CALIBIRATION OF GREENBERG AND GREENSHIELD MODEL FOR ABUJA TRAFFIC

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ABSTRACT

Despite the extensive use of Greenshields and Greenbergs models, there is a lack of comprehensive studies that specifically focus on their application to a particular road section. This research arises from the need to investigate the suitability of these models for accurately describing the traffic characteristics of road B6 and B12 in Abuja city, considering factors such as traffic volume, speed, and density. The result shows that; The range of stream speed for roads B6 and B12 are respectively 12km/h to 51km/h and 32km/h to 103km/h, the free flow speed for Greenshield model at road B6 was 36.35km/h which is approximately half that of road B12, consequently, Road B6 has a jam density of 58veh/km which was about three (3) times higher than that of road B12. The R2-value obtained for Greenshield model was 0.623 with a corresponding 0.942 of Greenberg model in Road B6, while for road B12, the R2-value obtained for Greenshield model was 0.719 with a corresponding value of 0.956 for Greenberg model. Hence, Greenberg was selected the best model for the two roads.

Keyword: Density, Flow, Abuja Road, Speed, Traffic models 2

1.0 INTRODUCTION

Traffic flow modeling plays a fundamental role in traffic engineering and transportation planning, aiding in understanding the behavior and characteristics of road traffic (Apostolos and Markos, 2001). Accurate traffic flow models assist in assessing traffic conditions, developing efficient traffic management strategies, and optimizing transportation infrastructure (NRTR 2012). There are two basic forms of traffic which includes, heavy and light traffic. These flow types are being controlled by different control system facilities. Traffic control forms part of the three traffic facilities which includes, fixed infrastructure, control facilities and flow entities. The control facilities are responsible for the regulation of traffic in a traffic stream (NRTR 2012). The control systems include traffic signals, interchange and rotary intersection. The choice of this control system depends on the capacity or volume of the road. Traffic flow characteristics can be model to ascertain the nature of the traffic and hence helps to determine the type of control system and other transport planning decision making (Kang and Hu, 2019). There are basically two classifications of these models which includes, macroscopic and microscopic model (Zhang and Kim, 2005). However, for this research, macroscopic model was adopted as it relates the traffic characteristics. Macroscopic traffic flow models describe traffic characteristics at an aggregate level, focusing on traffic variables averaged over a road section (Ogunsanya, 2002). The Lighthill-Whitham-Richards (LWR) model is one of the most widely used macroscopic models, incorporating a conservation law for vehicle density and a speed-density relationship (Oyesiku, 2001). Daganzo (1994) further improved the LWR model by introducing the Cell Transmission Model (CTM), which represents traffic flow as a series of cells and considers both free-flow and congested conditions. Microscopic Traffic Flow Models focus on individual vehicle behavior and interactions (Ogunsanya, 2002). The Intelligent Driver Model (IDM) proposed by Treiber *et al.* (2000) is a well-known microscopic model that captures vehicle dynamics, including acceleration, deceleration, and car-following behavior. The IDM considers factors such as desired speed, vehicle spacing, and time headway to simulate realistic traffic flow. There are other various models that have also been developed. Among the various traffic flow models, Greenshields (1934) and Greenbergs (1959) models have gained significant attention due to their simplicity and practicality. It has been 80 years since Greenshilelds (1935) proposed a parabolic function by suggesting a linear speed-density curve for the speed-density relationship. Numerous studies have been done to improve such an over-simplified relationship (e.g. Greenberg, 1959; Underwood, 1961; Newel, 1961; Northwestern, 1967). These models have been derived from different car following theories which are based on the follow-the-leader concept, in which The Greenshields model assumes a linear relationship between traffic flow, speed, and density; stating that as density increases, speed decreases while traffic flow increases (Greenshields, 1934). This model has been widely used in traffic flow analysis and capacity estimation studies (Mahut, 2015). Greenbergs model on the other hand, extends the Greenshields model by introducing the concept of a maximum flow (Greenberg, 1959).

2.0 MATERIALS AND METHODS

This chapter outlines the materials, experimental procedures, and methodologies employed in the Calibration of Greenberg and greenshield model for Abuja traffic.

2.1 **Materials Used**

The following materials were used for the data collection processes. These are;

Thing counter application

Stop watch

Measuring tape

2.2 Research Method

Traffic count of the selected routes (B6 and B12) which is known as Constitution avenue and independent avenue respectively;

Selection of the road sections in Abuja

Travel time determination

Determination of traffic parameters for all the road sections

Statistical analysis of the data for all road section

Fitting the traffic parameters into the mathematical models for all road sections

Comparing the critical parameters of the models for all the road section.

Selection of the road sections in Abuja: The following roads were selected for the study.

Road-1 representing B6 Road (Originating from Ring-road 1 to world trade Center (WTC)

Road-2 representing B12 Road (Originating from National Hospital to American Embassy)

Travel time determination: To determine the stream travel time for the different road sections, consider the defined trap length AB, the travel time for the different categories of the vehicles plying the road were calculated; say three (3) each. And the corresponding speeds for each were also computed. Hence, the harmonic speed otherwise known as the stream speeds were then measured. This procedure was repeated for all the other road sections.

Determination of traffic parameters for all the road sections: The traffic parameters such as; traffic speed, density (concentration) and flow for each section of the roads was determined as follows:

Traffic speed

The speed determination (average speed) was determined as the ratio of trap length of 721.2m (constant for all roads) to the average travel time for individual vehicle types before the harmonic speed (stream speed) was also computed.

$$Average\ speed = \frac{l_x}{t_i}$$

Concentration/Density

The traffic density of the roads sections was computed from the speed, flow and density relationship. This corresponds to ratio of total vehicle on the given road section to the trap length expressed in equation 3.2

$$Density, k = \frac{n_x}{l}$$

3 Traffic flow

The flow of the defined sections of each road was measured at one end and checked at the other end. Using a counters mobile application, each vehicle type was denoted and as the vehicle passes, counting takes place. At the end of every hour, the counting was reset (hourly flow), and the process continues from 6:00am to 6:00pm daily for a period of two (2) weeks. Flow was determined using equation 3.3

$$Flow, f = \frac{n}{1hr} \qquad (3.3)$$

Where, f = flow

n = number of vehicles

Statistical Analysis

Measure of dispersion and central tendencies

The measure of dispersion and central tendencies for each of the traffic parameters speed, flow and density were determined with respect to each road sections. Analysis of variance (ANOVA) was also carried out.

Fitting the parameters to the macroscopic models

The two macroscopic models used were the Greenshield and Greenberg. The traffic parameters data were fitted into the equations for all the roads. The Greenshield and Greenberg are represented thus;

Estimation and comparison of the traffic critical parameters

For each of the road sections, the generated equations were used to estimate the critical parameters such as jam density and free flow speed. These parameters were compared to each other for the different road section. In addition, the shockwave analysis and the capacity drop were also be analyzed.

Table 1: Result and Discussions

S/No	Time Interval	B6 Road Travel time (sec)	B12 Road Travel time (sec)
1	06:00-07:00	51	25
2	07:00-08:00	134	81
3	08:00-09:00	153	80
4	9:00-10:00	173	76
5	10:00-11:00	119	63
6	11:00-12:00	108	58
7	12:00-01:00	112	50
8	01:00-02:00	94	67
9	02:00-03:00	87	60
10	03:00-04:00	155	79
11	04:00-05:00	227	68
12	05:00-06:00	111	81

The travel times for the two roads were determined by taking a road section of equal length 721.2m. The road conditions were assumed to be the same with a varying traffic condition. At every hour, the numbers of travel times were measured and the averages are represented in Table 4.1. It was observed that, at road B6, the vehicles moved slower due to the traffic conditions, in fact, the vehicles on road B6 move at most 50% slower than those on Road B12.Also, the travel time was higher at 4:00 to 5:00pmwith a value of 3.78 minutes (227 seconds)for road B6 and 7:00-8:00am and 5:00-6:00pm for road B12 with a value of 1.35minutes. A clear illustration of the Travel time result for the two identified roads were represented graphically in Figure 1 and Figure 2.

Table 2: Statistics for the Roads Travel Times

Descriptive Statistics	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Road_1_Travel_time	12	176	51	227	127	45.722	2090.55	1.119	1.232
Road_2_Travel_Time	12	56	25	81	65.67	16.417	269.515	2.465	1.232
Valid N (listwise)	12								

The least travel time for road 1 and 2 are respectively 51 seconds and 81 seconds with the maximum travel times of 227 seconds and 81 seconds. The average travel time for the two road streams are 127 seconds for Road 1 and 65.67 seconds for Road 2.

Table 3: Roads Stream Speeds Result

S/No	Time Interval	B6 Road Stream Speed (km/h)	B12 Road Stream Speed (km/h)
1	6-7	51	103
2	7-8	19	32
3	8-9	17	32
4	9-10	15	34
5	10-11	22	41
6	11-12	24	44
7	12-1	23	52
8	1-2	28	39
9	2-3	30	43
10	3-4	17	33
11	4-5	12	38
12	5-6	24	32

The traffic stream speed depends on the individual spot speeds which also largely generally is a function of the vehicles travel times. On Road B6, it was observed that, the stream speeds are 50% less than those of Road B12. However, the maximum stream speed for Road B6 was 51km/h and that of road B12 was 103km/h. This was because, at early morning, there are fewer vehicles on the roads and as such, drivers are tempted to move with desired speeds with no obstruction that might leads to shockwave production as shown on Table 3. For the purpose of clarity, the frequency polygons for the stream speed for each road sections were illustrated in Figure 1 and 2.

Figure 1: Frequency of Road 1 Stream Speed

Figure 2: Frequency of Road 2 Stream Speed

The range of stream speed for roads 1 and 2 are respectively 12km/h to 51km/h and 32km/h to 103km/h. The mean stream speeds for Road 1 was 23.5km/h and 43.58km/h without outliers as observed in Table 4.

Table 4: Statistics for Roads Stream Speed Result

Descriptive Statistics	N	Range	Minimun	Maximur	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Erro	Statistic	Std. Erro
Stream Speed for Road 1	12	39	12	51	23.5	2.927	10.14	102.818	1.924	0.637	4.922	1.232
Stream Speed for Road 2	12	71	32	103	43.58	5.686	19.695	387.902	2.904	0.637	9.104	1.232
Valid N (listwise)	12											

Greenshield model

The linear relationship between the speed and densities was generated using Greenshileds equation as shown in Figure 3. The traffic stream speed against the traffic density results to equation 1. The R^2 value obtained for greenshield model was 0.623 which is smaller compare to 0.942 of Greenberg model. Hence, there is strong correlation of the data with Greenberg model compare to greenshield.

$$y = -0.556x + 36.35 \quad (1)$$

Comparing equation 1 with the standard greenshileds model, the critical parameters were determined.

$$U_s = U_f - \frac{U_f}{K_j} K_i \quad (2)$$

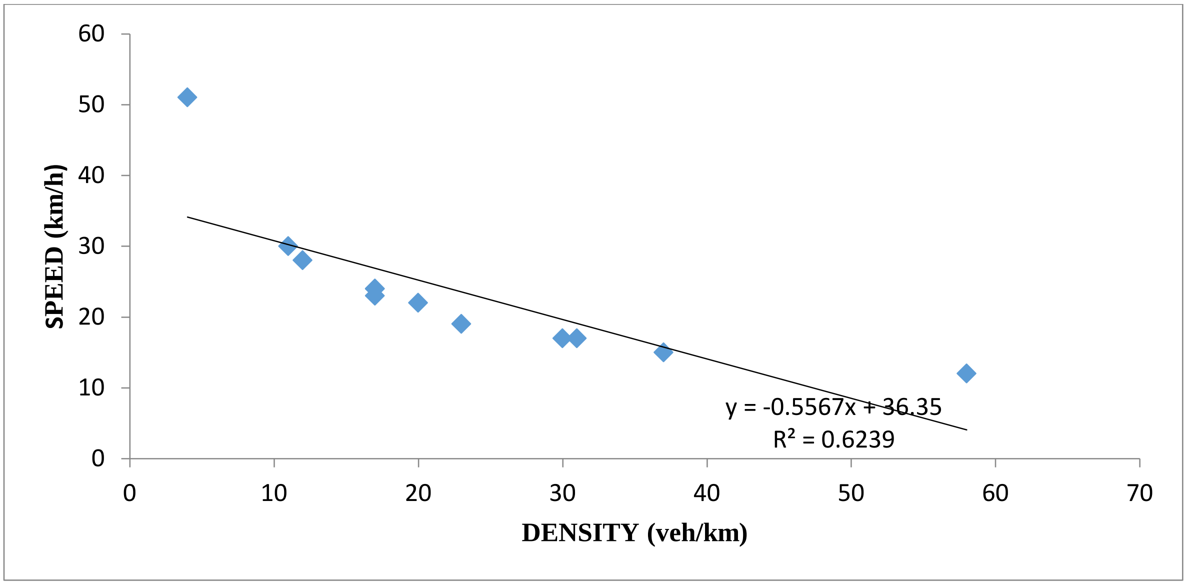

Figure 3: Road Greenshield Model

By comparing 4.1 and 4.2;

$$U_f = 36.35km/h$$

$$\frac{U_f}{K_j} = 0.556$$

$$K_j = 65veh/km$$

$$q_{max} = \frac{U_f K_j}{4}$$

$$= \frac{6.35\ x\ 65.37}{4}$$

$$q_{max} = 594veh/h$$

Greenberg model

The logarithmic relationship between the speed and densities was generated using Greenberg equation as shown in Figure 4. The traffic stream speed against the traffic density results to equation 3. The R^2 value obtained for greenberg model was 0.942 which is higher compare to 0.623 of Greenshiel model. The regression model gave;

$$y = -14.3ln(x) + 65.94 \tag{3}$$

Comparing equation 1 with the standard greenshileds model, the critical parameters were determined.

$$U_s = Cln\left(\frac{k_j}{k}\right) \tag{4}$$

Equation 4.4 simplifies to;

$$U_s = clnk_j - clnk \tag{5}$$

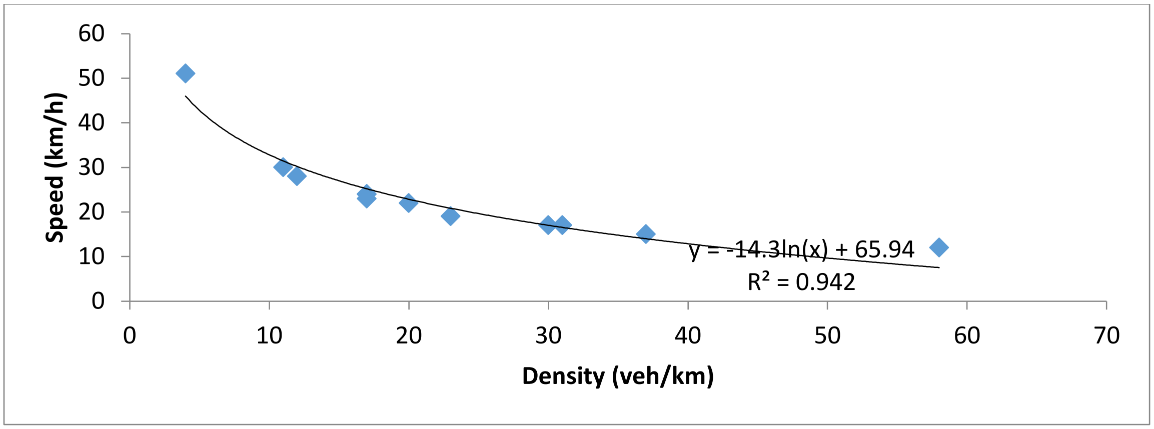

Figure 4: B6 Road Greenberg Model

By comparing Equation 4.3 and 4.5

$$clnk_j = 65.94$$

$$lnk_j = \frac{65.94}{14.3}$$

$$lnk_j = 4.61118$$

$$k_j = 100veh/km$$

$$U_s = 14.3ln\left(\frac{100}{k}\right)$$

$$from\ ln\left(\frac{k_j}{k_0}\right) = 1$$

$$lnk_j = 1 + lnk_0$$

$$ln100 = 1 + lnk_0$$

By simplifying,

$$k_0 = 37veh/km$$

$$q_{max} = k_0U_0$$

$$q_{max} = 36.78\ x\ 14.3$$

$$Maximum\ Flow, q_{max} = 526veh/h$$

Best Model

Table 5, present summaries of the most suitable of the macroscopic models. The result revealed that Greenberg has higher rank correlation coefficient compare to greenshield, Hence, Greenberg was selected the best model more suitable for the road traffic analysis.

Table 5: Most suitable of the macroscopic models.

Road	Most Suitable Model
1	Greenberg
2	Greenberg

Conclusion

The range of stream speed for roads B6 and B12 are respectively 12km/h to 51km/h and 32km/h to 103km/h with corresponding density ranges of 4 to 58veh/k B6 road and 2 to 19veh/km B12, hence B6 is twice denser than B12.

Greenberg prove to be more accurate when traffic characteristics are model with B6 and B12 resulting with B6 and B12 mathematical model having $y = -14.3\ln(x) + 65.94$, while B12 was $y = -30.33\ln(x) + 117.57$.

For the Greenberg only, Road B6 has a jam density of 100veh/km which is twice that of B12 with a corresponding speed of 14.3km/h which is approximately half that of B12.

REFERENCES

Agbonkhese, O., Yisa, G. L., & Daudu, P. I. (2013). Bad Drainage and its Effects on Road Pavement Condition in Nigeria. Civil and Environmental Research. *Journal of Geoscience and Enviromental Protection.*

Black, W. R. (2004). Sustainable Transport: Definitions and Responses. TRB/NRC Symposium on Sustainable Transportation Baltimore.

Fwa, T. F. (2005). Hanbook of Highway Engineering.

Finch, V. A. (1996). Surface Route Histories. Search Transit Toronto. Alness-Chesswood.

Galtima, M. (2006). The Structure of Intra-Urban Trip flows in Yola Metropolitan Areas. *Global Journal of Social Sciences Nigeria*. ISSN 1596-6216.

Garber, N.J. &Hoel, L. A. (2010). Traffic and Highway Engineering. Scientific Research. CengageLearing, U.S.A

Ikegbunam, F. F. (2014). Onitsha Urban Road Transport System: Implications for Urban Transport Planning. *International Journal of Applied Science and Technology.* Department of Environmental Management, Anambra State University Uli, Anambra State, Nigeria.

Lakshmanan, T. R., Peter, N. & Erik, V. (1997). Full Cost and Benefits of Transportation. Springer, Berlin, Heidelberg. http.//doi.org/10.1007/978-3-642-59064-1_14.

Kolo, S. S. (2021). Highway and Transportation Engineering Lecture note. Civil Engineering Department. Federal University of Technology, Minna.

Michael, L., David, L. & Ahmed, M. E. (2003). Models of Transportation and Land Use Change: A Guide to the Territory. *Journal of Planning Literature.* DOI:10.1177/0885412207314010.

Miller, H. &OKelly, M. (1994). The Hub Network Design Problem: A Review and Synthesis. *Journal of Transport Geography.*

Nwaegbe, K. (2008). Rescue and Management of Road Traffic Accident in Nigeria: Challenges and Possible Solution. *African Journals Online.*

Parker, H. (2007). Global Transportation. Application Solutions for Rail, Truck and Bus.

Pickering, K. & Owen, S. (1997). An introduction to Global Enviromental Issues. Taylor & Francis Group, London. DOI: http://doi.org/10.4324/9780203974001.