

TECHNICAL ARTICLE

Revitalization of Greater Khartoum Urban Transportation System

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Khartoum metropolis depends on a single-modal transport – vehicular road system. Mass transport modes are completely absent making Khartoum unable to meet citizens' mobility demand. Thus passengers facing long time delays in transport stations. Slow traffic speeds and severe traffic jams result in long trip periods, high traffic accidents rates and high suspended particulate concentrations accumulating in the air. This situation is attributed to:

- Use of small-sized vehicles running on limited paved road network.
- Adoption of extensive grid iron planning patterns lacking multi-grade intersections.
- Eroded public transport fleet and extremely overcrowded urban centres.

Negligence of public transport systems integration into landuse plans and urban structure restructuring difficulty crippled public transport revitalisation for no space is left for mass transport infrastructure construction. Moreover, transport systems' operation mismanagement and focus on economic development increased pressure on transport systems.

This paper endeavours to point out the deficiencies in public transport services and proposes the areas of reformation.

To revitalize urban transport, Khartoum main transport infrastructures must be efficiently operated by establishment of a talented transport authority supported by strong legislations and popular authorization and able to adopt sustainable mobility solutions to meet current and future traffic demands by:

- Rehabilitating and expanding the existing infrastructures.
- Deploying large-capacity multimodal transport systems including river transport, bus rapid transit systems, tramways and metropolitan railways to connect Khartoum polycentric and its sprawling outward growth.
- Mitigating environmental pollution and enforcing stringent road safety measures.
- Reviewing traffic laws to tighten traffic regulations and control traffic flows.

Investment priority should be given to river transport. It is economically feasible, has large carrying capacity and safe and almost accident free. Furthermore, Nile Rivers dominate the metropolis, dictate urban configuration, direct urban growth, impose urban expansions patterns and influence spatial organization.

Keywords: Khartoum; urban transport; mass transport systems; river transport; accidents; air pollution

1. Introduction

1.1 Greater Khartoum

Greater Khartoum, the national capital of Sudan, is placed in central Sudan at the confluence of the Blue Nile and the White Nile rivers as shown on **Figure 1**. It is located at longitude 32' 32 E and latitude 15' 36 N, and has an elevation of 1352 feet above sea level.

Greater Khartoum formed by three cities, Khartoum, Omdurman and Khartoum Bahri, **Figure 2**. It lies in the transitional zone between the Sahara and the Savannah belts and It has a tropical continental climate, characterized by very hot dry summers with occasional rainfall during July to September having an average rainfall of less than 150 mm per annum.

Greater Khartoum is the most populous state in Sudan as it is inhabited by eight million people; equivalent to almost 20% of Sudan population. This is in addition to its position as the largest administrative, industrial and



Figure 1: Country of Sudan.

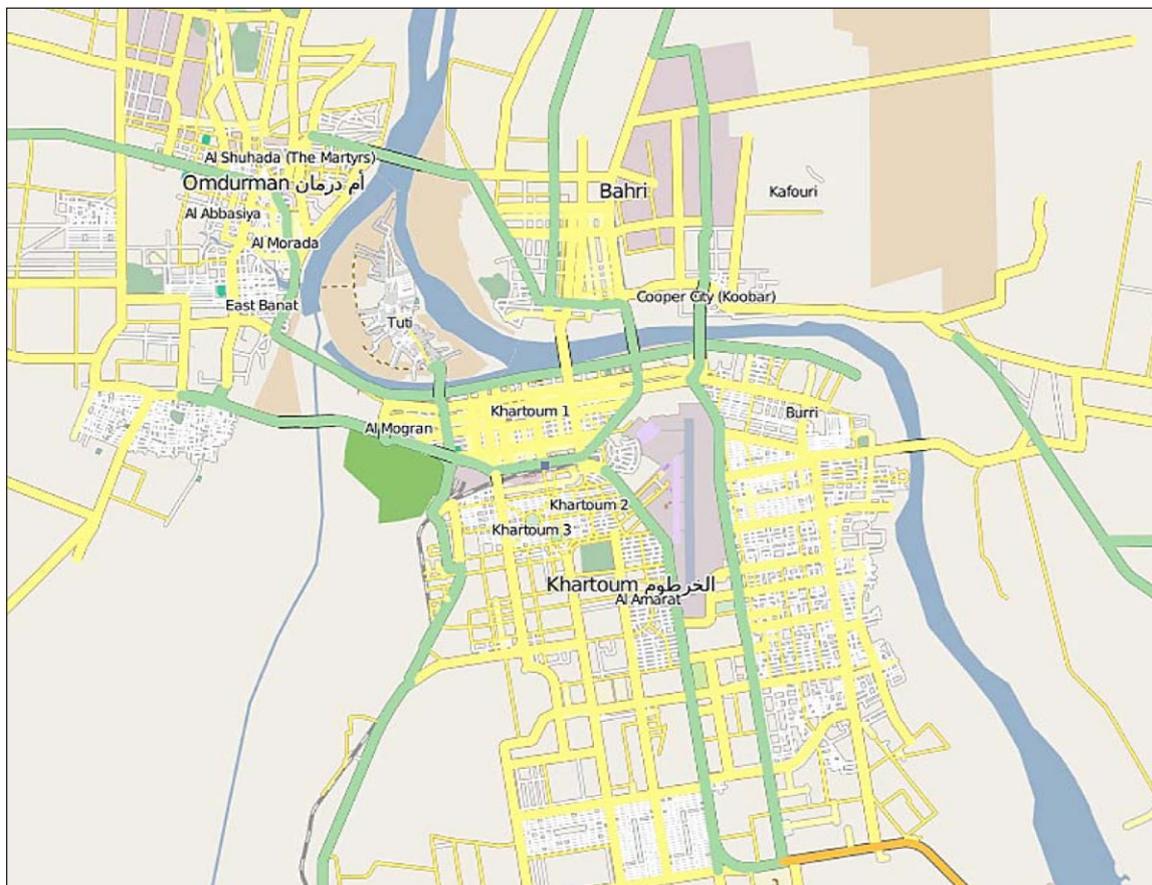


Figure 2: Greater Khartoum Core.

commercial centre of Sudan. This huge metropolis requires the use of efficient and effective transport systems.

1.2 Urban transport networks and urban growth

Urban transport, a multi-faceted activity, dictates the quality of life of millions of the urban dwellers, whether they are residents of developed or developing cities. The transport system plays a key role in cities' development and their future growth taking into account the many new extensions that are established on major transportation lines. Thus, the transportation plan is an integral part of landuse plans and landuse is the major driver of traffic generation. Inadequacy of public transport systems leading to limited people mobility disable the functioning of the impacted part of the city, particularly when the transport fleet is unable to deport workers in the desired working hours.

Public transport also facilitates unity and fusion of city parts by enhancing the social communication process between all layers of the urban society.

2. Methodology

This paper is edited to cover all issues addressing Greater Khartoum public transport reformation and its impacts on the urban environment. The primary data was gathered by the author and his associates through a number of household and field surveys conducted as part of a number of urban studies tackling Khartoum rapid urbanization, namely:

1. The study of the status and strategic environmental assessment and evaluation of the State of Khartoum conducted by (Bannaga Consult 2014).
2. The Arab Engineers Union prize winning project entitled: "Use of River Transport to Enhance Public Transport in Khartoum State" (in Arabic version), submitted by (Bannaga & Hassan 2016) who received the prize at the end of March 2016 in Manama, Bahrain.
3. "Measures towards Improving Traffic Safety Level in Khartoum State". A PhD thesis supervised by Dr. Bannaga and submitted by (Hassan 2016) for Sudan University of Science and Technology in December 2016, Khartoum.
4. "The Physical Planning Role in Solving the Transportation Problem in Khartoum State". A MSc thesis supervised by Dr. Bannaga and submitted by engineer (Himmad 2015) for the Higher Military Academy, Khartoum in 2015.
5. Studies carried out earlier by the author and studies conducted by the consultants who formulated Khartoum structural plans in 1991 and 2008 considering that the author was fully engaged in the preparation of both plans.

In all the mentioned studies, information was gathered from a number of sources:

- Questionnaires were used to collect information from the urban and rural households in Greater Khartoum.

- Road side's *field* surveys were conducted manually by counters employed by the designated consultants to count vehicles on streets, number of daily passengers, vehicles number and type, origin and destination of the journey and its type and duration.
- Interviews targeting concerned officials and the public were conducted in person to know their perspectives and opinions.
- Data from Khartoum State ministries and competent departments were compiled.
- Observations for seeking additional information on passengers on board and vehicle drivers' behaviours and conducts were recorded.

Data received from respondents' responses and field surveys were structured for use in SPSS and were analyzed to identify the current status of the public transport systems and to judge whether they are adequate and efficient to ease residents' mobility through Khartoum Metropolis and its peripheries. The data were also used to identify the impacts of public transport on the urban environment and to formulate present and future plans for revitalizing the transportation systems.

Therefore, the objectives of this paper are to:

- Quantify and present the serious Khartoum residents' needs for public transport considering Greater Khartoum phenomenal rapid urbanization.
- Evaluate the current status of Greater Khartoum urban transport, make an assessment and propose the projects that are required to be implemented to address the growing urban problems in public transport.

3. Greater Khartoum Demand for Transportation Services

3.1 Destination of population movements

No doubt, efficient urban transport systems ease people mobility and facilitate urban connectivity. Two of the main public transport service lines provide links between homes and the workplaces while the others connect the institutions of learning. **Figure 3** gives the destination of population movements in Khartoum. When commuters were asked about their destinations half of them replied by going home, 28% were going to work and 16.7% were school students heading for their schools and universities. Other trips are for social gatherings, shopping, recreation, etc.

3.2 Traffic demand

Although, as other services, transport systems follow the known theory of supply and demand the choice of using different types of vehicles (such as car, bus, Indian motorcycle "rucksha", minibus, etc for mobility) makes estimating traffic demand in Khartoum very difficult. However, the demand can be measured in the number of trips covering the total distance of a passenger on all vehicles or such as a passenger – kilometer on a public transport or vehicle-kilometer-trip (VKT) in private transport. The price of the trip and the trip time are also considered as measures of the capacity of the transport system. It is,

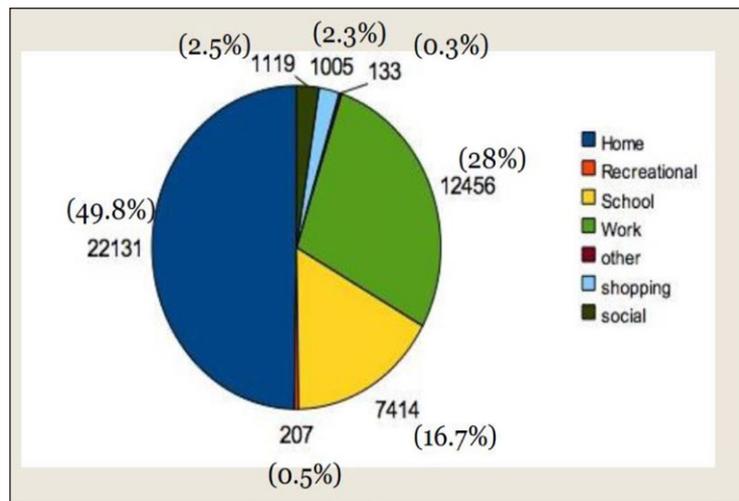


Figure 3: Population Mobility Indicators in Khartoum State. Source: MEFIT.

however, difficult to estimate systems capacity based on time, distance and price in Khartoum because these are complex issues. This is why (MEFIT 2011) has applied the number of passengers on the trip for calculating traffic demand. MEFIT estimated Khartoum traffic need in 2015 as more than 4 million passengers' trips per day, of which 2865080 trips are required to be covered by public vehicles as provided in **Table 1**. The percentage of passengers using public transport was 70% which is reasonable.

In comparison, the number of passengers using public transport and travelling throughout Greater Khartoum in 2005 was far less than the 2015 figure (42%) as exhibited in **Table 2**. This is of course obvious because of the rapid population growth which usually doubles in a decade.

Table 3 shows the estimated number of vehicle trips heading towards the main centres of Khartoum, Khartoum Bahri and Omdurman and the number of passengers moving during an average day in 2015. It indicates that one and a quarter million (124625) passengers per day move towards the main urban centers and this number represents more than 43% of the total number of passengers travelling using public vehicles.

According to (MEFIT 2011), the citizens who used Khartoum transport systems in 2014 were up to 70% of the total population of the state. The author study revealed that 53% of the passengers used medium to minibus and 16% move on foot and the majority of which is walking to school. It is to be noted that:

- Approximately 15% of the population (mostly children, overage, and elderly) does not use public transport.
- About 15.5% use motorcycles, private vehicles and public transport provided by private and government institutions.

4. The current status of Greater Khartoum urban transport systems

4.1 A Single mode transportation system

The public transport system in Greater Khartoum does not use all means of transportation but relies on one mode system which is road transport depending on vehicle

Table 1: The number of daily passengers' trips in the designated year.

Year	Passenger Trips in a Day	Passenger Trips in a Day Using Public Transport
2010	3087524	2161267
2015	4092297	2865080
2025	5425840	3798088
2035	9562137	6693496

Source: MEFIT.

Table 2: Public vehicles and numbers of passengers in Khartoum state/day in 2005.

Type	Licensed number	number of trips	Number of passengers/ trip	Total Number of passengers
Civil buses	69	8	50	27,600
Tourist buses	89	8	50	35,600
Mini-Buses	7705	8	25	1,541,000
Taxi	96	8	7	5,376
Medium	2203	7	7	107,947
Total				1717523

Table 3: Number of Passengers Travelling per Day in 2015 to Khartoum, Khartoum Bahri and Omdurman Centres.

Centre	Bus (25 passengers) On average	Number of trips per Bus per Day	Total Number of Buses	Number of Passengers Travelling per Day
Khartoum	3337	409	38382	959550
Khartoum Bahri	392	67	3398	84950
Omdurman	759	92	6006	201750
Total				1246250

operation. Systems such as river transport, railways and metros are not in use. The system is increasingly dependent on small vehicles despite the fact that transportation by means of vehicles running on roads is easy and fast, especially in remote subdivisions, which are difficult to access by other means. On the other hand, dependency on vehicle transport requires extension of roads and construction of multi-grade crossings to ensure smooth traffic flows.

4.2 Roads and bridges

It was observed that efforts during 1970s to 1990s towards achieving minimum goals in the transport sector were much less but some progress was made by the

State in the early nineties and at the beginning of this century when the road networks started to expand and in the middle of 2010 and large funds were allocated, which led to the expansion of road networks and increase of the number of bridges. In spite of these efforts the transport system is still operating at low efficiency. This is because intensification of economic developmental activities in Khartoum is placing an increasing pressure on the road network.

Currently the installed network of asphalt roads covers 1,723 kilometers which are spread across the central regions of the three main cities. This falls short of serving the remaining vast area dominated by a grid-iron layout pattern as indicated in **Figure 4**.

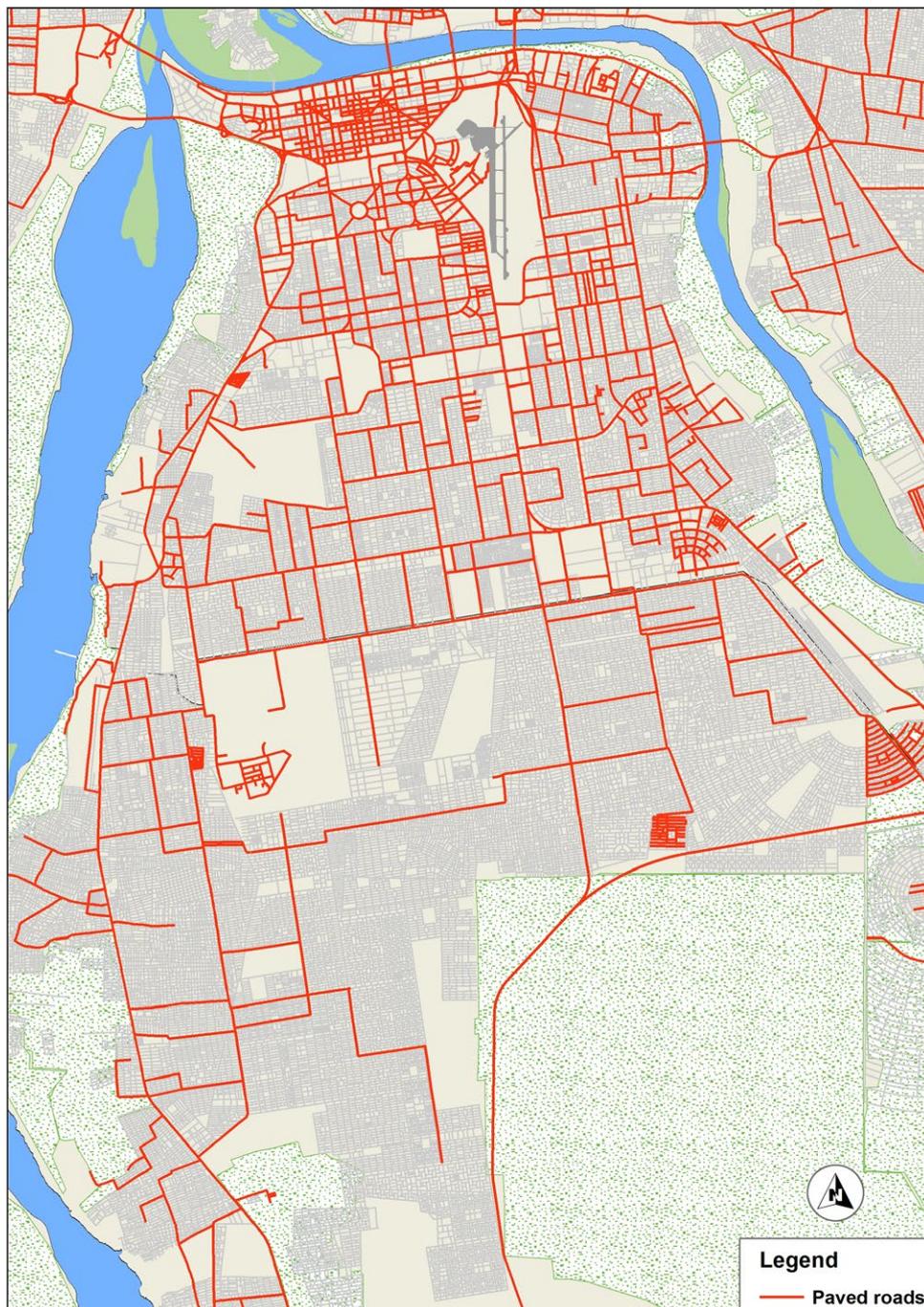


Figure 4: Road Network.

The newly executed Nile bridges and the flyover crossings constructed over selected road intersections are shown on **Figure 5** and **Table 4**. These limited multi-grade intersections and Nile bridges were constructed by the present government to facilitate traffic across the main roads and over the Nile rivers and they eased traffic flows tremendously.

It is to be emphasized that continuous rehabilitation of the road network is required and there is a strong need for institutional strengthening and personnel training to go along with the development of the road networks. Without training and capacity building, urban transport is expected to be a major obstacle to Khartoum’s growth.

4.3 Vehicles

Figure 6 Khartoum public transport system uses several different types of vehicles in terms of capacity as follows:

1. Large buses, each carries about 45 passengers or more and they connect the city centre with the surrounding areas.
2. Three types of buses having medium and small size capacity are in use, one of 25 passengers’ carrying capacity and the other two carry 14 or 11 passengers. These buses and other vehicles are causing traffic congestion in the urban centres.

3. A very small minibus called “Amjad”, which is a new type in Sudan and has been widely used in recent years. “Amjad” carries 7 passengers and works as public transport, and sometimes as a taxi.
4. An Indian motorcycle called “rucksha” with three wheels. It runs on selected streets and causes a lot of accidents.

The registered vehicles number in 2011 includes 171700 as private cars and only 15799 as mini-buses as exhibited in **Table 5**.

It is noticeable that private cars are increasing significantly in Khartoum, though cars ownership rate in developed countries is more than 20 times than in Sudan. Recently, in the a study conducted by the author, it was noticed that 47.6% of users use different types of buses followed by 20.7% using private cars which is a large proportion. In (MEFIT 2014) study, it was noticed that about 11% of the respondents own a car, of which about 3% have more than one car as provided in **Figure 5**.

4.4 Motor vehicle driving power (oil)

Khartoum consumes fueloil intensively where petroleum products are supplied for various energy consumption sectors particularly in urban transport which is the most important in modern urbanization. The transport sector

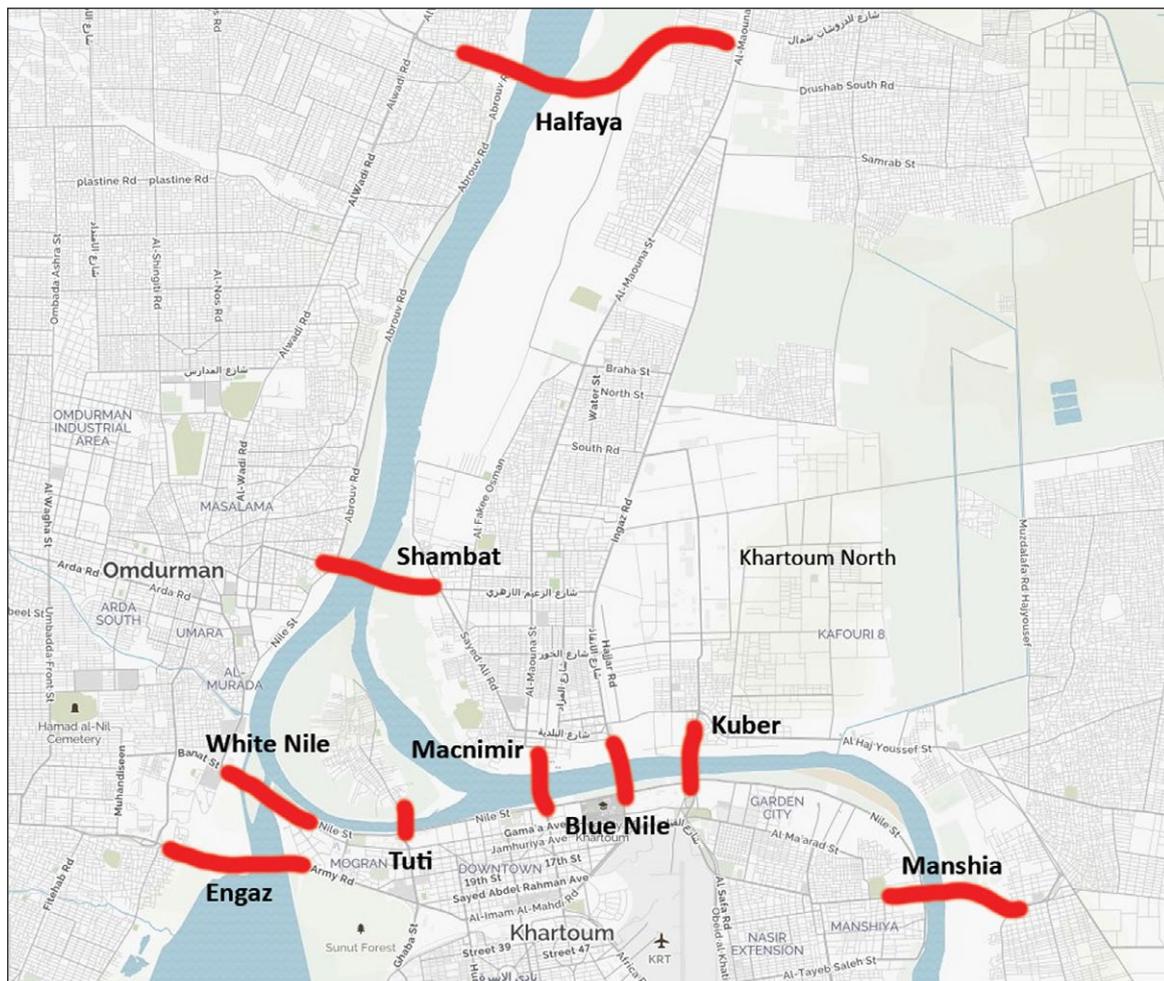


Figure 5: Blue, White and River Nile Bridges.

Table 4: Bridges and Flyovers on Road Intersections.

Name of Flyover or Underpass	Year of Construction
Ingaz multigrade intersection – Omdurman	2000
Ingaz multigrade intersection – Khartoum	2000
Afra Tunnel on Airport Road – Khartoum	2005
Khartoum Central Market Flyover	2011
Mandour Mahdi Flyover on Hurria street – Khartoum	2015
Wad al – Bashir Flyover on Ambaddah Front Road	2015
Cooper Bridge on Kassala Road – Bahri	2002
Sudan University Flyover on Al-Tabiya Street (Khartoum Stadium)	

Table 5: Number and type of vehicles during the period 2009–2011.

Year	2009	2010	2011
Type of Vehicle			
Private cars	142019	161817	171700
Mini Bus	20925	18920	15799
Large Bus	608	499	495
Taxi	2988	2216	1294
Freight transport	4460	4470	4849
Lorry & Trucks	6736	8922	9752
Motor Cycle	532	670	852
Investment vehicles	7062	8588	8147
Rucksha			3603
Government buses and vehicles			8800
Total	185578	206647	225892

is the largest consumer of oil in Khartoum, it consumes 66.5% out of 3 million (TOE) which are consumed by Khartoum annually.

4.5 Bus stations/terminals and bus stops

Bus Stations/terminals are important elements in the operation of bus systems. Some of the stations are more important in terms of the provided public and local bus services. The main station often provides such services as well as providing the type of business that a passenger needs.

At major transport stations Khartoum is almost suffocating from queues of stranded passengers waiting for seats in buses in the dark and peak hours. The intermediate stations are adjacent to municipalities' main markets. Khartoum State ignores bus stops where loading and unloading of passengers occur near their homes. Recently, Khartoum signed an agreement with DAL Group to finance and install 1000 bus stops shelters along the transportation lines. The bus stops are to be equipped with the necessary facilities in return for advertising the company's products.

4.6 Urban transport institutional framework

Some cities have the means to operate public transport and in others, the private sector undertakes almost all transportation activities while only governments construct and maintain public transport infrastructures. There are cities that operate public transport systems on the basis of partnership between private and public sectors. In Khartoum, a number of traffic management models were tried during different government rules. The current State Government merged Petroleum Department with Public Transport Department. The Directorate of Public Transport and Petroleum was then established to manage the three provinces' local offices: Khartoum, Khartoum Bahri, and Omdurman. After the establishment of the new provinces -Jabal Auwlia, Karari, (East Nile) and Umbadda urban transport has been managed by the transport departments established in the seven provinces operating

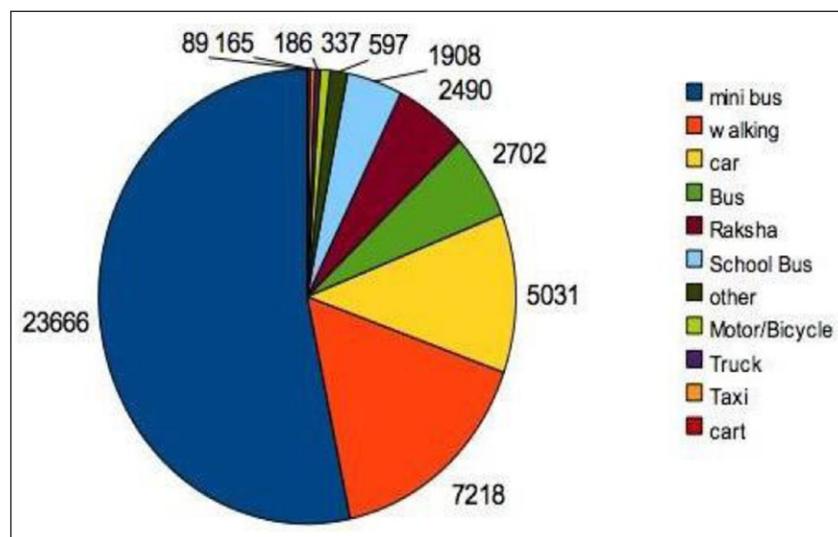


Figure 6: Number and Type of Vehicle 2011. Source: MEFIT.

under the umbrella of Khartoum State General Administration of Transport and Petroleum, Ministry of Finance and Economy. Recently, the Ministry of Infrastructure has replaced the Ministry of Finance and became responsible for managing public transport and the direct responsibility is given to Roads and Bridges Corporation. This order is in conformity with the Ministry of Infrastructure functions and responsibilities stated in the Local Government Law of 2001.

5. Assessing the present conditions of public transport systems in Khartoum

5.1 Assessment criteria

What is aimed at is an urban transport system meeting the following requirements:

- Covering all parts of Greater Khartoum and operating multi-modal transport system giving various options.
- Reliable, of large system capacities, supported by adequate transport infrastructures and fleet and operating efficiently while applying modern technologies in all practices.
- Environmentally safe, socially adequate, using sustainable energy technologies, maintaining safety measures and easily accessed and free from traffic congestion and accident.

What is observed is that Khartoum urban transport systems do not meet any of the above requirements.

5.2 Incomplete urban planning

Local planners ignore the transportation requirements in landuse plans despite the fact that layout plans of road networks are integral part of any landuse or base maps. There is no clear classification pattern of the existing road network i.e. neither having an order of sequence nor road hierarchy. Landuse is the most influential factor directing traffic and people mobility. Negligence of incorporating the transportation lines into structural plans has resulted in:

1. Lack of space for installing large-capacity transport systems infrastructure as well as for construction of new bridges and flyovers over road intersections considering that land acquisition is now terribly expensive.
2. Adoption of less than normal population density and this increases the lengths of the transportation lines.
3. Existence of physical barriers obstructing traffic.
4. Lack of adequate parking spaces and this compels motorists to park their cars on roads' edges thus, reducing roads' widths. In addition, vendors occupy the sidewalks and road shoulders thus, obstructing motor and people movement.
5. Difficulty in finding outlets to expand the Khartoum Center activities due to concentration of government institutions that are becoming obstacles to spatial reorganization and traffic restructuring.

5.3 Operating a single-modal transportation system

1. Khartoum lacks integrated intermodal public transport systems and relies solely on use of road running vehicles and this does not ease the movement of citizens and goods throughout the metropolis. Khartoum public transport does not use systems that depend on railways, metros, river transport, or rapid bus transit systems.

5.4 Use of small capacity vehicles

The capacity of public transport vehicles is inadequate and people suffer from a low speed traffic flow. For a long time, Khartoum relies on small and minibuses and vehicles operating intermittently. It is known that most developed and some developing cities are using trains. Western cities use trains running under and above ground. Budapest, Moscow, Paris, New York and London are among the most recognized cities using subway lines. The use of trains for urban transport maintains the cleanliness of the environment and solves the problems of traffic jams while reducing the incidence of disease and accidents.

5.5 Inadequacy of transportation infrastructure

Greater Khartoum is currently experiencing a high demand for public mobility and this is not met by the transportation system for road networks do not cover the entire urban mass and the transporting capacity is insufficient and vehicles run with very low traffic speeds. In addition, paved roads are limited and a terrible need exists for construction of multi-grade intersections in locations shown on **Figure 7** to convey direct movement and to cross Nile Rivers. Now passengers are forced to stay in vehicles for a long time before reaching their destinations.

The bus stations and terminals are neglected although they are important elements of public transport systems, as they provide passengers' access to transport vehicles. They are not integrated into public transport systems; instead hundreds of buses stay off roads on unprepared or temporary stations and on vacant areas in metropolis centres.

There is neither an interest in traffic route planning nor in installing street signs of all kinds including light signals. These are required to be intensified, protected and monitored frequently. It is known that the signals are the primary responsibility of traffic management because they organize traffic and they are vital in achieving safe and efficient traffic flows.

It is worth mentioning that the increased focus on economic development in Khartoum during the current government rule is creating an increased pressure on public transport systems because the efforts made during the previous governments' rule in executing public transport infrastructure were very weak and did not foresee the current huge traffic demand. But in the middle of the first decade of the 21st century, a large proportion of public investment funds was allocated to develop the transport sector and a relatively better situation now exists.

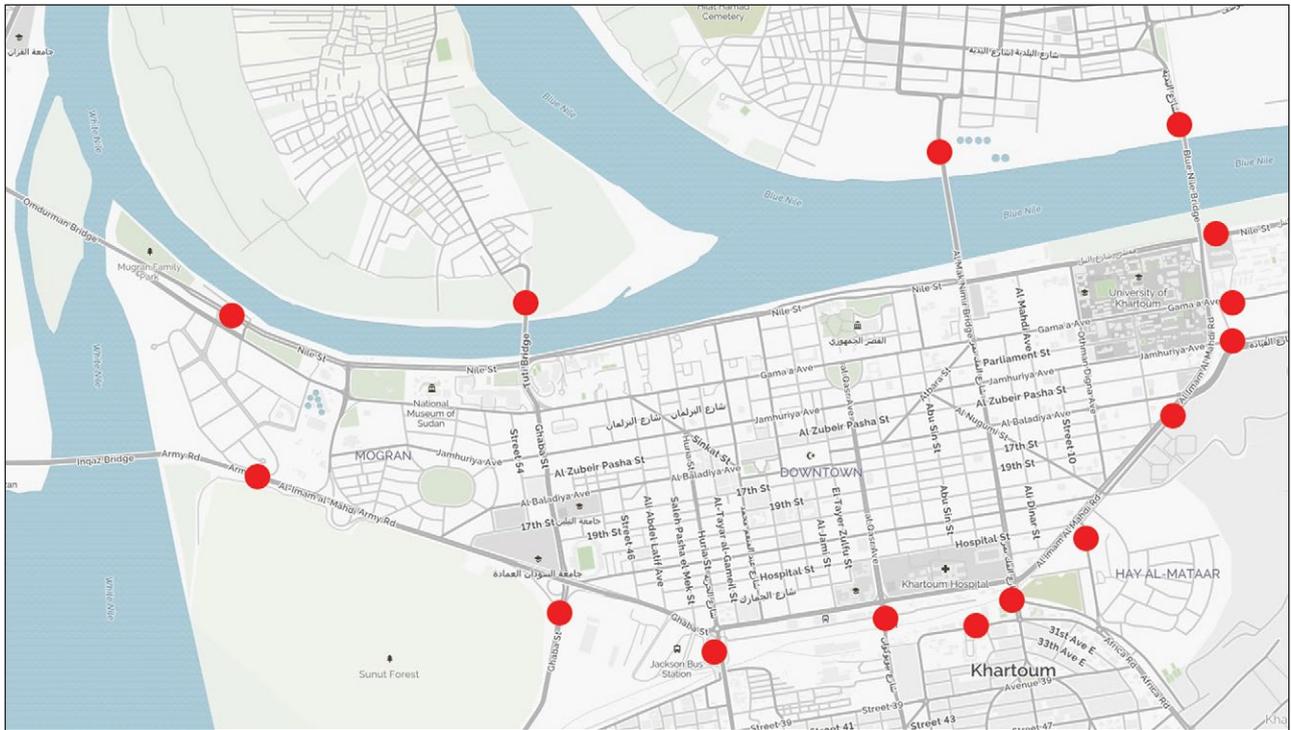


Figure 7: Location of Points of Traffic Jams and Conges.

5.6 Mismanagement of system operation

It is noted that Khartoum population suffering is attributed to the length of the wait time at first to get a seat in the public transport vehicles and secondly to reach the destinations because the vehicles rarely move at their designed speeds considering the state of poor roads and the bad conditions of the old public transport fleet. Low speeds cause delays, inconvenience, and distress. Khartoum still has a limited number of crossings over the rivers and over the railway lines. Passing through such crossings represents the bottleneck causing delays and traffic jams that lead to frustration and negative psychological impact on passengers.

The failure of traffic management is exemplified by:

1. Failure to use vehicles efficiently via adherence to allocated traffic routes while unable to force drivers to adhere to regulations.
2. Validity of system components is not maintained regularly while vehicles are not rigged and subjected to periodic inspection and maintenance.
3. No programme is sought for improving bus stations, especially the main stations where passengers' masses use daily. Disproportion exists between number and capacity of transport stations and the vehicles number in operation, which lead to the phenomenon of random parking and stopping along road sides.
4. Conflict and overlap of competencies exists in the management of transport stations by transport authorities, commissioners and concerned bodies.
5. Terminal stations overcrowded by informal business promoters, vendors and temporary traders who obstruct traffic flows.

6. Private sector partnership that is needed to operate various transportation systems is not sought.

5.7 Risks caused by transport systems

1. Air pollution and Disease

It is not argued that Khartoum urban transport system is unsafe for the following reasons:

Transport in Khartoum is the main consumer of fuel oil and its continuous burning leads to air pollution but not of the concentration that UN scientists resorted to considering that greenhouse gases emitted by vehicle exhausts are the main causes of global warming and climate change. This is may be in agreement with the verses of Quran:

“Then watch for the Day when the sky will bring a visible smoke. Covering the people; this is a painful torment”. Dokhan verse 12

Air is polluted by the emitted Greenhouse Gases – Carbon dioxide, Nitrogen Oxides, Sulphur Dioxide together with the Suspended Particulate matter and these are the most important contaminants that affect air quality and harm human health.

Although Khartoum does not contribute to Earth's pollution from greenhouse gases significantly, but suffers from dust and suspended particles accumulating in the air. This is confirmed by the higher concentrations of particulates in the surrounding air in some locations in Khartoum which are higher than the international standards. Their concentration figures range from 1729 µg/m³ in some of the old industrial areas to 2085 µg/m³ in the congested transport intersections while the specifications set by the European Union and other countries are far less as indicated in **Table 6**. The particulates levels are much

higher in Khartoum even compared to those in the developing world.

It is recognized that Respiratory Diseases are mainly due to air pollution resulting from the discharge of automobile exhaust gases. These cause health problems affecting the respiratory system, exacerbation of lung and heart diseases and changes in the shape and structure of vital organs because the inhaled particles deposit in the respiratory tract. In a report prepared on behalf of the tri-lateral research team of Austria, France and Switzerland (Sommer et. al. 1999) made an impact assessment for Austria, France and Switzerland on health costs due to road traffic-related air pollution. The report indicated that the number of deaths due to road traffic-related air pollution was 2411 person in Austria and 1762 person in Switzerland in 1996 and the road traffic-related air pollution costs amounted to 427 million EUR in Austria and 580 million EUR in

Switzerland. However, diseases caused by air pollution are widespread in Khartoum and they escalate by time. The most serious air pollutants in Khartoum are the suspended particulate matter. The results of the Household Survey in 2012 conducted by (Bannaga Consult 2014) show the common diseases are as follows: (19.2) Severe respiratory infections, (11.9) Malaria (5.0%) Diarrhoea, (4.8%) skin infections, (4.7%) typhoid fever, and (1.9%) eye injuries.

2. Traffic accidents

Failure to prevent traffic accidents is recognized as causing serious damages, loss of life and absenteeism from work. According to Red Cross reports, car accidents are the third most important cause of human death in the world. This problem poses as the most important issue in urban management. (Peden et. al. 2004) report for WHO considers that 90% of road traffic deaths occur in low- and middle-income countries, bearing a disproportionate number of deaths relative to their level of motorization as they account for only 54% of the world's registered vehicles.

Table 7 provides road fatalities/inhabitants and road fatalities/motor vehicles in selected countries. Information on this table is recorded by (Wikipedia), based on data from (World Health Organization 2015). The fatal accident rate per 100,000 of population is one digit for developed countries i.e. for: UK is 2.9% and for Norway is 3.4% and for Germany is 4.3% compared with two digits for developing countries i.e. 24.3% in Sudan and 20.1% in Ecuador and 16.8% in Colombia. When developed and developing countries are compared with regard to road fatalities/motor vehicles the gap is much greater and the rate in Sudan is catastrophic jumping to an alarming figure of 287 while most developed countries show one digit. This is really unacceptable. Car accidents are more severe in the Gulf for the high rate of deaths. **Figure 8**

Table 6: Standards of Maximum Particulates' Concentrations in Selected Countries.

Country	PM2.5, Fine Particles In $\mu\text{g}/\text{m}^3$	PM10 In $\mu\text{g}/\text{m}^3$
Australia	25	50
Canada	30	
China	75	150
Japan	35	100
European Union	25	50
WHO	25	50
USA	11 $\mu\text{g}/\text{m}^3$ average in 55 cities	70 average in 55 cities

Source: Gathered from different sources.

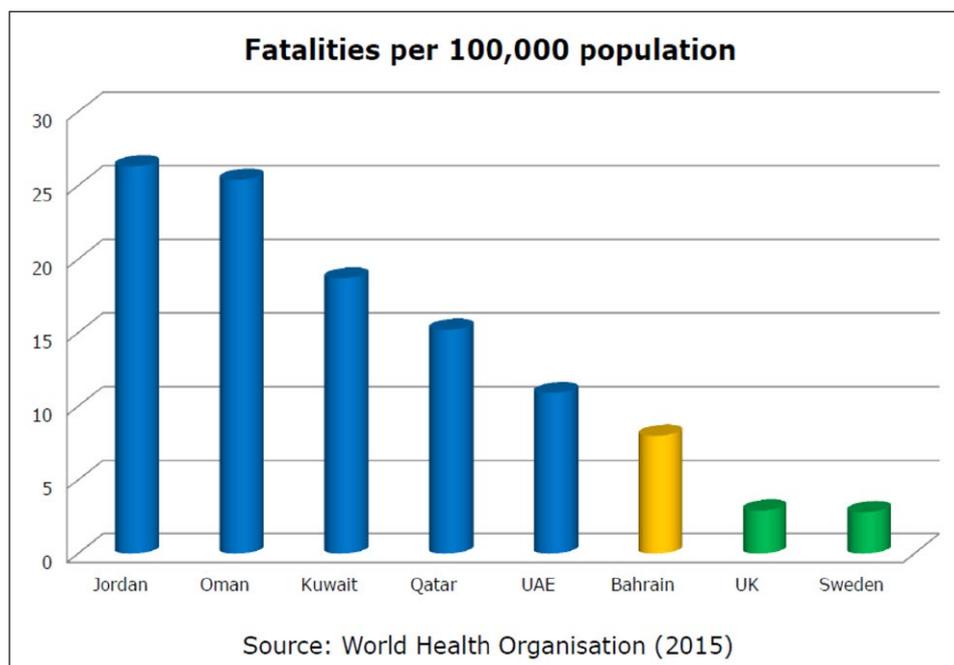


Figure 8: Rates of Fatal Car Accidents in Selected Countries.

Table 7: Road Fatalities/inhabitants and Road Fatalities/motor vehicles.

State	Road Fatalities per 100000 Inhabitants per year	Road Fatalities per 100000 Motor Vehicles	State	Road Fatalities per 100000 Inhabitants per year	Road Fatalities per 100000 of Motor Vehicles
Australia	5.4	7.3	Costa Rica	13.9	38.4
Belgium	6.7	10.7	Colombia	16.8	83.3
Canada	6.0	9.5	Egypt	12.8	148.7
Germany	4.3	6.8	Ecuador	20.1	183.8
Japan	4.7	6.5	China	18.8	104.5
Norway	3.8	5.2	Panama	10.0	38.4
UK	2.9	5.1	Mauritius	12.2	35.6
USA	10.6	12.9	Sudan	24.3	2872.6

Source: Wikipedia, based on information obtained from Global Report on Traffic Accidents, Data Tables, 2015.

Table 8: Traffic Accidents in Khartoum for period 1993–2012 and Death/100000.

Year	Drink	Damage	Simple	Gross	Death	Total	Death/100000
1993	163	3,398	1,070	1,258	254	6,143	7.2
1998	135	3,254	1,617	1,535	352	6,893	8.1
2002	393	10,918	3,179	2,328	462	17,280	9.0
2005	308	20,131	3,984	2,641	648	27,712	11.3
2006	338	24,922	4,969	3,052	748	34,029	12.4
2009	252	34,446	5,571	3,584	841	44,694	15.2
2010	260	33,752	6,156	3,695	891	44,754	15.5
2011	270	33,017	4,665	3,663	821	42,436	13.7
2012	245	32,903	4,651	3,058	768	41,625	12.3
Total	4,341	301,981	57,710	41,191	9,572	414,795	

shows the paradox between the rates of fatal accidents in the Gulf States and some European countries. While the numbers of deaths per 100,000 in Gulf States are of two digits they are less than 3 in UK and Sweden.

Table 8 and **Figure 9** present the number of traffic injuries and mortality rates in Khartoum for the period extending from 1993 to 2012. The accidents are annually increasing with exception of year 2011 and 2012. Mortality rates per 100000 of population increases from 7.2 in 1993 to 15.5 in 2010 which are similar to the rates prevailing in the Gulf States. There appears to be a direct relationship between the number of vehicles and the frequency of accidents, especially the accidents causing physical damage.

5.8 Transportation Services

1. Fares

No doubt citizens have difficulties in covering the cost of transport since the value reaches one fifth of the monthly income of low-income residents because the majority of

commuters using public vehicles spend up to 200 pounds per month. A citizen who lives on the outskirts of the three cities uses more than one vehicle to reach his final destination thus, he suffers a lot from paying the value of the transport tickets because of the high cost compared to his income and there is no room for reduction because vehicles pay high prices of fuel oil while operation and maintenance of vehicles are very expensive since these are imported in foreign currency. A family living outside the old urban area spends at least a quarter of its monthly income to cover the transport cost.

2. Trip Duration

It is found in the studies mentioned earlier that most of old neighbourhoods' passengers can reach their workplace within 30 minutes but there is a big difference in trip duration as per the time at which the commuter starts his journey according to **Table 9**. Residents from peripheral quarters take much long time to reach their workplace.

Table 9: Distribution of the respondents by the average time taken from home to work.

Number	Time (minutes)	Percent	Number	Time (minutes)	Percent
157	0–10	14.0	80	41–50	7.2
196	11–20	17.5	197	51–60	17.6
293	21–30	26.2	124	61+	11.1
71	31–40	6.4			

This length of trip duration is confirmed by MEFIT survey which results are given in **Figure 10**.

3. Unvaried Options for People mobility

As indicated earlier, Khartoum lacks integrated public transport systems of several modes of transport systems because it relies solely on one system, which is the use of vehicles that run on roads, and this does not guarantee smooth movement of citizens and transport of goods.

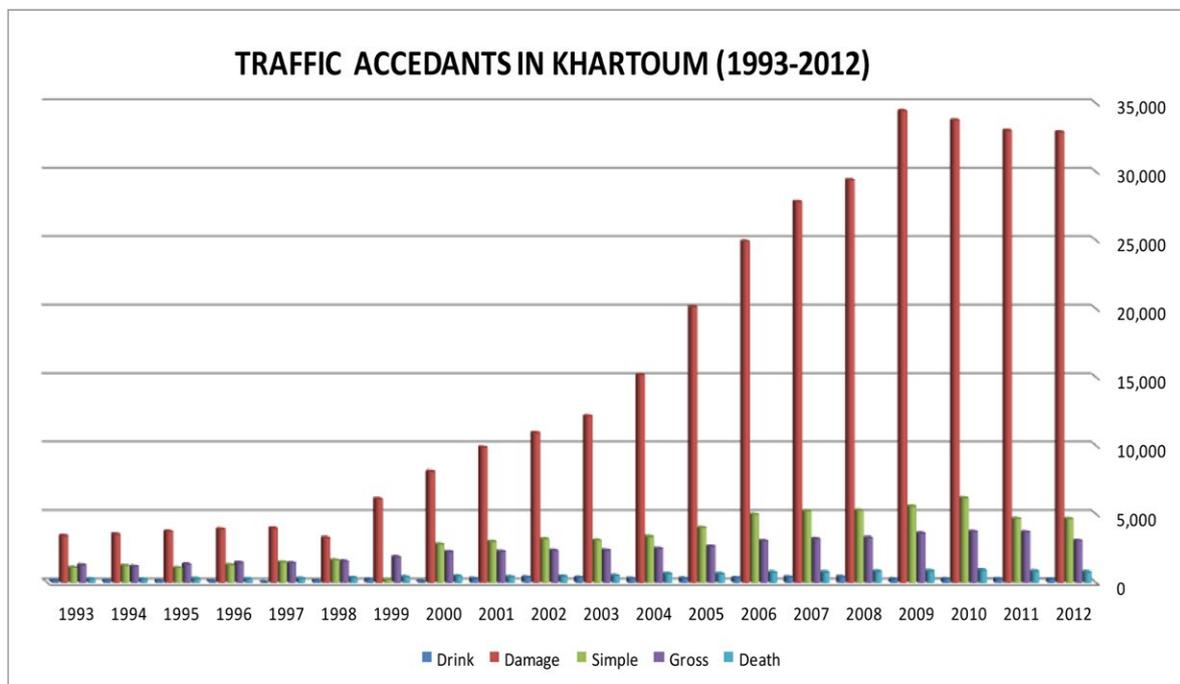


Figure 9: Traffic Accidents in Khartoum (1993–2012).

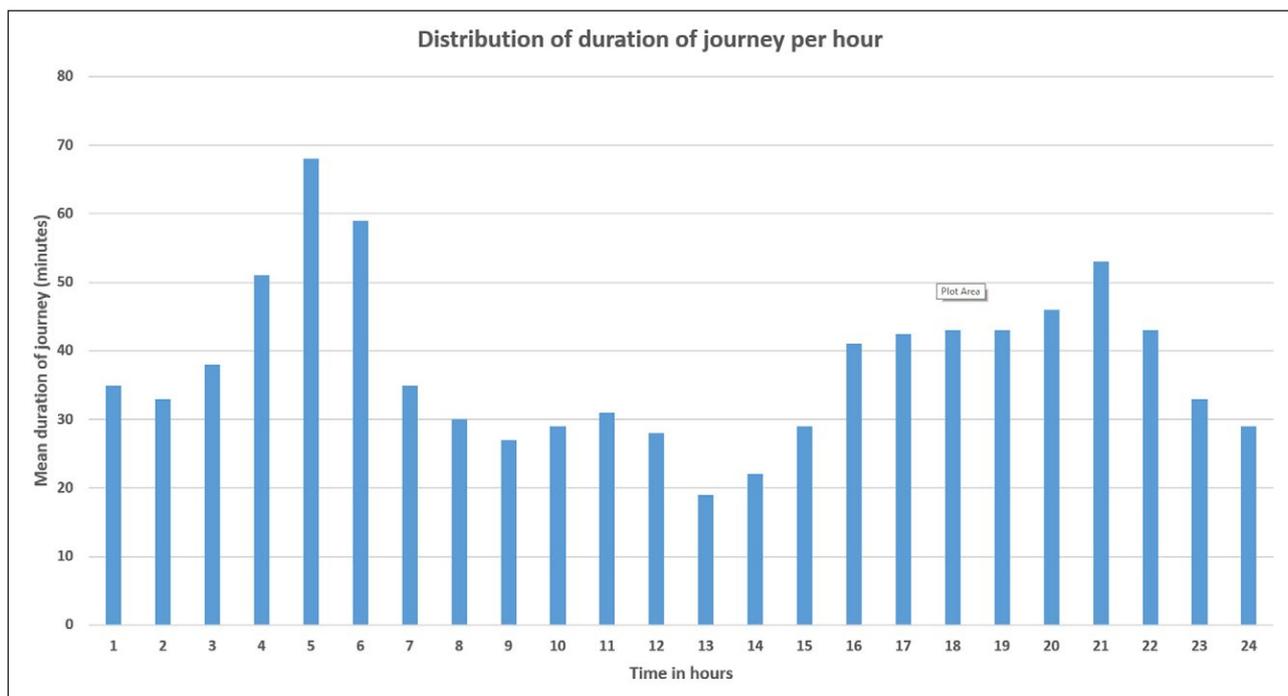


Figure 10: Time taken by commuters from old neighbourhoods to workplace as per the hour of the day. Source: MEFIT 2014.

6. Revitalizing public transport systems in Khartoum

6.1 Establishing a public transport authority in Khartoum

It is well known that city management is not difficult because it is supported by enormous economic and human resources. Khartoum has enormous potentials as multiple natural resources and if these potentials are sourced it will succeed in revitalizing its urban networking. What is needed is that Khartoum state sets up a public transport authority authorized to attract investors to revitalize public transport systems using advanced technology and sound management of resources. The first task that Khartoum State undertakes is appointing a new and effective administration, supported by state legislations and popular mandate and able to pursue an integrated approach e.g. adopting decentralization and applying democratic mechanism to ensure popular participation in decision-making without creating conflicts between local institutions. The Authority shall immediately undertake:

1. Building the system institutional capacity by strengthening public transport institutions and raising professional competence.
2. Preparing and implementing a comprehensive transportation plan (a number of studies are available for the preparation of this plan) based on operating multiple intermodal systems. The plan shall delineate all components of the transportation infrastructures and their phases of construction: road networks, tracks used by Transit Bus System, river transport lines, bus stations, rail and tram tracks, river bridges, multi-grade intersections on road crossings, etc.

6.2 Performing the necessary urban transformations and changes

No doubt that restructuring of the urban structure for accommodating transportation infrastructures and performing changes in urban activities and functions have a significant impact on enhancing urban transport networks. Restructuring of the urban structure is needed to improve the efficiency of public transport and ease traffic movement. However, it is known that restructuring may lead to the demolition and removal of many buildings and abandonment of many activities.

6.3 Implementing a comprehensive development programme

The programme shall include the followings:

1. Expansion of existing transportation lines to meet current and future traffic demands.
2. Constructing new roads, bridges and express ways to upgrade the transportation networks and to carry traffic flows away from the CBDs, without resorting to crossing the central areas of Greater Khartoum.
3. Constructing ring roads to link regional transportation lines and suburban centers.

4. Constructing varied Infrastructures to pave the way for operation of mass transport systems.

It is meaningful to begin with river transport because it capitalizes on Greater Khartoum location characteristics. Khartoum is endowed with three Nile Rivers forming water arteries suitable for river transport. These rivers dictate traffic paths, influence urban development and expansions. Furthermore, river transport is economically feasible, safer and causes less accidents and environmental pollution. It does not need construction of roads or bridges or expropriation of land. It is fuel efficient because its transport capacity is greater and consumes far less fuels. Therefore Khartoum State should immediately put in place a river transport infrastructure; reclaim waterways, clean the navigable lines, place navigational signs, construct river and marine stations and side steps. River transport development is not difficult because funding can be made available by the private sector if encouraged to do the job.

The daily movement of people bordering the Nile Rivers is sufficient to provide market for the river transport system knowing that the main destinations for passengers are adjacent to the rivers. A study conducted by the author revealed that a proposed river transport project cost can be returned within (8) years.

The second mode of transport that can be implemented is the Rapid Bus Transit System (RBTS) running at high speed but this system necessitates construction of new roads and expansion of some other roads which function is to ease the free movement of the rapid buses without crippling the system by road intersections. Rapid Bus Transit systems provide net positive benefits to society and are socially profitable investments. Trends at the local, national and international levels suggest their continued growth worldwide. In a report by the Transport and Energy Unit, WSIB, Global Division, UN-HABITAT, (Candiracci 2006) stated that BRT systems reduce: traveling times by 50%, noise and gas emissions by 40% and accidents rates by 90% in the corridors. Later in 2013 UN-HABITAT stated that the costs of BRT systems are one third to one fifth of those of alternative rail technologies.

The third mode of transport that can be implemented is the Light Rail Transit System (LRTS) or tram, powered by electricity but this system requires installation of rail lines (light rail lines) to pave the way for the tram to run through the urban area. The backbone of the LRTS depends on the design and construction of the light rails in addition to traffic signals and tram stations. The LRTS runs along road network and therefore proper planning requires the integration of the other modes of transport with the LRTS.

Operation of railway lines should be based on the existing lines and their expansion can be considered but as a last option. This option requires delineation of rail tracks and train stations at selected routes and sites as well as land acquisition where rail tracks, bridges and train stations would be built. The railway lines will connect rural/suburban and regional areas thus, serving many villages and small towns as well as linking Khartoum with

Sudan Railways. More details are found in (MEFIT 2014) report on Structural Plan for Traffic and Mobility.

6.4 Enhancing efficiency of public transport operation

The urban transport authority must resort to advanced operating systems having modern technologies and applications that enhance transportation operation processes, reduce congestion and traffic accidents as well as reducing pollution and energy consumption. Use of communication technologies and devices managed by computer (robot) and electronics enables the transport management to obtain information on the performance of all public and private transport utilities. The other requirements related to efficiency of public transport operation, environmental protection and traffic safety can be met through:

- Public awareness promotion.
- Media intensification for spreading traffic regulations and traffic ethics among residents.
- Deployment of traffic police to enforce road safety regulations.
- Review of traffic laws to tighten the control and monitor traffic flow and protect pedestrians.

Furthermore, the followings shall be considered to mitigate environmental pollution and degradation:

- Hindering use of small-capacity vehicles.
- Imposing use of unleaded gasoline and applying catalytic converter to convert automotive exhausts producing harmful gases to other less harmful substances.

Conclusion

Khartoum metropolis should adopt sustainable mobility solutions by deploying large-capacity multimodal transport systems including river transport, bus rapid transit systems (BRT), tramways and metropolitan railway lines to connect its polycentric and sprawling outward growth. This is because, throughout history, transportation operates cities and has been fundamental to defining and creating urban forms and it has always had a crucial influence on urban development patterns. It has therefore to realize that investment priority should be given to revitalize public transport systems, provide mobility options and improve their accesses and service efficiencies. And since Khartoum has a highest rate of traffic fatalities and higher concentrations of particulates in the surrounding air it must use a broad range of tools and measures to tackle air pollution and enhance traffic safety.

There is a need to upgrade and revolutionize the existing manpower and subjecting it to intensive training on transportation management. Unfulfilling such requirement, the urban transport is expected to constitute a major obstacle to Khartoum growth.

Competing Interests

The author has no competing interests to declare.

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