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# Development of a Framework for Reduction of Urban Traffic Congestion: Case Study of Akure Central Business District, Nigeria

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**ABSTRACT**

Traffic congestion has become a problem in the central business district of Akure. These roads during peak periods have defied measures to alleviate such congestion, leading to poor mobility and economic losses in form of costs of fuel, oil, as well as time cost of road users. The field survey was conducted on two major roads in the Central Business District (CBD) namely Oba Adesida and Arakale roads while considering the two directions along each route namely directions A and B, C and D respectively. Traffic parameters such as flow rate, speed and density were analyzed from the traffic data collected from each route along each direction. The field survey was carried out for a week (from Monday to Sunday) during the peak periods. The speed along direction A of Oba Adesida road was low due to more vehicles traversing the route. However, the speed of vehicles along direction D of Arakale road was lower than that along direction C. The traffic parameters were plotted against each other for the four directions for the morning, afternoon and evening periods. The derived linear models (equations) along the four directions gave minimum speeds for morning, afternoon and evening of 33.64 km/hr, 33.65 km/hr and 30.71km/hr respectively along direction A and 30.94 km/hr, 31.80 km/hr and 31.88 km/hr respectively along direction B for Oba-Adesida road; 36.59 km/hr , 35.30 km/hr, 33.58 km/hr respectively along direction C and 35.25 km/hr, 34.75 km/hr and 34.07 km/hr respectively along direction D for Arakale road for no congestion to occur.

**Keywords**: Traffic congestion, mobility, Central Business District, Level of Service

## INTRODUCTION

Transportation is very important to any economy and is one of the common tools used for development (Rodrigue et al., 2013). Economic opportunities have been increasingly related to the mobility of people, goods and services. When transport systems are efficient, they provide economic, social opportunities and benefits that result in positive multiplier effects such as accessibility to markets, employment and safety. However, inefficient transport systems have economic costs such as reduced or missed opportunity, lower quality of life and adverse effects on people's lives.

Traffic congestion means there are more vehicles trying to use a given road facility than it can handle. In major cities, this occurs mostly during certain times of the day called peak periods or rush hours. According to Kumarage (2004), there are two clear parameters within a single equation that cause congestion, that is, the balance between the demand and the supply of road space.

Speed is defined as a rate of motion expressed as distance per unit of time and generally in kilometres per hour (km/h). In characterizing the speed of a traffic stream, a representative value must be used, because a broad distribution of individual speeds is observable in a traffic stream. Average travel speed is used as the speed measure because it is easily computed from observation of individual vehicles within the traffic stream and is the most statistically relevant measure in relationship with other variables. Average travel speed is computed by dividing the length of the highway, street, section or segment under consideration by the average travel time of the vehicles traversing it (Highway Capacity Manual, 2000). A situation where the volume of traffic or modal split generates demand for space greater than the available road capacity is called saturation (Aderinlewo, 2020). Highway Capacity Manual (2000) defined density as number of vehicles (or pedestrians) occupying a given length of lane or roadway at a particular instant, it is expressed as vehicles per kilometre (veh/km). Bashiru

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(2008), Ogunbodede (2007), Owolabi et al (2016) and Ukpata and Etika (2012) listed causes of traffic congestion as poor road condition, road accidents, inadequate road infrastructure, inadequate traffic planning, absence of integrated transport system and drivers' behaviour.

The aim of this study was to develop a framework for reduction of urban traffic congestion in the CBD of Akure Metropolis. The study evaluated the traffic congestion on two roads namely Oba-Adesida and Arakale roads within the CBD considering both directions by taking the inventory of the traffic in morning, afternoon and evening peak periods for the week.

**Central Business District (CBD)**

The CBD or Central Business District is the focal point of a city. It is the commercial, office, retail and cultural centre of the city and usually is the centre point for transportation networks. The CBD was developed as the market square in ancient cities. On market days, farmers, merchants, and consumers would gather in the centre of the city to exchange, buy, and sell goods. This ancient market is the forerunner to the CBD. As cities grew and developed, CBDs became a fixed location where retail and commerce took place. The CBD is typically at or near the oldest part of the city and is often near a major transportation route that provides the site for the city's location such as a river, railroad, or highway. Over time, the CBD developed into a centre of finance and control or government as well as office space.

By the beginning of the 21st century, the CBD had become a diverse region of the metropolitan area and included residential, retail, commercial, universities, entertainment, government, financial institutions, medical centres, and culture. In recent decades, the combination of gentrification (residential expansion) and development of shopping malls as entertainment centres have given the CBD new life. In addition to housing, one can now find mega-malls, theatres, museums, and stadiums in the CBD.

**Linear regression modelling**

The goal of regression modelling is to develop a relationship between a number of independent variables upon which the behaviour of a totally different variable depends or to determine a mathematical function that describes the relationship between the input parameters and the output. Regression modelling assumes that the output can be explained using a linear combination of the input values. The basic linear regression model has the following form:

$$\gamma = \alpha + \mathrm{X}i\beta + \varepsilon \qquad (1)$$

where $\gamma$ denotes the dependent variable, $\alpha$ is a constant called intercept, $X_T = (X_{i....}X_n)$ is a vector of explanatory variables, $\beta = (\beta i........\beta n)$ is the vector of regression coefficient (one for each explanatory variable) and $\varepsilon$ represents randomly measured errors as well as any other variation not explained by the linear model (Kravchenko and Bullock, 2000).

**Description of the study area**

Akure is the administrative capital of Ondo State. Akure became the state capital of Ondo State in 1976. The town is located on latitude $70^0 15'$North of the Equator and Longitude $50^0 05'$East of the Greenwich Meridian. The climate is hot and humid with two distinct seasons, the rainy and dry seasons. The rainy season lasts for seven months (April – October) and the dry season for five months (November–March). The rainfall is about 1524 mm per year and the atmospheric temperature ranges between 28˚C and 31˚C with a relative humidity of 80 percent (Ajayi et al., 2016). The most noticeable of the physical expansion of the city is its population growth and urban landmass. The population rose from 123,000 in 1985 to 239,124 in 1991. The national population projection for the year 1996 and 2000 put the city population at 269,207 and 298,712 respectively. However, a sharp increase was recorded in the 2006 census, which put Akure South at 353,211 (NPC, 2009). The projection for the year 2020 put the city population at 571,740 with a growth rate of about 3.5 percent per annum (Okoko, 2002). Figures 1 shows Akure Street Map highlighting the Central Business District.

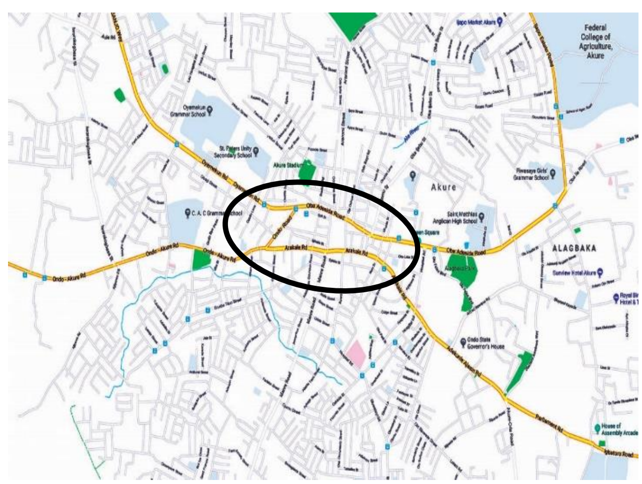


**Figure 1.** Akure Street Map Highlighting the Central Business District. **Source:** Google Map, (2019).

## MATERIALS AND METHODS

### Materials

The following are some of the materials used in carrying out this research: Stop watch, Traffic Jackets, Cine Camera and record sheets.

### Reconnaissance survey of the study area

At the initial stage of the work, a reconnaissance visit was made to the study area for on-the-spot evaluation of some selected traffic congestion points. Traffic data collected were on the field, using camera to capture three dimensional situations of traffic jam and traffic counts.

### Traffic data collection

The field survey was conducted on two major roads within the CBD namely Oba-Adesida and Arakale Roads. Cathedral junction to A division junction was considered as Oba Adesida Road (Direction A), from A Division junction to Cathedral junction as Oba Adesida Road (Direction B), Isinkan Roundabout to Nepa Roundabout was considered as Arakale Road (Direction C) and from Nepa Roundabout to Isinkan Roundabout was considered as Arakale Road (Direction D). These two routes were selected as they were the major feeders of other arterial routes critical to traffic flow in the study area. Traffic parameters were metered using cine cameras which were placed on the pedestrian bridge in front of the Akure central Mosque at Oba – Adesida Road (OAR) and Globec Plaza Opposite Adedeji Park at Arakale Road (ARR). These two points served as vantage points from the road section to take inventory of traffic during the morning, afternoon and evening peak periods. A previous study by Oyedepo (2016), Owolabi et al., (2016) established these peak periods to be between 7:00-9:00am, 12:00-2:00pm and 4:00-6:00pm for morning, afternoon and evening respectively on weekdays (Monday to Friday); 9:00-11:00am, 12:00-2:00pm and 4:00-6:00pm on Saturdays; 7:30-9:30am, 12:00-2:00pm and 4:00-6:00pm on Sundays.

Data on traffic composition and volume were collected by recording the types of vehicles i.e. motorcycle, cars, vans or buses and trucks captured by the video footage in a sheet. These were arranged on the sheet in ascending order of their vehicular capacities. The sheet was marked as vehicles passed the reference point on the road as shown in the video footage. The traffic volume was converted to passenger car unit per hour (pcu/hr) by multiplying each vehicle with their respective passenger car unit equivalents in order to get the approximate number of vehicles that ply the selected roads during the chosen peak periods.

Data on speed (Vs), density (K), traffic volume (q), were meticulously extracted from the cine camera by replaying it. Speed was measured by taking the travel time as vehicles traversed a short-measured distance along the intersection approaches.

Spot speed data were collected by measuring the time it took a vehicle to travel between two defined points on the roadway. Two reference points (50 meters apart) were marked on the roadway and the time vehicles took to travel between this two points were noted from the video footage and then recorded in a recording sheet according to Oloniyo (2018). Data on traffic density were collected by taking aerial photographs of the road section thrice in each flow regime i.e. for every 15 minutes' flow regime. Three aerial photographs were taken to measure the density of flow and the corresponding average density in vehicle per kilometre (veh/km) for each flow regime.

The headways were measured between the vehicles while replaying the cine-camera. The control delay was measured by taking note of how long a vehicle waited at a particular approach before having the right-of-way.

### Traffic data analysis

The traffic data collected were analysed and vehicle classification was used in determination of the proportions of various classes of vehicles plying the roads. Other field data were expressed as a function of independent predictors and dependent variables and was fitted to a multiple linear regression using the Statistical Package for Social Scientist (SPSS 21) to obtain the calibrated model equations for traffic congestion in the selected routes of the CBD; the model equations were validated using field data.

### Linear regression analysis

The next step after correlation was to carry out linear regression analysis. This involved predicting the value of a variable called the dependent variables in terms of the other variables called the independent variables. The period covers the 7 days (from Monday to Sunday) for each direction, the R values represent the simple correlation. The $R^2$ values indicate how much of the total variation lies in the dependent variable.

## RESULTS AND DISCUSSION

Table 1 shows the traffic composition for Oba-Adesida road during peak periods for a week. It can be observed that passenger cars constitute the highest volume at a total of 109,416 while bicycles constitute the smallest volume at a total of 94. From table 2, it can be seen that passenger cars also constitute the highest volume in the traffic composition for Arakale road during peak periods for a week while while bicycles again constitute the smallest volume. Figure 2 shows that the most predominant mode of transport along the two roads are passenger cars/taxi which constitute approximately 84.57% and 64.39% respectively, followed by motorcycles which constitute 13.26% and 32.48 respectively while tricycles, mini buses /vans, buses and trucks/lorries constitute the rest of the percentages.

**Table 1.** Traffic Composition for Oba–Adesida Road during Peak Periods for the week

| Vehicle Class | Morning Peak | Afternoon Peak | Evening Peak | Total | Percentage (%) |
|---|---|---|---|---|---|
| Bicycle | 51 | 11 | 32 | 94 | 0.07 |
| Motorcycle | 4,502 | 5,716 | 6,942 | 17,160 | 13.26 |
| Tricycle | 33 | 37 | 44 | 114 | 0.09 |
| Passenger Car | 35,132 | 33,172 | 41,112 | 109,416 | 84.57 |
| Mini van | 42 | 56 | 53 | 151 | 0.12 |
| Buses | 515 | 498 | 646 | 1659 | 1.28 |
| Trucks/Lorries | 151 | 342 | 294 | 787 | 0.61 |
| Total | 40,426 | 39,832 | 49,123 | 129,381 | 100 |

**Table 2.** Traffic composition for Arakale road during peak periods for the week

| Vehicle Class | Morning peak | Afternoon peak | Evening peak | Total | Percentage (%) |
|---|---|---|---|---|---|
| Bicycle | 34 | 13 | 43 | 90 | 0.08 |
| Motorcycle | 11,549 | 11,385 | 12,103 | 35,037 | 32.48 |
| Tricycle | 61 | 85 | 106 | 252 | 0.23 |
| Passenger Car | 23,042 | 20,567 | 25,859 | 69,468 | 64.39 |
| Mini van | 47 | 65 | 77 | 189 | 0.18 |
| Buses | 472 | 679 | 684 | 1,835 | 1.70 |
| Trucks/Lorries | 215 | 406 | 389 | 1,010 | 0.94 |
| Total | 35,420 | 33,200 | 39,261 | 107,881 | 100 |

**Traffic Flow**

Tables 3 and 4 present the maximum hourly volume (MHV) for Oba–Adesida and Arakale roads for the week. The MHV recorded for Oba–Adesida road for both directions is 2369.5 pcu/hr and 1860 pcu/hr while that of Arakale road is 1987.5 pcu/hr and 1876.5 pcu/hr. These values show the high level of commercial activities going on in the CBD. As more people commute towards and along these routes for their daily activities, this often times result in traffic hold-ups and jams. Ogunbodede (2007) asserted that such result is expected within the CBD because of the commercial activities constantly occurring there. The flow rate, speed and density values for traffic along Oba-Adesida road (directions A and B) and Arakale road (directions C and D) were calculated based on data obtained from the field. These parameters were plotted against each other and the corresponding linear relationships for morning (M), afternoon (A) and evening (E) were obtained from the graphs.

Figure 3 shows the graph of flow against density along Oba Adesida Road (direction A) for morning ($Y_M$), afternoon ($Y_A$) and evening ($Y_E$) from which linear equations were derived. It can be seen that flow decreases as the density increases, also when the flow increases the density decreases. The equations obtained had $R^2$ values for morning, afternoon and evening as 90.43%, 95.40% and 97.57% respectively indicating high degrees of correlation.

Figure 4 shows the graph of speed against density along Oba Adesida Road (Direction A) for morning, afternoon and evening. Speed decreases as the density increases, also when the speed increases the density decreases. The $R^2$ values were obtained as 97.43%, 89.52% and 87.82% for morning, afternoon and evening respectively showing high degrees of correlation.

Figure 5 shows the graph of Speed against Flow along Oba Adesida road (Direction A). The speed increases as flow increases and the speed decreases when the flow decreases. The $R^2$ values were determined as 90.25%, 92.14% and 90.04% for morning, afternoon and evening respectively showing high degrees of correlation. Similar graphs were obtained for traffic along Oba-Adesida road (direction B) and Arakale road (directions C and D). Based on the graphs the minimum speeds vehicles can travel along the roads were obtained as shown in table 5.

**Table 3.** Maximum and minimum flow and passenger car units for Oba Adesida road

| Direction A | | | | |
|---|---|---|---|---|
| **Week** | **Veh/hr** | | **PCU/hr** | |
| | **Max** | **Min** | **Max** | **Min** |
| Monday | 2171 | 1626 | 1815.5 | 1369 |
| Tuesday | 2257 | 1550 | 1866 | 1291 |
| Wednesday | 2856 | 1835 | 2369.5 | 1498.5 |
| Thursday | 2261 | 1528 | 1927.5 | 1427 |
| Friday | 2555 | 1867 | 2122.5 | 1459 |
| Saturday | 2837 | 2074 | 2259.5 | 1683 |
| Sunday | 2191 | 2025 | 1831 | 1604.50 |
| **Direction B** | | | | |
| **Week** | **Veh/hr** | | **PCU/hr** | |
| | **Max** | **Min** | **Max** | **Min** |
| Monday | 1992 | 1440 | 1613.5 | 1272 |
| Tuesday | 1932 | 1539 | 1631 | 1314.50 |
| Wednesday | 1919 | 1585 | 1680 | 1421 |
| Thursday | 1915 | 1457 | 1703 | 1260.50 |
| Friday | 1936 | 1702 | 1502.5 | 1355 |
| Saturday | 2110 | 1719 | 1720.50 | 1401.50 |
| Sunday | 2272 | 1828 | 1860 | 1505 |

**Table 4.** Maximum and minimum flow and passenger car units for Arakale road

| Direction C | | | | |
|---|---|---|---|---|
| **Week** | **Veh/hr** | | **PCU/hr** | |
| | **Max** | **Min** | **Max** | **Min** |
| Monday | 2298 | 1592 | 1805 | 1281.5 |
| Tuesday | 2317 | 1772 | 1776 | 1413.5 |
| Wednesday | 2515 | 1483 | 1987.5 | 1282 |
| Thursday | 2101 | 1699 | 1609.5 | 1265 |
| Friday | 2089 | 1895 | 1644 | 1423.5 |
| Saturday | 2167 | 1709 | 1697.5 | 1412.5 |
| Sunday | 1912 | 1490 | 1474.5 | 1170.5 |
| **Direction D** | | | | |
| **Week** | **Veh/hr** | | **PCU/hr** | |
| | **Max** | **Min** | **Max** | **Min** |
| Monday | 1968 | 1488 | 1557 | 1215.5 |
| Tuesday | 2008 | 1702 | 1684.5 | 1352 |
| Wednesday | 2274 | 1833 | 1796.5 | 1463.5 |
| Thursday | 2465 | 1807 | 1876.5 | 1459 |
| Friday | 2051 | 1752 | 1557.5 | 1343.5 |
| Saturday | 2060 | 1856 | 1630 | 1482.5 |
| Sunday | 2020 | 1789 | 1569.5 | 1482.5 |

*** Veh/hr; PCU/hr**

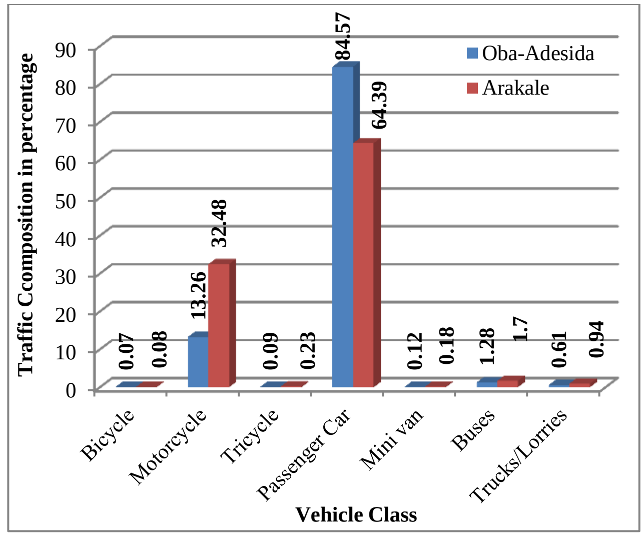


**Figure 2.** Traffic Composition Analysis for both Oba-Adesida and Arakale Roads

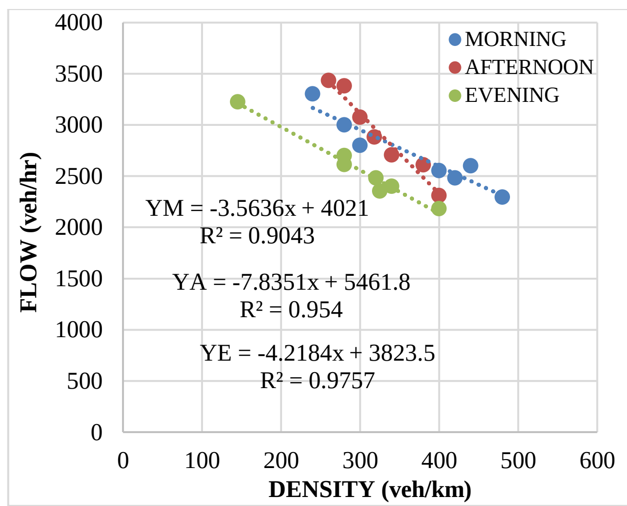


**Figure 3.** Graph of Flow against Density along Oba Adesida road, Direction A

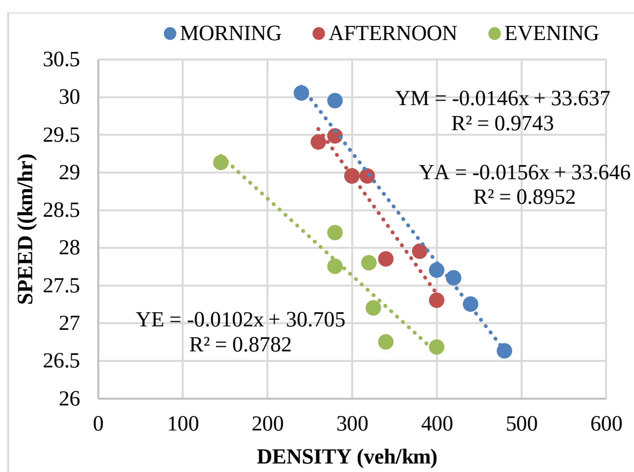


**Figure 4.** Graph of speed against density along Oba Adesida road, Direction A

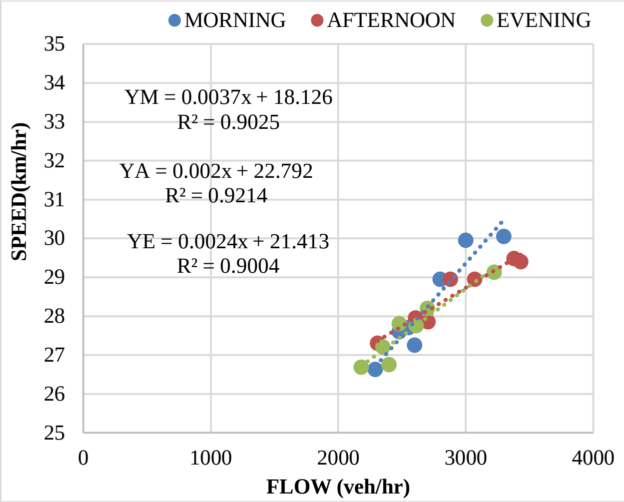


**Figure 5.** The graph of Speed against Flow along Oba Adesida road (Direction A).

**Table 5.** Summary of minimum speeds along Oba-Adesida and Arakale roads (in km/hr)

| Period | Oba-Adesida road | | Arakale road | |
|---|---|---|---|---|
| | **Direction A** | **Direction B** | **Direction C** | **Direction D** |
| Morning | 33.64 | 30.96 | 36.59 | 35.25 |
| Afternoon | 33.65 | 31.80 | 35.30 | 34.75 |
| Evening | 30.71 | 31.88 | 33.58 | 34.07 |

## CONCLUSION

The traffic volume data shows that vehicular traffic along Oba-Adesida road has the highest maximum volume of 2369.50 Pcu/hr on Wednesday and the lowest minimum of 1291 Pcu/hr on Tuesday. The vehicles along Oba Adesida road to A Division (Direction A) in the morning, afternoon and evening are to travel at minimum speeds of 33.64 km/hr, 33.65 km/hr and 30.71 km/hr respectively for no congestion to occur and along Direction B ('A' Division to Catheral), in the morning, afternoon and evening, the vehicles are to travel at minimum speeds of 30.96 km/hr, 31.80 km/hr and 31.88 km/hr respectively for no congestion to occur. Also, the vehicles along Arakale road from Isikan Roundabout to NEPA Roundabout (Direction C) in the morning, afternoon and evening are to travel at minimum speeds of 36.59 km/hr, 35.30km/hr and 33.58km/hr respectively for no congestion to occur and along Direction D (NEPA Roundabout to Isikan Roundabout), in the morning, afternoon and evening, the vehicles are to travel at minimum speeds of 35.25 km/hr, 34.75 km/hr and 34.07 km/hr respectively for no congestion to occur.

It was observed that traffic congestion usually occurs due to the large number of passenger cars/taxi and motorcycles plying both roads especially during peak hours and this is caused mostly by the undisciplined taxi drivers and motorcycle riders who most times drive against traffic and also park poorly to pick and drop commuters/passengers at un-designated places.

* Veh/hr referes to the unit of the number of vehicles passing a given section of the roadway in an hour while PCU/hr refers to the unit of the total sum of the number of each class of vehicles passing a given section of the roadway after each class has been multiplied by the passenger car equivalent or unit.

## DECLARATIONS

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**Authors' contribution**

The first author collected the field data, analysed the data obtained and wrote the manuscript. The second author developed the methodology and revised the manuscript. Both authors read and approved the final manuscript

**Conflict of interest**

The authors hereby confirm that there is no conflict of interest whatsoever with any third party.

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