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A PROPOSED BRIDGE INSPECTION AND MAINTENANCE MANAGEMENT SYSTEM (BIMMS) IN EGYPT

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ملخص البحث:

تعد الكبارى واحدة من اهم منشأت البنية الأساسية لشبكات النقل وهى تمثل ثروة قومية لأى دولة بإعتبارها أصل من الأصول الهامة. ومن العوامل الرئيسية التى تؤثر على عمر وأمان تشغيل الحركة المرورية فوق هذه الكبارى هو الحالة المادية لها. لذلك فإنه من الضرورى أن يتم وضع نظام محدد لفحص وصيانة الكبارى والذى يعتبر جزء هام من منظومة لإدارة الكبارى تهدف إلى الحفاظ عليها فى حالة مقبولة. ومن هنا يركز البحث على تطوير نظام لإدارة فحص وصيانة الكبارى فى مصر (Bridge Inspection & Maintenance Management System (BIMMS، ولتحقيق ذلك تمت مراجعة الادبيات العالمية فى هذا المجال وتلى ذلك تصميم استمارتين لاستقصاء الرأى عن مكونات منظومة فحص وصيانة الكبارى. ثم تم إجراء الاستقصاء الاستطلاعى للوصول إلى الشكل النهائى للاستمارات لتوزيعها على مجموعتين من المستقصى معهم، تشمل المجموعة الأولى عدد من الخبراء والمسئولين المعنيين بإدارة الكبارى فى الهيئات الحكومية مثل الهيئة القومية لسكك حديد مصر والهيئة العامة للطرق والكبارى بالإضافة إلى مديرية الطرق والنقل بمحافظة القاهرة، بينما تضم المجموعة الثانية عدد من الأساتذة الأكاديميين والخبراء بالجامعات المصرية فى مجالات هندسة إنشاء وإدارة الطرق والكبارى. وقد تم تجميع ٤٠ استمارة استقصاء كاملة، ولتحليل الإجابات التى تم الحصول عليها تم استخدام عدد من التحليلات الإحصائية المتنوعة، حيث تم إجراء التحليل الإحصائى الأول لاختبار استقلالية إجابات المجموعة الأولى عن إجابات المجموعة الثانية. وبناء على نتائج هذا الاختبار تم إجراء التحليل الإحصائى الوصفى للإجابات إما لكل مجموعة على حده أو لمجموعتين معا وذلك للتعرف على شكل النزعة المركزية لتلك الإجابات. وفى النهاية تم تطبيق التحليل الإحصائى الثالث باختبار جودة التوفيق للإجابات لتحديد ما إذا كانت البيانات التى تم جمعها تتبع أى من التوزيعات الإحصائية المعروفة أم لا (مثل: التوزيع الطبيعى أو التوزيع المعتدل)، واعتمادا على مراجعة الأدبيات فى هذا المجال بالإضافة إلى نتائج تحليل استمارات الاستقصاء تم التوصل إلى الإطار المقترح لنظام إدارة فحص وصيانة الكبارى فى مصر.

1. INTRODUCTION

Bridges are considered as one of the most valuable transport infrastructure assets. One of the major factors affecting the life span and the safety of traffic on bridges is their physical condition. In this context, bridges should be inspected and maintained in accordance with a management plan, which is part of a wider bridge management system aiming at sustaining the physical condition of bridges in an acceptable form.

CERM Vol. (25) No. (2) APRIL 2003 Page. 490-508

This paper is concerned with proposing a Bridge Inspection and Maintenance Management System (BIMMS) in Egypt. In pursuing this objective, the literature was reviewed and two questionnaire forms, concerned with details of the components of bridge inspection and maintenance, were designed, piloted, refined and distributed between two groups of specialized respondents. The first group includes a number of professional employees holding key positions concerned with bridge construction, inspection and maintenance at the Egyptian Railway Authority, the Egyptian Roads and Bridges Authority as well as the Roads and Transport Bureau at Cairo governorate. The second group includes a number of Egyptian academics specialized in the fields of structural, road and bridge engineering and management.

Completed questionnaires were collected. These were thoroughly analyzed using a number of statistical tests. The first test aimed at investigating the independence of responses between the two responding groups. Based on the results of this test, descriptive statistics, either for the two groups combined or for each group separately, were computed to show the central tendencies of the responses. Finally, goodness of fit tests were also applied in an effort to determine whether some of the collected data are fitting common statistical distributions. Based on the results of the questionnaire analysis as well as on the literature review, a proposed Bridge Inspection and Maintenance Management System (BIMMS) was envisaged for Egypt.

2. REVIEW OF BRIDGE MANAGEMENT SYSTEMS (BMS)

A BMS can be defined as the means that provide those responsible for bridges with all the relevant and necessary information and possible activities that assist them in making decisions aimed at preserving and improving the physical status of bridges. At the heart of a BMS is the database containing a register of the bridges and built up using information obtained from the regular inspection and maintenance activities. Some examples of BMS are presented below.

2.1. BMS in United States of America

The primary BMS developed for the United States Department of Transport under a contract with Cambridge Systematics and Optima, Inc. is known as PONTIS (Preservation, Optimization and NeTwork Information System). This was developed in the early 1990's. It became commercially available in 1992, and is now used in the majority of states. As shown in figure 1, maintenance optimization is undertaken to find the optimal long-term maintenance policy that minimizes expected life-cycle cost determined using cost models. An improvement model then seeks to quantify the benefits of functional improvements, which is then compared with the costs to determine the worthiness of the proposed maintenance action and to recommend the preferred one.

A very sophisticated computer-based platform is used to support PONTIS in a windows environment, and it is possible to customize the system for each user. Its greatest value is the simple way in which it translates the value of sound engineering decisions into tangible benefits and meaningful maintenance costs.

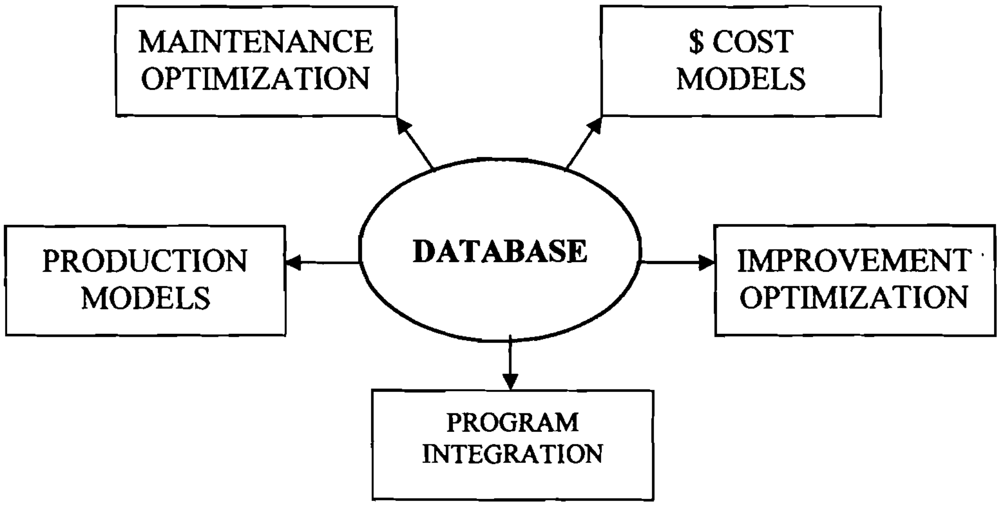

Figure 1: Overall Structure of PONTIS (Source: Thompson, P. D. et al., 1998)

PONTIS is also being used to calculate the expected annual maintenance cost for alternative bridge designs for new crossings, which are then combined with the initial capital construction costs to obtain the full life cycle costs of each bridge, and thus to enable a final selection to be made on economic grounds.

2.2. BMS in United Kingdom

In the UK a BMS called HiSMIS (Highways Structures Management Information System) was also developed in 1990. This is reputed to be the most widely used BMS in the UK. The layout of HiSMIS is shown in figure 2. The system administration module allows the user administrator to adjust and maintain the system for its particular use. The actual database is made up of five modules, which provide all relevant INPUT information for the system. OUTPUT is via the inquiry and reporting suite made up of six modules. It is user friendly, has adequate data storage volume, and can deal with structures other than bridges, namely tunnels, culverts, causeways, floodways, lighting system and retaining walls making it one of the most comprehensive systems. The system is not prescriptive, as facilities are built in to allow users to customize system for their own use.

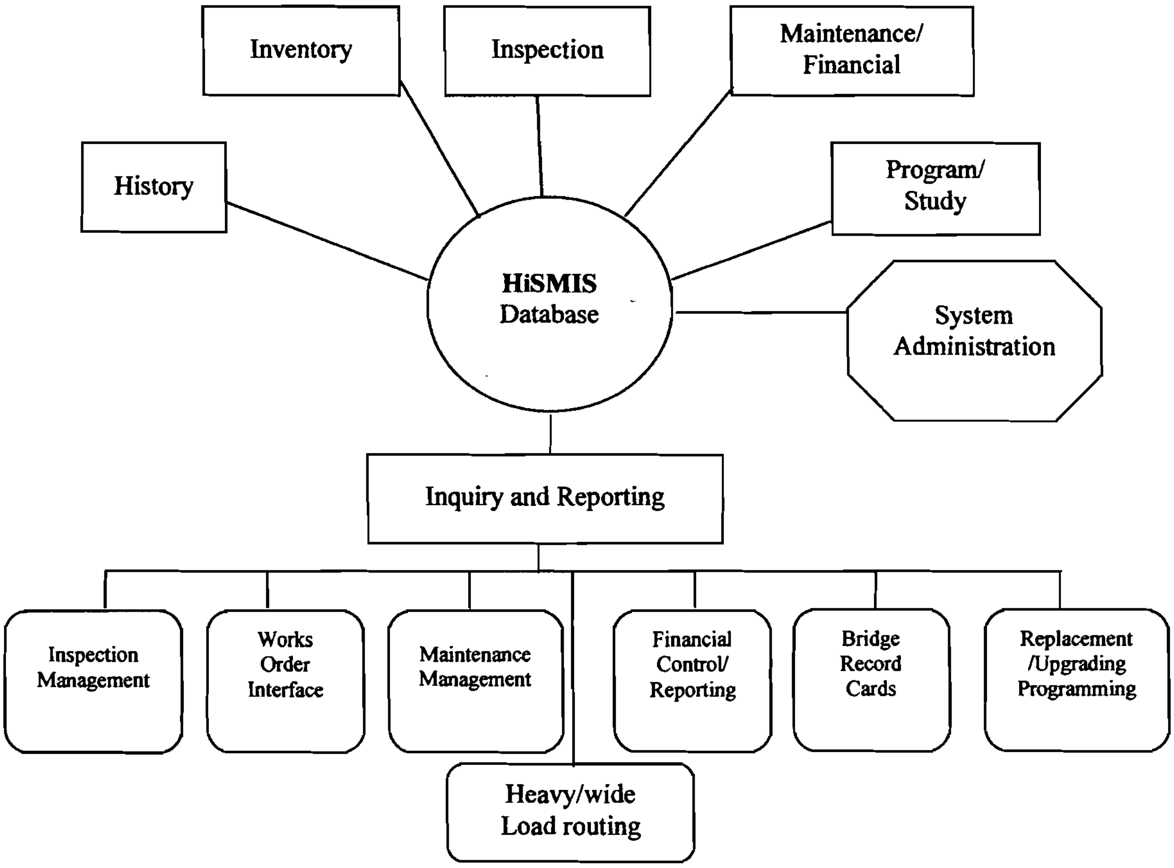

Figure 2: HiSMIS System (Source: Ryall M.J., 2001)

2.3. BMS in Finland

The Roads & Waterways Administration (RWA) in Finland developed a BMS as shown in figure 3. This BMS analyses information fed into it from the bridge directory and the bridge inspection modules, and provides information at two levels:

Network level: This defines the optimum condition level, i.e. a condition that is safe and poses little risk to users. However, it is not economically viable to maintain bridges in such condition.

Project level: This provides bridge engineers with data that they can use to formulate a maintenance action plan for the short and long term. The engineer can also interact with the system based on his professional experience and try to establish his own set of priorities.

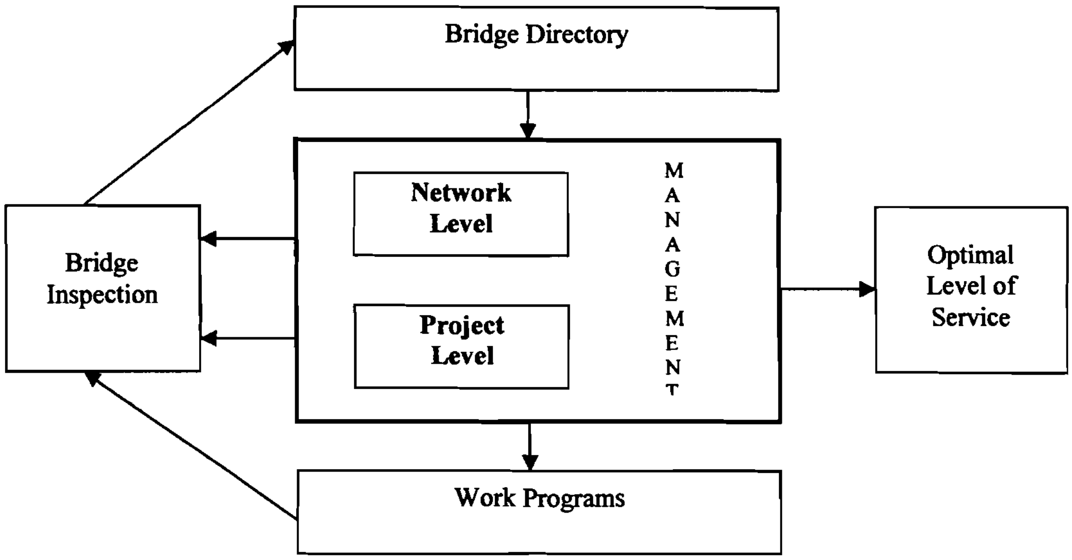

Figure 3: Finnish RWA, BMS (Source: Kahkonen and Marshall,1990)

3. DEVELOPMENT OF QUESTIONNAIRE TO ELICIT EXPERTS' JUDGMENT WITH REGARDS TO PROPOSED BIMMS

This paper is concerned with proposing a BIMMS in Egypt. In pursuing this objective, two questionnaire forms, concerned with details of the components of bridge inspection and maintenance, were designed, piloted, refined and distributed between two groups of specialized respondents. The first group includes a number of professional employees holding key positions concerned with bridge construction, inspection and maintenance at the Egyptian Railway Authority, the Egyptian Roads and Bridges Authority as well as the Roads and Transport Bureau at Cairo governorate. The second group includes a number of Egyptian academics specialized in the fields of structural, road and bridge engineering and management.

Before designing the questionnaires, site visits, interviews, discussions and an examination of published studies, see OECD 1976, 1981, Narasimhan and Waikbank, 1998, were carried out to identify the different components, factors and problem areas, which are related to inspection and maintenance of bridges in Egypt. These factors constitute the core of the questionnaires.

Pilot questionnaires were then introduced to a small sample of potential respondents representing the two targeted groups. These showed that the questionnaires needed some modifications and refining. Two questionnaires were finally designed and distributed among 65 professional and academic experts. Finally, around 40 completed questionnaires were collected.

4. STATISTICAL ANALYSES OF QUESTIONNAIRES RESPONSES

A number of statistical tests were carefully selected and applied in an effort to analyze responses to the questionnaires and elicit conclusions, see Siegel and Castellan,1988. All these tests were conducted using the Statistical Package for Social Sciences (SPSS 10), see Norusis, 1999. The first test aimed at investigating the independence of responses between the two responding groups. Chi-square test was applied for nominal data, Mann-Whitney test for ordinal data and T-test for cardinal data. In these tests, the null hypothesis (H_0) states that there is no significant difference in the responses between the two groups. This is rejected if computed significance level is ≤ 0.05. On the other hand, this is not rejected if computed significance level is > 0.05.

Based on the results of these tests, descriptive statistics such as mode for nominal and ordinal data and mean for cardinal data, either for responses obtained from the two groups combined or for each group separately, were computed to show the patterns and central tendencies of responses. It should be noted that in case the results of the tests are a combination of hypothesis rejection for some elements and no rejection for others, the most dominant result is the one taken into consideration.

Finally, goodness of fit tests such as chi-square test for nominal data and Kolmogrov Smirnov (K-S) test for ordinal and cardinal data, were applied in an effort to determine whether some of the collected data are fitting common statistical distributions. In case of nominal data, the null hypothesis (H_0) states that answer categories behave uniformly, i.e. these have the same expected frequency of occurrence. In case of ordinal data, H_0 also states that the distribution of the questionnaire responses coincides with the uniform distribution and in case of cardinal data, H_0 states that the distribution of the questionnaire responses coincides with the normal distribution. The results of all these tests are shown in tables (1) through (3).

Table 1: Statistical Analysis for Nominal Data of Questionnaire Responses

Analysis Type / Questionnaire Parameters	Independence Test Chi-square	Tendency Test (Mode) Group 1	Tendency Test (Mode) Group 2	Goodness of Fit Test (Chi-square) Group 1	Goodness of Fit Test (Chi-square) Group 2
Types of Data Recorded for Bridges					
Descriptive data for bridges	N.A.	Yes	Yes	N.A.	N.A.
Design data	N.A.	Yes	Yes	N.A.	N.A.
Traffic data	Rej.	No	Yes	Not Rej.	Rej.
Past inspection data	Not Rej.	Yes	Yes	Not Rej.	Rej.
Past maintenance data	Not Rej.	Yes	Yes	Rej.	Rej.
Medium Used for Recording Data on Bridges					
Using forms	Rej.	Yes	No	Rej.	Not Rej.
Using drawings	Rej.	Yes	No	Rej.	Not Rej.
Using computer data base	Rej.	No	Yes	Not Rej.	Rej.
Using microfilm	Not Rej.	No	No	Rej.	Rej.
Using Geog. Info. Sys. (GIS)	Rej.	No	Yes	N.A.	Not Rej.
Main Types (Strategies) of Inspection					
Preventative	Rej.	Yes	Yes	Rej.	N.A.
Corrective (Remedial)	Not Rej.	Yes	No	Not Rej.	Rej.
Frequencies of Inspecting Reinforced Concrete Bridges					
Visual for part of bridge	Not Rej.	Annually	Annually	Not Rej.	Rej.
Visual for all of bridge	Rej.	3-6 month	Annually	Rej.	Rej.
Equipment based for part of bridge	Rej.	No answer	At 4 years	Not Rej.	Not Rej.
Equipment based for all of bridge	Rej.	No answer	At 10 years	Not Rej.	Rej.
Frequencies of Inspecting Steel Bridges					
Visual for part of bridge	Not Rej.	2-4 week	Annual	Rej.	Rej.
Visual for all of bridge	Rej.	3-6 month	Annual	Not Rej.	Not Rej.
Equipment based for part of bridge	Rej.	No answer	At 2 years	Not Rej.	Not Rej.
Equipment based for all of bridge	Rej.	No answer	At 10 years	Not Rej.	Rej.
		Two Groups Combined		Two Groups Combined	
Standards Used for Inspection					
Local	Not Rej.	No		Rej.	
International	Rej.	No		Rej.	
Specially developed for authorities	Not Rej.	No		Rej.	
Internal guidelines	Not Rej.	No		Rej.	
Methods of Recording Inspection Data in Field					
Forms	Not Rej.	Yes		Rej.	
Notes	Not Rej.	Yes		Rej.	
Sketches	Not Rej.	Yes		Rej.	
Photographic camera	Rej.	Yes		Rej.	
Video camera	Rej.	No		Rej.	
Mobile laboratory	Rej.	No		Rej.	

Group 1: Professional government employees Group 2: Academics, consultants & contractors
N.A. = Not Applicable as all responses obtained from the two groups fall in one category

Table 1: Continued

		Two Groups Combined		Two Groups Combined	
Methods of Recording Inspection Data in Office					
Reports	Rej.	Yes		Rej.	
Drawings & sketches	Not Rej.	Yes		Rej.	
Computer data base	Rej.	Yes		Rej.	
Forms	Not Rej.	No		Rej.	
Human Resources for Inspection					
Sufficiency of human resources for inspection	Not Rej.	No		Rej.	
Preferable Methods of Assessment					
Used by Bay Area Rapid Transit Authority, USA.	Not Rej.	Most Preferable		Rej.	
Used by Bridges Department, The Netherlands.					
Used by Chicago Transit Authority, USA.					
Observed Defects at Inspection of Steel Bridges					
Corrosion	Not Rej.	Common		Rej.	
Fatigue	Not Rej.	Not Common		Not Rej.	
Bolt defects	Not Rej.	Average		Not Rej.	
Welding defects	Rej.	Not Common		Rej.	
Bearing defects	Not Rej.	Average		Rej.	
Stresses concentration defects	Not Rej.	Not Common		Rej.	
Fire defects	Not Rej.	Not Common		Rej.	
Accidents	Rej.	Average		Rej.	
Observed Defects at Inspection of R.C. Bridges					
Cracks	Not Rej.	Average		Rej.	
Spalling	Not Rej.	Average		Rej.	
Corrosion of steel bars	Not Rej.	Average		Rej.	
Expansion joints defects	Rej.	Average		Rej.	
Leakage	Not Rej.	Not Common		Not Rej.	
Foundation settlement	Not Rej.	Not Common		Rej.	
Accidents	Not Rej.	Not Common		Rej.	
Fire defects	Not Rej.	Not Common		Rej.	
		Group 1	Group 2	Group 1	Group 2
Main Types (Strategies) of Maintenance					
Preventative	Rej.	Yes	Yes	Not Rej.	Rej.
Corrective (Remedial)	Not Rej.	Yes	No	Not Rej.	Not Rej.
Frequencies of Maintaining Reinforced Concrete Bridges					
Periodic	Rej.	Monthly	Annually	Rej.	Rej.
Rehabilitation/strengthening	Not Rej.	At 5 years	At 5 years	Rej.	Not Rej.
Replacement	Rej.	Case Based	At 40 years	Not Rej.	Not Rej.
Frequencies of Maintaining Steel Bridges					
Periodic	Rej.	Monthly	Annually	Rej.	Rej.
Rehabilitation/strengthening	Rej.	Case Based	At 5 years	Rej.	Not Rej.
Replacement	Rej.	Case Based	At 20 years	Not Rej.	Not Rej.

Table 1: Continued

		Group 1	Group 2	Group 1	Group 2
Standards Used for Maintenance					
Local	Rej.	No	No	Not Rej.	Rej.
International	Rej.	No	Yes	Not Rej.	Not Rej.
Specially developed for authority	Not Rej.	No	Yes	Rej.	Not Rej.
Internal guidelines	Rej.	Yes	No	Not Rej.	Rej.
Methods of Recording Maintenance Works					
Forms	Not Rej.	No		Rej.	
Reports	Rej.	Yes		Rej.	
Sketches	Not Rej.	Yes		Rej.	
Computer data base	Rej.	Yes		Rej.	
Human Resources for Maintenance					
Sufficiency of human resources for maintenance	Not Rej.	Yes		Rej.	

Table 2: Statistical Analysis for Ordinal Data of Questionnaire Responses

Analysis Type / Questionnaire Parameters	Independence Test Mann-Whitney	Tendency test Mode (Groups 1 & 2)	Goodness of fit K-S Uniform Dist. (Groups 1 & 2)
Common Bridge Types in Egypt			
Reinforced Concrete Bridges	Not Rej.	First	Rej.
Steel Bridges	Not Rej.	Second	Rej.
Bricks and Arch Bridges	Not Rej.	Third	Rej.
Ranking of Inspection Objectives			
Checking safety of bridge	Not Rej.	First	Rej.
Assessment of bridge condition	Not Rej.	Second	Rej.
Determine bridge maintenance requirements	Not Rej.	Third	Rej.
Ranking of Factors Contributing to Bridge Deterioration			
Low quality in execution of bridge	Not Rej.	First	Rej.
Deficiency in maintenance	Not Rej.	Second	Rej.
Increasing traffic	Not Rej.	Third	Rej.
Increasing axle loads	Not Rej.	Forth	Rej.
Bridge age	Not Rej.	Fifth	Rej.
Harsh environment	Rej.	Sixth	Rej.
Ranking of Inspection Obstacles			
Lack of funds	Rej.	First	Rej.
Lack of tools and instrument	Rej.	Second	Rej.
Lack of qualified human resources	Not Rej.	Third	Rej.
Lack of bridge inspection standards	Not Rej.	Forth	Rej.
Ranking of Maintenance Objectives			
Insuring safety of bridge	Not Rej.	First	Rej.
Increasing life cycle of bridge	Not Rej.	Second	Rej.
Increasing efficiency of bridge	Not Rej.	Third	Rej.
Ranking of Maintenance Obstacles			
Lack of funds	Rej.	First	Rej.
Lack of qualified human resources	Not Rej.	Second	Rej.
Lack of tools and instrument	Rej.	Second	Rej.
Lack of bridge maintenance standards	Not Rej.	Forth	Rej.

Table 3: Statistical Analysis for Cardinal Data of Questionnaire Responses

Analysis Type Questionnaire Parameters	Independence Test T-Test	Tendency Test Mean (Groups 1 & 2)	Goodness of fit K-S Normal Dist. (Groups 1 & 2)
Theoretical Age for Bridges		Years	
Steel Bridges	Not Rej.	33.2	Rej.
Reinforced Concrete Bridges	Not Rej.	38.1	Rej.
Bricks and Arch Bridges	Not Rej.	25.1	Rej.
Average Age for Bridges		Years	
Steel Bridges	Not Rej.	62.7	Not Rej.
Reinforced Concrete Bridges	Not Rej.	64.6	Not Rej.
Bricks and Arch Bridges	Not Rej.	42.9	Not Rej.

As noted from the analysis, see table 1 that the two groups of respondents are not in consensus (i.e. the hypothesis of no difference is rejected) with regards to their judgement of the following issues:

- Types of data recorded for bridges
- Medium used for recording data on bridges
- Main types (strategies) for inspection and maintenance
- Frequencies of inspecting and maintaining reinforced concrete bridges
- Frequencies of inspecting and maintaining steel bridges

On the other hand, the same two groups are in relative consensus (i.e. the hypothesis of no difference is not rejected) with regards to their judgement of the following issues

- Standards used for inspection and maintenance of bridges
- Methods of recording inspection data in field
- Methods of recording inspection and maintenance data in office
- Human resources for inspection and maintenance
- Preferable methods of bridge assessment
- Observed defects at inspection of steel and reinforced concrete bridges

In most cases of relative consensus, the hypothesis stating that there is conformity of responses to uniform distribution is rejected. As for the five ranking questions, the hypothesis of no difference is not rejected with regards to judgement of the two groups of the following issues, see table 2:

- Inspection objectives
- Factors contributing to bridge deterioration
- Inspection obstacles
- Maintenance objectives Maintenance obstacles

Finally, table 3 shows the relative consensus of the two groups (i.e. the hypothesis of no difference is not rejected) with regards to the estimation of the two groups of theoretical and average life expectancies of different types of bridges. However, the responses with regards to the theoretical age did not prove to fit the normal distribution, while the responses with regards to the average age were not rejected with regards to fitting the normal distribution.

5. DEVELOPING BIMMS IN EGYPT

Based on results of the questionnaires' analysis as well as on the literature review, see Brinckerhoff P.1992, OECD, 1986, TRB, 1987, a BIMMS is proposed for Egypt as shown in figure 4. The BIMMS presents a management process that is recommended for executing both the inspection and maintenance activities for bridges in Egypt. The following is a detailed discussion of such process.

5.1. Management of Inspection of Bridges

The proposed BIMMS starts with setting the inspection objectives. As shown in table 2, the majority of respondents stated that checking the safety of the bridge is considered the major concern of inspection, this is followed by other objectives such as assessment of bridge condition, followed by determining its requirements of maintenance.

Based on determining the main inspection objectives, as well as on the sufficiency of available resources, the bridge inspection manager decides on the proper inspection strategy. It is well known that the two main available strategies are preventative or remedial inspection. In case sufficient resources are available, a preventative strategy should be adopted. However, in cases where resources are not adequate, one may resort to corrective inspection (i.e. inspection when incidents/problems are reported). Of course, this is not recommended, yet this strategy is practiced in many countries in the world where financial resources are limited.

After adopting a particular inspection strategy, the frequency of inspection is then determined based on the following three factors:

1- Bridge type (Reinforced Concrete or Steel or Bricks and Arch Bridges)

2- Inspection method ranging from visual inspection for part of the bridge to equipment based inspection for all bridge

3- Sufficiency of resources allocated for inspection activities

Also, respondents ranked the main obstacles to performing inspection activities in Egypt as follows:

1- Lack of funds 2- Lack of tools and instruments

3- Lack of qualified human resources 4- Lack of bridge inspection standards

5.2. Management of Maintenance of Bridges

As shown in table 2, the majority of respondents stated that insuring the safety of the bridge is considered as the major concern of maintenance, this is followed by other objectives such as increasing the life cycle as well as the efficiency of the bridge.

As stated above the main output of bridge inspection is to determine the required maintenance works. Taking this into consideration as well as the main maintenance objectives and the extent of sufficiency of available resources, the bridge maintenance manager decides on the proper maintenance strategy. It is well known that the two main available strategies are preventative or remedial maintenance. In case sufficient resources are available, a preventative strategy should be adopted. However, in cases where resources are not adequate, one may resort to corrective maintenance (i.e. maintenance when incidents/problems are reported). Of course, this is not recommended, yet this strategy is practiced in many countries in the world where financial resources are limited.

After adopting a particular maintenance strategy, the frequency of maintenance is then determined based on the following three factors:

- Bridge type (Reinforced Concrete or Steel or Bricks and Arch Bridges)
- Maintenance method ranging from periodic to rehabilitation and strengthening and ending by replacement for part(s) of the bridge
- Sufficiency of resources allocated for maintenance activities

Several requirements should be available to insure performing the maintenance activities in a proper manner. These include:

- Trained human resources to perform maintenance activities
- Necessary specialized equipment and tools for maintenance
- Maintenance standards and code of practices to refer to
- Financial resources allocated for maintenance activities

The costs for insuring such resources is presented to decision-makers who allocates the maintenance budget. One of two scenarios might result, the first is the sufficiency of allocated budget to perform the maintenance plan, while the second is the insufficiency of allocated budget, in which case modifications and adjustments to the previous steps should be thought and made, see figure 4.

Once budget is sufficient to perform the maintenance plan, such plan is executed. In the course of executing the maintenance plan, data and information are recorded both in field and in office. The end result of maintenance activities is to prolong the bridge life in a safe and efficient condition. It is to be noted that respondents identified a difference between the theoretical and actual average ages of the different types of bridges. These are shown in table 3. The table shows that the theoretical ages are in the range of 30 to 35 years, while average age is in the range of 50 to 55 years.

In this respect, analysis of the questionnaires has shown that respondents ranked the main obstacles to performing maintenance activities in Egypt as follows:

1- Lack of funds
2- Lack of qualified human resources
3- Lack of tools and instruments
4- Lack of bridge maintenance standards

5.3 Developing an Inventory (Data Base) for Bridge Inspection and Maintenance

Developing an inventory (database) is extremely important to support the efficient performance of the main tasks related to bridge inspection and maintenance. As shown in figure 4, such inventory should be formed through recording basic descriptive data on bridges such as name, location, type, age, length, cross-section, etc. In addition, other types of vital data include design data, data concerning quality control at construction, traffic data, axle loads, accident data as well as data pertaining to future planning and extensions.

Recording of executed inspection and maintenance activities represent a core for documenting the history sheet for bridges. Such recording is done using forms, reports, sketches and drawings. In this respect, it is highly recommended to develop a Geographic Information System for bridges. Such system is meant to include all this data using layers that can aid in presentations and taking informed decisions.

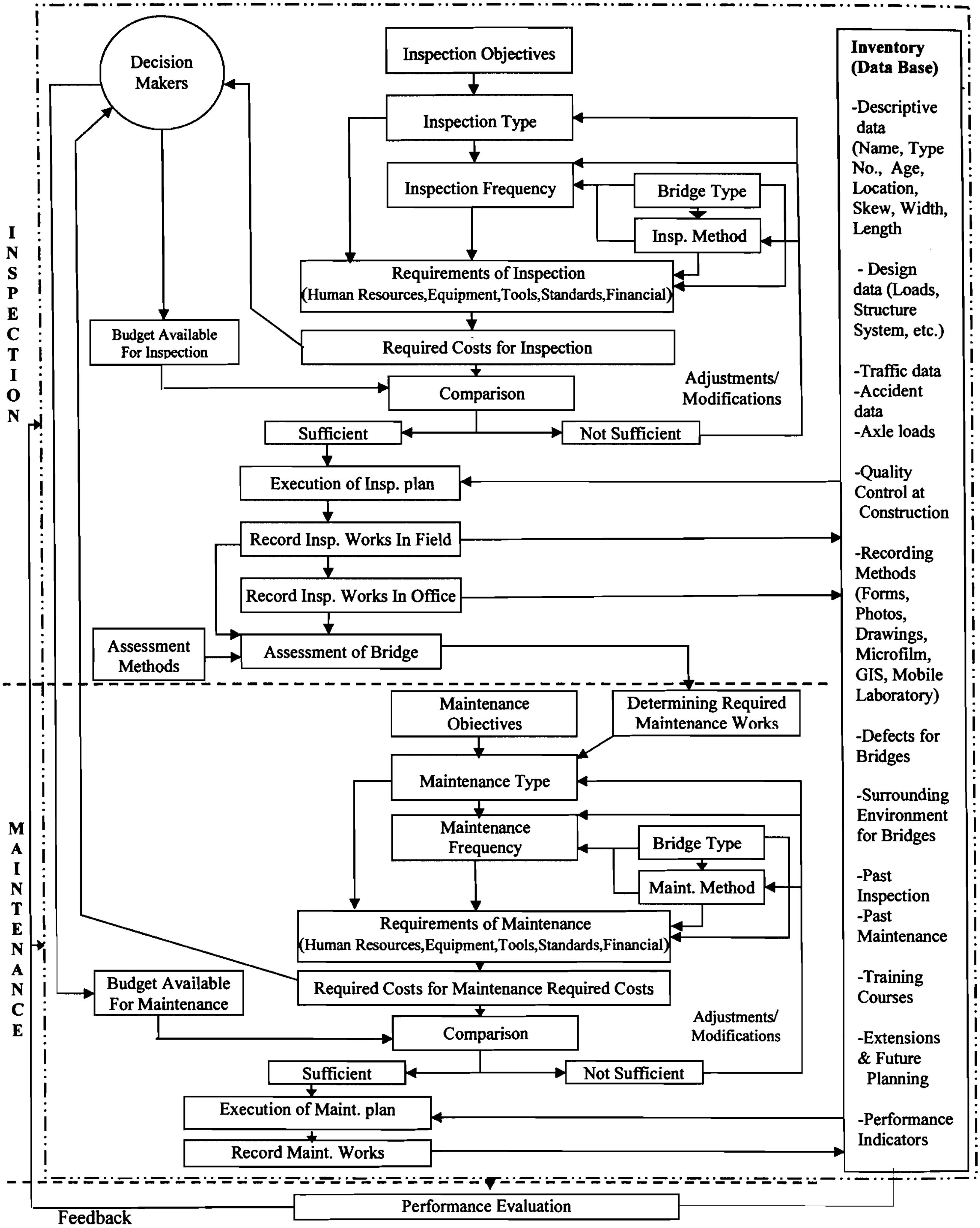

Figure 4: A Proposed Framework for A Bridge Inspection and Maintenance Management System(BIMMS) in Egypt

6. CONCLUSIONS

It is vitally important for all authorities in Egypt concerned with bridges to possess an appropriate Bridge Management System that enables them to perform the necessary tasks as well as make timely decisions with regards to the well being and safety of existing and future bridges. This paper presented a proposal for a BIMMS in Egypt. The development of such BIMMS was based on the analysis of questionnaires presented to experts as well as on a review of the literature. Several conclusions and recommendations can be drawn from the analysis of the questionnaires' responses. The following presents the most significant ones.

- The inspection and maintenance of bridges are considered as two of the most important activities constituting a bridge management system. The questionnaire surveys conducted with professionals at concerned Egyptian authorities showed that there is no distinct separation between these two important activities. This research draws attention to this conclusion and strongly recommends that a clear distinction should be made between these two activities to allow more attention to inspection procedures in addition to maintenance.

- Respondents stated that checking the safety of bridges is considered the major concern of inspection, followed by other objectives such as assessment of bridge condition and determining its requirements of maintenance. Also respondents were in consensus in stating that insuring the safety of the bridge is considered as the major concern of maintenance, followed by other objectives such as increasing life cycle as well as the efficiency of bridges.

- Limited finance was always pointed out by officials as a major constraint to properly performing the tasks of bridge inspection and maintenance. Concerns regarding insufficiency of trained personal necessary to perform the various tasks of bridge management were also pointed out. Proper and adequate training programs should be developed and applied. There are limited university courses concerned with bridge management. In addition very few training courses seem to be available. It is the responsibility of academics to put more emphasis towards developing specialized courses in bridge management. In this context, it is worth noting that a Bridge Inspector's Training Manual was developed by USDOT, 1991.

- Officials at some authorities have indicated that some information regarding the inventory of bridges is kept in an archive format. This is considered as a very limited way of keeping data. It is recommended that funds are directed towards gathering and storing basic inventory and condition data using computers and Geographic Information Systems. In this respect, it has to be noted that the Roads and Bridges Authority in Egypt developed such system for roads.

- Several respondents noted that absence of stringent quality control at construction of bridges is a major factor affecting the condition and the deterioration rates of bridges over time.

- Some authorities use a semantic assessment in reporting the condition of bridges. However, criteria behind such assessment is not clearly spelled out. It is highly recommended to develop standards for such semantic assessments and to provide inspector engineers with such standards to be applied in their inspection procedures.

- Recently, ministry of reconstruction and new communities issued a standards manual for roads. However, this was not aimed at bridges. It is highly recommended that proper codes of practices, standards and manuals pertaining to all activities related to bridges are developed. In this respect, it is worth noting the experience of other countries which could be used as starting point, see AASHTO, 1999, AREMA, 1999, USDOT, 1994, TRRL, 1988, and HMSO, 1984.

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Several requirements should be available to insure performing the inspection activities in a proper manner. These include:

- Trained human resources to perform inspection activities
- Necessary specialized equipment and tools for inspection
- Inspection standards and code of practices to refer to
- Financial resources allocated for inspection activities

The costs for insuring such resources are presented to decision-makers who allocate the inspection budget. One of two scenarios might result, the first is the sufficiency of allocated budget to perform the inspection plan, while the second is the insufficiency of allocated budget, in which case modifications and adjustments to the previous steps should be thought and made, see figure 4.

Once budget is sufficient to perform the inspection plan, such plan is executed. In the course of executing the inspection plan, data and information are recorded both in field and in office. The end result of inspection is to assess the bridge condition and hence to determine the required maintenance works. Several methods are used to semantically assess the bridge condition. These are reviewed in Farahat, 2002 and presented to the questionnaire respondents who selected the assessment method used by the Bay Area Rapid Transit Authority in the USA as the most appropriate to be used in Egypt. This method categorizes the results of inspection and hence the assessment of the bridge into five main categories:

1. No defects noted on inspection
2. Bridge condition is good, but it should be under constant observation
3. Bridge condition is acceptable, but a routine maintenance schedule should be developed
4. Bridge condition is poor and so a quick reaction in terms of maintenance is warranted
5. Bridge condition is dangerous and it need instant solutions to remedy and maintain

In this respect, analysis of the questionnaires has shown that respondents ranked factors contributing to the deterioration of bridges in the following order:

1- Low quality in execution of bridge
2- Deficiency in maintenance
3- Increasing traffic
4- Increasing axle loads
5- Bridge age
6- Harsh environment

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