the Pontis© Bridge Management System
Most state DOTs use the Pontis© portion of the AASHTO BRIDGEware© family of products to serve their comprehensive bridge management needs. The bridge information system described herein is a simpler and more modest alternative application intended to serve different needs of a general population of technical and casual users. While the National Bridge Inventory provides, for example, a crude rating system of 0-9 to record the condition of the deck, substructure and superstructure, Pontis© provides a much finer gradation of condition data by use of individual AASHTO bridge “elements” including abutments, wingwalls, bearings, joint seals, etc. Pontis© includes the means to rate these elements by condition and environment, and also provides improvement cost data and a module for deterioration modeling for use in plans for maintenance strategies and budgeting resources. Pontis© uses element information as described in the AASHTO publication “Manual for Bridge Element Inspection” [6] and serves as a comprehensive means of bridge management by owner agencies at both the local and network level. The SABIS system, by contrast, relies on historical National Bridge Inventory data which provides a coarser gradation of information. A disadvantage of the publicly available NBI data is the lag time between the last bridge inspection date and the availability of the compiled NBI information. This means that data are not provided in “real time”, and users are cautioned to consult with owner agencies when current data is required. Despite the disadvantages, the NBI Database nevertheless comprises the most comprehensive repository of publicly available bridge information and is of considerable value to a broad range of users. The advantages of a system such as SABIS include its minimal user cost, ready availability of two decades of detailed information from all states, the absence of user authorization requirements, and the ability to be quickly and easily deployed on a stand-alone workstation independent from agency specific resources. Another major advantage is that being locally owned and maintained, program updates and improvements are greatly streamlined, with both minor and major system enhancements often made in a matter of hours or days at little or no cost. A recent example is a case where an oversight agency was field inspecting damaged bridges following a major flood event and was unable to ascertain the bridge identification number and to examine available NBI information for various county owned structures. The agency requested the means to locate structures by latitude and longitude coordinates as determined on site, and the SABIS development team was able to provide this module at no cost for use by the requesting agency the following day. The feature permits users to either snap to the nearest bridge given defined coordinates or to locate all structures within a user defined radius. Figures 4a and 4b present representative examples displaying bridges located by latitude and longitude, and a bridge information report generated by SABIS. Figure 4c displays features of the program that allow users to manage multimedia and internet resources.
While the SABIS system provides a reasonably functional prototype of value to a wide range of technical and casual users, the application suffers from performance inefficiencies resulting from the fact that it was developed in-house by NMDOT staff with limited proficiency in software development. In order to provide a better product and to ensure continuity of service for future upgrades and code maintenance, the Federal Highway Administration proposed a project in 2012 to procure services from a professional services provider to reproduce, update and optimize the software. The contract executed between NMDOT and Clover Leaf Solutions Inc. includes the

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Updating the Bridge Information System

While the SABIS system provides a reasonably functional prototype of value to a wide range of technical and casual users, the application suffers from performance inefficiencies resulting from the fact that it was developed in-house by NMDOT staff with limited proficiency in software development. In order to provide a better product and to ensure continuity of service for future upgrades and code maintenance, the Federal Highway Administration proposed a project in 2012 to procure services from a professional services provider to reproduce, update and optimize the software. The contract executed between NMDOT and Clover Leaf Solutions Inc. includes the
development of two distinct programs, each developed in the Microsoft C# programming language. The first is an application that batch processes NBI text files from all states for a given program year and populates state-specific databases. The second is an application that permits users to review detailed information in a selected state’s NBI database and to produce a large number of maps and summary reports on commonly requested information including, for example, structurally deficient or functionally obsolete bridges, structures due for inspection, scour critical or fracture critical bridges, and bridge improvement costs. Together, these applications constitute a powerful and convenient tool for conducting research into the condition of the nation’s bridge infrastructure. The bridge information system provides detailed state-specific information for a given NBI program year, while the batch processing routine provides the means to compile and synthesize information from any given NBI program year for all states in a single operation. The source code may be easily modified to examine information of specific interest during the batch processing operation. Figures 1 and 2 present simple examples of information that may be extracted from the entirety of historical bridge records as embodied in the NBI database. Using more complex SQL query statements, the data may be mined for virtually unlimited combinations of selection criteria. For example, the data could be queried to identify fracture critical bridges (NBI Item 92A) on interstate highways (NBI Item 5A) that are also structurally deficient (NBI data field 427). Figure 5 presents a location map of bridges that fall into this category. This example illustrates the utility of the program for quickly identifying and generating detailed reports for groups of structures of particular interest.

![Illustrative location map of fracture critical, structurally deficient bridges on Interstate highways in the contiguous United States. Source: 2012 National Bridge Inventory.](image-url)

The batch processing application is useful for populating all state databases for a given program year in a single operation. The application also creates summary files for each state and for the entire NBI database as well as reports on various categories of bridges. Figure 6 displays a screenshot of the NBI database batch application as it processes the 2012 NBI data for all states.
The primary function of the NBI file processor is to translate encoded NBI text files from all states, and to populate state-specific databases in a single batch processing operation. A typically configured workstation processes approximately 100 bridge records per second. Figure 6 displays a typical NBI text file as processed by the application. NBI item information is encoded in these files in accordance with the NBI Coding Guide file format. For example, NBI Item No 1, State Code, as encoded in the first three digits in the example are “175”, which identifies the state through its Federal Information Processing Standards (FIPS) code. Similarly, other NBI items encoded in the text file are parsed from the file, translated and stored in a state-specific database for each NBI program year. This portion of the software provides researchers and others with the means to quickly create new state databases as annual NBI text files for subsequent program years become available.

The bridge information system portion of the software provides access to detailed bridge information and summary reports for a selected NBI program year on a state-specific basis. Figure 7 shows the Welcome screen from which users may select the state of interest and a representative bridge detail report generated through the system.

![Figure 6. Screen shot of the NBI batch processing application.](image)

![Figure 7. The Welcome Screen and representative bridge detail report generated through the new Bridge Information System, Source: 2010 Arizona NBI Database.](image)
The Main Page of the application as shown in Figure 7 provides access to detailed bridge records, and links to other parts of the program. To simplify the location of a particular structure, the user may apply search criteria and filter the bridge list by any combination of county, route and milepost, material and design type, feature intersected, and owner. Bridges in a user-defined proximity may also be found by clicking the general area of the state map, or by entering latitude and longitude coordinates. After a bridge is selected, the user may print a detail report that lists all available NBI information, and visit the structure in Google Maps. Figure 8 illustrates these features. In this example, “Big-I” bridges at the intersection of interstates 25 and 40 in New Mexico were selected by using search criteria of a) County: Bernalillo; and b) Design Type: Segmental Box Girder. This feature allows the user to quickly locate bridges of specific interest with minimal information. After selection, detailed reports may be generated for some or all of the selected structures.

![Filter Feature Example](image)

**Figure 8.** Example of the filter feature to find structures according to selected search criteria. Source: 2012 New Mexico NBI database.

**Features of the Public Private Partnership**

The SABIS system provides an easy-to-use means to access detailed information on more than 600,000 public bridges on the nation’s highways, and evaluation copies of the software are currently in use by dozens of agencies representing government, academia and the private sector. The application, while still considered to be a prototype, has consistently been favorably reviewed as a powerful and useful resource for a wide array of applications ranging from research to commerce. The developers, however, acknowledge that the software suffers from performance issues arising from sub-optimal coding and the absence of industry standard software development protocols. In recognition of this fact the New Mexico Department of Transportation, in cooperation with the Federal Highway Administration, initiated a contract with a software development company, Clover Leaf Solutions Inc., to provide professional support services. The objective of the project, which is ongoing as of the time of this writing, is to reconstruct the basic framework of SABIS and produce a more robust, stable, and sustainable program that incorporates a technically rigorous approach to software development in accordance with modern conventions. The new program will have its own unique design, structure and name, as yet undetermined, and it is expected that SABIS will be retired following acceptance testing.

While the contractor is expected to provide professional programming support services for software development, they are not expected to be subject matter experts. The project is under the guidance of a Technical Panel consisting of professionals with expertise in the field, including professional engineers and application developers with sufficient knowledge and skill to produce functional prototype coding modules to guide the contractor in developing the final software. These modules include the means to update state databases with the most recent NBI data, to produce standard reports of commonly requested information, to manage and view digital photos, videos and other multimedia resources, and to link to relevant internet resources. Figure 9
presents a representative screenshot of the Reports page and displays one of the many standard and special reports available through the software.

![Representative screenshot of the Reports Page](image-url)

**Figure 9.** Representative screenshot of the Reports Page in the new application displaying bridges due for inspection during the selected NBI program year. Source: 2012 Texas NBI Database.

The professional services agreement used in this project is an on-call contract that uses task orders to fulfill project objectives as these are identified. This provides the flexibility needed by the Technical Panel to customize work orders in accordance with overall project objectives as the project progresses. While the master contract calls for a functional bridge information system and documentation to support future objectives, the details for specific work are outlined in specific task orders. For example, the decision to use Microsoft C# as the programming language was made following the first task order, and the program is being developed incrementally through subsequent task orders. Each task order has its own scope, budget, timeline and deliverables, with one standard deliverable being a tentative long range plan that documents future activities. This allows the parties to regularly assess progress and to customize future task orders to ensure that project objectives are being met within available time and budget. The task order contract also allows the parties to incorporate changes and enhancements as these are suggested by industry practitioners using evaluation copies of the prototype system while adhering to the overall requirements of the project. It is expected that following development of a bridge information system that processes and reports information in accordance with the data file format documented in the NBI Coding Guide, the program will be enhanced to incorporate modules for managing information in the new NBI xml file format. This new file format is a requirement for NBI data submitted by owner agencies beginning in program year 2015, and requires a finer gradation of condition information in the form of bridge elements as documented in the *AASHTO Manual for Bridge Element Inspection* [6]. Future upgrades may include, for example, a module to assist owner agencies to perform inspections and create inspection reports for use with mobile devices as consistent with evolving federal requirements.

**SUMMARY**

In response to a recommendation from a visiting representative of the Transportation Research Board in 2008 to make better use of available data sources, the Research Bureau of the New Mexico Department of Transportation (NMDOT) initiated an in-house project to develop a bridge
information system using publicly available National Bridge Inventory (NBI) text files as its data source. While the project originated as a means to perform limited studies on state owned bridges in New Mexico, it soon became apparent that the application was of interest and utility to broad base of public, private and academic agencies. In 2010 the NMDOT completed work on a prototype bridge information system, named SABIS, that incorporates data from all 50 states as well as Washington DC and Puerto Rico. This work is documented in a technical paper produced by the software developers, “Development of a User-Friendly Application for Extracting Information from National Bridge Inventory Source Files” [1].

In 2010, the Federal Highway Administration (FHWA) suggested the use of 23 metrics to assess states' compliance with federal bridge inspection and management requirements as documented in 23 CFR 650, “National Bridge Inspection Standards” [3]. These metrics, which are broadly categorized into categories of bridge inspection procedures and frequency, qualifications of inspection personnel, and records management, were implemented in 2011, at which time the New Mexico Division of FHWA inquired into the feasibility of leveraging work performed on SABIS to include a module for managing these newly implemented metrics. The SABIS developers created a module for this purpose which uses available NBI source files to perform data analysis and to produce supporting maps and reports. These National Bridge Inspection Standards (NBIS) metrics were updated in 2012 and again in 2013, and the programming support work performed by NMDOT was documented in a subsequent technical paper, “Assessing National Bridge Inspection Standards Metrics Using Data Extracted from National Bridge Inventory Source Files” [4].

The SABIS system constitutes a functional prototype currently in use on an evaluation basis by dozens of users representing industry practitioners from public, private and academic institutions. The software developers, however, acknowledge that the SABIS system suffers from inherent inefficiencies arising from the fact that it was developed in-house by amateur programmers. In recognition of this fact, in 2012 the New Mexico Division of FHWA suggested that the NMDOT administer a research project that serves to investigate current needs and produce an effective bridge information system for use by a broad cross section of casual and technical users. A two year contract between NMDOT and a private software development company, Clover Leaf Solutions, Inc. was executed in 2013 to provide the required services. This paper describes collaborative efforts between the New Mexico Department of Transportation, the Federal Highway Administration and a private services provider to produce an efficient and effective bridge information system.
REFERENCES


