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Climate change and smart city development: The challenge of non- implementation of Abuja-Nigeria light rail project

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In the present century, there has been increasing global pressure on governments to implement policies to incentivize reductions in CO_2 emissions based on the devastating effects of global climate change. Researchers generally have established the fact that the automobile sector generates more than 50% of the atmospheric carbon concentration. It has also become obvious that FCC-Abuja Nigeria is merely a replica of Lagos transport-wise in all ramifications. The Abuja master plan as of 1979 specifically recommended the development of mass transport by light-rail when the city's inhabitants are about 1.6 and 3.1 million for airport. The non-implementation of the light rail in the city has aggravated the flood of vehicular traffic that generates a lot of Green House Gas that in turn swells up the city's ambient temperature. This research therefore used the handheld outdoor thermometer to measure the traffic corridors in Abuja in relation to the WHO and FEPA tolerance threshold standard. This is compared with the modern electric rail that is environmentally friendly, and the result reveals that the present transport system in the city negates the global crusade for Green Mobility. It is therefore recommended that the Federal Government of Nigeria should as a matter of urgency cease from her lip-service to the global SDGs and fully implements the overdue Abuja light rail that will positively woo the other cities of the federation.

Key words: Atmospheric temperature, climate change, mass-transit, light-rail, transportation.

INTRODUCTION

Globally, there has been a growing scientific consensus on the need for governments to implement policies that incentivize reductions in CO_2 emissions. Evidence from both instrumental temperature measurements, increased melting of glaciers and loss of polar-ice cover supported the fact that global temperatures are increasing, and this observation can be used to estimate the rate of temperature increase since the late 19^{th}century. According to IPCC (2007), a 10% decrease in snow cover since the 1970s, a 15-20% reduction in Arctic sea ice, and a shortened period of lake and river ice cover have been observed. It has also been observed that ocean heat content has significantly increased over the past several decades with an abnormal rise in sea level

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accompanying a hurricane or other intense storm, above the level of the normal or astronomic tide.

A small proportion of the atmosphere has long been composed of GHGs (water vapour, carbon dioxide, ozone, and methane). These gases actively hinder part of the heat emitted by the earth's surface from otherwise escaping to the outer space, and apart from the natural greenhouse effect explained above; a change is anticipated in the greenhouse radiation balance. Some GHGs are flourishing in the atmosphere because of the anthropogenic activities that are increasingly trapping more heat (Morris et al., 2001; Robert et al., 2010). Direct atmospheric measurements made over the past 50 years have shown abundant steady increase in the atmospheric carbon dioxide (CO_2). If projected climate changes thrust environmental variables beyond the range for which a country's system is designed and the scientific evidence surges, then there will be environmental catastrophes that must be managed and adapted.

LITERATURE REVIEW

The question that readily comes to mind is 'what warms and cools the earth'? The sun is the main energy source of man on earth, and although its output is relatively constant, a small change during an extended period of time can lead to climate changes. Greenhouse gases such as: Water vapour (H_2O), Carbon dioxide (CO_2), Methane (CH_4), Ozone (O_3), Nitrous oxide (N_2O), and Halocarbons have continued to be used as substitutes for chlorofluorocarbons (CFCs) in refrigerant fluids, and CFCs from pre-Montreal Protocol usage as refrigerants and as aerosol-package propellants remain in the atmosphere (Forster et al., 2007).

The anthropogenic and natural activities' impacts of these changes have now been fully established (IPCC, 2007). A series of researches have examined the nexuses between climate change and the transportation sector. Studies have also been conducted principally from the perspective of transportation's contribution to global warming through the automobile's partial burning of fossil fuels, which releases carbon dioxide (CO_2) and other greenhouse gases (GHGs) into the atmosphere. CO_2 from combustion of fossil fuels is the largest source of GHG emissions. Although the susceptibility of the transportation sector to these impacts has not been fully investigated, nor has it been widely considered by transportation planners and decision makers, designing, constructing, retrofitting, and operating the transportation infrastructure has since been operational.

The challenging question to which the answer is not far-fetched is why transportation professionals should be distressed with climate change? First, it is not just a problem for the future but the present challenges, such as global warming and resulting sea level rises, have revealed the effects of GHG emissions that were released into the atmosphere over the past centuries. What appears shocking is the greater certainty that human activity warms the climate and that the rate of change is likely to be greater than at any time in modern history (IPCC 2007, 2013).

Secondly, climate change may not occur gradually but higher temperatures will be amplified by normal variability in climate, leading to new extremes far outside current experience such as the heat wave in Europe in 2003 (Stott et al., 2016) and the near record heat of 2006 in the United States.

Thirdly, the transportation profession is futuristic in nature, typically planning for between 20 to 30 years into the future, many present curent decisions, particularly about the location of infrastructure; helps in shaping development patterns that endure far beyond these planning horizons. In the same vein, decisions about land use regulation, zoning activities, and development controls often create demand for long-term transportation infrastructure investments. Therefore, it is important for transportation decision makers to put into consideration the potential impacts of climate change now in making these investment choices as it will affect how well those infrastructures can be adapted to climate change.

Fourthly, other professionals in the built environment especially those in finance and building (where protecting against flooding, earthquakes, wildfires, or cyclone is a concern), and water resources (in the design of dams and canals), are continually making decisions in the face of global warming uncertainties about disaster risks. In addressing climate change, more quantitative impact assessments and contingency planning at the level of geographic and modal specificity are needed by transportation planners and engineers (Ali and Elsan, 2017; Gonzalez et al., 2005).

Finally, transportation professionals have already cooperated weather and climate-related factors in designing and operating the transportation infrastructure. For instance, many transportation networks and facilities are designed with adequate drainage and pumping capacity to handle a 100-year storm. Also materials and maintenance models are built with assumptions about temperature and precipitation levels. Thus, economic activity is projected to produce greenhouse gas emissions across this century, while exponential increase in human activities now exerts pressure on land use/ water resources, fossil fuels utilization and natural resources (Van Asselen and Verburg, 2013; Avis et al., 2011). These emissions of greenhouse gases are making the Earth to warm, and, in aggregate, the global warming effects are expected to be deleterious and thereby endangering the global welfare systems (Comrier 2000).

Generally, road pavement infrastructures cover about 40% of urban surfaces, as estimated by Akbari et al. (2009) and asphalt concrete which is the most used road pavement material; and dark pavement materials together with automobiles traffic flow significantly contribute to

UHI, as confirmed by Mohajerani et al. (2017). Black surfaces which usually absorb incoming solar radiant energy have low albedo and the different thermal characteristics of these materials are recognized by Doulos et al. (2004) as a strategic challenge in cooling urban spaces. Thermal infra-red images confirmed that the albedo significantly contributes to the urban microclimate (Baldinelli and Bonafoni, 2015). Comparison of air temperature above reflective concrete, porous asphalt, porous concrete and conventional asphalt pavements (Coseo and Larsen, 2015) shows the difference between these materials in terms of heating an urban landscape.

The agglomerations of cars in the urban centres have been adjudged to significantly contribute to urban temperature. Thus, mass transport by hybrid rail is already attractive for its carbon efficiency, for example direct CO_2 emissions per passenger km from London Underground (LU) are around one third of what is typical for a single occupant car (DEFRA, 2013). Global sales of plug-ins are up by 63%, topping two million units. Forecasts predict vehicles with at least some type of plug-in capability will account for nearly half of global auto sales by 2040 (Tom, 2019). In California and San Diego, it has been established that even though they are in love with their cars and driving to work is a precious right as far as most of them are concerned, if given a pleasant alternative, a large number of them will take advantage of it to get to work.

According to NRC (1982, 2008), North America Committee on Light Rail Transit defined this mode of urban transportation based on thoroughly proven electric railway technology as:

“Light rail transit is a mode of urban transportation that uses predominantly reserved, but not necessarily grade-separated, rights-of-way. Electrically propelled vehicles operate singly or in trains. Light rail transit provides a wide range of passenger capacities and performance characteristics at moderate costs”.

This definition clearly reveals the overriding benefits of light rail above other urban means of mobility and justifies the centrality of national investment on it.

The concept of smart city in urban mobility

In the recent decade, carbon-free energy such as wind and solar costs have decreased dramatically, yet there are still substantial challenges in completely decarbonising our electricity system, and even more challenges in completely decarbonising the transportation and industrial sectors (Davis et al., 2018).

A smart city therefore can be defined as an urban system driven by Information and Communication Technology (ICT) and Internet of Things (IoT) that provide useful information to effectively manage resources and assets. This involves data emanating from citizens and mechanical devices, which are processed and analysed to monitor and manage traffic and transportation systems, power plants, water distribution networks, waste disposal, etc. It is aimed at improving the quality of urban services and reducing its costs. It generally stands out for its specificities: smart management, lifestyle, mobility, housing, as well as a smart economy. It is also to harmonize technological innovation with the economic, social and ecological challenges of the city of tomorrow. Their leitmotiv is the quality of life: how to live better together while respecting our environment.

CO_2 footprint reduction is the main driven force behind the development of smart and sustainable cities. Improving energy efficiency and storage, waste management, and traffic conditions are among the greatest advantages. Smart grids and smart water management are recurring themes of smart cities. In the hope of optimizing mobility, many cities are turning to smart technologies to ease traffic congestion and provide users with real-time updates for clean and efficient transportation of goods, services and people as emphasized in the works of Laura and Giuseppe, (2018), and Fensterer et al (2014).

The concept of green mobility and light-rail

Light rail or light rail transit (LRT) is a form of urban public transportation system that generally has a lower capacity and lower speed than heavy rail and metro systems, but with higher capacity and speed than traditional street-running tram systems. The system typically operates with rapid transit-style features that usually use electric rail cars mostly in private rights-of-way separated from other traffic but sometimes, if necessary, mixed with other traffic in city streets as displayed in Figure 1. The key attributes of LRT service include: use of exclusive lanes usually in the medians of roadways, exclusive rights-of-way, and stations that are spaced further apart than with bus services, typically every half kilometre (although stations are often spaced more closely within the Central Business District (CBD).

Aim and objectives of study

The aim of this study is to assess the environmental implication of the non-implementation of Abuja light-rail as proposed by the first master plan in relation to the green mobility crusade and global Climate Change. This is to be achieved through the following objectives:

(i) Examine the concept of Climate Change and green mobility in the light of fossil fuel dependent vehicles.
(ii) Examine the importance of light-rail as urban mass transit and sustainable development strategy,

Figure 1. Typical electric powered Light rail in Africa.
Source: Adapted from Air-Rail Africa 2016

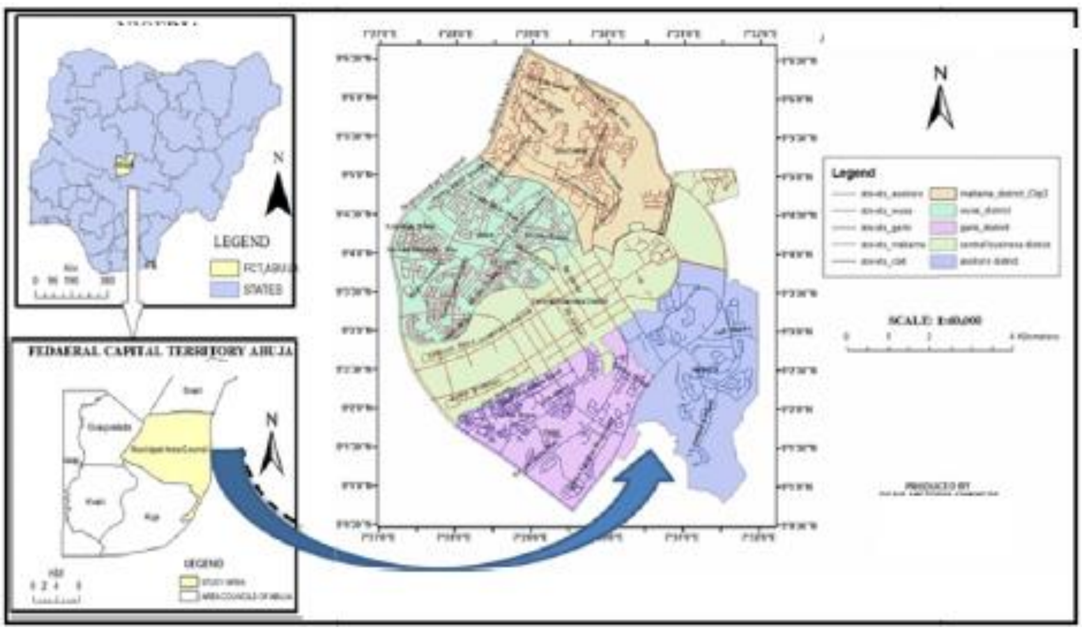


Figure 2. Study location, FCC-Nigeria.
Source: Adapted from Ayo et al. (2014).

(iii) Assess and map the vehicular heat emission level along the major transport corridors in Abuja,
(iv) Assess the environmental implication of the road corridor temperature in relation to ambient air temperature standards, and recommend planning solutions.

METHODOLOGY

Study area

Geographically, the Federal Capital Territory (FCT) lies between latitude 8° 25' and 9° 20; North of the equator and longitude 6° 45; and 7° 39; East of the Greenwich meridian, with a land area of about 7,315 km^2 (Figure 2). The estimated metropolitan population of Abuja is well over 3,000,000, but the population in 2012 was 2,245,000 making it the fourth largest urban area in Nigeria after Lagos, Kano and Ibadan.

Procedure

There are several ways of determining the mean radiant temperature (Tmrt) which is one of the main meteorological parameters governing human energy balance and has therefore a strong influence on thermo-physiological indices like Physiological Equivalent Temperature (PET) and Predicted Mean Vote (PMV) described in the literature. For instance, Thorsson et al. (2006) comparing integral radiation measurements and simple black globe temperature measurements measured. The mean radiant temperature (Tmrt) in two different urban structures, that is, a square and a courtyard in central Göteborg, Sweden. While George et al. (2015) used outdoor Wet-bulb globe temperature (WBGT) to examine the outdoor temperature stress on the FIFA players in Brazil. In carrying out this study, the entire city was divided into

Figure 3. Digital handheld outdoor thermometer and GPS.

quadrants of convenience, and the major roads were selected for survey nodes. On each of the roads, three different locations were identified where an ETL outdoor digital Thermometer was used to take temperature readings along the roads at about two-meters above the ground level. The readings captured the road corridor temperature during the peak periods of 7 to 10 am, 12 to 1 pm and 4 to 7 pm.

A geo-referenced map of Abuja was acquired and a hand-held Garmin 78 model Global Positioning System (GPS) was used to determine the survey nodes coordinates that was used to carry out the mapping in ArcGIS software (Figure 3). The corridor temperature readings were compared with the surrounding environment to determine the differences.

Status of vehicular growth and pollution scenario in Abuja

According to the National Bureau of Statistics (NBS), as at the end of the third quarter of 2017, Nigeria had about 11,547,236 motor vehicles in the country, of which about 4,656,725 of these vehicles are privately owned, while 6,749,461 of those vehicles are registered as commercial vehicles. A total of about 135,216 vehicles are registered as government owned vehicles, while another 5,834 vehicles are registered as diplomats. Vehicle-per-person in Nigeria is therefore about 0.06 as of the third quarter of 2017. This definitely presents huge opportunities for local vehicle production and assembly plants in Nigeria. For instance, the rate of motor vehicle ownership and use is growing faster than population in many places, with the vehicle ownership growth rates rising to 15 to 20% per year (Odeleye et al., 2008).

Vehicular transport emissions and air quality standard

Incomplete combustion of fossil fuels leads to the emissions of various pollutants (Larssen et al., 1993). Vehicles can emanate particles through exhaust emission, abrasion process, brake linings; road surface material and mechanical turbulence help in the re-suspension of the particles (Charron and Harrison, 2005). In the atmosphere, particles can experience further transformative procedures, including nucleation, coagulation, dissipation, build-up, and agglomerations, which change their shape, size, and piece (Lighty et al., 2000). Diesel-fuelled vehicles additionally transmit more nanoparticles, making a bigger contribution to particle number (PN) contrasted with gas-fuelled vehicles (Kittelson et al., 2004). There has been an exploration of the effects of alternative energy fuels. Modern Biofuel series has been found to significantly abate PM and vaporous toxins (counting CO and CO_2). Driving condition can also influence the molecule mass and number of outflow rates. Percentage share of pollutants emissions from different mode of transport is summarized in Figure 4.

Control over ambient atmospheric pollution has now become a big challenge not only due to the rising numbers of traffic volume as a source of non-point source pollutant but also due to the contribution of toxic risk resorted by the growing numbers of diesel cars. Diesel cars emit 7.5 times more toxic PM as compared to gasoline cars (Amrit, 2018). Keeping in mind the emission scenario, it is very much essential to create awareness among people to make their vehicles environmental–friendly in order to reduce emissions. Air quality standards are used to measure the air quality with respect to its effects on health. It identifies the amount of exposure permitted for the populace and ecological system. The permissible air quality standards prescribed by WHO, NAAQS and CPCB are mentioned in Table 1.

Abuja master plan and the light rail development

Population growth of the Federal Capital City (FCC) at the onset only supports initial development of bus transit services on the spine transit ways. In economic terms, operation of light rail does not begin to become attractive until hourly volumes of 6,000 or more passengers are reached according to the master plan. These volumes correspond to 60 or 70% of the population of 1.6 million inhabitants in the capital city. The population of Abuja based on the 2006 population estimate, the projected population of Abuja urban is 2.4million, while the metro estimate is 6 million as of 2011. The city was experiencing an annual growth rate of about 35% as of 2015, thereby still positioning the country as the fastest-growing city in Africa and as one of the fastest-growing cities in the world. As of 2016, the metropolitan area of Abuja is estimated at eight million (8,000,000) persons, placing it behind only Lagos, as the most populous metro area in Nigeria. The transit system of Abuja as evolutionary is long overdue for transition into a carbon-free rail system going by the master plan proposal. Figure 5a and b shows the proposed corridor design.

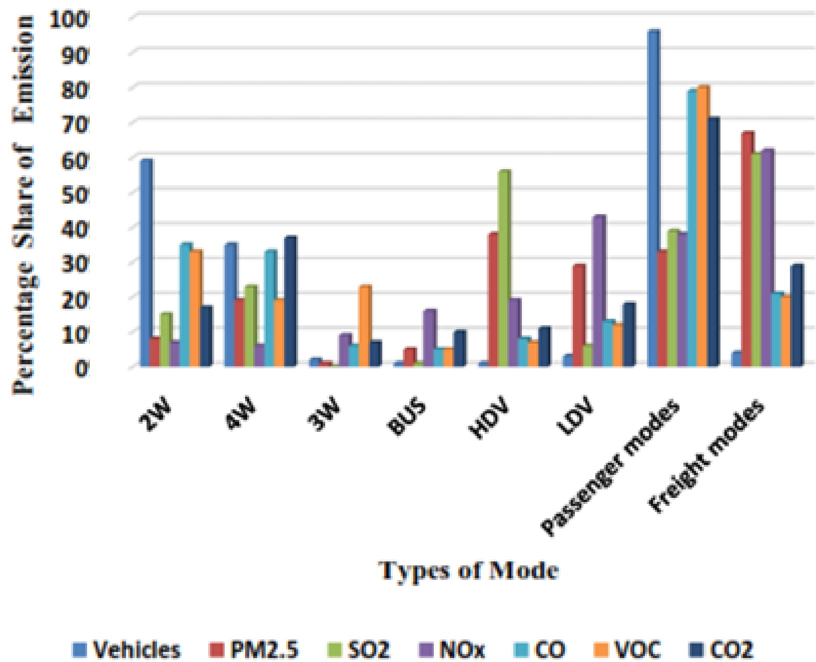


Figure 4. Share of emissions by passenger (2Ws, 3Ws, 4Ws and freight modes .
Source: Goel et al. (2015).

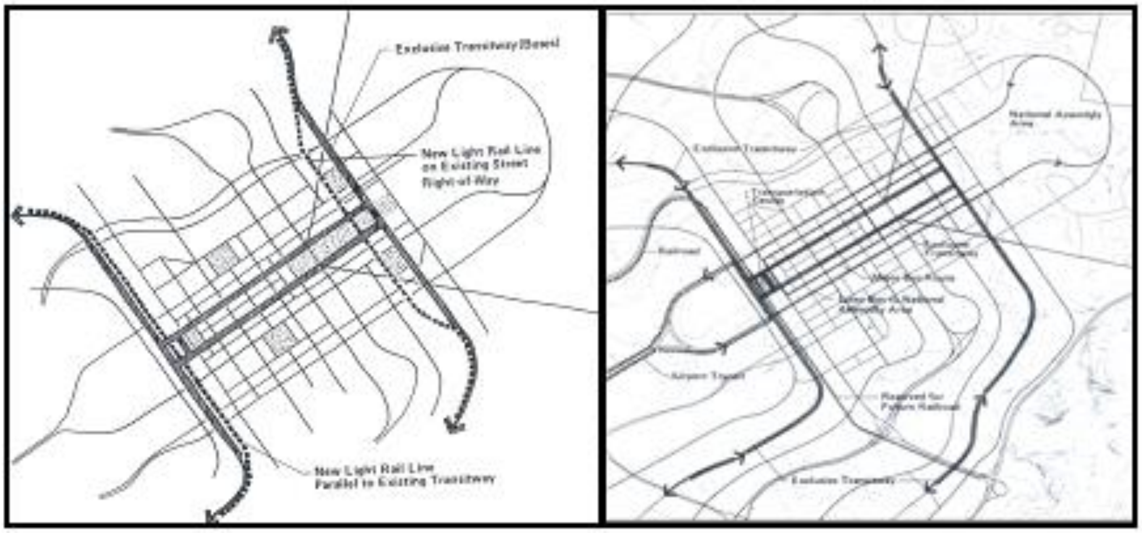
Table 1. WHO ambient air quality standard.

S/N	Pollutants	Time weighted average	Guideline values
1	Particulate Matter (Size less than 10 µm) or PM_{10} µg/m^3	Annual 24 hours	20 50
2	Particulate Matter (Size less than 2.5 µm) or $PM_{2.5}$ µg/m^3	Annual 24 hours	10 25
3	Sulphur Dioxide ($SO_{2)}$), µg/m^3	24 hours 10 minute	20 500
4	Nitrogen Dioxide (NO_2) µg/m^3	Annual 1 hour	40 200
5	Carbon Monoxide (CO), µg/m^3	1 hour Annual	30 50

Source: WHO (2013).

Implementation of light rail in Abuja

The initial Abuja Light Rail was first commissioned in 2007 by former President Olusegun Obasanjo as the first light rail network in West Africa. The Light Rail began operation after undergoing 11 years of construction during the time of four presidents gulping a total of $831million. The 45 kilometre rail connects the city to the Nnamdi Azikiwe International Airport and to later links other parts of the city to ease transportation. The China Civil Engineering Construction Corporation (CCECC) handled the project and was to have delivered the first phase of the project last year. The entire system wholly depends on fossil fuel power as against the modern electric system in even Ethiopia and other African countries. What was implemented in standard is far below the 21st century light rail



(A) (B)

Figure 5. (a) Interconnected light rail, (b) Central area public corridor and buses transportation system figure.

Figure 6. Rail transit in Nigeria and other African countries in the 21st century.
Source: Adapted from Air-Rail Africa (2016).

in comparison even to other African countries like that of Ethiopia in terms of the conveyor and the electric power infrastructure as revealed in Figure 6. The Abuja-Kaduna standard gauge rail is not environmentally friendly in terms of power source. Modern rails are expected to operate on electric power, Solar or Hydrogen cell as in Ethiopia.

A Light-Rail system has a lot of advantages above other commuter modes of transport that should move a country like Nigeria to readily adopt and implement without lip service and politicking. When it comes to System cost, Scheduling and reliability, Public comforts and social acceptability, light-rail is rated higher comparatively as revealed in Table 2.

RESULTS AND DISCUSSION

Meteorological aspects of air pollution and human health

In the words of Bob Patricelli, light rail should not be considered a panacea for the growing woes created by our increasing urban congestion. But, in conjunction with other traffic management strategies like park-and-ride, it is the right answer to the needs of a lot of commuters as it can make their lives more pleasant, and make the cities where they live more vital and interesting places which can contribute to the quality of the air they breathe.

Abuja has turned out to be a replica of Lagos in terms of the transport system and its woes. Atmospheric pollution is a widespread problem in Nigerian urban cities and is caused primarily due to fossil fuel combustion at point and non-point sources (Usman, 2014; Jaiyeola, 2017). Due to inadequate mass transit system in the various major cities like Abuja, the use of personal vehicles has continued to be on a steady increase. In addition to 70% two and three wheelers, petrol driven vehicles with four-stroke engines constitute about 14%, and diesel driven vehicles are about 8% of the total vehicles on the road.

Generally, an average normal human body temperature

Table 2. Key characteristics differentiating LRT from other transit modes.

Characteristic	Light rail	Bus	Commuter rail	Automated guide way	Rapid rail*
System costs					
Initial	Moderate	Low/moderate	Low-to-high	High	Very high
Operating and maintenance, per passenger mile(b)	………..	Higher	Higher	Similar	Lower
Attributes					
Schedule reliability	Excellent	Fair	Good	Superior	Excellent
Grade separation	Varies	Loss	More	100%	100%
Automatic operation	No	No	No	Yes	Maybe
Entrained vehicles	Yes	No	Yes	Maybe	Yes
Public perception					
Comfort, ride quality	Good	Fair	Good	Good	Good
Route comprehension	Easy	Hard	Easy	Easy	Easy/Hard
Social acceptability	High	Low	High	High	
Railroad involvement					
Operating labour	No	No	Yes	No	No
Freight coordination	Maybe	No	Maybe	No	No

is 98.6°F (37°C), and this ought to be maintained without the help of warming or cooling devices. The surrounding environment needs to be at about 82°F (28°C) as established in the work of Santamouris (2013). High environmental temperatures can be dangerous to the human body. In the range of 90° and 105°F (32° and 40°C), one can experience heat cramps and exhaustion. Some common symptoms of heat exhaustion already experienced in FCC as in Lagos include:

(i) Sweating heavily
(ii) Exhaustion or fatigue
(iii) Dizziness or light-headedness
(iv) Blacking out or feeling dizzy when standing up
(v) Weak but fast pulse
(vi) Feelings of nausea

Mapping of the Abuja rout corridor temperature

Mapping of Urban Heat Island (UHI) is a modern technique used in addressing urban temperature challenges as carried out by researchers like Heisler et al. (2007). The major streets in Abuja were selected, and temperature readings were taken simultaneously to determine the variation in the ambient temperature from the surrounding areas. Based on the field temperature readings, the streets were grouped into five, and Aminu Kano, Sani Abacha, Kashim Ibrahim, Ademola Adetokunbo, and Herbert Macaulay Way have the highest temperature range of 31.3-34.2°C as displayed in Table 3. The same data were imported into the ArcGIS to produce the map in Figure 7.

Conclusion

By the year 2050, around 66% of the world's population will be living in cities and this is no longer strange. But without commensurate planning in place, growing societal pressures in the built-up areas and the attendant climate change impacts could see the costs of managing an overwhelming city stacking up. For instance, economists from the UK, Mexico and the Netherlands suggested that around a quarter of the 1,692 cities surveyed could become warmer by as much as 8°C (14.4°F) by 2100 (Li et al., 2016; Robert et al., 2010). As a panacea, green mobility in the form of mass transit electric powered light rail is one of the solutions that Nigeria must key-in. Nigerian roads are littered with out-modelled and out-of-use vehicles. The heat island effect is a phenomenon that causes urban areas to become warmer than the surrounding rural regions, as concrete buildings and roads replace open land and vegetation (Al-Obaidi et al, 2014). According to the US Environmental Protection Agency (USEPA), pavement surface temperatures can be as much as 50-90°F (27-50°C) hotter than the surrounding air on a hot summer's day.

Apart from the direct impact on public health, higher-than-average temperatures could also cripple a city economically via civil unrest and reduced productivity due

Table 3. Abuja urban road temperature classified.

S/N	24.2 - 26.0°C	26.1 - 28.4°C	28.5 - 29.9°C	30.0 - 31.2°C	31.3 - 34.2°C
1	Ahmadu Bello Way	Alvan Ikoku Way	Aguiyi Ironsi Street	IBB Way	Aminu Kano Way
2	NnamdiAzikwe	Shehu Shagari Way	Shehu Shagari Way	IBB Way	Sani Abacha Way
3	Ahmadu Bello Way	Independence Avenue	Aguiyi Ironsi Street	Ademola Adetokunbo	Kashim Ibrahim Way By Wuse
4	Ahmadu Bello Way	Ladoke Akintola	Sani Abacha Way		Adetokumbo road
5	Muhammed Buhari Way	Obasanjo Way	Aguiyi Ironsi Street		Herbert Macaulay Way
6	LadokeAkintola way	By Tafawa Balewa Road	IBB Way By Ahmadu Bello		
7	Murtala Mohammed	Mashood Abiola Way	Constitution Avenue		
8	Independence Avenue	Funmilayo Ransome Kuti	Tafawa Balewa Opposite NICON		

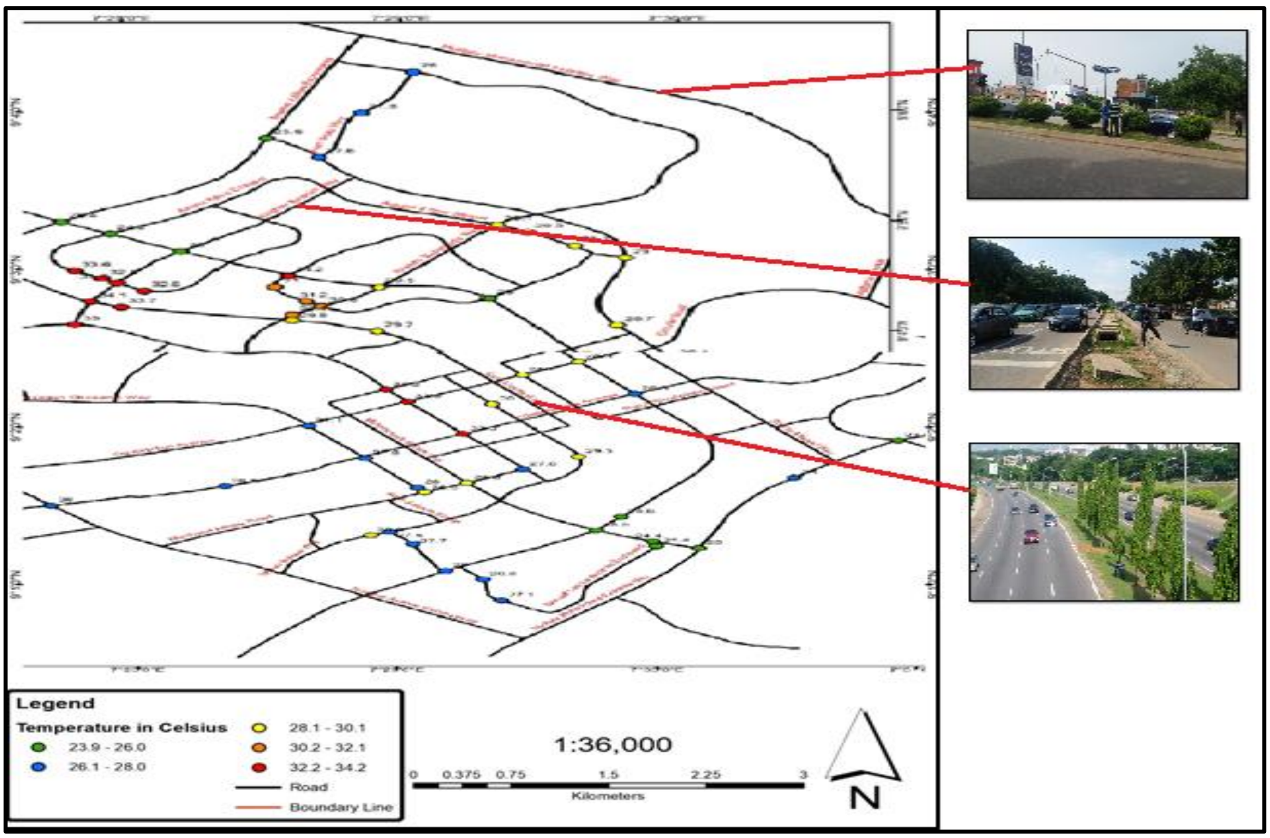


Figure 7. Abuja road corridor temperature distribution survey.

to heat stress and disrupted sleep as observed in the works of George et al (2015). This would also be exacerbated by an increased demand for electricity, which would in turn put more stress on a city's power grid, resulting in more frequent or prolonged outages, or a need for a whole new system entirely. This is not unconnected to the government policy on the evacuation of nation grid supply to Abuja to the detriment of other states of the federation.

Recommendations

Based on the above discussions, the following urgent approaches are recommended:

(i) The Abuja Development Authority in conjunction with Municipal Council should re-visit and renew the Abuja master plan

(ii) The federal government should as a matter of urgency

fully implement the overdue Abuja Light Rail as specified in the existing Abuja master plan, and that will positively woo the other cities of the federation like Lagos is presently doing.
(iii) To reduce the volume of traffic flow in the city, a Pack-and-Ride transport system should accompany the light rail system when implemented.
(iv) There should be a deliberate attempt to have a targeted year of moving the country from fossil fuel dependent automobiles to Eco-friendly ones in consonant with the global crusade on Global Warming and Climate Change Mitigation as in USEPA (2012).

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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