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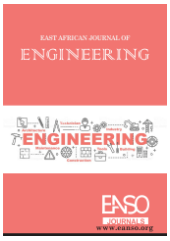

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Original Article

Performance of Roads Implemented under the Roads 2000 Strategy in Central Kenya

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Roads 2000, RMLF, Design Life, Deterioration, KeRRA, MoR, LVSR.

ABSTRACT

The road sector in Kenya is an integral part of its economy. The country has approximately 170,000 kilometres of road network, managed by the line ministry through the Kenya Roads Board (KRB), Road Authorities, and other Agencies. Insufficient financial resources and organisational and operational systems with inadequate investment in maintenance have led to the devaluation of the road network as an asset, as well as the aftermath effects of high vehicle operating costs which directly affect the economy negatively. The deplorable condition of these road assets led the Government of Kenya to shift its emphasis from the construction of new roads to the rehabilitation and maintenance of the existing road network using the maintenance strategy known as the Roads 2000 Strategy. The strategy aims to improve road maintenance and construction by introducing appropriate technology on a road network basis for the selective rehabilitation, spot improvement and maintenance of prioritised links. The strategic goal of the R2000 program is to bring the rural road network of Class D, E, and special purpose roads including parts of the unclassified network to a maintainable standard and ensure that KRB Road Maintenance Levy Fund (RMLF) resources are used to maintain the maintainable and recently improved road network. This study aimed to assess the success and impacts of the R2000 program in Central Kenya. Roads constructed under the three batches of phase two were investigated to establish the current condition of the roads. The present serviceability was assessed and compared to the design life of the roads. The condition survey investigated the traffic status, surface and structural conditions. All the data from these studies were analysed using the appropriate methods and the results were used to make a valid conclusion on the performance of the completed low-volume sealed roads. The major defects on the roads were noted and examined closely to determine the extent and cause of the defects. Such defects included pothole formation, delamination of pavement layers, longitudinal, transverse and crocodile cracking, encroachment of vegetation onto the carriageway and stone loss. Each road had its own specific dominating defects, arising from different prevailing

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weather, traffic or material conditions and road use. Tests and measurements conducted on the pavements showed the completed low-volume sealed roads generally have a strong pavement that is adequate to carry 15-year design traffic. Axle load surveys showed the 10 and 15-year design traffic classes for completed roads still fall within the expected low-volume sealed roads traffic classes. The roads surveyed generally had good to very good side drainage. The defects observed in the majority of the roads such as cracks, aggregate loss, edge breaks, rutting and potholes, among others, were only limited to the surfacing.

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INTRODUCTION

As part of research at the Department of Civil and Construction Engineering, University of Nairobi, on the evaluation of the Roads 2000 strategy in central Kenya, the performance of the implemented roads was analysed with a view of establishing the present and the desired serviceability indexes.

Planned labour-based road works in Kenya started in the 1970s with the Rural Access Roads Program (RARP), executed between 1974 and 1986, where approximately 8,000 km of farm-to-marketplace access roads were constructed. The Minor Roads Program (MRP) was implemented next, between 1986 and 1996, where approximately 4,500 km of the classified Secondary (D), Minor (E), and Special Purpose roads were improved (MRPW, 2013).

It was revealed in the 1990s that the road maintenance regimes in place were inadequate to maintain the high number of improved roads in good condition. In a bid to solve the problem, the government initiated the R2000 Strategy. The concept is a technique of road development and management that guarantees optimum utilisation and development of roads by the use of locally available resources where technically and economically feasible. The strategy was to be initiated countrywide to cover the whole road network, founded on the lessons gained from the two-preceding labour-based programmes. The concept was anticipated to be complete by the year 2000, hence the term "Roads 2000" (MRPW, 2013).

Nevertheless, owing to the numerous institutional and operational challenges, the concept was executed only in six districts by the year 2000 and its influence was limited. To increase the uptake of the strategy, the government established an R2000 Strategic Plan in 2004 for the period from 2005 to 2010. The plan was to offer a framework for the execution of the strategy. In 2010, when the plan was concluded, the strategy had been

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realised in numerous parts like Eastern, Nyanza, Central, and Rift Valley. Approximately 8,000 km of roads were upgraded by the program, and about four million man-days of employment were created in the rural areas, where such openings were limited. In addition, the programme advocated for the incorporation of social and environmental matters into the road sector (MRPW, 2013).

Invigorated by the accomplishments of the 2004-2010 Strategic Plan and the desire to increase the gains to people all over the country, the government developed the second R2000 Strategic Plan. The new plan was intended to address the difficulties met during the execution of the preceding R2000 programme, to additionally develop and roll out the R2000 strategy, and consolidate the achieved gains (MRPW, 2013).

LITERATURE REVIEW

Flexible pavement deterioration is normally brought about by actions of traffic and climate. The deterioration is exhibited by (a) 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 (O'Flaherty, 2002).

Performance can be evaluated by collecting data on/and analysing the road condition. Highway condition needs to be monitored effectively and in ways that minimise disruption to road users. Therefore, condition survey plans should apply quick, first-pass survey methods to acquire an indication of the condition of the pavement. The regularity of the surveys is informed by prior information regarding the pavement's condition and age. The rapid survey outcome determines the essence for and frequency of detailed surveys to establish if and what type of maintenance treatment is needed. Additional investigations may comprise material analysis to precisely establish the exact treatment (O'Flaherty, 2002).

For low-volume sealed roads, three methods are normally used to carry out condition surveys: (i) average speed, (ii) Road Inventory and Condition Survey (RICS), and (iii) Present Serviceability Rating (PSR). The Present Serviceability Rating (PSR) procedure involves the determination of the present serviceability rating of a road section based on a visual condition survey conducted through walking or windscreen inspection. The raters of the road section are required to observe its riding quality and defects and record impressions on a standard form. Rating varies from "0" (Very poor) to "5" (Excellent). Low ratings indicate poor surface conditions and suggest a more detailed examination of the pavement is required. The PSR may be used as a first step in evaluating the adequacy of a pavement. Each individual rating should be an overall opinion or impression of the pavement's present serviceability based on the past experience of the rater (Kenya Road Department, 1988).

The rules and procedure for determining the PSR are:

- The rater should consider only the present condition of the surface and consequently a pavement may be rated 'good' even if it is strongly suspected that it will fail in the near future;
- The rating should be based on the fact that the pavement has to carry mixed traffic (high-speed cars and low-speed trucks) under all types of weather conditions;
- The geometric characteristics (alignment, carriageway, and shoulders width) of the section of the road being rated should be ignored;
- The rating should be concerned primarily with longitudinal and transverse distortion of the surface, potholes, bumps, cracking, and patching;

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- The rater should ignore isolated conditions, such as bumps due to settlement at culverts and bridges, rough railway crossings;

- In rating a series of pavement sections, each section should be rated independently and the rater should not refer to completed forms to see what value was assigned to the previous section (Kenya Road Department, 1988).

Ratings of 0 to 5 are assigned to each criterion with a higher number indicating more satisfactory condition. The rating criteria are tabulated in Table 1. Immediately after driving over the section, the rater should note the main factors influencing his rating without weighing them and assign a rating to the pavement by assigning value to each of the twelve criteria given in *Table 1* (Kenya Road Department, 1988).

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Table 1: Rating Factors

Present Serviceability Rating (PSR) For Flexible Pavement							
Rating Factors							
A. Fracture (Cracking or Spalling)							
Crazing (Block & Alligator Cracking)		**Longitudinal Cracking**		**Transverse Cracking**		**Edge Spalling**	
Extent	**Points**	**Extent**	**Points**	**Extent**	**Points**	**Extent**	**Points**
None/0-5yrs	5	None/0-5yrs	5	None/0-5yrs	5	None/0-5yrs	5
None/>5yrs	4	None/>5yrs	4	None/>5yrs	4	None/>5yrs	4
1 location	3	1 location	3	1 location	3	1 location	3
2-5 locations	2	2-5 locations	2	2-5 locations	2	2-5 locations	2
6-10 locations	1	6-10 locations	1	6-10 locations	1	6-10 locations	1
>10 locations	0	>10 locations	0	>10 locations	0	>10 locations	0
B. Distortion (Permanent Deformation or Faulting)							
Rutting		**Corrugation/ Waves**		**Depression**		**Shoving/Heaving/ Upheaval**	
Extent	**Points**	**Extent**	**Points**	**Extent**	**Points**	**Extent**	**Points**
None/0-5yrs	5	None/0-5yrs	5	None/0-5yrs	5	None/0-5yrs	5
None/>5yrs	4	None/>5yrs	4	None/>5yrs	4	None/>5yrs	4
1 location	3	1 location	3	1 location	3	1 location	3
2-5 locations	2	2-5 locations	2	2-5 locations	2	2-5 locations	2
6-10 locations	1	6-10 locations	1	6-10 locations	1	6-10 locations	1
Entire length	0	Entire length	0	Entire length	0	>10 locations	0
C. Disintegration							
Bleeding/Gazing		**Stripping/ Ravelling**		**Patch**		**Pothole/ Disruption**	
Extent	**Points**	**Extent**	**Points**	**Extent**	**Points**	**Extent**	**Points**
None/0-5yrs	5	None/0-5yrs	5	None/0-5yrs	5	None/0-5yrs	5
None/>5yrs	4	None/>5yrs	4	None/>5yrs	4	None/>5yrs	4
1 location	3	1 location	3	1 location	3	1 location	3
2-5 locations	2	2-5 locations	2	2-5 locations	2	2-5 locations	2
6-10 locations	1	6-10 locations	1	6-10 locations	1	6-10 locations	1
>10 locations	0	>10 locations	0	>10 locations	0	>10 potholes	0
KEY: yrs. = Years Surfacing							

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METHODOLOGY

This study was intended to evaluate the Roads 2000 program in the Central region of Kenya, particularly in Kiambu and Murang'a regions. The recorded objectives of the program 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 Kenya Rural Roads Authority (KeRRA) at the 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; and,
- Maintenance of 6,000 km of roads within the Kiambu, Murang'a, Kirinyaga, Nyeri, Laikipia and Nyandarua regions.

To achieve the objectives of this study and to independently and quantitatively evaluate the program, the following aspects of the program were assessed:

- A condition survey of the completed and handed over for maintenance roads under the program was conducted.
- Based on the findings of the condition survey, an analysis of the deterioration and pavement design life of the roads was analysed.

A representative sample was taken, using the accepted contract project costs as the basis for sampling. Of the total cost of the batch under consideration, the sampled roads had a cumulative project cost of at least forty per cent of the total cost of implementation of the roads under that batch.

The present surface road condition of the sampled roads was assessed using the following measurements:

- Visual Condition Survey (on-carriageway and off-carriageway).
    a) Roughness Measurements (Rough-o-meter, Road-Lab, Merlin Meter)
    b) Rut Depth Measurements
    c) Road Condition Rating Criteria
- Visual Condition Survey of Pavement and Drainage

Visual assessment was used to identify signs of distress and pavement defects that can affect its performance. These included:

- Describing the surface type;
- Describing the degree of pothole formation;
- Describing the extent of edge breaks on the pavement;
- Checking surface cracking and describing the extent and type of cracking;
- Describing the geometry of each chainage section;
- Describing the drainage condition of the pavement.

Pavement Condition

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

Roughness Measurements

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The roughness of road pavement is a measure of its functional condition. High levels of roughness are the largest contribution to the part of the road user costs that are affected by road conditions. Most pavement defects contribute to increasing the roughness of the road pavement, either directly from a deformed surface or indirectly as a result of repair work of cracks and potholes. Changes in the roughness value over time are an indicator of the occurrence of pavement distress.

The road roughness for all roads was measured using the Rough-o-meter and Road-Lab equipment. The Merlin apparatus was 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 according to *Table 2*.

Table 2: Roughness Measurements

Parameters	**Condition Rating (Sound, Warning, Severe) Threshold values (IRI value m/km)**		
	All Traffic Classes		
	Sound	**Warning**	**Severe**
Roughness	< 6	3 - 6	> 6

Rut Depth Measurements

The rut depth was measured by the use of a three-metre-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 were recorded.

Road Condition Rating

The overall pavement condition based on the visual assessment was carried out and described based on *Table 3*.

Table 3: Description of overall pavement condition ratings

Degree	**Description**
Very Good	Very few or no defects. Degree of defects < 3 (less than warning).
Moderate	Few defects. Degree of structural defects mostly less than the warning.
Poor	A few defects with degree of defects are seldom severe. The extent is only local if the degree is severe (excluding surfacing defects).
Very Poor	General occurrence of particular structural defects with degrees warning to severe.

Present Serviceability Rating

The Present Serviceability Rating (PSR) provides a quantitative assessment of the overall condition of the pavement. The PSR for each pavement section rated is the mean of the individual rating values assigned to each rating criterion. The criteria consider the following twelve defects, while Table 4 shows the rating used to assess the performance of the road sections.

- Crazing (Block & Alligator cracking)
- Longitudinal cracking
- Transverse cracking
- Edge spalling
- Rutting
- Corrugation/Waves

Article DOI: https://doi.org/10.37284/eaje.5.1.883

- Depression/Longitudinal irregularity
- Shoving/Heaving/Upheaval
- Bleeding/Glazing
- Stripping/Raveling
- Patched areas
- Pothole/Disruption

Table 4: 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

Research Scope

The study focussed on Phase 2 of the R2000 program in the Kiambu and Murang'a regions. Phase 2 was implemented in three batches, with the level of investment as detailed in *Table 5*. *Table 6* gives the sample valuation taken in the research.

Table 5: Phase 2 Project Investment in Kiambu and Murang'a

Batch No.	**Gravel Roads Amount (Kshs)**	**Low Volume Sealed Roads Amount (Kshs)**	**TOTAL (Kshs)**
Batch 1	258,591,783.60	186,064,818.84	444,656,602.44
Batch 2	812,522,729.26	487,171,684.74	1,299,694,414.00
Batch 3	-	1,126,152,837.67	1,126,152,837.67
TOTAL (Kshs)	1,071,114,512.86	1,799,389,341.25	2,870,503,854.11

Table 6: Summary of the sample investigated

Batch No.	**Total Investment Amount (Kshs)**	**Sample Value Amount (Kshs)**	**Sample Percentage**
Batch 1	444,656,602.44	337,542,432.49	75.91%
Batch 2	1,299,694,414.00	892,775,079.84	68.69%
Batch 3	1,126,152,837.67	1,126,152,837.67	100%
TOTAL (Kshs)	2,870,503,854	2,356,470,350	82.09%

FINDINGS AND DISCUSSION

The required depth of the side drainage below the formation level is 0.4 m. The roads with a depth exceeding 0.4 m below the formation and those with depths less than the required have been summarised in *Table 7*, and it was found out of the nine roads surveyed, only one road has a depth meeting the requirement. Roughness measurements presented in the same table show that 40% of the roads surveyed were found to be in Severe condition while the other 60% were in warning, based on the roughness values measured using a rough-o-meter.

The results of the rut depth measurements, as summarised in *Table 7*, show that the rut depth values obtained are generally considered good to very good. The findings of the present serviceability rating have been summarised in *Table 7*. 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.

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Table 7: Findings of investigations

Road Name and length	Road Location and phase/Batch	Maximum Deflection (Mpa)	Drainage Assessment	Rut Depth Rating	Roughness Measurement	Present Serviceability Rating
Maragwa Town – Gikoigo Junction road - D419 (I) (2.52km)	**Location:** Maragwa Constituency in Murang'a KeRRA Region Phase: 2 Batch: 1	824	Left Hand Side – Inadequate Right Hand Side - Adequate	Good	Based on Rough-o-meter – Warning **Based on** Road-Lab Pro - Sound	2.8 (Fair)
Gikoigo Junction – Nginda Sec. School - D419 (II) (3.34km)	**Location:** Maragwa Constituency in Murang'a KeRRA Region Phase: 2 Batch: 1	818	Left Hand Side – Inadequate Right Hand Side - Adequate	Good	Based on Rough-o-meter – Warning **Based on** Road-Lab Pro - Sound	4.0 (Very Good)
Muruka - Kandara Town - D415 (I) (3.75km)	**Location:** Kandara Constituency in Murang'a KeRRA Phase: 2 Batch: 2	672	Left Hand Side – Adequate Right Hand Side - Adequate	Good to Very Good	Based on Rough-o-meter – Severe **Based on** Road-Lab Pro - Warning	2.2 (Fair)
Gichiengo – Kijabe Hospital Road – E443/1 (3.25km)	**Location:** Lari Constituency in Kiambu KeRRA Region. Phase: 2 Batch: 2	-	Left Hand Side – Inadequate Right Hand Side - Inadequate	Very Good	Based on Rough-o-meter – Severe **Based on** Road-Lab Pro - Warning	2.75 (Fair)
Kang'oo - Kamwangi Road - E1531 (5.6km)	**Location:** Gatundu North Constituency in Kiambu KeRRA Region. Phase: 2 Batch: 2	-	Left Hand Side – Inadequate Right Hand Side - Inadequate	Very Good	Based on Rough-o-meter – Warning **Based on** Road-Lab Pro - Warning	3.3 (Good)

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Road Name and length	Road Location and phase/Batch	Maximum Deflection (Mpa)	Drainage Assessment	Rut Depth Rating	Roughness Measurement	Present Serviceability Rating
Wangige- Nyathuna - D378 (6.4km)	**Location:** Kabete Constituency in Kiambu KeRRA Region. Phase: 2 Batch: 3	-	Left Hand Side – Adequate Right Hand Side - Adequate	Very Good	Based on Rough-o-meter – Warning **Based on** Road-Lab Pro - Warning	3.8 (Good)
Nyathuna - Ngecha – Rironi - D378-2 (5.4km)	**Location:** Kabete Constituency in Kiambu KeRRA Region. Phase: 2 Batch: 3	-	Left Hand Side – Inadequate Right Hand Side - Inadequate	Very Good	Based on Rough-o-meter – Warning **Based on** Road-Lab Pro - Warning	3.2 (Good)
Kimende - Kagwe Ruiru River - D402-1 (6.0km)	**Location:** Githunguri Constituency in Kiambu KeRRA Region. Phase: 2 Batch: 3	-	Left Hand Side – Inadequate Right Hand Side - Inadequate	Very Good	-	3.3 (Good)
Kirangari - Gikuni - Nyathuna Hosp - Junction - E1520 (6.0km)	**Location:** Kabete Constituency in Kiambu KeRRA Region. Phase: 2 Batch: 3	-	Left Hand Side – Inadequate Right Hand Side - Inadequate	Very Good	-	3.7 (Good)

Article DOI: https://doi.org/10.37284/eaje.5.1.883

CONCLUSION

The findings of the drainage analysis show that out of the nine roads surveyed, only one road has a depth meeting the 0.4 m depth requirement. Shallow side drainage is not desirable as it allows water ingress into the pavement through the edge of the pavement layers

Based on the roughness values measured using a rough-o-meter, 40% of the roads surveyed were found to be in severe condition, while the other 60% were in warning condition. The high roughness values obtained result from ruts and potholes, among other surface defects may be deduced as an indication of inadequate timely maintenance of the surface of the road. Properly planned routine maintenance is key in ensuring low roughness values and, thus low road user costs. It was noted that despite the improvement contracts having an in-built three years Performance-Based Routine Maintenance (PBRM) segment to be funded through Kenya Roads Board's Routine Maintenance Levy Fund (RMLF), maintenance is still a challenge as the authority prioritises other roads instead of the newly improved roads.

The results of the rut depth measurements show that the rut depth values obtained are generally considered good to very good. This indicates that there is no structural failure of the base, sub-base or subgrade. Low rut depths are likely to originate from the surfacing. It has also been deduced that rutting varies with the direction of traffic on all the roads surveyed. Generally, all the roads fall within agricultural regions where agricultural products are expected to be transported to various markets. All the low-volume sealed roads surveyed had a 20 mm thick cold mix asphalt concrete. From the foregoing observation this appears to be too thin to withstand loading from the heavily loaded medium-good vehicles carrying agricultural products on most of these roads. 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.

Recommendation

It is recommended that all the side drainage whose depths do not meet the requirement be deepened and regular maintenance of the roads be done. Routine maintenance of the side drainage is recommended as it is key in ensuring that the water in the side drains does not ingress into the pavement layers. During such maintenance, deepening all the shallow side drains is highly recommended. Others such as unblocking culverts, and desilting of side drains and outfall drains, should also be carried out effectively. Cutting off vegetation which may grow either in the side drains or at the edges of the pavement should be done promptly as such vegetation is usually not good for the pavement as they hold water thus keeping the moisture content of the pavement layers high.

Properly planned routine maintenance of all the completed LVS roads is recommended in order to lower the roughness values and thus lower the road user costs. The high roughness values obtained are a result of ruts, and potholes, among other surface defects, which were deduced to result from inadequate timely maintenance of the surface of the road. The recommended maintenance strategy should be such that interventions for the defects such as cracks, potholes, and edge breaks, among others are carried out as soon as they are identified (warning condition).

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