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Evaluation of Roads 2000 Program in Kenya

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Abstract

The low volume approach of road improvement guarantees optimum utilization of locally available resources where technically and economically feasible. Low volume roads in Kenya are distributed in rural and peri-urban networks and low-population areas, and are under the jurisdiction of local road authorities and county governments, who have funding constraints, and therefore optimal serviceability on the roads is not well maintained. This study was aimed at investigating the maintenance levels on low volume sealed roads, and come up with recommendations to be adopted on the current and similar problems in the future. Performance assessment was undertaken by carrying out surface condition surveys on sampled roads under the Roads 2000 program. It was determined that the priority for maintenance of completed low volume roads was normally affected by the surrounding poor network, and therefore, adequate maintenance was not routine. Review of performance of the low volume roads showed that whereas the improved roads were having great impact on the recipient populace, the lack of adequate maintenance was in most cases leading to early failure of the completed roads, and inadequate drainage was a leading factor in the uncontrolled deterioration of these roads. The study noted low serviceability index of below 2.5 on some roads, noting that rehabilitation was required, and timely corrective work was required on all roads. With proper and all-round conditional assessments, followed by timely, suitable and efficient maintenance regimes, the roads were expected to meet their design lives and continue serving the population in these regions.

Keywords: Roads 2000, low volume, design life, deterioration, maintenance, fuel levy.

INTRODUCTION

As part of a research at the Department of Civil and Construction Engineering, University of Nairobi, on evaluation of the Roads 2000 strategy in central Kenya, the performance of the implemented roads was evaluated.

The Government of Kenya has an agenda to increase the network of paved rural roads, as part of the strategy towards achieving its long-term development objectives. For this strategy to be successful, the roads have to be designed and constructed in the most cost-effective manner.

Low volume roads are roads designed for a traffic loading not exceeding one million equivalent standard axles per lane over their design lives. These roads are constructed using locally available natural materials that may be improved to meet the provided standards (Otto et al, 2020). The performance of low volume sealed roads is determined by an appropriate and adequate drainage, a strong bituminous seal that is resealed in a timely manner, and an allowance for occasional overloaded axles (Otto et al, 2022).

The Roads 2000 Program, apart from increasing the ease of travel, was also to contribute towards the alleviation of rural poverty and improved livelihoods and living standards in Central Kenya through increased agricultural production and marketing. The immediate objectives of the program were to: improve selected rural roads and markets; enhance movement of passengers and goods on roads; enhance usage of markets in the target area by local/regional traders, producers, consumers; increase in agricultural production in the catchment areas of the improved roads; and improve in socio-economic living standards of the target populations (MoR, 2013).

The roads under the program were distributed in rural and peri-urban networks and low-

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population areas, and are under the jurisdiction of local road authorities and county governments, who have funding constraints, and therefore optimal serviceability on the roads is not well maintained. This study was aimed at investigating the maintenance levels on low volume sealed roads, and come up with recommendations to be adopted on the current and similar problems in the future

THEORY

Kenya has nearly 170,000 kms of road network. Insufficient fiscal funds, administrative and functioning systems with insufficient investment in maintenance has prompted the depreciation of the network, as well as increasing the vehicle operating costs that negatively impacts on the economy (KeRRA, 2015).

The inadequate condition of these roads necessitated the Government of Kenya to change its emphasis from the construction of new roads to the maintenance and restoration of the existing road network using the maintenance strategy known as the Roads 2000 Strategy. R2000 concept as a technique of road construction and management warrants the optimal usage of locally available resources where technically and economically viable and in an environmentally receptive way (KeRRA, 2015). Low volume sealed roads have a design equivalent standard axle loading of maximum one million. Pavement design for such roads is carried out according to requirements of Pavement Design Guideline for Low Volume Sealed Roads manual (MoTIHUD, 2017).

The Agence Française de Développement (AfD)/ Government of Kenya (GoK) Phase one project was implemented in Nyandarua and Murang'a regions from 2007 to 2011 with an overall budget of 22 mill Euro, out of which AfD provided 20 mill and GoK Provided two mill Euro respectively. The project met most of its objectives including training of contractors and supervisors, rehabilitation of 1,000 km of gravel roads and construction of a 6.7 Km low volume seal demonstration road (KeRRA, 2018).

AfD (2010) provided financing of €40 million to assist the Government of Kenya in developing its rural road network, and thereby increase employment opportunities and wealth creation, and help reduce poverty in the central area of the country through the Roads 2000 Central phase two project covering Kiambu, Murang'a, Kirinyaga, Nyeri, Nyandarua and Laikipia regions. The Road Sector Investment Programme (RSIP) provided the sector framework within which this assistance was delivered. The Government of Kenya and AfD subsequently signed a financing agreement in which GoK provided four Mill Euro as development counterpart funding for road works, 11.4 Mill Euro for Maintenance and seven Mill Euro for taxes (KeRRA, 2018).

The phase two project was modelled on the Phase one project but with a wider coverage and a larger budget. The phase two project also put more emphasis on quality control and maintenance. The main outputs of the phase two project as formulated were;

- Training of routine maintenance, gravelling and low volume seal (LVS) contractors.
- Training of public and private sector contract managers and supervisors.
- Capacity building of KeRRA at regional and national level.
- Rehabilitation of 1,100 km of gravel roads.
- Construction of 165 km of low volume sealed roads.
- Maintenance of all phase one and phase two improved roads.
- Maintenance of 6,000 km of roads within the 6 regions

The road works under phase two consisted of improvement works to gravel and low volume seal standard which were implemented by trained labour-based contractors in three batches of contracts. The Kenya Rural Roads Authority (KeRRA), the implementing agency of the projects, procured two Design and Supervision Consultants (DSC) to support their Regional Managers (RMs). The two DSCs covered the projects of (i) Kiambu, Murang'a and Kirinyaga (Area 1) and (ii) Nyeri, Nyandarua and Laikipia (Area 2). The roads, upon completion, were scheduled to be handed over to the local authority for performance based routine maintenance for a period of three years, and further routine and periodic maintenance, in a bid to ensure the roads met their design lives (KeRRA, 2018).

All roads deteriorate with time, as a result of traffic and environmental effects. When carrying out structural design of low volume roads pavements, the aim is usually to limit the stresses in the subgrade, brought about by traffic, to a safe level at which subgrade deformation is inconsequential. Further, the design purposes to ensure that the layers of the pavement don't deteriorate to ultimate levels within a specified period of time (Rolt et al., 2022).

Flexible pavements deterioration is normally brought about by actions of traffic and climate. The deterioration is exhibited by (a) reduction in skidding resistance, as a result of polishing of the surfacing stone; (b) surface texture loss, leading to a reduction of skid resistance; (c) surface deformation as a result of traffic loading; (d) cracking and surface deterioration as a result of binder oxidation; and (e) foundation fatigue strain, that results in structural deterioration. For low volume sealed roads, three methods are normally used to carry out condition survey: (i) Average Speed (ii) Road Inventory and Condition Survey (RICS), and the (iii) Present Serviceability Rating (PSR) (O'Flaherty, 2002).

In the Average Speed Method, the average speed from the start to the end of the road is measured and the road condition is reported as three different types: Poor (< 30 kms/hr); Fair (30-45 kms/hr); and Good (>45 kms/hr). The survey is undertaken on each road twice a year (during the dry and wet season) and the average figure reported as the road condition for the year. The average speed method enables the survey to be done quickly (estimated 100-150 kms/day depending on the location and state of the roads). The method is cheap due to speed of data collection and simplicity as only one vehicle is required to undertake the survey. The method is particularly focused on the needs of the road user who is mainly interested in the time taken to travel along the road (and not the various maintenance defects). The method is also considered a fairly accurate assessment of the state of all elements of the road including the side drainage. It is based on objective data, that is the time taken to travel the length of the road and therefore minimises personal opinions as to the road condition. However, the method does not measure any major defects along the roads (other than what can be deduced by the average speed), although as the trend towards performance-based contracts is increased, major defects in the drainage system and road pavement should be minimised so as to make average speed more accurate as an indicator of road condition (Mariano et al., 2022).

Road Inventory and Condition Survey (RICS) method has a number of forms to be filled so as to give enough information of the road. The road condition is assessed as well as the need for spot improvements and repair of drainage structures. The road surface condition is assessed at 200m intervals stating the road surface, the drainage structures along the road and the sections requiring spot improvement. Good experience on roadworks is required of the raters. The average rate of deterioration is used to determine the type of road condition, rated from 1 (Excellent) to 5 (Very Poor). For a road to receive an Excellent (1) rating, it is new looking, in a good maintenance condition and completely functional. A Good (2) rating specifies that the road is in an almost new condition, and requires only some slight maintenance work. At a Good rating, the road's serviceability, functionality and capacity is expected to have reduced by a maximum of 10 percent. A Fair (3) rating shows that the road is demonstrating sporadic signs of distress that are instigating a conspicuous reduction in serviceability, functionality and capacity, of between 10 and 25 percent. At a Fair rating, a considerable maintenance or repair effort is needed. A Poor (4) rating shows that the road is displaying recurrent signs of distress, thereby reducing serviceability, functionality and capacity of the road significantly, in the range of 25 to 50 percent. At a Poor rating, significant maintenance or reconstruction is required to restore the road. A Very Poor (5) rating specifies that above half of the road is past the restoration condition by routine maintenance and reconstruction or replacement is essential (KRB, 2009).

The strength of a road pavement is inversely related to its maximum vertical deflection under a known dynamic load. The recommended frequency of deflection tests for project purposes is every 50 m for trunk and primary roads, and every 100 m for other roads. These should be made along the outer wheel path. The deflection tests are used to determine uniform sections for overlay design. For a section to be considered a uniform section, the coefficient of variation (CoV) of the deflection measurements must not exceed 20%. Otherwise, spot treatments are required, to bring the CoV down to 20%, or re-section should be carried out (Rolt et al., 2022).

Jithin et al. (2023) evaluated the deflection bowl parameters in low volume sealed roads. The study observed that evaluation of pavement deflection bowl using non-destructive testing was an effective way assessing the structural capacity of individual layers of a pavement system. The moduli of the separate pavement layers were computed and correlated with the deflection bowl parameters. The study concluded that the deflection bowl under dynamic loading was only 0.65–0.75 times that of the deflection bowl under static loading. The difference of deflection measured at radial distances of zero and 450 mm of the deflection bowl correlated well with the base-layer modulus, and the difference of deflection measured at radial distances of 300 and 600 mm correlated well with the subbase-layer modulus. Based on the deflection bowl data collected from nine test sections, it was found that emulsion-treated base layers exhibited 40%–60% higher moduli values than the conventional base layers during the monsoon season. Low-volume roads with dense surface mixes 30 mm thick exhibited significantly improved structural performance compared with that of low-volume roads with open-graded surface mixes 20 mm thick with a 6-mm seal coat (Jithin et al., 2023).

Present Serviceability Rating (PSR) procedure involves determination of present serviceability rating of a road section based on visual condition survey conducted through walking or windscreen inspection. Trained raters are required to observe the road's riding quality and defects and record impressions on a standard form. Rating varies from "0" (Very poor) to "5" (Excellent). The lower ratings give an indication of poor surface conditions and calls for a detailed examination of the pavement. The PSR is employed as an initial step in assessing the pavement adequacy. Each individual rating should be an overall opinion or impression of the pavement's present serviceability, based upon the experience and training of the rater (Kenya Road Department, 1988).

Successful pavement management practices require pavement condition data. A lack of maintenance accounts is a major challenge that face the pavement management process for local transportation agencies. The use of the rate of deterioration concept to generate performance models when the age of pavements is unknown has been utilised to solve the problem. Utilisation of a data-driven approach to detect probable maintenance activities on the network can be adopted. Pavement condition data can be used to generate performance models for flexible, rigid, and composite pavements (Abdallah et al., 2023)

Cook et al. (2005) investigated the performance of low volume unsealed rural roads providing basic access for communities in forty provinces in Vietnam. The roads were done to gravel surfacing. The research comprised data collection on key aspects including: general road environment, road linkage condition, comprehensive condition of selected profiles within each link and in-situ and laboratory test results. The study found that it was necessary to improve the evaluation of the appropriate usage of local natural gravel materials in rural road programmes in Vietnam. It was documented that an important objective in sustainable road construction was to properly match the available material to its road task and local environment. Local non-standard materials needed to be adopted within the design, as many designs in use did not incorporate this. The wide-ranging options for dealing with this situation were recommended as: (i) modifying the material to fit the designs, (ii) modifying the design choices to fit the materials available, and (iii) defining areas where the existing unsealed options are suitable. The study also found out that suitable maintenance was not being achieved on the roads. Gravel roads experiencing upwards of 20mm/year of gravel loss without adequate maintenance normally diminish sustainability after 4-5 years (Cook et al., 2005).

Pinard (2011) undertook an analysis of performance of constructed low volume sealed roads, and the design standards and specifications in use in Malawi. The study sought to establish an appropriate design methodology for low volume sealed roads, and give suggestions towards the development of appropriate guidelines on low volume road standards by the road sector. The study included initial activities like stakeholder awareness campaigns, desk study, site reconnaissance, development of programme on field investigations and laboratory testing, and traffic loadings determination. Field investigations included visual condition surveys, drainage analysis, rutting measurements, dynamic cone penetrometer measurements, and bulk sampling for lab testing (which included classification tests, compaction and strength tests). The study found out that all the low volume sealed roads investigated had performed tremendously well under the prevailing environments. Those roads harbouring light traffic, of less than a quarter million equivalent standard axles from the base year, remained structurally intact with a controlled deterioration. Based on conservative pavement design standards, the roads in question would have since failed. This was interpreted as an indication that conventional design standards and specifications were unsuitable for use with low volume sealed roads. The study also found out that despite the good performance of the examined low volume sealed roads, the drain conditions were rated to be mostly poor to very poor in terms of the Drainage Factor (DF). Adherence to a minimum DF > 7.5 would significantly improve the performance and life of low volume sealed roads (Pinard, 2011).

Otto et al. (2020) investigated the influence of drainage features including provision of sealed shoulders and adequate camber and crown height, on the performance of low volume sealed roads. The road features were evaluated individually, by employing three levels performance matrix for each factor. The study found out that the incorporation of a sealed shoulder meaningfully improved the road performance. Additionally, it was noted that a properly maintained and grassed shoulder could be efficient in improving performance of low volume sealed roads. The study further noted that natural gravels were vulnerable to rutting, which in turn could lead to rainwater ponding and ingress into the road pavement. With a high camber, rainwater has a high likelihood of draining off. Sufficiently sized culverts, giving consideration of periodic silting capacity would be used at critical points on all low volume roads (Otto et al., 2020).

Pardeshi et al. (2020) studied the loss of gravel on unsealed roads in Australia. Gravel loss monitoring stations were set up to evaluate the losses, and the consequences of using good quality gravel material. The study observed that there was a great possibility of cost savings by reducing gravel loss on roads that are unsealed. Major gravel loss rates ranged between 6 and 10 mm per year. The study concluded that gravel loss was a key setback for unsealed roads and it needed major maintenance every year. The recurrent loss of gravel process leads to the unsustainability of these roads. The management of unsealed road faces several problems that include the difficulty to predict behaviour, enormous data collection needs, and a susceptibility in the service and maintenance practices. The quality of gravel material used on a road additionally plays a significant role in the gravel loss process (Pardeshi et al., 2020).

Greenstein (2023) investigated the climate change challenges in terms of planning and implementation of low-cost low volume roads' drainage works. The study observed that developing countries faced excessive land development, higher ambient temperatures and storms intensity changes that varied between –70% to +45% of the local registered storm intensities. The study also reported that developing countries faced more probable severe flooding damages caused by extremely high tropical storms that produced rainfall intensity above and beyond previous storms; and probable prolonged drought periods, associated with the rise of the ambient temperature, that have decreased the ability of local native vegetations to support the stability of road slopes. The study concluded that the design for the drainage systems for low volume roads required to be optimised to address the local climate change in terms selecting the most probable project-level projected storm intensity and duration and related sea level rise, in addition to the land-use planning and related development investment activities (Greenstein, 2023).

In summary, maintenance regimes for low volume sealed roads are funded by Kenya Road Board, through the Road Maintenance Levy Fund (RMLF) charged on fuel. The roads are prioritised and incorporated in the annual road works program, which forms the basis of the fund allocation, determined by the current condition of the road. It is determined that the priority for maintenance of completed low volume roads is usually affected by the surrounding poor network, and therefore, maintenance is not routine. For road management and maintenance and rehabilitation planning purposes, visual condition assessments of the road network are usually routinely carried out at specified frequencies. These normally look at the road condition, classifying problems such as cracking, deformation, rutting and potholing, by degree and extent to prioritise and budget for follow-up management operations. Generally, only the road carriageway area is assessed. Similar assessments for bridge management systems are also carried out, and these are mostly related to the planning and management of maintenance and repairs of road structures. Information related to climate resilience assessments and the implementation of appropriate adaptation techniques to improve the climate resilience of the infrastructure are normally not collected nor analysed. Review of performance of low volume roads in other regions showed that whereas the improved roads were having great impact on the recipient populace, the lack of adequate maintenance was in most cases leading to early failure of the completed roads, and inadequate drainage was a leading factor in the uncontrolled deterioration of these roads.

RESEARCH METHODS

Research Design

This research aimed at evaluating the Roads 2000 Strategy in the central Kenya, and particularly in Kiambu and Murang'a regions. To achieve the objectives of this study, and to independently and quantitatively evaluate the roads under the program, the following aspects were assessed:

(i) A condition survey of the completed sample roads under the program and those handed over for maintenance was conducted, in in Kiambu and Murang'a regions
(ii) Founded on the findings of the condition survey, an analysis of the deterioration and pavement design life of the roads were analysed.
(iii) The prioritization for maintenance of the completed and handed over roads was also assessed.

Surface Condition Surveys

a) Visual Condition Survey (Pavement and Drainage)

Visual assessment was utilised to detect distress and defects on pavements that could affect their overall performance. The assessments included describing the type of surface, the extent of pothole formation and edge breaks on the pavement, examination of surface cracking including their extent and type, describing the geometry of each chainage section and the drainage condition of the pavement. A standard form was used to collect the required data on (i) type of surface; (ii) extent of pothole formation; (iii) degree of pavement edge breaks; (iv) presence of surface cracking, extent and type; and (vi) drainage condition of the pavement.

b) Pavement Surface Condition

The condition of the road surface (identified nature and extent of defects) was assessed and the cause of any defects established. The defect identified included cracks, potholes, edge breaks, pumping, shoving, depressions, and ruts. Based on the visual assessment, a Present Serviceability Rating was calculated in order to categorise the pavement condition. The PSR value of 2.0 which is the terminal value for low volume roads was used as the minimum failure criteria. **Table 1** shows the rating used to evaluate the performance of the road sections.

c) Side Drainage Condition

Even if a side drainage problem is not a type of pavement distress, problems with the side drains could lead to premature failure of the pavement, due to water ingress, which eventually undermines the underlying pavement layers. The side drains were assessed in terms of the depth of the side drainage below the formation level. Drainage depth measurements were taken by use of a straight edge and measuring tape. The minimum depth of 0.40m below the formation level and side slopes of 1:3 as specified in the Kenyan Low volume design manual (2017) were used to check the drainage depth adequacy.

d) Roughness Measurement

The road pavement roughness is a key determinant of its functional condition. High levels of roughness are an important contributor to the portion of the road user costs that are affected by road conditions. Pavement defects contribute in increasing the roughness of the road pavement. Changes in the roughness value over time is a good indicator of pavement distress taking place. The road roughness for all assessed roads was measured using both the Rough-o-meter and Road-Lab equipment. The Merlin apparatus was only used on two roads as a calibration for the two methods. The roughness values were expressed in terms of the International Roughness Index (IRI) value in m/Km for each road surveyed and the condition rated as Sound (IRI < 3), Warning (IRI 3 – 6) or Severe (IRI > 6).

e) Rut Depth Measurements

Rut depth measurements were undertaken using a three-meter-long straight edge and a wedge. The straight edge was placed on one side of the road, followed by the other side, in one continuous transverse profile. The rut depths were measured in both outer and inner wheel paths. Additional measurements were taken at spots with visible rut development and the exact location and extent of the problematic section recorded.

The rut depth rating was based on the following scale:

(i) Very good : < 5mm (difficult to discern unaided)
(ii) Good : 5 - 10 mm
(iii) Fair : 10 - 15 mm (just discernible by eye)
(iv) Poor : 15 - 30 mm
(v) Very poor: > 30 mm

f) Road Condition Rating Criteria

The overall pavement condition based on the visual assessment was carried out and described based on **Table 2**.

g) Present Serviceability Rating

The Present Serviceability Rating (PSR) provides a quantitative evaluation of the overall condition of the road pavement. The PSR for each pavement section rated is the mean of the individual rating values assigned to each rating criterion. The procedure used in this study involved a rater both walking and riding through the sections under examination, and determining the present serviceability rating of the section based on visual condition inspection. The rater observed the section's ride quality and defects and recorded impressions on a standard form. The criteria used in this study considered twelve defects: Crazing (Block & Alligator cracking); Longitudinal cracking; Transverse cracking; Edge spalling; Rutting; Corrugation/Waves; Depression/ Longitudinal irregularity; Shoving/Heaving/ Upheaval; Bleeding/Glazing; Stripping/Raveling; Patched areas and Pothole/Disruption.

The **Table 3** shows the rating used to assess the performance of a road section:

TABLE 1

Present serviceability rating scale

Average Points	4.5 - 5.0	4.0 - 4.5	3.0 - 4.0	2.0 - 3.0	1.0 - 2.0	0.5 - 1.0	0 - 0.5
Rating	Excellent	Very Good	Good	Fair	Poor	Very Poor	Failed

Source: Author, 2024

TABLE 2

Description of overall pavement condition ratings

Degree	**Description**
Very good	Very few or no defects. Degree of defects < 3 (less than warning)
Good	Few defects. Degree of structural defects mostly less than warning
Moderate	A few defects with degree of defects seldom severe. Extent is only local if degree is severe (exchuding surfacing defects)
Poor	General occurrence of particular structural defects with degrees warning to severe
Very poor	Many defects. The degree of the majority of structural defects is severe and the extent is predominantly general to extensive.

Source: Author, 2024

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TABLE 3
PSR rating scale

Degree	Rating
4.5 to 5.0	Excellent
4.0 to 4.5	Very Good
3.0 to 4.0	Good
2.0 to 3.0	Fair
1.0 to 2.0	Poor
0.5 to 1.0	Very Poor
0 to 0.5	Failed

Source: Author, 2024

RESULTS AND DISCUSSION

Drainage Performance

The required minimum depth of side drains below formation in both cuts and low fills needs to be 0.4m. The roads with depth exceeding 0.4m below the formation and those with depths less than the required have been summarised in **Figure 1**. It was observed that out of the fifteen roads surveyed, only one road had its depth of side drain meeting the requirement. Shallow side drainage is not desirable as it allows water to ingress into the pavement through the edge of the pavement layers, thereby undermining the underlying layers and eventually leading to early deterioration.

Roughness Assessment

The findings of the roughness measurement survey have been summarised in **Figure 2**. Based on the roughness values measured, 43% of the roads surveyed were found to be in Severe condition while the other 57% were in Warning. The measurements indicate high values of roughness and irregularities on the surface of the pavement, that unfavourably affect the ride quality of the road users. The high roughness values obtained result from ruts, pot holes, among other surface defects, and are attributed to inadequate timely maintenance of the roads surface.

Rutting Assessment

The findings of the rutting measurement have been summarised in **Figure 3**. The results show that the rut depth values obtained were generally considered good to very good. Low rut depths were likely to originate from the surfacing. It was also deduced that rutting varied with direction of traffic in all the roads surveyed.

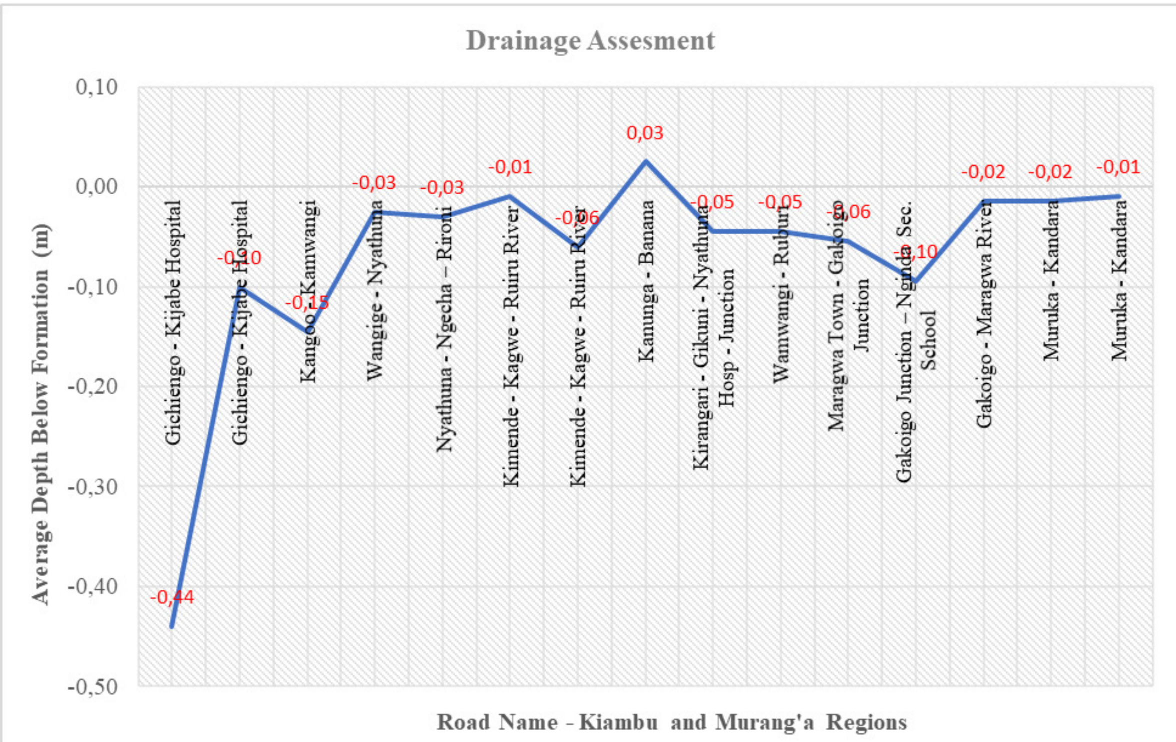

FIGURE 1
Drainage performance
Source: Author, 2024

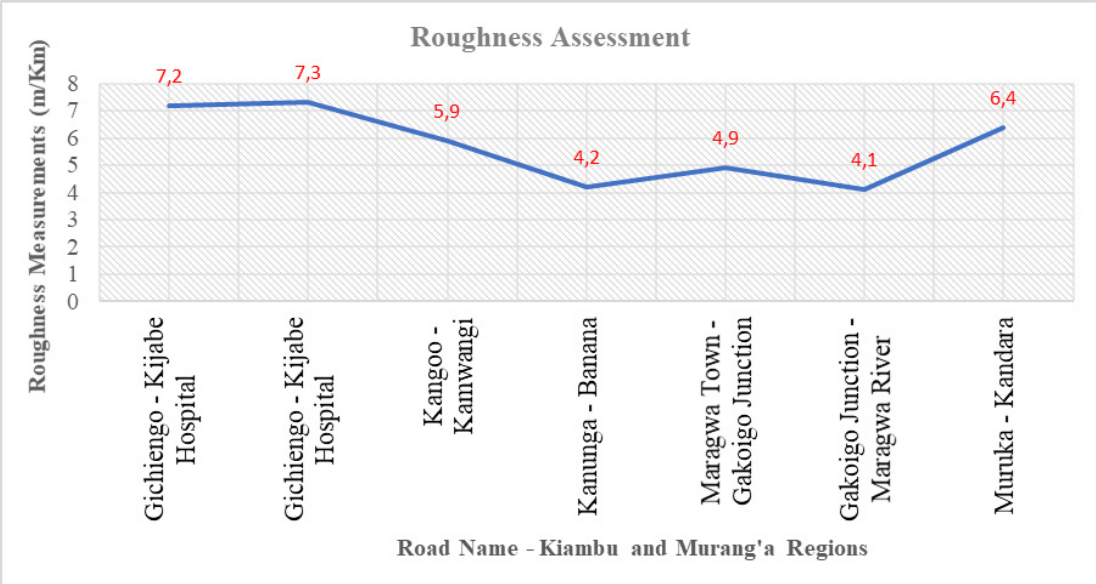

FIGURE 2
Roughness performance
Source: Author, 2024

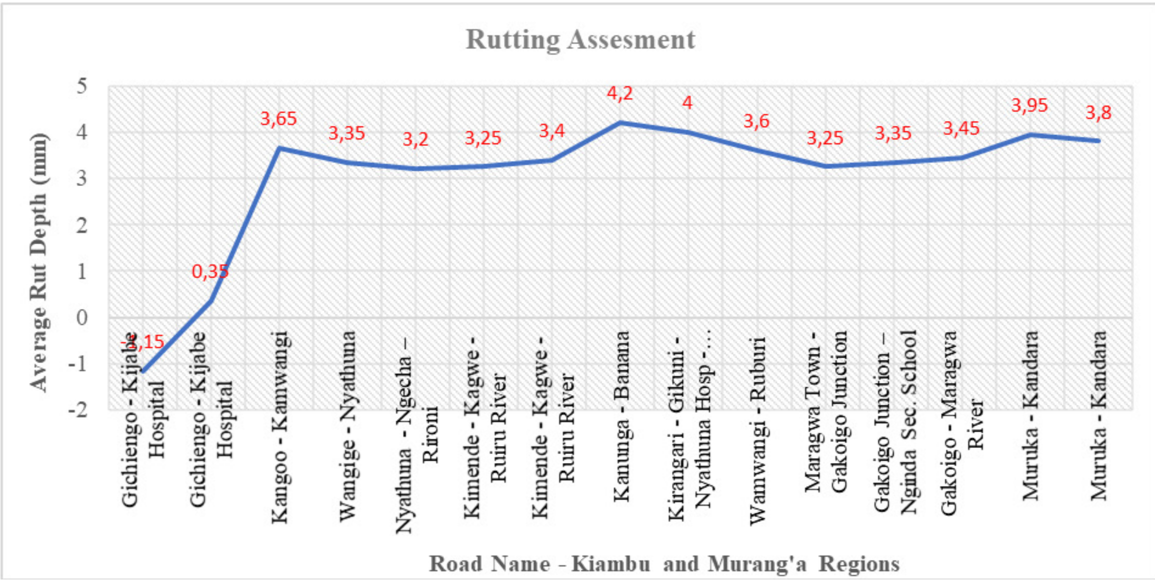

FIGURE 3
Rutting assessment
Source: Author, 2024

Present Serviceability Rating

The present serviceability ratings been summarised in **Figure 4**. The present serviceability is the ability of a particular road segment to offer a smooth, safe and comfortable ride at that specific time. The existing serviceability value was obtained by subjectively rating the pavement by visual observations.

It was deduced that all the surveyed roads have a PSR value above 2.0, which is the terminal value for low volume sealed roads. Low ratings specify poor surface condition, and point to the need of a detailed investigation of the pavement being required. Therefore, to allow for timely rehabilitation, the corrective works should be considered and arranged when the present serviceability values reach about 2.5.

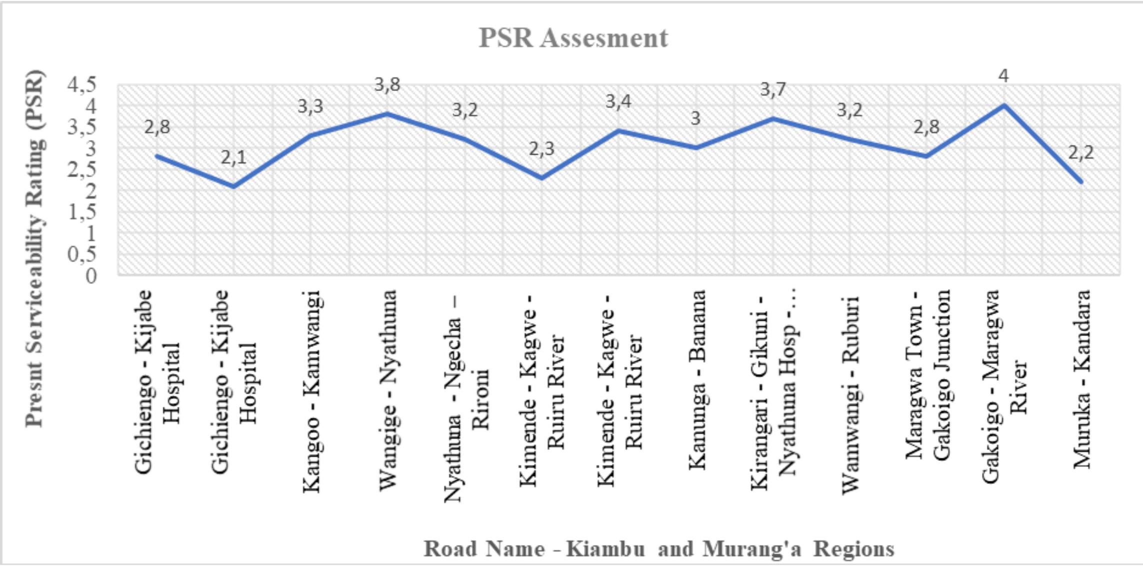

FIGURE 4
Present serviceability rating assessment
Source: Author, 2024

CONCLUSION AND RECOMMENDATIONS

Present Serviceability of the Implemented Low Volume Roads

It was established that of the thirteen assessed roads, 54% had a good serviceability rating, while 46% had a fair rating. Practice recommends that present serviceability values of 2.0 for low volume sealed roads need to be considered as the minimum that indicates when rehabilitation is required. Consequently, to allow for timely corrective works, pavement rehabilitation need to be considered and programmed once the present serviceability values reach about 2.5.

It was concluded that three roads, that is Gichiengo – Kijabe Hospital (E443/1), Kimende – Kagwe – Ruiru River (D402/1) and Muruka – Kandara (D415/1) had their present serviceability values below 2.5 and a more detailed investigation of their pavements was required to determine the appropriate rehabilitation method necessary to improve the structural capacity.

Performance of the Implemented Low Volume Roads

a) Drainage Assessment

It is crucial that runoff is efficiently drained from the road surface and surrounding areas into suitable side drains, and then further away from the road reserve via culverts and mitre drains. Where runoff is allowed to stagnate on the road for long, it has the likely effect of causing structural damage to the road pavement. The assessment carried out on the side drainage performance showed that 93% of the assessed roads had the drain depths inadequate to allow free flow of water. The presence of siltation and clogged trash on the drains was an indication of inadequate maintenance. Shallow side drainage is not desirable as it allows water to ingress into the pavement via the pavement edge.

b) Roughness Measurement

The high roughness values obtained from the field investigations of the roads were deduced to be as a result of ruts, potholes, among other surface defects. This was concluded as an indication of inadequate timely maintenance of the road's surfaces. Properly planned routine maintenance is key in ensuring low roughness values and thus low road user costs. It was observed that despite the improvement contracts having an inbuilt three years' performance based routine maintenance component, which was being funded by the road maintenance levy fund, and which was administered by local road authorities and County Governments, maintenance was still a challenge as the bodies prioritised opening of new roads and other roads instead of the newly improved roads.

c) Rut Depth Measurement

The rut depth values obtained were generally considered to be in good to very good condition. Such low rut depth values indicated that there was minimal structural failure of the base, sub-base or the subgrade. Low rut depths are likely to originate from the surfacing. It was determined that rutting varied with direction of traffic in all the roads surveyed. The surveyed roads traversed agricultural regions where farm produce is transported to the various markets. Thereby, medium goods vehicles were found to be the main contributor of traffic loading on the assessed roads.

Overall performance

The research established that the completed low volume sealed road pavements in Kiambu and Murang'a regions under phase two of the R2000 Strategy were in good condition, offering a fair to good ride quality and the deterioration stages as showcased by rut and pothole distresses which were not at terminal levels. With proper and all-round conditional assessments, followed by timely, adequate and efficient maintenance regimes, the roads were expected to meet their design lives and continue serving the population in these regions, composed of agricultural and peri-urban communities.

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