SYSTEMS APPROACH IN BRIDGE MANAGEMENT

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ABSTRACT

Great numbers of Malaysian bridges built some 40 years ago are showing varying degrees of deterioration. This situation is not unique to Malaysia. Indeed many countries are facing similar problem. A number of these countries are now either using some sort of bridge management systems to tackle their bridge problems or in the process of developing ones. These systems invariably involve the systematic inspection of bridges to collect bridge data and the customisation of the procedures for the storage, manipulation and retrieval of these data.

In Malaysia, a bridge management system called "JKR BMS" has been developed in house by the Public Works Department (JKR). This paper discuss the JKR BMS in comparison with some other existing bridge management systems used by other countries.

INTRODUCTION

Great numbers of Malaysian bridges built some 40 years ago are showing varying degrees of deterioration. This situation is not unique to Malaysia. Indeed many countries are facing similar problem. The great number of bridges in need of immediate attention has prompted many bridge agencies to adopt a new approach in managing their existing bridge stock in an attempt to extend the service life of these bridges and preserve the capital investment. This new approach aims to effectively and efficiently utilise the limited resources. It seeks to view a bridge management problem globally in association with other bridge-related activities and not in isolation. It involves the use of different problem-solving tools that are subjects of diverse disciplines. This is called the systems approach in bridge management and it involves the construction of a computerised bridge management system.

A number of countries around the world have already created and used some bridge management systems to tackle their bridge problems while many others are in the process of developing ones. Examples of these systems are: DANBRO (Denmark), ABRAMMS (U.S.A.), IBMS (Indonesia), HiSMIS (U.K.), BMMS (Thailand); etc. These systems invariably involve the systematic inspection of bridges to collect bridge data and the customisation of the procedures to store, manipulate and retrieve these data. In Malaysia, a bridge management system called "JKR BMS" has been developed in house by the Public Works Department (JKR).

This paper discuss the basic concepts of the systems approach in bridge management. In particular it describes the JKR BMS in comparison with other existing bridge management systems mentioned above. Information about these systems are obtained from references and also private communications with the personnels responsible for their developments.

BRIDGE MANAGEMENT PROBLEM

Bridge management is a term which covers all the activities carried out at various stages of the bridge's life cycle in order to keep it safe and serviceable throughout its life span. These activities are inter-related and include:

* planning and design for new bridges
* inspection and testing of bridges
* assessment of bridge performance
* maintenance of bridges
* administration of abnormal vehicle movement
* etc.

The traditional approach in bridge management tends to conduct these activities in an ad hoc manner. Bridges are planned and designed without much consideration of any future maintenance needs. Indeed, there is hardly any planned maintenance at all for existing bridges.

As regard to the *maintenance, rehabilitation and replacement* (MR&R) decision, it is up to the 'bridge expert' to select among the various options based on his subjective appraisal. While this approach manage to fulfill the management goal to ensure bridge safety, the decision derived may not be timely or optimal.

One important management question one tends to ask is how does one know which bridge is to be taken action first. And how does one improve the defect. A bridge management system is a management tool designed to address these problems.

COMPONENTS OF A BRIDGE MANAGEMENT SYSTEM

A bridge management system should have a minimum of four components for a successful implementation. They are:

* Data Bank
* Applications
* Staffing
* Manuals/guides

The Data Bank

The Data Bank stores all the necessary data needed for the system. These data are either collected in the field or generated by the activities within the bridge management system. Processed data or information is essential for a rational and informed decision making. The collection of data in a manageable database is indeed the core for any bridge management system. A database may or may not be computerised although the present-day database systems are invariably built around a computerised database.

In JKR BMS the Data Bank consists of a computerised database of bridge inventory and condition data, manual files, microfilms of structural drawings and a library of inspection reports.

Applications

Applications is the edp (electronic data processing) part of the system. It consists of a suite of computer programs written to manage and manipulate the data to provide decision supports in specific bridge decision problems. Hudson et al (1987) in the report for the U. S. National Cooperative Highway Research Program (NCHRP) has outlined some guidelines for a good computerised bridge management system. The report has recommended that a good bridge management system should have the following modules:

1. Database module
2. Network level major MR&R selection module
3. Maintenance module
4. Historical data analysis module
5. Project level interface module
6. Reporting module

These modules are designed to perform the basic bridge management functions, i.e., to provide bridge information, rehabilitation/ replacement plans, maintenance work orders, etc. Some of these functions will be discussed later in this paper.

Staffing

The database system with its database and application programmes sometimes lead people to think that the system software is itself ***the*** system. The importance of the human part of a system cannot be overemphasised. Working side by side the computer is the human part of the system - the staff. There are numerous activities that could best or perhaps only practical to be performed by human. They include the gathering of bridge data, their input into the computer and the interpretation of the processed data. These activities are necessary to keep the system going.

In JKR a Bridge Management Section will be created within the Bridge Unit under the Roads Branch. The main function of this section will be to develop, maintain and manage the JKR BMS. The proposed new setup will be headed by a Systems Manager who is a senior bridge engineer. Under him will be one System Administrator, two programmers, two Bridge Inspectors and one Bridge Testing Engineer.

It is believed that the proposed staffing is crucial for the successful implementation of the JKR BMS.

Manuals/Guides

The procedures to carry out the bridge management activities must be standardised such that they are consistent and uniform. This calls for the documentation of standard manuals or guidelines for the staff.

In JKR, a number of manuals/guides have been prepared in the context of the bridge management system. They are:

* 'Table File'
* User Manual
* Inspection Manual
* System Manual
* Maintenance & Rehabilitation Manual
* Standard Design Criteria for Bridges
* Standard Specification for Bridge Work
* Standard Drawings

'Table File' is a document which stipulates the duties and procedures of work for every post or portfolio in the Bridge Unit organisation. The other documents above are rather self-explanatory.

EXISTING BRIDGE MANAGEMENT SYSTEMS

Every organisation is unique with its own organisational goals. As such each bridge agency would have different systems needs. This section will discuss the functions provided by some bridge management systems in operation or under development today.

JKR BMS

JKR BMS is the name given to the bridge management system designed and developed by in house staff of Bridge Unit of JKR (Public Works Department Malaysia). A description of the system is available by Tham et al (1991).

The functions of JKR BMS are:

* Bridge Information
* Project Information
* Bridge Project Priority
* Bridge Improvement Decision
* Budgeting and Costing
* Control of Abnormal Vehicle

The JKR BMS prototype system has been reviewed by a consultant engaged under World Bank funding. Version 1.0 of the system is scheduled to be launched in early January, 1992.

IBMS (Interurban Bridge Management System)

Bina Marga of Indonesia has developed a bridge management system under a bilateral aid project funded by the Indonesian and Australian Governments. The system is to manage bridges on National and Provincial interurban roads and is thus called Interurban BMS (IBMS).

The system is designed to provide Bina Marga with the following facility for:

* inventory and condition
* preparation of treatment strategies
* priority ranking of bridge work
* optimum allocation of limited funds
* standard procedures for rehabilitation
* 5 year plan

The development is undertaken by Bina Marga and SMEC-Kinhill J.V. (Australia).

HiSMIS (Highway Structures Management Information System)

HiMIS is a bridge management system developed by Rendal, Palmer & Tritton of the U.K. The ground work for the system was laid in the National Axle Load Study conducted by the consultant for the Malaysian Government in 1986-1988.

HiSMIS consists of five modules:

* Inventory
* Inspection
* Maintenance
* History
* Programme/Study

In particular, HiSMIS assists in:

* Planning inspection
* Managing inspection information
* Making decisions on maintenance
* Prioritising maintenance
* Producing works orders
* Planning and managing maintenance
* Financial management
* Abnormal vehicle routeing
* Planning upgrading/replacement programmes

DANBRO:

DANBRO is a computerised bridge mangement system in use in Denmark today. The system is a second generation bridge management system which is based on the experience gained in the older system run by the Danish Road Directorate. It is created by the Danish Road Directorate in colloboration with the consulting firm COWI-consult.

The DANBRO system is built up of the 'Basic module', the 'maintenance module', the 'price catalogue', the 'optimisation module', the 'budget & cost module' and the 'experience module'.

This very comprehensive system provides the facility to:

* access to the administrative and structural databases
* choose the optimum repair
* budget for 5 year period
* evaluate the consequence of change in budget
* produce maintenance work orders
* control abnormal vehicle movements
* etc.

ABRAMMS (ARE Inc. Bridge Rehabilitation & Maintenance Management System)

ABRAMMS is a system software developed by ARE Inc., USA based on its work for the NCHRP Project. The system has all the modules described in NCHRP Report 300 and is an improvement to the Transportation Research Board Bridge Management System.

The system consists of six major modules:

* Data Base
* Network Level Major MR&R Selection
* Maintenance
* Historical Data Analysis
* Project Level Interface
* Systems Upkeep

By comparing the functions provided by varous bridge management systems in the world it is apparent that a bridge management system should at least provide bridge information and decision supports in bridge maintenance, rehabilitation and replacement plans. These two functions will be further discussed below.

BRIDGE INFORMATION

Bridge information is needed for sound, informed decision. All existing bridge management systems have a database module to manage the database. It allows reporting of data for a specific bridge record and also the subsetting of the database based on some user-specified conditions.

There are three major issues in the design of a database module. Each of this is discussed herebelow.

Referencing System

A referencing system is designed to uniquely determine the position of each bridge record (and identify a bridge record). It is a base for integration among files with other external systems. It also integrates data collected by different organisational units or at different time stored in different format.

A good referencing system must remain unaffected by changes like renumbering of roads, boundary changes and new construction. It must be easy to understand and use.

In JKR system, a bridge structure is uniquely identified with a Route Number followed by a Structure Number depending on its location from the point of reference pertinent to the route. Thus, structure FT001 329/41 is located along federal trunk route No.1 and is at 0.41 km from Section No. 329 which is **approximately** 329 km from the road origin, Johor Baru. At the moment the distance between two consecutive Section No. is 1.0 km but the Section No. will remain irrespective of any future change in the distance due to road realignment.

In the DANBRO system, a bridge record is identified by Route No, Section No, and Serial No. In addition to this reference, an x and y coordinate system is also used, which would be very useful for a GIS (geographic information system implementation.

The Indonesian sytem, IBMS adopts somewhat similar referencing system. A bridge is identified by a Province No, Link No, Serial No of the bridge along the link. Like DANBRO, this system has a weakness in that any new construction between two existing bridge records would upset the system. Both systems get round the problem by introducing an additional number for any new structure located between two existing structures in the records.

Inspection

Inspection is basically a means to gather bridge data. The OECD Report(1976) has categorised and discussed three types of bridge inspection: superficial inspection, principal inspection and special inspection. This categorisation is based on the scale and frequency recommended for each type of inspection.

In JKR BMS there are also three types of inspection, namely the Inventory/Condition Inspection, Improvement Inspection and Maintenance Inspection. Rather than describing the details and frequency of the inspections, the terms used suggest the purpose of the inspections.

JKR uses a rating of 1 to 5 to appraise the condition of each bridge member. When a particular member is not available, a rating of '0' is given. A rating of '1' is reserved for a bridge structure in an 'as new' condition while a rating of '5' represents a dangerous condition. Ratings of '2', '3' and '4' are just the scales between the two extremes. The rating system used in JKR BMS is a measure of the degree of deterioration of the member. JKR has found the range too restrictive and has considered to use a revised system which allows a rating with one decimal point.

In the DANBRO and IBMS systems, there are four categories of bridge inspections:

* Superficial Inspection
* Inventory Inspection

* Detailed Inspection
* Special Inspection

The definition for each type of inspection follows that of the OECD Report. Comparing these definitions with that in JKR BMS, Superficial Inspection is indeed equivalent to Maintenance Inspection of the JKR BMS. Inventory and Detailed Inspections are equivalent to Inventory/Condition Inspection; and Special Inspection is equivalent to Improvement Inspection.

In the DANBRO and IBMS systems, a rating of 0 to 5 is used:

0	wholly insignificant damage
1	improvement on occasion
3	improvement as soon as possible
4	improvement immediately
5	alarm

This rating system used is a subjective measure of how pressing an improvement may be necessary. Like JKR system, the rating is applied to the particular members. An overall rating for the bridge is then derived considering the ratings collected for each member and its significance toward the integrity of the whole system.

Database Management System

All the systems today are built around a relational database and are coded in a third generation language.
The following shows the database management system used by each bridge management system:-

ABBRAMS: FoxPro
HiSMIS: dBASE4
DANBRO: Dataflex
IBMS: Clipper
JKR BMS: dBASE4

PLANNING & PROGRAMMING

The MR&R Decision

One of the basic functions of a bridge management system is to produce a multi-year R&R plan to meet the goals in a cost-effective manner. Central to this is the decision as to which bridge to take action first, what type of MR&R action is recommended and when should the action be initiated.

In JKR BMS, the '*when* to do *what* with *which* bridge' decision is derived in two distinct steps. The first step addresses the 'which bridge' dimension by a Prioritisation Module which is based on a decision-tree model. The criteria used for ranking are the Weighted Condition, Load-Capacity, Carriageway Width, Vertical Clearance or Highest Flood Clearance and ADT (Average Daily Traffic). The second step aims to determine the best MR&R action. This is achieved by an economic analysis in which the discounted life-cycle costs of each option is worked out and compared. This is discussed by Wahid (1992).

The IBMS system also addresses this problem in two steps. The first step screens the bridge stock based on LOS goals and then rank them based on Weighted Condition, Load Capacity, Traffic, link importance and AADT. The second step involves the use of economic analysis (incremental NPV) to determine the best action.

The DANBRO and ABRAMMS systems have a very good approach in tackling the MR&R decision problem. Both systems have the ranking facilities described above for JKR BMS. They have in addition an optimisation module which compares and selects the most optimal action based on an incremental