Appendix B

Bridge Investment/ Performance Methodology

The National Bridge Investment Analysis System (NBIAS), first introduced in the 1999 edition of the C&P report, models the investment requirements for bridge preservation and functional improvements. This appendix contains a technical description of the methods used in NBIAS to predict future nationwide bridge conditions and investment requirements, including information on the system overview, determination of functional needs, determination of repair and rehabilitation needs, and planned improvements to future versions of the system.

The NBIAS is the successor to the Bridge Needs and Investment Process Model developed by the Federal Highway Administration (FHWA) in 1991 and last used in the 1999 C&P report. The NBIAS incorporates analytical methods from the Pontis Bridge Management System (Pontis). Pontis was first developed by FHWA in 1989 and is now owned by the American Association of State Highway Officials, which licenses the system to over 45 State transportation departments and other agencies.

NBIAS Overview

The NBIAS is an investment analysis tool used to analyze bridge repair, preservation and functional improvement investment needs. The system can be used to examine the backlog of needs, in dollars and number of bridges; distribution of work done, in dollars and number of bridges; aggregate and user benefits; benefit-cost ratios for work performed; and physical measures of bridge conditions. Outcomes can be presented by type of work, functional classification, whether the bridges are part of the National Highway System, and/or whether the bridges are part of the Strategic Highway Network.

The NBIAS begins with the National Bridge Inventory (NBI) database. To estimate functional improvement needs, NBIAS applies a set of improvement standards and costs that can be modified by the system user to each bridge in the NBI. The system uses the available NBI data to predict detailed structural element data for each bridge. The system then measures repair and rehabilitation needs at the bridge element level using a Markov modeling, optimization, and simulation approach and default models derived from Pontis.

The NBIAS is composed of two distinct modules. The Analytical Module allows the users to create an NBIAS database from NBI files, specify technical parameters, and define and run budget scenarios for analysis. The "What-If" Analysis Module provides a variety of interactive screens and reports that display the outcomes for a selected scenario.

The following paragraphs provide additional detail on components of the system that differ from the basic analysis approach in Pontis and/or that have been modified since the 2002 C&P Report.

Determining Functional Improvement Needs

The NBIAS determines needs for the following types of bridge functional improvements: widening existing bridge lanes, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity. Functional improvement needs are determined by applying user-specified standards to the existing bridge inventory, subject to benefit-cost considerations. For instance, a need to raise a bridge will be identified if the vertical clearance under the bridge fails to meet the specified standard and if the increased cost of diverting commercial vehicles around the bridge exceeds the cost of improving the bridge.

Because the benefit predicted for a functional improvement increases proportionately with the amount of traffic, the determination of whether a functional improvement is justified and the amount of benefit from the improvement is heavily dependent upon predicted traffic. In the current version of NBIAS, traffic predictions are made for each year in an analysis period based on NBI data. The NBIAS allows the user to apply either linear or exponential traffic growth projections. Linear growth was selected for this edition of the report to be consistent with the assumption used in the Highway Economic Requirements System (HERS), as discussed in Chapter 9. This approach assumes that the rate of traffic growth will decline over the course of the period being analyzed and is intended to provide more accurate estimates of benefits from functional improvements.

In evaluating functional improvement needs (as well as repair and rehabilitation needs discussed in the next section), the system uses a set of unit costs of different improvement and preservation actions. These costs, based on Pontis defaults, are scaled based on comparison of the defaults bridge replacement cost in Pontis to a nationwide average value determined based on analysis of the available NBI data.

Determining Repair and Rehabilitation Needs

To determine repair and rehabilitation needs, NBIAS predicts what elements exist on each bridge in the U.S. bridge inventory and applies a set of deterioration and cost models to the existing bridge inventory to determine the optimal preservation actions to take to maintain the bridge inventory in a state of good repair while minimizing user and agency costs. The following paragraphs discuss major aspects of the repair and rehabilitation modeling approach.

Predicting Bridge Element Composition

Because the NBIAS analytical approach relies on use of structural element data not available in the NBI, NBIAS uses a set of Synthesis, Quantity, and Condition (SQC) models to predict what elements exist on each bridge in the NBI and the condition of those elements. Previous versions of NBIAS used a set of stochastic models to predict the bridge elements that exist in the NBI at an aggregate level. The current version models preservation needs at the element level for each bridge in the NBI. Because the current version required bridge-level data, it was necessary to revise the SQC models for superstructure and substructure elements (including bridge joints and bearings) because previous models could not be used to generate estimates at the bridge level. Revised models were developed through analysis of NBI and element-level data for a sample database of over 10,000 bridges, including representative sample data from bridges across the United States.

Calculating Deterioration Rates

The NBIAS uses a probabilistic approach to modeling bridge deterioration based on techniques first developed for Pontis. In the system, deterioration rates are specified for each bridge element through a set of transition probabilities that specify the likelihood of transition from one condition state to another over time. For the current version of NBIAS, the deterioration models were recalibrated using the historical NBI data for the years 1992 to 2002, resulting in a significant revision of the transition probability matrices.

Applying the Preservation Policy

Using transition probability data, together with information on preservation action costs and user costs for operating on deteriorated bridge decks, NBIAS applies the Markov modeling approach from Pontis to determine the optimal set of repair and rehabilitation actions to take for each bridge element based on the condition of the element. During the simulation process, the preservation policy is applied to each bridge in the NBI to determine bridge preservation work needed to minimize user and agency costs over time.

Because the current version of the system models maintenance, repair and rehabilitation needs for each bridge, the cost of performing preservation work can be compared with the cost of completely replacing a bridge. The NBIAS may determine replacement of a bridge is needed if replacement is the most cost-effective means to satisfy the existing needs. Alternatively, if the physical condition of the bridge has deteriorated to a point where the bridge is considered unsafe (where the threshold for such a determination is specified by the system user), the system may consider bridge replacement to be the only feasible alternative for the bridge. The application of the preservation policy at the bridge level, and consideration of the trade-off between performing bridge rehabilitation or replacement, represents a new feature of NBIAS added since completion of the 2002 C&P report that is expected to significantly improve the quality of the system's results.

Planned Improvements to NBIAS

Prior versions of NBIAS were very limited in terms of the physical condition measures that could be produced, since bridge elements were modeled at an aggregate level only. The introduction of full individual bridge analysis in the current version will make it possible to include a much broader range of bridge condition measures in future editions of the C&P report. These measures may include average Health Index; average Sufficiency Rating; number of bridges Structurally Deficient and/or Functionally Obsolete; deck area for Structurally Deficient and/or Functionally Obsolete bridges; and predicted deck, superstructure, and substructure component ratings.

With the exception of the Health Index, all of the measures listed above have been defined by FHWA and are detailed in the *NBI Coding Guide* and/or Chapter 3 of this report. The Health Index is an additional measure that can be calculated directly from element data. This measure may range from 0 to 100, with a value of 0 indicating a bridge with all of its elements in the worst defined condition, and a value of 100 indicating a bridge with all of its elements in the best defined condition. The Health Index is useful for characterizing the physical condition of a bridge or set of bridges. It tends to be highly correlated with the Sufficiency Rating, which also is measured on a scale from 0 to 100. However, the Health Index excludes consideration of functional characteristics included in the Sufficiency Rating. This measure was initially defined by the California Department of Transportation and is now included in Pontis.

A series of further improvements are planned to the analytic approach and models in NBIAS. These improvements include:

- Consideration of a broader range of factors in calculation of functional improvement needs, including additional factors quantified in calculation of Sufficiency Rating and Structurally Deficient/Functionally Obsolete status;
- Improved handling of potential needs for adding lanes to existing bridges not presently being modeled in NBIAS (which considers needs for widening existing lanes) or HERS;
- Improved models for action costs and deterioration rates developed using additional baseline data for calibration. Additional work is planned for investigating the feasibility of modeling the dependence of deterioration rates on age and/or other factors not currently addressed in the Markov modeling approach; and
- Inclusion of actual element data rather than predicted element data where such data are available.