SCHOOL OF
CIVIL ENGINEERING

INDIANA
DEPARTMENT OF TRANSPORTATION

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-88/15 -2

Executive Summary, Vol. 1

THE DEVELOPMENT OF OPTIMAL STRATEGIES FOR MAINTENANCE, REHABILITATION AND REPLACEMENT OF HIGHWAY BRIDGES, FINAL REPORT VOL 1: THE ELEMENTS OF INDIANA BRIDGE MANAGEMENT SYSTEM (IBMS)

Kumares C. Sinha
Mitsuru Saito
Yi Jiang
Sudhir Murthy
Ah-Beng Tee
Mark D. Bowman

PURDUE UNIVERSITY

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-88/15 -2

Executive Summary, Vol. 1

THE DEVELOPMENT OF OPTIMAL STRATEGIES FOR MAINTENANCE, REHABILITATION AND REPLACEMENT OF HIGHWAY BRIDGES, FINAL REPORT VOL 1: THE ELEMENTS OF INDIANA BRIDGE MANAGEMENT SYSTEM (IBMS)

Kumares C. Sinha
Mitsuru Saito
Yi Jiang
Sudhir Murthy
Ah-Beng Tee
Mark D. Bowman

Digitized by the Internet Archive
in 2011 with funding from
LYRASIS members and Sloan Foundation; Indiana Department of Transportation

http://www.archive.org/details/developmentofopt1502sinh

Executive Summary

The Development of Optimal Strategies for Maintenance Rehabilitation and Replacement of Highway Bridges,
Final Report Vol. 1: The Elements Of The Indiana Bridge Management System

TO: Harold L. Michael, Director
Joint Highway Research Project

FROM: Kumares C. Sinha, Research Engineer
Joint Highway Research Project

August 30, 1988
Revised August 15, 1989
Revised January 22, 1991
Project: C-36-73I
File: 3-4-10

Attached is the Vol. 1 of the Final Report on the HPR Part II Study entitled, "The Development of Optimal Strategies for Maintenance Rehabilitation and Replacement of Highway Bridges." This volume provides an overview of the various components of the Indiana Bridge Management System developed in the study. It covers all ten tasks of the study and highlights the organization and data management aspects of the system. The research reported in this volume was conducted under my directions.

This report is forwarded for review, comment and acceptance by the InDOT and FHWA as partial fulfillment of the objectives of the research.

Respectfully submitted,

K. C. Sinha
Research Engineer

KCS/rrp

cc: A.G. Altschaeffl
J.L. Chameau
W.F. Chen
W.L. Dolch
A.A. Fendrick
J.D. Fricker
D.W. Halpin
G.L. Henneke
K.R. Hoover
C.W. Letts
C.W. Lovell
D.W. Lucas
J.F. McLaughlin
R.D. Miles
D.C. Nelson
P.L. Owens
B.K. Partridge
C.F. Scholer
G.B. Shoener
K.C. Sinha
C.A. Venable
T.D. White
L.E. Wood

THE DEVELOPMENT OF OPTIMAL STRATEGIES FOR MAINTENANCE, REHABILITATION AND REPLACEMENT OF HIGHWAY BRIDGES
FINAL REPORT VOL. 1: THE ELEMENTS OF THE INDIANA BRIDGE MANAGEMENT SYSTEM

Executive Summary

Kumares C. Sinha
Professor of Civil Engineering

Mitsuru Saito
Yi Jiang
Sudhir Murthy
Ah-Beng Tee
Graduate Research Assistants

Mark D. Bowman
Associate Professor of Civil Engineering

and

Joint Highway Research Project

Project No.: C-36-73I

File No.: 3-4-10

Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

Indiana Department of Highways

and the

U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessary reflect the official views or policies of The Federal Highway Administration. This report does not constitute a standard, specification, or a regulation.

Purdue University
West Lafayette, IN 47907

August 30, 1988
August 15, 1989 Revised
Revised January 22, 1991

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/IN/JHRP-88/15	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle THE DEVELOPMENT OF OPTIMAL STRATEGIES FOR MAINTENANCE, REHABILITATION AND REPLACEMENT OF HIGHWAY BRIDGES, FINAL REPORT VOL. 1: THE ELEMENTS OF THE INDIANA BRIDGE MANAGEMENT SYSTEM		5. Report Date Aug. 30, 1988 Rev. Aug. 15, 1989 - Rev. Jan. 22, 1991
		6. Performing Organization Code
7. Author(s) Kumares C. Sinha, Mitsuru Saito, Yi Jiang, Sudhir Murthy, Ah-Beng Tee and Mark D. Bowman		8. Performing Organization Report No. JHRP-88/ 15
9. Performing Organization Name and Address Joint Highway Research Project School of Civil Engineering Purdue University West Lafayette, Indiana 47907		10. Work Unit No.
		11. Contract or Grant No. HPR-1(24) Part II
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204		13. Type of Report and Period Covered Executive Summary Final Report Volume 1 of 6
		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration. Study title is "The Development of Optimal Strategies for Maintenance, Rehabilitation and Replacement of Highway Bridges".

16. Abstract

This report is the first of a six-volume final report presenting the findings of the research work that was undertaken to develop a framework for managing bridge maintenance, rehabilitation and replacement activities in Indiana. This volume provides an overview of the entire system with a particular emphasis on implementational aspects.

The titles of all six volumes are listed below.

1. The Elements of Indiana Bridge Management (IBMS)
2. A System for Bridge Structural Condition Assessment
3. Bridge Traffic Safety Evaluation
4. Cost Analysis
5. Priority Ranking Method
6. Performance Analysis and Optimization

17. Key Words Highway Bridge Management; Bridge Maintenance; Ranking; Optimization; Bridge Rehabilitation; Bridge Replacement; Organization; Cost Analysis	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-69)

EXECUTIVE SUMMARY

Introduction

Like many other states, Indiana also has a large number of bridges that need immediate attention. Because of the imbalance between the bridge repair and replacement needs and the fiscal constraint, it is important that a systematic bridge management system be employed to allocate available resources in an optimal manner. This paper presents the basic elements of the bridge management system that was developed for Indiana Department of Transportation (INDOT). The purpose of the overall research consisted of the following objectives:

1. Development of a method to better use the existing bridge inspection data in selecting bridges for maintenance, rehabilitation, and replacement;

2. Development of a method to provide consistent and statewide uniform measurements for rating bridges;

3. Analysis of bridge maintenance, rehabilitation, and replacement costs, and analysis of relationships between bridge attributes and costs;

4. Development of a method to estimate remaining service life of bridges and effects of bridge activities on condition rating and service life;

5. Development of a bridge traffic safety evaluation scheme that relates physical characteristics of bridge structure to accident potential;

6. Development of a project selection procedure using life cycle cost analysis, ranking, and optimization method; and

7. Development of a set of guidelines that can be used by the Indiana Department of Transportation in implementing a bridge management system including data bases and organizational requirements.

System Modules

The proposed Indiana Bridge Management System (IBMS) would consist of eight essential modules, as listed below.

1. Data Base Module
2. Condition Rating Assistance Module
3. Bridge Safety Evaluation Module
4. Improvement Activity Identification Module
5. Impact Identification Module
6. Project Selection Module
    a. Life cycle costing sub-module
    b. Ranking sub-module
    c. Optimization sub-module
7. Activity Recording and Monitoring Module
8. Reporting Module

The data base of a bridge management system must contain all necessary information about each state-owned bridge in the system to perform the tasks

of the other modules and to prepare various network summary reports.

The Condition Rating Assistance Module is a computer system that can assist in bridge inspection. The system divides a bridge into three major components: deck, superstructure, and substructure. Each component is further divided into simpler subcomponents for condition assessment. This approach promotes consistency in the condition assessment process and effectively reduces the likelihood of omitting significant subcomponents or committing significant assessment errors. A computer program has been developed for this module to filter out inconsistencies in the condition ratings, to assist a bridge inspector in performing a bridge inspection, to train new inspectors, and to predict the condition rating of a bridge as a result of certain improvement activities.

The Bridge Traffic Safety Evaluation Module allows bridge inspectors to translate their subjective judgements on bridge traffic safety into a quantifiable value. An interactive computer program was developed for this module. The bridge inspector inputs word ratings for the bridge components associated with traffic safety, and the program computes a "bridge Safety index" based on fuzzy sets principles.

The Improvement Activity Identification Module would help bridge inspectors identify appropriate improvement activities based on the evaluation of physical deficiencies. Presently, this module is not equipped with a detailed set of rules to select improvement alternatives. A data base must be created to develop distress - improvement relationships by highway type, condition rating, and traffic volume so that a computerized improvement alternative selection process can be developed. Presently, this module is designed to

provide information on the types of improvement activities that may be recommended at certain condition ratings.

The Impact Identification Module would help highway programmers identify the costs and other consequences that structurally deficient and/or functionally obsolete bridges would place on the highway agency, the highway user, and the surrounding community. A detailed analysis has been conducted on bridge costs. Impacts on the highway user and the community have not been well established. A community impact index has however been developed as a function of the expected detour length.

The Project Selection Module is a group of decision-making tools consisting of three sub-modules, as mentioned below:

1. Life cycle costing sub-module

2. Ranking sub-module

3. Optimization sub-module

They can be used singly or together to select and program a set of bridge improvement projects. The life cycle cost analysis sub-module would be used to find the most economic option at a bridge site based on the equivalent uniform annual cost for perpetual service approach. The ranking sub-module would be used to compare bridge projects on the basis of a set of objectives, in addition to economic desirability. The optimization sub-module would be capable of testing the effects of various combinations of fiscal and other constraints upon the initial selection of bridge projects.

The Activity Recording and Monitoring Module would be set up to keep

track of maintenance, rehabilitation and replacement of all bridges in the network and to accumulate historical data. The accumulated data on cost, timing, and sequence of bridge related activities can be used in the future to upgrade the project selection module of the proposed IBMS. This module can also be used for checking the backlog of needed bridge maintenance activities.

The Reporting Module encompasses all components of the IBMS. Reports generated by this module are actually outputs from other modules and sub-modules. The following reports would be produced from the reporting module:

1. Bridge Condition Summary
2. Bridge Characteristics Summary
3. Maintenance Need and Backlog Summary
4. Improvement Activity Summary
5. Network Level Impact Summary
6. Life Cycle Cost Analysis Report
7. Priority Ranking Report
8. Optimal Activity Programming Summary
9. Budget Reports
10. Other Reports

The bridge condition report would provide summaries on the distribution of condition ratings of state-owned bridges by district, by bridge type, by

highway class, or by bridge age. The bridge characteristics report would give summary statistics on bridge characteristics included in the IBMS, such as ADT, condition rating, safety index, and so on, to help bridge inspectors evaluate the current status of the state-owned bridges. The maintenance need and backlog report would help the Operations Division and the districts identify bridges which need immediate or future attention. The improvement activity report would be a summary given for the types of improvement activities included in the proposed IBMS by using the data kept in the activity recording and monitoring module. This summary would help the Programming Division estimate the amount of money needed to execute certain improvement activities. The network level impact report would give a summary of potential impacts of bridge related activities including user costs and community impacts. However, only a part of this report can be produced at present because the user costs and community impacts can not be explicitly determined.

The life cycle cost analysis report would give results of the economic analysis and help programmers identify bridges that should be recommended for rehabilitation or replacement. The priority ranking report would give a list of bridges ranked either by the total utility point or the utility point earned for each criterion. This report may not give an optimal solution to bridge project programming, but the ranking list can be effectively used in the initial selection of projects. The optimal activity programming summary would list rehabilitation and replacement options by programming period in a given planning horizon. It would also give the estimates of improvement costs for individual bridges, the extent of federal and state funds used, and the location of selected projects by district. The budget report would be an aggregate summary on expected budget schedule to maintain the state bridge

network at desired condition and safety levels. It would provide condition summaries and associated expenditure levels under various funding scenarios.

Other reports can consist of the following existing reports:

1. Annual SIA Report
2. Annual Inventory of Bridges
3. Unit Cost Computation Report
4. Overweight Vehicle Permit Report

In addition, two more reports can also be included: 1. Bridge Posting/Overload Route Report, and 2. Vertical Clearance Route Report.

Implementation Procedure

The modules discussed above would be used at different stages of IBMS. The overall procedure of the IBMS would not differ significantly from the existing practice, but it would make the process more systematic and efficient. The proposed system would streamline the project selection process and provide the programmers a tool to create different programming schedules for various funding scenarios.

Two separate data bases would be created for the IBMS: one for running the three submodules of the project selection module and the other for storing historical data monitoring all bridge related activities. The data base necessary to the project selection module should contain records relevant only to state-owned bridges. The second data base would consolidate in one file all

activity records currently scattered in several files. The information of the second data base will be necessary to update the cost and other models of the IBMS in the future.

Records of individual bridges are updated every other year, and the bridge inspector can take advantage of the following three modules of the IBMS in updating the bridge records: the condition rating assistance, traffic safety evaluation, and improvement activity identification modules. The condition rating assistance module would help the inspector assign appropriate ratings to bridge components. This module would be especially helpful to train a new inspector so that he or she can develop a condition rating system consistent with other inspectors in the state. The safety evaluation module would help the inspector compute a bridge traffic safety index to be used in the ranking and optimization procedures. The improvement activity identification module would help the inspector identify appropriate categories of improvement activities.

After organizing the basic input data possible consequences of undertaking various alternatives including "do-nothing" can be assessed. The impact identification module is to be used here to estimate potential impacts in terms of agency cost, highway user cost, and community impact.

Once the IBMS data base is fully developed and the updating task is accomplished regularly, the status of bridges can be obtained at any time upon request. The present condition summary report, the bridge characteristic summary report, the improvement activity summary report, and the network level impact summary report can be created whenever requested by manipulating the IBMS data base.

A life cycle cost analysis can be performed to determine which alternative should be selected for a particular bridge to incur the least life cycle cost. The approach can also be used to compare projects at different bridge sites. The ranking submodule of the IBMS is to be used when evaluating bridges with varying levels of service and a wide range of impacts. A priority ranking list is created from this step.

An initial list of bridges requiring rehabilitation and replacement activities is to be prepared by the central office bridge management group on the basis of life cycle costing and/or ranking submodule. This list would be sent to the district offices for review and modification. The bridge management group would then adjust the selected projects taking into consideration feedback from the district offices. The optimization program would be run at this point several times for comparison when various funding scenarios would have to be considered. A network improvement activity programming summary report and a budget report would be produced. A final activity programming schedule would then be sent to the highway improvement programming (HIP) group for evaluation with other highway related projects. If any adjustments are requested by the HIP group, the optimization step would be repeated to meet the requirements set by the HIP group in the development of the final highway improvement program.

The proposed IBMS has all the necessary elements to meet the requirements for programming bridge improvement works for inclusion in the Biennial Highway Improvement Program. However, the components of this system would need periodic updating. The activity recording and monitoring module is to be used to accumulate the necessary data for future analyses to improve the individual IBMS modules.

Organizational Framework

The initial implementation of IBMS will be accomplished by the Roadway Management Group. However, for continued use of IBMS it would be necessary to form a bridge management group within the Program Development Division of INDOT. Such a group would improve the efficiency of data collection, analysis and prioritization, and would facilitate communication between the central office and the district offices. The bridge management group would be made up of a bridge inspection subgroup and a bridge activity programming subgroup.

Under the supervision of the bridge inspection subgroup, the district bridge inspector would carry out the scheduled inspection of the bridges within the particular district. The inspector would fill in the bridge inspection report at the bridge site. The computation of condition ratings and traffic safety indices can be undertaken at the office where appropriate microcomputer facilities are available. Inspection reports would then be returned to the bridge inspection subgroup at the central office for record keeping and coding into the SIA data base. If the district bridge inspector needs assistance in inspecting certain bridges, requests can be made for an on-site inspection by the central office bridge inspectors.

The selection of candidate bridge projects would consist of a series of meetings between the district office and the programming subgroup. After meetings and discussions with district inspectors and with the assistance of the optimization routine a final set of bridges would be selected for inclusion in the HIP. After budgets are allocated, design drawings are to be prepared, environmental aspects cleared, and right-of-way purchased, if necessary, and the selected improvement projects are let for contract.

The bridge management group within the Program Development Division would maintain the IBMS data base and the bridge history data base. The group would also be in charge of running the three submodules of the project selection module and preparing reports as needed. This group should also be responsible for the orderly implementation of various elements of the IBMS.

In summary, the organization of the proposed bridge management group would have two major changes over the existing procedure. First, the bridge inspection sub-group would become an integral part of the bridge programming process. The direct involvement of the central office bridge inspectors into the programming procedure will help improve the communication between the district offices and the central office. Second, the bridge activity programming sub-group would serve as the in-house updating team that can continuously examine the effectiveness of the IBMS and make necessary modifications. This sub-group would also be able to promptly provide information on the effect of various funding scenarios for use of the executive office or other divisions of the INDOT.

COVER DESIGN BY ALDO GIORGINI