A SOUTH AFRICAN PERSPECTIVE ON BRIDGE MAINTENANCE MANAGEMENT

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ABSTRACT

A Bridge Management System enables road authorities to manage the allocation of limited available funds for maintenance of the infrastructure. This paper presents the results of the most recent series of inspections of four local authorities in South Africa. The results include bridge condition information and funding needs.

It is observed that of all bridge components considered when the condition rating of a bridge is determined, those components related to the road, road approaches and waterways are the components with the highest need for maintenance for the four authorities considered in this paper.

The number of bridges inspected is a function of the funds available for inspection and maintenance. Not all bridges have been inspected for all the authorities considered. In order to generate accurate network predictions, it is required that all the bridges in a network be inspected, and that the data be captured.

With the shortage of maintenance funding available, authorities tend to address only critical current problems. Exact figures of maintenance expenditure are not available, but it is most probable that current maintenance spending falls far short of the requirements. It is shown to what extend the bridge networks can deteriorate over a 25 to 30 years period if adequate maintenance funds are not available.

1. INTRODUCTION

A Bridge Management System enables road authorities to manage the allocation of limited available funds for maintenance of the infrastructure. This paper presents some of the results obtained from a System used by several road authorities over the last number of years.

In broad terms, a Bridge Management System (BMS) assist officials in four primary fields of activity namely:

- Serves as a database with all relevant inventory, condition and maintenance data
- Assist in allocating funds in an optimum manner by prioritising maintenance and rehabilitation activities,
- Assists to determine the need for upgrading of bridges,
- Allows prediction of future budget requirements and bridge network conditions.

A Bridge Management System was developed with the support of the South African Department of Transport, starting in 1988. Current users of the system include the Gauteng Provincial Government (1300 bridges), Eastern Cape Provincial Government (1500 bridges), Limpopo Provincial

Government (1100 Bridges), the Northern Cape Province Provincial Government (500 Bridges), the Johannesburg Roads Agency (320 bridges), Durban Metropolitan Council (250 bridges), North West Province (1100 bridges), the Kingdom of Lesotho (120 bridges) and Republic of Zambia (500 bridges).

This paper gives a brief overview of the System as background to the remainder of the paper. The paper then presents results of the most recent inspections by four local authorities. These results include bridge condition information and funding needs. An evaluation is made of the required maintenance funding versus available funding.

2. BRIDGE MANAGEMENT PROCEDURE

In order to set the background for the description of the Bridge Management system, and for the presentation of the most recent results of different bridge networks, a description is first provided of the procedures involved in a bridge management system.

A bridge management system is based on inventory information of a bridge network, and on the condition of the bridges in the network. It uses this information to assist a managing authority to determine maintenance priorities, and to allocate appropriate funds.

The first step in implementing a Bridge Management System is thus to obtain inventory information of the bridges in the network. Once this is available, regular inspections are needed to asses the condition of the bridges. Ideally, periodic inspections are held of all bridges approximately every 3 to 5 years. These inspections are normally carried out by bridge engineers with 3 to 5 years experience, using standard data sheets, defects and maintenance lists. The condition of defined bridge components are assessed against standard ratings, and finally an overall condition rating can be calculated for each bridge on the network. When specific problems are identified for a structure, a special inspection involving a more experienced engineer may be called for.

A full description is not provided of the specific Bridge Management System in this paper. The following paragraphs provide only a description of the relevant system modules as background to the results which are presented later in the paper.

3. SYSTEM DESCRIPTION

The following key components of the Bridge Management System are presented below:

- Database module
- Reporting module

3.1 Database Module

The database forms the basis of the System and consists of the following components:

- Inventory data that includes all information regarding the location, the design, the type of construction, geometrics, a specific span, or a specific support/pier/abutment of each bridge
- Condition, defect and maintenance data that include a condition rating, defect identification and description, and maintenance recommendations for each element /component of a specific bridge on a specific date. This information is obtained during a periodic inspection program.

3.2 Reporting Module

Amongst several available reports that can be generated, the following reports were specifically used to generate the information provided in this paper:

3.2.1 Detailed Maintenance and Rehabilitation Reports

Reports are generated to determine the cost and urgency of required maintenance.

3.2.2 Detailed Short Term Budgeting Reports
The database contains unit rates for each maintenance activity and enables a calculation of a detail maintenance budget amount.

3.2.3 Long Term Budget and Bridge Network Condition Predictions
A long-term budget and network report can be generated to ensure that adequate funds are provided for maintaining an acceptable level of service in the future. It also provides the Bridge Authority with a rational basis for motivating budget requirements.

3.2.4 Standard Network Reports
Other standard reports other than the above are available and depends on the requirements of the specific user.

Typical reports are:
- General condition report
- Condition report of sub-components
- Report on vertical clearance on a specific route
- Report on horizontal clearance on a specific route

4. BRIDGE CONDITION INFORMATION

The Bridge Management System described above has now been in use for several years by a number of local authorities in South Africa. The results obtained following periodic inspections and implementing the bridge management system for four of these authorities are now presented in the following paragraphs.

The bridge networks of the authorities considered in this paper are listed below. The results are obtained from the most recent series of inspections for each of these networks.

First, some general information is presented for each network. Then information specific to each network is presented separately, together with the results of the network condition survey.

The total estimated asset value of the bridges under jurisdiction of the following four authorities are shown in Table 1:
- Province of the Eastern Cape
- Gauteng Province
- Northern Cape Province
- Johannesburg Roads Agency

Table 1. Comparison of bridge networks (4 Authorities).

Authority	Number of bridges	Asset value	Average age	Average length	Structure
Province of the Eastern Cape	1382	R 1.6 billion	54 years (average of 565 bridges)	12–50m : 56%	90% Reinforced concrete
Northern Cape Province	507	R 950 million	45 years (average of 371 bridges)	10-49m: 80%	94% Reinforced concrete
Gauteng Province	869 (in-use)	R 2.25 billion	28 years (average of 198 bridges)	12-49m: 48%	79% Reinforced and prestressed concrete
Johannesburg Roads Agency	320	R 1.24 billion	Na	na	na

Other information also provided in Table 1 is the average bridge age, average length and type of bridge structure. The status of bridge inspections and the general conditions of bridges under jurisdiction of these four authorities are discussed in the following paragraphs.

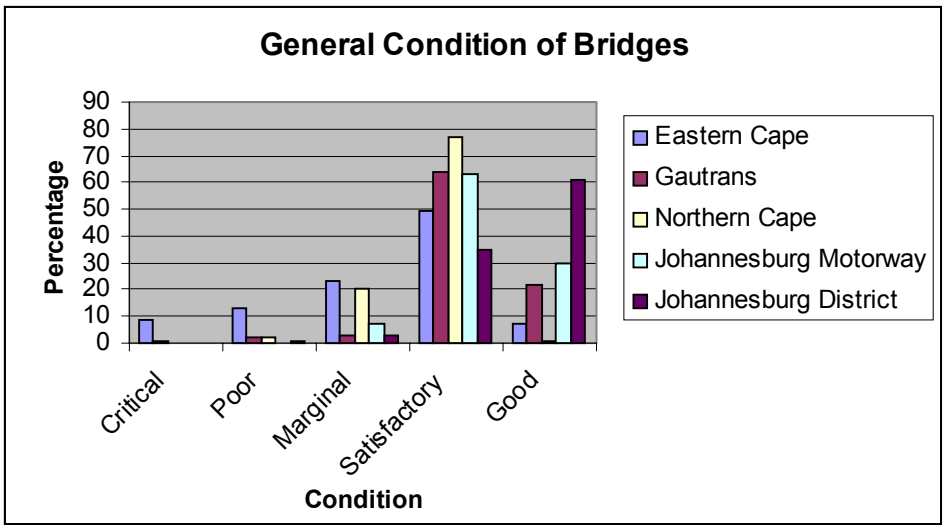

Figure 1. General condition of bridges from most recent series of inspections.

The general condition of bridges is a function of the condition of the *main components* of the bridge, which are defined as:

- Approaches
- Road
- Substructure
- Superstructure
- Waterway

Ideally, bridges should be prevented from reaching a critical state. A comparison of the general condition of bridges for the four authorities is shown in Figure 1. It can be seen that some bridges in the Eastern Cape and Gautrans are considered to be in a critical condition. The condition of the majority of structures is however considered to be either Satisfactory or Good. The condition for bridges under the various authorities is discussed separately under individual headings:

4.1 Province of the Eastern Cape

In the Province of the Eastern Cape, 1382 bridges and 386 culverts are currently registered in the official provincial Bridge Management System. These bridges are located mainly on paved roads (roads carrying the most traffic), or consist of bridges carrying features that are passing over paved roads. .

The history of bridge inspections in the Province is as follows:

- 75 bridges in 1995
- 181 bridges in 1997/1998
- 370 bridges and 174 culverts in 2001/2002
- 565 bridges and 180 culverts in 2002/2003
- 191 bridges remain to be inspected

The number of culverts is constantly being increased in the System. The culvert module of the System has only been in place since 2001/2002.

Figure 2 shows the condition of main components for the bridges in the Eastern Cape Province. It is observed that the Road, Road Approaches and Waterways are those main components with the highest percentages in the critical, poor and marginal conditions.

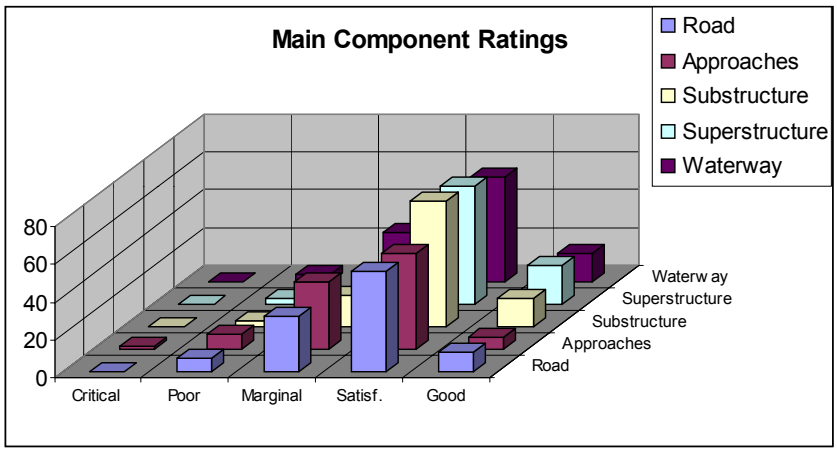

Figure 2. Eastern Cape main component ratings (2003).

4.2 Gauteng Province

There are 1558 bridges currently registered in the Gauteng Province Bridge Management System. There are 896 bridges in use under Gautrans' direct jurisdiction. The bridges are mainly on paved roads, or are bridges carrying features that pass over paved roads.

Inspection records, 2087 in total, date back to 1991. The following numbers of bridges were inspected in recent years:

- 2000: 144 bridges inspected
- 2002: 234 bridges inspected
- 2003: 301 bridges inspected

Figure 3 shows the condition of main components for the bridges in the Gauteng Province. It is observed that the components of the small number of bridges in the critical and poor conditions, relate mainly to Approaches and Waterways.

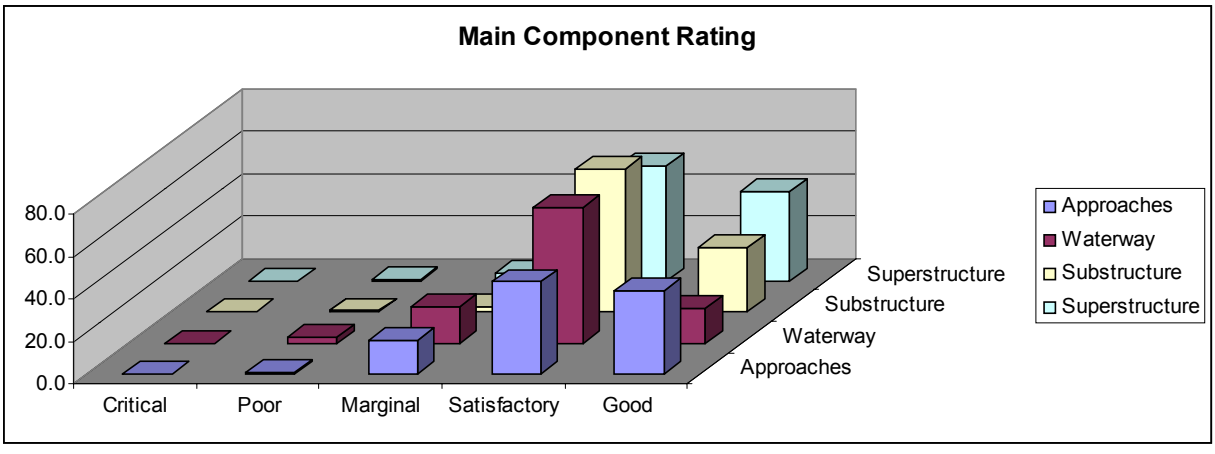

Figure 3. Gauteng Province main component ratings (2003).

4.3 Province of the Northern Cape

There are currently 507 bridges on the database of the Northern Cape Province. Of these, 260 bridges were inspected during the 1999/2000 financial year. Subsequently, only several series of special inspections have been undertaken, aimed at bridges with specific problematic conditions.

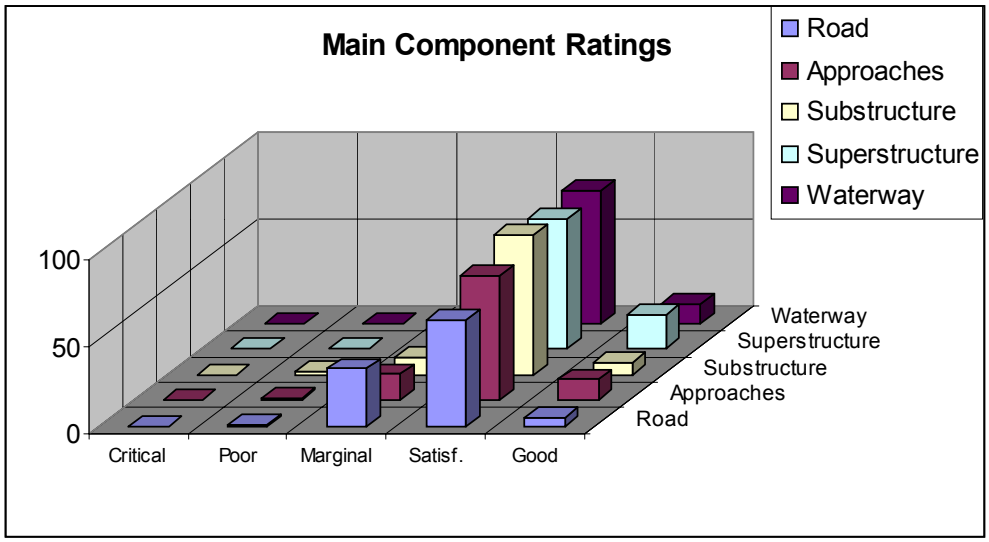

Figure 4. Northern Cape Province main component ratings (2000).

Figure 4 shows the condition of main components for the bridges in the Northern Cape Province. There are very limited bridges with main components in the critical and poor condition. Main components with the lowest condition ratings are Roads, Approaches and substructures (very limited).

4.4 Johannesburg Roads Agency

Currently 320 bridges are registered in the Bridge Management System. These bridges are on Agency roads, or are bridges carrying features that are passing over Agency roads. All bridges were inspected in 1997, and the bridges, which did fall under the jurisdiction of the previous Johannesburg City Council, were also inspected in 1994.

There are 152 Motorway bridges and 168 District bridges. 41 Major culvert drainage structures are also registered on the System.

Figure 5 shows the condition of main components for the bridges in the Johannesburg Roads Agency. There is only a small number of bridges with main components in the critical and poor condition. Main components with the lowest condition rating are Roads, Approaches and Waterways.

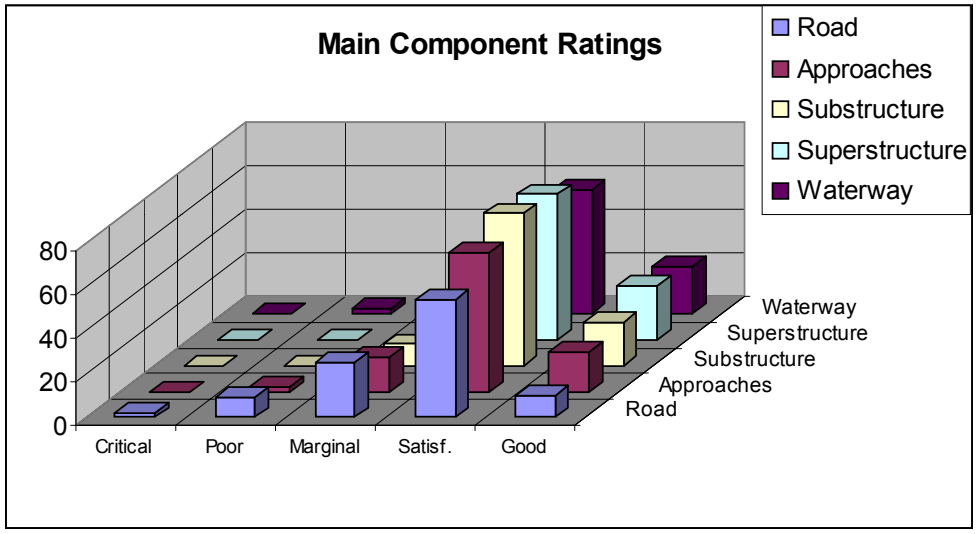

Figure 5. Johannesburg Roads Agency component ratings (1997).

5. BRIDGE MAINTENANCE REQUIREMENTS

Financial figures for maintenance of bridges as calculated following the most recent series of inspections are presented in Figure 6. These values represent the cost of the identified defects and maintenance requirements. As can be seen from Figure 6, the system with the highest number of bridges in a Poor and Marginal condition (Province of the Eastern Cape, Figure 1) also has the highest maintenance cost per structure. This tendency also coincides with the fact that the average age of structures is higher in the Eastern Cape (Table 1). There is quite a large difference in cost of required maintenance between the various authorities.

It is furthermore noteworthy that although the bridges in the Eastern Cape are of similar age to those of the Northern Cape, the bridges in the Northern Cape are in the best condition of the four authorities considered, while those of the Eastern Cape have the most bridges in poor and critical conditions. This is probably related to environmental (climatic) differences.

It must however be pointed out that the maintenance cost values presented in Figure 6, represent the total current maintenance requirement. The maintenance values are not prioritised and may either be critical or not.

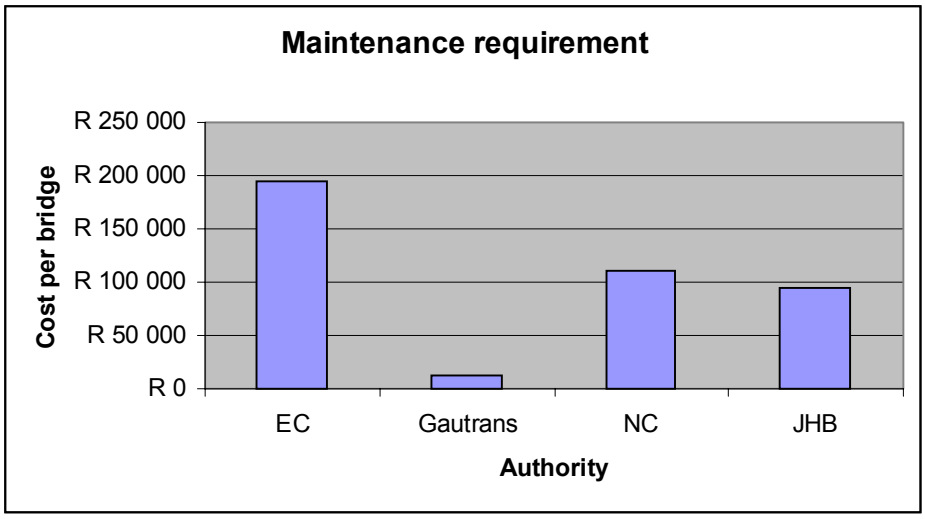

Figure 6. Current maintenance requirements.

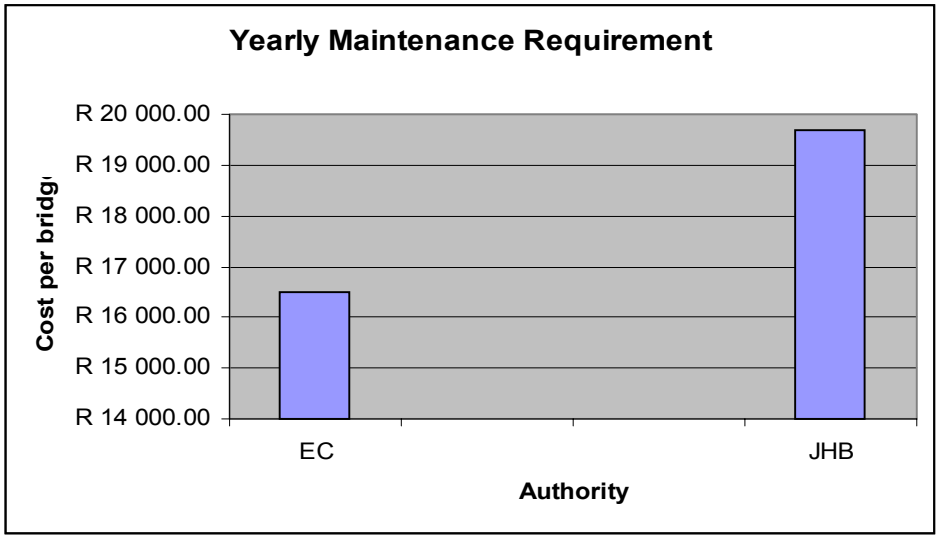

Figure 7. Yearly maintenance requirement over 25 years.

A more realistic value to consider for comparison between the networks, would be the maintenance costs required to maintain the bridge network in a condition where no bridge is allowed to deteriorate to a critical condition over the next 25 or 30 years. These figures are not available for all four authorities, but are shown in Figure 7 for the Province of the Eastern Cape and for the Johannesburg Roads Agency. These figures are a function of the age of the bridge, the traffic, type of structure, substructure and current condition rating. It is interesting to observe that the requirement for the Johannesburg Roads Agency is higher per bridge, than for the Province of the Eastern Cape

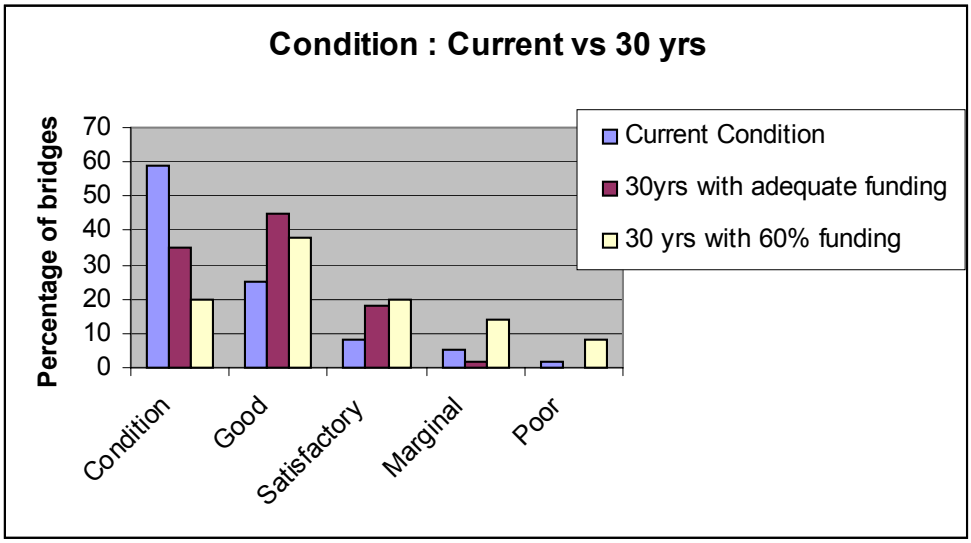

Figure 8. Province of the Eastern Cape: Current condition vs condition of bridges in 30 years with different available maintenance funding.

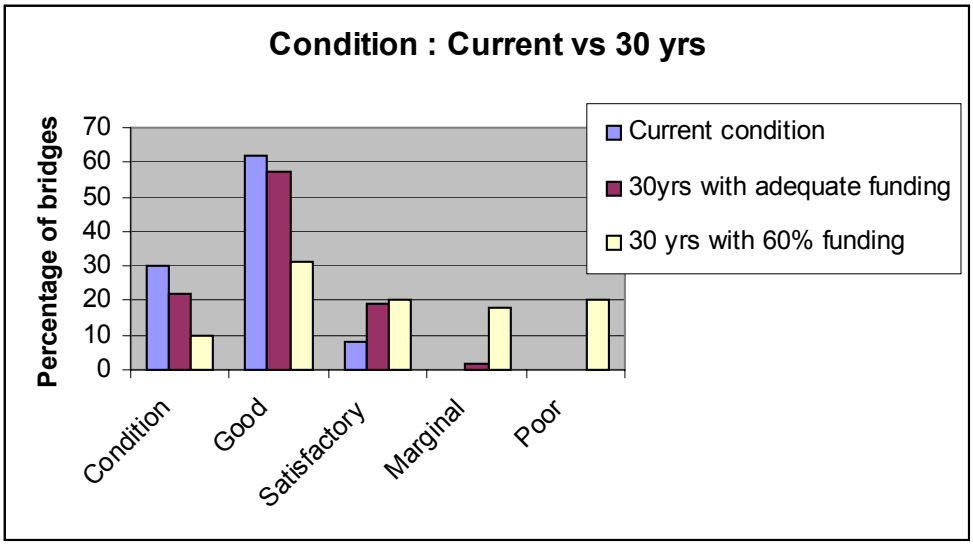

Figure 9. Johannesburg Roads Agency: Current condition vs condition of bridges in 30 years with different available maintenance funding.

Figure 8 shows a comparison for the Province of the Eastern Cape, between current bridge condition, and future bridge condition with different available maintenance funds. It can be seen that the percentage of structures in a critical or poor condition will increase substantially if only 60% of the required maintenance funding is available. Similar predictions can be made for different amounts of available funding. As mentioned earlier, the target should be to prevent any bridges from reaching a critical condition.

A similar result is presented for the Johannesburg Roads Agency in Figure 9. The alarming number of bridges in the poor and critical condition as a result of inadequate funding can clearly be seen.

6. CURRENT MAINTENANCE FUNDING

It would be most informative to be able to present available funds spent on bridge maintenance, against the maintenance requirements. A clear picture could then emerge of what the bridge network conditions would be in future.

Unfortunately, maintenance funds are not readily available from bridge authorities. For example, in the Province of the Eastern Cape, funds are often allocated to address critical issues such as bridges damaged in floods, or for construction of crossings where communities are in need, or to repair structures in critical conditions. These are mostly priorities which arise outside the scope of the maintenance management system.

In the Gauteng Province, funding is amongst others, channelled towards repairs of critical structures. Maintenance is also often performed as part of maintenance projects on roads, and a clear comparison is seldom possible of maintenance performed versus maintenance needs.

Johannesburg Roads Agency have since the last series of inspections (1997) not been able to effectively implement the Management System. A coordinated approach towards maintenance is therefore not possible.

It would thus appear that although a Bridge Management System is being used by several authorities, the shortage of maintenance funds makes it difficult to fully implement and address the identified needs. Although much more information can be generated, the Systems are often used mainly to address and identify critical bridges. The future deterioration of bridges as a result of limited funds can clearly be seen in FigureS 8 and 9 where the future condition of bridges is predicted for 60% available funding. The exact figure of available funding is however not known, and most likely falls far short even of the 60% value.

7. CONCLUSIONS

The paper presents a Bridge Management System which is being used by a number of road authorities in South Africa. Now that the system has been in use for a number of years, it becomes possible to compare the network data from different authorities.

The results of inspections on bridges under the jurisdiction of four roads authorities in South Africa are presented and compared in this paper. It is observed that of all bridge components considered when the condition rating of a bridge is determined, those components related to the road, road approaches and waterways are the components with the highest need for maintenance.

It is observed that not all bridges have been inspected for all the authorities considered. This is a function of the availability of funds for inspection and maintenance. In order to obtain a fair representation of bridge data and to generate accurate network predictions, it is required that all the bridges in a network be inspected.

Currently, due to lack of maintenance funds, Bridge Management Systems are mainly used by bridge authorities to identify and address critical bridges. It is shown to what extend the bridge networks can deteriorate over a 25 to 30 years period if adequate maintenance funds are not available. Exact figures of current maintenance expenditure are not available, but it is most probable that current maintenance spending falls far short of the requirements.

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BIOGRAPHY

Dr J A Wium worked as a structural engineer for a consulting firm from 1982 to 2003. He was responsible for management, design and supervision of a variety of building and bridge projects. From 2000 to 2003 he was responsible for a Bridge Management System used by several South African bridge authorities. In 2003 he joined the Department of Civil Engineering at Stellenbosch University where he is responsible for teaching reinforced and prestressed concrete. His research interests are structural dynamics, maintenance of structures and structural mechanics.