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Road and Rail Infrastructure IV

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THE LONG-TERM BRIDGE PERFORMANCE (LTBP) PROGRAM BRIDGE PORTAL

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Abstract

The Long-Term Bridge Performance (LTBP) Program is a 20-year research effort by the U.S. Federal Highway Administration (FHWA) to collect scientific performance field data from a representative sample of bridges nationwide that will help the bridge community better understands bridge deterioration and performance. The products from this program will be a collection of data-driven tools, including predictive and forecasting models, which will enhance the abilities of bridge owners to optimize their management of bridges. The paper describes a key product of the LTBP program, the Bridge Portal, which contains bridge performance-related data mined from existing sources (National Bridge Inventory, State Highway Agency bridge element level data, national weather data, traffic data, weigh-in-motion data, bridge maintenance data, and other data sources), but it also serves as a central repository for all field data collected through the LTBP Program. Additionally, the Bridge Portal also functions as a research and decision-making tool by implementing bridge life-cycle and deterioration modeling using both mined data sources as well as LTBP-acquired field data to allow users to investigate bridge performance on many different levels.

Keywords: Bridge Portal, National Bridge Inventory (NBI), National Bridge Element (NBE), Bridge Infrastructure Management, Bridge Database

1 Introduction

In 2008, the FHWA launched its largest bridge research effort, the LTBP Program. The LTBP Program is a 20-year research endeaver to collect scientific performance field data from a representative sample of bridges accross the U.S. This will assist the bridge community to improve understanding of bridge deterioration and performance. The products from LTBP pro¬gram will be a collection of data-driven decision making tools, including predictive models. The final outcomes will enhance the abilities of bridge owners to optimize their management of bridges [1].

Bridge performance is a multifaceted problem affected by performance of materials and protective systems as well as individual components of the bridge, and performance of the structural system as a whole. The behavior of any single bridge or element of a bridge is attributed to multiple factors, many of which are closely linked [2].

LTBP Bridge Portal was developed to bridge owners and scientists to get a better understanding of performance of bridges. It is an intelligent web based platform that mines different data set such as Historical National Bridge Inventory (NBI), National Bridge Element (NBE), traffic, environmental, bridge elevation, inspection, and maintenance data as well as data acquired through LTBP field testing. LTBP Bridge Portal utilizes all different mined dataset

to develop advanced forecasting and deterioration models to predict the future condition of bridges. LTBP Bridge Portal is publicly accessible form https://ltbp6.rutgers.edu web address.

2 LTBP Bridge Portal Datasets

This section explores the different datasets of LTBP Bridge Portal as a web based platform. In particular, the LTBP Bridge Portal provides the bridge information in three main categories, including NBI, NBE, and LTBP program field data.

2.1 NBI

With the purpose of having a unified system for bridges and tunnels, NBI has been compiled by FHWA since 1972 to create a novel database. NBI is a comprehensive database system including all the bridges and tunnels passing over/below the road network within the territory of the United States. The database includes more than 100 different characteristics mainly describing the structures' identification information, bridge types and specifications, operational conditions, geometric data and functional description, inspection data, etc. Currently LTBP Bridge Portal houses historical NBI data from 1992 to 2015 and is programmed in a manner to easily provide the detailed information about the status of each individual bridge or tunnel. Every year, at the beginning of February, FHWA provides the collected NBI data for the previous year which are instantly uploaded to LTBP Bridge Portal shortly afterwards. Additionally, NBI reports contain the structural condition of bridges in three main categories of deck, superstructure, and substructure.

2.2 NBE

As discussed, NBI provides the condition states only for bridge deck, substructure, and superstructure levels while it lacks detailed evaluation of bridge components. The FHWA and bridge owners nationwide have recognized the benefits of having more detailed element level bridge inspection condition data to better show the severity and extent of bridge condition deficiencies. This results in designing more efficient and successful repair and maintenance plans. In the proposed NBE system, the elements are defined under seven categories, including Deck/Slab, Superstructure, Substructure, Bridge Rail, Joint, Bearing, and Wearing Surface and Protective Coatings. All elements have four defined condition states ranking from good to serious condition. Starting from 2015, it is mandatory for all states to submit their NBE data to FHWA. Shortly after this data is publicly available on FHWA website, it will be transferred to LTBP Bridge Portal.

2.3 LTBP program data

Under the LTBP program, the scientific performance field data from a representative sample of bridges nationwide are collected to provide the bridge community with a better understanding of bridge deterioration and performance. The LTBP acquired data will be stored on LTBP Bridge Portal. The following data types are being collected and recorded from the selected bridges, followed by brief description for completeness:

2.3.1 Non-Destructive Testing (NDT)

Per the main objective of the LTBP Program, five different NDT techniques are employed on selected bridges in order to follow the deterioration and performance of bridge decks over the time spatial. The tests include Impact Echo, Ultra Sonic Surface Wave, Ground Penetration Radar, Half Cell Potential, and Electrical Resistivity.

2.3.2 Visual inspection

In addition to NDT data, LTBP program collects detailed visual inspection data from bridges and store them on LTBP Bridge Portal.

2.3.3 Bridge Weigh in Motion

Bridge Weigh-in-Motion (BWIM) is a technique which uses an existing bridge to weigh trucks while they are moving at full highway speeds. Different sensors are installed on bridge girders to measure the response of bridge components as the vehicles crossing over the bridge. The real-time outcomes of the BWIM system are fourfold: 1) providing each passing vehicle's individual axle weights, gross vehicle weight, time and lane of passage, 2) providing the vehicle speed as well as axel classification, 3) pre-selection of overweigh trucks for enforcement purposes, 4) calculation of Average Daily Traffic (ADT) data for individual and/or all lanes of bridge.

3 LTBP Bridge Portal Main Components

Besides the capability of LTBP Bridge Portal as a central repository for NBI, NBE, and LTBP Program data, it provides specific components to improve the existing knowledge of bridge performance. These Modules include deterioration modeling, data management toolboxes, and a set of complementary features; following is a brief description for completeness:

3.1 Deterioration modelling

Deterioration Modeling is an important part of bridge management and in order to maintain the inventory of bridges with optimal cost, bridge owners need to know how bridges deteriorate.
LTBP Bridge Portal uses advanced statistical methods to develop deterioration models for bridges. The expected condition-rating curve of a bridge is generated in two steps: 1) modeling, which generates the deterioration models for the said bridge; and 2) prediction, which utilizes the deterioration models to generate the curve. In order to predict the future condition of bridges, LTBP Bridge Portal uses Weibull models.
This process is solely based on the data, every year after new data is mined and new NBI and NBE is imported to the LTBP Bridge Portal, the system will update the available condition predictions for bridges and represent the data.

3.2 Data management tools

LTBP Bridge Portal has advanced capability for mining data from different data sources, storing the data in highly customized and optimized database, searching and retrieving data.
The database is optimized for optimum speed using the state of art method optimization techniques including normalization, denormalization and indexing. The tables in the Database are connected in a way that storing very large longitudinal datasets are possible but searching the system will be very quick. The most complicated queries will take less than 5-6 seconds to perform.
In addition, there is an advanced document management and file server which is used to host all LTBP field data as well as bridge documentation.

3.3 Advanced features and functionalities

In addition to data management and deterioration modelling functionalities described above, LTBP Bridge Portal comprise numerous functionality which enables users to query and visualize data in different ways. Below are a list of the most important functionalities with a short description of each:

3.3.1 Advanced search

LTBP Bridge Portal utilizes a state of the art search capability which is not only very easy to use but also extremely quick. The search boxes use auto completion so the user can fill the forms by only spelling part of a word. Upon execution, the search query is translated to a JavaScript Object Notation (JSON) object which will be transferred to different page for optimized performance. Users can perform any search on any field of the datasets available in the system.

3.3.2 GIS

LTBP Bridge Portal features a very advanced GIS module which is capable of rendering up to 150,000 bridges on the map. Each bridge is represented by a circle and user can change the size and color of the circles based on different attributes. For example it is possible to associate the size of circles to the traffic of the bridges and the color of bridges to the deck condition and observe if there is any relationship between the two. The map feature is developed using advanced WebGL technology and is only supported by web browsers that are developed after 2014.

3.3.3 Multi-Dimensional charts

In order to visualize the data, LTBP Bridge Portal offers different visualization methods, these include one dimension bar chart, pie chart, and donut chart and multi dimension bar charts. Using these charts, it is possible to quickly visualize the data based on different factors and discover particular trends in the data.

3.3.4 Historical trends

As explained before, LTBP Bridge Portal database keeps all historical NBI and NBE information. This includes historical condition and traffic data. Users can observe how the condition of a certain bridge changes through different years and using other methods available in the system, she can get an understanding of the factors that caused the change in the condition. LTBP Bridge Portal also visualize these trends in state level for different categories of bridges (e.g. state or locally owned bridge) which can be used by states to get a deep insight into the effectiveness of their rehabilitation and maintenance practices.

4 Case study

In this section, a brief case study is employed to introduce an example of LTBP Bridge Portal application. Here it is intended to select bridges with age of less than 20 years which are located in North-East of U.S., being in poor or worse deck condition.

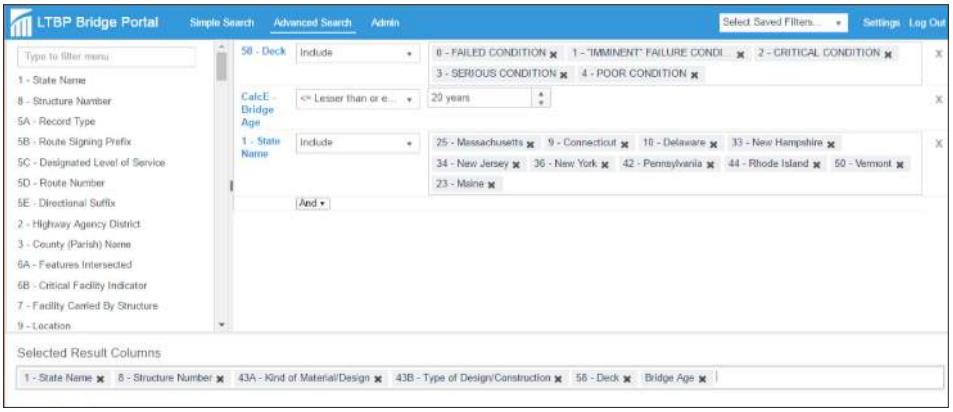

Figure 1 Search view, including the selected criteria with defined constraints

First, the advanced search is being employed to add the filters and set the constraints. Fig. 1 pertains to the LTBP Bridge Portal advanced search indicating the applied filters with designated constraints.
After executing the search, user can see the result in a tabular format from the results page. Fig. 2 shows the schematics of the results page.
Next, the data is visualized on the map, each circle is representative of a bridge. Fig. 3 shows the resulting bridges on the map.

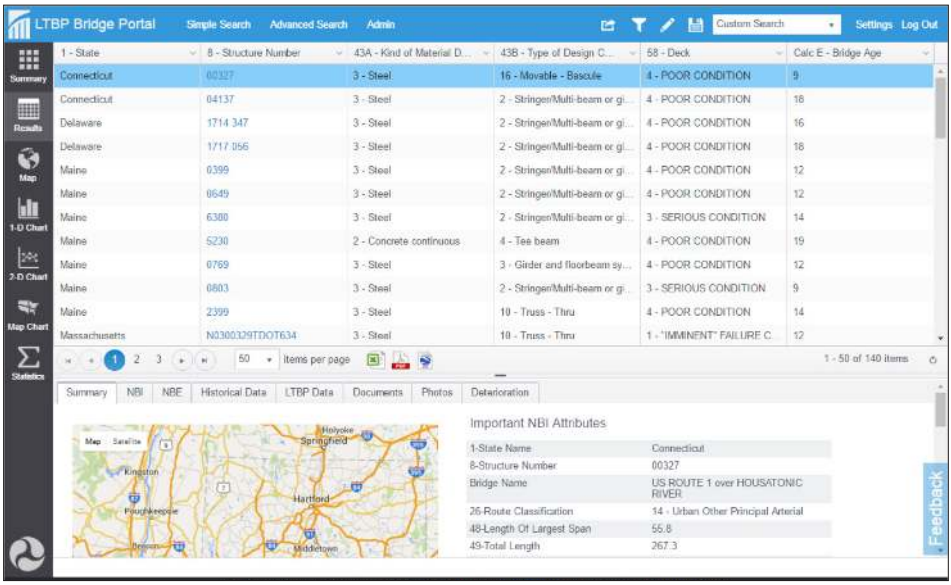

Figure 2 Results page showing bridge information in a tabular format

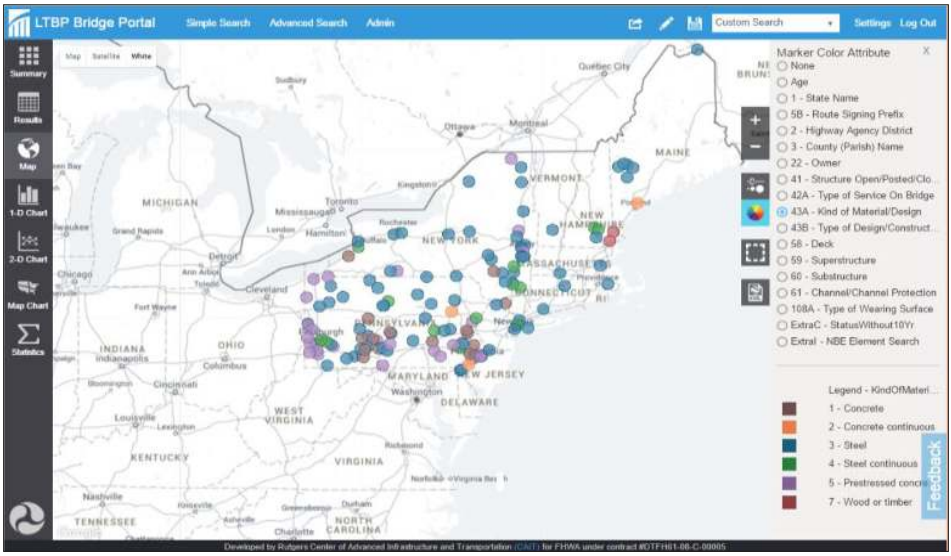

Figure 3 Bridges are shown on the map; color of each bridge corresponds to the material kind used in the bridge

In the following, the charting capabilities of the system is utilized to visualize the data based on different factors. Fig. 4 shows the number of bridges per state and Fig. 5 demonstrates the number of bridges per structure design and material type.

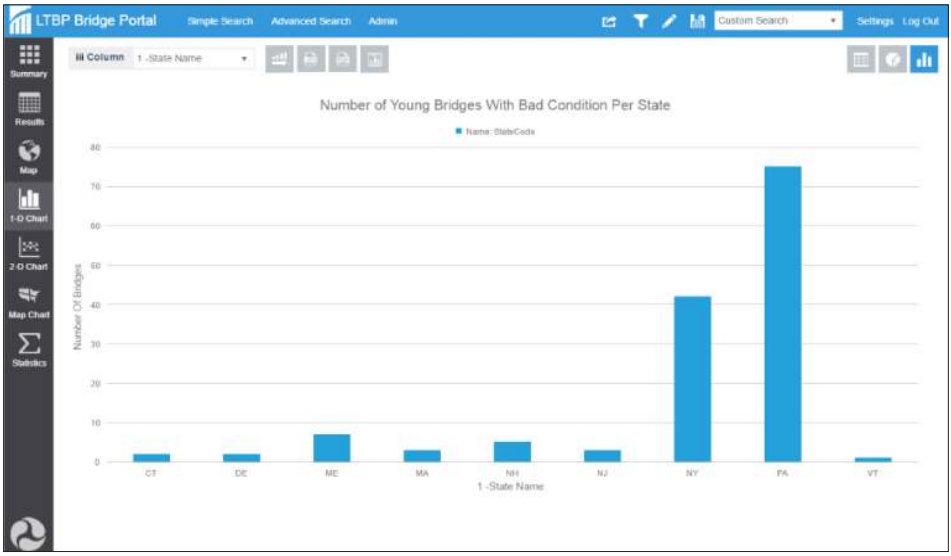

Figure 4 1-D chart, a bar chart displays the number of bridges in each state

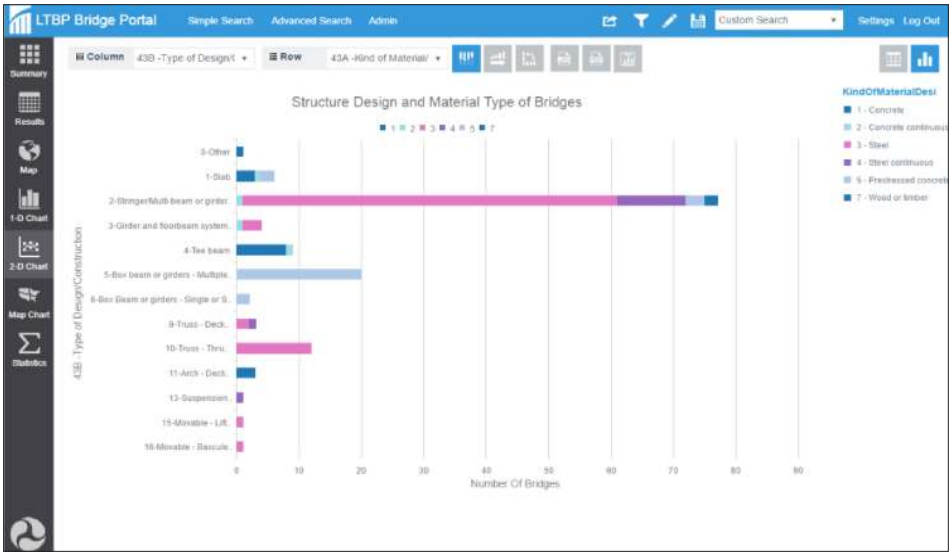

Figure 5 2-D chart, comparing the distribution of selected bridges based on material kind and structure design

5 Conclusions

In the work described herein, the basics of LTBP Bridge Portal is discussed. The LTBP Bridge Portal is a key product of LTBP Program which is a research effort by the FHWA to collect scientific performance field data from a representative sample of bridges nationwide. The basic components as well as advanced features of the platform was introduced to map a clear vision for bridge experts. The application of LTBP Bridge Portal was then described by an example of case study. For the case of study, the LTBP Bridge Portal was employed to select bridges with age of less than 20 years in North-East U.S., having a poor or worse deck condition. The outcomes of the case study were then portrayed using different toolboxes implemented in the system.

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