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Bridge Database Management System

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Abstract
A comprehensive framework has been outlined for the management of bridges on the road networks across Pakistan, after reviewing Bridge Management Systems (BMS) in operation in developed countries. As a core objective this Bridge Database Management System (BDMS) specifies the requirements to enable optimized bridge maintenance taking into account factors affecting bridge management and development of associated software. The developed system ably integrated existing procedures, while adopting certain principles and established new modules.

Indigenous adaptive core model of BDMS has been developed for highway and urban bridges; however, it has the capacity of coupling independent modules to make it a valuable tool for civic, highway and/or raliway agencies and similar organizations. BDMS provides quantitative assistant of bridges, based on inspections of each of the bridge components. The system can be used to determine priority on repair works to be carried. Bridges around the Karachi metropolitan area were assessed using this BDMS Software, and data collected has been tested for prioritizing using BDMS. The results demostrated that, BDMS is an effective and versitile tool for management and maintenance.

Keywords
Bridge Management System, Asset Management, Infrastructure Management, Structural Monitoring

1. Introduction

Research on various aspects of Civil Infrastructure research has been a topic of interest for decades and is usually focused more on the design and construction of new facilities than on the maintenance, repair, and rehabilitation of existing facilities. More recently, a focus on the latter part of the facility lifecycle has emerged as "asset management" or "infrastructure management". Bridges constitute a major part of country asset and as bridges age, deterioration caused by heavy traffic and aggressive environment becomes increasingly significant resulting in a higher frequency of repairs and possibly a reduced load carrying capacity.

Over the years, with resources largely dictated by economical and political forces towards expansion and growth, the maintenance component unduly shrank to little more than repair on as-needed basis. The authorities often find it difficult to justify the need of expenditure on bridge monitoring and maintenance program.

In spite of the significant advances in structural and material engineering, several bridges have failed due to various causes during last few decades. Investigations of the failure revealed that they could have been prevented through timely inspection and corrective action on the deficiencies discovered. Thus the need and importance of regular and periodic safety inspection and monitoring procedures became obvious.

With the ever-increasing weight and volume of traffic and deterioration and failure of bridges finally focused the attention of the concerned authorities in developed countries of the world towards the issue of bridge monitoring.

At present there is no legislative cover for bridge monitoring in Pakistan. To meet the challenge of continued safety and mobility in bridges, there is an impending need of a collaborative effort by all the concerned bodies to provide the procedures and policies for implementation and legislation for bridge monitoring in Pakistan.

2. History of Monitoring

In 1967, the failure of Point Pleasure Bridge (Silver Bridge) over the Ohio River, USA, marked a turning point in the maintenance practice of bridges, and from emerged the present bridge safety inspection and monitoring program in USA. The impact of the said failure was so powerful that for fear of a similar catastrophe, a nearly identical and contemporary bridge was dismantled in 1969.

The Point Pleasant Bridge disaster prompted the then American Government to order a special task force to investigate: the collapse of the bridge; to propose action for speedy reconstruction of the bridge and to suggest procedures and preventive actions to avoid future failures. Consequently, Federal Highway Administration (FHWA) directed all 50 states to review all existing highway bridges and prepare inventory by January 1970. All bridges longer than 20 feet were required to be described and registered in a national database, and thus the National Bridge Inventory (NBI) was established. Priority was to be given to the pre-1935 bridges.

An inspection criteria developed by AASHTO was published in the 1971 “Manual of Maintenance Inspection of Bridges.” The general policy required inspection of all structures on a five-year cycle, and that of important structures every two years. Concerns brought by the revelations of deteriorated conditions of several bridges resulted in 1978 Surface Transportation Act, requiring all owners of highway bridges to conduct biennial inspection with few exceptions. The 1988 revision of the National Bridge Inspection Standards (NBIS) gave states the authority to vary the frequency of inspections. However, this policy required prior FHWA approval if the inspection frequency was to exceed two years.

While bridge inspection methods progressed, unfortunately, some more bridges failed (Table 1). Since the disaster of Mianus River Bridge in 1983, FHWA started the rigorous program of inspection and monitoring of bridges all around the United States (Narendra Taly).

3. Bridge Management System Concept

Most of the developed countries of the world, are now putting greater emphasis on maintaining and repairing their existing structures for the structural integrity, public safety and to save the capital investment. It is needed that there must be a systematic consideration of all the problems to fulfill the safety requirements and to ensure the best value for the money spent. To cope with this sort of problem, a Bridge Management System, BMS was introduced.

Table 1: Examples of Bridge Failures in USA

Year	Bridge	Catastrophe	Outcome
1967	Point Pleasant Bridge (Silver Bridge) located between Point Pleasant, West Virginia and Knanuga Ohio.	Sudden failure caused by stress-corrosion fracture at the pin-hole of a single eyebar member. (Death toll 47 out of 67 commuters)	Federal Highway Act of 1968, creating the National Bridge Inspection Program (NBIP) which ordered state agencies to catalogue and track the condition of bridges on principal highways.
1980	Florida's Sunshine Skyway Bridge	Destruction of one span due to ship impact	Focused attention on pier protection and ship impact forces
1983	Connecticut's Mianus River Bridge	Collapse due to pin-end-hanger failure	Examination of non-redundant and fracture-critical members
1987	New York's Schoharie Creek Bridge	Collapse	Need for underwater inspection and hydraulic evaluation
1989	Bridges in San Francisco Bay Area	Collapses due to intensified earthquakes	Examinations of the integrity of bridge structures under dynamic loading

3.1 Bridge Management System (BMS)

A BMS, in general, is a system or series of engineering and management functions which when taken together, provide the actions necessary to implement a bridge program. These actions may include, but need not to be limited to, assessing bridge problems, prioritizing and detailing bridge improvements, and programming and initiating projects. It gives officials a system-wide perspective that allows them to examine all bridges collectively rather than individually. A comprehensive bridge management philosophy provides reliable short-term and long-term predictive capabilities. A BMS yields the most out of both the corrective strategies used and the timing and money expenditures for maintenance, repairs, rehabilitation or replacement of bridges, while ensuring public safety and convenience as primary goals.

3.1.1 Objectives of Bridge Management System (BMS)

The objectives of the BMS is to provide the bridge authority a tool that helps to:

- Identify and establish responsibility for data collection and its management.
- Generate an automated database of bridge inventory, condition data and historic data file.
- Develop multi-period inspection procedures and reporting capabilities.
- Ensure coordination between bridge maintenance and improvement actions and a process of priority programming on the basis of cost-effectiveness.
- Ensure changing from unplanned emergencies to stable planned maintenance.
- Identify costs related to feasible actions, user costs associated with deficient bridge condition and budget and other key components.
- Ensure achievements of requisite safety (structural as well as functional safety) standards.
- Ensure a clear method of communicating needs and programs to outside audiences (i.e. the government, legislature, media, and public interest groups).
- Ensure technical and economical feedback.
- Include a computerized decision support system to supplement the BMS.

3.1.2 The BMS Modules

To perform the above activities in a systematic manner, a BMS model is comprised of components listed in Table 2. Also the interdependency of the computerized module of BMS is shown in Figure 1.

Table 2: Present Day Bridge Management System Components

A computerized part which contains	*Handbooks and manuals*	*Training programmes*
• Data base module • Inventory module • Inspection and testing module • Bearing capacity module • Ranking and budgeting module • Recording module for all above activities • Administration module	• Guidelines for the Management of Bridges • Handbook for Bridge Inventory • Handbook for Bridge Inspection • Manual for work description of Bridge Maintenance Activities • User Guide Manual • Operator Manual	• The software • Bridge Inventory • Bridge Inspection • Bridge Maintenance

Figure 1: Interdependency of Computerized BMS Modules

3.1.3 Phases of Monitoring

A bridge structure always requires a proper monitoring of its physical condition in an advance stage of distress and a regular monitoring during its lifetime. For this purpose condition surveys are carried out. However, a periodical monitoring is done during the lifetime of a structure for the assessment of deficiencies that can occur in that structure with the passage of time. This monitoring process, whether for a network of bridges or for an individual bridge, consists of number of phases, outlined below:

- *Phase one* involves the collection of all the available data about a bridge or of a network of bridge in the form of a bridge inventory.
- *Phase two* involves the field inspection to know the state of bridge at desired intervals.
- *Phase three* involves the conduction of various tests recommended on the basis of visual observations taken in phase two to get the accurate condition of the elements.
- *Phase four* involves the evaluation of the test results based upon the data collected from the field.
- *Final phase* gives the recommendations for repair or replacement of elements.

4. Proposed Bridge Database Management System (BDMS)

Managing a bridge system is a complex decision making process. The vast bridge data having been collected has to be arranged and processed so that the maintenance can be prioritized. There are host of emerging tools and techniques that can be effectively applied in bridge management systems. The decision process is influenced by three major components, structural, functional and economical, and the ideal lies at the common point of all these as shown in Figure 2. However, in some cases optimality may be achieved by suppressing one of the conditions and giving priority to the rest.

Figure 2: Prioritizing Decision Making

4.1 Methodology

The bridge management model proposed for highway and urban bridges of Pakistan is based on concept discussed in the preceding section. It is adopted after reviewing the management systems of Transport and Road Research Laboratory, TRRL, UK, the Swedish management system, the Finland management system, the management system of Cyprus and the model given by American Association of State Highway & Transportation Officials, AASHTO, USA. All these systems are more or less same, but the difference lies only in the legislation of implementing the system.

Keeping in view the political, economical and technical scenario of Pakistan, adaptations are made to the system so that the implementation can be made easily and comprehensively.

4.2 Condition Evaluation

It is an assessment of defects and physical conditions of a bridge which in turn relates to the safety requirements and to the load capacity of a structural system (Petros). Ultimately this assessment provides the database of a bridge management system. The assessment or judgement of severity of condition of a bridge can be based on different investigative procedures such as visual observations, non-destructive testing techniques, structural capacity analysis, or a combination of these. However, structural capacity analysis is the most accurate representative of structural deficiency of a bridge.

By a subjective integration of different types of rating, an assessment of the general condition of structure can be derived, type of rating used and method of evaluation being primarily dependent on local conditions and budget limitations. This assessment gives the basis for priority ranking. Bridge rating, thus provides a framework for a rational approach towards priority ranking and ultimately leads to an effective BMS.

4.3 Priority Ranking System

The most feasible path for the development of the BDMS is ‘Priority Ranking System’, which is devoid of complexities and results more close to an optimal solution. The procedure is standardized to keep homogeneity between different rankings. The procedural steps involve assessment of inspection data by assigning deficient points to different structural components and then summing up these individual points to arrive at a final summed up figure to decide for the ‘maintenance urgency index’. From the above discussion the adopted monitoring procedural flow chart is as given in Figure 3.

Figure 3: Procedural Flow Chart of Monitoring

4.4 Maintenance Urgency Index (MUI)

For making optimum use of scarce resources for better results, defining when and how to intervene with a structure, urgency index is developed to categorize the structures according to their early or late, maintenance.

This urgency index is based on the total number of deficient points accumulated after the inspection of the bridge and ranges from H (Good condition) to A (Worst condition). If total deficient points are less than 50, MUI “H” is assigned with a rating of “Good Condition” meaning “No repairs are needed”. The worst condition is MUI “A” for deficient points greater than 350, with a rating of “Facility closed for repair works”.

4.5 BDMS Software

The software BDMS (Bridge Database Management System) is Windows based software developed on Lotus Notes, version 4.6.2, designed to help in the development and management of the optimal plan for the maintenance of bridge network (Rafeeqi, SFA. and lodi, SH.).

It has a data based structure for storing data, originated by the inventories and inspection procedures, so that, it can be easily retrieved when required. The BDMS is programmed such that it can automatically convert the condition of a bridge activity into deficient points.

The capability of quickly verifying the situation of each bridge, just by accessing the database, will contribute to optimize the use of always numerically insufficient staff, giving speed and accuracy to the inspection scheduling process. However, it is expected that the BDMS can grow from a micro curiosity to a full fledged system by incorporating new ideas about budgeting, project programming and project level management etc.

5. References

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