Predictive Modeling of Travel Time on Major Roads in Akure, Nigeria.

Ajayi S.A., Quadri H.A. and Sani R.O.
Nigerian Building and Road Research Institute, Nigeria
Corresponding Author: samuel.temitope@ymail.com

Abstract

Large cities in developing countries are characterized by growth in automobile ownership, insufficient transportation infrastructure and service development. These cities often suffer from congestion, poor mobility and accessibility, significant economic waste, adverse environmental impact and safety problems. This paper focuses on identification of travel time characteristics and other traffic parameters and to develop a predictive model for travel time on Akure major roads. Data on travel time were collected for vehicles during the morning and evening peak periods using floating car technique. The data was analyzed using Statistical Packages for Social Sciences (SPSS) and fitted into Multiple Regression model to establish a relationship between the Travel Time and other road traffic parameters. Travel time (T_t) was modeled as a function of section length (X_1), number of intersections (X_2), pedestrian/ economic activities (X_3), Traffic volume (X_4), enforcement agency (X_5) and road width (X_6). The Coefficient of multiple determination R^2 was 0.702 which means that there is 70.2% of the dependent variable (travel time) in the forward direction as explained (accounted) by the independent variables and 72.2% in the opposite direction. The result revealed that section length, pedestrian economic activity and traffic volume were all significant at 5% level and has a positive relationship with travel time in both forward and reverse direction. The model identifies the impact of these traffic parameters on travel time and recommend measures for improvement.

Keywords: Congestion, Floating car technique, Travel Time, Traffic Parameters, Regression model.

1.0 INTRODUCTION

High traffic demand and limited road capacities, growth in automobile ownership, insufficient transportation infrastructure and service development make people spend much more time on their daily journeys. Fast and reliable movement of people and goods is one of the key functions of the Arterial and Sub-Arterial roads in urban areas (Yang, 2005). Traffic pressure owing to the significant growth in vehicle population on such roads in most of the metropolitan cities, particularly in developing countries, has reached alarming proportion due to increased economic activities resulting in a longer and unreliable travel time. Travel time is affected by various attributes besides traffic and physical characteristics of corridors (Lin et al., 2005). Pedestrian encroachments and haphazard road side parking are further adding to the congestion level. Travel time variation and longer travel time not only add to the anxiety and stress of the commuters but also result in waste of productive time (Ravi Shekhar et al., 2012).

Travel time as defined by Kadiyali (2008) is the total elapsed time (in seconds) spent driving a specified distance. Vehicles travelling on the urban road are subjected to intersection delays due to queues and traffic control and mid-link delay caused by turning vehicles from cross streets, bus maneuvers at bus stops, parking vehicles along the roadside, crossing pedestrians and cyclists, etc. Travel time studies are used to document congestion and measure the efficiency of a highway. Determining the amount of time required to travel from one point to another on a given route requires a travel time study. Information may also be collected on the locations, duration and causes of delays in conducting such study. When this is done, the study is known as a travel time and delay study.

Data used to estimate the travel time on road networks come in two varieties, one being fixed sensors on the sides of the road such as magnetometer detectors or highway cameras. The second method is floating car. Jones et al. (2013) studied the problem of predicting travel times for links (road segments) using floating car technique. Floating car data is from actual vehicles driving around the Kanagawa prefecture in Japan with a GPS-based car navigation system. From this data a set of trip segments covering a particular link that consists of the start date and time of the trip segment over the link and the time to traverse the link (the travel time) were extracted. This is the raw data used to train a travel time predictor for a link. He recommended the floating car technique as an effective method for collection of accurate travel time.

Wang et al. (2016) recognizes that lane width and numbers of traffic stream have significant impact on travel time along with traffic volume. Impact of signalized system on travel time has been dealt by Liu et al. (2005) in their study travel time prediction in Adelaide, Australia. They found that travel time is considerably affected by signal system. Other factors that can be considered are certain events such as accidents, processions, repair work and weather conditions as part of non-recurring conditions.

Krishna et al (2018) on their study of travel time estimation under heterogeneous traffic with dominance of 2Ws (Two wheelers) and 3Ws (Auto rickshaw) developed an appropriate Corridor Travel Time Estimation Model using Multi-Linear Regression (MLR) approach and focused on travel time attributes such as heterogeneous traffic, road side friction and corridor intersections for recurrent traffic condition They concluded that certain mitigation strategies can be considered on the basis of present study to improve the travel time on urban corridors by controlling the travel impedances: restriction on heavy vehicles, access control at intersection of high intersection factor, regulating parking and pedestrians with provision of necessary facilities.

Travel time distribution and variability pattern which is essential for reliable route choices and sophisticated traffic management and control was explored by Peng et al (2018). In this study, based on a vast amount of probe vehicle data, 200 links inside the Third Ring Road of Beijing, China, were investigated, the day-of-week distributions of unit distance travel time were first analyzed and Kolmogorov-Smirnov, Anderson-Darling, and chi-squared test were employed to test the goodness-of-fit of different distributions and the results showed lognormal distribution was best-fitted for different time periods and road types compared with normal, gamma, and Weibull distribution. They deduced that in daytime the travel times on auxiliary roads of urban expressways and major roads share similar variability patterns and appear relatively stable and reliable, while urban expressways have most reliable travel times at night.

Owolabi and Makinde (2010) in their work on traffic delay study at unsignalised intersections in central business district in Akure collected traffic data at intersections legs through a semi-automatic method using radio recorder during the peak periods for each intersection. Delays experienced at each intersections approach were determined and compared with those obtained by Kimber/Hollis and Tanner's equations. The comparism of delays obtained by models with the observed delays revealed that the Kimber/Hollis equation better replicates the data on delays than Tanners model because Pearson's correlation coefficients of 0.95 and 0.61 respectively were obtained. The estimated delays ranged from 1 to 55 seconds at the three intersections considered. They recommended that economic activities around the intersections and indiscriminate parking of vehicles should be discouraged.

Using the test vehicle approach method of obtaining travel time, Oyedepo (2003) compared the results with the obtained traffic volume for those routes. He deduced that the delays were not as a result of over capacity for the selected routes. Rather he found the cause to be due to poor traffic management measures and poor highway geometry.

Owolabi and Ojuri (2004) worked on Akure Central business district to analyse traffic volume and revealed the cause of parking problem. This study revealed that increased volume of traffic, ribbon development /street trading, improper structural layout/land use pattern; within the Central Business District are factors responsible for this problem. From the result of the data collected and the analysis of traffic volume, spot speed and the number of weekly trips per capita for the CBD, the solution to the parking problem have been recommended. This includes provision of adequate off-street parking facilities, abolition of all unauthorized terminals, adjustment of the structural layout /land use in the CBD and the provision of an inner ring road around the Akure CBD.

Many research workers have attempted to build travel time estimation models using various techniques such as analytical method, time series method, soft computing and simulation technique. Skabardonis and Geroliminis (2008) developed travel time estimation model based on kinematic wave theory using loop detectors data as well as signal system. Bhaskar et al. (2007) has also used analytical method for travel time estimation based on cumulative plots using stop-line loop detector and signal controller data. Travel time modelling has been reported by Yang (2005) using time series data with GPS test vehicle technique. Khoei et al. (2013) have developed travel time prediction on signalized urban arte- rials by applying Seasonal Auto Regressive Integrated Moving Average (SARIMA) modelling on Bluetooth data.

Keeping this in view, an urban traffic routes has been considered to probe into the major travel time attributes for recurrent congestion conditions, so as to develop a predictive travel time estimation model employing Multi-Linear Regression analysis (MLR). The model finds application in urban transportation planning and traffic management apart from assessment of corridor traffic performance.

3.0 RESEARCH METHODOLOGY

3.1 Reconnaissance and Mapping

The field work began with a reconnaissance survey of the road to enable decisions making as to the extent and the nature of the actual traffic surveys to be conducted and the choice of roads to be considered. The routes were selected based on the criticality to traffic in the metropolis and are used daily by road users as they were major dual carriageway that connects to other feeder roads. These routes were segmented for easy data collection and geometric characteristics such as road width and length were taken with the aid of a measuring tape. The segmentation is shown in Table 1 while figures 1 to 3 are detailed maps on the studied routes. The detailed map on each routes were obtained through the Google Earth Mapping System.

Table 1: Selected Routes Details

Sections	Routes	Distance (m)
RA1	Road Block to Lafe bus stop	2560
RA2	Lafe bus-stop to Cathedral bus-stop	2200
RA3	Cathedral bus stop to Okelisa bus-stop	1620
RA4	Okelisa bus-stop to Fiwasaye junction	2000
RA5	Fiwasaye junction to NTA Oba Ile	4020
RB1	Fiwasaye junction to NTA Oba Ile	3080
RB2	Ondo Garage to Isikan market	2020
RB3	Isikan market to NEPA junction	1920
RB4	NEPA junction to Owena motel	2100
RC1	Owena motel to INEC office	1800
RC2	FUTA north gate to Road block	3580
RC3	Road block to Federal housing estate	3220
RC4	Federal housing estate to Fed Govt	3980
RD1	Girls College, Fed Govt	1960
RD2	Girls College to Airport	1300
RD3	Arakale to Fadaka junction	1820

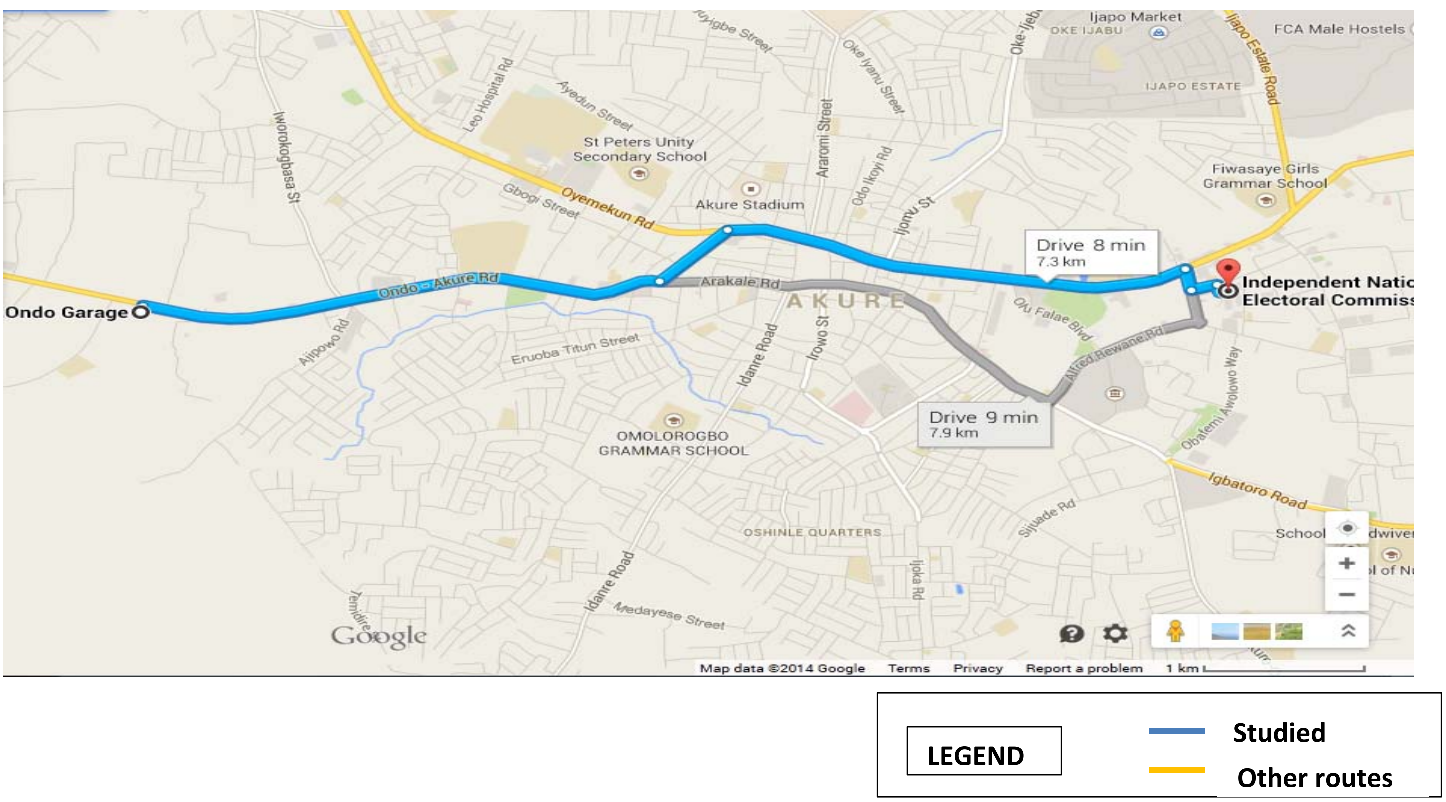

Figure 1: Google map showing routes between ondo garage to INEC office Akure.

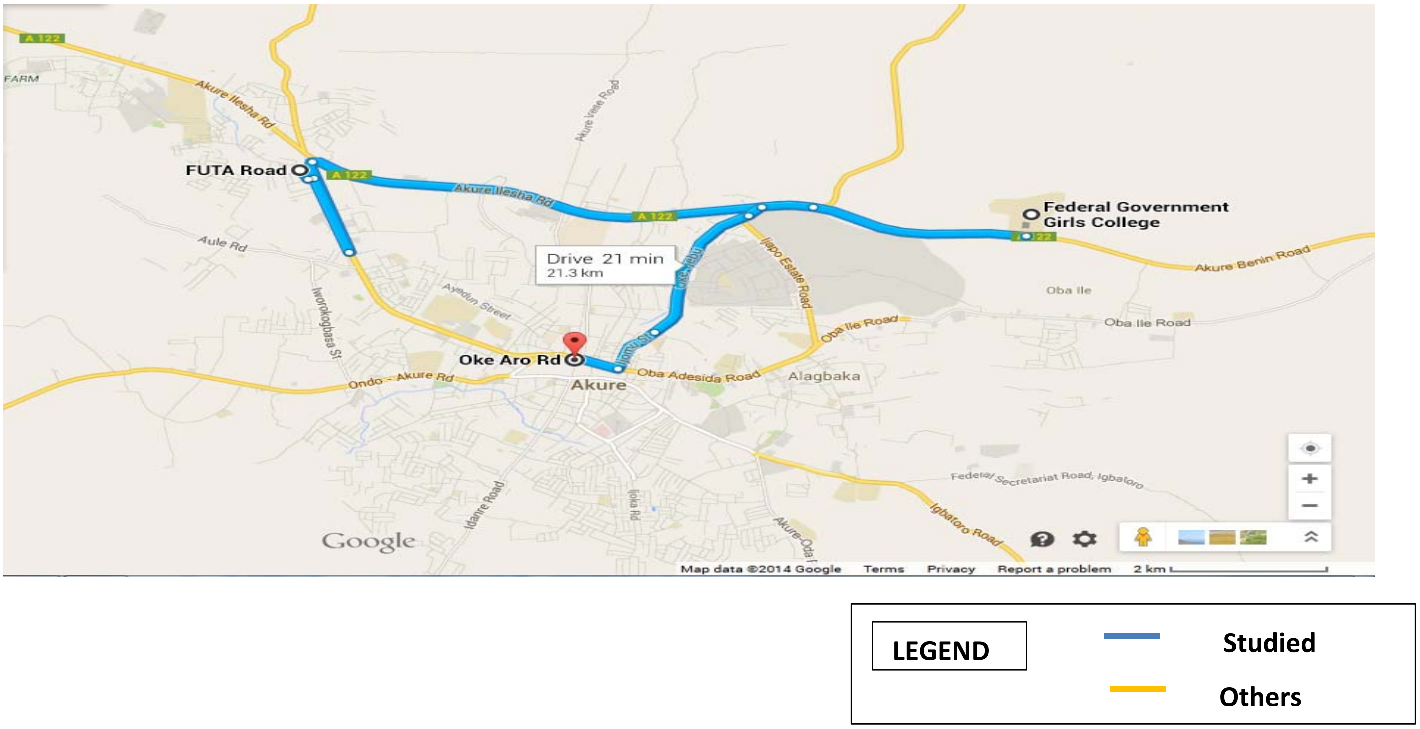

Figure 2: Google map showing routes between FUTA North gate to Airport to Oke Aro road Akure.

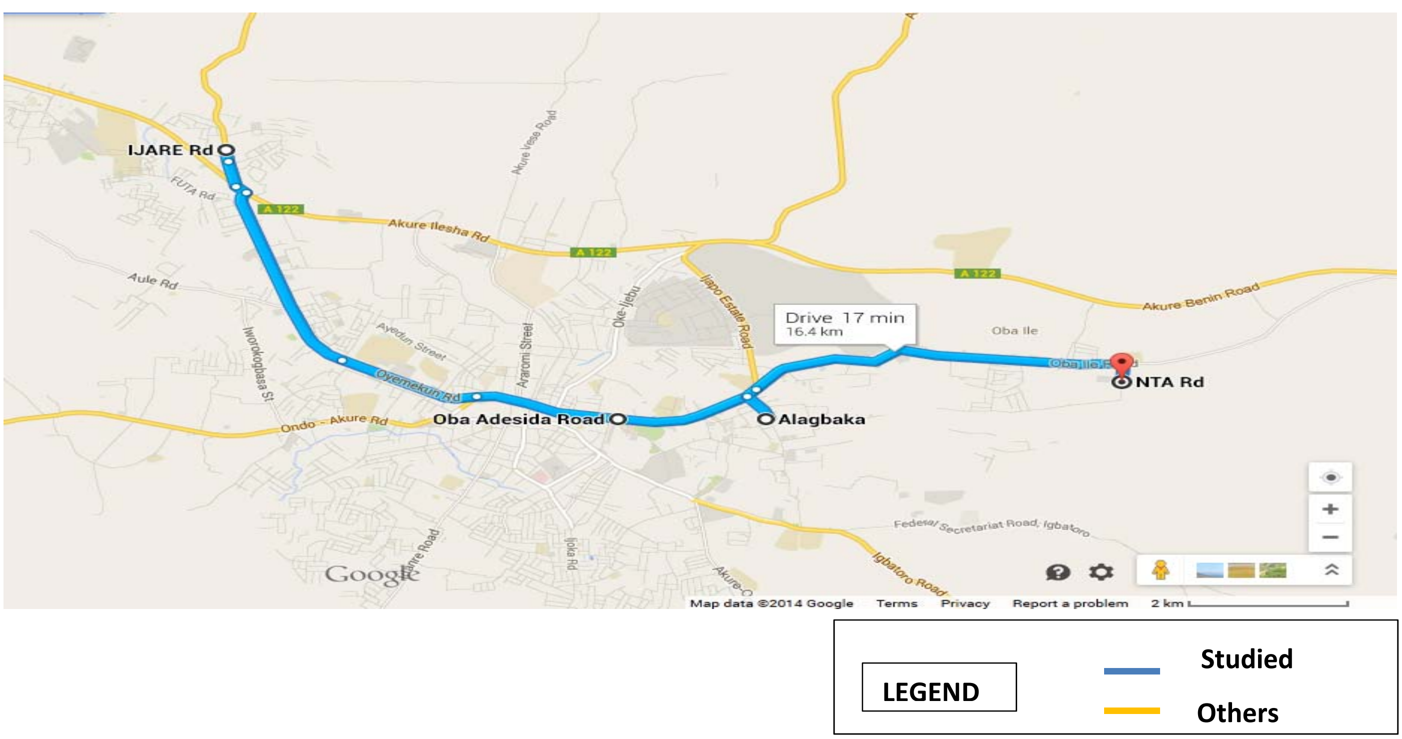

Figure 3: Google map showing routes between Road block to NTA oba ile road Akure.

3.2 Travel Time Collection:

Travel time data were collected using the floating car techniques. This techniques reqires a recorder, an observer, two stopwatches, data collection forms, Akure road network map and a test vehicle. The driver was instructed to safely float with the traffic situation by overtaking about the same number of vehicles that overtook him. This helped the test car to maintain an average position enabling measurement of average speeds and travel time. The recorder started the stopwatch as the driver passed the beginning of each section and recorded the cumulative elapsed time at the end of each section on the field sheet. This process was followed through the entire data collection until the time at the final section was recorded. Several runs were made on the same route for a period of six days i.e. Monday to Saturday and travel time were collected in minutes. The data was similarly collected on the reverse direction of traffic. This is better illustrated in figure 4.

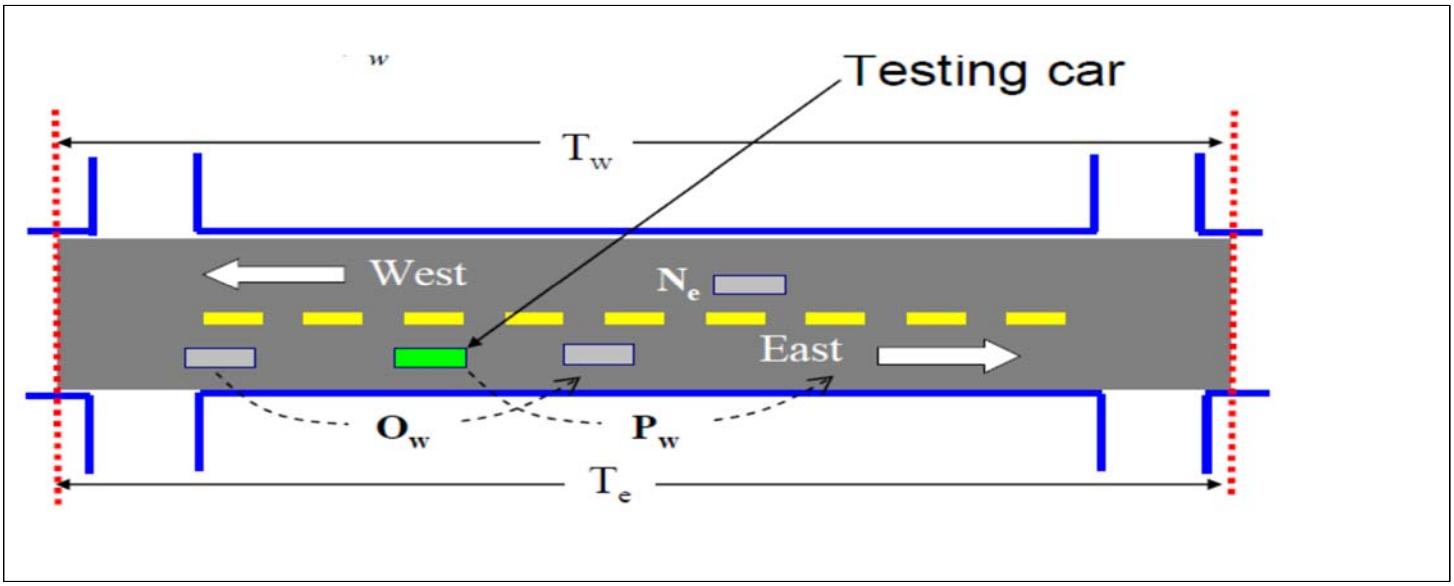

Figure 4: the floating car technique

N_e: -Opposing traffic volume
O_w: - traffic overtaking the test car
P_w: - traffic overtaken by the test car
T_e: - total travel time in minutes in forward dir.
T_w: - total travel time in minutes in reverse dir.

3.3 Other Traffic and Road Parameters:

On each section of the roads selected, information on number of intersections, pedestrian/economic activities and availability law enforcement agency/instrument were also collected. Traffic volume count was collected using Cine camera in both directions on the roads for the morning, afternoon and evening peak periods. Data from the camera were then decoded and transferred into recording sheets. The traffic volume were obtained in veh/hr and were between 7-9am, 12-2pm and 4-6pm for morning, afternoon and evening respectively on weekdays (Mon – Fri); 9-11am, 12-2pm on Saturdays;7:30-9:30am and 12-2pm on Sundays.

3.4 Analysis of Data

The data was analyzed using Statistical Packages for Social Sciences (SPSS) and fitted into Multiple Regression model to establish a relationship between the travel time and other road traffic parameters. The travel time in the model was expressed as the function of all other parameters. The coefficient of determination (R) was estimated to know the percentage of relationship between the dependent and independent variables.

The model is specified as:

$$Y= a_0 + b_1X_1 + b_2X_2 + b_3X_3 + \ldots\ldots\ldots\ldots + bnXn + e_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{(1)}$$

where
a0 = Constant
X_i ………X_n = Explanatory variable
b_i ……… b_n = parameters to be estimated (i= 1, 2, 3, ………n)
e_i = Error term or disturbance term

Y = Travel time (Dependent variable)
X_1= Section length
X_2= Number of intersections
X_3= Pedestrian/Economic activity
X_4= Traffic volume
X_5= Law Enforcement agency
X_6= Road width

It was calibrated by the method of least squares.

4.0 RESULTS AND DISCUSSIONS

Table 2 shows the field results which include the link length, traffic volume in veh/hr, number of intersections, travel time in min, pedestrian economic activity and law enforcement agency in the forward direction on each route. Table 3 shows the regression analysis results for each parameter where the coefficient of determination was derived. The presence and absence of pedestrian/economic activity are value as 1 and 0 respectively on each road sections as shown in Table 2. This also was applied for law enforcement/agency characteristics.

Table 2: Input Data for the Model (Forward Direction of Traffic)

Section	Link Length "L" (M)	Pedestrian Economic Activity 'Pe"	Traffic Volume Veh/Hr.	Road Width (M)	Law Enforcement Agency "E"	Number Of Intersections	Travel Time"T" (Min)
RA1	2560	0	1498	18.8	1	4	5.07
RA2	2200	1	2087	18.8	1	5	6.03
RA3	1620	1	2287	18.8	1	5	6.57
RA4	2000	0	1442	18.8	1	4	3.48
RA5	4020	0	1074	7.0	0	1	10.03
RB1	3080	1	1812	18.8	1	5	4.40
RB2	2020	1	1624	14.6	1	10	8.42
RB3	1920	0	1265	14.6	1	3	2.56
RB4	2100	0	967	7.3	0	0	2.00
RC1	1800	1	859	7.3	1	1	5.50
RC2	3580	0	640	7.3	0	3	6.12
RC3	3220	0	847	7.3	1	1	5.04
RC4	3980	0	568	7.3	0	1	6.47
RD1	1960	1	856	7.3	1	4	4.36
RD2	1300	1	680	7.3	1	3	3.75
RD3	1820	0	512	7.3	0	0	4.35
TOTAL		7			11	50	

Table 3: Regression Analysis (Forward direction)

Variables	Coefficients	T-Value
Constant	-0.159 (5.033)	-0.032
Section Length(X_1)	0.002 (0.001)	2.566*
Number of Intersections(X_2)	0.278 (0.284)	0.980
Pedestrian/Economic Activity(X_3)	2.6205 (1.307)	2.005*
Traffic Volume(X_4)	0.004 (0.002)	2.141*
Law Enforcement Agency(X_5)	-1.600 (1.418)	-1.129
Road Width(X_6)	-0.111 (0.684)	1.62
	R^2=58.2% S.E=1.75671 F- Value=2.103 ( ) = standard error * = significant at 5%	

Substituting the coefficient into the equation gives;

Tt= - 0.159 + 0.002 S+ 0.278 N+ 2.005 P+ 2.141 T- 1.129 Le+ 1.62 W…………….(2)

where
Tt= Travel time in minute
e= Error term
X_1……X_6= are the independent variables as stated in the table above
S: Section Length(X_1), N:Number of Intersections(X_2), P: Pedestrian/Economic Activity(X_3), T:Traffic Volume(X_4), Le:Law Enforcement Agency(X_5), W:Road Width(X_6).

The Coefficient of multiple determination R^2= 0.702 which means that 70.2% of the dependent variable (travel time) in the forward direction is explained by independent variables and that 29.8% is explained by other variables not included in the model or captured by the field work which were referred to as error term. The result revealed that section length, pedestrian economic activity and traffic volume were all significant at 5% level of significance and has a positive relationship with travel time. The positive relationship between the significant variables and travel time implies that as section length, pedestrian economic activity and traffic volume were increasing, travel time also increases. For instance, areas where economic activities are prevalent reduce the free flow of traffic thereby increase the travel time especially at Oja Oba areas. Oba Adesida and Arakale roads.

Table 4 shows the field parameters at the reverse direction while Table shows the regression analysis results.

Table 4: INPUT DATA FOR THE MODEL (Reverse Direction of Traffic)

Section	Link Length "L" (M)	Pedestrian Economic Activity 'Pe"	Traffic Volume Veh/Hr.	Road Width (M)	Law Enforcement Agency "E"	Number Of Intersections	Travel Time "T" (Min)
RA1	2560	0	1530	18.8	1	4	4.27
RA2	2200	1	2115	18.8	1	3	3.39
RA3	1620	1	2283	18.8	1	6	5.00
RA4	2000	0	1430	18.8	1	3	2.47
RA5	4020	0	1057	7.0	0	2	10.33
RB1	3080	1	1828	18.8	1	3	4.47
RB2	2020	1	1638	14.6	1	12	10.03
RB3	1920	0	1250	14.6	1	3	4.45
RB4	2100	0	955	7.3	0	3	2.70
RC1	1800	1	874	7.3	1	1	3.52
RC2	3580	0	653	7.3	0	2	7.47
RC3	3220	0	840	7.3	1	1	4.03
RC4	3980	0	560	7.3	0	1	6.44
RD1	1960	1	865	7.3	1	6	4.39
RD2	1300	1	685	7.3	1	2	5.08
RD3	1820	0	502	7.3	0	1	4.51
TOTAL		7			11	53	

The coefficient of multiple determination R^2= 0.722 which implies that there is 72.2% of the dependent variable (travel time) in the opposite direction is explained by the independent variables and that only 27.8% is explained by other variables not included in the model or captured by the field work which are referred to as error.

Table 5: Regression Analysis (Reverse Direction)

Variables	Coefficients	T-Value
Constant	4.452 (5.233)	0.851
Section Length(X_1)	0.02 (0.001)	2.711*
Number of Intersections(X_2)	0.507 (0.208)	2.441*
Pedestrian/Economic Activity(X_3)	0.756 (1.187)	0.637
Traffic Volume(X_4)	0.0031 (0.001)	3.156*
Law Enforcement Agency(X_5)	-1.347 (1.241)	-1.085
Road Width(X_6)	-0.502 (0.680)	-0.738
	R^2=72.2% S.E=1.60395 F- Value=3.890 ( ) = standard error * = significant at 5%	

The regression model for the reverse direction is given as;

Tt= 4.452 + 0.02 S+ 0.507 N+ 0.756 P+ 0.0031 T- 1.347 Le- 0.502 W+ e………………… (3)

where

Tt= Travel time in minute
e= Error term
X_1……X_6= are the independent variables as stated in the table above
S: Section Length(X_1), N:Number of Intersections(X_2), P: Pedestrian/Economic Activity(X_3), T:Traffic Volume(X_4), Le:Law Enforcement Agency(X_5), W:Road Width(X_6).
Table 6 and 7 shows the correlation coefficient of the Travel time.

Table 6: Correlation Coefficients (Forward direction)

Pearson Correlation	Effects on Travel Time
Link Length	0.490
Pedestrian / Economic Activity	0.140
Traffic Volume	0.170
Road Width	-0.040
Traffic control	-0.181
Number of Intersections	0.283

This shows the relationship between independent variables and the travel time. The variables such as road length, pedestrian/ economic activity, traffic volume and number in intersection with positive value show that as the variable increases, travel time also increases. The variables such as road width and traffic control with negative values show that as the parameter increases travel time decreases. For instance, when the traffic control wardens are monitoring the traffic conflict at the intersections, the travel time to transverse that route will tend to reduce. That means it has negative relationship with travel time as observed from the correlation results.

Table 7: Correlation Coefficients (Reverse Direction)

Pearson Correlation	Effects on Travel Time
Link Length	0.475
Pedestrian/Economic activity	-0.013
Traffic Volume	0.081
Road Width	-0.224
Traffic control	-0.340
Number of Intersections	0.381

4.0 CONCLUSION AND RECOMMENDATIONS

The study identified congestion location the causative factors, develop a model to predict travel time with other traffic conditions. Traffic parameters such as traffic volume (T), route length (L), and number of intersections (N) made significant contributions in predicting the Travel time ($T_{t.}$). However, both Road width (W) and Traffic control (Le) made a negative impact on the model. This model provide accurate predictions of Travel time on major roads. This agrees with the work of Krishna Saw et al (2018) even though this study did not consider the effect of traffic composition such as motorcycles, passenger cars, buses, trucks, lorries etc on the travel time characteristics. The generalized equations can be used to evaluate Travel time and used for planning and design of effective control of traffic congestion in the study area and in other cities with similar traffic characteristics.

The following recommendations are made based on the results;

a) The level of enforcement must be improved with respect to parking, stopping restrictions and traffic control e.g. fixed time signals.
b) A review of land use and zoning ordinance should be done with a view to minimizing journey to work.
c) The State Government should encourage the use of reliable mass transit buses to travel especially on Oba Adesida and Oke-Aro routes. This will also reduce the number of vehicles on the roads which will decrease the traffic volume which has a positive relationship with the Travel Time.
d) Travel time studies should be done more for the measurement of performance of road networks.

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