## TOWARDS EVOLVING A BRIDGE MANAGEMENT SYSTEM FOR JKR

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#### ABSTRACT:

Although there are well over 2300 bridge structures scattered over the major Federal roads network Peninsular Malaysia, no proper or systematic bridge management system exists to-date to coordinate the design, construction and maintenance activities related to bridges. Recent work carried out under the Malaysian National Axle Load Study (1986-1988) has discovered serious damages to many bridges. The majority of the bridges were damaged by environmental factors rather than by vehicle loadings. Although the damages could not be entirely eliminated, they could, however, be minimised with proper care in detailing, attention to factors affecting durability during design stage and proper quality control during construction. Finally, a proper maintenance system which stresses on regular inspection would arrest distress at an early stage and thus prevent widespread damage and consequent costly repairs.

This paper highlights the development towards evolving a systematic bridge management system for JKR Malaysia (the Public Works Department of Malaysia). This is in line with the realisation of the vital need to pay greater attention to the preservation and consolidation of bridge structures built during pre-independence days and over the past five Malaysian Development Plans.

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#### 1.0 INTRODUCTION

#### 1.1 Background

In Malaysia, it is the conventional role of Bridge Unit of JKR (Public Works Department) to carry out design works and offer technical services with respect to problems arising from construction of bridges or poor performance of existing bridges as reported from time to time.

Traditionally, bridge problems are dealt with on a case-by-case basis in an ad-hoc manner. Decisions are being made by individual bridge engineers based on their heuristic knowledge. As such, they are subjective and not uniform.

The National Axle Load Study in its bridge inspection exercise has made observations on the structural integrity of some Malaysian bridges. A large number of bridges need immediate attention of the Bridge Unit, due to structural inadequacy or functional obsolescence either as a result of deterioration or increase vehicular load of present day traffic. What is more worrying is the observation that most Malaysian bridges are suffering from premature failure brought about by the various factors to be highlighted later in this paper.

This calls for an overall bridge management system (BMS) that will provide a comprehensive system from the point of design, construction and maintenance. A microcomputer-based information system shall be created to provide decision supports to the Bridge Managers in the Bridge Unit.

The need to inventorise the nation's bridges was first realised when KAMSAX A/C, Denmark in association with SSP, K.L. was engaged to prepare a bridge inventory in 1972-74. This inventory was partially updated around 1978. The data contained in the Kamsax Inventory is somewhat limited. There is, for example, no data to support an analysis to assess the load carrying capacity of a bridge structure.

An attempt to initiate a systematic bridge inspection and strength assessment was made by Bridge Unit in 1984. Bridge inspection forms were designed to gather field bridge data so that some simple analyses could be performed to rate the bridges in terms of their load-carrying capacities [1].

In April 1987, the Senior Assistant Director of Bridge Unit in his working paper entitled "Establishing a bridge inspection and maintenance system for JKR" has again highlighted the need to systematically inspect and maintain the nation's bridges. The paper elaborated on a proposed organisational set-up of an 'inspection and maintenance' section within the Bridge Unit.

The National Axle Load Study (Phase I) started in December 1985 and completed in October 1987, has helped to create a bridge inventory of some 966 bridges on a few main Federal routes [2]. The second phase of the study, which comprises basically bridge inspection on major Federal routes not covered under the Phase I Study is underway at the present moment. The inventory prepared by the study, though helpful in many ways, does not in itself constitute a comprehensive bridge management system. The vast amount of data collected during the study however would be useful if a bridge management system is to be developed.

In June 1987, Kamsax International A/S and the Danish Road Directorate had presented to the JKR a project proposal for a bridge maintenance management system. The proposal was not accepted owing to the high cost involved. Besides, a few of the proposed items of work had already been undertaken in the National Axle Load Study.

At the same time, the Japanese International Cooperation Agency (JICA) has also proposed to conduct a 'Master Plan Study' on the maintenance and rehabilitation of bridges in Malaysia. To-date the matter is still being discussed by the Malaysian and Japanese Governments. The Master Plan Study shall be programmed and carried out in three phases, viz; 1) Phase I: reviewing existing data; 2) Phase II: systematic inspection and evaluation of existing bridges and preparing a bridge inspection manual and 3) Phase III: budgeting and feasibility study on packaging of rehabilitation or repair works within the particular chosen route. The emphasis of the study is on the identification of deteriorated or deficient bridges and the preparation of documents to repair or rehabilitate them.

#### The Trigger: The National Axle Load Study

In the course of bridge-by-bridge inspection, the National Axle Load Study team had discovered a large number of bridges suffering from severe distress, typically in the form of cracking/ spalling in reinforced concrete structures; and corrosion in the case of steel structures. Although vehicular overloading beyond the legal limits is common place, damage due to such factor is extremely rare.

The majority of the damages are caused by environmental factors. Carbonation, chloride ingress, corrosion, sulphate attack etc., could all be attributed to external agents. In the local scene, such factors are exacerbated by a lack of attention to details affecting durability such as type of cement and cover requirements, poor quality control and supervision at the site. In spite of this, it is felt that many of the structures could have been prevented from reaching the level of distress encountered had a system of regular inspection and rehabilitation been available. The National Axle Load Study, in coming up with a complete inventory of all bridge structures in the network under study, has set the framework for the establishment of an overall system to manage the nation's existing stock of bridges.

#### 2.0 THE APPROACH IN SYSTEM DEVELOPMENT

#### 2.1 System requirements

1.2

A JKR BMS System Development Team was formed to study and develop a bridge management system for JKR.

In developing the bridge management system, the following points have been taken into consideration:-

i.	a well-defined	boundary	of	the system	1

ii. a systems approach in system development

- iii. to ensure user acceptability
- iv. system to be simple but complete

v. possible future expansion of the system

To define the system boundary, the objectives of the system must first be established. This is discussed in item 4.1.3. A systems approach is imperative in the systems development process in order to avoid the 'hydra effect' common among programmers who write programmes before they properly plan and structure the algorithms. ('Hydra effect'=eliminating one defect leading to the creation of many more).

A systems approach is more than just being systematic. A seven-process system development life cycle (based on techniques used in Management Information System) is recommended [3]. It consists of:

1.	Conduct initial study		
ii.	Analyse current system		
iii.	Propose system solution		
iv.	Detail chosen design		
<b>V</b>	Design new physical system		
vi.	Construct new system		
vii.	Install and monitor system		

## 2.2 System Development

The seven-process methodology as discussed above has been translated into the following three phases:-

## 2.2.1 Phase I: Creation of a logical model

This phase includes literature research on systems used by other countries especially the U.S.; collection of system data; studies on the current practice in the Bridge Unit; identification of system objectives etc.

## 2.2.2 Phase II: Physicalising

This phase involves prototyping the man-machine system based on the logical model created in Phase I. The activities to be performed by man are being laid down in work procedures or standard manuals/guides. The operations that can best be performed by a computer are transformed into computer programmes.

## 2.2.3 Phase III: Installation & Monitor

This phase is the implementation of the proposed system. It shall include the acquisition of hardware and software needed by the system and the training of staff.

#### 2.3 Strategy

The users of the management system are basically engineers from the Bridge Unit. To afford user acceptability, the engineers and technical assistants of the Bridge Unit and Highway Planning Unit are directly involved in the development of the system. This is in line with the JKR's decision against acquiring an "off-the-shelf" system.

The strategy now is to come up with a simple but complete system with a provision for refinement in future when the need arises. To be complete means that the system must have the barest minimum components of a bridge management system (for e.g, a prioritisation model, a prediction model and a data bank). For a complete system to be simple, only few parameters in a model needs to be considered. Additional parameters may be included later when the system is expanded.

The system should now aim only at bridges along the federal routes. Future extension to state roads must be considered.

The need and possibility of integrating the proposed bridge management system to the existing pavement management system, BS(M) to effect an overall road management system has also been a consideration in the system development.

The BMS System Development Team shall detail the system design to whatever level it is capable. Private consultants may be engaged for more detailed system design.

#### 3.0 THE CURRENT PRACTICE

As a first step to proposing a logical model for the JKR BMS, the current practice of managing our existing bridges in the Bridge Unit is reviewed to identify weaknesses that have to be overcome in the proposed system. It is depicted in a data flow diagram in Fig. 1.

This semblance of 'system' was only established after 1.4.1986 with the re-organisation in Public Works Department whereby the Bridge Unit was transferred from the Design & Research Branch to the Roads Branch. With such re-structuring the objective and role of the Bridge Unit was



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expanded for it to be involved in the total management of bridges.

By studying the data flow diagram, the shortcomings of the current system were identified. They are:

- i. The current system does not allow the Bridge Manager to prioritise bridge projects.
- ii. The current system is passive; it is only reactive to outside triggers. Generally it is remedial rather than preventive in nature.
- iii. There is no efficient way of providing information about the safety of bridges to the public.
- iv. The current system does not provide information for budgeting purposes.
- v. There is no systematic way to update the bridge information in the Inventory Cards.
- vi. There is no consistent and uniform decision and no rational criteria for improvement works; like whether to repair or replace.
- vii. Data in the Inventory Card is insufficient to support bridge management decisions.
- viii. There is no standard format for reporting a bridge inspection.
- ix. There are too many physical media for data storage.
- x. Retrieval of information from existing media of storage is difficult.
- xi. Current system does not deal with maintenance at all (maintenance here refer to routine maintenance activities, preventive in nature).
- xii. No feedback mechanism to identify weakness in current design practice.

#### 4.0 THE PROPOSED SYSTEM IN CONCEPTS

#### 4.1 System Requirements

#### 4.1.1 <u>Organisation Objectives</u>

The organisation objective of the Bridge Unit is clearly spelt out in Bridge Unit Design Guide [4] as,

> "To plan and improve the development of the infrastructure and public facilities in the transportation system such as bridges, flyovers and culverts for roads; so that they are safe, of high quality and economical so as to promote the country's social and economic development."

To achieve such an objective, not only are new bridges to be constructed but also existing stock of bridges in the country has to be properly managed.

#### 4.1.2 <u>Organisation Tactics</u>

With regard to existing bridges, organisation tactics to achieve the organisation objectives mentioned above are:-

#### i. <u>Do nothing but routine maintenance</u>

In cases where the deficiency in a bridge structure is not likely to cause any severe effect, no course of action shall be taken. Routine maintenance shall proceed.

#### ii. Post a bridge with a weight limit

In cases where only very light vehicles (in terms of volume and weight) are expected to be using the facility, a bridge may be posted permanently with a weight limit.

#### iii. <u>Closure and Demolition</u>

For reasons such as obsolescence or severe deterioration, a bridge may be closed permanently. Demolition may follow.

#### iv. Bridge Repair

This consists of works of corrective nature to restore damages or deterioration on a structure or its member(s).

v.

#### Bridge Rehabilitation.

Rehabilitation involves extensive an inclusive of upgrading repair, and restoration. Upgrading is the raising of a structure's capacity or standard to a level above that of the original design. Restoration is to return a structure or its member(s) to their original conditions.

#### vi. Bridge Replacement

This is the construction of a new bridge in lieu of a previously existing bridge at or near the same location.

Bridge repair is often recognised as an essential activity in a routine maintenance and has thus been collectively called maintenance & repair (M&R). Routine M&R should be carried out reqularly in accordance with certain а maintenance policy to be established by the Bridge Unit. In many bridge management systems, such as that used in the Pennsylvania Department of Transport, U.S, the M&R decision is often separated from the bridge rehabilitation/ replacement decision.

Bridge rehabilitation/ replacement decision is concerned if a bridge structure should be rehabilitated or replaced. M&R decision, on the other hand, is concerned about when to intervene a certain maintenance activity. It is helpful to note that the distinction between rehabilitation and M&R is on their extent. Rehabilitation involves extensive restoration or upgrading work. Very often, it is due to the lack of M&R that a rehabilitation work becomes necessary.

Decision to post a bridge or to close and demolish a bridge is more a subjective matter depending on the severity of the structural deficiency. They are made independent of the M&R decision or bridge rehabilitation/ replacement decision; and as such are excluded in the prioritisation model to be discussed later.



#### Basic Components of the BMS

4.2

To-date the JKR BMS System Development Team has developed a logical model for the proposed system and work is underway to create a prototype based on it. The logical model of the proposed system is as shown in a data flow diagram in Fig. 3.

The proposed BMS concentrates on providing information to aid Bridge Managers with regard to improvement works on existing bridges. It consists of three basic components:-

i. The Prioritisation Modelii. The Prediction Modeliii. The Data Bank

#### 4.2.1 <u>The Prioritisation Model</u>

The Prioritisation Model provides decision supports to Bridge Manager by:-

- i. ranking the bridge projects in their orders of priority. This is known as "Prioritisation at the Network Level";
- ii. deciding the 'best' improvement alternatives. This is known as "Prioritisation at the Project Level".

The output is a list of bridges needing improvement in their orders of priory. Beside each bridge entry is the scope of improvement work recommended and its cost estimate.

At the Network Level, the Prioritisation Model helps the Bridge Manager to decide which bridge(s) in the network to take action. The attributes affecting the prioritisation decision are laid down in a "hierarchy of values" (Fig. 4). Values of the attributes are to be collected in a regular bridge inspection for each structure in the network. A priority point shall be worked out for every bridge. Higher priority of improvement action shall be given to structures with high priority points.

At the Project Level it helps the Bridge Manager to decide what action to take for each selected project. After a detailed bridge inspection, the Bridge Engineer shall prepare a few feasible improvement alternatives based on the severity of the deterioration as well as the site



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conditions. The alternative with the minimum present cost shall be recommended.

## 4.2.2 The Prediction Model

The Prediction Model supports the Prioritisation Model by predicting or estimating the impacts of each improvement alternative in terms of costs and extended service lives. Besides, the Prediction Model also forecasts future needs far in advance for the purpose of proper planning and budgeting; and the requisition for special funding. In order to do a conceptual cost estimate, the quantities and unit costs of the proposed work must first be determined. The estimated quantity of work for one or more improvement options shall be made by the Bridge Engineer during a detailed inspection. Standard unit costs are established in a database of bridge costs based on bid line item prices submitted by contractors on previous contracts.

### 4.2.3 The Data Bank

The Data Bank is the core of the overall bridge management system. It stores useful bridge data needed to support the Prioritisation Model and the Prediction Model. also stores It and manipulates data to provide basic bridge information to the users. The bridge data are stored in three formats; namely in computer data bases, files and microfilms. Α microcomputer-based database management system dBASE IV is used for the data bases. Fig. 5 shows the data elements to be stored in these data bases. Files are used to keep records of old correspondence and design-completion reports. As-built structural drawings are stored in microfilms.

## 5.0 RELATED DEVELOPMENTS

While the JKR BMS when fully developed and successfully implemented will eventually eliminate most of the weaknesses in the current practice in maintaining existing bridges, it cannot be over-emphasised the importance of the Bridge Unit looking into two other major areas of bridge engineering i.e. planning and design; and construction of bridges. The followings summarise the status of progress in these two areas:-

#### INVENTORY DATABASE

- Route No. 1.
- 2. Structure No.
- 3. Name of Structure
- 4. Name of River
- Name of District 5.
- 6. State
- 7. Year of Construction
- Correspondence File Ref 8.
- Type of Material 9.
- 10. Type of System
- 11. Crossing
- 12. Degree of Skewness
- 13. Maximum Span Length
- 14. No. Of Spans
- Total Length of Structures 15.
- 16. Carriageway Width
- 17. **Overall Width**
- 18. Load-Carrying Capacity
- 19. **Discounted** Capacity
- 20. Deck Type
- 21. Abutment Type
- 22.Pier Type
- 23.Foundation Type
- 24. Vertical Clearance
- 25.Horizontal Clearance
- 26.**Environment** Condition
- 27. ADT
- 28. % of Heavy Vehicles
- 29. Modified ADT
- 30. Navigable or Not
- 31. Any Electrical Services
- 32. Any Telecom Sevices
- 33. Any Lighting Services
- 34. Any Water Mains
- Highest Flood Clearance 35.
- 36. Foundation Cond. Rating
- 37. Abutment Cond. Rating
- 38. Pier Cond. Rating
- 39. Bearing Cond. Rating

- 40. Girder Cond. Rating
- Deck Cond. Rating 41.
- 42. Surfacing Cond. Rating
- Joint Cond. Rating 43.
- 44. Parapet Cond. Rating
- Approach Slab Cond. Rating 45.
- 46. Slope Cond. Rating
- 47. Weighted Cond. Rating
- 48. **Proposed Maintenance Cost**
- Equivalent Age 49.
- 50. Remark
- 51. Date of Entry

#### HISTORY DATABASE

- Route No. 1.
- 2. Structure No.
- 3. Project No.
- Nature of Work 4.
- 5. Year of Improvement
- 6. Designer
- 7. Contractor
- 8. Total Cost
- 9. Design File Ref.

#### COST DATABASE

- 1. Project No.
- 2. Contract Sum
- 3. Tenderer
- 4. State
- Date of Tender 5.
- Job No. 6.
- 7. Job Description
- Quatity of Work 8.
- 9. Amount
- 10. Unit Cost

## Fig. 5 Data Elements of Databases

# 5.1 Planning and Design of New Bridges

Based on the field inspections of the existing bridges in recent years the planning and design of new bridges have been continuously upgraded especially in areas of detailings, choice of materials and specifications. As a result of a continuous programme in recent years the followings have been achieved:-

## 5.1.1 Bridge Design Guide

A Bridge Design Guide was published in 1985. This book containing design procedures, guides and worked examples on simple bridge design was circulated to all JKR state and district offices. This served to create a greater awareness of bridge engineering among a wider spectrum of JKR engineers and helped to cultivate a healthy interest among the engineers besides providing basic guides.

# 5.1.2 Specification of Bridge Construction

A new specification for bridge construction was drafted. Part of the new specification was Road Standard the into incorporated Specifications launched in July 1989 while the balance of the Specifications will be fully implemented by 1990. The Specification serves to improve the quality control during construction improving the material at aim also and specifications in the light of current findings standard deterioration. The material on specifications will be implemented country-wide.

## 5.1.3 Bridge Loading Specification

A new bridge loading specification was being formulated in order to achieve standardisation for all future bridges so as to cater for the implementation of the Long Term Axle Load (LTAL) Policy. Full implementation of the policy could not be effected until all the existing stock of bridges are fully upgraded.

## 5.1.4 Bridge Design Criteria

A draft of Bridge Design Criteria incorporating the latest findings and departmental requirements was drafted for publication in 1990. This will complement the Bridge Design Guide and enable a uniform criteria in design of bridges by JKR and private consultants doing JKR projects.

### 5.1.5 <u>Standard Bridge Beams</u>

A new series of standard prestressed concrete beams will be developed in line with the new bridge loading specification. This will replace the existing series of standard beams developed over the years since 1970's.

### 5.1.6 <u>Detailing</u>

Attention to detailings and structural interaction of the various bridge components will be continuously upgraded.

## 5.2 Construction of New Bridges

In order to ensure the proper translation of design into the construction and completion of new bridges, the Bridge Unit has commenced taking a more active role in providing technical support to the construction and supervision teams.

Frequent interaction between design engineers and field engineers has afforded the proper execution of new bridges in recent years. Site problems were quickly settled and weaknesses in design and detailings could be readily overcome and relayed to the design engineers for further improvement.

#### 6.0 <u>CONCLUSION</u>

This paper outlines the basic process involved in the development of a Bridge Management System for JKR. It deals in some depth with the various problems and aspects to be considered in the elaboration of maintenance policy and some important factors necessary for the successful implementation of an overall system.

Although this management system is still in its infancy stage, it is hoped that as more and more information and data become available in the course of its implementation, any deficiencies or weaknesses in the system can be identified and rectified. At the current rate of progress, it is envisaged that the BMS will be in operation by 1992.

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