APPLICATION OF EXPERT SYSTEM FOR BRIDGE MANAGEMENT IN PAPUA NEW GUINEA

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Abstract: This paper presents a computer aided bridge management system (CADBMS) and its implementation in the context of Papua New Guinea. The expert system includes a bridge management information system database (BMISD) and knowledge based database (KBD) logically linking all bridge parameters to the repair, maintenance and rehabilitation (RMR) options. The KBD is written in Micro-soft Excel with its Visual Basic Interface (VBI). The data supplied by the user are processed by the expert system to produce best RMR options with due consideration of economy. CADBMS is developed and implemented in some provinces and work is now under progress to develop a global system to include the whole country.

Keywords: Bridge, Computer aided, Economic, Expert System, Knowledge based, Implementation, Maintenance, Management, Programming

1 INTRODUCTION

The importance of bridge maintenance and rehabilitation versus new bridge construction has become of great concern to the Department of Transport and Works (DTW) of Papua New Guinea. The cost of rehabilitation of a disrupted bridge can be bigger than the building of a new structure. Budgets for keeping or upgrading existing bridges are always limited. To identify existing problems and to develop a proper bridge management system, the project "BMS" is initiated. The project is vital, as it will fulfil the current needs of a proper bridge management system for DTW.

Recent history of bridge management systems began in 1967 after a major collapse occurred on the Ohio River Bridge in which 64 people were killed. Other notable disasters which reinforced the idea include: the 1983 collapse of the Chikasawbogue Bridge in Alabama, USA, and the 1985 collapse of the Manus River Bridge in Connecticut, USA [1]. In USA, such destruction and rehabilitation of bridges is expected to cost some $90 billion [2].

Due to such problem bridge management systems have been developed and used all over the world. The major obstacle in accurately determining and evaluating bridge inspections and maintenance is the installation of effective management systems. Bridge Management systems that initially presented only technical activities are now developing decision criteria for maintenance and rehabilitation. Since inspection and maintenance are costly, they are trade-offs between the extent and accuracy of inspection, required level of reliability and costs [3]. To rationalise the investment on maintenance and rehabilitation, bridge management systems are effective. The mandating of inspections and maintenance of bridges has reached a higher degree of refinement.

The biggest problem in PNG is the poor management of bridges after construction. This leads to structural deterioration and lack of functionality of most bridges. PNG had many disasters relating to bridge collapse, the recently being the Umi Bridge collapse. The costs of reconstruction of such disasters have been a strain to the economy.

This paper will focus on the various features of the developed Computer Aided Bridge Management System (CADBMS) and its development and implementation in PNG.

2. FEATURES OF "CADBMS"

Bridge management includes [4] all those processes necessary to ensure that all bridges on a road network are kept in a safe condition with the most cost efficient use of resources. With sound management system, the life span of bridges can be extended and can reduce life cycle costs.

The CADBMS is developed in three phases as shown in Figure 1. The phase 1 includes the development of a Bridge Management Information System Database (BMISD) for all bridges in PNG. The BMISD is the heart of CADBMS and will act as a source of knowledge. In phase 2, BMISD is used to create a Knowledge Based Database (KBD) in CADBMS providing feasible, economical and professional expert advice to the user on repair, maintenance and rehabilitation (RMR) of any arbitrary bridge in Papua New Guinea. The development of KBD from BMISD needs extensive analysis and is the key to the success of CADBMS. Phase 3 is the processing of user data in KBD to provide expert advice.

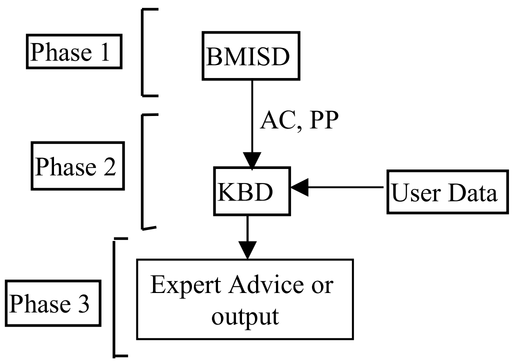

Figure 1: General layout of CADBMS

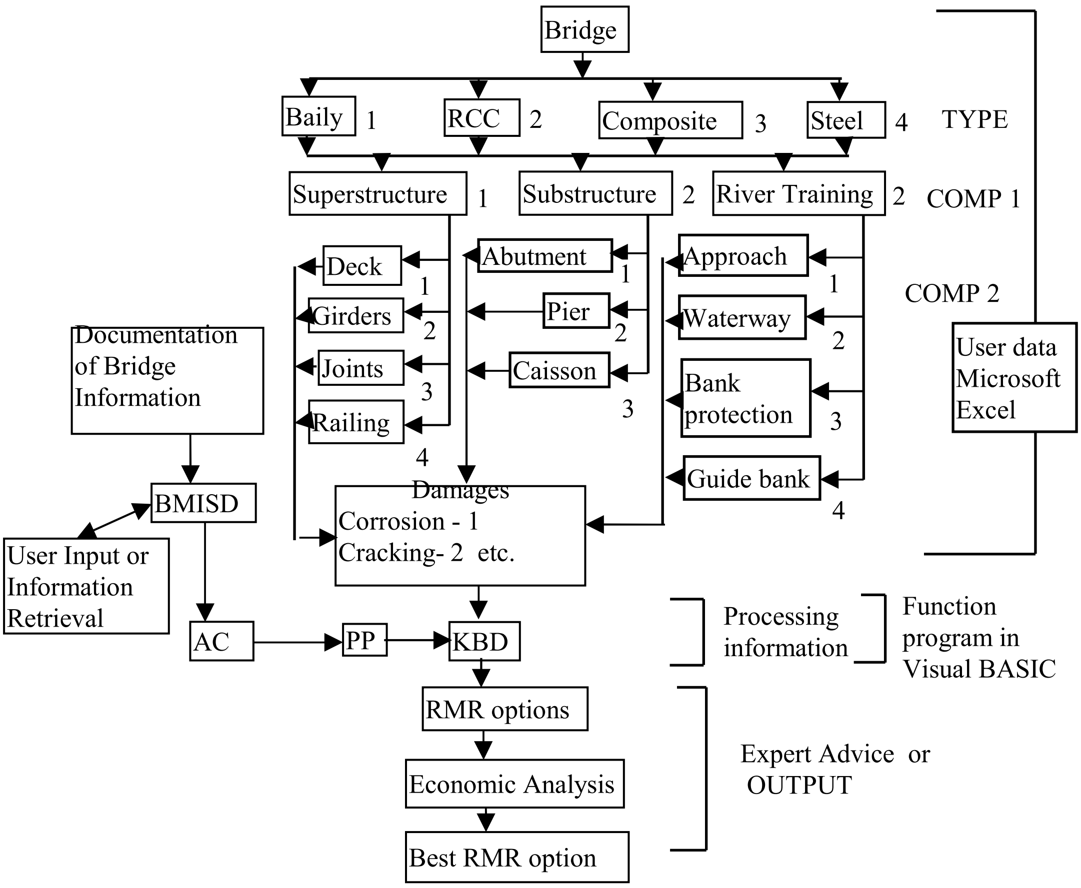

Figure 2: Typical simplified flow diagram of CADBMS for illustration

Phase 1: "BMISD" development

BMISD comprises all those systems necessary for the collection and storage of information relating to all bridges in all the provinces of Papua New Guinea. This includes documentation of all bridges. Documentation should be continuously updated to ensure that it is accurate and up to date. Systems for collecting updated information comprises inspection and rating reports and reports detailing construction, maintenance, rehabilitation, enhancement and replacement actions.

These actions should be reported fully and promptly because the planning and undertaking of all these actions requires access to up to date documentation. Documentation of all the bridges is performed based on available data in Microsoft Access as a database, which is described as BMISD.

Thus BMISD represents the whole picture of bridges in Papua New Guinea. The user can retrieve specific information from BMISD for a particular bridge providing bridge identification. The upgrading of BMISD is also possible with new information.

2.2 Phase 2: "KBD" Development

Phase 2 consists of two main steps. Step 1 is called analysis and co-relation (AC) and includes extensive and careful analysis of information from BMISD. Step 2 includes a comprehensive programming phase to develop KBD.

Step 1 (AC)

The information from BMISD for each of the bridge is analysed and reviewed to identify the damage and their cause for each of the bridge during its lifetime. The suitability of the repair, maintenance and rehabilitation (RMR) option as suggested by the engineer is analysed from the post RMR performance data of the bridge to identify the best RMR option for that specific damage. So for each bridge, it is possible to identify the best RMR option or options for a particular type of damage. These best RMR options are then compared with the best RMR options obtained from another similar type of bridge for the same type of damage to identify suitable general RMR options. The best option for a particular type of damage can then be identified based on economic analysis. In this way, a comprehensive analysis of the bridge data from BMISD is performed to logically co-relate all possible damages with best RMR options for all bridge types available in Papua New Guinea. This is the most complicated part of the whole project. The accuracy of the intelligent system depends on the success of this co-relation process.

Step 2: Programming Phase (PP)

The logically co-related information from AC is transformed into knowledge based database (KBD) through an extensive programming phase. KBD constitutes the main body of the intelligent system and is developed in Microsoft Excel in conjunction with its visual basic interface. The software fully utilises computational capabilities of the system. The knowledge based database is created in various function modules using codified numeric keys (say 1, 2, 3 etc.) to symbolize different types, component of bridges, the possible damages and all possible repair options. This can be seen from a simplified flow diagram of the entire CADBMS shown in Figure 2.

2.3 PHASE 3: OUTPUT: Economic Module:Expert Advice

This includes the processing of data supplied by the user (Figure 2) in KBD and to come up with RMR options. The expert system will display the best RMR option or options after economic analysis.

For decision making in bridge management it is necessary to quantify the global costs of bridges and to predict the benefits during the life cycle. To perform this analysis, a global cost function (C) is [5] developed: $C = C_O + C_I + C_M + C_R + C_F - B$in which C_O the initial cost (preliminary study, design, construction and testing), C_I the inspection costs (labour, testing and equipment) , C_M the maintenance cost, C_R the repair cost (structural assessment and structural repair) , C_F the failure cost (structural failure, bridge replacement, loss of lives, equipment, traffic delay, traffic flow re-routed, environmental or social impact) and B the benefits (traffic delay, traffic re-routed). Within the economic analysis, several options are [5] used to predict the bridge inspection, maintenance and repair costs: a computation based on the bridge dimensions and location, current costs of authorities (e.g. man-hour cost and daily cost of equipment), a prefixed calendar of inspection; use of regression techniques with data from previous years for similar bridges and a year to year imposed rate prediction. Failure costs (C_F) are associated [5] with the partial or total impairment of a bridge to fully comply with its design function. $C_F = C_{FSF} + C_{FFF} + C_{FEI}$, in which C_{FSF} are the structural failure costs, C_{FFF} the functional failure costs and C_{FEI} the environmental/social costs. The costs associated with structural failure can be obtained from the probability of failure P_f and even though collapse does not occur under normal circumstance, these costs can still be considered as insurance costs: $C_{FSF} = P_f * C_{FSF'}$ In the economic analysis, estimation of the probability of failure considers a linear variation in time during the life of the bridge. This failure path is based on degradation mechanism of the bridge.

Best RMR option is related to economy and a global cost analysis is included in CADBMS. The linking of RMR options with economic criteria can lead to a more economical decision on whether to repair or replace a bridge. The economic analysis module in CADBMS will allow the estimation of overall cost of the RMR options.

3. IMPLEMENTATTION OF CADBMS

CADBMS is intended to be used by the Department of Transport and Works (DTW) of Papua New Guinea and for educational purposes.

The DTW is responsible for management of bridges in Papua New Guinea. The transportation system of Papua New Guinea is not developed due to the geographic features of the country. The mountainous terrain with network of rivers, swamps and forests makes it very difficult to construct roads or rail network in the country. It is interesting to note that only communication system between the capital Port Moresby and other provincial cities of the country is by air. Poor transport system is one of the causes for the development of rural areas of Papua New Guinea. The major highway of the country is named as highland highway connects second largest city, Lae of Morobe province to other provincial cities in the highlands. The government of Papua New Guinea is now trying to develop transport system through DTW with support from various donor agencies. Major projects have been undertaken for the last few years to develop new highways and to rehabilitate old ones.

Existing highways and road networks have numerous bridges and management of such bridges through DTW is very important.

The DTW of each of the provinces has been given the responsibility to accumulate all relevant information about all the bridges in the province. The information covers full details of the bridge including:

- Structural information
- River training works
- Rehabilitation or repair works
- Traffic characteristics
- Souci-economic impact of the bridge

For the last two years, effort has been made to collect information of every bridge in Papua New Guinea. It was not an easy job; however, response from some of the provinces was very good. Still collection of information is under progress. The BMISD will reserve the bridge information for each of the provinces under different headings so that it is very easy to retrieve and process information for management process. DTW of each of the provinces is given the responsibility to create BMISD for their own province. Once all the provinces finish their database, they will be combined to a single data base and constitute global BMISD for the whole country. So far a total of 224 bridges have been included in the provincial BMISD systems.

DTW of Morobe province has already documented all the bridges in the province and BMISD for this province is ready and incorporated in the complete CADBMS. For the last six months, DTW of Morobe province in association with the PNG University of Technology has been using CADBMS for the management bridges. The CADBMS already attracted the attention of the local government for its various service:

- provides a versatile and useful means of bridge management and to generate expert advice on best RMR options.
- easy to use, a person with basic knowledge of Microsoft Excel and a knowledge of bridge management can be able to use this software.
- BMISD itself represents the complete information of bridges in Papua New Guinea and can be used for retrieval of information for any bridge in PNG or for updating existing information.
- use of expert system will provide economy and ensure an efficient bridge management system.
- the user can generate multiple RMR options within a very short time before he or she selects a particular one.
- Efficient resource allocation
- Budget preparation

The Civil Engineering Department of Papua New Guinea University of Technology is now using CADBMS as a package programme to teach students.

It will be a big achievement when CADBMS will be ready for the whole country and every provincial office will be linked with global network system through Internet.

The successful development of CADBMS and its implementation depends on the following factors:

- Sincere co-operation of all provincial offices to complete BMISD.
- Support from the local and provincial governments in implementation
- Staff training
- Establishment of computer networks for the whole country

Currently implementation of CADBMS in the Morobe province inspired other province to do their jobs. It is hoped that CADBMS will be implemented globally to the whole country by the middle of 2001.

4. CONCLUSIONS

The development of a computer aided bridge management system (CADBMS) for Papua New Guinea is essential from management and economic point of view. BMISD can be used as a data bank for retrieval and updating of bridge information. The successful development of KBD will ensure the reliable generation of expert advice on RMR option compatible to the request of the user. CADBMS is fully developed for some of the provinces and successfully implemented. Development of CADBMS is now under progress to include the whole country and it will be completed and implemented by the middle of 2001. The expert system developed is easy to use and proved useful and attractive to students, teachers, consulting firms, practicing engineers and government organisation.

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