A ROAD BRIDGE MAINTENANCE MANAGEMENT FRAMEWORK: A CASE OF NIGERIA ROAD NETWORK

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Road infrastructure suffers extreme deterioration and unexpected failures in most developing countries. Nigeria, without exception, undergoes a similar problem and several attempts to tackle the issue have not been successful. A critical review on the current road and bridge conditions, existing maintenance practices and the limitations associated with these practices suggested that a scientific maintenance management tool applied in other countries could apply to the Nigeria context to address the problem. NIG ROAD framework was developed following the review conducted on PMS and BMS used in other countries. The framework was presented to multiple stakeholders to critique and comment on the benefits, challenges and barriers of implementing such framework. Findings revealed that the framework would aid the Nigerian Government and relevant agencies with making effective budgetary plans and with the planning of maintenance work. However, the challenges of implementing such framework far outweigh the benefit, and a prominent problem is the people's attitude towards maintenance and new technologies. It is recommended that a cultural shift plus an emphasis on the monetary savings and benefits of implementing the framework is needed amongst policymakers and ministry of highway maintenance.

Keywords: road bridge, maintenance, management system, sustainability

INTRODUCTION

The idea of road maintenance management is globally shared, but not much considered in the developing world, as many of the roads are poorly managed and maintained (Salih *et al.,* 2016). The seriousness of this matter is further compounded by the lack of environmentally- driven maintenance practices in most African Nations. However, road Infrastructures cannot be ignored in sustainability matters because their construction and life cycle maintenance contribute to resource depletion and general global warming issues. In fact, road infrastructures and transportation have received serious attention in the developed world, after realisation has dawned about the contribution of this sector to current sustainable development matters (Burrow *et al.,* 2013). Despite the gravity of the issue, adequate road infrastructure management is absent in developing economies, stemming from poor leadership, mismanagement of resources and political bureaucracy (Word Bank 1981; Heggie and Vickers, 1998; Robinson, 2006; Snaith and Khan,2008) and these matters attract greater attention instead. Sadly, road infrastructure is a major means of transportation for most

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developing countries, allowing for easy transportation of goods and services between the rural and urban settlements and is vital to the people's wellbeing (Khan, 2014). However, Salih *et al.,* (2016) argue that, while effective road transportation systems are critical for the socio-economic growth of most developing countries, inadequate funding sources, poor management strategy and insufficient consideration for environmental issues is a major problem.

Maintaining infrastructural assets such as roads and bridges requires a holistic life-cycle environmental appraisal to identify and reduce activities and operations with most environmental footprints (Balogun *et al.,* 2019), and therefore critical to the delivery of sustainable development plan within the global construction sector. This paper presents a review of the status of road and bridge infrastructure in Nigeria, evaluates maintenance strategies and approaches currently in use, explores their limitations and proposes a conceptual maintenance management framework to address the current limitations.

Status of Road-Bridge Infrastructure in Nigeria - A Synthesis

Road transportation is undoubtedly the prevalent means of transportation in Nigeria responsible for 90% of passenger and freight movement across cities, towns and regions and therefore critical to the wellbeing and socio-economic prosperity of the country (Akpogomeh, 2002). The Nigerian Transport system is in a dilemma, stemming from the Government's inability to provide adequate transport facilities to meet the needs of the society (Oviedo *et al.,* 2018). According to AfBG (2013), the infrastructural deficit in Nigeria is disheartening and ranked the worst in Africa, with road infrastructure being a major pitfall.

Though a recent study suggests that urban policy and programming could enhance the delivery of adequate infrastructural needs (URN, 2017), planning and managing these infrastructures to carter for the increasing population is a different matter (Olatunji and Diugwu, 2013). Nigeria as at independence had an estimated road network of 65704km (Oke, 2007), which has since increased to 195,000km, out of which, only 60,000km is paved and a large proportion of these being in poor and unacceptable conditions due to insufficient funds and inadequate maintenance practice (ICRC, 2017). The Nigerian road network is valued to be worth between 35 and 43 trillion Naira. Still, only 19 billion Naira is allocated for preventative maintenance out of 87 billion Naira recommended per year (World Bank, 2007).

Bridges are one segment of infrastructure that receive little or no attention amongst Nigeria's highway assets. According to the Minister of Works and Housing, Hon. Babatunde Raji Fashola, many of the bridges across the Nation suffers and have not undergone any form of maintenance for the past five decades. Over ninety bridge collapse cases have been recorded in Nigeria in the last two decades and a study between the period of 2010 and 2018 revealed that flooding, overloading, terrorist attack, design and construction errors and lack of proper maintenance inspections are the prevalent causes (Ede *et al.,* 2019).

Twenty-eight of the forty-five cases examined were attributed to flooding however, lack of proper inspection and maintenance was an underlying root cause. Regular maintenance inspections via monitoring tool can determine the resilience of the structure in advance of potentially life-threatening events such as flooding, overloading etc., and as such, improve the economic resilience of the region or state. Aside from the terror of bridge collapse, the relaxed attitude of government officials and lack of data tracking technology to help engineers capture relevant information to

analyse causes of failure and proffer sustainable solution constitute a serious challenge. More recently, Lagosian have described the poor state of the three major bridges connecting Lagos Mainland and Island; Eko, Carter and Third Mainland, as life-threatening, owing to vibrations and instability particularly, Third Mainland bridge.

Unfortunately, no significant measures have been considered, and a plan to construct a Forth Mainland bridge is currently being nursed (Premium Times, 2017). Constructing new roads and bridges rather than maintaining current ones is prominent within the Nigerian transport sector and largely attributed to poor maintenance culture, combined with political factors where the current administration neglects the existing infrastructure built by the previous administration (Ede, *et al.,* 2019). This leads to early deterioration, sudden failure and exponential Vehicle Operating Cost (VOC) cost (AfBG, 2013; Bindir, 2013; Oviedo *et al.,* 2018) which could have been prevented if consistent maintenance practice is in place.

Evaluating Road-Bridge Maintenance Practice in Nigeria

Road and bridge maintenance practice cover the various activities, operations and application of remedial actions applied to existing roads and bridges to ensure the serviceability, structural health, integrity and longevity of the infrastructure. However, while enormous resources are spent on the construction of new roads and limited provision is available for the maintenance of existing networks. The resultant effect leads to avoidable loss of lives, psychological trauma on road users, and reduction of productive man-hours (Adetola, 2014). Previous attempts to address the poor maintenance practices in Nigeria falls under two categories:

Establishment of Road Maintenance Agencies

Lack of public administrative system responsible for efficient management of road and bridges in Nigeria necessitates the need to develop a separate road maintenance agency (Central Bank of Nigeria 2003). Aside from this, it seems to be a consistent trend amongst the developing world to create a separate authority bestowed with the responsibility for road maintenance with the hope to derive funds from levy on gasoline, toll gates fees, license fees on motor vehicles, international transit fees, fees on overloaded vehicles and allocations by parliament without needing to rely on the erratic government funding's (Federal Ministry of Works and Housing, 2003). In this respect, the Federal Roads Maintenance Agency (FERMA) was created in 2002 with the holistic goal to facilitate and accelerate routine maintenance and interventions across most Nigeria states (Adetola, 2014). This has not worked very well, and many roads and bridges continue to deteriorate without appreciable measures taken to restore them.

Funding Sources

Many literatures within this domain suggested a review of the public infrastructural procurement methods and capacity (Manu *et al.,* 2019). Others suggested alternative funding methods and cost models, including PPP and PFI (Oladele *et al.,* 2011; Olatunji and Dwwuigu, 2013). Whilst others recommended exploring more flexible collaborative models between public and private sector for road management (Adetola 2014). Central Bank of Nigeria also suggested funding road maintenance projects with capital markets and pushed for a joint venture between the private and public sector (Central Bank of Nigeria 2003). The challenge, however, is that the Nigerian government fail to explore other funding sources but instead rely on government's

traditional budget allocations which are often less than what is required to maintain the road (Queiroz and Kerali, 2010). Besides, reliance on external loans for funding road-bridge maintenance has been catastrophic due to the bureaucratic nature of the system (Salih *et al.,* 2016). Moreover, a scientific system with the capacity to breakdown sources of funding into segments and recommend suitable funding choices, depending on the maintenance activity required is not readily available.

Limitations with Current Practices and Approaches

Creating separate agencies to facilitate timely and effective road-bridge maintenance activities has several limitations. Mainly, the lack of a functional scientific tool to support the agencies with making useful and timely maintenance decisions is critical to the limitation. Nearly all the literature reviewed emphasised the improper maintenance culture, inadequate strategy and approaches currently in place and recommends a change in policy, procurement practice and better funding sources. Others emphasised on the importance of road maintenance management system, although the attitude towards implementing this has been poor (Salih *et al.,* 2016). Kahn (2014) revealed that Botswana as at 2013 did not hold any maintenance policy nor maintenance strategy and recommended that a comprehensive management tool to empower current road management institutions is critical having been successfully implemented across the developed nations.

According to Ede *et al. (*2019), the developed countries have adopted structural health monitoring tools to update and inform decisionmakers as to when a structure requires intervention, repair etc. However, the framework, technical expertise, logistics, for developing and implementing such intelligence is yet to exist for the Nigeria road sector. Nigeria does not currently hold any scientific tool for the Federal Ministry of Transport, or any other road management agency to make effective road maintenance decisions to match world-class standard. This problem, unfortunately, compromises the Nigerian government's vison 2020 to implement technological advancement across the country (AfBG, 2013).

The developed world is keen to implement digital technologies in every sector as a strategic tool for achieving sustainable development goal, and Nigeria needs to catch-up. The use of Artificial Intelligence (AI), Virtual Reality (VR) and Digital Twin (DT), Machine Learning, smart and robotic technology is on the increase in the construction and the built environment field. While these can be attained, a good point to begin is to develop a framework with the capacity to proffer sustainable maintenance actions, plans and suggest effective funding choices. The proposed framework will potentially address the limitations identified and optimised in the future to accommodate new intelligence such as AI when required.

METHODOLOGY

A review of management systems in other countries was conducted to unveil their underlying features or decision-making models that could be adapted to develop a management framework for the Nigeria road Network. The developed framework was presented to multiple stakeholders to critique and validate the benefits, challenges and barriers of implementing such technological framework.

PMS and BMS Models and Features - A Synthesis

A Pavement Management System (PMS) conference, held in Toronto, Canada, in 1985, suggested PMS as a vital tool to support road network administration (Meneses *et al.,* 2013). PMS, in many industrialised countries, has proven effective and

developing countries should equally embrace the system (Wong *et al.,* 2003). PMS can support road management agencies; Federal and State Government responsible for road rehabilitation and maintenance should choose appropriate treatments with minimum cost implications.

PMS developed in recent times embeds Multi-criteria decision-making functions to allow multiple criteria to be factored into the decision-making process. However, conflicting requirements, such as the ability to make sustainability decisions on a low budget, environmental impact, social and community impact and safe traffic operation, can be challenging to deal with (Burrow *et al.,* 2013; Meneses *et al.,* 2013). Developers of PMS model will need to understand whether the system will be used as a central database, at a network-level or at project-level, to determine which criteria will be considered and at what point. Similarly, activities such as pavement conditions, performance prediction, maintenance and rehabilitation options, economic analysis and evaluation, budgeting options, ranking and optimisation of options are primary criteria to be designed with the tool (Wong *et al.,* 2003).

However, constraints such as acceptance and technical capacities, automatic data collection tool, technological advancement and geographic coverage undermine the implementation of such a system in most developing countries (Wong, *et al.,* 2003). A detailed information-gathering exercise to retrieve information on sub-base requirement, asphaltic content, dimensions and sizes, traffic data, maintenance options, frequency of maintenance etc., using the state-of-the-art equipment is needed to design relevant PMS for the Nigeria road network. PMS is typically used for asphaltic, bituminous, paved or unpaved (sandy) road management, while Bridge Management Systems (BMS) applies to bridges alone. BMS stores information relating to maintenance operations and guides the best available options considering limited resources (Deshmukh and Bernert, 2000; Hallberge and Racutanu, 2007).

Early development of BMS dates to first, second and third generations of the system, where inventory analysis, assessment, inspection, repair and maintenance data and decision-making capacities were considered respectively (Flaig and Lark, 2000). More recently, BMS has been considered to include life cycle environmental impact attributes (Balogun, 2014). A PMS and BMS, both of which are examples of a typical road-bridge maintenance system used in other countries were reviewed. A summary of their key features or the scientific models underpinning their operations is presented in Table 1 and 2 and useful to consider in the development of a suitable maintenance management framework for the Nigeria Road network.

A framework for the development of Road-Bridge maintenance management systems (NIG-ROAD SYSTEM) is presented in Figure 1. The framework combines the features of a PMS and BMS. It breaches the limitations identified with other countries approaches of having two separate systems (i.e. either a PMS or BMS) for the same network. As such, the novelty of the framework is the duality of functions that provides guidance for both road and bridge maintenance in one system. The proposed framework embeds three core sections, i.e., data collection for the databases; mathematical models for predictions and relevant analysis required for decision support; and an output report to guide the selection of maintenance and rehabilitation actions. The data collection process will require collaborating with integral agencies and government bodies responsible for road management in Nigeria as well as the department of transport to collect the right amount of details.

Table 1: PMS in other countries and key features

PMS/Country	FEATURES			
	Input data & Evaluation models	Prediction model	Decision models	Cost models
MODAT/Portugal	Yes	Yes	Yes	Yes
CPMS/China	Yes	Yes	Yes	Yes
GIS-based/Lisbon	Yes	Yes	Yes	Yes
RMMS/Cyprus	Yes	Yes	Yes	Yes
PMMS/Punjab India	Yes	Yes	Yes	Yes

Table 2: BMS in other countries and key features

BMS/Country	FEATURES			
	Input data & Evaluation models	Prediction model	Decision models	Cost models
PONTIS/US	Yes	Yes	Yes	Yes
WYO/Wyoming	Yes	Yes	Yes	Yes
OBMS/Canada	Yes	Yes	Yes	Yes
SAFEBRO/Sweden	Yes	Yes	Yes	Yes
BRIGEMAN/UK	Yes	Yes	Yes	Yes
COSMO/UK	Yes	Yes	Yes	Yes
EIRSPAN/Ireland	Yes	Yes	Yes	Yes
BRUTUS/Norway	Yes	Yes	Yes	Yes

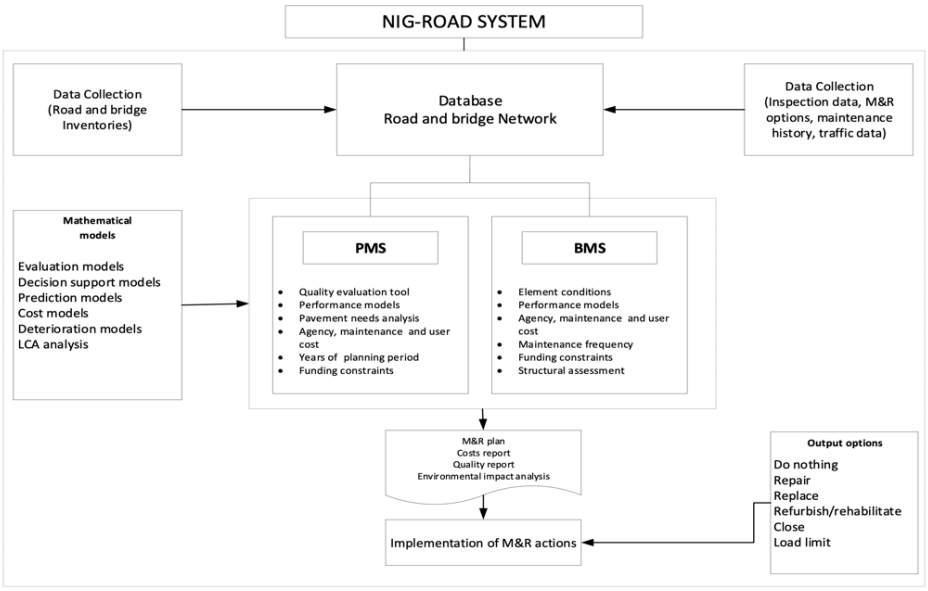

Figure 1: NIG-ROAD FRAMEWORK

Validating the Framework

An online survey was conducted with multiple stakeholders involving civil and structural engineers, construction manager, project managers, quantity surveyors, road design technicians and academics (involved with road and bridge construction and maintenance in Nigeria). Open-ended questions were asked to allow respondents to validate, critique and comment on the benefits, challenges and barriers of

implementing the developed framework. The issues identified were ranked from 1 to 4, depending on the number of times mentioned in the survey. With this being the supplementary phase of the research, not many responses were required. Therefore, issues mentioned more than five times were classified four stars, between (4 -5), three stars, between (3 - 2), two stars, between (1-0), one star.

FINDINGS

Perceived benefits of implementing the framework are presented in Table 3, amongst which helping to manage the cost and budgeting of maintenance work seem to be popular. The barriers and challenges of implementing the framework were captured, and political bureaucracy, poor maintenance culture and poor government policies is a significant limitation. Although, the acceptance attitude from policymakers and relevant agencies is also low and new technologies are barely celebrated. Access to new technologies is not the problem, but the view of the people generally towards maintenance need shifting. People traditionally refute change and are happy to get things done the same way. Generally, the framework was well embraced, but the problem of implementation cannot be overemphasised, especially with the political climate of man-know-man and matters of corruption, tribalism and nepotism prevalent in Nigeria.

Table 3: Benefits and Challenges/Barriers

NIG-ROAD BRIDGE FRAMEWORK			
Benefits	Rank (star)	Challenges/barriers	Rank (star)
Effective for auditing road -bridge maintenance work	2	Framework is seen as theoretical	2
Mitigate budgeting constraints	4	Bureaucratic political issues	4
Good for planning and organising workforce	2	Stakeholder issues	2
Efficiency of management	2	Lack of transparency	2
Provides a road map for maintenance	1	Poor maintenance culture	4
		Poor government policies	4
		Corruption, tribalism and nepotism	3
		Low moral for new technologies	3
		Acceptance by policy makers and ministry of highway and transport	2

CONCLUSIONS

A synthesis of existing literature in the domain of road-bridge maintenance practice in Nigeria has been presented. It was argued that the degraded condition of Nigerian highway networks, resulting from poor management and non-administration of adequate maintenance treatment as and when due, constitute a major problem. The initial creation of road maintenance agency to potentially address this problem has not been successful, and effective funding sources have also not been fully explored. Meanwhile, the Nigerian government is not only constrained by limited funds, but lack of a scientific or digital tool to diagnose and guide the selection of rehabilitation and maintenance options as and when due and suggest alternative funding sources

within limited resources further compounds the problem. The recurring theme emerging from the literature review led to the proposal of NIG-ROAD framework and validated by multiple stakeholders. However, the validation process revealed that implementing such a framework in Nigeria is constrained by other factors listed in Table 3, and a definite recommendation is a shift in the people's attitude towards maintenance. The money-saving potential of the framework should be promoted and the return on investment potentials, because many see this has a prominent benefit of the framework. Lastly, considerable communication is required to prepare people (that is, agencies responsible for road and bridge maintenance work) for new ways of working.

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