TRAFFIC FLOW CHARACTERISTICS MODELLING OF A CENTRAL BUSINESS DISTRICT – CASE STUDY OF CHALLENGE AREA, IBADAN, NIGERIA.

by Olumoyewa Atoyebi

TRAFFIC FLOW CHARACTERISTICS MODELLING OF A CENTRAL BUSINESS DISTRICT – CASE STUDY OF CHALLENGE AREA, IBADAN, NIGERIA.

Atoyebi Olumoyewa D.[1*], Modupe Abayomi E.[1,2], Jegede Segun L.[3]

[1]Department of Civil Engineering, Landmark University, Omu-Aran, Kwara State, Nigeria
[2]Department of Civil Engineering, University of KwaZulu-Natal, Durban, South Africa
[3]Landmark University, Omu-Aran, Kwara State, Nigeria

Urbanization is setting an increasing pressure on already confined road traffic networks. The study seeks to identify the significant difference between the traffic flow of the different location within a central business district (CBD) and make useful Engineering recommendations regarding the observation and inferences drawn from the research. Vehicular traffic data was collected at different locations within challenge area of Ibadan (one of its major CBDs), Oyo state, Nigeria. The f-statistics was employed for the two-way analysis of variance used in comparing the vehicular counts across eleven locations within the CBD per time and per vehicle type. The result shows significant differences in locations and vehicle type. The study recommended that ordered parking facilities should be provided at strategic points especially at available open spaces at the sides of the road, a little restriction should be introduced to motorbikes' time of operation, and enforcement of traffic laws and diversification of land mode of transportation such as the use of the rail system for town services can optimally ease up road congestion.

INTRODUCTION

Urbanization is setting an increasing pressure on already confined road traffic networks. According to [1,2], the global call for passenger transport service is predicted to increase from 26 trillion passenger kilometres in 1990 to 103 trillion passenger kilometres in 2050 on average. This implies that the world's demand for transport services is growing at an alarming rate. A lot of intelligent techniques are being investigated to improve the efficiency of urban traffic control (UTC) by making the systems function by themselves without human intervention, that is, autonomous [3]. Although it is expected that fast and continuous rise in housing and land expenses are expected in towns with transportation improvements, rapid population and economic boom, however, along with the increase in transport demand comes an increase in various environmental pressures such as disruption of nature, traffic congestions and accidents, waste accumulation and resources depletion; air and noise pollution [4,5], and intense intermodal competition especially on narrow routes.

[6] defines transportation as the movement of people, goods and services by specific modes such as roads, airlines, shipping lines and railways. It basically affects the relationships within societies, and adjustments in transportation influence the organization of human activity in urban and regional areas. It structures the built environment, spurs urban growth, as well as orders relationships among cities in a national urban system [7]. Transportation development is a growth-generating infrastructure in terms of the manner of the socio-economic developmental process of a nation [8]. Patriksson (2015) added that traffic study for the planning of urban roads is good and important, it provides indispensable information to estimate its social and economic behavior [9].

The interest of various researchers has been drawn towards traffic cordon studies especially in urban centres, thereby generating different models and methods to analyze traffic counts. Rajeswaran and Rajasekaran in a study to model heterogeneous traffic at a congested place in Chennai using Cellular Automata (CA) and traffic simulator called VISSIM (Vissim is a microscopic multi-modal traffic flow simulation software package), concluded that there will be a decrease in delay time and an increase in maximum achievable velocity when there is reduction in 2W (Two Wheeler i.e. motorcycle and bicycle modes) population [10]. Agunloye [11] focused his study on the motorized trips of public transport passengers who travelled by road from Ayangburen Taxi Park, Ikorodu, Lagos to Igbogbo and Ebute, Lagos Nigeria with the primary aim of identifying its challenges and contributions to travel demand. Hazelton and Parry described the class of day-to-day models under consideration based on [12]. Hustim and Ramli [13] attempted to develop an empirical model for an RTN prediction model while Chakraborty and Chakroborty did an empirical analysis of short period traffic counts using the Indian data [14].

Based on past studies, 75% of the population in cities has been estimated to depend on the use of public transport while about 25% depended on private transport modes [15,16]. Few researchers take into account the transportation count with respect to specific vehicle types, truck traffic data are believed to play a key role in highway infrastructure planning, design, and management [17]. In the study by Willumsen [18], he recommended that the generation of the traffic model comes from surveys and counts in situ because they are not highly expensive and constitute the most truthful starting point there can be.

This traffic count study takes into consideration one of the major central business district (CBDs) in Ibadan popularly known as Challenge area. The study seeks to identify the significant difference between the traffic flow characteristics and densities of the different location within the considered CBD and make useful recommendations regarding the observation and inferences drawn from the research. Ibadan is the capital city of Oyo State in the south-west region of Nigeria and the third largest metropolitan area by population after Lagos and Kano and it is the country's largest city by geographical area. At independence in 1960, it was the largest and most populous city in the country and third in Africa after Cairo and Johannesburg. Challenge area is fast becoming a beehive of commercial activities with many of the corporate institutions locating their offices there.

METHODOLOGY

Method of Data Collection

The various locations within the challenge area are presented in Table 1 with their respective designations as used in this study. Vehicular trip attractors in the CBD include corporate institutions, shopping centers and other business establishments whose business activities on a daily basis attract a large volume of customers, hence making parking an issue. There are about 150 traffic attractors in the considered CBD.

Table 1: Location Key for Streets in Challenge Area, Ibadan.

Designation	Location Name
C1	Food and Wine
C2	Union Bank/Felele
C3	Iyana anfaani
C4	Ososami
C5	Iyana Adeoyo
C6	liberty junction
C7	Joyce B
C8	MTN

C9	SUMAL
C10	Iyaganku Junction
C11	110

The traffic flow survey was done for Four (4) days with an average of 40 enumerators in the CBD. The enumerators were grouped into two, each group taking tallies for 6 hours only (Group 1 – 7:00 am to 1:00 pm and Group 2 – 1:00 pm to 7:00 pm) to reduce fatigue, hence increasing the accuracy of the exercise. The data was categorized hourly for six (6) different classifications of vehicles, namely; Private Car, Taxi, Bus, Motorcycle, Tricycle and Truck.

Method of Analysis

One of the suitable statistical tools for factorial experiments is the Analysis of Variance (ANOVA). It considers a continuous random variable known as the response variable measures under different factors with nominal levels. The method was pioneered by Ronald Fisher in 1925 and Yates (1934) [19,20] published procedures for the unbalanced case. Other extensive studies have been conducted since then, such as the multilevel model approach proposed by Gelman [21]. ANOVA is basically used to test equality among several means by comparing variance among groups relative to the random error which is the variance within groups. There are basically two distinct types of factors in experimental design; fixed and random factors. The factor is said to be fixed if the levels of factors are been controlled by the investigator and random if the investigator randomly sampled the levels of a factor from a population.

Modelling data using ANOVA techniques holds under four (4) assumptions. The first is the need for individual observations to be mutually independent and this is basically checked from the research design. The data needs to adhere to an additive statistical model comprising fixed effects and random errors, else, this could lead to nonhomogeneous variances. The third assumption is known as the homogeneity of variance, that is, the random errors within each group have identical variances across all the treatment groups. The Levene and Bartlett's test are appropriate for the homogeneity check [22], Zar [23] stated that Bartlett performs poorly with non-normal data. Lastly, normality is another important assumption which should be followed by ANOVA. The widely adopted test for this assumption is the Shapiro and Wilk [24] procedure especially when there are few than 2000 observations.

However, when the sample is large and design is balanced, that is, equal sample size across groups, ANOVA becomes robust with regard to moderate deviations from assumptions of homogenous variances and normal error. Lindman , Ehiwario [25,26] and others have argued the F-test statistic which the ANOVA technique employs to be remarkably robust to the deviation from normality and homogeneity of variances. Suppose we have two factors A and B, the statistical model for a two-way ANOVA is expressed as:

$$x_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij} \quad and \quad i = 1,2,\dots,m, \qquad j = 1,2,\dots,n \;\dots\dots\dots (1)$$

Where μ is the grand mean, α is the factor effect of A, β is the factor effect of B, $\alpha\beta$ is the interaction effect of both factors and ε is the random error. The estimations are performed and presented basically as Table 2.

Table 2: Two-way ANOVA summary table

Sources	Sum of Squares (SS)	Degrees of Freedom (DF)	Mean Squares (MS)	F
Factor A	SSA	m – 1	MSA = SSA/(m – 1)	MSA / MSE
Factor B	SSB	n – 1	MSB = SSB/(n – 1)	MSB / MSE
Interaction	SSI	(m – 1)(n – 1)	MSI = SSI/(m – 1) (n – 1)	MSI / MSE
Error	SSE	n(m – 1)	MSE = SSE/n(m – 1)	
Total	TSS	nm – 1		

Statistical software will be used to generate the table and the null hypothesis to be tested states an equal factor effects and interaction effect. The null hypothesis will be rejected when p-value < 0.05, the p-value can be estimated from each calculated F statistics. In cases where the null hypothesis of equality is been rejected, the pairwise test will be used to specifically identify where the difference lies.

Application

In this study, two-way ANOVA was employed for three in three different null hypotheses:

- There is no significant difference in the traffic count across locations, per time and their interaction.
- There is no significant difference in the traffic count across locations, per vehicle type and their interaction.
- There is no significant difference in the traffic count in vehicle type, per time and their interaction.

The analysis was performed at 5% level of significance using Statistical Software for Social Sciences (SPSS version 23.0).

Results and Discussion

The mean traffic count by time, vehicle type and across locations can be graphically observed in Figure (1-3). The difference in traffic counts per time across locations can be described from Figure 1, for instance, location C7 and C10 had close traffic counts, the same goes for C8, C9 and C10 at T7, and so on. It was observed that the traffic counts at locations C1 and C2 were very high within Challenge area, while C3 experienced the lowest traffic counts from 07:00 am to 07:00 pm. Trucks and Tricycles had the lowest traffic count across time; from 07:00am to 11:00 am, tricycles were more than trucks while the two had equal traffic counts on the average above 11:00 am. Private cars and Motorcycles frequented Challenge area more than other vehicle types throughout the day; more motorcycles than private cars at morning periods between 08:00 am – 11:00 am and fewer motorcycles than private cars from noon till evening (Figure 2). Generally, more private cars passed through challenge area compared to every other vehicle type, followed by motorcycles, cabs, buses, Tricycles and Trucks (Figure 3).

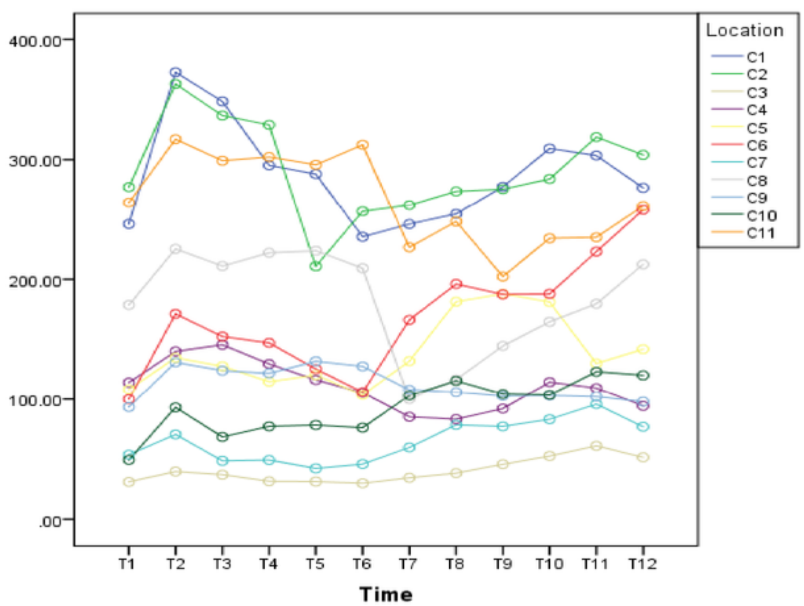

Figure 1: Estimated Marginal Means of Traffic Count per Time across Locations

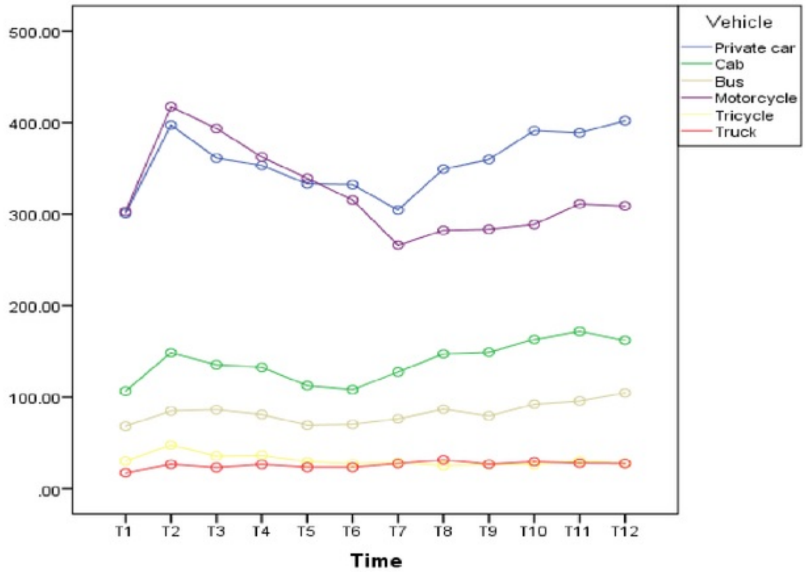

Figure 2: Estimated Marginal Means of Traffic Count per Time across Vehicle

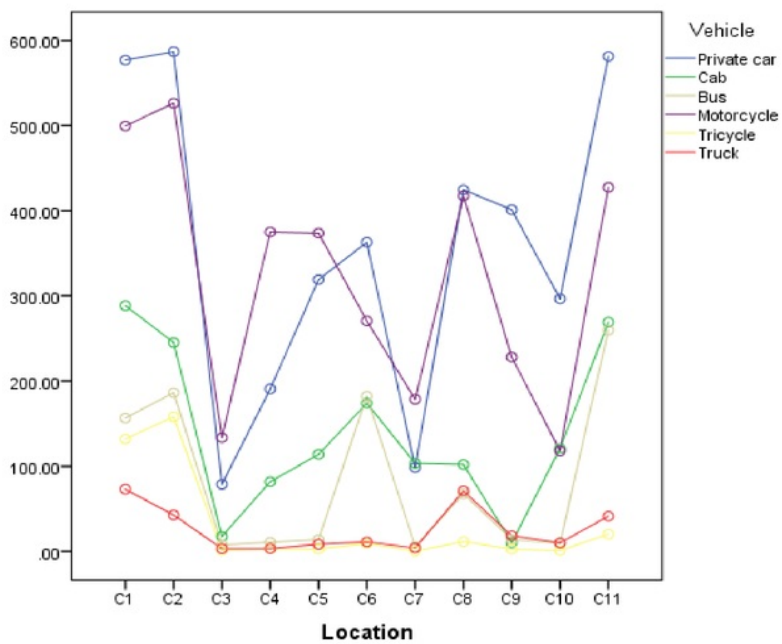

Figure 3: Estimated Marginal Means of Traffic Count across Locations for each Vehicle type

Table 3: Analysis of Variance of Location against Time

SV	SS	df	MS	F	Pvalue
Corrected Model	6388634.44[a]	131	48768.20	1.66	0.000

Intercept	20176935.35	1	20176935.35	688.63	0.000
Time	166016.69	11	15092.43	0.52	0.894
Location	5642107.88	10	564210.79	19.26	0.000
Time * Location	580509.86	110	5277.36	0.18	1.000
Error	19338064.05	660	29300.10		
Total	45903633.84	792			
Corrected Total	25726698.49	791			

R Squared = 0.248, **Key:** SV – Source of Variation SS – Sum of Squares
Df – Degree of Freedom MS – Mean Squares

The ANOVA result (Table 3) showed that there were no significant differences in the mean traffic count across time and the interaction between the times and location (pvalue < 0.05). However, there was a significant difference in the mean traffic count across locations. Conducting multiple pairwise tests showed that, the mean traffic around C1, C2 and C11 were not significantly different and generally experienced the highest traffic. The mean traffic count of C3, C7 and C10 were not significantly different from each other and so on, at pvalue < 0.05 (Table 4).

Table 4: Pairwise Comparison between Locations and Times

Time	M ± S.E.	Location	M ± S.E.
T1	137.77 ± 21.07a	C1	287.75 ± 20.17f
T2	187.10 ± 21.07a	C2	290.86 ± 20.17f
T3	172.61 ± 21.07a	C3	40.32 ± 20.17a
T4	165.42 ± 21.07a	C4	110.79± 20.17bcd
T5	151.26 ± 21.07a	C5	138.61± 20.17cde
T6	146.18 ± 21.07a	C6	168.40 ± 20.17de
T7	138.47 ± 21.07a	C7	65.10 ± 20.17ab
T8	153.79 ± 21.07a	C8	182.33 ± 20.17e
T9	154.27 ± 21.07a	C9	112.41 ± 20.17bcd
T10	165.24 ± 21.07a	C10	92.66 ± 20.17abc
T11	171.01 ± 21.07a	C11	266.50 ± 20.17f
T12	172.22 ± 21.07a		

Key: M ± S.E. = Mean ± Standard Error
Treatments with different alphabet are significantly different

Table 5: Analysis of Variance of Vehicle Type against Time

SV	SS	df	MS	F	Pvalue
Corrected Model	14456008.54[a]	71	203605.75	13.01	0.000
Intercept	20176935.35	1	20176935.35	1288.95	0.000
Time	166016.69	11	15092.43	0.96	0.478
Vehicle	13967207.76	5	2793441.55	178.45	0.000
Time * Vehicle	322784.08	55	5868.80	0.37	1.000
Error	11270689.95	720	15653.74		
Total	45903633.84	792			
Corrected Total	25726698.49	791			

R Squared = 0.562, **Key:** SV – Source of Variation SS – Sum of Squares
Df – Degree of Freedom MS – Mean Squares

No significant differences could also be inferred from the ANOVA result (Table 5) of mean traffic count across time and the interaction between the times and vehicle (pvalue < 0.05). However, there was a significant difference in the mean traffic count in vehicle type. Multiple pairwise tests showed that the mean traffic count between trucks and tricycle were not significantly different from each other but differed from others. Private car, motorcycle, cab and bus traffic counts were also significantly different from each other and had decreasing counts in that order, at pvalue < 0.05 (Table 6).

Table 6: Pairwise Comparison between Vehicle and Times

Time	M ± S.E.	Vehicle	M ± S.E.
T1	137.77 ± 21.07a	Private Car	356.11 ± 10.89e
T2	187.10 ± 21.07a	Cab	138.79 ± 10.89c
T3	172.61 ± 21.07a	Bus	83.06 ± 10.89b
T4	165.42 ± 21.07a	Motorcycle	322.57 ± 10.89d
T5	151.26 ± 21.07a	Tricycle	31.094 ± 10.89a
T6	146.18 ± 21.07a	Truck	26.058 ± 10.89a
T7	138.47 ± 21.07a		
T8	153.79 ± 21.07a		
T9	154.27 ± 21.07a		
T10	165.24 ± 21.07a		
T11	171.01 ± 21.07a		
T12	172.22 ± 21.07a		

Key: M ± S.E. = Mean ± Standard Error
Treatments with different alphabet are significantly different

No significant differences could also be inferred from the ANOVA result (Table 5) of mean traffic count across time and the interaction between the times and vehicle (pvalue < 0.05). However, there was a significant difference in the mean traffic count in vehicle type. Multiple pairwise tests showed that the mean traffic count between trucks and tricycles were not significantly different from each other but differs from others. Private car, motorcycle, cab and bus traffic counts were also significantly different from each other and had decreasing counts in that order, at pvalue < 0.05 (Table 6).

Table 7: Analysis of Variance of Vehicle Type against Location

SV	SS	df	MS	F	Pvalue
Corrected Model	23107258.78[a]	65	355496.29	98.53	0.000
Intercept	20176935.35	1	20176935.35	5592.21	0.000
Vehicle	13967207.76	5	2793441.55	774.23	0.000
Location	5642107.88	10	564210.79	156.38	0.000
Vehicle * Location	3497943.13	50	69958.86	19.39	0.000
Error	2619439.71	726	3608.04		
Total	45903633.84	792			
Corrected Total	25726698.49	791			

R Squared = 0.898, **Key:** SV – Source of Variation SS – Sum of Squares
Df – Degree of Freedom MS – Mean Squares

The ANOVA result (Table 7) showed a significant difference in mean traffic count across location, by vehicle type and the interaction between the location and vehicle type (pvalue < 0.05). At pvalue < 0.05, the multiple comparisons showed that the traffic mean count of C1 and C2 were not significantly different. The traffic mean count of C4, C9 and C10 were not significantly different. However, these two insignificant sets were significantly different from C3, C5, C6, C7, C8 and C11 which were also significantly different from one another (Table 8).

Table 8: Pairwise Comparison between Locations and Vehicle Type

Location	M ± S.E.	Vehicle	M ± S.E.
C1	287.75 ± 20.17g	Private Car	356.11 ± 10.89e
C2	290.86 ± 20.17g	Cab	138.79 ± 10.89c
C3	40.32 ± 20.17a	Bus	83.06 ± 10.89b
C4	110.79± 20.17c	Motorcycle	322.57 ± 10.89d
C5	138.61± 20.17d	Tricycle	31.094 ± 10.89a
C6	168.40 ± 20.17e	Truck	26.058 ± 10.89a
C7	65.10 ± 20.17b		
C8	182.33 ± 20.17e		

C9	112.41 ± 20.17c
C10	92.66 ± 20.17c
C11	266.50 ± 20.17f

Key: M ± S.E. = Mean ± Standard Error
Treatments with different alphabet are significantly different

CONCLUSION

This study was carried out to investigate traffic counts on a typical Nigerian Central Business District Roads taking samples from Challenge area, one of the major CBDs in Ibadan, Oyo state. The study revealed a significant difference in the mean vehicular traffic count across the various considered locations in the CBD with respect to time and the different types of vehicles plying the road. The major vehicles-type around the CBD were private cars (356.11 ± 10.89), motorcycles (322.57 ± 10.89) and cab (138.79 ± 10.89). Having evaluated the volume of traffic in the study area, routes with heavy traffic densities should be recommended for expansion first before ordered roadside parking can be recommended at strategic points. Given the present situation, an off-street parking facility is recommended to reduce the congestion due to intermodal competitions. Some problematic streets can also be labelled as one-way streets with sanctions given to violators.

The study was not able to categorize the motorbike as either private or commercial, it is however recommended that a little restriction should be introduced to the motorbikes operation with respect to time of operation. Generally, enforcement of traffic laws and diversification of land mode of transportation such as the use of the rail system for town services can optimally ease up road congestion.

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Authors Contribution

Atoyebi Olumoyewa D. did the field work and collected the data, Jegede Segun L. analyzed the data, all authors wrote the manuscript, review and approved the manuscript.

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