International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 8, August - 2014

Bridge Management System in Sabah

S. Dullah
Faculty of Engineering,
Universiti Malaysia Sabah, Jalan UMS,
88400 Sabah, Malaysia

M. K. N. Jausus
Faculty of Engineering
Universiti Malaysia Sabah, Jalan UMS,
88400 Sabah, Malaysia

H.Ghazali
Faculty of Engineering,
Universiti Malaysia Sabah, Jalan UMS,
88400 Sabah, Malaysia

***Abstract*—A good bridge management starts with good information on bridge conditions. In many developed and developing countries, including Malaysia, a bridge management system has been implemented for the maintenance of bridge structure. This paper discusses the components of bridge management system in Sabah, its advantages and disadvantages of the system. Comparison on various bridge management systems in established countries are also discuss in order to provide ways to improve the existing system in Sabah. This paper will also discuss the new system which can use to overcome the weakness of the existing system. The methodology used to conduct this study includes literature search and interview with the professional involved on bridge management system in Sabah.**

Keywords—bridge management system, components, advantages, disadvantage, sabah

I. INTRODUCTION

Bridges are important links in any national road or rail network, and the fund required to build them is high. If its carrying capacity is impaired or collapsed, resulting cost as a result of road closure and rehabilitation could double [1]. Bridges are susceptible to many defects during their service lives [2]. A 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. Hence, in many developed and developing countries, including Malaysia, a bridge management system (BMS) has been implemented for the maintenance of bridge structure. This project researches and investigates the maintenance technology and system on bridges.

This project also focuses on ways or methods that can be added or replaced with outdated process/procedures in the existing bridge management system in order to improve the system itself. A study on various bridge management systems in established countries are conducted in order to provide ways to improve the existing system. It will also serve as a comparison between BMS of other developed countries to the BMS used in Malaysia, particularly Sabah.

Interviews are conducted to collect data on the nature of the bridge management system being implemented, understand the practices used for determining bridge conditions and the advantages and disadvantages of the current BMS. End results will provide detailed information on the bridge management systems in Sabah's urban areas, with suggestions on improvement of the system wherever possible.

Objectives of this study include:

1. To investigate the components of bridge management system (BMS) in Sabah.
2. To identify the advantages and disadvantages of BMS in Sabah
3. To suggest measures to improve BMS used in Sabah.

II. BACKGROUND STUDY

A. Definitions of Bridge Management System

The following is a list of definitions of BMS according to different authors.

1. Assisting decision makers in maximizing the safety, serviceability and functionality of bridge networks within the available budget by making cost-effective maintenance, rehabilitation, and replacement (MR&R) decisions [3].
2. A tool designed to help maximize the use of available information for the inspection, rehabilitation, and replacement of bridges and optimal time to perform necessary improvements for any bridge [4].
3. A decision support tool that supplies analyses and summary data, uses mathematical models to make predictions and recommendations, and provides the means by which alternative policies and programs may be efficiently considered [5].

B. Main Functions of BMS

Function of BMS:

1. To develop strategies to improve bridge owner's sustainability in the maintenance and enhancement of its bridge and culvert infrastructure assets, to reduce exposure to public risk and to satisfy legislative requirements.
2. To determine future cash flow requirements for the replacement and rehabilitation of bridge infrastructure assets.
3. To continuously improve inventory information including data on the condition and performance of bridge owner's bridge assets.
4. To adopt appropriate renewal and maintenance programs to maintain low life-cycle costs for the community.
5. To review maintenance and rehabilitation strategies to improve the economic life of the infrastructure assets.
6. To review and improve the bridge management system used to manage the bridge owner's bridge assets.
7. To effectively manage the level of service and condition for bridge owner's bridge assets.

C. Introduction to Components of a Bridge Management System

The most basic component or module that is present even in the most lacking of BMS is the inspection module and inventory module. Since usually the inventory or the database is referred to as the heart of a BMS, it would be considered the most important component in a BMS. For the database to be functional, it must have data input in it. These data are collected via inspection.

The maintenance component refers to the maintenance-related options that can be provided or assisted by the system itself, such as an embedded decision-making tool in the system. Life cycle cost recorded all the cost associated in the life cycle of a bridge structure and usually assist maintenance module in the decision making. The prediction model is common in any new developed system but not so much in the old one. All these components will be elaborated more.

D. Database Module

The database module stores inventory, condition and appraisal data. The heart of a BMS is a database derived from the regular inspection and maintenance activities. The integrity of a BMS is directly related to the quality and accuracy of the bridge inventory and physical condition data obtained through field inspections.

Information such as the bridge name (ID), the location, and the construction are stored. These data are considered the starting point for the system: drawings, maintenance records, and surveys are reviewed. The database and inventory allow bridge managers to be fully informed about the bridge stock under their control so that they can make informed decisions about future maintenance and repair activities [6].

E. Maintenance Optimization Module

Aggressive environmental conditions and ever-increasing traffic loading effects contribute to progressive deterioration of bridge structures over their lifetime. Different maintenance interventions, depending on the type of the structural component and on its structural functionality, are suitable for various types of deterioration processes [7].

Inspection and selection of repair methods and materials are the essence of any bridge maintenance system. The condition rating system used by most department of transportation does not provide detailed information necessary for accurately selecting repair strategies. Many efforts have focused on enhancing the inspection and maintenance procedures. The development of a decision support system for bridge maintenance will complement these efforts [8].

F. Life Cycle Cost (LCC)

In a BMS user costs are an important issue. For instance, a weak bridge may cause considerable extra expenses for some users as a result of a longer transport route. A narrow old bridge that causes a bottleneck for traffic results in extra expenses to all road users. Normally, the owner costs form a descending curve and the user costs an ascending curve as a function of increasing degradation of a structure [9].

A BMS with an integrated comprehensives LCC tool can be defined as a rational and systematic approach to organize and carry out all the activities related to managing a network of bridges, including optimizing the selection of maintenance and improvement actions in order to maximize the benefits while minimizing the life-cycle cost.

LCC is appropriately applied to compare project implementation alternatives that would yield the same level of service and benefits to the project user. The agency that uses this tool has already decided to undertake a project or improvement and is seeking to determine the most cost-effective means to accomplish the project's objectives. To effectively implement LCC for bridges, it is important to be aware of the different bridge investment phases and their internal activities. It is also important to be familiar with the various types of bridge contracts [10].

G. BMS in Malaysia

In Malaysia, the Public Works Department (locally known as "JKR") headquarters is responsible for the management of some 6000 federal bridges in the country. It is the conventional role of Bridge Unit of JKR 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.

There are several studies done on the bridge in Peninsular Malaysia. One particular study which is the National Axle Load Study (NALS) which started in 1985 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 [11].

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. JKR then created its own computerized bridge management system called JKR BMS. At the same time, the bridge data collected during NALS became handy as it is entered into the JKR BMS [12].

III. METHODOLOGY

A. Interviews

In Sabah, Public Works Department (Jabatan Kerja Raya, JKR) is one of the departments who are responsible in handling all government's building, roadways, and bridges projects. In order to obtain information on the nature of the bridge management system implemented by JKR, questions regarding monitoring and maintenance technology applied on bridge under JKRs supervision are asked to the personnel/engineer from the bridge structures branch in Kota Kinabalu.

Information such as the advantages and disadvantage of the system is also asked to the interviewee based on their personal experience in using the implemented system.

B. Desk Study/ Literature Review

Desk study is the act of gathering and analyzing information, already available in print or published in the internet. In order to propose steps or measures to further improve the bridge management system, studies based on past researches done by others are conducted. Studies related to the topic of bridge management system, such as BMS in other countries, are reviewed and relevant information is recorded and used in the thesis.

IV. RESULTS AND DISCUSSION

A. JKR BMS in Sabah

JKR BMS is not introduced in Sabah until 2005. It started when JKR Malaysia hired consultants and engineers to assess each and every federal bridge throughout Sabah and Sarawak (East Peninsular Malaysia). The purpose of the study is to come up with an inventory of federal bridges in Sabah and Sarawak and at the same time implement bridge maintenance. The inventory study is titled "Kajian ke atas Pemeriksaan, Inventorisasi dan Penyenggaraan Jambatan Persekutuan Sabah dan Sarawak".

At the same time that the inventory study is conducted, JKR BMS is introduced in Sabah by JKR Malaysia. JKR Malaysia introduced JKR BMS by conducting a course for JKR Sabah Bridge Unit personnel. This course includes hands-on approach of JKR BMS for the personnel who will use the JKR BMS later. At the end of the course, the JKR BMS software is given to Bridge Unit of JKR Sabah.

B. Components of JKR BMS in Sabah

From the data collection, it has been found out that the JKR BMS implemented in Sabah has only the following modules/ components:

1. Inspection Module
2. Database/ Inventory Module

C. Comparison with other BMS

Some BMS have additional components compared to others. The reason may be due to the BMS being made by different developer and also the availability of technology during the time of development. The developer for the BMS may design the BMS according to the needs of the agency using it, therefore making each BMS different and unique from other BMS. The common components are classified into groups as shown below.

TABLE 1. GROUPS OF COMPONENTS

Type I	1) Database/Inventory 2) Inspection
Type II	1) Database/Inventory 2) Inspection 3) Maintenance 4) Life Cycle Cost
Type III	1) Database/Inventory 2) Inspection 3) Maintenance 4) Life Cycle Cost 5) Prediction Model

From TABLE 1, JKR BMS can be classified as Type I. TABLE 2 shows BMS from other countries in their respective categories.

TABLE 2. CLASSIFICATION OF BMS ACCORDING TO THEIR GROUP OF COMPONENTS

Type I	1) BridgeMan (Vietnam) 2) JKR BMS
Type II	1) Eirspan (Ireland) 2) Lat Brutus (Latvia) 3) DISK (Netherland) 4) SMOK (Poland) 5) SZOK (Poland) 6) SGP (Spain) 7) BaTMan (Sweden) 8) KUBA (Switzerland) 9) ABMS (USA)
Type III	1) OBMS (Canada) 2) QBMS (Canada) 3) DANBRO (Denmark) 4) FBMS (Finland) 5) GBMS (Germany) 6) APT-BMS (Italy) 7) BMS@RPI (Japan) 8) KRMBS (Korea) 9) Pontis (USA) 10) EBMS 11) PEI-BMS

The other components are left out of the system except the Inspection and Database Module. In this study the inspection part is accounted as part of the system since the database is updated from data gathered from inspection. There are maintenance being done by JKR but it is not part of the BMS.

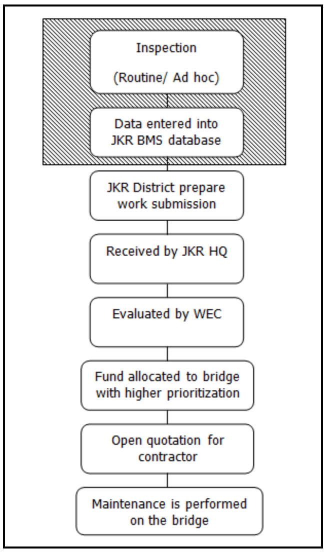

Figure 1. Ideal work flow for JKR BMS

From Figure 1, the shaded region is the only components of JKR BMS implemented in Sabah. A BMS usually helps in making prioritization of which bridge to be repaired based on data from inspection. This will help the in the decision-making. JKR BMS in Sabah however only stores the data entered into its database without analyzing the data. This is because the database did not have any integrated analyzing tool.

D. Advantages and Disadvantages of BMS implemented in Sabah

After investigating the component in JKR BMS, the advantage and disadvantages of the system can be identified. However the advantages of the JKR BMS are much less than its disadvantages. It is also found out that JKR BMS is not fully implemented in Sabah. This may be due to its disadvantages overshadowing its advantages. The advantages and disadvantages are listed in TABLE 3.

TABLE 3. Advantages and Disadvantages of BMS in Sabah

Advantages	**Disadvantages**
i) Database function eliminates the need for archived file.	i) Stand alone database software. ii) Lack of crucial component iii) Difficulties in retrieving information from the database. iv) System not updated. v) Database only accepts certain format of data. vi) No manual for the JKR BMS

E. Ways to Improve the System

This section actually focus more on developing a new system altogether instead of modifying the existing BMS since it would be more practical and easier.

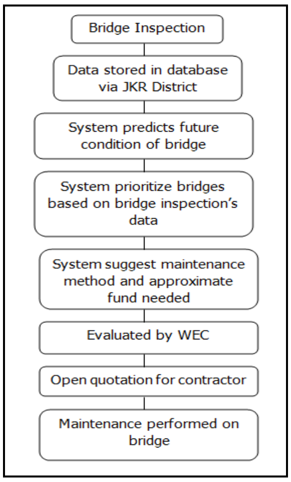

Figure 2. Flowchart for proposed system

Figure 2 shows the flowchart of a single system which incorporates all the components of a bridge management system to assist the decision-making process. The proposed system is designed to eliminate all the weakness of the JKR BMS discussed in previous section. The 3 major properties that the new system should have are:

1. Web-based system
2. Integrated analyzing tool
3. Thorough Training Course and available User Manual

Inspection Module	i. Data gathered include bridge condition rating, damage reports, suggestion on maintenance method, etc. ii. Data will be entered into database via PDA.
Database	i. Beside the data from bridge inspection, the database should also save other data such as the cost related to the bridge in its whole lifetime, traffic condition, etc.
Deterioration Prediction	i. The deterioration prediction module should already have a predetermined formula in the system. ii. The deterioration prediction module should also be integrated in the system so that it can automatically forecasts the future condition of bridges immediately after key parameters such as condition rating is entered in the database.
Maintenance Optimization	i. The maintenance optimization helps in making decision on maintenance method after the prediction module prioritize which bridge that needs to be maintained. ii. There should be a predefined catalogue of standard maintenance method in the system. Based on the type of damages, the system will propose the suitable maintenance methods from the catalogue.
Life Cycle Cost Analysis Module	i. Data from Life Cycle Cost Analysis should assist in determining maintenance method. Therefore, it can also be considered one of the components in Maintenance Optimization Module. ii. However it is a module of its own since it also deals with other costs related to a bridge during its life cycle such as traffic cost.

Figure 5. Summary of the Proposed System

V. CONCLUSION

It is found out that there are only two components in the JKR BMS, which are Inspection Module and Database Module. Comparison is also made with other BMS from other developed countries and it is determined that the JKR BMS is lacking other crucial components of a common BMS. Most BMS have at least Inspection Module, Database Module, Life Cycle Cost Module, and Maintenance Optimization Module. The most similar BMS to JKR BMS is BridgeMan of Vietnam.

It is found out that there are many flaws of the JKR BMS. This is to be expected since it is developed a long time ago with budget restriction. The proper solution to eliminates all the disadvantages of the existing system is to propose a new system altogether.

ACKNOWLEDGMENT

The authors would like to thank Public Works Department of Sabah for their assistance.

REFERENCES

[1] Gholami, M., Sam, A. R., and Yatim, J. M. 2013. Assessment of Bridge Management System in Iran. *Procedia Engineering.* 54: 573-583

[2] Miyamoto, A. and Tarighat, A. 2009. Fuzzy concrete bridge deck condition rating method for practical bridge management system. *Expert Systems With Applications*. 36: 12077-12085

[3] Morcous, G., Lounis, Z. and Cho, Y. 2009. An Integrated System for Bridge Management Using Probabilistic and Mechanistic Deterioration Models: Application to Bridge Decks. *KSCE Journal of Civil Engineering*. 14(4): 527-537

[4] Minchin Jr., R.E., Zayed, T., Boyd, A.J, and Mendoza, M. 2006. Best practices of bridge system management - A synthesis. *Journal of Management in Engineering*. 22(4): 186-195

[5] FHWA. 1996. *LCCA final policy statement*. Docket No. 94-15. Office of Asset Management, FHWA, US Department Of Transportation.

[6] Elbehairy, H. 2007. Bridge Management System With Integrated Life Cycle Cost Optimization. Ontario. University of Waterloo.

[7] Orcesi, A.D., Frangopol, D.M. and Kim, S. 2009. Optimization of bridge maintenance strategies based on multiple limit states and monitoring. *Engineering Structures*. 32: 627-640

[8] Yehia, S., Abudayyeh, O., Fazal, I. and Randolph, D. 2007. A decision support system for concrete bridge deck maintenance. *Advances in Engineering Software*. 39: 202-210

[9] Sundquist, H. and Karoumi, R. 2009. Life Cycle Cost Methodology and Computer Tool WebLCC. *ETSI Bridge Life Cycle Optimisation Stage 2 Subproject 1 (SP1)*. TKK Structural Engineering and Building Technology Publications B. Helsinki University of Technology

[10] Safi, M., Sundquist, H. and Karoumi, R. 2014. Life-Cycle Costing Integration with Bridge Management Systems. *Civil Engineering and Architecture*. 2(1): 11-23

[11] Tham, K. W., Khoo, C. L. and Ng, S. K. 1990. Towards Evolving a Bridge Management System for JKR. Proceedings of the 6th Regional Conference of Road Engineering Association of Asia and Australasia, Kuala Lumpur, March 1990.

[12] Tham, K. W., Ng, S. K., Hashim, S. M. and Jasmani, Z. 1991. The JKR Bridge Management System (JKR BMS). Proceedings of the 2nd Regional Conference on Computer Application in Civil Engineering, UTM, Johor Bahru, Malaysia. Nov 1991.