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ENVIRONMENTAL RISK ASSESSMENT OF TRANSPORTATION INFRASTRUCTURE DEVELOPMENT USING GIS IN LAGOS STATE

***OLADAPO OLAITAN MARIAM; **FORTUNE UCHECHUKWU ADIKE; ***OKENIYI RUTH FOLAKE; ****SOWEMIMO KAYODE SODIQ; *****BRIDGET NNENNA CHUKWU; ******TOHEEB ABBEY ANIMASHAUN; *******CHIDOZIE EBUBE EBENMELU; ********TIAMIYU TAOFEEK AKORIOLA; & *********CONFIDENCE ADIMCHI CHINONYEREM**

*Obafemi Awolowo University, Department of Urban and Regional Planning. **Federal University of Petroleum Resources Effurun Delta State. ***University of Lagos, Civil and Environmental Engineering. ****Federal University of Agriculture Abeokuta, Department of Chemistry. *****North Dakota State University, Agribusiness and Applied Economics. ******Obafemi Awolowo University Ile- Ife, Department of Civil Engineering. *******University of Illinois, Urbana Champaign, Department of Agricultural and Consumer Economics. ********Federal University Oye-Ekiti, Department of civil Engineering. *********Abia State Polytechnic.

Corresponding Author:
olajideolaitan395@gmail.com

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Abstract

Transportation infrastructure development poses significant environmental risks, including habitat disruption, air and water pollution, and climate change. This study develops a GIS-based framework for ecological risk assessment of

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transportation infrastructure development. This research identifies high-risk areas and prioritizes mitigation measures by integrating spatial analysis, multi-criteria decision analysis, and expert consultations. The GIS-based approach evaluates environmental sensitivity, proximity to ecosystems, and potential hazards. Results provide valuable insights for sustainable transportation planning, policy-making, and ecological management. This study explored its application in solving Environmental Risk Assessment of Transportation Infrastructure Development GIS application in environmental Risk Assessment monitoring has mainly been divided into three aspects: water, soil, and atmosphere. Based on ArcGIS 10.1 software and ArcGIS 9.3.1 version, GIS has been applied in Transportation system monitoring and soil heavy metal concentration monitoring, respectively. A major function of planners is to promote the best use of a community's land and resources for different construction projects; especially critical are infrastructure projects on which economic development relies. Transportation projects typically involve both environmental and economic issues facing a community as it grows and changes. Considerations of sustainability, as well as the widespread use of collaborative planning, design, and construction, require tools that facilitate long-term impact analysis and easy communication among built-environment professionals. Environmental impact assessment (EIA) is instrumental in studying transportation project impacts, but it is a time-consuming process because of the large number of dependent and independent variables involved. A vulnerability grade map and road distribution map were produced, providing an overall vulnerability score for each of the three planning alternatives considered. A road alignment was indicated as the preferred corridor, which was further recommended for a project development and environmental (PD&E) study.

Introduction

Transportation infrastructure development is a crucial driver of economic growth, social progress, and urbanization. However, it also poses significant environmental risks, including habitat disruption, air and water pollution, soil contamination, and climate change. The construction and operation of transportation infrastructure, such as roads, railways, airports, and seaports, can have far-reaching consequences on ecosystems,

human health, and the environment. In recent years, the importance of environmental sustainability has become increasingly recognized, and governments, policymakers, and stakeholders are seeking innovative solutions to mitigate the ecological impacts of transportation infrastructure development. Geographic Information Systems (GIS) offer a powerful tool for environmental risk assessment, enabling the spatial analysis of ecological sensitivities, hazards, and vulnerabilities.

This study aims to develop a GIS-based framework for environmental risk assessment of transportation infrastructure development, integrating spatial analysis, multi-criteria decision analysis, and expert consultations. By identifying high-risk areas, prioritizing mitigation measures, and providing insights for sustainable transportation planning, this research seeks to contribute to developing environmentally sustainable transportation infrastructure that balances economic growth with environmental stewardship.

Solving an environmental problem traditionally includes extracting data from the sensor collector, and the data must be stored within particular platforms. Data transformation is also required so that the data collected can be editable during further analysis. An example is mentioned in the book "atmospheric monitoring with Arduino: building simple devices to collect data about the Environment". After detecting the tropospheric gas using gas sensors, specific components must be connected to the sensor to display and store the data. For instance, liquid crystal displays (LCDs) are used to display the data, and electrically erasable programmable read-only memory (EEPROM) is used to store data. These components are cheap and easy to obtain. However, it needs human effort to complete the transitional work. Improving efficiency is optimal if the data collection can be combined with the data processing software.

Compared with other software, geographic information systems (GIS) have recently been preferred in different industries, as their efficiency is improved. GIS has its way of capturing different types of data. For those data printed out on paper, it is possible to scan and digitize the data directly. There are also survey data that can be entered into a GIS from the coordinate geometry. Position data are also possible to be directly imported into the system. In

addition, remote sensing data can also be processed using the GIS in the form of a raster. It is becoming the mainstream tool in different disciplines such as assessments of biomass resources, mineral resource analysis, groundwater, and air quality investigation.

Basically, a GIS includes five main components: hardware, software, data, people, and methods. The system captures geographic information and stores it for further analysis to present a product, mostly maps, to deliver themes like crisis forecast, risk assessment, and evaluation. GIS helps to organize data sets that are seemingly unrelated to making individuals and organizations understand spatial patterns clearly. Figure 1 shows the workflow of GIS [1].

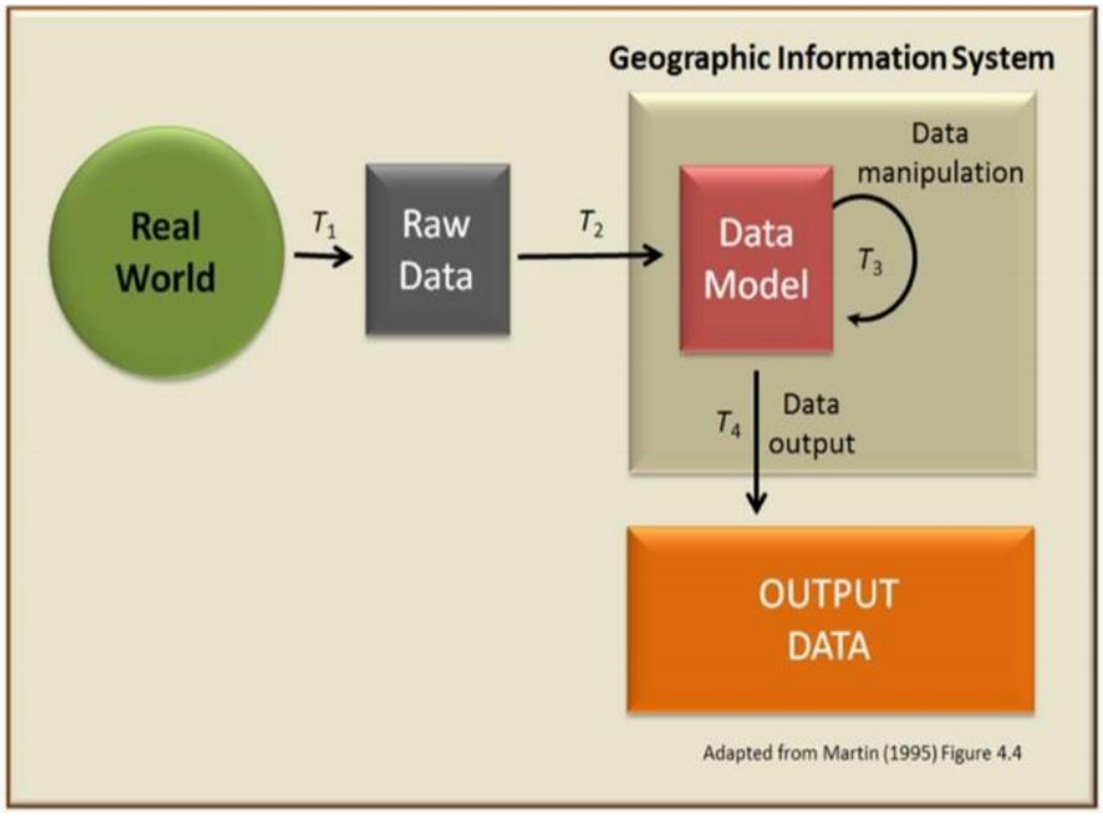


Figure 1 illustrates the Geographical Information System (GIS) workflow, which encompasses diverse data models facilitating spatial analysis. Specifically:

Topological Model: Examines spatial relationships within datasets, uncovering intricate connections. Hydrologic Model: Uniquely analyzes variables such as slope, watershed, and catchment area, differing from traditional hydrologic

models. Cartographic Model: Seamlessly integrates multiple thematic layers of the same region, enabling comprehensive spatial representation.
GIS's layer overlay capability allows for the visualization of interrelationships between disparate factors within a region. When combined with the system's mathematical models, this functionality generates actionable insights from input data layers.

The road network system in Lagos state faces numerous difficulties according to Odesanya Joseph (2020). The main difficulties acknowledged are the convenience and connectivity of the road network system in Lagos State which is "last mile connectivity" Rapid infrastructure development has resulted in land alteration, heat island effects, and transportation-related issues worldwide. Strategies to control these phenomena are essential for sustainable development. In addition to LULC variations, urban expansion has become a primary topic of discussion in anthropology. Pal S., Ziaul S.(2017) , Halder B., Banik P., Almohamad H., Al Dughairi A.A., Al-Mutiry M., Al Shahrani H.F., Abdo H.G. 2022. A road network can cause a reduction in areas with vegetation, climate variation, groundwater shortages, and air pollution; Khalid Hardan Mhana, Shuhairy Bin Norhisham, Herda Yati Binti Katman 2023
therefore, Natalia Neposhvvailenko, Iryna Omelych, and N. Dziuba's (2024) examination of the environmental impact and other road construction-related issues is essential to prevent unexpected developments, build awareness, and reduce deforested areas. Economic growth and population pressure are among the factors that produce rapid urban expansion. Lack of preparation for LULC transformation management at the municipal level affects the local environment and zonal climate, which can lead to the expansion of the urban heat island (UHI) Kikon A., Singh P.N., Singh S.K., Vyas. Sustain. Cities Soc.; 2016. The association between transportation networks and urban growth is at the centre of discussions about development, sustainability, cohesion, regionalization, and coreperiphery relation. Furthermore, the search for accessibility has been a driving factor of multifaceted projects and the appearance of subcenters Angelika Krehl Stefan Siedentop (2016). In 1981, the position distribution with advanced convenience standards was gathered in

the principal cummerbund everywhere in Madrid, which might be understood as an incomplete number of residences captivating fragments in the metropolitan procedures. The transportation corridors were the focus of attention during this period, and an individual southwestern subcentre cluster appeared. In 2011, the situation was comparable, but the number of subcentres increased. Nonetheless, the northern areas did not advance as much as the southern ones, undoubtedly because new infrastructure just started to be built and was less developed than in the southern direction. In 2011, the land occupied in the southern belt was notable. Thus, additional experimental methods have been applied to mobility to disentangle polycentric constructions. Consequently, research on LULC transformation at specific locations might help to comprehend the spatial magnitude and degree of the variations, in addition to other anthropology-related ecological fluctuations. Although Malaysia has extensively used satellite images in research, additional analysis is still required to understand the multi-temporal LULC in Lagos metropolitan city.

Land surface temperature (LST) is an important indicator of the Earth's surface energy budget when measuring LULC fluctuations and additional transformations on the Earth's surface Pal S., Ziaul S (2017). Using RS and GIS approaches to investigate and examine extreme variations, numerous studies have established that LULC affects LST Asmaa Hamed Fahmy, Mohamed Amin Abdelfatah, Gamal El-Fiky (2023). Lagos State City experiences an equatorial climatic change throughout the year. It has a yearly thermal fluctuation between 17 and 38 °C and a regular everyday mean LST of approximately 28 °C, with minimum and maximum temperatures of 23 and 32 °C, respectively Idris Aderinto (2017). In this study, the urban heat island phenomenon was evaluated through the inventorying of the static LULC pattern, assessment of the spatiotemporal changes, and the LST parameter for the years 1986 and 2016. This study employed Remote sensing and GIS techniques to interpret and classify the satellite images (Landsat TM, ETM+, and OLI) and generate the spatial characteristics of LULC for 1986 and 2016. Remote sensing and GIS techniques were also employed for the evaluation of the LST parameter to identify areas of urban heat islands. The result of the LULC classification

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showed that the Built-up area and Waterbody had a spatial extent of 31,221ha and 30,087ha. While Vegetation, Bare Surface, and Wetland had 37,458ha 3,634ha, and 15,717ha respectively. For the year 2016, the results showed that the Built-up area had an aerial extent of 57,046ha, while Vegetation and Waterbody had 22,214ha and 27,120ha respectively. Bare Surface and Wetland had aerial extents of 2,634ha and 9,103ha respectively. Findings of the LST presented that the temperature ranged from 150C to 240C in 1986 and 230C to 330C in 2016. The areas of urban heat island were thus defined by areas experiencing temperatures of 240C in 1986 and 330C in 2016. The settlements experiencing urban heat island in 1986 included Mushin, Bariga, Shomolu,
Yaba, Itire, Shomolu, Alimosho, Agege, Alagba, Ijaiye, Coker, Ifako, Egba, Oshodi, Ojota, Ososun,
Ikeja. Whereas, for the year 2016 they included Mushin, Bariga, Ojota, Ikeja, Surulere, Igando,
Eggan, Ijegun, Okun-Ibese, Itire, Iganmu, Agege, Ifako, Coker, Ijaiye, Ososun, Ejigbo, Alimosho,
Maryland, Oshodi. With these results, it shows that there has been an increase in the Land Surface Temperature of about 70C. This increase in the Land Surface Temperature is a result of urbanization and the level of human activity. This human activity talks about anthropogenic heat release i.e. heat from industries, cars, air conditioners, etc. From this study, the major causes of the UHI effect in the Lagos metropolis were found to be human factors and urbanization.

RESEARCH MOTIVATION AND AIM

The development of transportation and expansion of the road network in the urban–fringe–rural position is intensifying, and relevant studies are indispensable for developers and policymakers Martinez S., Sanchez R., Yañez-Pagans P. Road safety: (2019). Analyses of the interrelation between road infrastructure and ecological problems are limited; therefore, further studies can help researchers, scientists, and administration teams improve the application of new approaches on a specific domain. The aforementioned studies indicate that road-related accidents are an additional risk. Road Safety

Annual Report 2017. Road Saf. Annu. Rep. 2017. GIS-based approaches can help future disasterrelated decision-making with improvements in spatial analyses using short-term epochs Dereli M.A., Erdogan S. (2017) Truong L., Somenahalli S (2011). There are particular restrictions on the road network analysis system, LULC-related evidence, and ecological influences on the Earth's surface. Traffic volume estimation. Kumar P., Hama S., Omidvarborna H., Sharma A., Sahani J., V Abhijith K., Debele S.E., Zavala-Reyes J.C., Barwise Y., Tiwari A. 2020, Bakar M.F.A., Norhisham S.,

Katman H.Y., Fai C.M., Azlan N.N.I.M., Samsudin N.S.S. 2022. road density analysis Mohaymany

A.S., Shahri M., Mirbagheri B 2013, shortage distance, accident-prone area analysis Qiu C., Xu H., Bao Y 2016, suitable sites, and numerous LULC singularities are associated with land use, which is why road network analysis or review-related presentations are interwoven with LULC. The objective of this research is to (a) determine the LULC alteration of Lagos State Nigeria based on analyses of changes in vegetation and built-up areas; Katabarwa Murenzi Gibert, Yishao Shi 2023(b) use geospatial indices such as NDVI, SAVI, NDBI, and NDMI for understanding the land alteration and its impact on the environment; (c) utilize UHI and UTFVI for measuring thermal variations and ecological fluctuation in those major cities; and (d) use road network-related GIS applications such as kernel density estimation (for both roads and railways). This information is essential for city planning to ensure a sustainable and healthy life. Because current transportation development and the worldwide heat island effect are harmful to livelihoods, proper planning, management, and novel techniques can help reduce these issues. Recent road-related observations and transportation information might help to reduce traffic congestion and air pollution caused by vehicles, promote healthy vegetation, and achieve an overall reduction in the environmental impact over the selected study areas Mohamed A.H., Adwan I.A.I., Ahmeda A.G.F., Hrtemih H., Al-Msari H. 2021. This investigation also helps with decision-making regarding heat island effects, ecological alteration, and land transformation, along with transportation construction-related issues, in the major cities of the two selected countries.

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MATERIAL AND METHOD

Applied datasets and information

The examination of LULC alterations necessitates a considerable quantity of Earth's observational datasets to conduct an operative investigation. Earth observational datasets function as countless data sources from which rationalized LULC maps and variations can be examined based on simulations. Different datasets have been applied to investigate the environmental issues and ecological alteration in Lagos state Nigeria. Optical datasets are widely applied for landmass change analysis, in addition to environmental issues such as vegetation damage, urban expansion, moisture losses, heat variation, and temperature fluctuations. The datasets were used in this investigation:

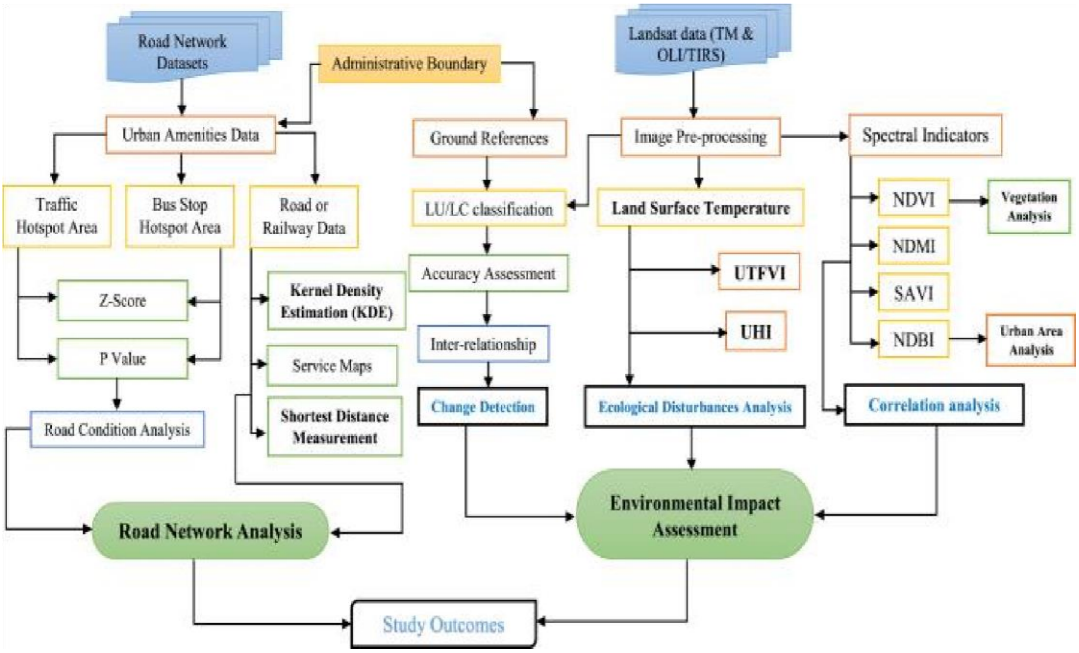
Landsat 5 TM and Landsat 8 OLI/TIRS, which were derived from the LAGOS GS website https://www.google.com/maps/search/lagos+GS+WEBSITE/@6.5535979,3.3610574,13z/data=!3m1!4b1?entry=ttu&g_ep=EgoyMDI0MTAxNi4wIKXMDSoASAFQAw%3D%3D and an open-source platform for identifying network-related information worldwide. These datasets were used for road and railway density estimation, shortage distance measurement, and hotspot analysis of bus and traffic signals. Furthermore, satellite images of four different dates were used to calculate the environmental fluctuations from 1991 to 2021 with ten years of interval. Table 1 lists the overall data acquisition information for the satellite-use dates. ArcGIS software version 10.8 and ERDAS Imagine (version 2014) were used for the classification, data analysis, density estimation, and map layout.

Table 1.
Details about the data information and acquisition date.

Lagos State

Satellite Sensor	Acquiring Date	Path/Row	Cloud Cover
Landsat 5 TM	21-02-1991	147; 043	<5%
	12-09-2001	147; 043	<5%
	06-07-2011	147; 043	<5%
Landsat 8 OLI/TIRS	07-02-2021	147; 043	<5%

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Methodological flowchart of this investigation.

The sampling frame is a complete list of all the members of the population that was sampled. The sampling frame for this research includes the users of the Lagos-Abeokuta expressway i.e. the operators (drivers) and commuters that ply the Lagos-Abeokuta expressway. The sample is adequate and represents a reasonable confidence level since the selected sample size is above the 392 obtained by using Yaro Tamane's (1967) formula in the determination of the respondent's views of transport facilities in the selected area along Lagos-Abeokuta expressway (table 1).

Table 1 shows the Sample Frame and percentage to be sampled (sample size)

S/n	LGA	Population	Sample Size
1	Agege	459,939	671
2	Alimosho	1,277,714	1920
3	Ifako-ijaiye	427,878	643
4	Ikeja	313,196	472
	Total	2,478,727	3706

Source: Authors fieldwork, 2019.

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The corresponding will represent the total population of people passing through the LagosAbeokuta expressway. This is necessitated by the fact that it will be impossible to administer questionnaires to a large number of road users. From the above calculation, it can be concluded that a total number of 3706 questionnaires were distributed and analyzed for this research work.

DATA COLLECTION INSTRUMENT

This involves data gathering or collection from specific sources in order to have full knowledge of the situation surrounding the research and make generalizations about the study. The methodology of this study involves the collection of data from both primary and secondary sources. The main instrument that was used to collect primary data for this study is through personal observation (field survey) and questionnaires. The questionnaire, which comprises of three major sections. The section examined the specific objective of seeking information for this research work.

METHOD OF DATA ANALYSIS

Descriptive statistics techniques such as percentages, frequencies, and means were used to highlight the socio-economic characteristics of the respondents in the study area. The analysis involves the expression of data in percentages. It is a single variable analysis that describes the necessary features of the sets of data. The relative importance index was used to rank the challenges facing infrastructure development by using the Likert scale. The Relative importance index is calculated from the below formula: RII = Summation W/ (A*N)
Where w = the weight attached to the respondents, scales in the order of 1 to 5 A = the greatest weight = 5N = numbers of all respondents.

CONCLUSION

Road transport infrastructure development is multifaceted and accordingly requires a coordinated methodology for its accomplishment from the investigation of this undertaking; we reasoned that road transportation infrastructure is a major force in the effective and efficient movement of people and goods across any nation.

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Generally, the study revealed that road transport infrastructure is important to the success of road transportation as a mode of transport in the country. Road infrastructure plays a crucial role in every country's socio-economic development by ensuring smooth movement from one point to another. However, despite this vital role, road transport infrastructures have been insufficient and poorly maintained, especially in most parts of developing countries like Nigeria. This study has shown a similar situation in Lagos State. The study revealed insufficient and inadequate infrastructure along the Lagos-Abeokuta Expressway. There is therefore the need for proper planning and provision of road infrastructure development in Lagos State.

RECOMMENDATIONS

This research work has examined the road transport infrastructure in Lagos state, Nigeria. The study has also shown various components of road transport infrastructure which is necessary for the effectiveness and efficiency of movement of people and goods from one location to another within Lagos state which could directly have an upward effect on the economy and development in other parts of the state.

It is against this that the following recommendations are made with the hope of helping the government in areas of dealing with the issues affecting and hindering sustenance of providing necessary road transport infrastructure. Efforts ought to be made by the legislature of Lagos state to evaluate the quantity of existing road transport infrastructures while also setting up a state maintenance board to restore them directly.

The government should broaden its aim and objectives on the provision of road transport infrastructure through partnerships with the private sector on the public-private partnership (PPP) to rehabilitate existing and construct new road transport infrastructures. There should be provision of alternative modes of transport like the rail system to reduce the burden on the roads in the long run. The Government should make use of the tolling systems in some selected places to raise additional funds for the maintenance and repair of bad roads. There should be general sensitization of the public on the proper use of the roads by the Federal Ministry of Transport or the Ministry of Transport in Lagos

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state, to prolong its usage and economic value. Finally, the Government should ensure that the road infrastructure distributions in the state are equally distributed.

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