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Research Article

Influence of Road Rehabilitation on Flexible Pavement Performance in Nigeria

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Abstract

Road rehabilitation is the processes involved in repairing portions of an existing pavement in order to reset the deterioration process. This paper establishes the influence of road rehabilitation on flexible pavement performance in Nigeria. A structured questionnaire was prepared to obtain the primary data for this research. The survey population consisted of 75.7% experts who have been involved in flexible pavement rehabilitation process, the population also included the 24.3% less educated but experienced equipment operators who have reasonable years and wealth of experience in pavement rehabilitation works, hence, confirming their suitability as respondents for this study. Data obtained from the survey were subjected to both descriptive and statistical analysis through one-way analysis of variance (ANOVA) on the survey data using statistical package for social sciences (SPSS) to establish or otherwise the influence of road rehabilitation on flexible pavement performance. The findings revealed that the design factors variable indices under the Likert scale of 5-strongly agree which were 2.15, 2.51, 3.34, and 3.61, likewise the performance variables under the same category which were 0.83, 0,55, 1.64, and 2.63 are the highest which means design factors affect rehabilitation significantly and performance factors affects pavement performance significantly. These category factors were cross-analysed and the results established the significance of the study and confirmed the influence of road rehabilitation on flexible pavement performance in Nigeria. In conclusion, rehabilitation of flexible pavement should be carried out by experts with the intent to achieve the factors of pavement performance.

Keywords

Rehabilitation, Pavement, Analysis of Variance ANOVA, Cross-Analysis

1. Introduction

The road network is one of the most important infrastructures for the development of a country. Flexible pavement should not be seen solely as a means of transportation, but as a crucial asset to economic and social growth and development because it facilitates job creation which makes it profitable, and also ensures mobility and accessibility of peoples and goods within the country and beyond [1]. A paramount component of the road network is the pavement, which provides a smooth riding surface that allows ease of movement to the end users; motorist and pedestrians alike throughout the

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pavement's life cycle. The pavement can either be "Flexible" as in the case of asphaltic road surfaces or "Rigid" as in the case of concrete road surfaces [5, 6]. The process of accumulation of damage is called deterioration and the pavement at this point is said to have reached the limiting stage of serviceability [9].

Road deterioration is very common in developing countries. [4] refers to road deterioration as the visible evidence of an undesirable condition in the pavement affecting serviceability, structural condition or appearance. He also indicates that the definition of "road failure" includes any part of a road, highway, or construction site that does not meet the regulations for a safe road. [7] Emphasized that flexible pavements deteriorate under traffic loads and climate effects. This effect depends on the technology and materials of the road, but the greatest effects depend on traffic loads and volumes. On his study on Nigeria highway, [11] has identified some of the factors that cause highway failure. These factors were; poor design and construction, poor maintenance of already built highways, use of low-quality materials in construction, poor workmanship and poor supervision of construction work and the applying of heavy traffic that were not meant for the road. Furthermore, he also suggests that the following will lead to highway failure such as; poor highway facilities, no knowledge base, inadequate sanction for highway failure, no local standard of practice, poor laboratory in situ tests on soil and weak local professional bodies in highway design, construction and management.

In a study investigating the effect of poor drainage on road condition it was found that the increase in moisture content decreases the strength of the pavement [12]. Therefore, poor drainage or flooding causes the premature failure of the pavement. On the same line, pavement tends to crack at some point of their life under the combined action of traffic and the environment and climate conditions [8]. [7, 8] In their investigation said that pavement fatigue is as a result of the number and weight of axle loads. They also discussed how wheel loads, number of truck axles, number of truck tires, quality of sub-grade, pavement thickness and changing seasons contribute to pavement fatigue. [3] Found that potholes, cracks, edge defects, depressions and corrugation are significant road defects observed in the field. At the same time, he emphasized that traffic, age, road geometry, weather, drainage, construction quality as well construction material, maintenance policy plays the major role as road deterioration agents. [9] Suggested that in the pavement or embankment, water plays a primary role in giving shorter service life and in increasing the need of rehabilitation measures. However, it is clear that highway pavement globally deteriorates for a number of reasons and factors as indicated earlier. Therefore, understanding the causes for highway pavement failures is essential and important step towards achieving good pavement performance.

The pavements however, on completion for use starts suffering from deterioration over time as a result of both the ever-growing traffic volume and environmental conditions. Therefore, rehabilitation interventions are required throughout the life cycle of the pavement in order to maintain its performance [10].

Flexible pavement rehabilitation comprises of a very sensitive and complex set of operations. Not only does this process rely on the use of expensive mechanical equipment, it often involves closing of road lanes resulting in travel delays for road user and other setbacks [13].

In their study, [11, 9] examined the method of road rehabilitation in Nigeria. To do so, they defined and analyze the causes of structural failure of highway pavement and suggest some factors; action of weather, rain and heat, unstable ground conditions and poor drainage, poor construction material and methods, post construction activities like digging of trenches along the road etc., poor workmanship and inadequate maintenance. Up to the present, most field research on flexible pavement rehabilitation focuses on developing and improving methods for scheduling of rehabilitation interventions, but attention has not been given to the influence of rehabilitation on flexible pavement performance.

The main contribution of this paper is the attempt to establish the influence of rehabilitation on flexible pavement performance in Nigeria. In the past five years annually, on the average, about 7 billion Naira has been invested by the Nigerian government on flexible pavement rehabilitation interventions. This raises the concern of the suitability of the road rehabilitation interventions and its influence on flexible pavement performance. Hence, the need for this paper. To achieve this objective, there is yet need to pin point factors contributing to pavement under-performance, understand their connectivity, and establish a frame work to identify them. This, through proper analysis will develop a comprehensive basis for pavement performance assessment which will in turn determine the influence of road rehabilitation on such a pavement based on extant literatures and statistical analysis.

2. Study Area

The study concentrates in Uyo a metropolitan city in the heart of Akwa Ibom State, Nigeria. It is located on 5.0377^0N and 7.9128^0E and the capital of Akwa Ibom state created in 1987 and located at the south-south region of Nigeria, thus, having tropical climate condition. Uyo has a total land area of 188.035 km2 and an estimated population of 3.920,208 peoples. Akwa Ibom State has a total road network of 6,288Km out of which 9.6% (602km) are federal government roads [2].

Akwa Ibom State has an effective Roads Maintenance and Rehabilitation Agency (AKROIMA) in Uyo. They are responsible for the maintenance and rehabilitation of dilapidated roads sections in Uyo metropolis and the state at large [2].

Figure 1. *location of Uyo, Akwa Ibom State.*

Evaluation of Road Conditions

The assessment of pavement conditions is an important step to know the level of road damage. Depending on which characteristic is being surveyed, a pavement evaluation can be classified as functional or structural [14]. Functional evaluation provides information about surface characteristics that directly affect the user's safety and comfort or serviceability. Structural evaluation provides information on whether the pavement structure is performing satisfactorily under the traffic load and environmental conditions [8].

Pavement evaluations are performed in the field through manual surveys or using specialized equipment. Evaluated characteristics of the pavement are quantified by means of indicators or condition indices. Data collection equipment should be reliable, efficient and secure. To ensure cost effective surveys and data referencing consistency, it is recommended to collect multiple pavement characteristics during a single phase of the data collection [13, 15].

3. Methodology Data Collection

3.1. Interview and Questionnaire Administration

The research design for this study was through structured questionnaire placed on a five-point Likert scale (1-5) 1-disagree, 2-strongly disagree, 3-neutral, 4-agree, 5-strongly agree. Interviews were conducted with the prospective respondents on their willingness to contribute to the research before the questionnaires were given to them. The responses from this structured questionnaire formed the primary data used for this study. A stratified random sampling method was employed in engaging the respondents chosen for this research. The target population were road construction companies and personnels working within the perimeter of Uyo metropolis 5.0377^0N, and 7.9128^0E in Akwa Ibom State, Nigeria. The available population for this study was about 800 but only 200 representing 25% of the total population were considered. The questionnaire was self-administered by the researchers, 148 questionnaires were duly completed and returned. 25% of the population surveyed should be considered in the light of the 148 respondents out of 200 and not in the fraction of the total population.

3.2. Data Collection

The respondents were grouped into 4 distinct and independent groups; Project Managers, Engineers, Surveyors, and Equipment operators.

Table 1. *Demography of respondents.*

Profession	Frequency	Qualification	Experience	Member	%
Pjt. Mgr	3	M.Sc.	10-20	MNIM	
"	5	B.Sc.	10-20	MNIPM	
"	5	Others	20 and above	Others	

Profession	Frequency	Qualification	Experience	Member	%
	13				8,8
Engineers	8	M.Eng.	10-20	MNSE	
“	15	B.Eng.	0-10	MNSE	
“	18	B.Eng.	10-20	MNSE	
“	15	HND	0-10	MNATE	
“	12	HND	10-20	MNATE	
	68				45.9
Surveyors	11	B.Sc.	0-10	MNIS	
“	8	HND	0-10	MNIS	
“	12	HND	10-20	MNIS	
	31				21.0
Operators	7	SSCE	0-10	Nil	
“	8	Trade Test	0-10	Nil	
“	21	Trade Test	10-20	Nil	
	36				24.3

According to table 1, about 75% of the respondent are well informed on the subject of the research. 45.9% are engineers who have been directly involved in road rehabilitation projects, while 24.3% of the respondents were operators who are equally skilled and experienced in road rehabilitation. More importantly the years of professional work experience for the respondent span within 0-20 years above, these years of experience is absolutely sufficient for the respondents to give dependable information on the influence of rehabilitation on flexible pavement performance.

Data from the survey were obtained as rating data. Mean value of the variables were subsequently analysed as ratio scale to make them amendable to parametric test which was made possible through descriptive computation. Likert rating scale was used to measure the variables and rate the ANOVA agreement indices.

4. Results and Discussions

The result of this study conducted in Uyo, Nigeria base on the structured survey questionnaire and painstaking selection of the respondents corroborates the findings of [11] who established public perception on influence of rehabilitation on flexible pavement performance. Simple regression analysis was employed to analyse and establish the index of pavement performance for the results of the 148 respondents. From the survey, 12 factors were identified as factors necessitating rehabilitation of flexible pavement as shown in table 2, they were categorized as 3 independent variables which were management (M), construction (C), and design (D). Likewise, 6 variables were selected for assessment of pavement performance as seen in table 3, they were categorised as 2 dependent variables which were trips (T), and performance (P)c. The dependent and independent variables were summarized into a single composite function and regressed over each other in cross analysis in other to establish the significance of the dependent over the independent variables which will in turn establish the influence of road rehabilitation on flexible pavement performance. One-way analysis of variance (ANOVA) on the survey data was carried out using statistical package for social sciences (SPSS).

4.1. Pavement Assessment

The assessment of the pavement in need of rehabilitation by the survey resulted in categorizing factors as seen in table 2. Considering the likert scale (1-5), at scale rating of 5-strongly agree, the design factors; Poor design, Heavy vehicle/traffic plying the road, Flooding, and Road defects recorded highest index of assessment of 2.15, 2.51, 3.34, and 3.61. this implies that, the respondents collectively and strongly agreed that the design factors are the most influential factor that causes pavement under-performance necessitating rehabilitation. Also, the ANOVA results in table 3 indicated that design factors had the highest insignificance (B), which again implies that, these factors were the list significance during pavement assessment to justify need for rehabilitation.

Table 2. Pavement Assessment.

S/N	Factor	Category	5	4	3	2	1
1	Lack of proper and timely maintenance	M	0.84	0.63	0.64	0.94	0.29
2	Lack of effective quality control	"	1.30	0.69	0.87	1.40	0.32
3	Non-adherence to specification	"	1.76	1.25	1.27	1.86	0.35
4	Lack of skilled supervision	M	0.78	0.64	0.36	1.18	0.30
5	Construction errors	C	0.82	0.80	0.66	1.16	0.67
6	Construction with low quality materials	"	1.64	0.94	1.22	1.14	0.91
7	Poor compaction and drainage	C	2.04	1.09	1.28	1.12	1.21
8	Poor design	D	2.15	0,99	1.29	1.10	1.50
9	Heavy vehicle/traffic plying the road	"	2.51	1.32	1.93	2.61	0.26
10	Flooding	"	3.34	1.52	2.08	2.51	0.29
11	Road defects	D	3.61	1.72	2.23	2.30	0.50

Table 3. ANOVA Results for Pavement Assessment.

S/N	Category	Statistics	5	4	3	2	1
1	Management	F	19.32	16.07	9.32	19.04	0.24
		dF	2.00	2.00	2.00	2.00	2.00
		Ss (between)	1.29	0.27	0.62	1.27	0.01
		significance	A	A	A	A	B
2	Construction	F	38.56	4.54	27.17	0.12	24.40
		dF	2.00	2.00	2.00	2.00	2.00
		SS (between)	5.14	0.36	2.17	0.01	2.60
		significance	A	A	A	B	A
3	Design	F	29.30	5.40	2.03	2.46	2.24
		dF	2.00	2.00	2.00	2.00	2.00
		SS (between)	1.95	0.24	0.04	0.04	0.01
		significance	A	A	B	B	B

4.2. Pavement Performance

Table 4 shows that the performance category at scale rating of 5 collectively had the highest index of performance, but singularly, end user satisfaction as it relates to smoothness or roughness had the highest performance index. This implies that, of the seven factors of pavement performance, end user satisfaction should be considered the most during rehabilitation. But on the whole, performance factors should be given prime attention in other to establish the influence of rehabilitation on pavement performance. The ANOVA results in table 5 shows that performance rating index were all significant (A) except those that strongly-disagreed (1). Unlike the trip factors index which had the highest insignificance (B).

Table 4. Pavement Performance.

S/N	Factor	Category	5	4	3	2	1
1	Travel motivation	T	1.54	0.64	0.71	1.60	0.72
2	Reduced travel time	“	1,00	1.67	0.87	1.51	0.42
3	Reduction in road issues	T	1.71	0.82	0.65	1.51	0.72
4	Reduced stress	P	0.83	1.33	0.61	1.16	0.91
5	Reduced wear/tear on vehicles	“	0.55	1.51	0.64	0.32	2.01
6	Increased economic activity	“	1.64	0.96	2.20	1.60	0.80
7	End user satisfaction(smoothness)	P	2.63	1.60	0.53	1.54	0.64

Table 5. ANOVA Results for Pavement Performance.

S/N	Category	Statistics	5	4	3	2	1
1	Trips	F	5.34	8.28	0.36	13.66	6.00
		dF	2.00	2.00	2.00	2.00	2.00
		SS (between)	0.02	0.04	0.73	0.61	0.00
		significance	B	B	A	A	B
2	performance	F	16.57	17.29	3.23	4.54	0.12
		dF	4.00	4.00	4.00	4.00	4.00
		SS (between)	2.21	2.31	0.43	0.36	0.01
		significance	A	A	A	A	B

4.3. Test of Significance

In tables 6 and 7, the result of the cross-analysis of variance where the indices of the dependent factors variable category; management (M), construction (C), and design (D) were cross-analysed over the indices of the dependent factors variable category; trips (T), and performance (P), confirmed that this study is significant because all the indices came back significant except few. Where there is no index (-) means there is no significance. Consequently, figure 2 expresses the influence of road rehabilitation on flexible pavement performance.

Table 6. Cross-Analysis of Variance.

Category	Rating	M	C	D
Trips	5	0.41	-	-
	4	0.81	1.69	-
	3	0.96	1.78	0.89
	2	1.01	2.01	1.09
	1	1.51	2.16	1.15

Table 7. Cross-Analysis of Variance.

Category	Rating	M	C	D
Performance	5	0.37	-	-
	4	0.41	0.77	-
	3	0.63	0.89	1.45
	2	0.66	1.18	1.72
	1	0.91	1.25	2.36

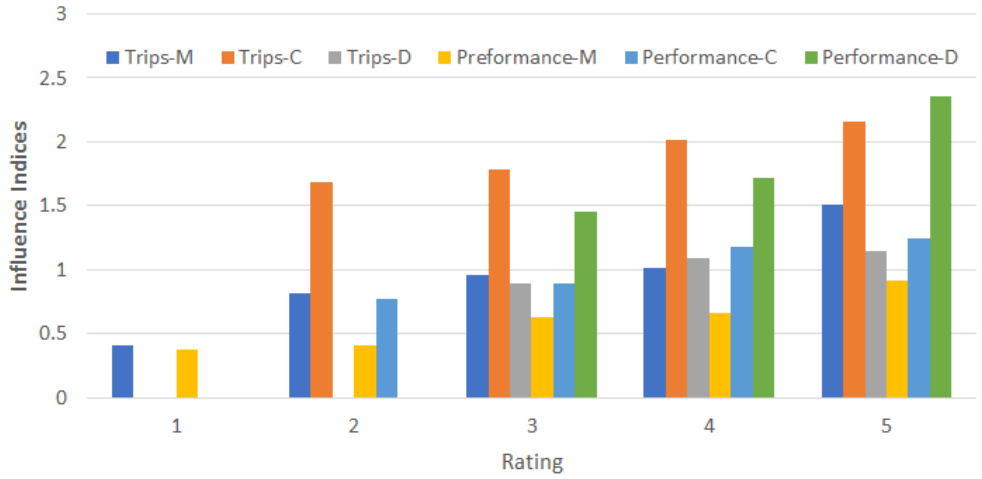

Figure 2. Influence of rehabiltation on flexible pavement performance by indices.

5. Conclusion

This research has indicated factors that necessitate road rehabilitation, it has also highlight on factors that assesses pavement performance and categorized both. It was seen that presence of design factors demands rehabilitation, and rehabilitation should be done by experts solely with the intention of achieving increased trips and pavement performance. This study is significant and road rehabilitation significantly influences flexible pavement performance.

Abbreviations

ANOVA	Analysis of Variance
SPSS	Statistical Package for Social Sciences
HND	Higher National Diploma
MNATE	Member Nigerian Association of Technologist in Engineering
MNSE	Member Nigerian Society of Engineers
MNIS	Member Nigerian Institute of Surveyors
MNIPM	Member Nigerian Institute of Project Managers
MNIM	Member Nigerian Institute of Management

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] J. Morgado, J. Neves (2013) An integrated methodology for planning road pavement maintenance and rehabilitation interventions within high-traffic context, in: Proceedings of the 13th WCTR, World Conference on Transport Research, Rio de Janeiro, Brasil.

[2] AKGSonline. Population of Akwa Ibom State. Available online: https://www.aksgonline.com/about_people_population.html (accessed on 5 May 2023).

[3] J. Morgado, J. Neves, (2014), Work zone planning in pavement rehabilitation integrating cost, duration, and user effects, J. Constr. Eng. Manag. 140 (11) https://doi.org/10.1061/(asce)co.1943-7862.0000888

[4] Harischandra, A. S. P. Randu (2004). "Identification of road defects, causes of road deterioration and relationship among them for bitumen penetration macadam roads in Sri Lanka." Master Thesis at The University of Moratuwa, Sri Lanka, 2004. Available at: http://dl.lib.uom.lk/theses/bitstream/handle/123/1343/82434.pdf?sequence=1

[5] Abdulkareem Y. A. And Adeoti K. A 2004 "Road Maintenance and National Development." National Engineering Conference, Federal Polytechnic Offa, Kwara State.

[6] Kati Kõrbe Kaare, Kristjan Kuhi, and Ott Koppel, (2012). "Tire and pavement wear interaction monitoring for road performance indicators." Estonian Journal of Engineering, 18, 4, 324–335. Available at: https://doi.org/10.3176/eng.4.04

[7] Minu, P. K., Sreedevi and Babu R., (2014) International Journal of Engineering Research 3 908.

[8] Bennet C., (2007) The Road and Rural Transport Thematic Group Washington DC (Washington DC Transport Note) p 2.

[9] Korkiala-Tanttu L., and Dawson A. (2007). "Relating full-scale pavement rutting to laboratory permanent deformation testing." International Journal of Pavement Engineering, Vol. (8).

[10] Nordengen, P. A., and Oberholtzer, F (2006). "Self-regulation initiative in heavy vehicle transport to address road safety, accelerated road deterioration and transport.

[11] Okikbo, K. (2012). Causes of Highway Failures in Nigeria. International Journal of Engineering Science and Technology (IJEST), Vol. 4 No. 11 November 2012.

[12] Patil Abhijit, D. Y. Patil Prathisthan's Y. B. Patil Polytechnic, Akurdi, (2011) "Effects of Bad Drainage on Roads." Civil and Environmental Research, Vol 1, No. 1. Issue.

[13] Tseng E. (2012) The construction of pavement performance models for the California Department of Transportation new pavement management system M.Sc. Thesis University of California, Davis.

[14] Transport in Canada, (2005). http://www.tc.gc.ca/eng/policy/anre-menu.htm Accessed on 13th of Aug, 2023, 11: 30 p.m.

[15] Wee, Chan and Teo (2009). "POTENTIAL MODELING OF PAVEMENT DETERIORATION RATE DUE TO CRACKING." UNIMAS e-Journal of Civil.