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AN EFFECTIVE MATHEMATICAL MODEL FOR THE CONTROL OF ROAD TRAFFIC GRIDLOCK: A CASE STUDY OF THE BENIN CITY/ONITSHA HEADBRIDGE ROAD.

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ABSTRACT

This research develops a mathematical modeling approach to mitigate road traffic gridlock on the Benin/Onitsha Headbridge Road. The time-dependent model accounts for variations in vehicle arrivals during high and low traffic periods. It incorporates traffic flow dynamics, vehicle density, and speed. Vehicular data were collected from selected road sections and fitted using a technical computing software. The resulting empirical model, based on a sum of sinusoidal functions, effectively predicts road traffic congestion in the area of study.

1. INTRODUCTION

Road traffic congestion is defined by [1] as the impedance vehicles impose on each other due to the speed flow capacity of a transport system. Again, [2], defined congestion as the saturation of road network capacity due to regular and irregular reductions in service quality. The highway traffic conditions across highways in Nigeria are in an extremely bad condition caused by daily congestion and daily accidents.

The demand for transport especially in cities in developing countries has been on the increase following the rapid socio-economic growth and development of these countries. For instance, [3] stated that the rate of motor vehicle ownership and use is growing faster than population in many places, with the vehicle ownership growth rates of 15 to 20 percent per year.

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Traffic management has been quite poor in many developing countries, despite the growth in transport demand and supply. The resultant traffic congestion has become impediment to our livability.

The Benin/Onitsha express way is a 150 km road which is very important to the socio-economic development of the country. The road, which before the commencement of the on-going dualization work, was a single lane before it was awarded by the Federal Government of Nigeria [4]. The road is characterized by high traffic density gridlocks. Sometime, excessive speed by the commuters leads to reported cases of road traffic crashes.

Presently, the road is under construction or major rehabilitation with the transformation of the road from the initial single lane to a dual carriage way, which is billed for completion soon [5].

Traffic congestion is an ever-increasing problem, with high social and economic costs. According to [6], conceptualization of road traffic congestion is a situation where urban road network could no longer accommodate the volume of traffic on it. Predicting, managing or controlling traffic gridlock requires appropriate and accurate models.

Developing traffic control strategies to reduce road traffic congestion requires scientific techniques, and hence the scientific study of road traffic flow will provide support to the various established organs of government in tackling the menace of urban road traffic congestion [6].

In Nigeria, road transportation is the major means of mass movement of goods and services. Therefore, the study of road traffic flow issues becomes imperative. Traffic congestion is usually associated with urban areas as a result of influx of people looking for white collar jobs. The extent to which the urban town will be able to meet the challenge of rapid urbanization and continue to offer a favorable environment for further economic development remains a crucial question for the planners, engineers and decision makers. Striving for an efficient transportation system is a crucial requirement of the urban development strategy. Any constraints or bottle neck in this regard, will seriously affect the economic potential of the city, especially in the contest of global market and world trade [7]

In most of the developing countries, particularly in Nigeria, most of the vehicles on the roads are used vehicles, popularly known as “Tokumbo” imported from Europe, America etc. The maintenance culture is very poor. Such vehicles, left at the mercy of illiterate mechanics and fake spare parts vendors, often break down and cause the already narrow road to further get congested. Broken down vehicles, and those involved in crashes that are not immediately cleared away from the road often cause traffic to build up and causing inevitable traffic congestion

Traffic composition and driver’s behaviour in the metropolis are unique in the world. Motorized vehicles are very prevalent in the metropolis. Also, while developing long term policies; one has to be very careful in selecting the future modes of transportation. Many developed countries, especially European countries, have been vigorously promoting none motorized modes like walking and cycling [8]. It is well recognized that public transportation has the potential to play an important role in improving traffic and environmental situation. For the purpose of developing a sustainable transportation system, long term policies should be established. For congestion management, adequate considerations must be provided on this issue.

The components of the transportation system—such as land use, economic activity, and residential location—are interrelated. [9], any change in a single component of the system affects the other components as well. So, to develop transportation policies and to reduce traffic congestion, the alternative options are required to be analyzed by using transportation model.

Road traffic congestion is prevalent in almost all Nigerian roads especially areas where there are bad roads. Benin/Onitsha road are most hit with these traffic congestions especially the Benin city axis. Researchers have attempted to solve various traffic problems in different localities without looking at the problems in these areas and also have not been able to predict future occurrence and possible way out.

In this research, we employed empirical least square model to examine the traffic congestion and these predicted future occurrence and best possible way out.

Mobility is regarded as an essential citizen right [10], the need for improvements to transportation system cannot be over emphasized

Expansion of road network seems a practical solution to the ubiquity of road traffic congestion. A case in point is the construction of a thick mankind building. But construction of new roads and expansion of old ones by successive administration has never ameliorated problem rather traffic congestion has been getting worse as population and vehicular volume continue to grow by the day.

In Nigeria, traffic congestion in the major cities has remained part of the operating transportation system especially during the morning and evening peak periods. Attempts made by governments to ensure that congestions were managed through various traffic managements techniques have not yielded the desire results [11]

This study is motivated by the traffic congestion prevailing in cities as the situation deteriorates rapidly with increasing urban population and economic activities. Traffic congestion has become an unbearable situation in the cities. The extent of the problem can be accessed from the fact that during peak hours (6.00am – 9.00am and 4.00pm – 7.00pm), it takes more than an hour to travel a short distance which would have taken not more than 20 minutes. In addition to other losses (economic losses, discomfort), traffic congestion worsens the environmental condition, which is already extremely poor in commercial areas.

1.2 Objectives

The overall aim of this research is the modeling of road traffic congestion in Benin city/Onitsha express way. The specific objectives are to:

(i) Collect data on traffic congestion in key sections of the highway.

(ii) Formulate an empirical model using data that accounts for the number of vehicles at various times of day.

(iii) Examine how vehicle speed and frequency affect road traffic congestion.

1.3 Literature Review

Here, we give a review of articles relevant to the problem of road traffic flow considered in this thesis. The central theme of this research is modeling of road traffic congestion. To address the subject matter, a review of the literature on vehicles, as a basis for developing the model.

Traffic congestion occurs when a city road network is unable to accommodate the volume of traffic that uses it. This situation is caused by rapid growth in motorization and with less than corresponding improvement in the road network traffic management techniques and related transport facilities. Thus, traffic congestion is a phenomenon that is associated with urban environment all over the world. This is because we need transport to move from one place to another, especially when trekking becomes inefficient, while traffic congestion has been managed very well in some developed countries, it has continued to defy solutions in the developing world.

The negative contributions of the global geometrical growth trend in car ownership, as it affects free flow of traffic in cities, has been a point of worry among researchers in urban transportation. Hence, [12] chronicled the growth trend and its implications. Thus, private car use has grown rapidly during the last decade. The number of motorized vehicles in the world grew from about 75million to about 675million between 1950 and 1990 (USA transport system). Around 80% of these vehicles were primarily used for personal transportation, i.e., cars and motorcycles. The increase in the use of car has generated various environmental, social and economic problems. The environmental problems include the emission of toxic and harmful substances, which among other things, contribute to global warming. Also, the extension of road infrastructure causes distortion of natural areas, which might disrupt natural habitats.

In another study on UK, [13] found that the impact of road transport was positive particularly regarding capital increase in residential property values. However, the study put less emphasis on exact values, and some of the observed increase may be due to optimism of the markets rather than actual effects. Similarly, there is also some evidence that residential property prices might decreased immediately around the transport investment or station. Value increase was determined in the study in a narrow way and mainly through changes in property and land values whereas wider range of measures ought to have been used. The measures should have included changes in accessibility, ownership patterns for land and property, site consolidation, numbers of transactions and yields as well as composite measures such as density of development.

[14] stated that the chronic problems of traffic flow which have bedeviled many poorly planned city is one of the experiences that cannot be adequately described in words. The traffic jams and accidents constitute the real cankerworm of the city. The traffic problem of the city of Lagos has been estimated to be perhaps three or four times more severe and frustrating than those of a similar sized city in other parts of the world. Afolabi

Road traffic congestion is imminent when users of a particular facility begin to interfere with other users, due to the limited capacity of the infrastructure [15]. Again, traffic congestion on a freeway sets in once the density of vehicle exceeds a certain critical number, which is the designed capacity of such roads. The addition of a single car to a road that has already reached its saturation levels (i.e. designed traffic capacity) will result in “dead weight, which is also known as road traffic congestion. Studies have shown that above the dead weight both vehicle speed and vehicle flow will drop thereby making travel time between two points on the road in question to become unpredictable. Also, it encourages fluctuating transportation cost, elevates fuel consumption and auto-induced pollutants. This is a daily noticeable phenomenon on roads in the city.

[16] identified two prominent types of road traffic congestion namely recurring and non-recurring congestion. The former result from over saturations of the road capacity of vehicles of various sizes while the latter is as a result of happenings such as multiple accidents, disabled vehicles, and natural disasters to mention a few.

Road traffic congestion, according to [17] is always there in any industrial cities such as New York, Chicago, Tokyo, New Delhi**,** Lagos, Benin City, etc. In the last six years, Benin city metropolitan has been experiencing acute traffic congestion as a result of a phenomenal growth in vehicle ownership relative to the growth of road space. Because of this, the share of road space per vehicle had been declining over the years irrespective of the Federal Government’s massive road expansion program. The worsening of traffic situation in Benin City had continuously affected the social economic life of the city.

[18] further added that when flow rates approach optimum, there is the likelihood of congestion setting in, causing excessive delay to vehicles. He added that the highway capacity manual (HCM) has been the standard reference work used in this regard. Over the year, the HCM has emerged as a collection of the latest proven techniques for estimating highway capacity.
According [19], the generalized definition of capacity of a highway system is the maximum number of vehicles which has a reasonable expectations of passing over that section (either one or both directions) during a given time, under a prevailing roadway and traffic conditions.

Drivers behaviors on the road are difficult to analyze because drivers are unpredictable. Nevertheless, driver behavior is an important component of road traffic flow and report in the literature.

In this section we focus on the review of model that can used to describe the effect of driver behavior on road traffic congestion. Several definition of driver behavior have proposed in literature e.g. In the test before the US congressional sub-committee, aggressive driving was definition as the operation of motor vehicle in a normal which endangers or is likely to endanger people or properties [20].

Some observed implication of deviant, drivers, behaviors and blocking of roads in other to gain entrance to another lane. Some mini bus conductor as well as uniform personnel on their own journey take undue advantage of the chaotic road condition and turn themselves to traffic wardens. They ensure that the lane in which their vehicles are moving in the queue is given priority to detriment of the system.

Another form of indiscipline, is when drivers of articulated vehicle block the road with their vehicles while protesting encounter of one or some of their colleagues from law enforcement agency. Such disruption to traffic flow usually takes several hours as it takes a long time to agree to terms of negotiation. This attract long queues of vehicles and huge man hour loss. Traffic have been paralyzed many times on Benin/ Onitsha road etc. due to this blockage of the road by this categories of drivers

The scientific study of patterns of traffic congestion as an urban phenomenon in the [21], paints a gloomy picture of the helplessness of commuters thus before leaving for work you can check the weather from the Newspapers, radio or TV report. You can just look at the sky and make your own guess. But you can’t determine much about current traffic conditions.TV and Radio traffic reports provide only a summary (traffic is running smoothly this morning) and spotty coverage of incidents.

[22] examined traffic congestion problems and their causes at selected road intersections in Ilorin, Nigeria. The characteristics of the intersections that predispose them to congestion problems and the spatial pattern of traffic congestion at the road intersections. They deduced that spatio-temporal variations exist in traffic flows and delays at the studied intersections and hence advised that vehicle parking be strictly prohibited at road intersections to reduce traffic congestion and delays at road intersections in the city which all attempt to checkmate these parking failed.

[23] employed the stochastic approach in the formation of platoons and their velocity-size distribution in freeway traffic with the aim of reducing traffic congestions, maintaining safety, increasing highway capacity, limiting the speed of a car by the spacing between it and the car directly ahead and above all reducing motor accidents. Traffic systems was also modeled and applied to traffic problems of different kinds to find their solutions.

1.4 `Research methodology

In this research, the following were considered during the design phase of this research

The road traffic congestion examined is the Benin/Onitsha headbridge end road.

Two methods for collection of data require for this research, are the primary and secondary sources.

The primary source of data collections involves direct collection of information on the field, using traffic count, oral interviews and observations. The data collected from primary source therefore include pictures of traffic congested area, the roads (lines), the land use (areas), physical counting etc.

The secondary source of data collection involves sourcing information from existing records, such data includes land use images of the area, traffic counts for different junction in the area, which were collected from the Ministry of works and planning.

Modeling of Road Traffic Congestion in Benin/Asaba/Onitsha headbridge end

Data were collected at high traffic density area in Benin road. An empirical mathematical model based on the data collected was formulated. Hence, fitting the data, this was made possible using the line of best fit, based on the observation time data and observed response data, which is the number of cars at the location of interest. Note that the aim is to have a mathematical model that shows the relationship between the time of any day of any week typically spent on the road (which in this research is between 6am to 6pm each day) and the number of cars at the target location, while striving for accuracy of fit. Models of this type are very useful when the data can significantly help shape the relationship between these variables, time and number of cars.

Data on road traffic congestion was collected at Asaba on Benin/Onitsha road and was collected by manual count and also from Federal Ministry of Works. Again, a location was chosen and called Observation point, that is Asaba and kilometer 5 respectively for data collection. The personnel take a count of every vehicle that arrived for every period of one hour.

Traffic distribution in Benin/Asaba/Onitsha road.

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
6 – 7am	1186	1031	961	911	996	921	591
7 – 8am	1271	1204	1321	1289	1359	1061	992
8 – 9am	1243	1283	1263	1191	1267	1137	893
9 – 10am	1006	1003	1001	1064	1201	1001	890
10 – 11am	880	907	899	990	997	995	739
11 – 12pm	852	853	909	932	874	896	658
12 – 13pm	606	851	989	977	873	940	779
13– 14pm	709	909	998	1049	893	951	998
14– 15pm	893	1134	1198	1191	1190	1149	1201
15– 16pm	1145	1139	1201	1188	1184	1198	1198
16– 17pm	1147	1173	1308	1333	1344	1311	1191
17– 18pm	1273	1363	1399	1426	1389	1392	1298

The one week data above were averagely taken for one month. It was assumed that all vehicles passing through Asaba express way was going to Onitsha, hence the high volume of vehicles from the data collected as seen above. The highest number of vehicles passing through the observation point occurred between am to 10am and 3pm to 6pm for all days. These periods are known as the morning and evening rush hours.

Derivation of Relationship between the Frequency, Speed and Expected numbers of Vehicles

We can also examine the Mathematical formulation to show the effect of speed and frequency of vehicles on the road traffic gridlock. Data on road traffic flow frequency was collected at different locations.

Baykal-Gursoy (2009) examined road traffic flow interrupted by incidents and obtained the number of vehicles on a road link.

Kakooza (2005) analyze the performance of vehicles on roads and road intersection. In this, we used the method of Kakooza (2005), to study the performance of road traffic congestion on Benin City/Onitsha headbridge as it relates to the frequency and speed of vehicles.

The general queues with exponential service times is stable if

$$\lambda < \frac{r}{r+f}\mu \qquad (1)$$

where, λ the vehicle arrivals

r is the rate of disappearance or clearance of delays.

f is the rate of occurrence of delays according to poison process

μ service rate with no delay

The same generating function techniques had been used earlier to obtain the performance measures in a network of queues of varying degrees (Ikpotokin,1999 and 2003)
Using the generating function G(z), of the number of vehicles on the link, we can determine the effect of speed and frequency on the gridlock

$$G(Z) = \frac{(r\mu - (r+f)\lambda)(-\lambda z + \lambda + r + f)}{(r+f)\left(\lambda^2 z^2 - \lambda(\lambda + r + f + \mu)z + \mu(\lambda + r)\right)} \quad (2)$$

$$= \frac{\frac{r}{r+f}\left(1 - P\frac{r+f}{r}\right)(1 - \lambda z|\partial)}{\left[(1-p^z)(1-\lambda\partial^z) - \frac{f}{\partial}\right]} \quad (3)$$

For single lane system, Kakooza (2005) stated that the expression for the expected number of vehicles in the system and average waiting time of the vehicle in the system are

$$E(x) = \frac{\lambda[(r+f)^2 + \mu_o f]}{(r+f)[r(\mu_o - \lambda) - \lambda f]} \quad (4)$$

and

$$W = \frac{E(x)}{\lambda} \quad (5)$$

Where λ is the average number of vehicles arriving.
[24] noted that the number of vehicles on the link decreases as service rate increases. For equation (4) to be useful, we need to interpret μ_o as number of vehicles departing from a particular cell in one second under free flow. We need a relationship between the expected number of vehicles E(x), speed of vehicles (v) and frequency (F).
According to the journal of institute of transport Engineer [25], the average length of occupancy of a vehicle is L=17.5 feet. Thus, the length of an s lane link which can accommodate c vehicles is

$$L = \frac{17.5 \times c feet}{s} \quad (6)$$

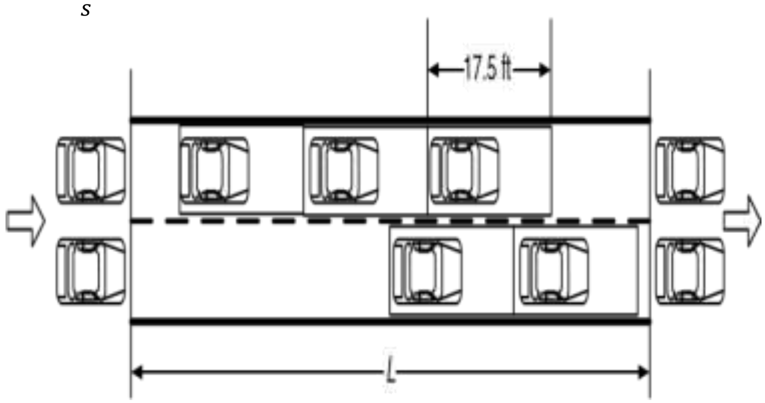


Fig. 1: Moving vehicle on a double lane

where c is the number of vehicles in the link measured in feet and s in the number of lanes. It is reasonable to assume that the vehicles at the front leave first or are in service channel.

The frequency (Fr) of vehicles per hour is given by

$$Fr = 3600\lambda \text{ (veh/hr)} \quad (7)$$

From (5), the line $\mu_o = \left(\frac{r+f}{r}\right)\lambda$ (8)

For example, equation (5) shows the number of vehicles that will be in the traffic for various values of speed. As the speed gets closer to zero (but not zero), the expected number of vehicles in the traffic blows up.

We have

$$V = 0.005251\left(\frac{r+f}{r}\right)Fr \quad (9)$$

Where Fr is the frequency of vehicles per hour. Thus, the critical speed of the vehicles is proportional to the frequency of vehicles using the road link.

From above, we have

$$E(x) = \frac{0.00028Fr\left[(r+f)^2 + 0.0529vf\right]}{(r+f)\left[r(0.0529v - 0.00028Fr) - 0.00028Frf\right]} \quad (10)$$

MATLAB software was used on the data collected for one month-31days (October,2024) in Benin/Onitsha road and an empirical mathematical model was formulated, while ensuring the best fits to the data. Based on the collected data, after an initial scatter plot, we found that the sum of Sinusoidal functions of the form asin (bt+c), where t is time data was collected (now redesignated using natural numbers).

Assumptions made for the Model.

The model is empirical, based purely on data collected. Hence,

i. we assume a model with superimposition of 8 sine functions

ii. the model has 24 coefficients, $a_1, b_1, c_1, \ldots, a_8, b_8, c_8$

iii. F(t) is the estimated number of cars

With these in mind, we formulated the following empirical model that could be used to predict the density of cars at the target location for the seven days of the week for an entire month;

$$F(t) = a_1\sin(b_1t+c_1) + a_2\sin(b_2t+c_2) + a_3\sin(b_3t+c_3) + a_4\sin(b_4t+c_4)$$
$$+ a_5\sin(b_5t+c_5) + a_6\sin(b_6t+c_6) + a_7\sin(b_7t+c_7) + a_8\sin(b_8t+c_8) \quad (1)$$

In the model (1), F(t) represents the number of cars at the target location at time t (with t determined as discussed below).

Where a,b,c are constants/parameters of the model, to be estimated using the data, gave the best fit. The parameters $a_1, a_2, \ldots, a_8$, $b_1, b_2, \ldots, b_8$ and $c_1, c_2, \ldots, c_8$ are estimated for each day of the week and gives the best fit to the collected data using model (1)

ln the plots that follows, the blue curve represents the actual number of vehicles while the red curves represents the predicted number of vehicles using the model (1).

RESULT FROM DATA COLLECTED ON BENIN/ONITSHA ROAD

The results for the averagely seven days of the month across on Data collected at Benin/Onitsha road are shown below. Still using model 4.1,

$$F(t) = a_1\sin(b_1t+c_1) + a_2\sin(b_2t+c_2) + a_3\sin(b_3t+c_3) + a_4\sin(b_4t+c_4)$$

$+ a_5\sin(b_5t+c_5) + a_6\sin(b_6t+c_6) + a_7\sin(b_7t+c_7) + a_8\sin(b_8t+c_8)$

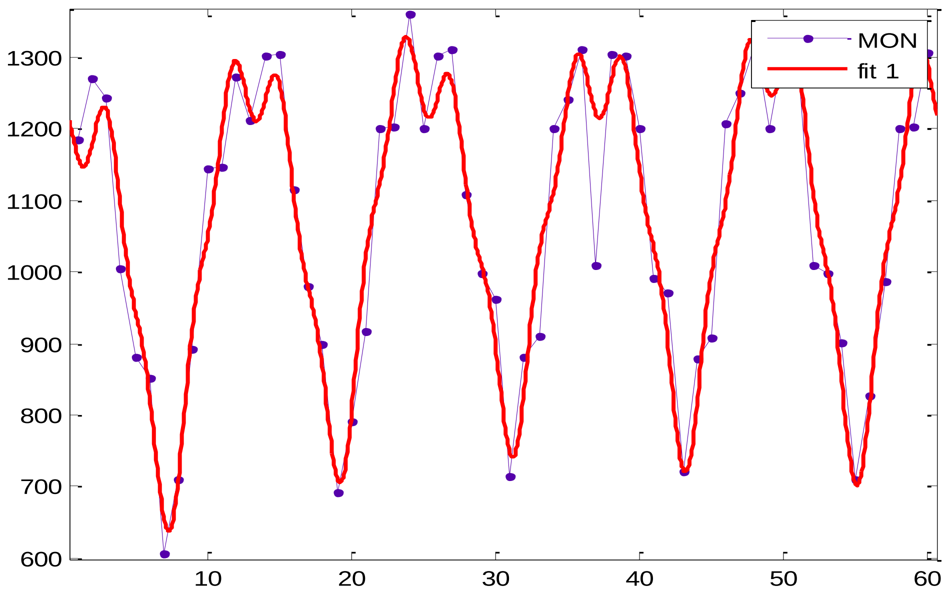


Figure 2: Plot of Monday data with the predicted values of model (4.1) for Benin / Onitsha road

Model: $F(t)=a_1\sin(b_1t+c_1) + a_2\sin(b_2t+c_2)+a_3\sin(b_3t+c_3) + a_4\sin(b_4t+c_4)$

$+ a_5\sin(b_5t+c_5) + a_6\sin(b_6t+c_6) + a_7\sin(b_7t+c_7) + a_8\sin(b_8t+c_8)$

Coefficients (with 95% confidence bounds):

a_1 = 2183 (-1.703e+008, 1.703e+008)

b_1 = 0.04874 (-1239, 1240)

c_1 = 0.2657 (-3.205e+004, 3.205e+004)

a_2 = 1472 (-1.196e+008, 1.196e+008)

b_2 = 0.08396 (-3423, 3423)

c_2 = 2.485 (-9.076e+004, 9.076e+004)

a_3 = 253.8 (213.5, 294.2)

b_3 = 0.5254 (0.4588, 0.5921)

c_3 = 0.9567 (-1.186, 3.1)

a_4 = 724.4 (-8.237e+007, 8.237e+007)

b_4 = 0.1394 (-4091, 4091)

c_4 = 4.1 (-1.19e+005, 1.19e+005)

a_5 = 70.43 (39.68, 101.2)

b_5 = 1.05 (1.019, 1.082)

$c_5 =$ 3.365 (2.272, 4.458)

$a_6 =$ 348.8 (-1.311e+008, 1.311e+008)

$b_6 =$ 0.1589 (-2342, 2342)

$c_6 =$ 6.66 (-7.186e+004, 7.187e+004)

$a_7 =$ 19.43 (-67.28, 106.1)

$b_7 =$ 0.6779 (0.2502, 1.106)

$c_7 =$ -0.876 (-15.18, 13.42)

$a_8 =$ 42.85 (13.72, 71.98)

$b_8 =$ 2.107 (2.067, 2.147)

$c_8 =$ 1.657 (0.2511, 3.063)

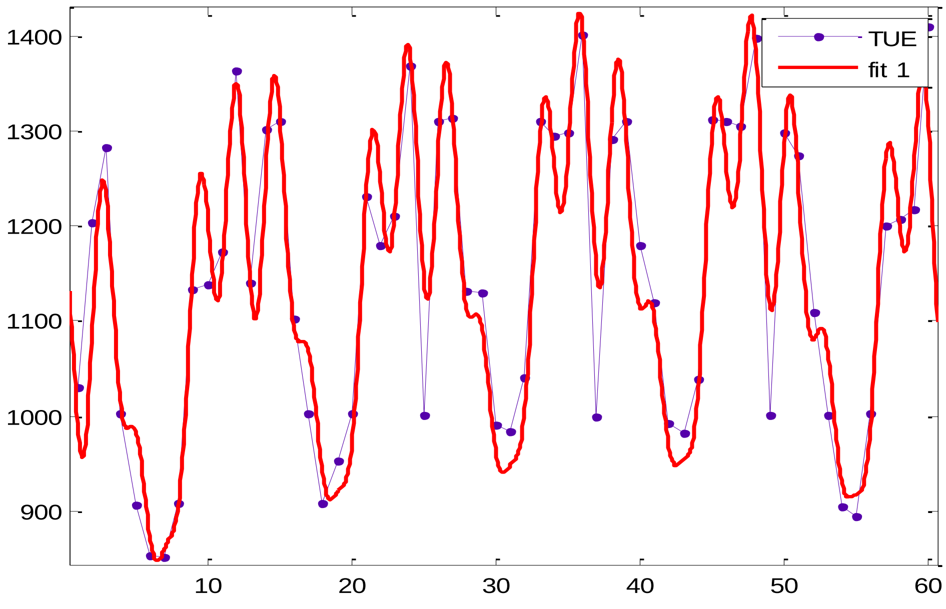
Goodness of fit:

SSE: 2.121e+005

R-square: 0.9141

Adjusted R-square: 0.8592

RMSE: 76.76



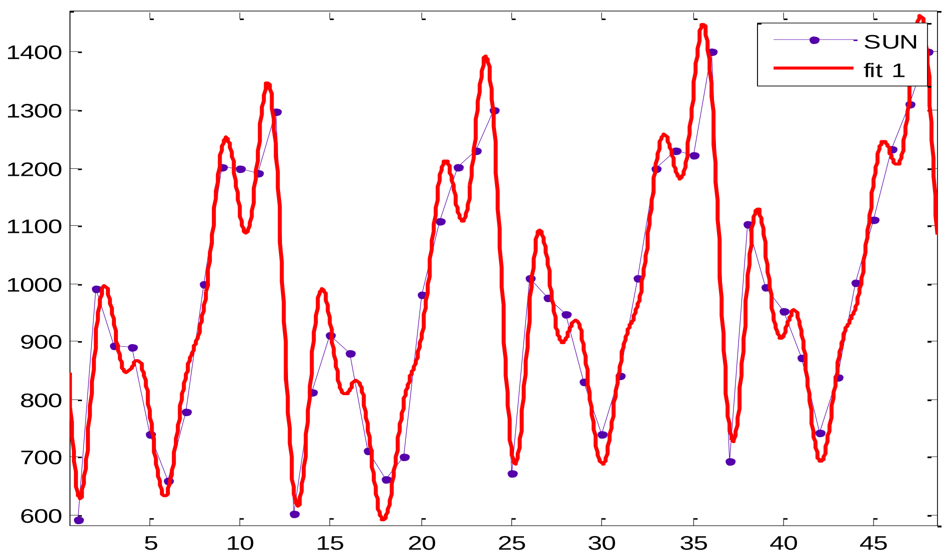
Plot of Tuesday data with the predicted values using model (1) for Benin / Onitsha road

Model: $F(t)=a_1\sin(b_1t+c_1) + a_2\sin(b_2t+c_2)+a_3\sin(b_3t+c_3) +a_4\sin(b_4t+c_4)$
$+ a_5\sin(b_5t+c_5) + a_6\sin(b_6t+c_6) +a_7\sin(b_7t+c_7)+ a_8\sin(b_8t+c_8)$

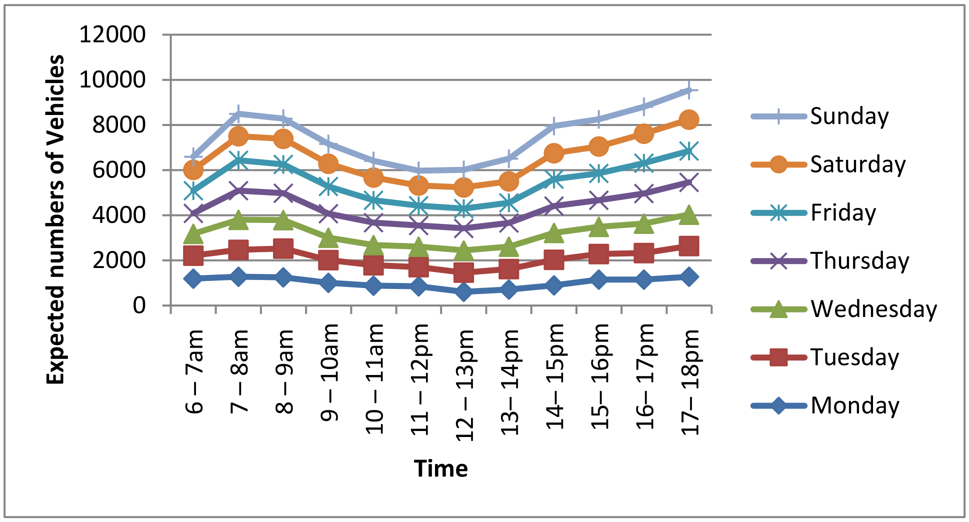
Coefficients (with 95% confidence bounds):

$a_1 =$ 2486 (-2.211e+013, 2.211e+013)

b_1 = 0.04646 (-1.96e+006, 1.96e+006)
c_1 = -0.1635 (-2.098e+009, 2.098e+009)
a_2 = 1422 (-5.771e+009, 5.771e+009)
b_2 = 0.06826 (-2.96e+004, 2.96e+004)
c_2 = 2.393 (-1.083e+006, 1.083e+006)
a_3 = 165 (136.6, 193.3)
b_3 = 0.5316 (0.5147, 0.5486)
c_3 = 1.139 (0.5929, 1.685)
a_4 = 88.16 (-1.353e+007, 1.353e+007)
b_4 = 0.1302 (-1753, 1753)
c_4 = 3.331 (-6.101e+004, 6.102e+004)
a_5 = 70.24 (45.6, 94.89)
b_5 = 2.11 (2.09, 2.13)
c_5 = 1.449 (0.7377, 2.16)
a_6 = 74.37 (48.75, 99.99)
b_6 = 1.045 (1.024, 1.066)
c_6 = -2.226 (-2.951, -1.501)
a_7 = 58.69 (33.95, 83.42)
b_7 = 2.636 (2.612, 2.659)
c_7 = 1.171 (0.3479, 1.994)
a_8 = 389.9 (-5.549e+012, 5.549e+012)
b_8 = 0.04624 (-2.956e+006, 2.956e+006)
c_8 = 89.39 (-5.651e+010, 5.651e+010)



Plot of Sunday data with the predicted values using model (1) for Benin / Onitsha road



Plot of expected number of vehicles against time (Benin / Onitsha)

The conclusion from the analysis are:
(1) for every speed, there is a frequency of vehicle that will induce road traffic gridlock.
(2) that whatever will make the speed of the vehicle using a road to drop and approach the critical value is a potential cause of gridlock. This include road interception, adverse weather conditions such as flood etc.

Remedies to Traffic Congestion

1. Public Awareness and Education – Implement continuous traffic education and awareness campaigns to promote compliance with traffic regulations and courteous driving behavior.
2. Parking Management – Introduce and enforce parking fees, and strictly prohibit illegal roadside parking to ensure smooth traffic flow.
3. Capacity Building – Train and equip transport and traffic management personnel with modern skills and tools for efficient operations.
4. Public Transport Enhancement – Increase the number of reliable commercial buses and promote mass transit systems to reduce dependence on private vehicles.
5. Urban Planning Enforcement – Remove roadside trading and hawking, and demolish illegal structures encroaching on roadways.
6. Bus Stop Optimization – Reduce the number of closely spaced bus stops and ensure designated stopping zones.
7. Road Rehabilitation and Expansion – Repair damaged roads, expand existing roadways, and improve drainage to prevent flooding-related congestion.
8. Alternative Transport Modes – Introduce ferry services, construct railway lines, and encourage non-motorized transport such as cycling and walking.
9. Traffic Flow Management – Provide dedicated lanes for trucks and heavy-duty vehicles, and enforce restricted operating hours where necessary.
10. Pedestrian Facilities – Construct pedestrian bridges, walkways, and crossings to improve safety and reduce vehicle stoppages.

SUMMARY AND CONCLUSION

This study has shown that traffic congestion in Nigerian urban areas, especially on the Benin/Onitsha Headbridge Road, can be effectively modeled using empirical techniques. The use of sinusoidal-base models accurately captured vehicle density patterns and enabled predictions for peak traffic hours. The insights gained from this research can support traffic management efforts by informing infrastructure planning and policy formulation

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