# Investigating the Road Maintenance Performance in Developing Countries

Jamaa Salih, Francis Edum-Fotwe, Andrew Price

*Abstract*—One of the most critical aspects of the management of road infrastructure is the type and scale of maintenance systems adopted and the consequences of their inadequacy. The performance of road maintenance systems can be assessed by a number of important indicators such as: cost, safety, environmental impact, and level of complaints by users. A review of practice reveals that insufficient level of expenditure or poor management of the road network often has serious consequences for the economic and social life of a country in terms of vehicle operating costs (VOC), travel time costs, accident costs and environmental impact. Despite an increase in the attention paid by global road agencies to the environmental and the road users' satisfaction, the overwhelming evidence from the available literature agree on the lack of similar levels of attention for the two factors in many developing countries. While many sources agree that the road maintenance backlog is caused by either the shortage of expenditures or lack of proper management or both, it appears that managing the available assets particularly in the developing countries is the main issue. To address this subject, this paper will concentrate on exposing the various issues related to this field.

*Keywords*—Environmental impact, performance indicators, road maintenance, users' satisfaction.

## I. INTRODUCTION

THE road network in every country serves as a principal foundation for the effective functioning of transportation and contributes in delivering a wide range of economic and social benefits. Adequate maintenance of the road infrastructure is essential to achieve and preserve those benefits. The significance of road maintenance is acknowledged by most commentators including key political decision makers. Such acknowledgement however, hardly translates into adequate funding and appropriate management of these national assets to ensure effective and optimum value is derived from road networks. Insufficient levels of expenditure or poor management of the road network often has serious consequences for the contribution made by the road assets.

What constitutes adequate funding often becomes a contentious issue, and will be influenced by national and political agenda. In many developing economies, while some effort has been made to assess the cost and benefits of budgeting road maintenance, the economic benefits of good road maintenance, have not been systematically determined [1].

Jamaa Salih is with the School of Civil and Building Engineering, Loughborough University, United Kingdom (e-mail: J.Salih@lboro.ac.uk).

Making the proper assessment for road networks will help the road authorities and decision makers on different levels to demonstrate the value for money and efficiency of investment in road maintenance.

## II. LITERATURE REVIEW

The importance of addressing road maintenance properly is now well understood and is illustrated by the consequence of neglect [2]. It is acknowledged that roads enhance mobility, taking people out of isolation and therefore, poverty. For example, the World Bank as one of the organisations who perform and fund various studies has assessed the 85 countries receiving support for their roads, and found that the cost of re-construction has ranged between three and four times the cost of the preventative maintenance that should have been carried out earlier [1]. In its study on road policy, the World Bank estimated that $45 billion worth of road infrastructure had been lost due to the absence of adequate maintenance in those 85 developing countries. The study also suggested that such a loss could easily have been avoided by spending $12 billion (or the equivalent of 25% of the impact of the lack of maintenance) on preventative maintenance [3]. Worldwide, it is considered to be a political advantage to be in favour of investing money in constructing new roads [4]. On the other hand, maintenance does not have the same prominence or does not offer the same opportunity to stakeholders or decision-makers to present themselves to the public.

Even though the need for maintenance is broadly shared globally, it is still not being adequately addressed. Several countries spend just 20–50% of what they should be spending on the maintenance of their road network [4]. Burningham and Stankevich [5] have identified a number of reasons to explain this low expenditure. Despite the importance of roads in terms of both their intrinsic value and the role they fulfil, most are poorly managed and badly maintained in the developing world. It is estimated that in Sub-Saharan Africa alone, it would take in the range of £30 billion to repair all the roads requiring immediate rehabilitation and reconstruction. Likewise, for Latin America it is expected that between 1-3% of GDP is being squandered every year due to additional VOC and rehabilitation produced by inadequate maintenance. More effective management of the infrastructure would consequently free up limited capitals and hence contribute to the economic security of such countries [2].

Roads are made up from different layers, such as, sub-grade, sub-base, base and surface layer. Together, these layers constitute the road body or so-called "pavement". Different types of pavements (rigid or flexible) can be used depending

World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:10, No:4, 2016

upon the traffic requirements. Badly designed pavements leads to early failure of roads and affects the comfort of the driving experience.

According to [6], a road is more than just a pavement on top of a base course. It contains several elements, all of which a specific functions and contribute to the service provided by the road. Typically, most roads would contain the following elements: (1) Streetlights, (2) Traffic lights, (3) Drains, (4) Guard rails, (5) Street furniture, (6) Street markings, (7) Shoulders, (8) A variety of structures, such as bridges and flyovers.

The surface layer seals the pavement and prevents surface water from penetrating and weakening the base and sub-grade. The most common surface for rural roads is constructed from natural gravels. Bituminous and concrete surfaces provide more impermeable surfaces and are more resistant to the abrasive forces, caused by the combined effects of traffic and weather. You need to make the case for design not addressing maintenance (design for maintenance).

*Pavement Life Cycle and Cost:* Life Cycle Cost Analysis (LCCA) is the process used to determine the economic performance of pavements. This has received increasing attention as a tool to assist transportation agencies in order to be able to make more economical investment decisions [7]. There are two ways of using LCCA: (1) For the prediction of future costs of proposed pavements over a given period of time, using the available information as total costs and predicted performance; and (2) For the determination of actual costs of existing pavements over a given period of time, based on historical or recorded data from the road agency. The life-cycle cost of a road includes the money spent on initial construction of a road, maintenance over its lifetime, and the costs to users for their delays during maintenance and reconstruction.

*Road Deterioration:* Studies showed that there is a strong correlation between the road surface condition (such as, rutting, smoothness, roughness, potholes) and the VOC. So, leaving the surface of the road without treatments will lead to a substantial increase in the cost of operating the vehicles and the economic investigation into road maintenance indicates that the implementation of maintenance programmes leads to high rates of investment profit [8]. Infrastructure systems deteriorate over time due to external factors such as, climate, usage and aging. Generally, the older the pavement is, the more rapidly it deteriorates. It has been claimed that, road deterioration is affected by a combination of factors including, the original design, material types, traffic volume and its axle load characteristics, environmental conditions, age of pavement, and the maintenance policy implemented [9]. Application of preventative maintenance in the first 15 years of pavement life (before the pavement condition deteriorates to a fair condition), will cost less and also extend the life of the road

The failure to respond to the maintenance needs in the right time will result in a high VOC and rampant potholes, leading to a decline in road safety and a deterioration of service levels

for those who are using roads to transport people or to deliver goods to markets.

Road deterioration will have severe impact in terms of:
- VOC: If road conditions deteriorate, there is an increased cost to road users (e.g. vehicles consume more fuel and may need more frequent maintenance).
- Travel time costs: If the road conditions deteriorate, vehicles generally travel at slower speed but this effect is offset by fewer planned disruptions (due to less maintenance work being carried out if budgets are reduced) resulting in less delay at road works.
- Accident costs: As a result of road condition deterioration, and thus lower skid resistance, there will be an increased risk of accidents.
- Environmental impact: Changes in $CO_2$ emissions are directly related to the above mentioned impacts.

*Road Maintenance Management:* In many publications maintenance is defined as "all the technical and associated administrative functions intended to preserve an item or system in, or restore it to, a state in which it can carry out its required function.

The Road Maintenance Management System contains five main systems including Pavement Management System (PMS), Bridge Management System, Non-pavement Management System, Database Management System, and Maintenance Follow-up Management System [10]. The management of road maintenance activity as one of the components of the road maintenance management system can be discussed in terms of four main functions: strategic planning, programming, preparation and operations.

*A. Types of Maintenance*

*Routine maintenance:* All maintenance activities that have to be performed at least once a year, if not more frequent. Such activities involve inspections, cleaning of drains, controlling of vegetation and filling of potholes and ruts. Routine maintenance has a lower cost in comparison with any other type of maintenance and new construction projects.

*Emergency maintenance or repairs:* All maintenance activities that have to be performed immediately to save lives or prevent disastrous consequences of damaged infrastructure. Maintenance departments need unrestricted access to emergency maintenance budgets that allow them to carry out repairs that mitigate immediate dangers.

*Periodic maintenance and reconstruction:* These are the repairs that are performed less frequently. This type of maintenance includes all sorts of repairs including resurfacing, overlays, and reconstruction of pavement, base and even sub-base course. Periodic maintenance intervals vary according to the demand and may be irregular.

Road authorities often allocate a fixed budget on the basis of an inventory that quantifies the assets in terms of age, length, area or volume.

The role of management at all levels includes comparing options, organising activities, making decisions and seeing that they are applied in an efficient and economical way" [11].

World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:10, No:4, 2016

According to a previous study performed in Nigeria, postponing road maintenance results in high direct and indirect costs [12]. If road defects are repaired on time, the cost is usually minimal; if defects are neglected, a whole road section may fully fail, requiring complete reconstruction at three times or more the cost, on average, of maintenance.

*B. Requirements for Efficient Maintenance*

*Institutional:* Establishing Competitive Environment primarily increases specificity, improving organisational effectiveness and efficiency, but also introduces a competitive element for the interested parties. The aim of the competition should be to gain work of sufficient quality at the most economic price. Competition can be based on price, quality, performance or a mixture of all three. However, the introduction of competition, and business-oriented objectives, into a public organisation, requires a change in culture and the implications can be threatening to existing civil or public workers.

*Technical:* "Full range of techniques used dependent on the nature of the deterioration; this comprises anything from minor potholes or surface patches through to universal pavement construction and drainage upgrades dependent on the source of the damage" [13].

*Financial:* In order to achieve the objectives of the road maintenance agencies, activities require large funds. As a consequence, most agencies are now trying to improve the efficiency of their maintenance plans by adopting several new strategies. The main target of these newer strategies is to accomplish a possible maintenance at the least possible cost. Some of these strategies include; (1) Maintenance contracting methods, (2) Improving the management of available resources, (3) Standardising and improving production processes, (4) Prioritising of the work activities, (5) Implementation of new technologies.

Despite the importance of roads in terms of both their intrinsic value and the role they fulfil, most are poorly managed and badly maintained in the developing world. It is estimated that in Sub-Saharan Africa alone, it would take in the range of £30 billion to repair all the roads requiring immediate rehabilitation and reconstruction.

Recently, there has been a general trend towards increasing the use of the private sector in road maintenance worldwide, which has been seen by many as a means of encouraging more efficient and effective use of resources.

A number of different mechanisms are available for delivering road maintenance services. The traditional method was for all administration, management and service provision to be executed by the road owner within the organisation. Different countries have experience with reforms, whereby some or all of the functions of the road administrator, manager and service provider have been contracted out. The majority of road maintenance contracts in use world-wide reflect the different levels of development as well as cultural issues.

*Road Maintenance Performance:* A comprehensive definition of Performance Measurement is offered by the US Federal Highway Administration: "Performance measurement is a process of evaluating progress toward reaching predetermined goals, comprising information on the efficiency with which assets are transformed into goods and services (outputs), the quality of those outputs (how well they are delivered to clients and the extent to which clients are pleased) and outcomes (the results of a program activity related to its proposed purpose), and the effectiveness of government operations in terms of their particular contributions to program objectives" [14]. When selecting a set of performance measures, it is essential to recognise the difference between input, output and outcome measures. Input measures reflect the assets that are devoted to a program, output measures reflect the products of a program, and outcome measures look at the impact of the products on the objectives of the agency. Input- and output-based Performance Measurement was more common in the past, but current trends are to increase use of outcome-centered performance measures, in combination with output-based measures [15].

*Measurement of Performance:* Generally, performance of organisations can be defined as the right combination of efficiency and effectiveness. Efficiency and effectiveness are the fundamental terms used in evaluating and assessing the performance of organisations. Efficiency, effectiveness and productivity are closely connected concepts which could easily confuse a reader.

"Efficiency refers to doing things in a right manner. Technically, it is defined as the output to input ratio and concentrates on getting the maximum possible output with minimum resources. Effectiveness, on the other hand, refers to doing the right things" [16].

*Road Maintenance Performance Indicators:* Road network authorities bring together and retain widespread datasets related to their services and the life cycle of their infrastructures. It is significant to note, though, that accurate collection, analysis, improvement and production of that data is a requirement for using them and for appropriate reporting to wider spectators. As such, development of suitable performance measures (or indicators) is necessary for linking transport and infrastructure data for road management. Karlaftis and Kepaptsoglou, outline performance indicators as follows; a tool enabling the effectiveness of an operation or an organisation to be measured; or, an achieved result to be assessed or evaluated in relation to a set of goals [15].

Performance indicators are important to measure the output of programs which is made by road administrator, despite how far the target have been achieved by them or how far the road users feel, or if they make any improvement on level of road services. According to Suslo and Hartanto, the role of performance indicators could be functioned as monitoring, diagnosis, management, prognosis, effectiveness and efficiencies and comparison which is could be used by road user, road administrator, transport company, contractor and road material supplier and other related units [17].

The research on Performance Indicators for the Roads Sector was initiated in 1995 by a scientific expert group under the leadership of the RTR Secretariat OECD. A major recommendation of this Group was to create a Taskforce to

World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:10, No:4, 2016

conduct a coordinated set of field tests for selected performance indicators. The Taskforce was established in 1997 with the objective of refining the indicators selected by the Scientific Expert Group and testing them over a period of two years. The task force concluded that quantitative comparison between administrations is of limited usefulness unless it is accompanied by a thorough examination of the underlying reasons for any differences [18].

The fifteen performances were tested are: (1) Average road user costs, (2) Level of satisfaction regarding travel time and its reliability and quality of road-user information, (3) Protected road-user risk, (4) Unprotected road-user risk, (5) Environmental policy/programmes, (6) Processes in place for market research and customer feedback, (7) Long-term programmes, (8) Allocation of resources to road infrastructure, (9) Quality management/audit programmes, (10) Forecast values of road costs vs. actual costs, (11) Overhead percentage, (12) Value of assets, (13) Roughness, (14) State of road bridges, and (15) Road users' satisfaction with road system.

## III. RESEARCH METHODS

A systematic review was performed in order to highlight the defined problem. If we rank the different issues according to their aggregate number of times mentioned in the literature review as the following: (0-15) 1 star, (16-30) 2 stars, (31-45) 3 stars, (46-60) 4 stars, (61-75) 5 stars, (76-90) 6 stars, (91-105) 7 stars, (106-120) 8 stars, (121-135) 9 stars and (136-150) 10 stars.

As it can be seen in Table I, categories 5, 6, 7 and 14 were marginally the least to be mentioned among 15 other chosen issues. The review identified less than 20 sources either related to or mentioned each of the three.

## IV. RESULT AND FINDINGS

The review of the road maintenance in general and particularly in the developing countries shows that most of the published sources emphasised on the importance of road maintenance management systems in order to benefit the national economies of those countries. In addition, several studies highlighted in figures the consequences of lacking the proper and timely road maintenance. Other studies emphasised on the assessment of road maintenance agencies performance using the tools called performance indicators (OECD). In this regard, it was found from the literature review that despite some efforts from individuals and authorities in the developing countries more research and work is still needed to be done in order to uncover the facts and to investigate the road performance indicators and how to use the outcome of such studies in improving the performance of the related agencies. The review of the road maintenance management system sources shows that most of the studies published in the last two decades or so (with the exception of some studies) were not specific to the trend of decision making in developing countries in particular to how they are dealing with the environmental impact and road users' satisfaction.

In addition, even those sources dealt with or mentioned these issues were not specific in giving clear idea about how the decision makers in developing countries are considering these factors (category 14 in the table), which establish a good base for these indicators to be investigated. Furthermore, discovering such issue may contribute in providing guidelines for decision makers which may help in improving the overall performance of organisations.

TABLE I
SYSTEMATIC REVIEW

| No. | Description | Aggregate Number of Sources Dealt with or Refereed to the Issue | Remarks (stars) |
|---|---|---|---|
| 1 | Road Maintenance Management | 95 | 7 |
| 2 | Road Construction Management | 90 | 6 |
| 3 | Road Deterioration | 72 | 5 |
| 4 | Performance Indicators | 55 | 4 |
| 5 | Environmental Impact on Decisions | 16 | 2 |
| 6 | Road Users' Satisfaction | 18 | 2 |
| 7 | Decision Making Trend | 16 | 2 |
| 8 | Asset Management | 75 | 5 |
| 9 | Road Maintenance Performance | 84 | 6 |
| 10 | Cost | 128 | 9 |
| 11 | Quality | 135 | 9 |
| 12 | Maintenance types | 74 | 5 |
| 13 | Sustainability | 40 | 3 |
| 14 | Decision Making Trend in Developing Countries | 3 | 1 |
| 15 | Efficiency | 82 | 6 |

## V. CONCLUSION

The review concluded that huge road maintenance backlog is identifies in the developing countries which will have great negative impact on the national economies of those countries. This deficit caused either because of the lack of expenditures or the proper management. In the same context, performance indicators are the clear tools for assessing the road agencies performance. Among the various indicators, environmental impact and road users' satisfaction have more potential to be investigated in the developing countries because of the evidence of less attention has been paid to them. This paper paves the way for further studies goes deep into the two mentioned parameters and how the decision makers are considering them in their policies and plans.

## REFERENCES

[1] Adling, S. & Gupta, A., 2009. Pavement Deterioration and its Causes. *Mechanical and Civil Engineering*, pp.9–15. Available at: www.iosrjournals.org.
[2] Parkman, C., Madelin, K. & Robinson, R., 2000. Managing Change to Improve The Delivery Of Road Maintenance, Available at: http://r4d.dfid.gov.uk/pdf/outputs/R68891.pdf.
[3] Hiep, D. V, 2009. PhD Thesis Optimisation of Pavement Designs and / or Maintenance Strategies using Gradient Search with Option Evaluation Systems. *Engineering*, p.134. Available at: http://www.lpcb.org/index.php/component/docman/doc_view/927-2009-japan-optimizing-pavement-investments-using-the-gradient-method?Itemid=32.
[4] Harral, C. & Faiz, A., 1988. *Road Deterioration in Developing Countries: Causes and Remedies*.
[5] Burningham, S. & Stankevich, N., 2005. Why road maintenance is

World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:10, No:4, 2016

important and how to get it done. (June), pp.1–10. Available at: https://openknowledge.worldbank.com/handle/10986/11779 (Accessed September 29, 2014).

[6] Rijn, J. Van, 2006. Road maintenance planning. *Indevelopment*.

[7] Ferreira, A. & Santos, J., 2013. Life-cycle cost analysis system for pavement management at project level: sensitivity analysis to the discount rate. *International Journal of Pavement Engineering*, 14(7), pp.655–673. Available at: http://www.tandfonline.com/doi/abs/10.1080/10298436.2012.719618#.VTLljvnF-So.

[8] Ibraheem, A. & Gani, S., 2014. Evaluation of Common Maintenance Methods for Flexible Pavements. *American Journal of Engineering and Applies Sciences*, 4(3), pp.413–424. Available at: http://thescipub.com/PDF/ajeassp.2011.413.424.pdf.

[9] Watanatada, T. et al., 1987. *Description of the HDM-III Model the Highway Design and Maintenance Standards Model*, World Bank. Available at: http://www.worldbank.org/transport/roads/rd_tools/hdm-iii_vol-1.pdf.

[10] Mubaraki, M., 2010. *Predicting deterioration for the Saudi Arabia Urban Road Network*. Nottingham. Available at: http://etheses.nottingham.ac.uk/1171/.

[11] Ralph, H., 2001. Reinventing The (Pavement Management) Wheel. In *Fifth International Conference On Managing Pavements*. Seattle, Washington, pp. 1–67. Available at: http://asphalt.org/downloads/Haaslecture.pdf.

[12] Emeasoba, U., Ogbuefi, J. & Enugu, C., 2013. Sustainable Socio-Economic Development in Nigeria: A Case for Road Infrastructure Maintenance. *Journal of Environment and Earth Science*, 3(5), pp.129–137. Available at: file:///C:/Users/cvjs8/Downloads/5725-7821-1-PB (1).pdf.

[13] Barton, J. & Burns, J., 2012. *Road Maintenance Review International Comparison*, Available at: file:///C:/Users/cvjs8/Downloads/wra_uk_road_maintenance_review_-_international_comparison_41111.pdf.

[14] Karlaftis, M. & Kepaptsoglou, K., 2012. *Performance Measurement in the Road Sector: A Cross-Country Review of Experience*, Available at: http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201210.pdf.

[15] Transport Association of Canada, 2006. Performance Measures for Road Networks: A Survey of Canadian Use. (March), p.67. Available at: http://tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/report-perf-measures.pdf (Accessed December 17, 2014).

[16] Ephraim, S., 1996. Difference Between Efficiency and Effectiveness Difference between Efficiency vs Effectiveness. p.1. Available at: http://www.differencebetween.net/business/difference-between-efficiency-and-effectiveness/ (Accessed April 17, 2015).

[17] Suslo, Y. & Hartanto, B., 2001. Performance Indicators as a Measurement of Successful of Road Development. 3(1). Available at: http://easts.info/on-line/proceedings/vol3no1/310026.pdf (Accessed September 2, 2015).

[18] OECD, 2001. Performance indicators for the road sector. *Transportation*, p.88. Available at: http://www.oecd-ilibrary.org/transport/performance-indicators-for-the-road-sector_9789264192942-en\nhttp://link.springer.com/article/10.1023/A:1005152400108 (Accessed January 1, 2015).