(RESEARCH ARTICLE)

Effect of defects on highway quality

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Abstract

This study investigates the causes, effects and remedies to defects on highway as it affects quality along Pipeline road in Kamazo, Chikun Local Government Area of Kaduna State. The methods used in data collection are, GIS used in mapping the congested area, use of questionnaire and oral interview. One hundred (100) copies of questionnaires were administered to drivers and passengers using the road, in which Cross-Tabulation and 5-point Likert Scale was used for the analysis.

Common defects observed are: Potholes, cracks, silt deposit on roadway, honey combs, depression, grasses on shoulders, scouring, fade markings, road signs, vegetation in hydraulic structures, structural failure of hydraulic structures, loss of materials, failed pavement, etc.

Common causes of quality defects on highways are: High volume and frequency of heavy duty trucks; roadway as predominant mode of transportation; Lack of maintenance culture; Poor budget allocation for maintenance. Poor funding; defective Design; Poor construction; Defective constructional materials; Poor supervision; Poor drainage system; Defective implementation of QC/QA protocols; Age of road, etc.

Common effects of quality defects on highways are: Defective road quality; Inability to forecast travel time; Fuel consumption; Induces stress on road users; Frequent vehicle breakdown on the roadway; High cost of transportation fare indices for inflation; Loss of time on the roads; Accident; Defective distribution of goods and services; Defective security emergency response, etc.

Possible remedies to these defects are: provision of adequate funding to maintenance agencies; collate data from monitoring and evaluation; schedule and plan for maintenance; diversify travel modes; improve on QA/QC required for roadwork; provide coordinated and computerized weigh bridge and regular collection of axle loads data; tax vehicles according to axle load beyond certain boundaries to generate fund required to maintain roads; road markings and furniture to be in place; provision of lightings; quality supervision; use of quality materials to required standard & specifications; adopt build-operate-transfer (road retainer ship).

Keywords: Defects; Highway; Quality; Maintenance

1. Introduction

Highway became important means of transportation during the reign of Roman Empire. Romans kingdom modernized the use of road effectively compared to the existing usage of road whereby ox, man, chariot, camel, and bull were used

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as major carrier in road transportation. But the invention of the motor vehicle meant that, roads were no longer for pedestrians, chariot and animals alone, [1]. The invention called for improvement of the state of the roads, which led to increased speeds and danger to road users. This then called for a proper construction and control of highway to increase efficiency of the roads in highway performance. Demand for highway travel by people continues to grow as population increases, particularly in the metropolitan area and the construction of new highway capacity to accommodate this growth in travel has not kept pace. Pavement deterioration is the process by which distresses develop in pavement under the combined effects of traffic loading and environmental conditions. Deterioration of pavement greatly affects serviceability, safety and riding quality of the road. After construction, roads deteriorate with age as a result of use and therefore, they need to be maintained to ensure that the requirements for safety, efficiency and durability are satisfied. Normally, new paved roads deteriorate very slowly in the first ten to fifteen years of their life, and then go on to deteriorate much more rapidly unless timely maintenance is undertaken [2].

The research became necessary because the present situation of defects along the road is negatively affecting the road quality, road users and citizens economically; also results in the consumption of more fuel, spending more on travel time, increase pollution and accidents, etc.

The aim of this study is to evaluate the effects of defects on highway quality on Nigerian roads considering the causes, effects and remedies using Pipeline road in Kamazo, Chikun Local Government of Kaduna State, as a case study. The aim is going to be achieved by identifying the common defects observed on roads especially in Nigeria; to find out the possible causes of defects; to identify the impact of the defects on highway quality, road users and their economy and to identify and proffer possible remedies to the present challenges faced by road users.

2. Literature review

The catalogue on road defects (1992) refers to road defects as the visible evidence of an undesirable condition in the pavement affecting serviceability, structural condition or appearance. The definition of a "road defect" includes any part of a road, highway, or construction site that does not meet the regulations for a safe road. In Nigeria the defects that most often cause injuries to people or damage to vehicles include: inadequate road shoulders, lanes that are uneven, pavement that is uneven, improperly marked signs, malfunctioning stop lights, construction negligence, and municipal negligence. These leads to accidents on Nigeria roads which lead the national emergency agency NEMA to put up a programme that engaged the competent hands from other stake holders such as the Nigerian police, Nigerian army, Nigerian security and civil defense corps, federal road safety commission, National air space management authority, Nigerian red cross, the states ministries of health and environment. For the programme, national and state emergency agencies were to train the volunteers [3].

[3] stated that Nigerian roads were death traps. In the developing world which includes Nigeria, road network is the most developed transport mode and the vastest in usage. The Nigerian government over the years has tried to construct and rehabilitated the roads. According to [4], roads represent the major areas of investment in transportation and are the most dominant travel mode accounting for over 90% of passenger and goods transport in Nigeria. One of the main problems of road work in Nigeria is the lack adequate informational data on the Nigerian roads. Some studies have been done on the state of Nigerian roads. [5] Examined the method of road maintenance in Nigeria. To do so, they defined and analyzed 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.

Okigbo 2012 [6], on his study on Nigeria highway, has identified some of the factors that cause highway failure. They include Poor design, construction and maintenance, use of low quality construction materials, poor workmanship and poor supervision of construction work and the applying of Heavy traffic that were not meant for the road. Furthermore, he also suggested that the following will lead to highway failure; poor highway facilities, no knowledge base, inadequate sanction for highway failure, no local standard of practice, poor laboratory and in-situ tests on soil and weak local professional bodies in highway design, construction and management.

The most significant road defects observed in the field are potholes, cracks, edge Defects, depressions and corrugation [7]. At the same time he emphasized that traffic Overloading, pavement age, road geometry, weather, drainage, construction quality as Well as construction materials, maintenance policy play the major role as road deteriorate agents. However, understanding the causes for pavement deterioration Failures is essential step towards minimizing risks to have good road performance.

3. Methodology

This study was conducted in Kaduna state. Kaduna is said to be the 3rd most populated state in Nigeria. The state is a commercial/civil servants city in the northern part of Nigeria. Kaduna metropolis was founded in 1917 as an administrative Headquarters of northern Nigeria. Apart from presently being the administrative Headquarter of Kaduna state; it has experienced a high concentration of Federal parastatals and industries [8]. It is the third most populous city in Nigeria with an estimated population of over 8,252,366 (National Bureau of Statistic, 2016).
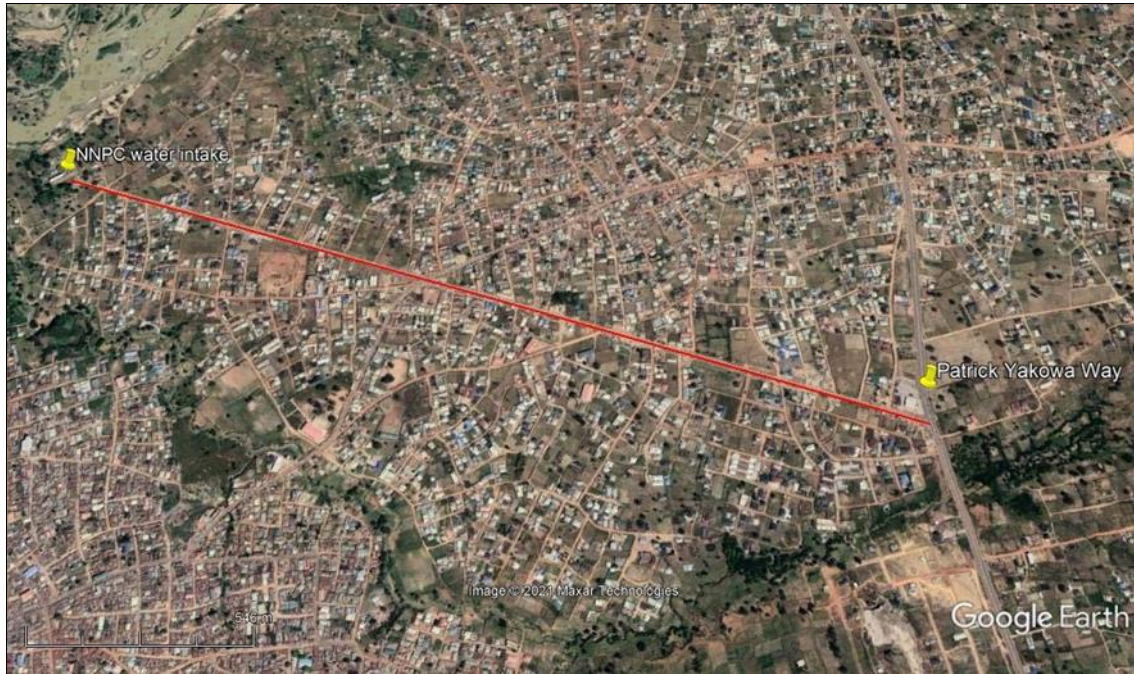

Figure 1 Part of Kaduna showing the study area (Source: Google Map 2021)

The methods used in data collection are, GIS used in mapping the congested area, use of questionnaire and oral interview. One hundred (100) copies of questionnaire were administered to drivers and passengers using the road, in which Cross-Tabulation was used for the analysis.

3.1. Sampling Techniques and Sample Size

Sample size according to [9] is the representative of the entire population for a study, and from whom the findings can be generalized for the entire population, thereby making inference for a valid judgment and research conclusion. The required sample size is determined using the Slovin's formula for calculating sample size.

$$\text{The Slovin's formula is given as n} = \frac{N}{3+N(e)2}$$

Where
n = desired sample size;
N = population size;
e = margin of error;

For the purpose of this research study, the margin of error is taken to be 10% i.e. e = 10% (0.1) and N = 1826883, so when we substitute we have;

$$n = \frac{1826883}{3+1826883\ (0.1)2} = 99.98$$

Approximated to 100

This implies that a sample size of 100 will be required to achieve 90 % precision from the sample.

The sampling technique adopted in drawing the sample is the simple random sampling because of the fairly heterogeneous nature of the research population and for fairness.

3.2. Sources and Instruments of Data Collection

In the conduct of this study, the researcher made use of both primary and secondary data which were generated with the use of questionnaire and documentary method. The primary data comprises of those facts gathered by the researcher in the field of study while the secondary data comprises various facts that have been processed by other researchers or writers before getting to the hand of the researcher.

3.3. Sources of Primary Data (Questionnaire)

Questionnaire according to [10] is a common instrument of investigation in a social science. Various questions relevant to the objectives of this study were brought together into a document called questionnaire. That is, the questionnaire was formulated in line with the research questions targeted at capturing responses in conformity with the research objectives.

3.4. Source of Secondary Data

The researcher equally made use of secondary instrument to develop the literature by consulting the works of previous researchers, writers, scholars and authors who have at one time or the other expressed their opinions, views and discoveries on the subject matter. This was made possible with the use of textbooks, extracts from journals, internet materials, seminar and workshop papers. All these references gave this study the necessary backing.

3.5. Method of Data Analysis

The collection of data was done by the researcher personally by soliciting for information from the road users who served as respondents. After distributing the questionnaire, respondents were given two days to fill the questionnaire. This time frame has been given in order to give ample opportunity to the respondents to reflect on the items generated on the questionnaires so as to facilitate valid response.

Data obtained from the respondents were presented on tables, analyzed and interpreted accordingly with the aid of descriptive statistical techniques such as mean score and simple percentage.

3.5.1. Simple percentage

This was used in the analysis of each of the questions relating to respondents' demographic variables.

3.5.2. Mean score

This was adopted in analyzing each variable in the questionnaire to weigh the degree of responses.

The Mean score is calculated using the formula:

$$\text{Mean Score} = \frac{\sum FX}{\sum F}$$

Where: $\sum$ = summation
F = Frequency
X = Variables

Each value of the acronyms on the five points scale was multiplied by the corresponding frequency of the variable. The frequency (F) column was multiplied by (X) to get (FX). The mean score of each of the variable was obtained by dividing the sum total of (FX) by the sum of (F).

3.5.3. Likert scale

A likert scale is a psychometric scale commonly involved in research that employs questionnaires. It is the most widely used approach to scaling responses in survey research.

The questionnaire in this research was structured using 5 points Likert's rating scale of 5–1 respectively. The scale of strongly agree, agree, undecided, disagree and strongly disagree options were drawn to elicit responses to address the research questionnaires.

Table 1 The 5 points Likert's rating scale is shown thus

	SA	A	UD	D	SD
Grade Point	5	4	3	2	1
Range	4.5-5.0	3.5-4.4	2.5-3.4	1.5-2.4	0.5-1.4

Key: SA = Strongly Agree; A = Agree; UD = Undecided; D = Disagree; SD = Strongly Disagree

$$\text{Control Mean} = \frac{5+4+3+2+1}{5} = \frac{15}{5} = 3.0$$

Therefore, mean score of 3.0 is regarded as the cut-off point; any response that falls below 3.0 is considered rejected while any response above 3.0 is considered as an accepted response.

4. Results and discussion

The data collected for this research study is presented in figures and also tabular form. The data shows the frequencies and percentages of response to all the questions asked in the questionnaire. The data interpretation will show the distribution of demographic factors and respondents' responses and opinion on the defects along Pipeline road, Kamazo, Kaduna in terms of its causes, effects and remedies.
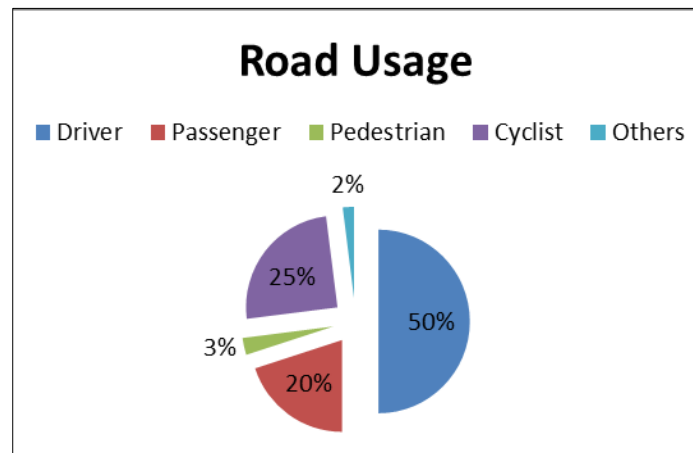
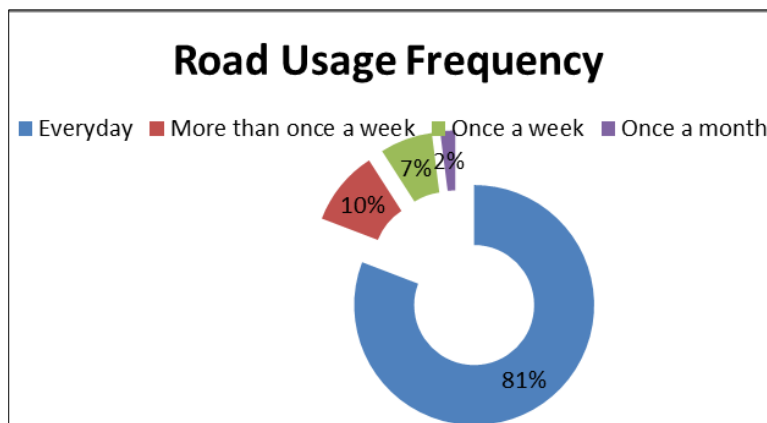**Figure 2** Road Usage (Source: Field Survey (2021))

Figure 3 Road Usage Frequency (Source: Field Survey (2021))

From the analysis of data presented in figure 2, 50 road users representing 50% of the sampled respondents were using the road as drivers, 20 among them are passengers, which represent 20% of the total respondents, 3 person representing 3% of the total respondents are using the road as pedestrian, while 25 road users representing 25% of the total respondents are using the road cyclists, and 2% of the road users representing 2 people are in the others' option. This implies that greater percentages of the road users with 50% are using the road as Drivers.

From the analysis of data presented in figure 3 above, 80% among the road users representing 80% of the sampled respondents were using the road every day, 10% uses the road more than once a week, 7 person representing 7% of the total respondents uses the road once a week, while 2 road users representing 2% of the total respondents uses the road once in a month. This reveals that greater number of the road users with 80% uses the road every day, followed with those that use the road more than once a week recording 100 %.
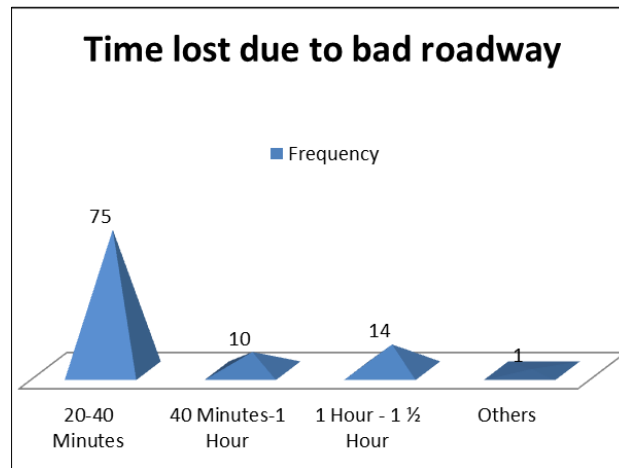

Figure 4 Time lost due to bad Roadway (Source: Field Survey (2021))

Table 2 Causes of defects

S/N	Statement	SA	A	UD	D	SD	X	σ	Comment
**What are the causes of quality defects on highways?**
1	High volume and frequency of heavy duty trucks	35	48	6	8	3	4.04	1.96	Accept
2	Corruption & lack of value system	52	42	3	1	2	4.41	2.23	Accept
3	Monitoring & Evaluation Data not accessible or put to use	21	48	12	12	7	3.64	1.74	Accept
4	Lack of maintenance culture	28	54	6	10	2	3.96	1.91	Accept
5	Poor budget allocation for maintenance	37	52	4	5	2	4.17	2.05	Accept
6	Poor funding	46	45	6	2	1	4.33	2.17	Accept
7	Collaboration with relevant agencies for data sharing	35	61	1	2	1	4.27	2.13	Accept
8	Defective Design	54	34	2	5	5	4.27	2.13	Accept
9	Failed drainage system	39	43	5	7	6	4.02	1.95	Accept
10	Defective constructional materials	42	48	2	3	5	4.19	2.07	Accept
11	Poor supervision	45	47	2	6	0	4.31	2.16	Accept
12	Poor drainage system	51	42	3	2	2	4.38	2.21	Accept
13	Defective implementation of QC/QA protocols	48	49	1	1	1	4.42	2.24	Accept
14	Road markings and furniture are absent	37	39	8	11	5	3.92	1.89	Accept
15	Age of road	47	26	6	18	3	3.96	1.91	Accept

Source: Field Survey (2021); SA= strongly agree, A = agree, UD = undecided, D = disagree; SD=strongly disagree, X=mean and σ = standard deviation

From the analysis of data presented in figure 4 above, 75 among the road users representing 75% of the sampled respondents were wasting much time range of 20-40 minutes due to bad road, 10 among them wastes range of 40minutes – 1 Hour, which represent 10% of the total respondents, 14 person representing 14% of the total respondents wastes 1 Hour – 1 ½ Hour due to bad road, while 1 road users representing 1% of the total respondents are in the others' option of time due to bad roadway. This signifies that greater number of the road users with 75% wastes a range of 20 – 40 minutes in the road due to bad road.
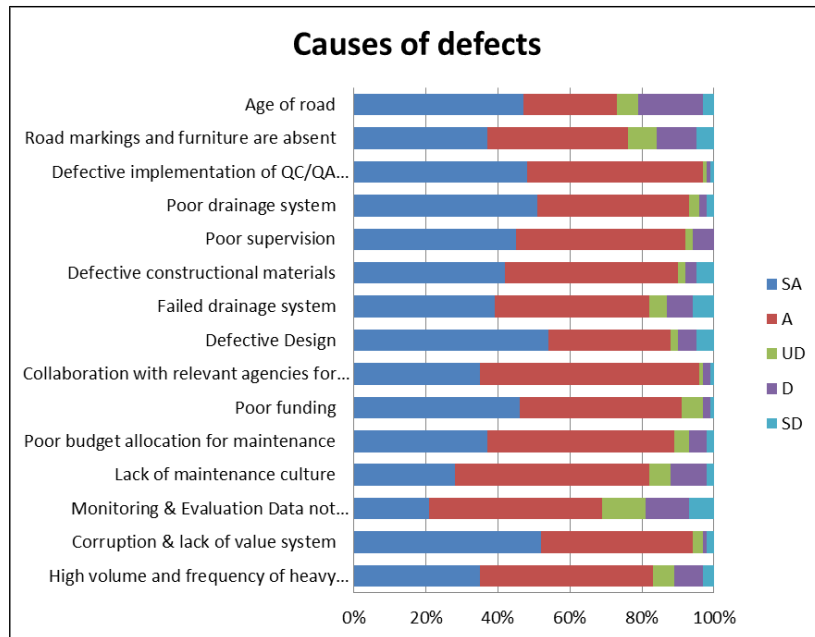

Figure 5 Causes of defects

Table 3 Effects

S/N	Statement	SA	A	UD	D	SD	X	σ	COMMENT
	What are the effects of quality defects on highways?								
1	Defective road quality	36	47	6	8	3	4.05	1.97	ACCEPT
2	Inability to forecast travel time	55	37	2	4	2	4.39	2.22	ACCEPT
3	Fuel consumption	46	32	1	18	3	4.00	1.94	ACCEPT
4	defective highway Induces stress on road users	58	36	2	2	2	4.46	2.27	ACCEPT
5	Frequent vehicle breakdown on the roadway	34	38	12	5	11	3.79	1.81	ACCEPT
6	High cost of transportation fare indices for inflation	55	32	2	6	5	4.26	2.12	ACCEPT
7	Pollution	24	42	23	9	2	3.77	1.80	ACCEPT
8	Loss ot time on the roads	47	36	5	9	3	4.15	2.04	ACCEPT
9	Defective road can serve as crime vectors	45	45	3	3	4	4.24	2.10	ACCEPT
10	Accident	39	40	4	6	11	3.90	1.87	ACCEPT
11	Defective road removes quality of safety	40	51	1	5	3	4.20	2.07	ACCEPT
12	Defective distribution of good and services	40	49	3	6	2	4.19	2.07	ACCEPT
13	Defective security emergency response	51	36	5	4	4	4.26	2.12	ACCEPT
14	Defective roods remove quality of smooth ride & comfort	44	46	2	6	2	4.24	2.10	ACCEPT
15	Defective roads deviate from acceptable standards	27	42	23	3	5	3.83	1.83	ACCEPT

Source: Field Survey (2021); SA= strongly agree, A = agree, UD = undecided, D = disagree; SD=strongly disagree, X=mean and **σ** = standard deviation

From table 2 above, most of the items listed scored more than 3.0 on a 5-point likert scale from the response of the respondents. This indicates a positive response on all the statements itemized in the table. For example; High volume and frequency of heavy duty trucks have a mean of 4.04, lack of maintenance culture score 3.96, etc. It is observed that, the highest mean value recorded is 4.42 which is defective implementation of QA/QC protocols in the construction of road works.
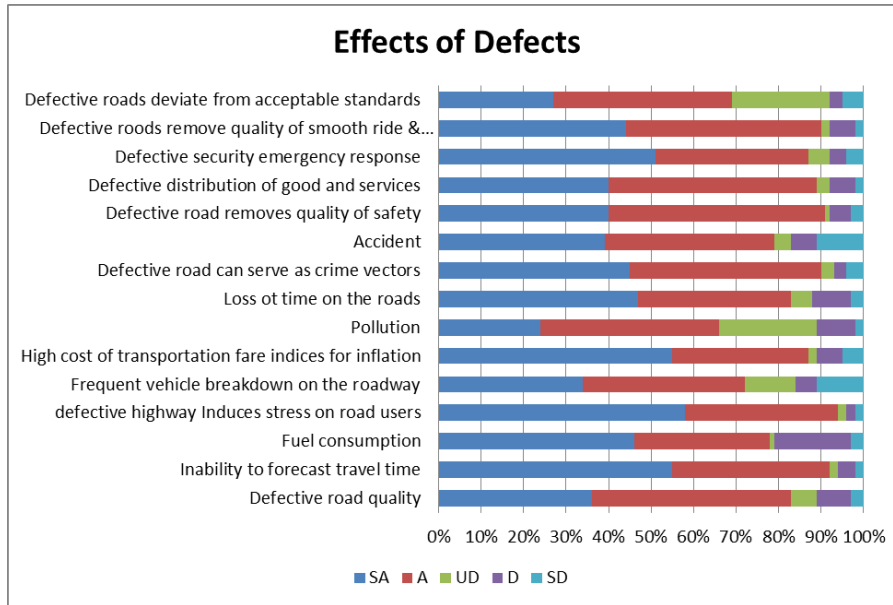

Figure 6 Effects of Defects

Table 3 revealed the various and common effects of quality defects on highways in Nigeria with case study using Pipeline road in Kamazo, Kaduna South are: Defective road quality; Inability to forecast travel time; Fuel consumption; Induces stress on road users; Frequent vehicle breakdown on the roadway; High cost of transportation fare indices for inflation; Pollution; Loss of time on the roads; Accident; Defective road removes quality of safety; Defective distribution of good and services; Defective security emergency response, etc

The highest mean value of 4.46 recorded was that of defective highway induces stress on road users; inability to forecast travel time; etc are major effects of defects on highway affecting road quality in Nigeria, considering Pipeline road in Kamazo, Kaduna South.
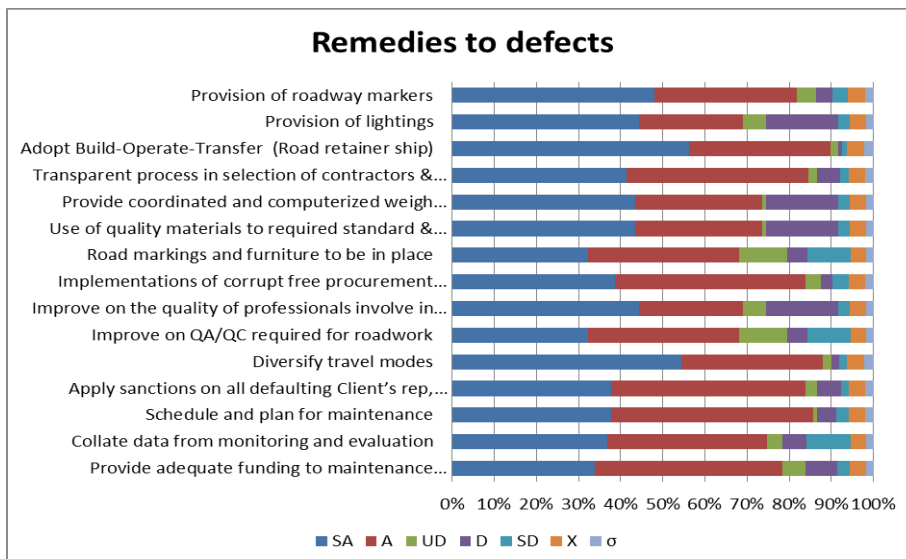

Figure 7 Remedies to defects

Table 4 Remedies

S/N	What are the possible remedies to quality defects on highways?								
	Statement	SA	A	UD	D	SD	X	σ	COMMENT
1	Provide adequate funding to maintenance agencies	36	47	6	8	3	4.05	1.97	ACCEPT
2	Collate data from monitoring and evaluation	39	40	4	6	11	3.90	1.87	ACCEPT
3	Schedule and plan for maintenance	40	51	1	5	3	4.20	2.07	ACCEPT
4	Apply sanctions on all defaulting Client's rep, Contractors & Consultants involve in road projects	40	49	3	6	2	4.19	2.07	ACCEPT
5	Diversify travel modes	58	36	2	2	2	4.46	2.27	ACCEPT
6	Improve on QA/QC required for roadwork	34	38	12	5	11	3.79	1.81	ACCEPT
7	Improve on the quality of professionals involve in roadwork	47	26	6	18	3	3.96	1.91	ACCEPT
8	Implementations of corrupt free procurement exercise	41	48	4	3	4	4.19	2.07	ACCEPT
13	Road markings and furniture to be in place	34	38	12	5	11	3.79	1.81	ACCEPT
19	Use of quality materials to required standard & specs	46	32	1	18	3	4.00	1.94	ACCEPT
11	Provide coordinated and computerized weigh bridge and regular collection of axle loads data	46	32	1	18	3	4.00	1.94	ACCEPT
16	Transparent process in selection of contractors & consultants	44	46	2	6	2	4.24	2.10	ACCEPT
20	Adopt Build-Operate-Transfer (Road retainer ship)	60	36	2	1	1	4.53	2.33	ACCEPT
14	Provision of lightings	47	26	6	18	3	3.96	1.91	ACCEPT
15	Provision of roadway markers	51	36	5	4	4	4.26	2.12	ACCEPT

Source: Field Survey (2021); SA= strongly agree, A = agree, UD = undecided, D = disagree; SD=strongly disagree, X=mean and σ = standard deviation

Table 4 revealed the various possible remedies to quality defects on highways in Nigeria with case study using Pipeline road in Kamazo, Kaduna South are: provide adequate funding to maintenance agencies; collate data from monitoring and evaluation; schedule and plan for maintenance; apply sanctions on all defaulting client's rep, contractors & consultants involve in road projects; diversify travel modes; improve on QA/QC required for roadwork; computerized weigh bridge and regular collection of axle loads data; tax vehicles according to axle load beyond certain boundaries to generate fund required to maintain roads; road markings and furniture to be in place; provision of lightings; use of quality materials to required standard & specs; adopt build-operate-transfer (road retainer ship); because their mean are all above the 3.0 cutoff point on a five-point Likert scale used.

5. Conclusion

This research, at the end of the questionnaire analysis using Likert scale and statistical parameters; mean and standard deviation, it was observed that causes of roadway defects affecting highway quality are:

- High volume and frequency of heavy duty trucks on our roads for which some of them exceed design carriage capacity.
- Lack of maintenance culture on the road whether routine, periodic, corrective or reactive. The maintenance culture is not seen to be effectively enforced.
- Poor budget allocation/funding for maintenance and implementation for various categories of maintenance
- Defective Design has been observed in relation to geometry, road furniture, etc contributing to defective roadway and quality standard
- Poor supervision and Defective constructional materials are some contributory factors to soon defect on highway and this is as a result of defective implementation of QC/QA protocols

- Poor drainage system required to protect the structural integrity of highway in most cases are not in place such as stone protection of drainage system so also age of road indicates that wear and tear of the road pavement has depreciated to lower carrying capacity leading to noticeable defects.

On the other hand, this study, at the end of the questionnaire analysis using Likert scale and statistical parameters; mean and standard deviation, it was discovered that the effect of defects on roadway are:

- Defective road quality as prevalent on the highway under study which have a negative effect on distribution of goods and services, quality of smooth ride & comfort expected by road users and security emergency response.
- Inability to forecast travel time and frequent vehicle breakdown on the roadway is not good for business or the economy and this also Induces stress on road users especially for the ages, the sick or expectant mothers.
- Fuel consumption due to defective road and High cost of transportation fare indices for inflation as transports and food sellers hike an hang cost of goods and services on this basis
- Pollution is also noted to be a factor of pollution due to emission of dust into the atmosphere
- Loss of time on the roads as with reduces average speed.
- Accident where vehicles accidentally bump into pot holes or ditches due to poor visibility and thereby lost control of have vehicle parts breaking off
- Defective roads indicated deviation from acceptable standards

Lastly, this part of the study, after the questionnaire analysis using Likert scale and statistical parameters; mean and standard deviation, it was discovered that the study suggests the following remedies:

- Provide adequate funding to maintenance agencies for effective employment and implementation of all component of maintenance strategies
- Collate data from monitoring and evaluation necessary to improve on existing network or integration of other mode of transportation.
- Schedule and plan for maintenance strategies is a necessity
- Improve on QA/QC required for roadwork
- Provide coordinated and computerized weigh bridge and regular collection of axle load data
- Tax vehicles according to axle load beyond certain thresholds to generate funds required to maintain highway quality
- Road markings and furnitures like lightings should be in place to serve as guides, aesthetics and also to prevent accidents
- Quality supervision as well as use of quality materials to required standard & specifications.
- Adopt Build-Operate-Transfer (BOT) road retainer ship where highway ownership is privatized.
- Diversify travel modes

Recommendations

It is recommended that further studies are required in other parts of Kaduna metropolis and other metropolis of other states in Nigeria to validate claims or otherwise. This is because the ratio of the road used for this case study compared with other roads in Nigeria is very small and therefore may not be fully used to generalize defects in Nigeria except when compared with a larger scale of research work in this area.

From the analysis of this research work, it is recommended that aforementioned remedies may be implemented base on its benefits as a culture.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors declare that there is no conflict of interest.

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