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Autor(en): **Mehta, Ramesh / Garrabrant, Richard**

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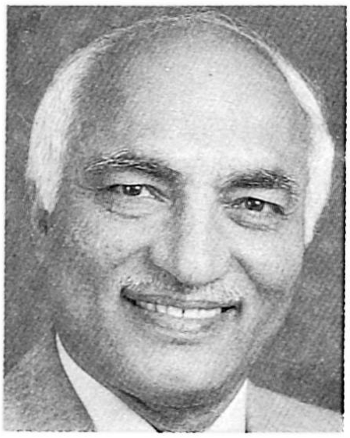
# Bridge Management System for the New York State Thruway Authority

Système de gestion des ponts pour l'Etat de New York

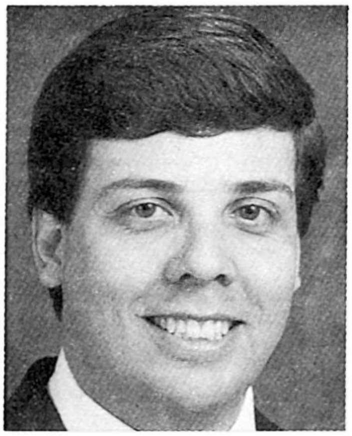
Brückenverwaltungssystem für den Staat Neu York

**Ramesh MEHTA**
Director
NY State Thruway Auth.
Albany, NY, USA



Ramesh Mehta is a registered Professional Engineer in the State of New York and is responsible for managing the Authority's program of inspection, maintenance, and rehabilitation of bridges. Previously, he worked for the Indian Railways and also served as Bridge Maintenance Expert on the Asian Development Bank's project in the Phillipines.

**Richard GARRABRANT**
Senior Eng.
NY State Thruway Auth.
Albany, NY, USA



Richard Garrabrant is a registered Professional Engineer in the State of New York. A Senior Soils Engineer for the Thruway, he also directs the development of all computer applications for the Bridge and Pavement Management Systems of the Authority.

## SUMMARY
A Bridge Management System (BMS) for the New York State Thruway Authority (Authority) is being developed through a joint research effort between the Authority and Rensselaer Polytechnic Institute (RPI), Troy, New York. This paper discusses the development of the BMS Plan, BMS development tasks, and implementation issues. The term BMS is used to describe a computerized decision-aiding system incorporating both expert knowledge of bridge deterioration processes and effectiveness of management activities. Economic models of life-cycle costs are included in a process designed to provide a predefined level of service to the travelling public at a minimum cost The BMS should assist in the optimization of available resources.

## RÉSUMÉ
Un système de gestion de la maintenance des ponts (BMS), à l'intention de l'Administration des voies express de l'Etat de New York (Administration), est en cours de développement et résulte d'un effort de recherche conjugué entre cette Administration et le Rensselaer Polytechnic Institute (RPI), Troy, New York. Le présent article examine le développement du plan BMS, les tâches impliquées et les problèmes soulevés par la réalisation de ce développement. Le terme BMS définit un système d'aide à la décision assisté par ordinateur, qui implique des spécialistes connaissant d'une part les processus de détérioration des ponts et, d'autre part, la gestion efficiente des affaires. Des modèles de coûts d'exploitation et de maintien économiques sont inclus dans un procédé destiné à fournir un service prédéfini à coût minimal pour le passage public. Le BMS doit pouvoir servir à optimiser les ressources disponibles.

## ZUSAMMENFASSUNG
In Zusammenarbeit mit dem "Rensselaer Polytechnic Institute" in Troy, NY entwickelt die "New York State Thruway Authority" ein Brückenverwaltungssystem. Beschrieben werden die Entwicklung des Vorhabens, seine Ziele und Fragen der Implementierung. Das System soll als computerisierte Entscheidungshilfe sowohl Expertenwissen über den Alterungsvorgang Vorgang enthalten, als auch die Brückenverwaltung effizient gestalten. Durch ökonomische Modelle der Lebenszykluskosten soll den Verkehrsteilnehmern ein im voraus festgelegter Unterhaltungsstandard zu einem Minimum an Kosten geboten werden. Es dient damit dem optimalen Einsatz vorhandener Mittel.

## 1.0 BACKGROUND

1.1 The Governor Thomas E. Dewey Thruway, commonly referred to as the New York State Thruway, is the longest toll road in the United States. It is a 570-mile long superhighway which serves as a main corridor of New York State and makes direct connections with other States major highway networks. An independent public benefit corporation, the New York State Thruway Authority (Authority) is separate from the New York State Department of Transportation (NYSDOT) in both its management and funding. The inventory of Thruway bridges includes 858 structures classified into 24 different types. The most common bridge type is the "composite I beam" simply supported structure which comprises 65% of all Thruway bridges. Other types include built-up girders, continuous I-beams, trusses, box culverts, concrete frames, and concrete arches. Span lengths vary from 20 feet for an ordinary box culvert to 1212 feet for the main truss span of the three mile long Tappan Zee Bridge which traverses the Hudson River. Other major structures include the one mile long Castleton-on-Hudson bridge, two, twin Grand Island bridges near Niagara Falls, and the 1.3 mile long viaduct in the Niagara Section.

## 2.0 IMPETUS FOR DEVELOPMENT

2.1 The majority of the toll highway system was constructed and opened to traffic between 1954 and 1960. The original construction of most structures utilized non-air-entrained concrete and non-waterproof bridge joints. These construction features in combination with intensive snow and ice control procedures utilizing chemical de-icing agents and an increasing traffic loading have resulted in a deteriorating bridge infrastructure. The goal of the BMS under development is to enhance the Authority's decision making capability through a programmatic approach to selecting and implementing bridge projects. Special emphasis is placed on preventive maintenance which will help to avert or delay the excessive deterioration of bridges through planned actions that are less involved than major rehabilitation or reconstruction.

## 3.0 APPROACH

3.1 A detailed evaluation of the Authority's bridge program was conducted over a two year period while developing the BMS Plan. Interviews at all levels of the Bridge Program were conducted starting with the Executive Director, Chief Engineers, Bridge Maintenance Engineers, and all supervisory personnel engaged in bridge inspection, maintenance, design, and construction. Emphasis during the evaluation was placed on the maintenance planning and implementation process, a review of products currently used to support the decision making process, and the needs of the bridge program.

3.2 The Plan for the development and implementation of the BMS [1] was prepared in a cooperative effort with faculty and staff from Rensselaer Polytechnic Institute and personnel at the Authority involved with the bridge program. The BMS Plan provided a description of the various components, functions, and organizational framework of the Authority's BMS.

## 4.0 MAJOR TASKS

4.1 The development of the BMS is divided into the four major tasks described below:

**4.1.1 Part 1** <u>Macro-Analysis of Bridge Condition and Needs</u>
This part involves reviewing and evaluating the present bridge conditions and needs from the system level perspective. It will utilize 13 years of bridge condition ratings generated from the existing biennial bridge inspection program, historical maintenance information, and experience. It will establish causes and costs of deterioration and bridge needs. The findings of this part are useful for possible adjustments in the current bridge program.

**4.1.2 Part 2** - <u>Development of a Bridge Database</u>
This part involves developing a comprehensive database management system capable of supporting the specific needs of the BMS, maintaining compatibility requirements with the NYSDOT, and integrating BMS with the existing Pavement Management System (PMS). The ORACLE relational database management system tool will be utilized to achieve the BMS database implementation and the interfaces between the respective systems. Existing databases located within the Authority will be enhanced and restructured to allow expanded data analysis not currently available.

**4.1.3 Part 3** - <u>Development of Decision Methodologies</u>
This part involves the development of decision methodologies required to achieve the BMS goals at the project and system levels. At the project level, methodologies will focus on each element to predict service lives, evaluate life-cycle costs of treatment options, and establish maintenance plans. Methodologies will be developed to provide a span-by-span description of conditions and needs that will facilitate development of a detailed maintenance program (e.g., Scope of Work, schedules, resources, etc.). At the system level, the methodologies will enable project selection, establishment of priorities and forecasting of future conditions and needs. The selection of a treatment option that is the best fit from not only the project basis but also from the system level basis is a very involved analysis.

**4.1.4 Part 4** - <u>Program Development and Monitoring</u>
This part involves the development and monitoring of the bridge program. It will provide the procedures and documentation required for planning and implementing the bridge program, provide a mechanism for program control and on-line progress monitoring. Additionally, it will be possible to evaluate the effectiveness of the maintenance program.

Major functions and the functional framework of the BMS are shown in figures 1 and 2.

FIGURE 1. MAJOR FUNCTIONS OF BMS

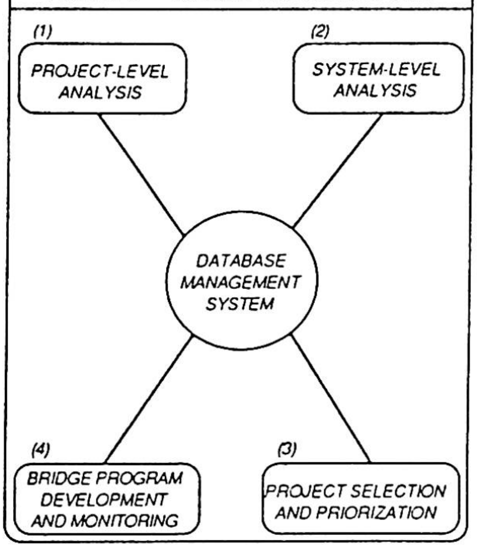
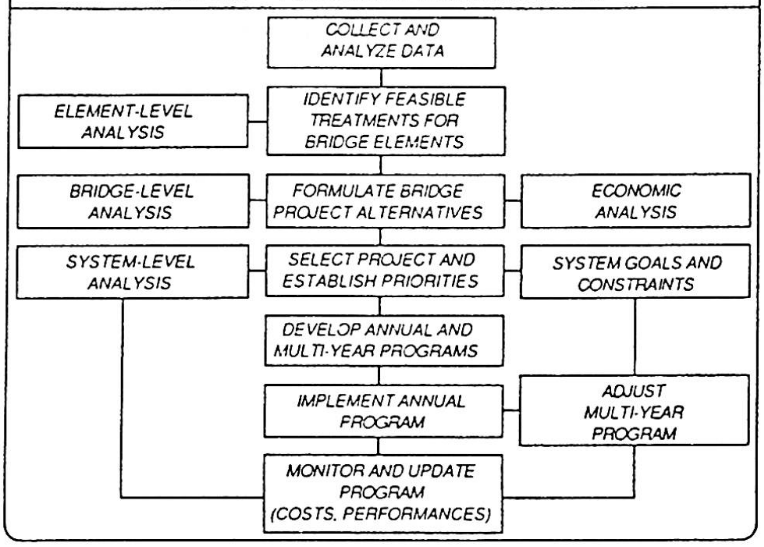



FIGURE 2. FUNCTIONAL FRAMEWORK OF BMS



## 5.0 ENHANCEMENTS TO EXISTING BRIDGE PROGRAM BY THE BMS

5.1 The principal goal of the Authority's bridge program is to ensure the safety and serviceability of Thruway bridges in the most cost-effective manner through bridge inspection, planning, maintenance, design, rehabilitation, and reconstruction.

5.2 Major aspects of the bridge program which will be enhanced by BMS are described below:

### 5.2.1 Bridge Inventory and Inspection System
Additional guidelines will supplement the current bridge inspection techniques in order to clearly identify the relations between inspector's ratings and distress features on bridge elements and to better interpret condition ratings and develop maintenance needs.

### 5.2.2 Data Collection, Analysis, and Management
Selective data will be collected to enable a comprehensive analysis of the condition and assess needs of Thruway bridges. Data entities and their relationships will be structured in an efficient and easy to use manner, and a state-of-the-art database management system will be developed to facilitate data operations and interface with other databases.

### 5.2.3 Project-Level Analysis
Predictions of deterioration and remaining service lives of major bridge components will be determined and evaluated. Maintenance, rehabilitation, and reconstruction alternatives will be formulated for each bridge element and for each bridge as a whole and their cost analysis performed.

### 5.2.4 System-Level Analysis
Methodologies will be used to forecast deterioration and future condition of bridges, analyze short and long-term maintenance and capital (rehabilitation and reconstruction) needs, select the most cost-effective mix of maintenance and capital projects, prioritize projects (based on life-cycle costs), and establish a system wide perspective to project-level analysis.

### 5.2.5 Maintenance Planning, Monitoring, and Control
Based on established needs, plans of the annual and multi-year maintenance programs will identify preventive and corrective maintenance activities (together with their scope, required resources, schedule and frequency of application), and will provide real-time monitoring and control of the program. Furthermore, it will avail up-to-date and complete information needed for individual bridge related planning activities and will assist in historical effectiveness.

### 5.2.6 Support to Engineering Services Department
It will enhance the current load rating technique, structural and functional capacity evaluations, identify pertinent design concepts, and support the overall bridge design, rehabilitation, and reconstruction function.

### 5.2.7 Integration with PMS and Interface with NYSDOT
It will integrate BMS with the Authority's PMS to phase bridge projects along with highway projects to affect savings on traffic control etc. It will provide an interface with NYSDOT for a continuous exchange of information with a centralized database pertaining to the bridge inventory, inspection, load rating, and other bridge related issues.

5.2.8 **Staged Implementation with Early Products**
The development of BMS will take place in accordance with a phased plan which emphasizes an early introduction of products in the Authority's operation. It will evaluate historical data on the condition of Thruway bridges, susceptibility to scour and other identified vulnerabilities such as fatigue cracking, fracture critical members, seismic hazards, ship collisions etc. Past maintenance and rehabilitation practices and specific characteristics pertaining to design, construction, materials etc. used for Thruway bridges will also be evaluated.

## 6.0 BRIDGE INVENTORY AND INSPECTION DATA

6.1 Three major types of data are required to implement a comprehensive BMS: bridge inventory, inspection and load rating data; improvement activity data; and cost data related to maintenance, rehabilitation and reconstruction. The primary database containing such data as the bridge inventory, inspection, and load rating already exists in the Authority.

6.2 The condition of each Thruway Bridge is currently assessed through the Bridge Inspection Program involving biennial inspections of all structures. Elements of each bridge are rated in accordance with procedures described in the Bridge Inspection Manual developed by NYSDOT [2], a modification of the manual developed by the Federal Highway Administration (FHWA). Each bridge element is rated on a numerical rating scale of 1 to 7 by the Bridge Inspector. A rating of 1 represents a potential hazardous condition and 7 of new condition. The condition of a bridge as a whole is also assessed by the inspector on a numerical scale of 1 to 7 with 1 representing very poor condition and 7 as good condition.

6.3 The condition rating of each bridge is computed as the weighted average of the ratings received by the various elements of a bridge considered most important for its unrestricted use. These elements are assigned weights in proportion to their importance to the bridge. Principal structural elements include: primary members, abutments, piers, and the structural deck all of which have high weightage.

6.4 Presently, condition ratings are used in the initial screening for bridge project selections. However, the condition ratings sometimes provide misleading information especially in the case of multi-span bridges. A possible result of the misleading rating is the assignment of resources on an inappropriate structure. A condition assessment for each span is needed to assist in the identification of the span with the lowest condition rating and to identify the low structure condition assessment of various elements in the span. This approach will provide a logical method for the identification of problem areas and the proper assessment of bridge needs.

## 7.0 DETERIORATION MODELS

7.1 Deterioration models for individual bridge components, spans, and each bridge as a whole will be developed. These models will be based on the inspection ratings captured since the inception of the inspection program in 1978 and information on bridge maintenance and rehabilitation. It will be difficult to develop deterioration models due to the lack of inspection ratings prior to 1978 and the lack of clear and definitive maintenance records for each structure. Stochastics or probabilistic regression models will be utilized to analyze and represent the bridge deterioration process. A non-linear deterioration model developed by West et al [3] appears to be a good effort in predicting future conditions.

## 8.0 LIFE-CYCLE COSTS MODELS

8.1 The evaluation of alternative treatments for each bridge will include not only the first or initial cost but also periodic maintenance costs and possibly the rehabilitation or reconstruction cost required as the bridge approaches the end of its service life. Treatment alternatives for bridges have unequal life expectancy, level of service, and maintenance costs, and it is appropriate to include maintenance costs in the life span of each structure.

8.2 The development of life-cycle cost models requires a strong understanding of the behavior and life expectancy of various materials used in the structure and the effects of various maintenance practices. A typical example is a concrete deck supported on steel or pre-stressed concrete girders which are subject to de-icing chemicals in the process of snow and ice control operations. These de-icing chemicals provide a safer traveling surface for the motorists yet have adverse effects on the concrete deck and also on the steel or pre-stressed girders. The importance of washing the superstructure is being advocated at present and the frequency at which this task should be performed to negate the effects of the de-icing chemicals has to be determined. The cost of deterioration induced by not washing the superstructure has also to be evaluated. These aspects of bridge maintenance practices and their associated cost will be considered in developing life-cycle cost models, a major component of the BMS.

8.3 The Authority has comprehensive Bridge Maintenance Guidelines which direct the maintenance of bridges through the use of Demand, Preventive, Corrective Maintenance and Bridge Rehabilitation. These guidelines also list preventive maintenance tasks which have to be performed on cyclic and non-cyclic (need based) basis. The frequencies for various cyclic preventive maintenance tasks have been fixed empirically and the cost-effectiveness of these tasks have to be evaluated. The BMS will assess and adjust the recommended frequencies of all bridge maintenance tasks to ensure the safe and cost effective operation of Thruway bridges.

## 9.0 CONCLUSIONS

9.1 The BMS when completed will provide an organized method for entering, retrieving, and analyzing information about Thruway bridges. It will provide needed engineering and economic analysis methodologies for evaluating, selecting, and optimizing the allocation of available resources. The BMS will support the entire range of decisions associated with the preservation of the Authority's bridge infrastructure.

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