Assessment of Pavement Damage Caused by Speed Bumps Along Nyanya – Jikwoyi Road Abuja

Ukinvore Ushiki Adamu[1(✉)], Abubakar Dayyabu[1], and Abdulhameed Mambo[2]

[1] Department of Civil Engineering, Nile University, Abuja, Nigeria
Ukinvoreushiki@gmail.com, adayyabu@nileunversity.edu.ng
[2] Faculty of Environmental Sciences, Nile University, Abuja, Nigeria
abdulhameed.mambo@nileuniversity.edu.ng

Abstract. Unauthorized speed bumps installed by communities contribute to various problems such as road accidents, passenger discomfort, and potential pavement deterioration. This study focused on assessing pavement damage and the compliance of these speed bumps with design standards along the Nyanya – Jikwoyi road in Abuja utilizing the Pavement Condition Index (PCI) and a design guideline for traffic calming devices based on the City of Federal Heights, Colorado, the study examined variables including speed bump geometry, pavement distress types, severity levels, and their locations. Survey results revealed a significant interplay between speed bumps and pavement health, with 75% of sections showing moderate to high distress levels and an average PCI of 26.625, indicating poor pavement condition. Analysis indicated that 11 out of 34 speed bumps failed to meet the minimum spacing requirement of 121.92 m, highlighting design discrepancies. Additionally, only four surveyed locations had proper speed bump warning signs, suggesting a lack of adherence to safety standards. Recommendations include involvement of urban planners and traffic engineers in speed bump placement is suggested, along with routine pavement maintenance, especially in areas with high concentrations of speed bumps. Moreover, integrating speed bump placement into pavement design stages to deter unauthorized installations is proposed. In conclusion, this study underscores the importance of adhering to guidelines and involving professionals in speed bump placement to enhance road safety and pavement integrity.

Keywords: Pavement damage · Speed bumps · Road infrastructure · Pavement Condition Index (PCI) · Design standards · Traffic calming devices · Pavement integrity

1 Introduction

1.1 Background of Study

Speed bumps are crucial road traffic safety features designed to enhance pedestrian and vehicle safety, finding utility in various locations. The speed breaker, characterized by a rounded shape and a width wider than most vehicles' wheelbases, serves as a surface

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over the roadway. Positioned in areas where speed control is essential, a speed breaker acts as a potent stimulus to engage brain activity. In comparison to visual stimuli, audible and tactile cues prompt quicker reaction times in drivers, leading them to instinctively decrease their speed [1].

The Institute of Traffic Engineers (ITE) defines traffic calming as the combination of primarily physical interventions that improve conditions for non-motorized road users, alter driver behavior, and reduce the adverse effects of motor vehicle use [2]. The objective of traffic calming is to decrease traffic speeds and volumes to acceptable levels, thereby enhancing road safety. Various traffic calming devices, including speed humps, speed bumps, speed tables, roundabouts, transverse rumble strips, optical speed bars, textured pavement, and cat-eye reflectors, are employed for this purpose.

Speed humps and speed bumps are widely employed as common measures to prevent speeding and enhance road safety for vulnerable road users in urban areas globally [3]. In addition to decreasing speed by 20 to 40%, these devices are effective in reducing the occurrence of traffic accidents by 50–79%, particularly those involving pedestrians and cyclists, and lessening their impact. Furthermore, they help in decreasing traffic congestion, discouraging overtaking, and promoting changes in driving behavior. [4] These devices are known for their ease of installation and maintenance, resulting in low overall costs. [5–8].

Despite the mentioned benefits, the utilization of traffic calming devices comes with certain drawbacks. These include reduced driving comfort for all road users, potential delays for emergency and public transport vehicles (up to 10 s per obstacle), risks of vehicle damage and associated repair expenses, extended travel times and traffic congestion, challenges in snow clearance during winter, the formation of ruts and potholes around these obstacles, increased fuel consumption (by 40–50%), amplified traffic noise, and the emission of harmful gases due to braking and acceleration (e.g., CO increasing by approximately 60%, HC by around 50%, and CO2 by about 25%) [3, 9, 5 6, 7, 8]. Consequently, these traditional traffic calming measures are frequently criticized by urban road users worldwide [4].

1.2 Statement of Problem

Communities randomly install unauthorized speed bumps on roads, leading to road accidents, vehicle damage, discomfort for passengers, and potential deterioration of the pavement.

1.3 Aim and Objectives

This study aims at assessing asphalt damage caused by speed bumps along Nyanya – Jikwoyi Road Abuja by analyzing the interaction between vehicles and speed bumps.

To accomplish this goal, the ensuing objectives are established:

i. To determine the pavement condition in sections with speed bumps
ii. To determine the compliance of the speed bumps placement according to standards of design and specifications

2 Literature Review

Previous studies have made diverse contributions to understanding the relationship between speed bump characteristics and factors influencing pavement deterioration in various global regions. Studies have explored the geometry of speed bumps, its impact on highway safety, and its potential for causing pavement damage. However, there exists a contextual research gap in the specific case of the Nyanya–Jikwoyi road. To address this gap, the present study focused on evaluating the condition of areas where speed bumps are situated in the case study. The objective is to provide valuable insights into the state of these areas and propose mitigations to address the identified issues. This research contributes to the understanding and improvement of road conditions affected by speed bumps.

2.1 Theoretical Review

The Pavement Condition Index (PCI) is a depreciation model defined on a scale of 0–100. A rating of 100 indicates that the pavement is considered to be in perfect condition, while a score of 0 signifies a completely failed section. The PCI is determined by assuming an initial perfect condition (PCI of 100) for the pavement and then subtracting Deduct Values (DV) assigned to each observed distress. These Deduct Values are based on the type, and extent of severity of each distress. The Deduct Value provides relative weights, indicating the importance of distress severity levels concerning pavement performance. Shahin and Kohn developed the PCI model in 1981. This initiative aims to collect ground information for parking lots, streets, and roadways using visual inspection to assess road surface conditions. The effectiveness of the assessment is based on its capacity to identify different kinds of roadway problems and link them to the corresponding causes. Understanding the causes of current issues is an important part of this process since it helps you select the best maintenance or restoration strategy [10].

A research study was conducted on the effects of speed hump characteristics on pavement conditions in Sohag, Egypt, specifically on a two-lane, two-road scenario. The findings indicated that the availability of speed humps led to significant accelerations and decelerations before and after these road features. Consequently, this resulted in increased travel time, potential vehicle damage, passenger discomfort, elevated fuel consumption, heightened pollution, and a decline in pavement condition [11]. Additionally, the study identified significant and strong correlations between the Pavement Condition Index (PCI) and the characteristics of the examined speed humps. Interestingly, there was a positive link found between PCI and both the width of the speed hump and its spacing from the previous hump. The speed bumps height, on the other hand, showed a negative link with PCI. The researchers utilized regression analysis to establish the most significant relationships between PCI and speed hump variables. This study generated several models, with the most effective being the multivariate model incorporating three independent variables (bump height, spacing from the previous bump, and hump width). They emphasized the utility of this model, suggesting its application for pavement quality assessments based on characteristics of speed bump [11].

Due to insufficient guidelines and instances of illegal speed hump placements, a research study on the geometry of speed humps was carried out. The objective was to establish a model using multiple linear regression to define the criteria for designing speed humps, focusing on a particular 85th percentile speed reduction and degree of discomfort. Their study concentrated on residential streets and collector roads, which usually had speed limits of 50 km/h or less [12].

The Alexandria Governorate's pavements' performance was assessed in a research study, finding the predominant patterns of pavement deterioration and examining the possible effects of unlawful speed bumps on pavement conditions were the key goals. The Pavement Condition Index (PCI) of parts with speed bumps is substantially lower than that of sections without speed bumps, the researcher concluded. The pavements with and without speed bumps had different conditions, averaging around 24 PCI points apart [13].

3 Materials and Method

3.1 Study Area

The case study is a dual carriageway that connects Nyanya and Jikwoyi settlement within the Abuja Municipal Area Council (AMAC) of the Federal capital Territory-Abuja, which goes further to Karshi (Fig. 1), as a case study. The road measures approximately 5 km in total length. It runs straight through a level terrain without sharp turns or unusual sight distances. The choice of this particular road for the study was based on the presence of a significant number of speed humps that vary in their characteristics. Along the entirety of the road, there are a total of 34 speed humps, with 19 positioned on the right-hand side and the remaining 15 on the left-hand side. These bumps were constructed with concrete asphalt and exhibit domed shapes, featuring varying heights and widths.

Fig. 1. Nyanya – Jikwoyi road (source; Google Earth)

3.2 Data Analysis

Pavement Section

To provide a uniform area for each portion under consideration, the road stretch was divided into 16 sections of equal area (900 m^2). This was done in order to capture the distresses surrounding the speed bumps.

The road data such as Speed bump geometry and spacings were collected at sections where speed bumps or speed breakers are found.

Pavement Distress

ASTM D6433-11 provides a comprehensive distress identification manual, wherein the degree of distress within a pavement segment is assessed based on the nature of the distress. Measurement is done using a variety of measurements, including linear meters (m), square meters (m^2), and the number of occurrences.

This approach allows for a detailed and standardized evaluation of various distress types within the pavement, considering their specific characteristics and impact on pavement performance.

Pavement Condition Index
Guide for computing PCI of flexible pavement

The PCI was determined by utilizing the data gathered through the manual examination method. The following procedure were taken to determine the PCI and PCR:

According to ASTM, the procedure used to determine PCI for a pavement section can be divided into following four steps:

1. Convert raw data to distress density (%) using area of surveyed section as denominator;
2. Find deduct value (DV) using DV-Density graph;
3. Sum the largest 7 DVs resulting in total deduct value (TDV);
4. Find corrected deduct value (CDV) using CDV-TDV graph and PCI equal to 100-CDV.

4 Result and Discussion

4.1 Pavement Distress

Distresses in Asphalt Pavement: Table 4.1 lists the 19 different types of distress for AC pavements in alphabetical order (Table 1).

TYPE OF DISTRESSES MEASURED IN THIS STUDY

1. Alligator cracking
2. Longitudinal & Transverse cracking
3. Patching & Utility patch
4. Potholes
5. Raveling

Table 1. Alphabetical arrangement of asphalt pavement distress [14].

S/N	Types of distress
1	Alligator/Fatigue cracking
2	Bleeding
3	Block cracking
4	Bumps and sags
5	Corrugation
6	Depression
7	Edge cracking
8	Reflection cracking
9	Lane shoulder drop
10	Longitudinal & Transverse
11	Patching & Utility patch
12	Polished Aggregate
13	Potholes
14	Rutting
15	Railroad crossing
16	Shoving
17	Slippage
18	Swell
19	Raveling & Weathering

4.2 Site Survey

The results from the site survey are represented in Table 2 showing the sections, locations of speed bumps, pavement distresses represented in numbers according to ASTM D 6344 with their respective level of severity, speed bump heights & weights, spacing between each bump and warning signs. The measurements and observations were all carried out using manually inspection method (Tables 2 and 3).

Pavement Survey Result for Sect. 1 RHS
The PCI was determined by utilizing the data gathered through the manual examination method. The following procedure were taken to determine the PCI and PCR:

1. Determine distress types and severity levels

The sample units were surveyed and the distress data, including types and severity, were meticulously recorded on a data report form, as illustrated in Table 4.

2. Find the deduct values:

The overall quantity of every distress at various severities were summed and then computed with formulas for calculating density of distress as discussed in the previous

Table 2. Results from site survey and measurements

SECTION	STATION	BUMP	DISTRESS AND SEVERITY	DIRECTION - BOTH SIDES	HEIGHTS (cm) 7.62 - 10.16	WIDTHS (M)	SPACING BETWEEN BUMPS	DISTANCE FROM INTERSECTION	WARNING SIGN
	0+000	NIL							
	0+412	1		RHS	10	1.2			
	0+439	2	1 M, 10 L, 13 L,	RHS	10	0.5	27		NO
1	0+451	3	11 H, 19M	RHS	10	0.5	12		
	0+612	4	1 H, 10 H, 10	RHS	6	0.8	161		NO
2	0+651	5	M, 11 L, 13 L,	RHS	6	0.8	39		
3	0+711	6	10 L, 10 M, 11 L, 13 L, 13 H, 19 M	RHS	6	0.8	60		NO
	1+107	7	10 M, 13 L, 13	RHS	6	0.8	396		NO
4	1+125	8	M, 13 H, 19 M	RHS	6	0.8	18	16.45	
	1+238	9	10 M, 13 L, 13	RHS	6	0.8	113		NO
5	1+259	10	M, 13 H, 19 M	RHS	6	0.8	21	16.86	
	1+503	11		RHS	8	0.8	244		
	1+516	12		RHS	8	0.8	13		
	1+542	13		RHS	8	0.8	26		NO
	1+557	14	1 M, 1 H, 10 L,	RHS	8	0.8	15		
6	1+569	15	10 M, 19 M	RHS	8	0.8	12	196.32	
	2+235	16	1 M, 10 L, 10	RHS	10	0.8	666		YES
7	2+251	17	M, 11 H, 11 L,	RHS	10	0.8	16	4.36	
	2+644	18	1 M, 10 L, 10	RHS	8	0.8	393		YES
8	2+662	19	H, 13 L, 13 M,	RHS	8	0.8	18	10.37	

Table 3. Results from site survey and measurements cont.

SECTION	STATION	BUMP	DISTRESS AND SEVERITY	DIRECTION - BOTH SIDES	HEIGHTS (cm) 7.62 - 10.16	WIDTHS (M)	SPACING BETWEEN BUMPS	DISTANCE FROM INTERSECTION	WARNING SIGN
	0+656	1	13 L, 13 H, 19	LHS	4			111.86	NO
1	0+682	2	M	LHS	8	0.8	26		
	1+173	3		LHS	8	0.8	491	26.75	NO
2	1+194	4	10 L, 13 L, 19 M	LHS	8	0.8	21		
	1+307	5	10 L, 10 L, 13 L,	LHS	8	0.8	113	20	NO
3	1+334	6	19 M	LHS	8	0.8	27		
	1+569	7	10 L, 13 L, 13	LHS	8	0.8	235		NO
4	1+597	8	M, 19 M, 1 M	LHS	8	0.8	28		
	2+285	9	13 L, 13 M, 19	LHS	8	0.8	688	9.19	YES
5	2+297	10	M, 1 M	LHS	8	0.8	12		
	2+718	11		LHS	10	1.5	421	15	YES
6	2+742	12	10 L, 13 L, 19 M	LHS	8	0.8	24		
7	3+201	13	10 L, 19 M	LHS	8	0.8	459		NO
	4+187	14		LHS	8	0.8	986		NO
8	4+204	15	10 L	LHS	8	0.7	17		

chapter. ASTM D 6433 supplied distress deduct value curves from which the DV of all distress types and severity combinations was determined.

Table 4. Evaluation sheet for sample 1.

MODIFIED DATA SHEET FOR EVALUATION AND CONDITION SURVEY		100m / 9m
ROAD: NYANYA	SAMPLE UNIT: SECTION 1 RHS	
SURVEYED BY: GROUP	DATE: NOV-2023	

1. Alligator Cracking	5. Depression	11. Patching & Utility Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Lane/Shoulder Drop Off	13. Potholes	18. Swell
4. Bumps and Sags	9. Jt. Reflection Cracking	14. railroad Crossing	19. Weathering/Ravelling
5. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY								TOTAL	DENSITY	DEDUCT VALUE
10 L	65								65	7.22	13
13 L	5								5	0.56	48
11 H	0.5								0.5	0.127	8
19 M	900								900	100	44
1 M	4								4	0.44	14

Table 5. Calculation for corrected deduct value.

M = 1+(9/98)*(100-48) = 5.77551

NO	DEDUCT VALUE								Total	q	CDV
1	48	44	14	13	6.16				125.16	5	66
2	48	44	14	13	2				121	4	70
3	48	44	14	2	2				110	3	68
4	48	44	2	2	2				98	2	70
5	48	2	2	2	2				56	1	56

Max CDV = 70
PCI = 100 - Max CDV = 30
Rating = Poor

3. Determine the corrected deduct value (CDV):

If none or only one individual deduct is greater than two, the total value was used in place of the maximum CDV in determining the PCI; otherwise, maximum CDV must be determined. The individual deduct values were listed in descending order, the allowable number of deducts **m**, was calculated using the following formula:

$$\mathrm{M} = 1 + (9/98) * (100 - \mathrm{HDV}) \leq 10 \tag{4.1}$$

where:

m =allowable number of deducts including fractions (must be less than or equal to ten).

HDV = highest individual deduct value. For example:

$$\mathrm{m} = 1 + (9/98)(100 - 48) = 5.77$$

The number of individuals deduct values was reduced to the ‘**m’** largest deduct values, including the fractional part. For the example in Table 5 the values are 48, 44, 14, 13 and 6.16. (the 6.16 is obtained by multiplying 8.0 by (5.77-5.0) = 6.16)).

4. The total deduct value was calculated by aggregating individual deduct values.
5. ‘q’ was established as the count of deducts with a value exceeding 2.0.
6. The DVs were replicated from the present line to the subsequent line, with the modification of the smallest DV exceeding two being set to two. This process was iterated until ‘q’ equaled 1.
7. The CDV was calculated from the summation of deduct values and ‘q’ by referring to the corresponding correction curve for AC pavements.
8. The PCI was calculated by subtracting the maximum CDV from 100 [15]

The PCI of the sections of the road under consideration, as outlined in Fig. 2, delineates the outcomes for the road under evaluation.

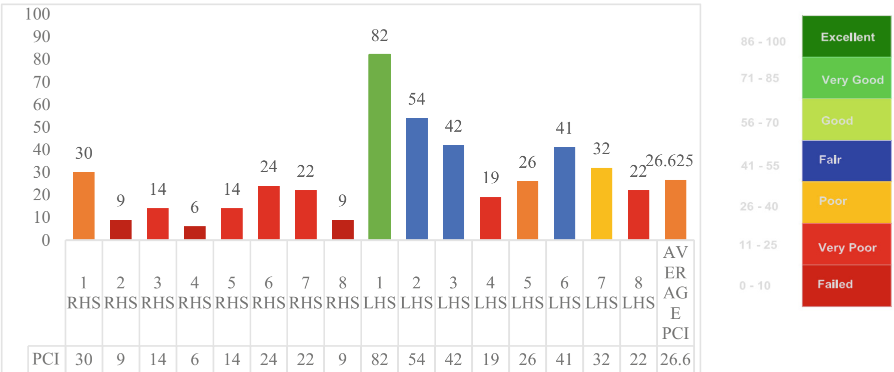

Fig. 2. Bar chart showing the summary of results for all sections with legend.

The highest PCI for the sections calculated is 82 which is rated very good, and it was noted that the section contained only one speed bump unlike the sections with PCIs of 6 and 9 which were rated as failed all contained more than one speed bump and also had poor spacing of bumps in-between them. The mean PCI for all sixteen Sects. (16) calculated is 26.625 which was rated as Poor according to the ASTM D6433 rating scale. It can be noted that, the availability of speed bumps on a road can reduce the life cycle of the road due to its effects on pavement integrity as seen in the pavement condition index values.

4.3 Speed Bump Characteristics

The following parameters will be used in the analysis of the compliance of placement and geometry of speed bumps in the study area in accordance with [16].

1. Height and width of the speed bump
2. Spacing between speed bumps

3. Distance from intersections
4. Speed bump sign before or at the location of the bump

4.4 Summary of Results for the Speed Bump Compliance to Standards

The road at intersections already had traffic lights and so the need for having speed bumps very close to intersections is not necessary as the traffic lights already function as a traffic management system which eliminates the need for speed bumps at those locations. It was observed that the speed bumps were not installed at regular intervals in accordance with standards. Here is further breakdown of the results:

1. From the results of speed bump geometry measured from the road it was discovered that they were in line with the specifications provided.
2. The spacing between the bumps were not in line with the specifications as different locations had multiple bumps within a short radius. Eleven (11) out of thirty-four (34) speed bumps passed the minimum spacing of 121.92m.
3. Four (4) out the twelve (12) bumps located near intersections passed the minimum specification of 60m away from an intersection.
4. There were only four speed bump signs at the various locations which is not in line with the specification of placing of speed bumps.

It was also observed that the road had no streetlights, posing a potential danger when traveling at night due to the high concentration of speed bumps and the poor condition of the road.

4.5 Discussion

The analysis of results from the study shed light on the significant impact of speed bumps on pavement integrity. Through a meticulous site survey and data collection process, it was revealed that the Pavement Condition Index (PCI) for the road sections inspected indicated a poor rating, with most sections ranging from Fair to Failed due to the presence of speed bumps.

The study highlighted that while the geometry of the speed bumps generally met specifications, issues arose concerning the spacing between bumps, their proximity to intersections, and the lack of proper signage. These factors contributed to the accelerated deterioration of the pavement, emphasizing the need for better adherence to design standards and guidelines for speed bump placement.

Furthermore, the results underscored the importance of strategic planning and professional oversight in the installation of traffic calming devices which highlights the critical need for a holistic approach to road design and maintenance that considers the impact of speed bumps on pavement condition.

5 Conclusion and Recommendation

5.1 Conclusion

Based on the findings presented in the thesis, it is evident that the condition of the road sections inspected is poor, with ratings ranging from Fair to Failed due to the presence of speed bumps. The study revealed that the spacing between speed bumps did not adhere to specifications, leading to accelerated pavement deterioration. Furthermore, the absence of speed bump signs at most locations and their proximity to intersections highlighted the need for better traffic calming measures. In conclusion, the installation of speed bumps along the Nyanya - Jikwoyi Road has significantly impacted the pavement integrity, as reflected in the Pavement Condition Index values.

The assessment of pavement damage caused by speed bumps along Nyanya - Jikwoyi Road in Abuja has provided valuable insights into how speed bumps affect pavement integrity. Significant findings were uncovered through the systematic evaluation of pavement condition index (PCI) and adherence to design standards.

Pavement conditions on the sections of road inspected ranged from Fair to Failed, indicating substantial damage near speed bump locations. Out of sixteen sections assessed, 15 were rated Fair to Failed, with an average Pavement Condition Index of 26.625, indicating extensive deterioration caused by the presence of speed bumps.

A further key discrepancy was found in the placement of speed bumps, with only two out of ten bumps near intersections meeting the specified distance of 60 m and 11 out of 34 bumps meeting the minimum spacing requirement of 121.92 m. As an added indication of non-compliance with design standards, most locations did not have speed bump signs. The results emphasize the urgent need for improved management and design of speed bumps to minimize pavement damage and ensure road safety. It is possible to significantly improve the longevity and performance of roads pavements by implementing the study's recommendations, such as utilizing alternative traffic calming devices and improving maintenance practices.

Overall, this research contributes valuable numerical insights to the field of Civil Engineering, particularly Highway and Transport Engineering, by quantifying the extent of pavement damage caused by speed bumps and providing a basis for informed decision-making to enhance the sustainability and efficiency of urban road networks.

5.2 Recommendations

The following recommendations not only address the challenges uncovered in this research but also pave the way for a more sustainable and economical installation of speed bumps within the urban areas:

1. The development and implementation of innovative speed bump designs that prioritize road safety without compromising pavement integrity with considerations to materials, shapes, and dimensions that distribute impact forces more evenly.
2. Only Urban Planners and Traffic Engineers should be allowed to plan, design and install speed bumps, considering factors like traffic flow, road type, and proximity to sensitive infrastructure.
3. Speed bumps placement should be incorporated right from the design stage of a pavement in a bid of reducing illegal placement of speed bumps.
4. Routine and proactive pavement maintenance should be carried out particularly in areas of high concentration of speed bumps.
5. Streetlights should be installed on roads to aid visibility and promote safety of road users.
6. Street bumps should be placed at standard interval of 120m for better traffic management.

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