Appendix B

Bridge Investment/Performance Methodology

This appendix contains a technical description of the methods used to predict future nationwide bridge conditions and investment requirements. It primarily describes the National Bridge Investment Analysis System (NBIAS), the latest and most comprehensive bridge model used by the Federal Highway Administration (FHWA).

NBIAS is the successor to the Bridge Needs and Investment Process model (BNIP), developed by FHWA in 1991. It incorporates analytical methods from the Pontis Bridge Management System model (Pontis), developed by the American Association of State Highway and Transportation Officials (AASHTO) in 1989 and licensed by AASHTO to over 45 Ssstate transportation departments.

Overview of the Model

NBIAS users can construct a variety of scenarios that simulate nationwide bridge needs and investments. These scenarios can examine bridge repair, rehabilitation, and improvement needs, in dollars and number of bridges; the distribution of work done, in dollars and number of bridges; and aggregate and user benefits, and the benefit/cost ratio, for performed work. Outcomes can be presented several ways, including by the type of work, functional class, and whether the bridges are part of the National Highway System (NHS).

NBIAS starts with the National Bridge Inventory (NBI) database. To estimate improvement needs, it applies a set of improvement standards and costs that can be modified by the user. To measure preservation needs, NBIAS uses a Markov modeling, optimization, and simulation approach, along with default cost and deterioration models derived from Pontis. Because this approach relies on having element-level condition data, NBIAS applies a series of stochastic models to the NBI information to generate synthesized element condition data. Then, deterioration models are applied to estimate changes in element data over time, and an optimal preservation policy is developed and applied to the bridge stock.

NBIAS Structure

NBIAS is comprised of two distinct modules:

- The Analytical Module allows the user to create a database from NBI files, specify technical parameters, and define a budget scenario for analysis.

- The "What If" Analysis Module provides interactive screens, displaying the outcomes for a selected scenario.

The Analytical Module creates budget scenarios based on user-defined parameters for needs and costs. The budget scenarios are based on four distinct components:

- The module generates improvement needs for widening, raising, and strengthening bridges.

- A bridge replacement need is recognized when one of three conditions are met: (1) when a bridge has an improvement need that is considered infeasible for the structure's design type; (2) when a bridge has multiple improvement needs; or (3) when the benefit/cost ratio for replacement is greater than that for improvement.

- Based on the NBI description of each structure, NBIAS creates a statistical model that assigns a typical assortment of elementary components to the bridge. These elements include specific deck types, railings, girders, and piers. The total quantity of each element that is likely to be present on a given bridge is estimated, as well as the condition state distribution of the element. In the database, this element-level data is stored in an aggregated form. Totals are accumulated for each stratum of the bridge stock.

- The database retains much of the auxiliary input data that was used to generate improvement needs for both individual structures and element quantities and condition states by stratum.

The scenario approach allows NBIAS users to see how variations in assumptions affect estimates of future needs and expenditure patterns. Each scenario produces results in the form of a set of measures of effectiveness that result from an assumed budget. Alternatively, the user may create a benefit/cost cutoff scenario, which results in a set of measures of effectiveness that result from an assumed minimum benefit/cost ratio. The measures of effectiveness are quantitative indicators of the outcome of a simulation of needs and investments over time. The following types of measures of effectiveness are produced:

- Bridge repair, rehabilitation, and improvement needs, in terms of dollars and numbers of bridges;
- The distribution of work done, in terms of dollars and number of bridges;
- The benefits of work done (total and user); and
- The benefit/cost ratio for work done, weighted by project costs.

Separate indicators are included for different types of needs (local maintenance, federally-eligible repair and rehabilitation, and federally-eligible widening, strengthening, raising, and replacement projects).

NBIAS and Earlier Models

NBIAS retains several general capabilities from BNIP—the ability to rely on the NBI for all bridge level output, to forecast over 20 years for multiple funding periods, and to analyze different budget scenarios; however, the main analytical concepts of the NBIAS methodology are inherited from Pontis. Bridges, for example, are considered to be collections of elements. On a particular bridge, elements are characterized by their quantities and their fractional distribution across a number of discrete condition states corresponding to the degradation levels.

Although NBIAS inherits its analytical approach from Pontis, the functional implementation of the two systems is very different. NBIAS does not perform a bridge-by-bridge analysis of preservation needs, and although it does examine decomposition of the bridge stock, its object of analysis is the entire national bridge network. NBIAS generates its output not through bridge-level projects, but through quantitative indicators that demonstrate the impact of policy and budgeting decisions on multiple measures of effectiveness obtained for the entire bridge network.

Compared to Pontis, NBIAS has some input limitations. While Pontis works with databases of individual states that contain both bridge and element-level data, NBIAS is limited in its input to the NBI, the standard database of bridge-level data institutionalized on the federal level. To overcome this limitation, NBIAS relies on a set of Synthesis-Quantity-Condition (SQC) stochastic models that synthesize and quantify the element condition data using information contained in the NBI.

One area where NBIAS is far more advanced than Pontis is its user interface and the ability to support the "What If" analysis in a true interactive mode. All simulation results are calculated in a separate storage area, so very few calculations are performed during the interactive phase. Furthermore, BIAS adds consideration of user costs to the preservation models, an important factor not explicitly considered in Pontis.

Planned Modifications to NBIAS

A basic characteristic of NBIAS is that it models preservation needs at an aggregate level. This approach was adopted when NBIAS was developed in 1994, primarily due to limits in computer memory. The SQC models in NBIAS, in their current form, provide reliable aggregate estimates, but they are not suitable for predicting which elements are on a particular structure.

Work is currently underway to incorporate full individual bridge analysis into NBIAS. This involves modifying the NBIAS infrastructure to accommodate data on individual bridges and optimizing analytical procedures in NBIAS to take advantage of the additional information provided by a bridge-by-bridge analysis.