A PLANNING MULTI-LEVEL BRIDGE MANAGEMENT SYSTEM FOR TAIWAN

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Abstract: Bridges are the most important components in expansive transportation networks. And bridge management systems (BMS) have been developed to help government agencies maintain the bridges in their districts. However, bridge management systems vary with the different bridge types and the different management requirements for each maintenance level. The multi-level framework of a set of bridge management systems for the Ministry of Transportation and Communication (MOTC), for the central and district offices of the Highway and the Freeway Bureaus, and for county and city governments in Taiwan are developed in this work. In addition, major issues and tasks for building a multi-level bridge management system for Taiwan are discussed in this paper.

Keywords: Bridge management system, Information system

1. INTRODUCTION

In the Taiwan area, bridges very easily deteriorate and show damage due to high humidity, frequent earthquake loading, and overloading by heavy vehicles. Because of this, government agencies became concerned and started to inspect, maintain, and repair the bridges. Bridge management systems were also developed to assist government agencies in maintaining and managing the existing bridges. For example, the Freeway Bureau, Highway Bureau, Railway Bureau, and several county governments have independently developed their own bridge management systems (BMS). The Ministry of Transportation and Communication (MOTC) of Taiwan government is presently planning to establish “A Bridge Management System for the Taiwan Area” as well. However, because bridges belong to different districts and the management requirements of each maintenance level varies, it is very difficult to develop a universal BMS that could meet the needs of these various users [1]. Therefore, this study starts from the perspective of diverse management and maintenance levels and attempts to develop an overview plan of BMS.

Developing a BMS includes several aspects. In a broader sense, the plan can include the structuring of the management system, the establishment of management methods and principles, and the development of a computerized management system. In a narrow sense, the plan may mainly stress the development of a computerized bridge management information system (BMIS). This research focuses on the strategic study and planning of BMS for various management levels and its development structure, meanwhile investigating the development of BMIS at various management levels and their structure of data integration.

2. CLASSIFICATIONS OF BMS

Taiwan’s roads are divided into freeways, highways, county roads, city roads, etc. The railroad system is divided into railway, MRT, high-speed railway, etc. In this paper, the BMS focuses on the freeway, highway and road system instead of railway system. The level of the agencies in charge of these roads and railways do not correspond to the ranks of the bridges, their safety requirement, or their maintenance standards. Therefore, it is necessary to classify the bridges by their ranks, their types, their maintenance and their agencies before we develop a BMS; the development of a BMIS must also takes these classifications into consideration and not assume that the agencies can entirely share the same computerized management system [1]. The following is a further discussion of the classification of bridges and the factors that affect the development of BMS’s.

2.1 Differences between users of the information system

The users of a BMIS include central government agencies, such as MOTC, Ministry of Internal Affairs (MOIA), etc. and local government agencies, such as county governments, city governments, etc. The users are many and their purposes and requirements vary. Therefore, the development of BMIS must consider the diversity of these users and suit their practical needs.

2.2 Types of BMIS

To meet the demands of different management levels, BMIS can be divided into two types: the network level and the project level. Both types meet the present needs of Taiwan's different management levels and deserve further research and development. Please refer to Table 1 for the suitability of these two types.

2.3 Classification of bridges

The types of the bridges affect the planning and development of BMIS, so the classification of bridges deserves further study. The most important factors are the structure type and construction material of the bridges; Table 2 shows whether or not the data can be shared. The planning of the information system also needs to consider these factors.

2.4 Factors affecting the development of BMIS

From the above, we realize that we should consider the factors affecting the development of BMIS when we plan and develop a BMIS. Table 3 lists the factors that affect the development of a BMIS.

3. STUDY OF BRIDGE INSPECTION AND EVALUATION METHODS

The inspection and evaluation of bridges is a vital part of the bridge maintenance and management system, because the results will become the basis of the judgment of the bridges' conditions, as well as the reference of the schedule, amount and budget of the bridges' maintenance. The rating value of the inspection and evaluation further assists the decision of maintenance priority and budget. However, the methods of inspection and evaluation in Taiwan are not standardized, and each method has its merits. Therefore, one of the important tasks of the development of BMS is to study the current bridge inspection and evaluation methods, integrate their respective merits, omit subjective misjudgment, and achieve a standardized method.

3.1 Current inspection and evaluation methods in Taiwan

The major inspection and evaluation methods currently used in Taiwan are the D.E.R.U. [2] and the A.B.C.D. [3] deterioration rating methods, which rely on the visual inspection of bridges. The D.E.R.U. is widely use in most of the government agencies in Taiwan. The Degree, Extent, and Relevancy (DER), using a 1 to 4 rating scheme (see Table 4). Degree (D) is defined as the severity of the element defect under consideration. If the element has more than one defect, then choose the most severe defect for rating. Extent (E) is the extent to which the defect occurs over the area of the bridge element. Relevancy (R) is the importance of the defect of the element on the serviceability and structural safety of the bridge. The Relevancy forces the bridge inspector to evaluate the consequences of the defect in terms of the bridge's serviceability.

After inspection, the sub-item condition index, Icij, for each sub-item of the twenty main items is calculated as follows:

$$Ic_{ij} = 100 - 100 \times \frac{(D+E)\times R^{a}}{(4+4)\times 4^{a}} , \qquad (1)$$

(1)

where i=1~20, j=1~n (number of sub-items), and parameter "a" is related to the importance of the bridge. Then, the condition index for each of the twenty main items is calculated as follows:

$$Ic_{i} = \frac{\sum_{j=1}^{n} Ic_{ij}}{n} . \qquad (2)$$

(2)

Finally, the Condition Index (CI) of the bridge is calculated by using the Ic_i value and its corresponding weighting, w_i, as follows:

$$CI = \frac{\sum_{i=1}^{20} Ic_{i} \times w_{i}}{\sum_{i=1}^{20} w_{i}} . \qquad (3)$$

(3)

The D.E.R. rating system described above provides the bridge manager a better knowledge of the specific problems being experienced in the bridge network. The CI index can also be used to help the bridge manager determine a priority ranking for bridges requiring repairs.

The A.B.C.D. rating system categorize the condition of the bridge structural members as A, B, C, and D levels. This method can not calculate the bridge condition index like D.E.R. rating system does.

3.2 The modified rating method

After studying and comparing the D.E.R.U. and the A.B.C.D. methods, we propose a modified rating method that combines the merits of both methods. We use the structure of the D.E.R.U. method but provide a checklist of the inspection items as the A.B.C.D. method. Furthermore, we set the R-value of each item beforehand and list them on the checklist so that the inspector will not have to personally decide on an R-value, which might result in subjective or inconsistent judgments. We also, unlike the A.B.C.D. method, quantify the degree of deterioration, at the same time recording the scope of deterioration (the E value) and the urgency of maintenance (the U value), so that the inspection record is quantified and available for the calculation and analysis of rating value. With this method, the inspector does not have to determine the R-value, which not only simplifies the recording on site, but also standardizes the evaluation of the R-value, thus remedying the A.B.C.D. method's inability to calculate and analyze the rating value.

4. PLANNING IN DEVELOPMENT OF BMIS

The agencies and management levels responsible for bridge management in Taiwan are very complex. The central government agencies are not directly in charge of the maintenance and management of bridges, but supervise the local governments and district bureaus. Therefore, the central government agencies definitely differ from the local government and district bureaus in their needs on bridge management information.

4.1 The planning direction of different levels of BMIS

The planning direction of different levels of BMS should follow the following guidelines.

(1) The development of the information system should consider the needs, the purpose, and the data processing of the user.

(2) The responsibilities of the central government agencies.

(3) The data collection system and the planning of data transmission and integration.

(4) Function and purpose should decide the planning of BMIS at different levels; different levels could also develop their own systems.

(5) The central government agencies should develop an open and expandable reference system.

(6) The technology of the data transmission and data integration.

(7) Executor of data transmission and integration.

(8) Classification of the information system of bridge management agencies.

(9) The suitable types of information system for different bridge management agencies.

(10) Main points of system planning and technology development.

4.2 Feasible proposals for data transmission and integration

Data transmission and integration are important tasks in the development of information systems. Using the practical cases of MOTC's "basic information chart of bridges" and Taipei County Government's "basic information chart of bridges," this research tried to combine the proper items between the two charts and set a standard more suitable for central government agencies. We also used the practical cases to test the transmission and integration of information. In the process we paid particular attention to the following problems:

(1) The transferring of codes.

(2) The consistency of code location.

(3) The combination or division of locations.

(4) The consistency of location type.

(5) The consistency of location length.

(6) The corresponding relation between the locations.

4.3 Application of new technology in information transmission and file transference

Due to the new progress in the Internet, the standard generalized markup language (SGML) of electronic mail has now evolved into a more simplified standardized language, extensible markup language (XML). Because we can personalize the definition of labels in XML and communicate and exchange information by writing document type definition (DTD) for specific fields, XML has become a standard form of information exchange and integration[5].

5. RESEARCH ISSUES IN DEVELOPMENT OF BMIS

5.1 Research in the planning of a BMIS

Central government agencies need to consider three principles in their planning of the development of a BMIS, which is listed in Table 5.

The main purpose of the planning and development of BMIS for local government agencies is to transfer information to the central government for integration. Therefore, the planning of a BMIS for local governments should consider the information items demanded by the central government and the functional purpose demanded by the local government. The BMIS for local governments should at least be able to gather, analyze, transmit and integrate information, but not necessary to use the same computer program and database for different levels of government agencies.

5.2 Research in application of Internet technology

The network system is mainly divided into client/server and Web-based platforms. With the improvement of Internet technology, Web-based construction has become the future of all kinds of information systems. Moreover, because district bureaus and local (county) government are located in different regions, from the viewpoint of system renewal and operation interfaces, Web-based construction for BMIS has a definite advantage.

5.3 Research in bridge information coding

Information coding is an important task in the development of information systems. We compared and analyzed the basic bridge information from the Freeway Bureau, the Highway Bureau, the Railway Bureau, the Keelung Harbor Bureau, the Taipei County Government, etc., in search of more suitable items or those that needed coding. Then we combine and integrate the bridge terminology and coding systems of the various agencies and established a practical coding system.

The major principles of coding are as follows: the codes should accurately represent the items, they should not be too long, and they should not be combined into complex codes. The characteristics and amount of information and the grouping and expandability of the codes should also be taken into consideration. In addition, the number of codes should be limited, for fear of causing inconvenience in the development and management of the system.

The lack of standards for bridge information transferring among the different government agencies sometimes can lead to some crucial problems during the life cycle of bridge management. The concept of information standard within Construction CALS (C-CALS) can bring some benefits for developing the bridge management system; such as information standard sharing, one time information input, and reducing maintenance cost in the life cycle of bridges [6].

CONCLUSIONS

1. The central government agencies should set, as their major work in the information collection of their BMS, the integration of the information of various agencies and bureaus.
2. The bridge inventory and inspection database of the central government agencies should focus on the aspects of the management, decision, and hazard prevention.
3. The development of BMS should use the web-based platform.
4. The ideas and implementation of C-CALS should be incorporated in developing BMS.

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7. REFERENCES

[1] Chan, C. H. (1999), *A Study on the Planning of the Bridge Management Systems*, M. S. Thesis, National Taipei University of Technology (in Chinese).

[2] Lin, A. Y., (1998) "The Bridge Management System of Freeway Bureau at Taiwan," Civil Engineering Technology, Vol. 2, No. 2, pp. 97-110 (in Chinese).

[3] de Fleuriot, E., P.A. Nordengen, Y.-F. Li, and A.-Y. Lin (1995), "A Bridge Management System for the Taiwan Area National Freeway Bureau," Proceedings of the International Bridge Conference - Bridges into the 21st Century, 2-5 October, Hong Kong, pp. 601-608.

[4] The Inspection Manual of Concrete and Steel Bridges, CECI (1996) (in Chinese).

[5] Summer Institute of Linguistics, *"Extensible Markup Language (XML),"* http://www.sil.org/sgml/xml.htm(1997)

[6] Wang, M.-T., S.-H. Shieh, and H.-P. Tserng, "Study on Information Standardization for Construction Industry Using CALS Strategy," Proceedings of the 6th East Asia-Pacific Conference on Structural Engineering and Construction, pp. 14-16, Taipei, Taiwan, R.O.C. (1998)

Table 1 Major potential government agencies and bridge types for applications of network-level and project-level bridge management information systems

	Government Agencies	Bridge Type
Network Level BMIS	● MOTC ● Highway Bureau ● Freeway Bureau ● City or county Governments	● All Bridges on the network of freeway, highway, or road system
Project Level BMIS	● The district office of Highway or Freeway Bureau ● City or county governments ● Others	● Viaduct ● MRT bridges ● Special bridges ● Important bridges ● Very long bridges

Table 2 The influence of different types of bridge attributes (material, structure, loading and structural member) on bridge information items in BMIS forms

	Inventory information form	Structural information form	Inspection information form
Different material types	Items are the same	Items are the same	Items are different
Different structure types	Items are the same	Items are different	Items are different
Different loading types	Items are the same	Items are different	Items are different
Different structural member	Items are the same	Items are different	Items are different

Table 3 Major influence factors in development of BMIS

Bridge factors	Information factors
● Bridge structural type ● Member material type ● Service level of the bridge (in terms of importance and safety) ● Special characteristics of the bridge	● Targeting users of the information system (Different management levels and/or application demands) ● Orientation of the information system (project level or network level)

Table 4 DER Rating for visual inspection

Rating	1	2	3	4
D	Good	Fair	Poor	Severe
E	< 10% < 30% < 60% <			
R	Minor	Small	Medium	High

Table 5 Major tasks in building a multi-level BMIS for Taiwan

Target	Major tasks
Central Government (such as MOTC and MOIA)	● Develop a top-level BMIS focusing on decision support, hazard prevention, and high-level management) ● Develop BMIS information standards for information sharing among same administrative levels and across different administrative levels ● Develop a generic prototype BMIS that can be easily adopted and extended by them to save BMS development efforts
The government agencies without their own BMIS	● Define their own BMIS development guidelines based on their specific needs ● Follow the BMIS information standards developed by the central government to define their BMIS database formats
The government agencies with their own BMIS	● Develop an information exchange and sharing mechanism between their existing BMIS and newly-developed BMIS following the BMS information standards