# Prioritizing maintenance of highway bridges in Uganda

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**Abstract**
Highway bridges constitute the most critical components in surface transportation infrastructure. Reliable bridge stock is crucially important for interlinking road transport networks. The negligence of bridge maintenance and delayed actions may translate to enormous costs of repair, rehabilitation and replacement. In view of the importance of bridges to the sustenance of the economy and livelihoods in the face of limited funds, there is a need to prioritize highway bridges for maintenance actions. The study made use of data and information obtained through field surveys which were conducted in the months of May, June and July in 2011, 2012 and 2013, respectively, using a combined methodology, non-destructive (NDT) and semi-destructive techniques (SDT). A priority ranking system to support highway bridge maintenance has been developed. The system can be useful in the process to develop a suitable model of a Bridge Management System (BMS) for Uganda

**Keywords:** Highway bridges, priority ranking, bridge maintenance, non-destructive and semi-destructive techniques.

## 1.0 INTRODUCTION

Worldwide, inadequate maintenance is the major reason for deficiencies in surface transport infrastructure which undermine their safety and functionality. A reliable bridge stock is crucially important for interlinking road transport networks. Aging, increase in traffic volumes and the harsh environmental conditions coupled with the limitation of funds justify for bridge managers to prioritize maintenance. The laxity in bridge maintenance may translate to huge costs of repair, rehabilitation and replacement. Therefore, for an effective maintenance, bridge managers must invest more time and energy in strategic planning.

Previous studies (Bakamwesiga *et al*., in press; UNRA, 2009) indicate that the bridge network in Uganda is marred by neglect, defective maintenance, environmental actions as well as aging. As a result, in the past decade, bridge failures and collapses have become of great concern for managers, policy makers and the donor communities. This coupled with the absence of a formal Bridge Management System (BMS) and the fact that the bridges are crucially important linkages in a highway network are factors that motivated this study.

Elsewhere, studies on priority maintenance of bridges have been done. The ranking procedures, widely used to prioritize bridges for maintenance (Wakchaure *et al.*, 2013), suggest that bridge condition cannot be regarded as the only criteria for prioritizing bridge maintenance activities. Chassiakos, *et al*. (2005) suggested a knowledge-based maintenance planning of highway bridges. Decision parameters, such as defect type, severity and extent, bridge age and environmental conditions are employed. The system was evaluated to provide a valuable tool for short-term maintenance decisions. Wakchaure *et al*. (2013) developed factors affecting priority of maintenance for bridges. The 27 factors which were obtained through preliminary results, expert consultations as well as literature reviews were later used for the development of Maintenance Priority Index (Wakchaure *et al.,* 2014).

From literature, bridge management systems may use the knowledge from other systems to capture site-specific information which can be adjusted to existing bridge management techniques in order to come up with a system to plan and prioritize the maintenance actions.

This paper aims to develop decision support regarding the prioritization of highway bridge maintenance needs, to provide an insight of bridge condition with careful consideration of environmental conditions as a major causal factor of deterioration for reinforced concrete and give necessary policy options regarding bridge maintenance. It is, then, reasonable to combine different methodologies which consider the bridge surface integrity, environmental conditions and aging.

The results from the study will be a methodology for prioritizing bridge maintenance which will help to minimize premature bridge failures through timely and cost effective maintenance. This will improve the ability of the Uganda National Roads Authority (UNRA) to make bridge specific-decisions and allocate funds for specific intervention programmes. The study recommends that priority maintenance planning be an integral process to the development and establishment a BMS.

## 2.0 METHODS

A total of 18 highway bridges were sampled. Of these, 68.4% were steel-concrete composite bridges and the rest were concrete. The study sites and highways (Figure 2) were identified during a survey carried out in the months of June and July 2011, as part of an ongoing PhD programme. The bridges, located along 5 highways, radiate from Kampala city to the western, south western, northern and eastern parts of Uganda (Bakamwesiga *et al*., 2014a). All the chosen sites were under the management of UNRA. A big proportion of bridges (67%) were constructed in the 1950s and 1960s. The bridge age range is 52 years.

### 2.1 Field surveys and data

A combined methodology of simple and inexpensive non-destructive (NDT) and semi-destructive techniques (SDT) was used to assess bridges' condition without affecting their functionality and serviceability (Table 1). Field surveys were carried out in the months of May, June and July in 2011, 2012 and 2013 (Bakamwesiga *et al*., 2014a).

Table 1. Bridge damages identified, their description and methods used.

| Distress | Description | Methods |
|---|---|---|
| Corrosion | Exposed rusty steel bars | Visual and photography |
| Rust | Brown discoloring | Visual and photography |
| Cracks | Cracks on the deck, pier and abutment | Visual |
| Spalls | Detached concrete cover | Visual and photography |
| Carbonation | Drilling a hole in concrete | Phenolphthalein test |
| Chloride | Powdered concrete collected from drilled hole | Chloride ex-situ test |
| Compressive strength | In-situ compressive strength on deck, pier and abutment | Rebound hammer tests |

The methodology maximises advantages and overcomes the limitations of the individual methods (Table 2). The methodology assumes "more-is-better-than-less", and hence by combining more than one method errors produced by one method (Qasrawi, 2000) are reduced. This is important because the quality of inspection heavily influences the accuracy of condition assessment which, in turn, determines the reliability of decisions to prioritize bridge maintenance (Rashidi and Gibson, 2012).

Table 2. Advantages and limitations of semi- and nondestructive techniques

| Technique | Advantages | Limitations | Reference |
|---|---|---|---|
| Rebound hammer test | Easy to use, portable, and cheap | Type of formwork and carbonation on bridges could result in variable rebound values and ultimately the predicted concrete strength. | Rens and Kim, 2007; Long *et al.,* 2001 |
| | | Suitable to evaluate the surface of the concrete and therefore has limited use in massive structures and relatively old structures. | Rens and Kim, 2007 |
| Carbonation and chloride content | Minimal destruction to the structure | Require a great deal of work, time and money. | Mitra *et al*., 2010 |
| Visual inspection | Rapid and inexpensive | Only superficial flaws can be detected. | Yehia *et al*., 2008 |
| | | Qualitative data. Subjective judgment of the inspector is crucial. | Mitra *et al*., 2010 |
| | | Broad knowledge on concrete materials and construction methods is needed in order to extract most information. | ACI, 1998 |

The data gathered were largely qualitative as summarized in Table 3.

## 2.2 Why the proposed system?

Road and bridge construction activities often impact on traffic, livelihoods of nearby communities and natural environment. The impacts may be direct or indirect. While the indirect impacts include increased road accidents, noise and dust pollution, the direct impacts include soil erosion, changes to rivers and streams and underground water. These impacts may vary in severity depending on magnitude and extent of coverage of the project. However, in the design and execution of road and bridge works, environmental issues are seldom overlooked (http://web.worldbank.org). It is for this reason that this study puts more emphasis on environmental factors that may affect the safety and functionality of bridges. This work aims to provide a methodology to support decision-making in prioritizing bridge maintenance.

### 2.3 Criteria for selecting and ranking bridges

Several criteria have been used for ranking priority maintenance of bridges. These are described below.

#### *2.3.1 Damage types*

The number, severity and extent of damage types vary between bridges. Previous survey (Bakamwesiga *et al*., 2014a) on visible damage types indicate that although all bridges have damages, some bridges are more affected than others.

#### *2.3.2 Surface concrete strength*

Normal rebound values reflect the soundness of concrete cover. Average Rebound values obtained during field surveys which were carried out in the months of May, June and July, 2013, showed that a couple of bridges had below- normal (30 – 50) concrete strength values (Bakamwesiga *et al*., 2004b).

#### *2.3.3 Age*

The assumption is bridges degrade with age. Analyses conducted on the average Rebound values obtained in 2.3.2 revealed slightly higher negative correlation between age and abutment than age and pier values. Considering this information, bridges which are less than 20 years old were rated Low, 20-50 year, Medium and above 50, High.

#### *2.3.4 Flood potential*

Bridge inspection reports by UNRA reveal flooding as a major factor that leads bridge failures and collapses between 2010 and 2013 (Bakamwesiga *et al*., in press). Although the causes of floods are numerous, in this study a combination of soil types, vegetation cover and topography (Table 4) have been considered and weighed based on previous study on flood risk (PreventionWeb, 2011) and researchers' experience.

#### *2.3.5 Erosion potential*

Factors that influence soil erosion include rainfall erosivity, soil erodibility, slope steepness, slope length, and vegetation cover (Claessens *et al*., 2008). In assessing the individual bridges a weighing system shown in Table 4, soil type which determines soil erodibility, catchment slope and flood potential have been used. The assumption is that given the same rainfall intensity over the study area, the steeper the catchment, the lower the flood potential.

### 2.4 Multi-criteria model structure

A multi-criteria type model structure depicted in Figure 1 is used to compute the maintenance priority index for each bridge. First is the composition of the input parameters to assess the criteria. Second the criteria are weighed and rated. Third is to provide priority index and ranking.

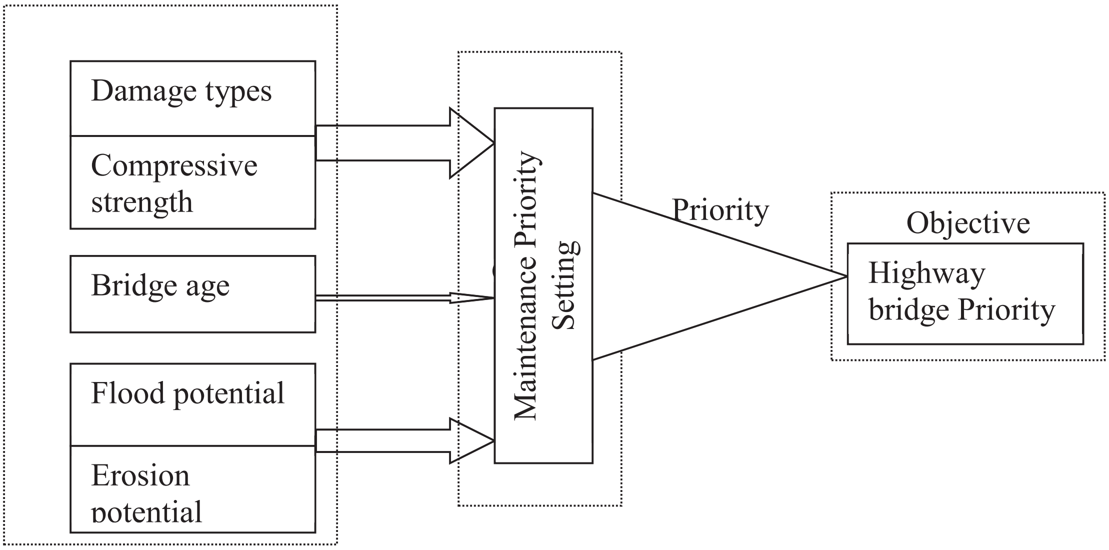


Figure 1. Multi-criteria model structure of bridge maintenance priority

Table 3. Decision parameters of maintenance selection

| Attribute | Parameter | KAF | TIT | KAR | TOR | MP1 | MP2 | RWI | MUB | NYA | KAT | NGM | KAN | OMU | KEM | MAT | KIB | MAL | MAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Damage type | Corrosion/rust/cracks | √ | √ | √ | √ | x | √ | √ | x | √ | √ | x | √ | x | x | x | √ | √ | x |
| | Delamination/spalls | √ | √ | √ | √ | x | √ | x | x | √ | x | x | - | - | x | - | √ | √ | √ |
| | Blocked deck drainage | x | x | √ | √ | x | x | x | √ | √ | √ | - | √ | √ | - | √ | √ | √ | √ |
| | Abrasion/gabion rupture/pitch failure | √ | x | √ | x | x | x | √ | √ | √ | x | √ | x | x | √ | x | √ | √ | x |
| | Railing damage | x | x | x | x | √ | c | √ | x | x | c | x | √ | x | x | c | m/c | x | x |
| | Carbonation[&] | A | - | - | A | A | P | A | A | A | P | A | - | A | P | - | A | - | A |
| | Chloride content[#] | 7.5 | - | - | 15.0 | 7.5 | 4.3 | 3.2 | - | 2.8 | 14.5 | - | - | 4.0 | 11.2 | - | 16.5 | | 17.0 |
| | Av. rebound values | 43 | 41* | 36 | 46 | 43 | 23 | 47 | 43 | 28* | 45 | 41 | 42 | 50 | 46 | 47* | 43* | 39 | - |
| Bridge physical condition | Age | 48 | 48 | 48 | 48 | 58 | 59 | 7 | 7 | 24 | 46 | 45 | 46 | 46 | 46 | 11 | 40 | 41 | 42 |
| | Soil type | si | si | si | si | w | w | w | w | w | w | w | w | w | w | p | w | w | w |
| | Catchment type | v | m | r | m | h | r | h | mo | h | v | m | m | v | m | v | v | m | v |
| | Land use | sva | sva | dve | sva | gco | gco | icu | icu | sva | icu | icu | sva | sva | sva | sco | icu | est | icu |
| | Catchment slope (%) | 0.32 | 0.6 | 0.25 | 0.25 | 0.3 | 0.3 | 2.0 | 8.3 | 8.0 | 0.4 | 1.4 | 3.5 | 3.5 | 3.5 | 0.62 | 0.5 | 0.7 | 4.0 |
| | Clear height (m)[@] | 5.1 | 2.6 | 8.5 | 5.1 | 3.5 | 3.4 | 4.4 | 7.5 | 3.9 | 2.8 | 8.1 | 5.2 | 3.8 | 2.7 | 2.2 | 1.6 | 1.1 | 4.4 |
| Bridge characteristic | Span length (m) | 73.7 | 24.7 | 84.5 | 30.5 | 16.45 | 16.4 | 16.35 | 31.5 | 18.5 | 35.2 | 55.3 | 31.3 | 30.8 | 13.1 | 61.7 | 64.1 | 35.4 | 20.3 |

[*] Either the bridge abutment or the deck was tested
[&] and[#] Previous results show absence and negligible concentrations of carbonation and chloride and, therefore, excluded in the system.
[@] Average height of river channel as measured from the topmost water level up to the deck-bottom.

Key:
**Site codes:** KAF = Kafu, TIT = Titi, KAR = Karuma, TOR = Torchi, MP1 = Mpanga 1, MP2 = Mpanga 2, RWI = Rwimi, MUB = Mubuku, SED =Sebwe, NYA = Nyamwamba, KAT = Katonga, NGM = Ngaro-Mwenda, KAN = Katinda-Ntinde, OMU = Omungyenyi, KEM = Kemyenda, MAT = Mate, KIB = Kibimba, MAL = Malaba, MAN = Manafwa.
**Damage types:** - no data, x = damage absent, √ = damage present, N/A = not applicable, c = concrete barrier, m/c = metal and concrete railings
**Carbonation and chloride content:** A = absent, P = present
**Bridge physical condition:**
*Soil type*: si = soils with slightly impeded drainage; w = well drained; p = poorly drained
*Land type*: v = very flat; m = moderate; r = rolling; h = hilly; mo = mountainous; e = ephemeral stream
*Land use*: sva = Swamp filled valley; dve = dense vegetation in valleys; gco = grass cover; icu = intense cultivation; est = Ephemeral stream

Sources of information: Bakamwesiga *et al*., 2014a, Claessens *et al*., 2008, http://chimpreports.com/index.php

## 2.5 Priority setting and rating

The objective was to set maintenance priorities according to existing bridge damages and other characteristics such as environmental exposure, age and concrete surface strength. The decision parameters are appropriately weighed (Table 4) to reflect the urgency of repair.

In this study, a multi-criteria analysis and scoring model suggested by Chassiakos *et al*., (2005) were adopted to calculate the priority index:

$$\mathrm{PI}(y) = \sum_{x} w_x r_{xy} \quad (1)$$

Where $w_x$ is the weight for attribute $x$; $r_{xy}$ is the weight of option $y$ with respect to attribute $x$. These were then allocated ratings of *High*, *Medium* / *Moderate* and *Low*, based upon criteria shown in Table 4. For the sake of modelling the priority ratings are transformed into numerical values. Relative weights initially set by experience of the researchers, were then adjusted to fit the expert views. Priority rating values are based on consideration of bridge safety and functionality and expected damage rates. A priority index was automatically calculated through an MS-Excel application using actual data inputs for each bridge.

Table 4. Decision parameters and their weights

| Attributes | Weight | Options | Rating | Weight |
|---|---|---|---|---|
| Damage types | 0.30 | Rebar corrosion/cracks/rust/delamination/spalls<br>Railing damage/absent<br>Abrasion/gabion raptures/failed stone pitch<br>Deck drainage failure | | 0.40*<br>0.15*<br>0.25*<br>0.20* |
| Compressive strength | 0.05 | Normal rebound values, 30 -50 | | 0.45 |
| | | Less than normal rebound values, <30 | | 0.55 |
| Bridge age | 0.10 | Less than 20 years | Low | 0.26 |
| | | Between 20 and 50 years | Medium | 0.32 |
| | | More than 50 years | High | 0.42 |
| Flood potential | 0.35 | Dense vegetation/grass/swamp filled valleys<br>Well drained soils<br>Mountainous/hilly; Catchment slope, >2% | Low | 0.25 |
| | | Dense vegetation/grass in valleys<br>Poor/well/slightly impeded drained soils<br>Moderate terrain; Catchment slope, <4% | Medium | 0.30 |
| | | Intensely cultivated valleys<br>Well drained/slightly impeded soils<br>Very flat/rolling; Catchment slope <1% | High | 0.45 |
| Erosion potential | 0.20 | Intensely cultivation valleys<br>Well drained soils<br>Hilly/Mountainous<br>High flood potential | High | 0.45 |
| | | Densely vegetated/Swamp filled valley<br>Well drained soils<br>Mountainous/Hilly/Moderate terrain | Medim | 0.30 |

| | | |
|---|---|---|
| High/Medium flood potential | | |
| Grass/Swamp filled/densely vegetated valleys<br>Well/poorly drained/slightly impeded soils<br>Moderate/rolling and very flat terrain<br>Medium/Low flood potential | Low | 0.25 |

*The weights for damage type are multiplied by 1.5, 1.3, and 1.0 to account for high, medium or low severity extent, respectively.

Table 5 presents input information from 18 bridges located along 5 highways. The study bridges present single and multiple damage types in almost equal numbers, 10 and 9, respectively. For bridges with multiple defects, because the damage types are independent of each other, they are considered separately, and then summed up to determine total weight per bridge.

Table 5. Bridge priority ratings of input information

| Bridge Code | Damage type | Damage extent | Compressive strength | Age | Flood potential | Erosion potential |
|---|---|---|---|---|---|---|
| KAF | Rust and cracks | Medium | Normal | 20-50 | Low | Moderate |
| | Blocked drainage | Low | | | | |
| | Abrasion on abutment | Medium | | | | |
| TIT | Cracks and spalls | Medium | Normal | 20-50 | High | Low |
| KAR | Corrosion on pier | Medium | Normal | 20-50 | Low | Low |
| | Blocked drainage | Low | | | | |
| | Abrasion on pier | High | | | | |
| TOR | Deck cracks and spalls | Low | Normal | 20-50 | Low | Low |
| | Silted surface drains | Low | | | | |
| MP1 | Blocked drains | High | Normal | >50 | Moderate | Low |
| MP2 | Crack on abutment | High | Less than normal | >50 | Low | Low |
| RWI | Corrosion under deck | Low | Normal | <20 | Low | High |
| | Railings damaged | High | | | | |
| | Abrasion on substructure | Medium | | | | |
| MUB | Blocked drains | Medium | Normal | <20 | Low | High |
| | Abrasion on substructure | High | | | | |
| NYA | Delaminations/Spalls | Low | Less than normal | 20-50 | Low | Moderate |
| | Blocked drainage | High | | | | |
| | Abrasion on abutments | Low | | | | |
| KAT | Cracks and spalls | High | Normal | 20-50 | High | Low |
| | Blocked drainage | High | | | | |
| NGM | Abrasion on pier columns | Low | Normal | 20-50 | High | Moderate |
| KAN | Delamination and spalls | Low | Normal | 20-50 | Moderate | Moderate |
| | Silted drains | High | | | | |
| | Railings damaged | High | | | | |
| OMU | Silted drainage | Medium | Normal | 20-50 | Moderate | Moderate |
| KEM | Abrasion of abutments | Medium | Normal | 20-50 | Moderate | Low |
| MAT | Silted drainage | Low | Normal | <20 | Moderate | Low |
| KIB | Deck crack and rust | High | Normal | 20-50 | High | Low |
| | Gabions needed | High | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Blocked drainage | Low | | | | |
| MAL | Corrosion and spalls | High | Normal | 20-50 | High | Low |
| | Stone pitching/gabions | High | | | | |
| | Blocked drainage | Medium | | | | |
| MAN | Delamination and spalls | Medium | Normal | 20-50 | Low | High |
| | Blocked drainage | Low | | | | |

Table 6 also shows the priority index calculated for each bridge using Eq. (1) and the parameter weights from Table 3. The priority index reflects the degree of urgency of maintenance in relation to other bridges. For the ease of differentiating the PI values, the calculated PI is further converted to percent PI using Eq. (2).

$$\mathrm{PI}_{100} = {PI_{cal}}/{PI_{\max}} \times 100 \tag{2}$$

Where $PI_{\mathrm{cal}}$ is the bridge (calculated) priority index value, $PI_{\max}$ is the maximum total priority index for a bridge, which is 0.767.

**2.6 Priority ranking and model validation**

The priority indices obtained were sorted in descending order and then assigned ranks; 1 and 18 being the highest and lowest ranks (denoted as $x_1$ in Table 6), respectively. To validate the multi-criteria model used, a bridge expert was asked to independently rank the bridges (denoted $x_2$ in Table 6). The question posed to the expert based at the bridge unit in UNRA was; *supposing you are given resources for maintenance, prioritize the following bridges, 1 being the highest and 18 the lowest priority rank*? To evaluate the performance of the model the root-mean-square deviation (RMSD) and the normalized root-mean-square deviation (NRMSD) expressed as percentage were used in this study. The two criteria are frequently used to measure differences between predicted and actual observations, neither of which is accepted as the standard. They are defined as follows:

$$RMSD = \sqrt{\frac{\sum_1^n (x_1 - x_2)^2}{n}} \tag{3}$$

$$NRMSD = \frac{RMSD}{x_{\max} - x_{\min}} \times 100 \tag{4}$$

where $x_1$ and $x_2$ are the actual (system ranking) and prediction (expert ranking) values, respectively, $x_{\max}$ and $x_{\min}$ are the difference between the maximum, 18, and the minimum expert, 1, ranking values. From Eqs. (3) and (4), the values of RMSD and NRMSD are found to be 2.6 and 15.4%, respectively.

Table 6. Priority ranking for maintenance

| Bridge code | Priority Index ($PI_{cal}$) | Percent Priority index, ($PI_{100}$) | Priority ranking | | $x_1 - x_2$ | $(x_1 - x_2)^2$ |
|---|---|---|---|---|---|---|
| | | | $x_1$ | $x_2$ | | |
| KAF | 0.511 | 66.6 | 5 | 6 | -1 | 1 |
| TIT | 0.452 | 58.9 | 7 | 5 | 2 | 4 |
| KAR | 0.576 | 75.0 | 3 | 4 | -1 | 1 |
| TOR | 0.390 | 50.8 | 12 | 15 | -3 | 9 |
| MP1 | 0.309 | 40.4 | 16 | 12 | 4 | 16 |
| MP2 | 0.387 | 50.5 | 13 | 11 | 2 | 4 |
| RWI | 0.444 | 57.8 | 9 | 10 | -1 | 1 |
| MUB | 0.417 | 54.3 | 10 | 9 | 1 | 1 |
| NYA | 0.484 | 63.1 | 6 | 8 | -2 | 4 |
| KAT | 0.532 | 69.4 | 4 | 3 | 1 | 1 |
| NGM | 0.369 | 48.2 | 14 | 7 | 7 | 49 |
| KAN | 0.365 | 47.6 | 15 | 14 | 1 | 1 |
| OMU | 0.409 | 53.3 | 11 | 15 | -4 | 16 |
| KEM | 0.380 | 40.0 | 17 | 17 | 0 | 0 |
| MAT | 0.282 | 36.7 | 18 | 18 | 0 | 0 |
| KIB | 0,615 | 80.1 | 2 | 2 | 0 | 0 |
| MAL | 0.633 | 82.5 | 1 | 1 | 0 | 0 |
| MAN | 0.450 | 58.4 | 8 | 12 | -4 | 16 |

## 3.0 DISCUSSION

This section presents the results of the ranking system used. Inferences are drawn from the results, and complimented by previous studies and the experience of the authors.

Altogether, the prioritization exercise indicates a variation in the condition of bridges. From the ranking system the highest maintenance priority should be given to Malaba, followed by Kibimba, Karuma Katonga bridges. Kibimba, Malaba and Katonga bridges are located in the eastern and central parts of Uganda. The finding concurs with previous report (PreventionWeb, 2011) that the eastern and central regions are most vulnerable to flooding. The report further reveals that risk to soil erosion is comparatively higher in western and southwestern Uganda than most of the rest of the study area.

In general, the system and expert rankings compare adequately, with a difference of 15.4% in the rankings. The system registered same ranking of 2 highest and the 2 lowest priority bridges for maintenance. Several other bridges registered slight differences in between the highest and the lowest ranks. There were considerable differences among a few bridges. A number of reasons could explain the findings. The few similarities are probably due to obvious damages which were easy to identify by both the researchers and expert. The differences could be a result of several factors, which this study will not cover. However, perhaps a major limitation to model verification, the study used one expert. Results of several experts would probably change the trend.

Nevertheless, a couple of advantages endeared us to use the knowledge-based system. First, it is quite adjustable and easy to use in varying conditions. Second the system helps keep record of expert knowledge for future reference. Quite often specialized knowledge disappears with the death or unavailability of the experts because of lack of documentation. As a result, a lot of resources are spent to get the same information time and again. This justifies the importance of this kind of study to bridge management agencies.

## 4.0 CONCLUSION

In this paper, a knowledge-based system that can be used for maintenance planning of bridge has been presented. The system is intended to aid decision-making process on the urgency of maintenance, repair and rehabilitation of some bridges over the others. Bridge damages such as reinforcement corrosion, spalls, and delamination, and age and environmental conditions, flood and erosion potential are employed to determine priority bridges for maintenance. Flood potential was considered to pose more risk than superficial bridge damages. The multi-criteria model has been evaluated with expert's views and is seen as one of several decision supports which can be used by bridge managers for planning maintenance actions. In a multi-criteria model structure each bridge is considered with respect to every parameter and a value is assigned depending on how the bridge is rated with regards to the parameters. Then, a total index is calculated for each bridge. For better results it is important to consider other factors such as availability of funds, design factors, bridge importance and political considerations, among others. Once these factors are considered, the system can be useful in the process to develop a suitable model of a BMS for Uganda.

## 5.0 RECOMMENDATIONS

This ranking system should be integral element of wider decision-making and policy formulation processes on priority planning of bridge stock countrywide. In order to achieve the best compromise, priority planning should be done as part of the processes to develop and establish a BMS. The BMS will help establish cost effective maintenance strategies at both bridge-specific and countrywide levels. However, it is worth noting that the allocation of funds is a sensitive political issue, therefore, decisions made on the establishment of programmes for maintenance of highway bridges should be politically defensible.


## 6.0 ACKNOWLEDGEMENTS

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