DEVELOPMENT OF BRIDGE HEALTH INDEX AND FRAMEWORK FOR MAINTENANCE PLANNING

by

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CERTIFICATE

This is to certify that the thesis entitled, **"Development of bridge health index and framework for maintenance planning"** being submitted by **Sanjay Sampat Wakchaure** to the Indian Institute of Technology Delhi for the award of the degree of **DOCTOR OF PHILOSOPHY** is a bonafide record of the research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the requisite standard, fulfilling the requirement of the said degree. The results contained in the thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Bridges are vital links in any road/rail network. A weak bridge can either reduce the load carrying capacity or safety which may hinder the flow of traffic and severely affect the economy. Hence, it is necessary to maintain the bridges in traffic-worthy condition with requisite levels of safety and serviceability. Generally, funds made available to maintain the bridges are insufficient. Scientific Bridge Management System (BMS) helps in utilization of resources in an optimal manner. Before developing the ways and means to utilize funds efficiently, it is necessary to study the reasons for the failure of a bridge. The aim of this study is to investigate the various factors causing bridge failure and evolve criteria for efficient fund utilisation.

It is also necessary to ascertain the present condition and immediate maintenance requirements of a bridge prior to taking any decision regarding the maintenance planning. Physical condition of bridges is often described by discrete condition states on the basis of visual inspection. The results of visual inspection are subjective and vary according to the knowledge and judgement of the bridge inspector. It is of utmost importance to redefine the condition states and correlate them to various defects which affect the serviceability of a bridge. This will reduce the subjectivity and ensure uniform results. Use of indices is one of the best tools of decision making. Indices can be divided into two categories namely, health indices and priority indices. Health indices are generally based on condition states and need to be developed on the basis of defects which ultimately affect the condition of a bridge. Assessment of a number of factors, besides the condition of a bridge, influences the final decision on selecting bridges for the maintenance planning. Other factors are: importance of the bridge, deck area of the bridge, the maintenance cost required, traffic volume, age of the bridge, etc. It is necessary to develop a method which takes into consideration these factors and also enables efficient utilization of the available funds.

Fourteen bridge failure factors have been identified through literature survey and interaction with bridge experts in India. Interpretive Structural Modelling (ISM), which is a structural analysis tool for interactive learning, has been used to evolve a hierarchical structure of the phenomenon of bridge failure showing the interrelationship of factors. The ISM model shows the factors for failure in a structured hierarchy as well as their interrelationship. 'Environment' has emerged as the most influential factor while the most dependent factor is 'aging'. Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) has been used to quantify and classify the factors on the basis of their influence and dependence. MICMAC analysis shows that bridge failure may not be attributed a single factor.

Components of a bridge are indentified and grouped into seven categories. Analytical Hierarchy Process (AHP) is applied for determining weights (relative importance) of bridge components. Five condition states namely, 'excellent', 'good', 'fair', 'poor' and 'critical', have been selected and comprehensively described. A total of 28 types of distresses have been enumerated and assigned a range of values corresponding to the condition states. The relative weights of bridge components, condition states and range of values for different types of defects have been used to develop a Bridge Health Index (BHI).

An alternative approach of Data Envelopment Analysis (DEA) has been used for taking into consideration various factors that affect decisions on maintenance planning. Maintenance of bridges based on efficiency scores obtained by DEA has been found to be cost-effective compared to that based on BHI.

Effectiveness of a bridge can be judged from various attributes, such as strength, stability, safety, serviceability, aesthetics and reliability, etc. The relative importance of bridge attributes has been established both by Likert and AHP scales. 'Stability' and 'Safety' have emerged as the top attributes while aesthetics has been ranked the lowest in terms of priority.

A number of factors such as importance of bridge, deck area of the bridge, traffic volume, age of the bridge etc affect the selection of bridges for maintenance planning. These factors have been categorised into nine select groups/factors using factor analysis.

It is expected that the proposed BHI and DEA approaches would enable the bridge authorities to formulate better strategies for planning and executing the maintenance actions in an economical manner. An appropriate strategy will maximize the life span of bridges and enhance their performance thereby serving the society in the best possible manner.

Keywords: Bridge, BMS, failure factors, ISM, MICMAC, AHP, BHI, DEA

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