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Evaluation of Pavement Performance: A Case of Bushenyi-Ishaka Road, Uganda, East Africa

Ahmed Abdirahman Bile, Kolawole Adisa Olonade and Muhaise Hussein

Department of Civil Engineering, School of Engineering and Applied Sciences, Kampala International University, Western Campus, Kampala, Uganda

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Abstract

Pavement evaluation plays vital roles in the life of any road system. It is needed to assess performance and identify appropriate maintenance methods to adopt. Bushenyi-Ishaka road is the major road that links Ishaka Town to Bushenyi and Mbarara towns. There have been several maintenances on the road but the road pavement kept failing. It was observed that there has not be pavement assessment on the road to suggest appropriate maintenance methods. This study, therefor, carried out pavement evaluation of the road with the view to identify its performance and providing suitable maintenance methods. Information were obtained from relevant stakeholders such as engineers and users to understand the frequency of maintenance and maintenance methods deployed on the road. Field study was also conducted to measure various pavement surface distresses at every 50 m on the span of 7km of the road. The 50 respondents cut across professionals working in relevant agencies. It was gathered that the road is of economic value to the people of Ishaka and damage frequently despite routine maintenance. There has not been any pavement evaluation study of the road. The outcome of the pavement evaluation indicated that potholes was the common distress on the road with average distress density (ADD) of 0.67 followed by alligator cracking at with ADD of 0.65, Edge cracking at 0.62, Rutting and Transverse & longitudinal cracking at 0.55 each. The least distress found was bleeding (0.27). In terms of Pavement Condition Index (PCI), the overall average value of the road obtained was 33% (0.33) indicating poor performance. Different maintenance techniques were then suggested depending on the distress obtained. It is important therefore that such studies are carried out in order to timely inform people in charge when they are supposed to carryout maintenance and which strategy/techniques to employ economically.

1.0 Introduction

The type, timing, and quality of care that a pavement receives is widely acknowledged to have a significant impact on its performance(Agarwal et al., 2017). Low maintenance efforts, according to research, contribute to quicker pavement deterioration and, as a result, increased user expenses and future repair cost (Chen et al., 2021). Pavement performance is the ability of road pavement conditions to meet various driving requirements, including functional and structural performance (Aghera et al., 2017). The state of the current flexible pavement must be assessed in order to determine which improvement approach should be used to increase its quality (Arambula et al., 2011).

According to (Hicks and Simpson, 2011) road pavement maintenance entails monitoring pavement health, addressing and repairing delamination, cracking, and potholes, and maintaining adequate pavement lane markings and striping, while (Gichaga, 2017) defines it as dealing with snow and ice on roads, keeping roads clear and drivable, and snowplow fleet maintenance and control. According to (Deng et al., 2017) asphalt pavements deteriorate as a result of a range of load impacts and environmental factors. Repetitive large truck loads and water infiltration of pavement areas are the most severe impacts, according to the study. The combined effect of these factors leads in a progressive degradation curve.

The Pavement Design and Management Guide from the Transportation Association of Canada and the Pavement Management Guide from the American Association of State Highway and Transportation Officials both provide useful information on pavement management processes like pavement performance prediction, maintenance and rehabilitation treatment selection, and more. It is noted that choosing the right maintenance therapy can be challenging, and that the cause of a particular ailment, the expected life of various therapies, as well as the cost and function of the road, must all be taken into account.

In developed countries, various important agencies, companies, and organizations have adopted a sustainable approach to planning and decision-making that considers economic, environmental, and social impacts; in this regard, pavement

management has become increasingly important, as roads age and deteriorate over time (Tiza et al., 2022). Pavement management has already been created in the United States and Canada, and it is widely used in North America. There has also been a significant advantage from using pavement management technology. Since they can be updated, Pavement Management Systems have been used to explore different strategies, determine the best alternative, base judgments on measurable attributes, criteria, and limitations, and employ feedback information about the system (Adefemi and Ibrahim, 2015).

In developing countries especially in Africa, road management agencies have limited resources, technical capability and staff, and for this reason, pavement performance is at low level with high level of decoration (Corazza et al., 2016). Africa is one of the biggest continents in the world, hence it's extended over an area of nearly 30 million km^2 with a population of nearly 760 million people. In sub Saharan Africa, the roads and highways play an important role in the transportation system however currently the state of the road network is that 44% of roads in a good condition of service, 22% and 34% respectively for the roads in a poor and medium condition of service (Corazza et al., 2016). Overall it can be said that the sub Saharan Africa's roads system is relatively at low level of service and this is due to different situations pavement deterioration being the leading factor.

Like other developing countries, many pavement maintenance projects are never performed within the estimated time, cost, quality and scope (Ssendawula, 2019). Health and safety considerations, environmental concerns, functionality issues, low profitability and difficulty in satisfying the project parties have all remained a tight spot. Several researches have been done on construction project performance aimed at improvement, but the problem continues to manifest itself (Agarwal et al., 2017). The developed countries like the United States of America, Germany and Britain, have however given hope that something can still be done to reduce the severity of the problem and this has only been through research and development.

However, pavement maintenance is essential in order to preserve the pavement in its originally constructed condition, protect adjacent resources and user safety; and provide efficient, convenient travel along the route, In Uganda, many road pavements whose lifespan would have been prolonged through maintenance are left to deteriorate to levels that would require major rehabilitation to make them motor able. Despite the, government expenditure on routine periodic road maintenance, pavements on highways

are poorly managed and maintained (MPED, 2012). Overlays, seal coats, pothole repair, and crack sealing are just a few of the maintenance techniques that have been used. The conditioned deficiencies on highway pavements indicate that the methods have not been used to their full potential as either corrective or preventive measures. (Gichaga, 2017). It is therefore based on this background context that this study focused on assessing pavement maintenance methods and pavement performance on highways in on Bushenyi - Ishaka Road South western Uganda.

Pavement management has become increasingly crucial as roads age and deteriorate in industrialized countries, as several significant agencies, firms, and organizations have embraced a sustainable approach to planning and decision-making that incorporates economic, environmental, and social implications (Ozer et al., 2016; Wakefield, 2022).

Preventive maintenance has been found to be considerably more cost effective than corrective maintenance in several circumstances when maintenance budgets are low, agencies are forced to focus on remedial repair rather than preventive maintenance (Ssendawula, 2019). Despite the methods used in pavement maintenance, pavement performance on Uganda highways is still poor. It is important therefore that such studies are carried out in order to timely inform people in charge when they are supposed to carryout maintenance and which strategy/techniques to employ economically. In this study therefore the researcher intended to evaluate pavement maintenance methods and pavement performance on Bushenyi - Ishaka highway in south western Uganda in order to identify relationship on pavement maintenance methods for improved pavement performance. Corrective maintenance is used to address day-to-day issues as well as defects as they occur. It could include both short-term and long-term solutions. Preventive maintenance seeks to keep the pavement at or above a certain minimum acceptable level at all times, and it is used to keep the pavement from deteriorating further and necessitating corrective work. It may include structural and nonstructural changes to a pavement surface. The objective of the study is to evaluate the pavement maintenance practices conducted on the Busheyin-Ishaka road.

2.0 Materials and Methods

2.1 Study Area

The study was conducted on Bushenyi- Ishaka highway in the South western of Uganda, which is about 7 kilometers in length and 6.5 m in breadth. The road is a national road and it is of economic importance to the people of Ishaka as it is the main road that people from major cities like Mbara, Kampala approached Ishaka. More importantly, thousands of students of the Kampala International University Western Campus travel through the road. Most goods entering Bushenyi-Ishaka are transported through this road. The study was conducted for a period of one year i.e. April, 2021 to November 2022. This study adopted mixed methods research which involves both qualitative and quantitative data. A mixed method was adopted because it allows the researcher to get both breadth and depth of knowledge by combining quantitative and qualitative research.

2.2 Data Collection

To find out the most commonly used pavement maintenance methods and how often the road is maintained among other information on the study road, purposive sampling techniques were employed. Since the study road is a national road, it is being managed by both UNRA and Ministry of Works and Transport (MoW&T) where UNRA is directly in charge of its maintenance operations. Base on that, researchers interviewed all the key UNRA and MoW&T engineering team of Mbarara regional station that covers Bushenyi/Ishaka. To broaden the sample size, the researchers also interviewed top engineering staff of Bushenyi district / Municipal engineering team since the study road serves as their main trunk road. The research assumed that they are aware of what has been happening although they are not directly in charge of its maintenance operations. The sample size of those that provided information is as shown in the Table 1. Data relating to pavement maintenance was collected from professionals working with UNRA, MoW&T, Bushenyi district local government and Bushenyi-Ishaka Municipality.

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Table 1. Sample Size

Category	Sample Size	Participants	% Participation
Mbarara UNRA Team	21	19	90.5
Mbarara MoW&T Team	23	21	91.3
Bushenyi District Local Government Engineers	04	04	100
Ishaka / Bushenyi Municipal Council Engineers	06	06	100
Total	57	50	

Data pertaining to this objective was collected with the aid of a questionnaire, which was analyzed with the help of MS-Excel and later presented in form of tables, graphs and charts. To achieve this objective, the researchers developed research questions for a questionnaire. Part A of the questionnaire contained information relating to the background of the respondents such as profession, level of education, employer and work experience. Part B of the questionnaire contained information relating to the maintenance practices on the study road such as seeking to Data relating to Surface distresses and Pavement condition was collected through field observations, riding on the study road and counting for the case of potholes. The road pavement from Bushenyi to Ishaka which is 7 kilometers was divided into 15 sections (Chainages of 500metres with a starting point; CH 0+000 at Bushenyi district headquarters and the last chainage CH 7+000 at Ishaka roundabout) as shown in Equation 1. Each chainage was divided into 10 equal subsection each 50metres. Measurement was taken in 8 points within 10 subsections of a particular chainage, making a total of 80 data points for the chainage. The average value obtained was recorded as the distress measured for that chainage. This approach is based on the provision of ASTM D6433-18 (1996).

3.0 RESULTS AND DISCUSION

3.1 Demography of the Respondents

3.1.1 Profession of the Respondents

According to Figure 1, 72% of the respondents were Civil Engineers, 18% Mechanical Engineers, 6% Environmental Health and Safety specialists and 4% Project Managers. All the project managers had a background in civil engineering but had specialized in project management at post graduate level. Considering the professional background of the respondents was important because the nature of research questions require understanding of know triggers Pavement Maintenance, Pavement Maintenance Strategies deployed, basis of choosing maintenance strategy, methodology applied to develop the strategies, Pavement Maintenance Techniques and lastly problem areas/deficiencies that are faced while providing the needed maintenance strategy and Techniques.

2.3 Pavement Evaluation

$$N = \frac{\text{Total length of the Road}}{Length\ of\ \ a\ Sample\ Unit} + 1 = \frac{7000}{5000} = 15\ samples \quad [1]$$

where N = number of sample sizes

Thereafter, the following parameters were then estimated for each chainage for the whole road span.

a) Distress type
b) bSeverity level of the distress
c) Total Distress
d) Density of the distress
e) Deduct Value (DV) for individual distress types and Corrected Deduct Values (CDV)
f) Pavement Condition Index, PCI

technicalities involved in pavement maintenance so the researchers purposely interviewed groups of teams that are directly involved or been around as pavement maintenance activities are carried out. Civil Engineering teams develop maintenance plans and programs while mechanical teams are involved in maintenance and operation of equipment used. The Environmental Safety and Health Specialists provide a traffic management plan while maintenance works are in progress while Project Managers mostly do supervisory works. This feature of the respondents ensure confidence in the information provided on the characteristics of the road under study.

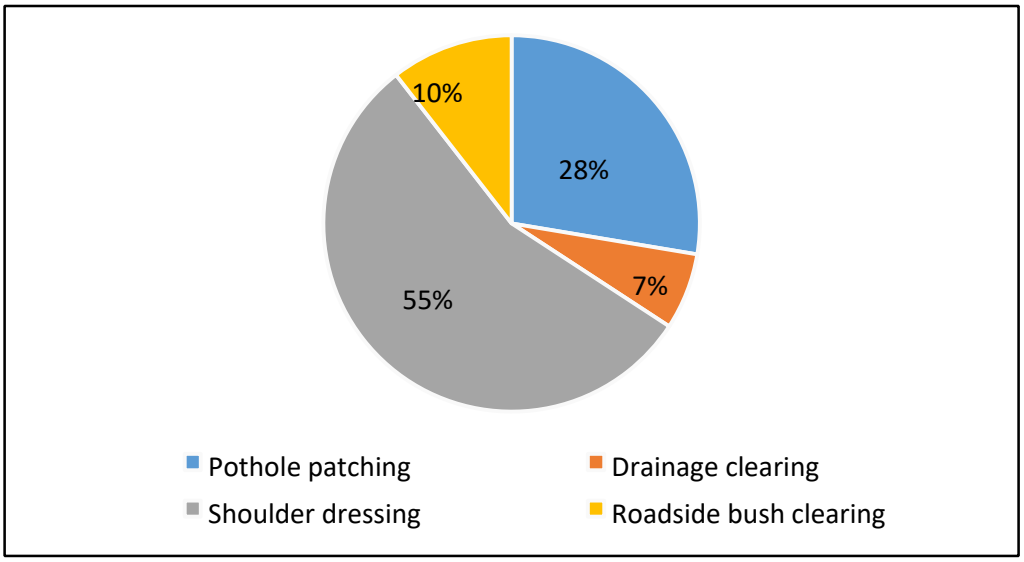

Figure 1: Professions of the Respondents

3.1.2 Education Level of the Respondents

Another vital features of the respondents that has strong impact on the information obtained is their level of education. This information further will enable the researchers to know if the respondents possess the adequate skills and knowledge to respond to the research questions. According to Table 2, 42% of the respondents have attained a Bachelor's degree, 24% have ordinary/advanced Diploma, 22% post graduate diploma and 12% master's degree. It can be deduced from this data that the respondents had the necessary skills and knowledge regarding to pavement maintenance, since the possess relevant qualifications.

Table 2. Educational Level of the Respondents

Education level	Frequency (N=50)	Percentage (%)
Advanced Diploma (AD)	12	24
Post Graduate Diploma (PGD)	11	22
Bachelor Degree (BSc)	21	42
Master Degree (MSc)	6	12
Total	50	100.0

3.1.3 Employer of the Respondents

To achieve this objective, data was collected from professionals working with Ministry of Works and Transport, Uganda National Roads Authority and Bushenyi district/Municipal council. The selection of these individuals was purposive because we needed people that are familiar to the road therefore knowledgeable on what has been taking place on and around it. According to figure 2, 48% of the respondents were employed by the Ministry of Works and Transport (MoW&T), 38% Employed by Uganda National Roads Authority (UNRA), 12% Bushenyin-Ishaka Municipality and 8% were from Bushenyi District Local Government (DLG). Since Bushenyi-Ishaka Road is a national road under MoW&T being managed and maintained by UNRA, the percentages reflected in Figure 2, confirms that we got information on its maintenance from the right people.

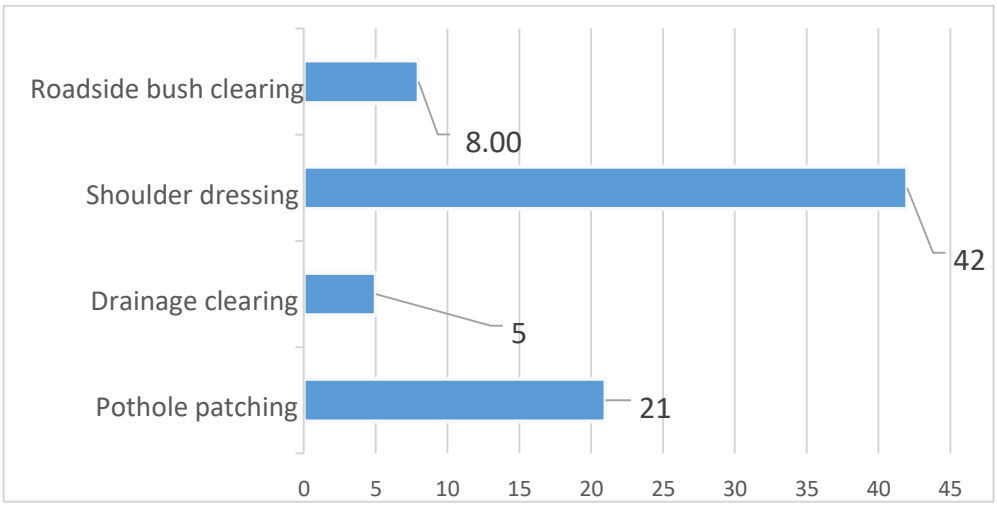

Figure 2: Employer of the Respondents

3.1.4 Work Experience of the Respondents:

In terms of work experience, 48% had 5-10 years of work experience, 36% less than 5 years, 12% 10-15 years and 4% with more than 15 years' work experience as shown in table 3.

Table 3. Work Experience of Respondents

Age bracket	Frequency (N=50)	Percentage (%)
Less than 5Years	18	36.0
5-10 Years	24	48.0
10-15 Years	6	12.0
More than 15 Years	2	4.0
Total	50	100.0

Having interviewed more respondents with a relative experience of 5-10 years, it is believed that they provided relevant and enough information in relation with the study under investigation.

3.2 Evaluation of Pavement Maintenance Methods

This section gives the information concerning the previous maintenance activities on Bushenyi-Ishaka road among other factors influencing the choice of maintenance as gathered from the stakeholders.

3.2.1 Factors influencing time for maintenance activities on the road

As presented in Table 4, it can be observed that maintenance activities on the road are mostly carried out whenever funds are available followed by according to a designed maintenance schedule, upon complaints from the users. Existence of visible defects and the need to protect the pavement are other factors that call for road maintenances. Meanwhile, availability of funds seems to be the major influencing factor. It was observed road maintenance funds released annually are not usually adequate which means that the road does not receive proper maintenance as evidenced in the deplorable condition of the road.

Table 4. **Factors influencing time of maintenance**

Triggers	Frequency (N)	Percentage (%)
Visible defects	5	10.0
Complaints from users	8	16.0
Availability of funds	20	40.0
Maintenance schedule	15	30.0
To protect the pavement	2	4.0
Total	50	100.0

3.2.2 Common Pavement Maintenance Strategy Deployed on the Road

From the study, it was established that the most maintenance strategy deployed on the study road is routine followed by corrective and lastly urgent strategies as shown in figure 3. Routine maintenance strategies are always conducted on the study road to keep it at a minimum level of service. According to the respondents, such routine activities conducted include shoulder clearance, grass cutting and removal of trees that obstruct sight clearance. It was equally gathered that pavement patching formed the major corrective measure undertook, but there was no record of rehabilitation and surfacing laying maintenance in the last decade.

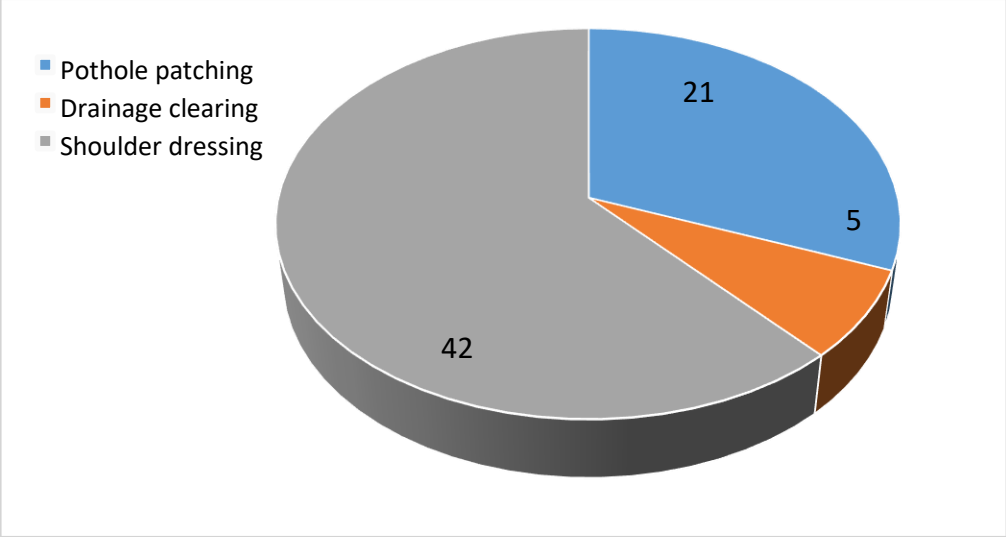

Figure 3: Most maintenance strategies that are deployed on the road

In adopting maintenance method as prescribed in the Ugandan Road Design Manual, cost effectiveness was a main criterium chosen as against the defects to be corrected. This further affirm that cost is a significant factor that dictates when to do maintenance and what type of maintenance to adopt.

While selecting the maintenance strategy to be deployed, all the respondents agreed that they only consider methodologies prescribed in the Uganda

Road Design Manual of 2010. It is evidenced from their responses that there has not been pavement evaluation to dictate the type of maintenance to adopt. Event though this might have been considered in the development of the manual, but exigencies of time and changes in weather call for review of the Manual that was developed over a decade ago.

3.2.3 Prevalent Pavement Maintenance Activities on the road

From the study, most respondents asserted that potholes patching was the leading maintenance technique deployed followed by shoulder repairs and lastly drainage cleaning and road side bush clearance as shown in Figure 4. Nevertheless, there has not been any major rehabilitation like pavement overlay in the recent past on the road. Without doubt these maintenance activities have positive impact in keeping the road in serving the users. Meanwhile, the performance is still low as established in the pavement performance index computed in the next section of this paper.

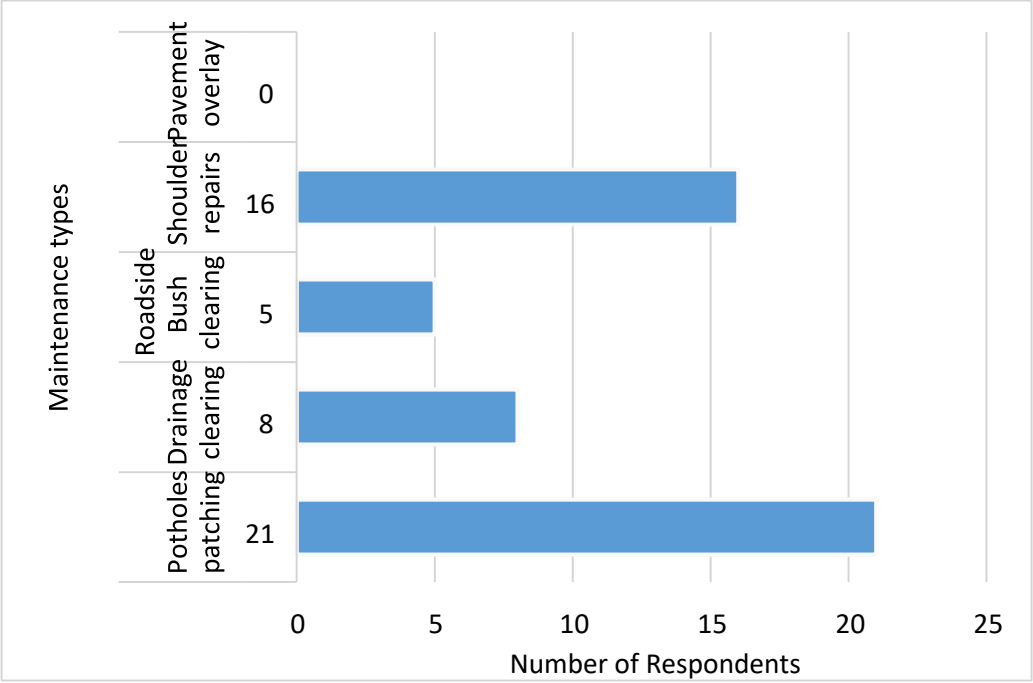

Figure 4: Prevalent maintenance types of the road

In getting understanding why the road performance was still low, 72% of the respondents attributed the poor

state of the road to inadequate funding to run maintenance activities, while 28% believed that there's lack of a proper system to select the appropriate order of repairs. They believe that some maintenance activities should be given priority over others because they make the pavement stay longer yet they are not expensive. It is evidence from the information obtained that there has not been road performance evaluation on the road. The next section gives results of the road performance evaluation conducted on the road under study.

3.3 Pavement Evaluation of the Road

3.3.1 Pavement Surface Distress Densities

Pavement distresses observed on the road were measured and distress density of each defect was determined. Figure 5 shows the different defects observed on the roads as well as their distress densities. The highest distress type on the pavement surface was found to be Potholes with an average distress density of 0.67 (67%) followed by alligator cracking at 0.65 (65%), Edge cracking was 0.62, while Rutting and Transverse & longitudinal cracking at 0.55. Bleeding with a least distress density (0.72) was least distress found on the road. The implication of this is that the road would not perform optimally. For instance, a frequent pothole as indicated by the density means that

 https://doi.org/10.59568/KJSET-2023-2-2-04

the road is rough. Apart from causing discomfort to the motorists, it could also result into severe damages to the vehicles plying the road. As for the alligator cracks, if it is not adequately repaired, it will give room for water to penetrate to the subbase and subsequently to the subgrade. This can degenerate to potholes and complete damage to the whole pavement.

Apart from identifying the distresses, the location where theses distresses equally identified (Figure 6). This is to facilitate ease of locating where adequate attention is required. As it is seen (Figure 6), Chainage 0+700 (within Ishaka from KIU to the Ishaka town) has the least form of distresses. Apart from Chainage 0+500 that has highest quantity of distress, there is continuous pockets of pavement distresses from 3+000 to 5+000 (2 km). At this range, it is difficult for motorist to travel beyond about 10km/hr. Any attempt to over speed in this region, will need to accident and severe damages to the vehicle cum serous discomfort to passengers. Therefore, there is urgent need to give the region special attention. The corrective measure here should be complete overlaying of the surface with adequate drainage

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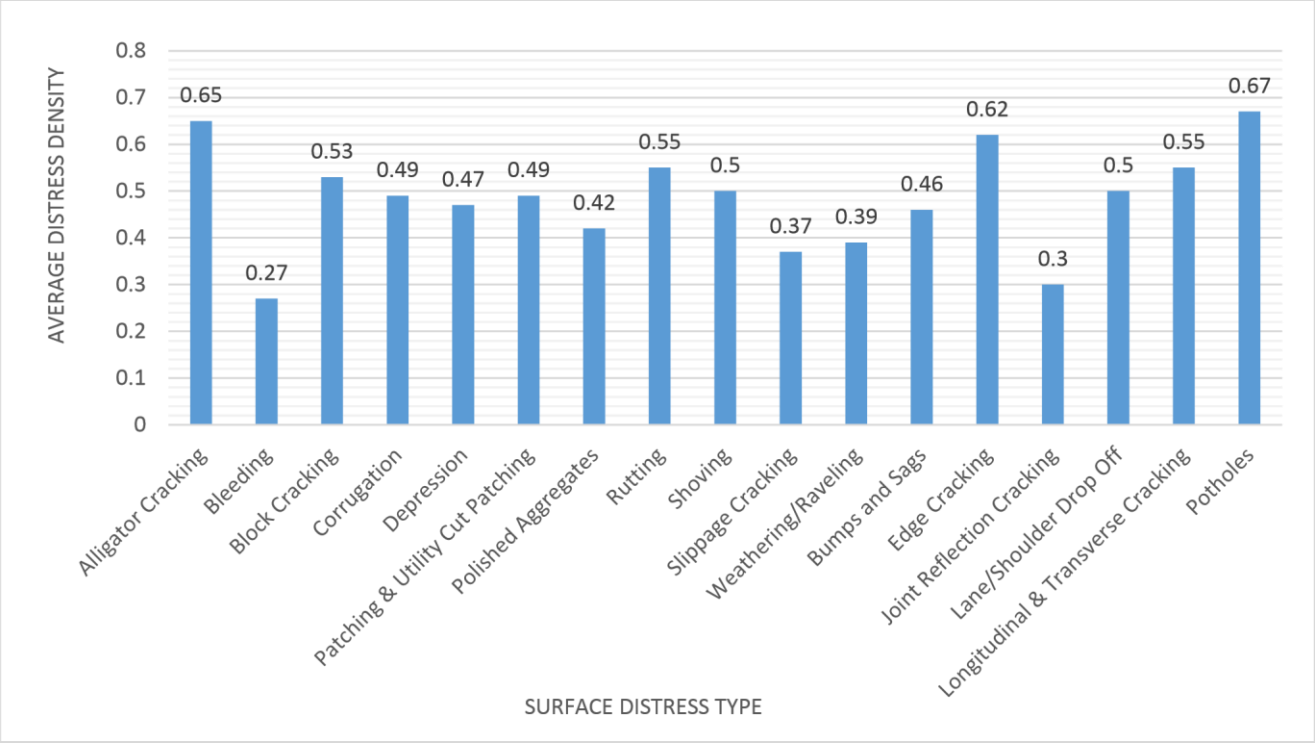

Figure 5: Different Surface Distresses present on the entire pavement and their Densities

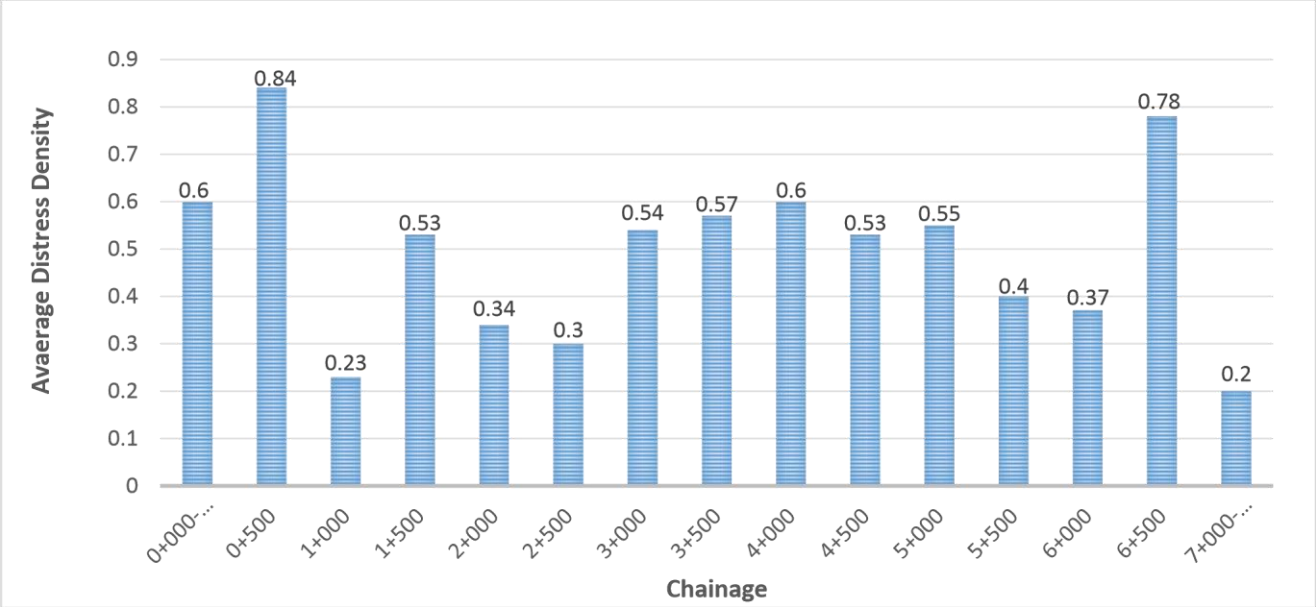

Figure 6: Surface Distresses Densities present at different chainages

3.3.3 Pavement Condition Index of the Road

Pavement Condition Index (PCI) is a numerical means of rating the pavement performance of a road. It provides an insight to the type of maintenance or rehabilitation to deploy to a road depending om the value of PCI. In this study, the PCI values of the road under study was computed first at every chainage of 500m and then average values for the entire roads was determined. The PCI values at designated chainages are presented in Figure 7, CH 7+000 has the highest value of 70% indicating that it has the best pavement performance compared to others. This is an indication that it has relatively low distresses and more convenient motorists as well as less damaging effect on the vehicle. Generally, the PCI values range between as low as 6% (CH 0+500) and 70% at CH.,7+000.

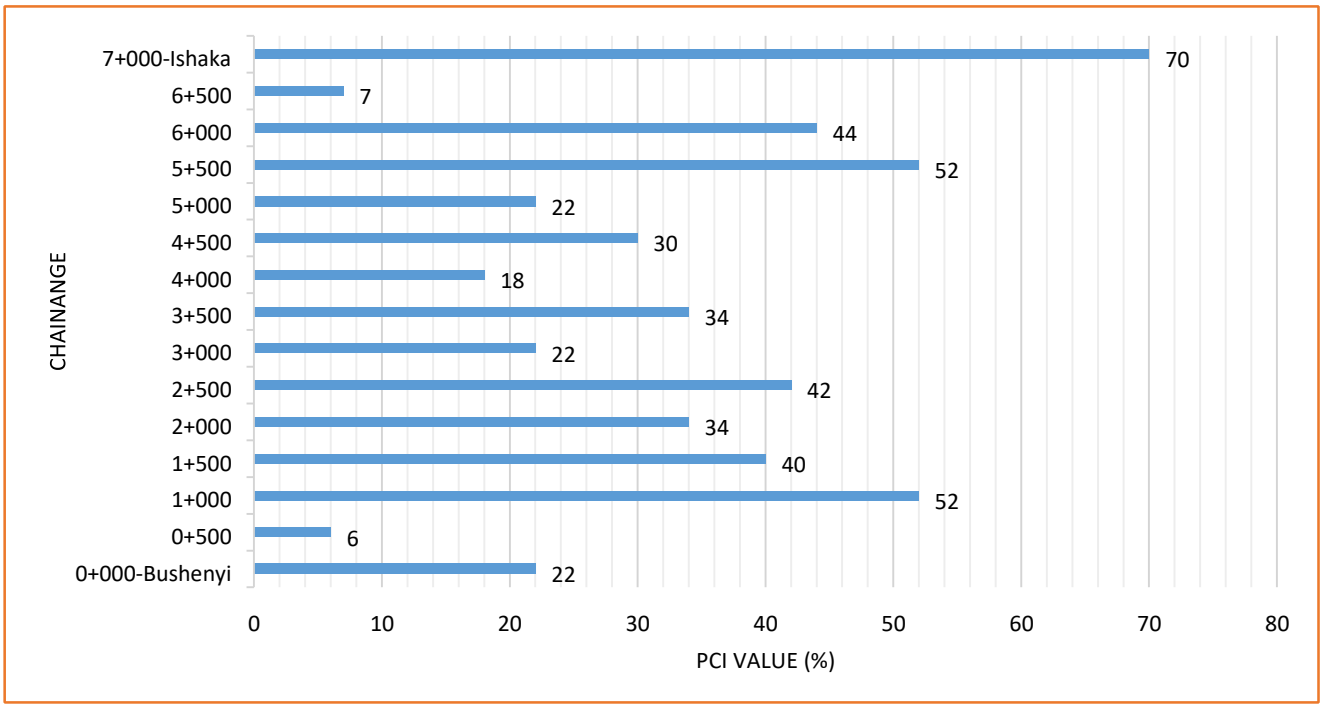

Figure 7: PCI at the different chainages on the road

Based on the classifications of PCI as recommended by (British Columbia Ministry of Transportation, 2020; Denso, 2009), the road portion between CH6+500 and CH7+000 it is adjudged as "Good" because it its PCI falls within 60 and 80. The portion of the road in the chainages CH 1+500 and CH 5+000 (PCI < 40) are classified as "Poor" indicating that that portion is not friendly for riding vehicle. Only two portions of the road (CH 1+000 and CH 5+500 to CH 6+000) are accepted to be fair because their PCI values fall in the range of 40 - 60.

Nevertheless, the overall PCI for the entire road is 33% indicating that the road is poor in terms of performance. Based on the overall pavement assessment, pavement maintenance methods are recommended depending om the PCI values. The recommendations are presented in Table 5. It can be seen that current maintenance approach on the road may not salvage the road from imminent collapse.

Table 5: PCI Values, Rating and Recommended Maintenance Techniques

S/N	CHAINAGE	PCI (%)	RATING	Recommended Maintenance
1.	0+000-Bushenyi	22	Very Poor	Reconstruction
2.	0+500	06	Failed	Reconstruction
3.	1+000	52	Fair	Routine
4.	1+500	40	Poor	Periodic
5.	2+000	34	Poor	Periodic
6.	2+500	42	Fair	Routine
7.	3+000	22	Very Poor	Reconstruction
8.	3+500	34	Poor	Periodic
9.	4+000	18	Very Poor	Reconstruction
10.	4+500	30	Poor	Periodic
11.	5+000	22	Very Poor	Reconstruction
12.	5+500	52	Fair	Routine
13.	6+000	44	Fair	Routine
14.	6+500	07	Failed	Reconstruction
15.	7+000-Ishaka	70	Good	Routine
AVERAGE		**33**	**POOR**	**PERIODIC**

4. CONCLUSION

The pavement condition evaluation of Bushenyi-Ishaka, a 7km asphaltic road was conducted. The following conclusion could be concluded from the study:

The road of economic importance to the people living and having business in Ishaka of the Bushenyi District. Different efforts have been geared towards keeping the road in shape but the laxity of fund has been major challenge. iii. Past maintenance methods on the road limited in scope and could not address the pavement condition of the road.

Overall performance of the pavement based on the PCI computation is adjudged to be Poor, the best portion of the road is just about 500m out of the 7 km length of the road.

It is therefore recommended that appropriate maintenance methods should be deployed to safe the road from complete collapse.

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Declaration of conflict of interest

I declared that there was no financial/personal interest or belief that affect our objectivity in the before, during or after the study presented in the manuscript with the article reference stated above.

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