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Urban Morphology, Transport Demand and Climate Change: A Review of Conceptual Issues and Empirical Evidence

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Abstract

City designs influence transportation networks, available transport modes and ultimately travel behaviour. Within the context of Green House Gas Emissions leading to climate change, available transport modes are probably the most significant factor. Globally, road transport is considered a major contributor to transport emissions and this mode accounts for a significant share of movements in many developing countries including Nigeria. The study attempts to relate the morphology of cities to existing transport systems and thus draw implications for transport emission induced climate change. The paper adopts a case study approach. The sample cities (Lagos, Shanghai and New York) are drawn to achieve a spread in global economies-developing, emerging and developed economies. The analysis is largely descriptive and relates city designs and transport planning practices to real and potential emissions. Emerging and developed economies appear to be making progress in mitigating transport induced climate change. This is being achieved by prioritising mass transit modes which are more efficient in terms of energy use and by implementing fundamental land use planning policies. In developing countries, mass transit modes are still inadequate and the private car's modal share of vehicle fleet is enormous. These private cars are inefficient energy users because they are low capacity vehicles which offer higher emissions per capita of passenger moved. It is seen that the morphology of cities influences the available transport systems. Where land use planning is fundamentally deficient, adaptation methods will include the need to patronize technologically improved vehicles, but more practically, to prioritize mass transit.

Keywords:
Cities, Transit, Cars, Emissions

Introduction

In a world already committed to significant warming through activities and inactivity which amount to turning up the thermostat, cities are playing a crucial role in the global warming phenomenon. For cities in the developed world, global warming induced climate change threatens to weaken progress achieved to date; and in developing economies, climate change is exacerbating poverty and vulnerable conditions in the cities. Transport modes are a

significant factor in Green House Gas (GHG) emission levels and are therefore the focus of this study. Transport systems and modal choices are themselves influenced by the morphology of cities. The paper draws linkages between city form and transport systems and thus draws implications for transport emission induced climate change.

Research focus

Three cities are used as case studies namely New York, Shanghai and Lagos. All three cities are major commercial centres in their respective nations and are reputable urban centres known for achieving remarkable economic growth in the last few years. The cities also accommodate significant shares of national population and are in fact the most populous in their respective countries. They all fall within the ambit of the first 125 largest cities in the world ranked by population density. The choice of the cities as case studies is further informed by their spread across nations regarded as developed (New York in the United States), emerging (Shanghai in China) and developing (Lagos in Nigeria) economies. While there are several Green House Gases, carbon dioxide seems to be the most prevalent; hence emissions from GHG are often measured in carbon equivalents. The study therefore emphasizes carbon emissions from transport.

Materials and Methods

Data is sourced from secondary sources; these include electronic data from government statistical data pools and other relevant country/city literature. The paper adopts a case study approach and employs a largely descriptive analysis of the issues of city designs, transport systems and their linkages to real and potential emissions.

Conceptual Issues

Methodologies in Urban Geography

Urban geography is the study of towns and cities. These are areas commonly characterized by a high concentration of buildings and infrastructure, high population densities and in some cases by the prevalence of manufacturing and/or services. Primarily, urban geography focuses on the ways in which towns and cities are constructed, governed and experienced. These issues are hardly exclusive of each other and as such urban geography studies often include issues in urban sociology and urban economics.

There are basically two approaches to urban geography studies, one approach represents a descriptive and analytical discussion of the structure within individual cities, while the other locates individual cities within a system of cities at a larger scale. Both approaches are useful depending on the scale of analysis. This study adopts the former approach.

History of Cities and Models of City Structure

The emergence of cities dates back several centuries. At the time, natural constraints were the determining factors for settlement survival and prosperity. With the advent of improved technology however, natural constraints, though still a factor in the emergence and formation of cities, are no longer major determinants of city structures. While moderately sloping land have traditionally provided the best urban sites, astounding effects have been achieved on hilly sites such as San Francisco, Rio de Janeiro and Athens (Ellis Cliff, www.art.net).

In modern times, urban forms have been traced to the functions that informed their emergence and formation. Contemporary cities function as government/administrative centres (most country capitals such as Abuja and Washington DC), service centres for hinterland locations (Lagos, New York), break bulk points offering transportation services (such as Houston, Texas) and specialized centres for mining (Dawson, Canada), manufacturing (Shenzhen, China and New South Wales in Australia) or tourism (Dubai). Cities would naturally perform a mosaic of functions but many times there is a predominant one.

As noted in urban economics literature

(Alonso, 1964; Muth, 1969; Mills, 1970; Muth, 1985 and Bertaud, 2006), the classical categorization of cities includes monocentric, composite and polycentric models.

- Monocentric cities- these have a dominant high density centre (Central Business District) with a high concentration of jobs and amenities. Hence there is a radial pattern movement of people from periphery towards the centre.
- Composite cities- these have a dominant centre and several sub centres. These types generate simultaneous radial and random movements of people across the city.
- Polycentric cities- cities of this type have no dominant Central Business District (CBD), rather, there are several sub centres with jobs and amenities distributed in a near uniform manner across the built-up area. Movement of people is therefore random across the city. This corresponds to the muli-nuclei city model.

Monocentricity occurs sometimes from the need to exploit the advantages of agglomeration. Industries and commerce are therefore concentrated in a location to reduce unit cost of production and also provide access for large markets. Allied services are equally formed around these centres of production concentration. With increased resources and improved technology, these agglomerations may be duplicated in other parts of the city, thus causing the erstwhile dominant CBD to lose its primacy.

Indeed there may not be a sharp divide between city types as explained by the models, rather what we have is a continuum with monocentricity at one end and composite at the other with opportunities for cities to progress along the scale, very often towards the optimal composite model. This progress will often happen with diversification of city economies.
There is also the 'urban village model' where people live next to their places of employment and can actually walk or bicycle to work. This model, though available in urban master plans, and attractive to planners, are rare to come by in the real world. Theoretically, the urban village model represents the most transport energy efficient city structure as it dramatically reduces vehicle kilometres as well as passenger kilometres travelled and as a consequence, GHG emissions. According to this model, everybody could walk or bicycle to work even in a very large metropolis.

The five satellite towns built around Seoul in South Korea are an example of the urban village concept. When the towns were built, the number of jobs in each town was carefully balanced with the number of inhabitants with the assumption that these satellite towns would be self-contained in terms of housing and employment. Subsequent surveys have shown that most people living in the new satellite towns commute to work to the main city, and most jobs in the satellite towns are taken by people living in the main city (Bertaud *et al.,* 2011). This finding faults the underlying hypothesis of the model that planners would be able to perfectly match work places and residences. The principle of labour mobility, which may not often be associated with residential mobility, equally punctures the urban village concept. Better paid jobs may in fact precipitate movements to distant residences as transport costs become more affordable.

More importantly for this research, the models show that urban spatial structures dictate movement and trip patterns and consequently inform the modes of transport to be adopted. Polycentric and composite models provide a better understanding of modern city forms as they approximate reality much more. The density profile of most large cities however shows that the traditional monocentric city model is still a good predictor of density patterns (Bertaud *et al.,* 2011).

A significant point in the exposition of city models is the fact that networks are probably the most important of the three elements of urban structure which also include buildings and open spaces. The challenge for planners is to weave a complex, ever changing array of elements into a working whole to achieve optimal city performance. This optimization also applies to transport energy usage.

City Forms, Transport Modes and GHG Emissions

In monocentric cities where most jobs and commercial activities are concentrated in the CBD, public transport offers a convenient and efficient means of movement. This is so because even though trip origins are dispersed, the CBD remains the most common trip destination. Smaller buses therefore bring commuters from the various origins to the radials, where a Bus Rapid Transit (BRT) or a metro system can bring them in large numbers and at high speed to the CBD.

Due to its potential for higher load factors, high capacity modes in the form of public transport offer lower grams of carbon emissions per passenger kilometres than individual cars and smaller capacity collective modes such as taxis or mini buses. Difference in performance in terms of GHG emissions between public transport and cars in New York city for example show that emissions per car passenger per year are nearly six times more than the emissions per public transport passenger. Table 1 gives GHG emissions for various vehicle types from some studies conducted in the USA and Germany.

Table 1: GHG Emissions for Vehicle Types with Average Passenger Load Assumptions

Vehicle Type	Grams of CO_2 Per Passenger KM
SUV	258
Average U.S car	227
Motor buses	137
Light rail	111
Commuter rail	93
Hybrid gas	91
Toyota prius	73
Hybrid diesel	63
Metro	58
New York MTA	45
New York subway	96

Sources: Demographia, 2005; EIU, 2008 and O'Toole, 2008

The table shows that personal cars are the most polluting, while public transport modes are the least polluting modes. In the composite city model where there is a dominant centre as well as a large number of jobs and commercial activities in the suburbs, an efficient transport system will combine public transport and individual modes. Public transport will take care of most trips between the suburbs and the dominant CBD, while individual cars, collective taxis and mini buses will be used for trips between the suburbs. In this case, trips between suburbs will necessarily generate higher GHG emissions than those destined for the dominant centre. This will be the case if appropriate public transport systems are in place to serve CBD bound trips. As with other city structures, good traffic management is crucial in composite cities, with priority given to public transport.

The polycentric city is the least efficient in terms of collective mobility potential. Most trips are from suburbs to suburbs as there is no dominant centre. Intrinsically, this city structure has the advantage that several travel routes are available to a given destination. These routes will however have low passenger densities since trips are dispersed in both origins and destinations. Given the multiplicity of destinations and few passengers per route, public transport systems are inefficient and expensive to operate for polycentric city structure. Individual cars will therefore be dominant and so GHG emissions per passenger are likely to be relatively high in polycentric urban structures.

In reality, polycentric city structures may transit into composite structures. As the city grows, the tendency for some suburbs to assume higher dominance than others cannot be excluded. While the theoretical model of ploycentric cities assumes that jobs and amenities are distributed in a near uniform manner, growth in the city is not likely to occur uniformly. With adequate threshold conditions created within a particular suburb axis therefore, some dominant centres may emerge, giving way to a composite model city. This makes room for more efficient transport energy modes and possibly less GHG emissions per passenger kilometres travelled.

The lesson essentially is that transport strategies must be consistent with cities' spatial structures. Public transport is efficient when trips origins are dispersed but destinations are concentrated. Individual transport and small

capacity modes are more efficient when origins and destinations of trips are both dispersed and for linked trips if amenities are dispersed. The tendency for a modal shift to public transport is high when prices, speed and comfort are competitive with individual and other modes.

Empirical Discussions

In line with the review of conceptual issues, this section discusses existing transport systems and implications for climate change in the chosen cities. These are done against the background of an elucidation of the cities demographic/ geographic profiles.

City Profiles

A summary profile of the cities showing some geography and demographic details is presented in table 2. Lagos has the highest share of national population, though the entire Lagos region represents only 0.4% of the national geographic landscape. It also has the highest population density of over 13,000 persons per sq km and the highest upper limit growth rate of eight percent. New York city is the smallest of the three in terms of land area; while Shanghai is the largest of the three in area size and population wise. Shanghai is indeed the largest city in the world by population; in spite of this, the city has the least share of national population compared to New York and Lagos. Understandably, this is due to China's massive population of over one billion.

Net migration is a significant factor of population growth in the three cities. Shanghai's population growth is due entirely to in-migration. Main origins of migrants are Anhui (29%), Jiangsu (16.8%), Henan (8.7%), Sichuan (7%) and others from the rural areas. Natural increase in Shanghai has been negative since 1993 due to extremely low fertility rates (www.unescap.org). Population growth in New York is also due in large part to net migration. Migrants are mostly from foreign countries of Asia, Africa and the Middle East. The city is called the cultural capital of the world and is said to accommodate over 800 languages. Average fertility rate for the city has traditionally been lower than rates for the United States underscoring the fact that natural increase has not been significant in the city. In Lagos, net migration is equally considered a more potent factor in its population growth especially of the metropolitan area (Aluko, 2010).

Urbanization is therefore a key factor in the growth of these cities. These areas have continually attracted populations from other areas due chiefly to the economic opportunities offered in various sectors. The urbanization phenomenon has however exerted much pressure on the resources and infrastructure of recipient cities. Transport systems constitute part of these resources. Our interest is on modes used for internal movements in the cities.

Table 2: Abridged City Profiles

Geography/Demographics	New York city	Shanghai	Lagos city
Land area (Sq km)	784	6,340	1,323
Population[1] (millions)	8.3	23.7	17.6
City population % of National	2.6	1.8	11.5
Population density (pp/sq km)	10,633	3,700[2]	13,298[3]
Population growth rate (%)			
City	2.0	3	8
National	1.7	0.5	5
Climate	Humid continental	Humid sub- tropical	Tropical wet and dry

Sources: *US Census Bureau (2013), www.shanghai.gov.cn, www.lagosstate.gov.ng*

[1]Population figures are 2012 estimates.

[2]As high as 8,265 in the central city

[3]As high as 20,000 in the built up areas of the city

Urban Structure and Internal Transport Systems in Shanghai

Following the 1949 revolution, city planning in China emphasized integrated industrial centres consisting of complementary industries clustered together, with workers' housing within a reasonable walking or cycling distance, much in line with the urban village model. The same design principles have applied in Shanghai to more than 150 integrated developments built since 1949, albeit, modern developments and economic diversification have altered the structure reasonably. Currently, the city is administratively equal to a province, and is divided into 17 county-level divisions- 16 districts and one county. Each district has its own urban core, but a dominant city centre between Bund to the east, Nanjing Road to the north, old city Temple and Huaihai Road to the south. Other prominent central business areas include Lujiazui on the east bank of the Huangpu river, and the Bund and Hongqiao areas in the west bank of the Huangpu river.

Shanghai has a significant heavy industry sector, primarily, machinery, manufacturing, textile and steel. The city produces a large percentage of the power generation equipment and ships in China. Proximity to the cotton regions of China as well as access to the coast for easy international transportation has contributed to the strategic importance of the city. Currently home to citizens of many countries and all continents, it is no longer practicable to maintain the initial designs of workers housing situated close to working places, although industrial clusters still subsist.

To enable residents cope with its comprehensive commercial and industrial activities, Shanghai has an extensive public transport system, largely based on metros, buses and taxis. The city also has a rapid transit system- the Shanghai metro which incorporates both subway and light railway lines. These lines extend to every core urban district of the city as well as to neighbouring suburban districts. As at the year 2010, there were twelve metro lines, 273 stations and over 420km of tracks in operation, making it the third largest network in the world (Barboza, 2010). Shanghai's metro set a daily ridership record of 7.548 million on October 22, 2010. This amounts to close to a third of the city's population. The city also has the world's most extensive network of urban bus routes, with nearly a thousand bus lines operated by numerous transportation companies. Taxis are equally plentiful. Shanghai acts as a major hub of China's expressway network as many national expressways pass through or terminate in Shanghai. There are four major railway networks, three of which are connected to the metro system.

As part of its environmental protection policies, the government provides incentives for transportation companies to invest in Liquefied Petroleum Gas (LPG) buses and taxis. Although LPG has a similar calorific value to petrol, its energy density per volume is lower. It is therefore known to have a less damaging effect on the ozone layer than chlorofluorocarbons.

The promotion of such clean development mechanisms coupled with a well-articulated system of mass transit in a composite structured city has helped to steadily improve Shanghai's air quality since the 1990s.

Urban Structure and Internal Transport Systems in New York City

The modern city of New York was formed in 1898 with the consolidation of Brooklyn (until then a separate city), the County of New York (which included parts of Bronx at the time), the County of Richmond, and the western portion of the County of Queens. The opening of the subway in 1904, first built as separate private systems helped bind the new city together. Since the first half of the 20th century, the city became a world centre for industry, commerce and communication.

The five boroughs of NewYork city (Manhattan, Brooklyn, Queens, Bronx and Staten Island) easily define its non-monocentric nature. However, Manhattan and Brooklyn appear to have a relatively higher degree of dominance accounting for a higher number of jobs and population respectively. The city is a leading world centre for trade and finance.

The New York City subway is the most extensive public transport system in the world by number of stations. It has 468 stations in operation. The subway is one of the world's oldest public transit systems and contains 337 km of routes translating into 1,056km of revenue track and a total of 1,355km including non-revenue trackage. In 2012, the subway delivered over 1.65 billion rides. By annual ridership, the New York City subway (also called the lifeblood of the city) is the busiest rapid transit rail system in the United States and Americas, and the seventh busiest in the world, coming behind Tokyo, Seoul, Moscow, Beijing, Shanghai and Guangzhou.

New York City is distinguished from other U.S cities for its low personal automobile ownership and its significant use of public transportation. It has by far the highest rate of public transportation use of any American city, with 54.2% of workers commuting to work by this means in 2006. New York is the only city in the United States where over half of all households do not own a car (Manhattan's non-ownership is said to be as high as 75%). Nationally, the rate of non-ownership is 8%. The city however has the longest mean travel time for commuters (39 minutes) among major U.S cities. This is closely linked with the subway speed which ranges between 48-88km/hour. Safety limits are set at 80km/hour. While speed ranges do not outwit the average speed of private automobiles, subway riders use only half the time taxis and private automobiles will go on the same route especially during peak periods.

The city's uniquely high rate of public transit use makes it one of the most energy efficient cities in the United States. Current gasoline consumption in New York city is at the rate of the national average in the 1920s. The city's high rate of transit saved 6.8 million cubic metres of oil in 2006 and $4.6 billion in gasoline costs. These reductions meant that 11.8 million metric tons of carbon dioxide pollution was kept out of the air (US Public Interest Research Group, 2008). The New York City metro area was ranked by the Brookings Institution as the U.S metro area with the lowest per-capita transportation-related carbon footprint and as the fourth lowest overall per capita carbon footprint in 2005 among the 100 largest metro areas of the United States.

Urban Structure and Internal Transport Systems in Lagos

The present day metropolitan Lagos developed from a narrow low-lying island along the West African coast, a location which presents an economic advantage to her economic activities. Lagos contributed as much as 31.89% of National Gross Domestic Product (GDP) in 2004 and 65% of the nation's value added tax. The informal sector constitutes 65% of the city's working population. By the same token, informal transport services dominate the transport scene.

Lagos state itself comprises 20 Local Government Areas (LGAs), 37 Local Council Development Areas (LCDAs) and 2,600 communities. The metropolitan area (Lagos city), which is considered a statistical rather than an administrative division comprises 16 of the LGAs and contains about 88% of the population. Lagos Island is the city's traditional Central Business District (CBD), other CBDs have however developed over several years, notably Ikeja,Agege, Ikorodu and Apapa. The concentration of population and commercial enterprises as well as industries within the Lagos Metropolitan area has serious implications for its transport system.

Like many African cities, the urban sprawl phenomenon has become a common feature of Lagos. This means that commuting distances are becoming more far flung than ever before. Increasing transport requirements for obligatory trips is being met mostly with the use of private cars and para-transit modes. Although organized public transport systems such as the Bus Rapid Transit and more recently rail exist, these fall short of current transport demand. Additionally, the coaches currently utilized in the rail system are not comfortable and not decent enough for passenger travel. A modern Light rail transit has been proposed but is yet to commence.

Mobility in Lagos has therefore relied heavily on private cars and a fleet of about 75,000-90,000 minibuses (called *danfos*) together with a fewer number of midi-buses

(known as *Molue*) and shared taxis. Initially, only local journeys employed motorcycles (popularly known as *Okada*), in recent times however, motorcycles have been used for major intra region journeys in Lagos. Unfortunately, mini and midi buses are of low quality, fares are unstable and journey times slow and uncomfortable. In addition, these buses ply relatively short distances for profit maximizing motives at the expense of serving passenger demand. The bus drivers and their mates (popularly called conductors) are also reputed for aggressive driving and passenger intimidation.

The challenges with the informal and unorganized public transport services further predispose residents to opt for the use of private cars. The shortcomings with existing para-transit modes also prompted the formation of the Bus Rapid Transit (BRT) in Lagos which became operational in 2008. This organized public transit scheme is estimated to carry 200,000 people per day and had carried a total of 29 million people in the first six months of operation. Although not quite in the category of the highest specification of a rapid transit scheme, the Lagos BRT Lite pilot corridor consists of a 22km route connection between Mile 12 and Lagos Island which is the traditional Central Business District (CBD). The Ikeja-IyanaIpaja route has also been added to the Lagos BRT route.

For approximately 60 per cent of its length, the Lagos BRT has service roads. It crosses over one of the three bridges that connect the mainland with Lagos Island and as such the route effectively connects extended suburbs and satellite centres to the premiere CBD of Lagos. The scheme, the first of its kind in Nigeria however has its challenges. Its evaluation after the initial six months of operation showed that users were saving journey time, had less road interchanges to contend with, were travelling cheaper and felt safer. The major problems identified by users are the need for more buses and to cover more routes. The Lagos BRT scheme in this vein has a target of 4,500 high capacity buses.

There is a concentration of work places and activity centres on Lagos/Victoria Islands and Apapa axis. This influences the direction and the flow of traffic and is largely responsible for the perennial traffic congestion in the city. This spatial structure of concentration of work and activity centres is itself not problematic; in fact the structure lends itself to efficient public transit schemes. Trip length for commuters in the city region is said to range between 10-30km daily (FRN, 2006). A great part of these trips during traffic peak periods will be in snarling conditions given the vehicle density of 224 per kilometre of road. This is in contrast to the national average figure of 15 vehicles per kilometre of road. Currently there are people residing in the local governments of neighbouring Ogun state who commute to work in the central business district of Lagos daily. Lagos is an urban area with a massive population around a web of commercial activities. It is not likely that growth in this city can be slowed down, it can only be managed, and so must its transport needs.

In response to increasing transport demands in the city, the vehicle population in Lagos has increased consistently in the last decade (2001-2009) by as much as 234 percent from 235,542 to 788,436 (see figure I). This increase has been composed mostly of private cars (Figure 2). Private cars which make less efficient use of road space per passenger, and higher per capita emissions, accounted for an average of 78 percent of the vehicle fleet in the last decade. Globally, about two thirds of greenhouse gas emissions from road transport have been attributed to the private car primarily in the form of CO_2.

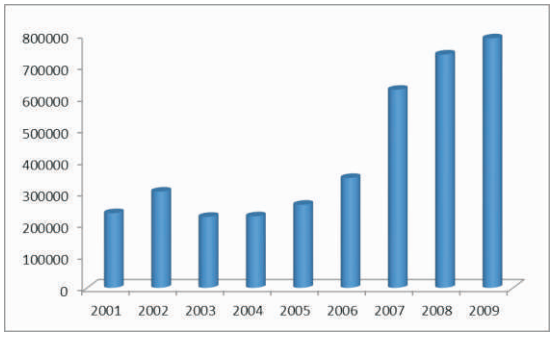

Figure 1: Total Vehicle Registrations in Lagos
Source: Lagos State Government, 2010

The Lagos state government household survey of 2010 gave the respondents' main mode of transportation as public bus (70.24%), walking (11.9%), motorcycle (7.89%), private car (7.08%), bicycle (1.73%), water (1.03%) and train (0.04%). The modal shares of the vehicle fleet inventory (average figures for 2000-2010 are used to calculate proportions) is tabled side by side the modal share of trips (as given in the Lagos 2010 household survey) and presents a vehicle profile/modal shift paradox in table 3. The Bus Rapid Transit (BRT) share of trips was calculated from Lagbus and Lagos Metropolitan Area Transport Authority (LAMATA) figures.

Table 3: Vehicle Profile/Modal Split Paradox in Lagos.

Vehicle type	Modal share of vehicle fleet (%)	Modal share of trips (%)
Private car	78	7.08
Public bus	10	70.24
Bus Rapid Transit (BRT)	<1	2.3

Source: Calculated based on Lagos state government (2010)

This paradox underscores the shortage of public transport and congested road scenes from low capacity private cars and motorcycles. The situation therefore escalates real and potential emissions from the Lagos transport sector. Owing to economic constraints from low disposable incomes, poorly maintained, older vehicles are often imported, leading to an automobile fleet dominated by a class of vehicles known as 'super emitters' which release higher concentrations of harmful pollutants in comparison to properly maintained vehicles. In developed countries, these super emitters represent 10% of the vehicles on the road, yet generate 50% of emissions (Brunekreef, 2005). While there is no hard data on proportion of vehicles bought as used and those bought new in Nigeria, a reverse of the order that exists in developed countries is probably what obtains in developing countries. In Nigeria, probably less than 10 percent of vehicles in the national fleet were purchased new. Given the relative economic prosperity of Lagos state, it is generous to say that 10 percent of vehicles in the fleet were purchased new, while the other 90 percent would fall into the 'super emitters' category.

Apart from a consistently increasing vehicle fleet composed mainly of private cars as shown in figure II, the use of motorcycles has also been on the increase.

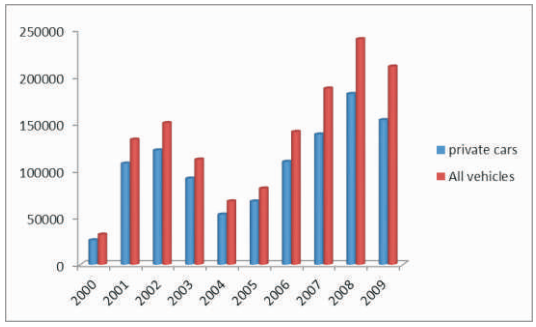

Figure 2: New Registration of Vehicles in Lagos
Source: Lagos state government (2010)

During the decade 2001-2009 new motorcycle registrations increased from 13,140 to 80, 414. This represents an increase of 511 percent over a decade. The rate at which motorcycles are being churned out for commercial transport in many Nigerian cities and specifically in Lagos have assumed disturbing proportions. Consequently, restrictions are being placed, barring them from operating in dual carriage roads and highways.

However, restrictions on motorcycle operations in some Nigerian cities have often been short lived, probably because their emergence is acutely fundamental. Motorcycle use for personal and public transport has come about partly as a result of the urban sprawl phenomenon. Urban areas like Lagos, have spread out into largely unplanned spaces and these sprawls do not have well laid out routes to attract buses for public transport. Access roads in some areas are in very poor conditions, such that only two wheelers like motorcycles can venture in. Motorcycles have also emerged as a preferred means of transport for some in the metropolitan area due to the perennial traffic congestion problem. They are therefore patronized by city dwellers because of their flexibility and ability to manoeuvre through traffic congested streets and so reduce travel time. Water transport, which forms one of the

most environment friendly modes of transport accounts for only about 1% of Lagos trips. This is in spite of the fact that Lagos metropolis is abundant in inland waterways.

Implications of City Transport Systems for Climate Change and suggested actions

Research has shown that the best cities in the next decades will be low carbon cities, mass transit must therefore be prioritized as they offer lower carbon emissions per capita. While we cannot directly ascribe all the change in climate parameters to emissions from transport, evidence from literature suggests that CO_2 emissions lead to warming which leads to extreme weather events and over time to changes in climate patterns.

Shanghai has a two pronged attack for ameliorating carbon emissions from climate change -the mass transit system and the promotion of LPG vehicles. These are steps in the right direction. The fact that transit accounts for a significant share of trips in New York city also gives it reasonable leverage with regards to reducing carbon emissions from transport. The city will do well to provide incentives for fuel efficient vehicles for private use.

The preponderance of private car use in Lagos predisposes the city to increased carbon emissions from transport. While anecdotal evidence suggests that environmental protection agency limits have not been reached in Nigerian cities, the current state of transport infrastructure deficit exacerbated by energy inefficient transport modes, points to the fact that these limits need not be reached before the fallouts of climate change and extreme weather events become unbearable.

In order to achieve a decrease in the use of private cars and the promotion of public transport, public transport systems must be organized and decent. The BRT scheme needs to be promoted and prioritized in Lagos. Presently, some operate in mixed traffic. This will not assure reduced trip times for commuters. Decency and reduced trip times in addition to cheaper fares in public transport are the incentives that can trade off for the flexibility of private cars and so ensure a migration of commuters away from one to the other. Cheaper fares (cheaper relative to operating the private car) is however not a sufficient condition for commuters to change modes from convenient private modes to public transit modes. With the added incentives for public transport use in place, there may be the need for disincentives for private car use. This could be in the form of on street and off street parking charges. Proper maintenance of existing BRT buses and facilities are suggested otherwise, what we will have on our hands in the next few years will resemble the adapted vehicles popularly called '*Molue*'. An increase in the BRT fleet is equally suggested. This increase may however be limited because road space constraints to ensure the segregation needed for BRT is already becoming an issue. In the medium and long term, the proposed rail transit scheme should therefore be made operational. Evidence from literature (Bertaud *et al.,* 2011) show that rail transit schemes are even more energy efficient than the BRT.

Air pollution from rapid industrialization / urbanization and energy use has been recognized as a major health concern. The World Bank (1997) estimated that air pollution caused 178,000 premature deaths in China in 1995. Health damages in the year were valued at nearly 5% of GDP. Reduced CO_2 emissions have since resulted in fewer cases of respiratory illnesses, reduced premature deaths, reduced values of health damages and increased GDP (Garbaccio, et al, undated). This shows clearly, that there are health and economic benefits in controlling carbon emissions.

Conclusions

Total distance travelled worldwide is projected to increase by about 90 percent from current levels by the year 2030. As the number of vehicles increase, this growth needs to be managed. There is therefore a need to develop policies, technologies and infrastructure for the future delivery of transport services that are consistent with global emission reduction goals. It has been demonstrated that the morphology

of cities influences available transport systems. However, once cities have been formed, what is left is to balance efficient transport systems with attempts to reduce emission levels. Where land use planning is fundamentally deficient, adaptation methods will include the need to patronize technologically improved vehicles, but more practically, to prioritize mass transit.

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