Kasetsart J. (Nat. Sci.) 49 : 806- 816 (2015)

Mathematical Model to Determine the Relationship Between Road Traffic Flow, Vehicle Speed and Road Traffic Gridlock in a Road Link

L.I. Igbinosun[1,*] and S.E. Omosigho[2]

ABSTRACT

The effects of the frequency and the speed of vehicles on road traffic gridlock were examined. Steady state queueing models were used to develop a mathematical relationship between the road traffic frequency of vehicles, the speed of vehicles and road traffic congestion. The model was applied to both a single lane and a double lane road. The results showed a substantial rise in the number of vehicles in the queue for a very low speed beyond some value(s) called the critical value(s) of speed. The work explains why there is road traffic congestion on some roads without seeing the actual cause. It also provides a clue to the theoretical approach to the management of road traffic congestion and underscores the need to engage in serious scientific study of congestion on roads as opposed to the *ad hoc* strategies currently employed in Nigeria to address road traffic congestion.

Keywords: traffic gridlock, road traffic frequency, road traffic speed, gridlock vectors.

INTRODUCTION

Road congestion has become a common phenomenon, both on urban roads and suburban highways and there have been several attempts to identify the main causes of road traffic congestion and propose possible strategies to tackle the problem (Omiunu, 1998; Zhao and Chung, 2001; Aworemi *et al*., 2009; Oni, 2010; Ziliute *et al*., 2010). The determination of the rate of incidents and clearance times can be difficult to determine in a developing country like Nigeria. Nevertheless the gap between theory and practice is widening especially in developing countries where the road infrastructure for collecting and managing road traffic flow data is virtually absent.

This study used empirical data on road traffic flow to provide an insight into the observed congestion on two road links in Nigeria. The study underscores the need to collect empirical data on road traffic flow and engage in serious scientific study of congestion on Nigerian roads as opposed to the fire brigade tactics currently employed in many developing countries, including Nigeria, to address road traffic congestion (Daniel, 2013).

LITERATURE REVIEW

There are two major types of traffic flow models: macroscopic and microscopic. Both traffic models have various descriptions, scattered throughout literature and many engineering books

[1] Department of Mathematics and Statistics, University of Uyo, P.M.B. 1017, Uyo, Nigeria.
[2] Department of Mathematics, University of Benin, P.M.B. 1154, Benin City, Nigeria.
[*] Corresponding author, e-mail: luckyigbinosun@uniuyo.edu.ng

Received date : 27/01/15 Accepted date : 15/07/15

(Otuoze *et al*., 2012). The work reported in this paper belongs to macroscopic study. In road traffic analysis, traffic flow, space-mean speed and traffic density are the three main variables used to measure performance (Lighthill and Whitham, 1955). This study used the term "traffic frequency" instead of "traffic flow", while the number of vehicles on the road link is used as a proxy for "traffic density".

Aworemi *et al*. (2009) examined the causes and effects of road traffic congestion in some selected areas of Lagos State, Nigeria. They used a structured questionnaire administered through personal interviews to obtain data. They identified poor road conditions, accidents and driver behavior as some of the factors responsible for traffic congestion. Omidiji (2010) investigated the causes of road traffic crashes on major intersections within Abuja, Nigeria. He demonstrated using data obtained from a survey that traffic engineering measures reduced road traffic accidents and identified the need to have data on road crashes on a routine basis so that studies can be carried out on how to reduce the number of crashes on roads. Furthermore, such data should be readily available. For example, Dickerson *et al*. (1998) in their study used traffic flow data for the period mid 1993 to the end of 1995 taken from the Department of Transport's automated recording devices which are distributed throughout London and police data on all road traffic accidents in the corresponding period.

Forecasting traffic flow frequency in a road network is a fundamental prerequisite for the management of road traffic congestion. It is also the basis for developing an Advanced Traveler Information System (ATIS) and Advanced Traffic Management System (ATMS) (Leduc, 2008). These systems require the availability of real time data and a rich data warehouse on both traffic flow and travel time data. For example, de Fabritiis *et al*. (2008) explored the use of real time Floating Car Data (FCD) for speed prediction. Wahle *et al*. (2010) proposed the use of real traffic data to calculate actual travel times and traffic loads on the road. Kamarianakis and Prastacos (2005) examined the use of space time integrated moving average (STARIMA) models to analyze road traffic flow patterns. The model can be used to forecast the traffic flow pattern and assess the impact of traffic flow changes on other parts of a road network. Of considerable interest is the report by Kamarianakis and Prastacos (2005) that used traffic flow data for a set of 25 loop-detectors located at roads that went direct to the centre of the city of Athens, Greece. Several methods for collecting road traffic data are described in Leduc (2008), including pneumatic road tubes, piezoelectric sensors, magnetic loops, manual counts, passive and active infrared, passive magnetic, microwave radar, ultrasonic and passive acoustic, video image detection, and FCD. Leduc (2008) included details of these methods and pieces of information that can be gathered by each technology such as volume or count, speed of vehicles, classification of vehicles, occupancy and presence. According to Leduc (2008), "two very important types of traffic data delivered by transport centres around the world concern the Average Annual Daily Traffic (AADT) and the Vehicle Kilometers' Travelled (VKT). These two raw traffic variables, mainly derived from fixed sensors measurements, play a key role in traffic engineering analysis (e.g. model calibration, determination of traffic exposure functions, etc.) and policy decisions." Arosanyin (2007) examined the types, sources and shortcomings of transport data required for planning, and international comparison in Nigeria and concluded that "transport data as published in Nigeria are deficient in terms of transport development indicators, projections, comprehensiveness, consistency, adequacy, and classification accuracy, among others" In Nigeria, the Federal Road Safety Commission in an attempt to respond to observed road blocking incidents resorted to the use of aircraft and helicopters to detect road traffic congestion spots (Bashir, 2010). Such phenomena can be predicted with the availability of data and a good model.

Baykal-Gürsoy *et al.* (2009) examined road traffic flow interrupted by incidents using steady state M/M/c and M/M/∞ queuing systems and obtained the steady state distribution of the number of vehicles on a road link. Earlier, Kakooza *et al.* (2005) also used the M/M/c queuing model to analyze the performance of unsignalized, signalized and roundabout road intersections. Using probability generating functions, they obtained expressions for the steady state expected number and waiting time of vehicles for single and double lane road links stopping at a road intersection interrupted by delays. Indeed, for a single lane system, (M/M/1), Kakooza *et al.* (2005) stated that the expression for the expected number of vehicles in the system and the average waiting time of vehicles in the system are given by Equation 1:

$$E(X)=\frac{\lambda[(r+f)^2+\mu_0 f]}{(r+f)[r(\mu_0-\lambda)-\lambda f]} \qquad (1)$$

where, λ is the average number of vehicles arriving at an intersection per unit time; r is the rate of disappearance or clearance of the delays; f is the rate of occurrence of delays; and μ_0 denotes the service rate with no delays. The same expression is also given in Baykal-Gürsoy *et al*. (2009). As can be seen, a reason for a decreased capacity at the incident site is a decline in the number of available lanes in the road network. However, in addition, the capacity decreases because the remaining lanes are less optimally used because road users are distracted.

The application of the model proposed by Baykal-Gürsoy *et al.* (2009) and Kakooza *et al*. (2005) requires the computation of the rate of occurrence of delays and the rate of disappearance or clearance of the delays, respectively. Igbinosun *et al.* (2013) showed that the number of vehicles in the queue will increase whenever the speed of vehicles is reduced in a road link with the assumption that the rate of occurrence of a delay and its clearance rate were equal (with a pre-determined value of 0.5). However, in developing economies like Nigeria, the respective rates of occurrence and clearance of delays can be very difficult to obtain realistically. The current study considered both single lane and double lane road links. Due to limited data availability and the required computational power to perform all analyses involving the determination of the rate of occurrence and clearance of an incidence, the current work was restricted to investigating the measures of performance at the position of an incident in a road link. The situation was considered where there was no incidence and clearance rate, respectively. However, the speed of vehicles and the frequency of vehicles passing a road link are needed amongst other parameters. The expression for the expected number of vehicles in the queue was used to evaluate the road links in the current study. The number of vehicles on the link decreases as the service rate increases, provided the incidence rate and clearance rate are constant (Baykal-Gürsoy *et al*., 2009)

EVALUATION OF ROAD LINK

The multiple server model was used, $m/m/s$: $GD/\infty/\infty$, to obtain the steady state distribution of the number of vehicles on a road link. Using probability generating functions, expressions for the steady state expected number and waiting time of the vehicles in the queue are shown in Equations 2 and 3:

$$E(X)=\frac{\rho^{s+1}}{(s-1)!(s-p)^2}\left[\sum_{n}^{s-1}\frac{\rho^n}{n!}+\frac{\rho^s}{s!}\left(\frac{1}{\left(1-\frac{\rho}{s}\right)}\right)\right]^{-1} \qquad (2)$$

$$W=\frac{E(X)}{\lambda} \qquad (3)$$

where, $\rho=\dfrac{\lambda}{\mu}$ is called the road utilization factor or traffic intensity (Sharma, 2013). Here, λ is the number of vehicles arriving at a road link per second, μ is the service rate, that is, the number of vehicles using a particular cell in one second under free flow; s is the number of servers (the number of lanes in the road link).

Equation 2 (the expression for the expected number of vehicles in the queue) was used to evaluate the road links. Empirical data on road traffic flow was used to explain the observed congestion on some road links in Nigeria. The work underscores the need to collect empirical data on road traffic flow and engage in serious scientific study of congestion on Nigerian roads as opposed to the fire brigade tactics currently employed in the country to calm road traffic congestion. For example, the Nigeria Police in conjunction with the Federal Road Safety commission in December, 2013 deployed helicopters to monitor and control road traffic during the Yuletide period (Daniel, 2013).

For Equation 2 to be useful, it is necessary to interpret $\rho = \frac{\lambda}{\mu}$ which requires a relationship between the expected number of vehicles [$E(X)$], the speed of the vehicles (v) and the frequency (F).

Equation 2 can be rewritten as a function of the vehicle speed and its frequency as Equation 4:

$$E(X) = h(v,F) \quad (4)$$

where v is the speed and F is the frequency of vehicles.

According to the Journal of Institute of Transport Engineers, reported in Kakooza *et al.* (2005), the average length of a vehicle is L = 5.3 m. Thus the length of an s lane link which can accommodate C vehicles is Equation 5:

$$L = \frac{5.3 \times C}{s} m \quad (5)$$

where C is the number of vehicles in the link and s in the number of lanes.

This study considered two cases: a single and a double lane road link, respectively (that is, when s = 1,2).

Case 1 (single lane road link): It is reasonable to assume here that the vehicles at the front leave first or are in service channels; Consequently, we take $C = s = 1$. Thus: $L = 0.00525\ km$.

The travel speed (v) at full capacity is given by Equation 6:

$$v = L \times \mu_0 \times 3{,}600\ km.hr^{-1} = 18.9\ \mu_0 \quad (6)$$

where v is measured in kilometers per hour and μ_0 is the service rate.

Therefore:

$$\mu_0 = 0.0529\ v \quad (6)$$

The frequency (F) of vehicles per hour is given by Equation 7:

$$F = 3600\ \lambda\ (km.h^{-1}) \quad (7)$$

Substituting Equations 6 and 7 into Equation 2 yields Equations 8 and 9:

$$E(X) = \frac{\rho^2}{(1-\rho)^2}\left(1 + \frac{\rho}{(1-\rho)}\right)^{-1} \quad (8)$$

$$E(X) = \left(\frac{0.00525F}{v - 0.00525F}\right)^2 \left(1 + \frac{0.00525F}{v - 0.00525F}\right)^{-1} \quad (9)$$

Equation 9 is used to generate the expected number of vehicles in the queue for various speeds. For example, Table 1 gives the expected number of vehicles in the queue when the frequency of vehicles in the road is approximately 441 vehicles.hr^{-1}.

Case 2 (double lane) For the double lane road link (s = 2), it is expected that two vehicles can be at the exit service point at a time; however, in reality, it is possible for either, one, two or three vehicles to be served. Here, $C \in [1,2,3]$. Taking s = 2, results in the length and formulation of the vehicle speed as in case 1, but with modification as follows in Equation 10:

$$L = \frac{5.3 \times C}{2} m$$
$$L = 2.65 \times C \quad m \quad (10)$$
$$L = 0.00265 \times C \quad km$$

Travel speed, v is given by Equations 11 and 12:

$$\begin{aligned} v &= L \times \mu_0 \times 3600 \quad km.h^{-1} \\ &= 0.00265 \times 3600 \times \mu_0 \times C \quad (11) \\ &= 9.6012 \times \mu_0 \times C \end{aligned}$$

$$\mu_0 = \frac{0.1041536 \quad v}{C}, \qquad C \in [1,2,3] \quad (12)$$

Putting s = 2 in Equation 2 yields Equation 13:

$$E(X)=\frac{\rho^3}{(2-\rho)}\left[1+\rho+\frac{\rho}{2}\left(\frac{2}{(2-\rho)}\right)\right]^{-1} \quad (13)$$

Using Equation 13, yields Equation 14:

$$E(X)=\left(\frac{FC}{375v}\right)^3\left(\frac{750v-FC}{375v}\right)^{-2}\left[1+\frac{FC}{375v}+0.5\left(\frac{FC}{375v}\right)^2\left(\frac{750v}{750v-FC}\right)\right]^{-1} \quad (14)$$

Various values of the critical speed and expected number of vehicles in the link can be obtained from Equation 14 when C=2 and C=3.

APPLICATION

The data in Igbinosun *et al.* (2013) were used. The data were applied to the case when C=2, Table 2 shows the hourly distribution of vehicle frequency for a six-hour daily period for one month on one of the busy roads in Benin City.

Table 1 Expected number of vehicles (E) in the queue with a frequency of approximately 441 vehicles.hr^{-1}.

Frequency (vehicles.hr^{-1})	Velocity (km.hr^{-1})	E
441	2.32	904
441	2.35	70
441	2.4	27
441	2.45	12
441	2.5	3
441	2.6	1
441	2.8	0
441	3	0
441	4.5	0
441	5	0
441	10	0
441	20	0
441	30	0
441	40	0
441	50	0

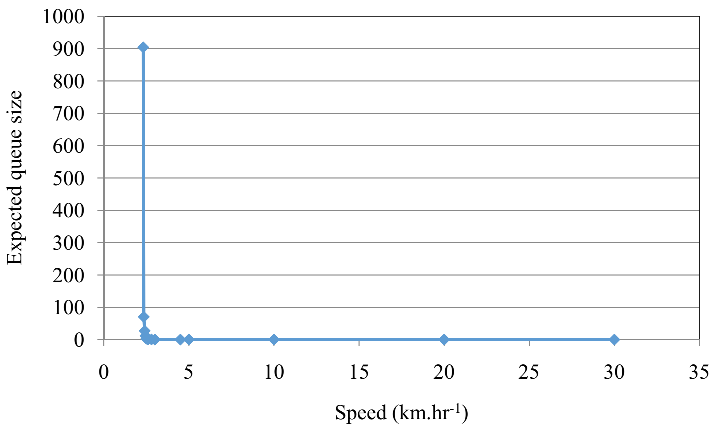

Figure 1 Graph of expected number of vehicles in a road link versus speed for a single lane road.

The expected number of vehicles in the queue is shown in Table 3 for a double lane road for an average traffic flow of 1,286 vehicles on a Monday morning (0600–0700 hours)

Consider a case when C=3: This scenario pictures where three vehicles are neck-to-neck in a double lane (Figure 4).

There was a sharp increase in the number of vehicles in the queue when the speed of vehicles reduced beyond some value(s) (called critical value(s) of speed). Figures 3, 5 and 6 show the expected number of vehicles that will be in the queue when the speed of vehicles on the road link is reduced for the double lane road link. The queue length can be as high as 91 vehicles when the speed is reduced to 5.2 km.hr^{-1}; a further small reduction in the speed can lead to a chaotic situation where the road link cannot accommodate the volume of vehicles that will be in the queue. There can be as many as 5,144 vehicles in the link at a speed of 5.1 km.hr^{-1}, as a result of a drop in the vehicle speed below the critical value. From Table 4, for

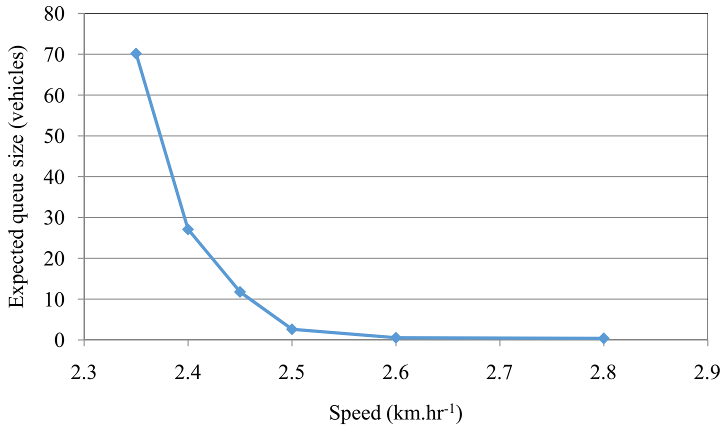

Figure 2 Graph of expected number of vehicles in a road link versus speed ($v \in [2.3,3.9]$) for a single lane road.

Table 2 Traffic distribution by time of day at the kilometer three point on the Benin-Asaba Road.

Time (24 hour format)	Mon	Tues	Wed	Thu	Fri	Sat	Sun
0600–0700	1,286	1,038	1,061	995	1,045	962	661
0700–0800	1,373	1,303	1,429	1,335	1,452	1,165	1,072
0800–0900	1,334	1,385	1,367	1,256	1,362	1,239	983
0900–1000	1,107	1,112	1,042	1,163	1,242	1,153	923
1000–1100	990	1,021	998	1,000	1,000	1,059	833
1100–1200	942	950	1,013	1,042	949	961	748
1200–1300	701	915	1,027	998	979	1,033	859
1300–1400	817	1,033	1,094	1,077	992	1,050	1,011
1400–1500	997	1,233	1,299	1,139	1,260	1,240	1,241
1500–1600	1,243	1,238	1,273	1,289	1,224	1,294	1,238
1600–1700	1,245	1,278	1,409	1,435	1,445	1,378	1,230
1700–1800	1,377	1,466	1,490	1,526	1,485	1,472	1,370

example, the critical speed is 6 km.hr^{-1} for vehicles using the road link. This analysis explains why there is road traffic congestion on some Nigerian roads without seeing the actual cause (one such example is deviant driving behavior where a vehicle driver reduces his speed below the road link's accepted critical level to greet a friend for few seconds, before increasing the vehicle speed again).

Table 3 Expected number of vehicles (E(X)) in the queue for an average of 1,286 vehicles.hr^{-1} for average hourly traffic for Monday on the Benin-Asaba Road for the period 0600–0700 hours).

Frequency (vehicles.hr^{-1})	No. of lanes	Speed (km.hr^{-1})	E(X)
1,286	2	3.46	111
1,286	2	3.5	48
1,286	2	3.9	7
1,286	2	4	5
1,286	2	5	2
1,286	2	6	1
1,286	2	7	0
1,286	2	8	0
1,286	2	9	0
1,286	2	10	0
1,286	2	11	0
1,286	2	12	0
1,286	2	15	0
1,286	2	16	0
1,286	2	17	0
1,286	2	18	0
1,286	2	19	0
1,286	2	20	0

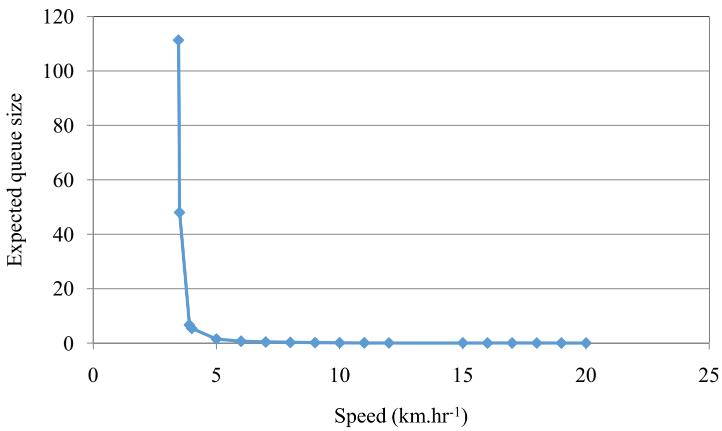

Figure 3 Expected number of vehicles in the link when C=2, λ=0.3572 and an average of 1,286 vehicles.hr^{-1} for a Monday on the Benin-Asaba Road.

DISCUSSION AND CONCLUSION

One of the aims of Kakooza *et al*. (2005) and Baykal-Gürsoy *et al.* (2009) was to propose queueing models to describe the traffic flow on a road link that is subject to roadway incidents. However, the results they presented were for very low traffic intensity and did not consider the scenarios used in the current study. In addition, the determination of the rate of incidents and clearance times can be difficult to determine in a developing country like Nigeria. These rates were assumed, both in Baykal-Gürsoy *et al*. (2009) and Igbinosun *et al.* (2013).

The approach and analysis in the current study was an extension of the work of both Kakooza *et al*. (2005) and Baykal-Gürsoy *et al.* (2009). The current study presented a relationship between the speed and the frequency of vehicles with regard to road traffic congestion. The analysis provided an explanation of the formation of road traffic congestion; the relationship between the

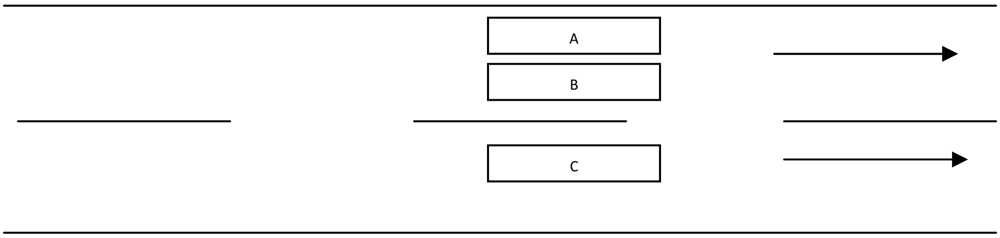

Figure 4 Schematic diagram of three vehicles using a double lane road.

Table 4 Speed and expected number of vehicles (E(X)) in the link for C=3 and λ=0.122616 and an average of 442 vehicles.hr^{-1}.

Frequency (vehicles.hr^{-1})	No. of lanes	Speed (km.hr^{-1})	E(X)
1,286	3	5.145	5143
1,286	3	5.15	857
1,286	3	5.2	91
1,286	3	5.4	20
1,286	3	5.5	14
1,286	3	6	5
1,286	3	7	2
1,286	3	8	1
1,286	3	9	1
1,286	3	10	0
1,286	3	11	0
1,286	3	12	0
1,286	3	13	0
1,286	3	14	0
1,286	3	15	0
1,286	3	16	0
1,286	3	17	0
1,286	3	18	0
1,286	3	19	0

frequency of vehicles on a road link and the road traffic congestion is not data specific. It also provided insight into the theoretical approach to the management of road traffic congestion. Since congestion results from "gridlock vectors" and the critical speed resulting in congestion is proportional to the frequency of the vehicles using a road link, then congestion can be managed by paying attention to the speed and frequency of the vehicles using a road link by increasing the speed of vehicles using the road link for a given frequency or by taking action to reduce the frequency of vehicles using a road link for a given range of speed.

On very busy roads, it is important to ensure that vehicles do not move at speeds close to the critical speed. This is the idea behind having fast lanes. The use of flyover bridges and signalized intersection has been found to affect the speed of vehicles in such a way that road traffic congestion is effectively managed. On the other hand, actions such as fee charges to use a road link, restricted use of a road link (for example, having bus lanes or requiring permission before purchasing a vehicle); providing other means of travel (such as a rail system) and having ATIS have

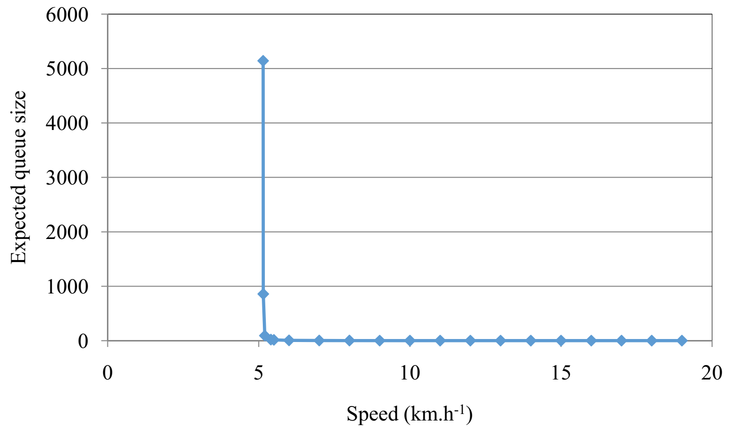

Figure 5 Expected number of vehicles in the link when C=3 and an average of 1,286 vehicles.hr^{-1} for a Monday on Benin-Asaba Road.

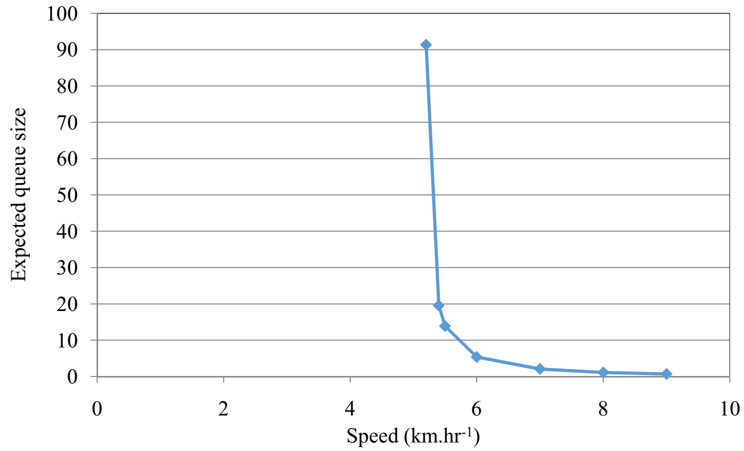

Figure 6 Expected number of vehicles in the link when λ=0.3572 and an average of 1,286 vehicles. hr^{-1} for a Monday on Benin-Asaba Road and C=3.

been found to reduce the frequency of vehicles using a road link.

In practice, whatever action is to be taken must be based on an empirical study of the situation. This means that infrastructure for collecting data on road traffic activities must be available.

LITERATURE CITED

Arosanyin, G.T. 2007. Issues in Nigeria's transport data for planning and international comparison. **Central Bank of Nigeria Economic and Financial Review.** 45: pp 45–72.

Aworemi, J.R., I.A. Abdul-Azeez, A.J. Oyedokun and J.O. Adewoye. 2009. A study of the causes, effects and ameliorative measures of road traffic congestion in Lagos metropolis. **Eur. J. Soc. Sci.** 11: 119–128.

Bashir, M. 2010. **409 Motorists Arraigned Over Traffic Offences.** Daily Trust newspapers. [Available from: www.dailytrust.com.ng/.]. [Sourced: 27 December, 2010].

Baykal-Gürsoy, M., W. Xiao and K. Ozbay. 2009. Modeling traffic flow interrupted by incidents. **Eur. J. Oper. Res.** 195: 127–138.

Daniel. 2013. FRSC deploys 34,000 personnel, four helicopters, 848 vehicles for special patrol at Christmas, new year. [Available from: http://www.informationg.com/2013/12/frsc-deploys-34000-personnel-four-helicopters-484-vehicles-for-special-patrol-at-christmas-new-year.html]. [Sourced: 13 Nov 2015]

de Fabritiis C., R. Ragona and G. Valenti . 2008. Traffic estimation and prediction based on real time floating car data, pp 197–203. *In* **Proceedings of the 11th International IEEE Conference on Intelligent Transportation Systems.** 12–15 October 2008. Beijing, China.

Dickerson, A., J. Peirson and R. Vickerman. 1998. **Road Accidents and Traffic Flow: An Econometric Investigation.** [Available from: ftp://ftp.repec.org/opt/ReDIF/RePEc/ukc/ukcedp/9809.pdf.]. [Sourced: 15 May 2014]

Igbinosun, L.I., S.E. Omosigho and O.E. Enwemasorb. 2013. Effect of road traffic frequency and speed of vehicles on congestion. **J. Math. Sci.** 2: 315–326.

Kakooza, R., L.S. Luboobi and J.Y.T. Mugisha. 2005. Modelling traffic flow and management at un-signalized, signalized and roundabout road intersections. **J. Math. Stat.** 1: 194–202

Kamarianakis, Y. and P. Prastacos. 2005. Space-time modelling of traffic flow. **Comp. Geo Sci.** 31: 119–133.

Leduc, G. 2008. **Road Traffic Data: Collection Methods and Applications, European Commission Joint Research Centre Institute for Prospective Technological Studies.** [Available from: ftp.jrc.es/EURdoc/JRC47967.TN.pdf.]. [Sourced: 15 May 2014].

Lighthill, M.J. and G.B. Witham. 1955. On kinematic waves. II. A theory of traffic flow on long crowded roads. **Proc. Roy. Soc. Lond. Ser. A Math. Phys. Sci.** 229: 317–345.

Omidiji, A.A. 2010. Observational studies of road traffic engineering measures of Federal Capital Territory roads in Abuja, Nigeria, pp 1–13. *In* **Proceedings of the 20th Canadian Multidisciplinary Road Safety Conference.** 6–9 June 2010. Niagara Falls, Ontario, Canada.

Omiunu, F.G.I. 1998. Flooding and traffic management in Benin City region. *In* P.O. Sada and F.O. Odenerho, (eds.). **Environmental Issues and Management in Nigerian Development.** Evans. Ibadan, Nigeria.

Oni, O.A.G. 2010. Tackling road traffic congestion in a developing country: A contemporary approach. **J. of Appl. Sc. Res.** 6: 529–542.

Otuoze, H.S., Y.D. Amartey, B.H. Sada and A.H. Ahmed. 2012. Macroscopic approach to modeling of road traffic data in Zaria, Nigeria. **World J of Engineering and Pure and**

Applied Sci. 2: 125–130.

Sharma, J.K. (2013) **Operations Research: Theory and Applications.** 5th edition. Macmillan. New Dehli, India.

Wahle J., O. Annen, C. Schuster, L. Neubert, and M. Schreckenberg. 2001. A dynamic route guidance system based on real traffic data. **Eur. J. of Oper. Res.** 131: 302–308.

Zhao, F. and S. Chung. 2001. Contributing factors of annual average daily traffic in a Florida County–Exploration with Geographic Information System and Regression models. **Pav. Mgmt., Mon. and Accel. Tst.** 1769: 113–122.

Ziliute, L., A. Laurinavicius and A. Vaitkus. 2010. Investigating into traffic flows on high intensity streets of Vilnius city. **Transport** 25: 244–251.