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Impact Of Climate Change On Road Transport Infrastructure In Port Harcourt City, Rivers State, Nigeria

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***Abstract:** The study examined the effect of climate change on road transport infrastructure in Port Harcourt City, Rivers State, Nigeria. Two hundred and twenty copies of questionnaire were randomly administered among the respondents. Both descriptive and inferential statistics were used for data analysis. Findings revealed that 77.3% were males and 22.7% were females. Majority (66.4%) made use of their vehicles for commercial purpose. Results also showed that 56.8% agreed on rainfall as the mostly disturbing climate variable when driving. Thus, rainfall was ranked first based on severity to driving. It is also found that 23.3% of respondents agreed that climate change has to do with the damages of drainages in the various routes, while 17.3% of the respondent agreed that pavements have suffered damages from climate change. More than 50% strongly agreed that5 constant rain usually affects the strength of asphalt. Findings revealed that the impact of climate change on road transport infrastructures in Port Harcourt vary significantly from one route to another (Fcal=33.43; p<0.05). Similarly, the effect of climate change on road infrastructure vary significantly from one infrastructure to another (Fcal=78.94; p<0.05). The study concluded that climate variables that affect road infrastructure included temperature, rain, wind and change in climate greatly affects road transport infrastructure within Port Harcourt City. The study recommended among others that special emphasis should be given to road design, maintenance and rehabilitation processes, securing recurrent funding to account for increased costs and understanding of road infrastructure interdependencies to fully comprehend social and environmental challenges.*

***Keywords:** Climate change, Road infrastructure, Port Harcourt, Nigeria*

I. INTRODUCTION

Transportation systems are designed to withstand weather and climate. Transportation engineers typically refer to historical records of climate, especially extreme weather events, when designing transportation systems. For example, bridges are often designed to withstand storms. However, due to climate change, historical climate record is no longer a reliable predictor of future impacts (Emenike, 2015). Climate change is projected to increase the frequency and intensity of extreme weather events. Specifically, heat waves will likely he more severe, sea level rise could amplify surges, and storms will likely be more intense. These changes could increase the risk of delays, disruption, damage and failure across road transport infrastructures. Most road transport infrastructure being built now are expected to last 50 years or longer. Therefore, it is important to be aware that future climate might affect the road transport infrastructure in the coming decades (NRC, 2008).

Road Transportation is the lifeline of our society. Serious disruption to this transportation infrastructure can have catastrophic impact on the ability of the community, business and economy to recover from a disaster. It is of utmost important to address issue of building resilient transportation infrastructures with regards to recent changes in climate. There is an increasing body of evidence suggesting that the earth's climate is changing with some of the changes attributable to human activities. The concentration of carbon dioxide in the atmosphere today is likely to be higher than ii has been for the past 20 million years and the current rate of increase of carbon dioxide is greater than at any time in the past 20,000 years (IPCC, 2007). Climate models predict that increasing atmospheric concentrations of greenhouse gases will lead not only to global warming, but also to changes in climatic variability and the frequency, intensity and duration of extreme events such as hot days, heat waves, and heavy storms. Climate change in Port Harcourt is expected to increase both the overall volume of rainfall and the likelihood of rainstorms, which causes problems on roads. Rising groundwater level may weaken roads in places, shortens their useful lives, and increase the risk of damages to road infrastructure. Rainstorms are likely to increase erosion on road sides and around bridge supports. The capacity of drainage wells and tunnels and bridge arches may prove inadequate in the face of increasing frequency of rainstorms and the resulting floods. The increasing use of salt and rising average temperatures accelerate corrosions in bridges and higher flow rates increase wear on underwater structures. These factors also contribute to the rising costs of maintaining roads and bridges. Climate change can have direct and indirect impacts on road infrastructure in Port Harcourt. The direct impacts are due to the effects of the environment, primarily moisture, which weakens flexible pavements, rendering them more susceptible to damage by heavy vehicles and shortening their lives.

There are five major weather factors that affect road transport: temperature, rain, wind, moisture stress and fog haze. Low and high temperatures, rainstorms, increasing average rainfall, flood and fog can cause disruptions in road transport, damage road infrastructure and complicate road maintenance. The level of road maintenance required also depend on many other factors such as materials used to build roads, the number of road users, and earlier repairs. Weather is a major factor influencing the useful life of road transport infrastructure and the transport safety, Maintenance and repairing road transport infrastructures are indispensable to ensure their durability and the transport service that they can support. For instance, cold conditions and heat stress induce deterioration on e.g. road pavement that need to be routinely repaired. Such deteriorations affect the performance of road transport infrastructure together with other wear & tear factors, especially traffic load. Such repairing activities are part of the normal annual maintenance activities. On top of the routinely applied maintenance activity, more profound repairing interventions (bridges repairs, slope stabilization) are also required in case of severe damages incurred in case of extreme weather events. Both normal maintenance and repairing activities represent costs for the infrastructure owners (public/private) and a significant fraction of the total maintenance costs.

Road transport infrastructures are naturally exposed to various degradation factors (Wear & Tear). Traffic load and weather conditions represent two major causes of degradation. Other adverse factors include traffic accidents, robbery, construction defects. Reducing the level and the rate of these degradations by appropriate maintenance and repairing activities represents a cost for road transport infrastructure owners and builders (public and or private). Asphalt rutting, cracking, potholes, drainage system obstruction, are examples of weather-induced degradations which need to be taken into account in road transport infrastructure design and maintenance operations. Separating the two main factors for wear and tear (weather conditions and traffic) is rather difficult: asphalt rutting for instance is induced by high temperatures, but the effect is enhanced under high truck traffic load. Road infrastructure is a long-lived investment. Roads typically have design lives of 20 to 40 years and bridges of 100 years. An understanding of the expected impacts of future climate change by road planners, designers and asset managers could engender considerable cost savings in the long term (FHWA, 2008). On the basis of the aforementioned, this study is undertaken to examine the impact of climate change on road transport infrastructures in Port Harcourt City, Rivers State, Nigeria.

II. MATERIALS AND METHODS

The study was carried out in Port Harcourt City, Rivers State, Nigeria. Port Harcourt was built in 1912, but not given a name until August 1913, when the governor of Nigeria, Sir Frederick Lugard named it "Port Harcourt" in honor of Lewis Vernon Harcourt, then the secretary of state for the colonies. The Port Harcourt Urban Area (Port Harcourt metropolis) is made up of the city itself and part of Obio/Akpor local Government Area. Port Harcourt City which is the capital of River State is highly congested as it is the only major city in the state. As the capital of Rivers State, the metropolis is situated at the southern tip of Nigeria, a littoral state covering 10379km^2 and bordering the Atlantic Ocean. It is bounded to the north by Etche and Ornuma; east by Oyigbo, Tai and Eleme; west by Emohua; south by Okirika and Degema local government areas. It lies approximately between Latitude 4° 42' and 5° 15' North and longitude 6° 53' and 7° 18' East (Figure 1). The metropolis is sited on a relatively firm land about 661cm from the Atlantic Ocean on the Bonny River (Oyegun, 1999; Ukpere, 2005).

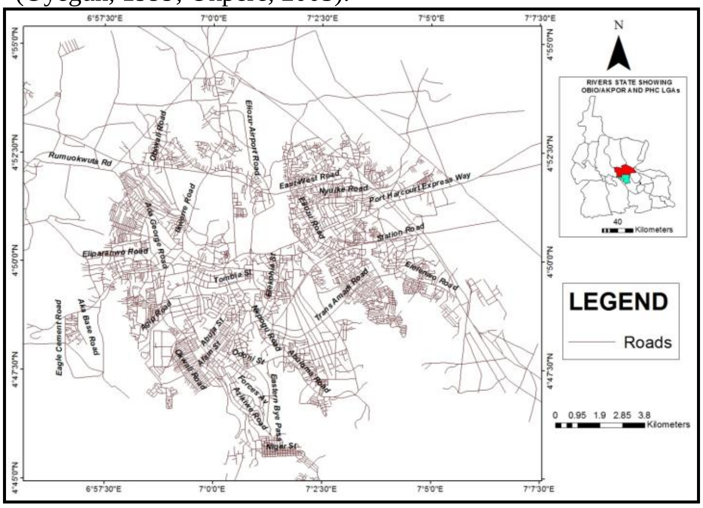

Figure 1: Port Harcourt Metropolis showing Roads

The study adopted a field survey research design method. The target population includes Ministry of works Rivers State, road construction companies, and road users which comprises of drivers that ply the chosen routes. Roads were chosen based on route capacity and vehicular flow. The data for this research were gathered from two sources namely primary and secondary sources. Primary data included questionnaire, oral interview and personal observation while secondary data that was used in this study were collected from journals, publications, newspapers, magazines and textbooks.

In determining the sample size, a total enumeration of the traffic route in the study area was spatially analyzed. However, in the selection of the sample size, the sample size for the study was based on route capacity and vehicular flow of the chosen routes. This now gives the number of roads to research upon; these routes were categorized into 3: namely; the major route, minor route and local routes respectively (Table 1).

Major routes	Minor routes	Local routes
Aba road	Churchill-Borokiri	Obiwali road
Ikwerre road	Creek road	Woji road
East/west road	Abuloma road	Elelenwo Toad
	Rumuokwuta road	Ordinance road
	Ada George road	Eleparanow road
	Rumuola road	Tank road
	Olu Obasaujo road	Rurnuodara road
	Agip road	
	Mgbuoba road	
	Artillery road	
	Stadium road	
	Aggrey road	

Table 1: Selected Roads in Port Harcourt

A total number of 22 routes were chosen, from each of the routes viz: major 3 routes, minor 12 routes, and local 7 routes. On each of these routes chosen, a total of 10 questionnaires were administered using random sampling technique. This was to enable the researcher have a manageable sample size given the time and financial constraints involved.

Research instruments that were used to gather the required data for this study included reconnaissance survey, road-side and in-car observation, questionnaire and oral interview. The questionnaire was structured into sections. Section A was concerned with information on socio-economic background of respondents. Section B, examines trip challenges. Section C asks questions relating to indices of climate change. Section D asks questions concerning impact of climate change on road transport infrastructure while Section E sought the opinion of respondents. The questionnaire was administered by the researcher.

Descriptive and inferential statistics were employed for data analysis in the study. Descriptive included frequencies and percentages. Inferential statistics involved the use of analysis of variance (ANOVA) to test the hypothesis that states that impact of climate change on road transport infrastructures in Port Harcourt does not vary significantly from one route to another. Also effect of climate change on road infrastructure does not vary significantly.

III. RESULTS AND DISCUSSIONS

SOCIO-ECONOMIC CHARACTERISTICS OF RESPONDENTS

The socio-economic characteristics of respondents are presented in Table 2. The sex distribution of respondents shows that 170 (77.3%) of the respondents were males and 50 (22.7%) were females. This indicates that most road users plying Port Harcourt routes were males. The age distribution of respondents shows that 42 (19%) of the road users were within the age brackets of 0-20 years, 67(30.5%) were within the age of 21-10 years, 88(40%) were within the age of 41-60 years and 23(10.5%) were within the age of 60 and above. This indicates that most road users fell within the age bracket of 41-60 years.

Sex	Frequency	Percentage (%)
Male	170	77.3
Female	50	22.7
Total	**220**	**100**
Age (Years)		
0-20	42	19
21-40	67	30.5
41.60	88	40
61 and above	23	10.5
Total	**220**	**100**

Table 2: Socio-economic Characteristics of Respondents

PURPOSE OF USING VEHICLE

Table 5 shows respondents use of vehicle: 34 (15.4%) of the respondent vehicle is for personal use. 146(66.4%) of the respondents vehicle is for commercial purposes. 28(12.7%) of the respondents vehicle is for heavy duty purposes and 12(5.5%) are for other purposes. The analysis shows that most vehicles that ply the routes are for commercial purposes.

Purpose of Vehicles	Frequency	Percentage (%)
Personal	34	15.4
Commercial	146	66.4
Heavy Duty	28	12.7
Others	12	5.5

Table 3: Purpose of Vehicle

IDENTIFICATION OF CLIMATE VARIABLES THAT AFFECT ROAD INFRASTRUCTURE IN PORT HARCOURT CITY

The analysis in Table 4 reveals that 59 (26-8%) of the respondents considered temperature as disturbing to driving, 125(56.8%) consider rainfall as disturbing to driving, 23(10.4%) of the respondents consider wind as disturbing, while 10(4.6%) consider fog and haze as disturbing while driving. The analysis of respondent's responses indicates that rainfall and temperature are most climate indicators that are disturbing while driving.

Table 4 still shows the ranking order of climate indicators that are most severe to disturbing driving on the road. Based on the respondent's opinion, rainfall is ranked as the most severe followed by temperature, wind, fog and haze and moisture stress.

Climate indicators Disturbing Driving	Frequency	Percentage (%)
Temperature	59	26.8
Rainfall	125	56.8
Wind	23	10.4

Moisture stress	3	0.4
Fog and haze	10	4.6
Others	0	0
Total	220	100
Climate Indicator Ranks Based on Severity to Driving		
Temperature	59	2nd
Rainfall	125	1st
Wind	23	3rd
Moisture stress	3	5th
Fog and haze	10	4th

Table 4: Perception towards Climate Indicator Disturbing Driving due to Road Infrastructural Damage and Climate Indicator Ranks Based on Severity to Driving

SPATIAL ANALYSIS OF ROAD NETWORK IN PORT HARCOURT CITY

Roads in Port Harcourt can be categorized into three major classes, namely: the major arterial, feeder roads and minor roads. This classification is based on their function and authorities responsible for their maintenance

MAJOR ARTERIALS: The major arterials in Port Harcourt City are Port Harcourt-Aba expressway, East-West Road and Ikwerre Road. These roads are trunk A roads as such are owned and maintained by the Federal Government. They serve the highest traffic volume corridors in the city. The Port Harcourt-Aba Express way, popularly called Aba road by residents of the city runs northeast wards. It links Aba and Umuahia in Abia State and Enugu in Enugu state. It access Uyo and Calabar, capitals of Akwa Ibom and Cross Rivers States.

East-West road which is one of the major arterials in the metropolis run west wards linking the metropolis with Yenagoa and Kaiarna in Bayelsa State and Patani, Ughelli, Warn, Effurum in Delta State. It also links the Core city with Bori and Onne in Rivers State and Ikot Abasi in Akwaibom State.

Ikwerre road otherwise called Owen road by residents of the city runs south- north. Its north link the city with Owen, capital of Imo State; and Onitsha in Anambra State. The Por (Harcourt-Aha express way intersects the East-west road at Onne junction while at Rurnuokoro junction, the East-west road intersect the Ikwerre road.

FEEDER ROADS: These roads link various part of the city to the major arterials in the metropolis. These roads link the metropolis with other land uses within the state. Unlike the former, they are not interstate roads. They are owned by the State government who constructs and maintain them. In recent times, new Feeder roads have been constructed and existing ones expanded to standard gauges (dual carriage). Some of these roads are Olu Obasanjo road, Trans-Amadi/Abuloma road, NTA-Mgbuoba (otherwise known as University of Port Harcourt) road, Rurnuola road, Rumuepirikom/Ada George road, Woji/Old Aba road, Harold Wilson Churchchill road, Abonnema Wharf road, Azikiwe road, Marine junction/Hospital road, LNG road, Elekohia/Mmarket road, Obi Wali/Rumuigbo road, Orazi road, Mgboshimini road, Okporo road, Eliozu road, Ogunabali road, Elelenwo/Refinery road.

MINOR/STREET ROAD: These roads distribute traffic within the major residential areas or neighborhood. They connect traffic with the feeder roads. As the name implies they are street roads. They have access to the buildings and land within the neighborhood. Some of these are Abel Jumbo street, Nsukka street, Egede street, Uruala street, Emenike street, Timber street, Nnewi street, Njernanze street, Abakililci street, Abba street, Ojoto street, Akukwa street, Ovim street, Okuzu street, Eliahuchi street, Ogu street, Egeba street, Ernekuku street, Wogu street, Agudama street, Isiokpo street, Oloihiri street, Kana street, Afam street, Kaduna street etc.

ROAD INFRASTRUCTURE AND CLIMATE CHANGE

Table 5 shows respondents opinion on road infrastructures that are affected by climate change in their various routes. It is found in the analysis that 51 (23.3%) of respondents agreed that climate change has to do with the damages of drainages in the various routes, 38 (17.3%) of the respondent opinion is that pavements have suffered damages from climate change, 29 (13.2%) ascertain that bridges and flyovers has also been damaged, 29 (132%) ascertain that culverts has been damaged, 68(30.9%) of the respondents said that tunnels has suffered damages from climate change in the various routes in Port Harcourt.

Table 6 summarizes the impacts on the transportation system from changes in temperature, precipitation, sea level rise, and hurricanes. The potential impacts of changes in climate on the city's road system are wide ranging. This underscores the importance of considering climate change in all phases of transportation decision making where vulnerability is expected. A long range perspective on possible threats to infrastructure in the future and the how risks to this infrastructure should be considered in today's decision making. This long range perspective needs to be balanced with monitoring for near term changes that may require more immediate adjustments. In addition to the direct effects on transportation infrastructure and services, climate change will likely cause changes in the environmental, demographic, and economic contexts within which transportation agencies conduct their work. In the long run, these broader changes may have very significant secondary impacts on the transportation sector that will need to be examined as part of the planning process.

Routes	Damage	Pavements	Culverts	Bridges/ flyover	Land	Tunnels	Total	Percentage (%)
Aba Road	4	1	1	1	3	-	10	4.55
Ikwere Road	2	3	1	2	2	-	10	4.55
East/West Road	3	1	1	2	2	1	10	4.55
Aggrey Road	2	1	3	2	2	-	10	4.55
Churchill Borokiri	1	-	5	1	1	2	10	4.55
Abuloma Road	3	1	2	2	2	-	10	4.55
Rumuokwauta	2	2	2	2	2	-	10	4.55
Ada George	5	1	-	1	3	10	10	4.55

Road								
Wimpy Road	2	2	1	-	5	-	10	4.55
Rumuola Road	3	1	1	-	5	-	10	4.55
Elewhia Road	3	2	-	1	4	-	10	4.55
Trans-Amadi Road	2	3	1	2	2	-	10	4.55
Agip Road	4	1	1	1	3	-	10	4.55
Mgbuoba Road	2	2	1	-	5	-	10	4.55
Aitillery Road	2	2	1	2	3	-	10	4.55
Habour Road	1	1	1	1	5	1	10	4.55
Garrison Road	2	4	1	1	2	-	10	4.55
Woji Road	1	2	1	3	3	-	10	4.55
Elelenwo Road	2	2	1	1	3	1	10	4.55
Rumuodar a Road	2	2	1	1	3	1	10	4.55
Ordinable Road	1	2	2	2	3	-	10	4.55
Tank Road	2	2	1	1	4	-	10	4.55
Total	51	38	29	29	68	5	220	100
Percentage s	23.2	17.3	13.2	13.2	30.9	2.3	100	

Table 5: Road Infrastructures that are affected by climate change in their various routes

Climate Impact	Potential Infrastructure	Impact Potential Operations
Increased Temperature	Highway asphalt Rutting Rail buckling Thermal expansion of Bridges, Overheating of diesel engines Increased vegetation — leaf fall	Potential for derailment and malfunction of track sensors and signal sensors, Increased travel time due to speed restrictions, Increased risk of hazardous material spill Frequent detours, traffic Disruptions Reduced efficiency of engines Ineffective braking of rail cars. visual obstruction
Increased Precipitation - Rain	Frequent and increased flooding of roads/rails /airport ran ways /bikeways and walkways Highway, rail, and pipeline embankments at risk of subsidence/heave Flooding of underground transit systems	Infrastructure deterioration (quicker with acid rain), impacts on water quality, Service disruption, Travel and schedule delays and Stranded motorists. Increased accidents, Loss of life and property. Increased safety risks, Increased risks of hazardous cargo accidents and spills. Landslides and wash-outs, Increased malfunctions of track and Signal sensors, Power outages
Sea Level Rise Storm Surges	Erosion of coastal. Highways Coastal road flooding Damage to infrastructure: roads, railways, pipelines, seaports, airports	Increased accidents, Evacuation route delays, Stranded motorists. Closures or major disruptions of roads, airways, airports, transit systems, pipelines, marine systems and ports; emergency evacuations; Travel delays Safely risks to personnel and equipment (risks of injury or death from accidents); Damages to roads, rai1 and runaways;
Increased Wind Speeds	Bridges, signs. overhead cables. railroad signa1sta1l structures at risk	Increased accidents, Roadways: loss of visibility from drifting Loss of stability /manocuvrability, Lane obstruction (debris), Railways: Rail car blow over: schedule delays; Safety risks to personnel and equipment (risks of injury or death from accidents);
Lightning Adopting nil preventive measures against lightening and electric shock	Disruption to transportation electronic infrastructure, signaling/Electrical disturbance etc.	Risk to Personnel from lightning, Operations/maintenance activity delays, Track signal sensor malfunction resulting in possible train delays and stops, threats to barge tow equipment, communications and data transfer may fail

Source: European Scientific Journal April 2014 edition vol. 10 No 11

Table 6: Impacts of climate change on road infrastructure

EXTENT OF DAMAGES CAUSED BY CLIMATE CHANGE TO ROAD INFRASTRUCTURE

Table 7 shows respondents opinions on the extent of damages caused by climate change on road infrastructure the analysis indicates that most of the respondents agreed that it has a severe and very severe effect on road transport. Only few of the respondents said it has no severe or has slight severe effect on road transport.

Road Transport Infrastructure	Not Severe	Ss	S	Vs	Total	Percentage
Land erosion	32	46	85	57	220	100
Drainage	22	26	82	90	220	100
Pavements	14	40	74	92	220	100
Broken bridges /fly over	12	25	85	98	220	100
Vehicle over healing	6	18	140	56	220	100
Vehicle fire deteriorate	13	32	77	98	220	100
Road expansion and crack	11	24	94	91	220	100
Traffic signs and signaling	23	41	68	88	220	100
Telecommunication installing	21	36	93	90	220	100
Lighting installation	32	36	96	56	220	100
Delays and disruption from heavy downpour	18	42	84	76	220	100
Road way immoderation from sea level rise	15	1	175	99	220	100
Current	18	6	120	76	220	100

Table 7: Extent of Damages Caused by Climate Change to Road infrastructure

EFFECT OF CONSTANT RAIN ON THE STRENGTH OF ASPHALT

Table 8 shows respondents opinion on how constant rainfall affects the strength of asphalt. 116 (52.7%) of the respondents strongly agreed that rainfall affects the strength of asphalt, 48 (21.8%) of the respondents agreed, 25 (11.4%) of the respondents undecided on the opinion that constant rainfall affects strength of asphalt. 23(10.5%) disagreed and 8(3.6%) of the respondents strongly disagreed that constant rainfall affects strength of asphalt. The analysis indicates that majority of the respondents strongly and agreed that constant rainfall affects the strength of asphalt.

1.	Strongly Agreed	116	52.7
2.	Agreed Undecided	48	21.8
3.	Disagreed	25	11.4
4.	Strongly disagreed	23	10.5
5.	Strongly Agreed	8	3.6
	Total	220	100

Table 8: Effect of constant rain on the strength of asphalt

PERCEPTION OF ROAD CONSTRUCTION COMPANIES AND RIVERS STATE MINISTRY OF WORKS TOWARDS CLIMATE CHANGE

From Table 9, the nine companies interviewed all claimed to incorporate climate change in road construction and climate factors considered in construction of roads includes temperature, rainfall, wind etc. These companies revealed that the strength of the asphalt has been increased following change in climate from 100-150mm to 150-200mm. Some of these companies claimed to be conducting risk assessment and research before the construction of roads, unfortunately, no evidence or supporting documents was provided. It is thus shown that 11.1% of the road construction companies believed that risk assessment is always done. Also, 44.4% believed that risk assessment is sometimes done and 44.4% had no comments on t5he issue.

Name of company	Importance of Climate Change	Climate factors considered	Research on Impacts	Risk Assessment	Asphalt level before Global warming	Asphalt level after Global warming
RCC	Very important	Temperature and Rainfall	Done	Sometimes	100-150mm	200mm
JULIUS BERGER	Very important	Temperature and Rainfall	Done	Always done	100-150mm	200mm
DATATA and SAWOE	Very important	Temperature and Rainfall	No comment	No comment	100-150mm	200mm
SETRACO	Very important	Temperature and Rainfall	No comment	Sometimes	100-150mm	200mm
LULU BRIGGS	Very important	Temperature and Rainfall	No comment	Sometimes	100-150mm	200mm
GITTO construction company	Very important	Temperature and Rainfall	No comment	Sometimes	100-150mm	200mm
RAFFUL Construction Company	Very important	Temperature and Rainfall	No comment	No comment	100-150mm	200mm
JDP Construction	Very important	Temperature and Rainfall	No comment	No comment	100-150mm	200mm
MCC Construction Company	Very important	Temperature and Rainfall	No comment	No comment	100-150mm	200mm

Table 9: Climate Change and Road construction companies

VARIATION OF THE IMPACT OF CLIMATE CHANGE ON ROAD TRANSPORT INFRASTRUCTURE AMONG THE TRANSPORT ROUTES

Impact of climate change on road transport infrastructures in Port Harcourt does not vary significantly from one route to another. Since the calculated value (F_{cal}=33.43) is greater than the table value (F_{crit}=2.61) (Table 10), the null hypothesis which states that climate impact to road transport infrastructures in Port Harcourt do not vary significantly from one route to another was rejected and accept the alternate hypothesis which states that the impact of climate change on road transport infrastructures in Port Harcourt vary significantly from one route to another.

Similarly, in Table 10; it is shown that the calculated value is greater than the critical value and as a result, the null hypothesis which states that the extent at which climate change affects road infrastructure do not vary from one to another was rejected while accept the alternate hypothesis which states that the extent at which climate change affects road infrastructure vary significantly from one infrastructure to another.

Source of variation	**Sum of square**	**d/f**	**Estimate of variance**	**F_{cal}- Value**	**$F_{critcal}$- Value**
TSS	233.3	119	1.96		
BSS	125.7	4	31.43	33.43	2.61
WSS	107.6	115	0.94		
Source of variation	**Sum of square**	**d/f**	**Estimate of variance**	**F_{cal}- Value**	**$F_{critcal}$- Value**
TSS	59352	51	1163.8		
BSS	49351	3	16450.3	78.94	2.61
WSS	10001	48	208.4		

$F_{cal} < F_{critcal}$: Null hypothesis is rejected for the hypotheses

Table 10: Analysis of Variance

IV. DISCUSSION OF FINDINGS

Respondents profile on age and sex shows that most of the respondents are between age bracket of 21-60 years and majority of them are male. Most of the respondent vehicles are for commercial purposes. Respondent's opinions on the impact of climate change on asphalt show that climate change reduces the strength of asphalt. Climate indicator that disturbs driving most is rainfall among others which are temperature wind, fog and haze, and moisture stress consecutively. It was also observed that climate change causes changes in pavement, changes in strength, putting. Crack blocking of drainage. The analysis carried out H_0 indicate that climate impact to road transport infrastructure in Port Harcourt vary significantly from one to another. While H_0, indicate that the extent which climate change affects road infrastructure varies significantly from one to another. Again, the interview with the construction companies revealed that some type of asphalt with stand climate conditions more than others. But because of cost issues, types selection for asphalt are affected. Although most of these companies are aware of climate change, not much is done in reducing the risk of damages caused by climate change on road. It was also discovered that climate change brings about changes in pavement, changes in strength, Rutting, cracking and blocking of drainage. This results to constant repair and maintenance of roads. Tests or researches on potential impacts of climate on roads are not regularly review in most of the construction companies. These companies reveal that because of climate change, the level of asphalt has been increased from 150mm to 200mm in order to withstand adverse weather effects. During the interview with the ministry, though the ministry is aware of climate change, they claimed that actions are in place with regards to its impacts on road transport infrastructures, construction companies are selected based on certain criteria. Follow-up/supervision of awarded roads to make sure that standards are met is sometimes not done. Also, the ministry has no emergency contingency plan in place for emergencies. It has been reported that increased temperature and more heat waves and has led to melting asphalt (dark surface); increased asphalt rutting due to material constraints under severe exposure to heat; and thermal expansion on bridge expansion joints and paved surfaces, and damage to bridge structure material. In addition, climate change hassled to more frequent droughts (and less soil moisture) which has resulted to degradation of road foundation due to increased variation in wet/dry spells and a decrease in available moisture. It was also reported that sea level rise and coastal erosion has been another challenge of climate change and this has led to the risk of inundation of road infrastructure and flooding of underground tunnels; degradation of the road surface and base layers from salt penetration; and more extreme rainfall events and flooding. Furthermore, climate change has led to more intensive and frequent storms which can lead to damage to bridges, flyovers, street lighting, signs and service stations; risk of inundation by the sea and blocked roads due to fallen trees, damaged buildings and vehicles. Each mechanism by which weather-induced deteriorations occur is specific to the infrastructure and, the level of deterioration, depends on a multiplicity of environmental parameters (e.g. locations, soil, traffic load etc.). For instance:The scouring of bridges over passing rivers is determined by the velocity of water, river bed sediment type (sand or other) and the level of protection of foundations (e.g. riprap, reinforced foundations). It has to he noted that intensive research effort are still ongoing to fully understand and describe all the physical mechanisms and parameters in play. High temperatures can damage road asphalt by inducing cracking but this highly depends on the type of asphalt applied, and binder types used. Precipitation-induced road degradation is assumed to be significantly aggravated where annual precipitation increases average by 100 mm/day (Chinowsky, et al., 2011).

V. CONCLUSION AND RECOMMENDATIONS

From the study, it could be concluded that climate variables that affect road infrastructure included temperature, rain, wind etc. Change in climate greatly affects road transport infrastructure within Port Harcourt City and most drivers finds it difficult to cope with it when climate indicators are at its extreme levels. Again, it is evident from this study that the intensity of rainfall, temperature, relative humidity, and pressure are all increasing, thereby confirming the existence of the phenomenon of climate warming in Port Harcourt City. It is therefore recommended that special emphasis should be given to road design, maintenance and rehabilitation processes, securing recurrent funding to account for increased costs and understanding of road infrastructure interdependencies to fully comprehend social and environmental challenges. Furthermore, local and state government agencies need to improve their knowledge of road transport infrastructure assets and associated life cycles to not only increase their capacity to adapt to climate change hut also account for future expenditure linked to their rehabilitation. Recognition of the impact of climate change using, for example, numerical analysis tools for road deterioration may help clarify and thereby help identify the effects of climate change. Perhaps assessments of climate change risks to infrastructure should be made mandatory to road construction companies. Frameworks need to he developed within existing planning processes that will assist road authorities to adequately respond to the projected impact of climate change on road as well as determining appropriate investment and adaptation responses for decision makers. Decision frameworks should accommodate uncertainty, incorporate probabilistic approaches to assessing risk and make appropriate investment decisions. Adequate planning including vertical alignment, horizontal alignment, holistic approach to water management, design and construction drainage and culverts, bridge design, landslide protection, road structure and pavements, environment protection and signs and lighting. Finally, tipping-points, new road designs, new decision making frameworks and asset management plans incorporating climate change considerations will aid adaptation by ensuring increased provisions costs.

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