Original Article *Journal of Sustainability and Environmental Management (JOSEM), Vol. 2, No. 3 (2023), 190 – 202*
p-ISSN 2822-1729, e-ISSN 2822-1737 Available online at https://www.nepjol.info/index.php/josem

Trip Generation Model for Gboko Town, Benue State, Nigeria

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Abstract: Nowadays many urban planning authorities especially in less developed countries have been struggling with traffic related challenges like traffic congestion, air pollution and traffic accidents in their cities. However, solutions to these problems cannot be achieved without rational planning decisions and cannot be attained without the basic understanding of the urban transport system. This study was carried out to assess commuter trip generation in Gboko town, Benue State with a view to estimate long-range future travel demand that would accommodate future transportation needs. Trip generation data was collected from 440 households using questionnaire and travel diary. The information from questionnaire and travel diary was used to prepare the origin-destination matrix, and gravity model was used to translate trip distribution into trip length frequency. Work trip had the greatest trip percentage (%) share among other trip purposes and was proxy for trip distribution. The 25-minute work trips dominated the urban trip pattern in Gboko town with 17.01 % annual increase. It implied that people would take much longer time and distance to reach their destination in Gboko town due to the large expanse of the town, or due to deficiency in public transit facilities and poor road infrastructure. Trip generation and distribution models for Gboko town provided accurate scenarios of the current travel pattern in the town and aided in forecasting future travel situations in the study area. The study recommended that urban transportation policy should encourage provision of public transit buses, incentives for public transit users and improve on the road network system to shorten the trip length frequency of the town.

Keywords: *Gboko, Trip distribution, Trip generation, Trip length segment, Trip productions*

Conflicts of interest: None
Supporting agencies: None

Received 30.04.2023; Revised 26.07.2023; Accepted 27.08.2023

Cite This Article: Mchi, A.A., & Umoren, V. (2023). Trip Generation Model for Gboko Town, Benue State, Nigeria. *Journal of Sustainability and Environmental Management*, 2(3), 190-202.

1. Introduction

Migration and mobility have not just continued to attract much interest, but also growing concern worldwide. Today, more than half the world's population live in cities, and the UN expects this figure to rise to two-thirds by 2050 (Moriartya and Wang, 2014) while the proportion would be highest in low- and middle-income nations in Africa and Asia. In an increasingly urbanised world, substantial transformations in population distribution seem inevitable. As most of the world's population is living in urban areas, it is in these areas that the main economic, social and environmental processes that affect human societies take place. Urbanisation is now commonly regarded as one of the most important social processes, also having enormous impact on the environment at local, regional and global scales (Barredo and Demicheli, 2003; Tacoli and Saterthwaite, 2014). The rapid urban migration, agglomeration and sprawl, natural population increase in cities has created traffic related problems especially in developing countries like Nigeria. These problems are more visible in poorly managed cities that were designed in a monocentric manner. The urban planning authorities in such countries have been struggling with traffic challenges that are concerned with the mode of travel and travel behaviour of the commuters. To change the inherent traffic related problems, it becomes essential to determine the number of trips generated and distributed in an area through rigorous transportation planning studies.

In general, the focus of urban transportation planning is to create alternatives for improving transportation systems that will meet future demand and supply, and finally select the best alternative mode after proper evaluation. It drives towards identifying where transportation demand and supply will be in the future. Therefore a thorough understanding of existing travel pattern is compulsory for identifying and analysing existing traffic related problems. Acquisition of detailed data on existing travel pattern and traffic volumes are

required for developing travel prediction models.

In recent years, the desire for intelligent city planning models based on rational thinking has become eminent as it enhances equitable distribution of facilities and services, thereby reducing traffic related problems along the major urban roads and minor streets in the cities. These have put forward the needs for an efficient transportation system to enhance safe movements of people and goods within the towns. However, this cannot be achieved without rational planning decisions and attained without the basic understanding of the urban transport system. The system for transportation planning includes not just the hardware infrastructure (vehicles) with which people and goods move about but also the software infrastructure (volume and characteristics of traffic). These infrastructures seem to be lacking in Gboko town and prompt the need for the study.

The aim of the study was to assess commuter trip generation in Gboko town, Benue State with a view to estimate long-range future travel demand that would accommodate future transportation needs. Specific objectives of the study were followed to:

a) assess trip generation within the study area;
b) distribute trips within the study area; and
c) determine the total number of trips made in each trip length segment for the horizon year.

The estimation of future travel demand is a vital long-range transportation planning procedure for determining strategies that would tackle or accommodate future transportation needs. These strategies may include land use policies, pricing programs and expansion of transportation supply-highway and transit service (Hassan et al., 2016; Nwafor et al., 2018).

2. Relevant Literatures

2.1. Trip generation

Trip generation is the first step of the travel demand model that estimates how trips are produced and attracted to different land use parcels in an urban area (Solanke, 2015). To understand the term, a trip is a unidirectional journey or the act of travelling from one place to another in one direction. It is also regarded as the information related to all activities attached to the travel from the point of start to the point of finish, the stay and return journey. A trip for the purpose of this study is a one way movement from an origin to a destination that are zone centroids (Montello, 2018).

Trip generation is the process through which the intensity of urban activities can be measured and converted into numbers of trips. The principal task in the analysis is to relate the intensity of trip making from one point to several other points in an urban area. Urban transportation planners usually quantify the relationship between urban activities and travel with a view to assess the effective usage of different land use types, and intensity of travels in an urban area. Trip generation analysis phase answers the questions to how many person trip ends originate at each zone, and consider zone centroids as the origin-destination points for all the trips. The trip ends may be classified as either origins or destinations (O-D). Trip generation analysis also computes all trips associated with each zone as person trip ends without identifying the mode used by individuals. It measures the occurrence of trips based on trip ends of production and attraction to estimate the propensity and magnitude of travel (Acheampong, 2015).

Scholars (Umoren and Oafiji, 2016) indicated a positive relationship between predictor variables (socio-economic characteristics) of commuters and trip generation/ volume. The coefficient of determination (R^2) of 0.520 implies that about 52 % of the variations in trip generation/ volume in the study area were explained by the changes in the socio-economic characteristics of the commuters. The study further revealed that as the socio-economic characteristics increase, the interactions among the various traffic analysis zones (TAZ) will tend to increase, resulting in an increase in trip generation.

The trip generation model is developed from the number of trips as a function of population, income and car ownership, and calibrated using base year data obtained from household travel survey to determine the trip making pattern of households in TAZ. Two types of trip generation models have been identified as production and attraction models. Trip production model estimate the number of home-based trips to and from zones where commuters reside. The trip attraction model estimates the number of trips to and from each zone at the non-home end of the trip (Atoyebi et al., 2015).

2.2. Trip distribution

Trip distribution is the second stage of travel demand modelling. It starts with the decision to travel for a given purpose which makes the commuter generate a trip. The trip generated from each zone centroid is then distributed to other zones based on the commuter's choice of destination. The trip distribution stage uses balanced person trip production and attraction ends from the trip generation model, allocating trips among all zone pairs by trip purpose to construct a trip matrix table based on trip purpose.

The trip table matrix contains both intra-zone trips on the diagonal and inter-zone trips in all other zone interchange cells. Trip distribution model applies gravity equations and friction factors to represent the effect of travel time between zones. The gravity model begins with postulation about trip making behaviour and how it is influenced by external factors such as attractiveness. Such models are used to study the relationship between transport demand and resulting land use patterns, and to predict their changes in the future (Raza *et al.*, 2022).

Gravity Model: The Newton’s law of gravitation states that “the force of attraction between two bodies is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them" (Anderson, 2011) usually written as Equation 1:

$$F = g\frac{M_1 M_2}{D^3}$$

Equation 1

where;

F = force of attraction;

g = constant or scaling factor;

$M_1 M_1$ =two bodies of respective masses and

D =distance separated by two bodies of respective masses;

The same Newton's gravitation principle can be applied in human societies to develop a model for trip distribution.

According to (Rahman *et al.*, 2015), the application of this concept to model trip distribution takes the mathematical form as equation 2:

$$T_{ij} = K\frac{P_i A_J}{w_{ij}^c}$$

Equation 2

where;

T_{ij}= the interaction between places *i* and *j*;

K = a constant;

P_i= measures of the size (productions) of place i such as population or number of jobs;

A_J= measures of the size (attractions) of place j such as population or number of jobs;

w_{ij}^c = the friction factor (distance between places i and *j*; and c is the costs of travel).

Trip productions and attractions of the zones replace the masses of the bodies, and travel impedance between the zones substitutes D^2. The exponent of the impedance term may not be exactly two but can be replaced by a model parameter *c*, which is derived based on calibration. Equation 2 implies that the interchange volume between trip producing zone *i* and the trip attractiveness of zone *j* is directly proportional to the magnitude of the trip productions of zone *i* and the attractiveness zone *j* and inversely proportional to a function of the travel impedance W_{ij} between the zones.

The gravity model is a mathematical model used to predict the interaction between two or more places separated by a distance. It has been used to create a representation of many flow patterns, such as traffic and trade flows, and migration. Essentially, the gravity model can be used to account for any interaction or flow that is expected to move from one place to another (Anderson, 2011). The above equation can be mathematically transformed into to generalised gravity model (Wills, 1986) as equation 3:

$$T_{ij_k}^m = \left[\frac{P_i A_{jk} F_{ij}^m K_{ij}}{\sum_{j=1}^n A_{jk} F_{ij}^m K_{ij}}\right]^p$$

Equation 3

where;

p = trip purpose;

$T_{ij_k}^m$ = trips produced in zone i and attracted to zone j by mode m in k^{th} iteration;

F_{ij}^m = empirical derived travel time factor or friction factor for mode m which expresses the average area-wide effect of spatial separation on trip interchange between zone *i* and zone *j*, and;

k = iteration number.

It is important to segregate data based on trip purpose and mode use when applying gravity model because the distances covered by two different modes may vary. For instance, mandatory trip made for work by car may cover several kilometres while discretional trip for recreation by foot may cover a few kilometres. In general, gravity model (Wills, 1986; Nwafor *et al.*, 2018) could be written as Equation 4:

$$T_{ijk} = \frac{P_i A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}}$$

Equation 4

where;

P_i = trips produced from zone *i*;

A_j = trips attracted to zone *j*;

$F_{ij} = \frac{1}{w_{ij}^c}$ = friction factor and

K_{ij} = socioeconomic adjustment factor for interchanges between zones *i* and *j*.

Friction Factors: The friction factors (F_{ij}) otherwise called impedance function is the generalised cost function of travel from zone *i* to *j*. For trip modelling, impedance can be expressed as costs or distance but travel time is a better measure. However, with careful calibrations, distance and monetary cost can be converted to travel time. It is important to the trip modelling process to obtain the best practical measure of impedance. This is achieved through testing model output against historical information for the same situation. Impedance functions which give the closest match are used. The measures may be different for different transport activities. Impedance function can be defined in exponential terms of travel time (costs) between each pair of zones (Wills, 1986; Mann and Dawoud, 1999; Nwafor *et al.*, 2018) and expressed as Equation 5:

$$F_{ij} = e^{-\beta c_{ij}}$$

Equation 5

where;

e = the base of the natural logarithm (2.7183);

β = a dispersion parameter measuring sensitivity to cost, calibrated as:

$e^{-\beta \times 6} = 2$, then $\beta = 0.1155$ and

c_{ij}= cost of travel between zones *i* to zone *j*.

Impedance is the travel cost (sometimes called generalised cost) that includes real perceived costs of travel between two locations. Travel time is one component of travel cost because it has implicit cost to the trip and could be assigned on an hourly wage or price basis. It could be observed that two different persons will value time for a trip differently depending on their hourly 'price'.

Similarly, two assumed individuals will probably use a different travel mode in getting from an airport to a hotel on a trip; the former may take a taxi whereas the latter will probably take a bus (if available). Private car owners have other cost dimensions to consider. There are real operating costs in the use of a vehicle like fuel, oil, insurance and maintenance. The aim of impedance function is to establish shortest paths between all zone pairs using the travel time, costs or distance. Travel time along these minimum paths are calculated and recorded in the skims table (McNally, 2007) using travel time (costs or distance) for each trip purpose.

The outcome of the cost matrix table is converted to impedance factor values between each zone pair using the path with the minimum travel time for each trip purpose using Equation 5. The gravity model uses impedance factor values (travel time skims) to distribute trips among the zones in the study area. The friction factors are calibrated to trip length distributions using data on journey to work. Since journey to work data only define trip lengths for home-based work trips (HBW trips in the model), trip length distributions for other trip types are defined relative to HBW trips because HBW trips are the longest trip type in urban areas.

K-Factors: This is the socio-economic adjustment factor.The socioeconomic factor, *K*, can be a matrix of values rather than just one value for a study area. The K-Factors improve the gravity model in the base year, and it is assumed that special conditions will prevail for K-Factors to remain stable in future years and scenarios. However, it must be remembered that too much reliance on K-Factors limits gravity model sensitivity and undermines gravity model's ability to predict future travel behavior. Therefore, the use of K-factors in a strict sense makes it more difficult to figure out the real travel problems.

Trip Distribution for Different Zones (First Iteration): The trip distribution model employs gravity model equation to distribute trip productions and attractions to each traffic analysis zone. The gravity model uses impedance factors to represent the effect of travel time between zones. Zone centroids are attractive areas where many people travel to carry out several activities like shopping, eating and leisure. Attractiveness indices are defined quantitatively to compare the importance of zone centres. The attractiveness of a zone centroid (location) can be determined as the product of zone attractions and impedance factor for the zone (Vikerman, 1974) written as Equation 6:

$$A_z = (A_j) \times (F_{ij})$$

Equation 6

where;

A_z = zone attractiveness;

(A_j) = attractions; and

(F_{ij}) = impedance function.

The probability of being attracted to a zone is expressed as Equation 7:

$$A_{rz} = \frac{(A_j \times F_{ij})}{(\sum_{i=1}^{n} A_j \times F_{ij})}$$

Equation 7

where;

A_{rz} = relative zone attractiveness;

$(A_j \times F_{ij})$ = zone attractiveness; and

$(\sum_{i=1}^{n} A_j \times F_{ij})$ = sum of zone attractiveness.

As travel time between zones increases, the number of trips between the zones will decrease. The first iteration outcome is recorded as the Origin-Destination (O-D) matrix. Trip productions and attractions in the O-D matrices are compared for equality since trips productions must be equal to trip attractions.

Adjustments of Trip Distribution for Different Zones (Second Iteration): This is a process that ensures observed trip productions and attractions of trip distribution in O-D matrices are equal to the expected trip productions and attractions. This means, the resultant base trip matrix will more closely reflect observed behaviour (McNally, 2007). Adjustments of trip distribution are necessary when the trips produced after the distribution agree with the corresponding target trip attraction values but the target trip attraction values do not equal the calculated trip attraction values in the O-D matrix. The second iteration is applied to adjust trip attraction values for subsequent iterations as Equation 8:

$$A_{jk} = \frac{A_j}{C_{j(k-1)}} \times A_{j(k-1)}$$

Equation 8

where,

A_{jk} = adjusted attraction, iteration k

A_j = desired attraction

$A_{j(k-1)}$ = adjusted attraction, iteration (k-1) and

$C_{j(k-1)}$ = calculated attraction, iteration (k-1)

2.3. Trip length segment

The trip length segment is defined as the increased total number of trips made in each trip length segment for the horizon year when compared to the base year. If there are more trips in each trip segment after the base year, and it indicates increased number of trip makers in each trip length segment in the horizon year. The trip length segments are calculated based on classified minute's trips and expressed as per cent increase. Scholars (Nwafor et al., 2018) performed trip distribution analysis in the Makurdi metropolis, and found that five minute trips were substantial when compared to other intra-zonal trips and 10 minute trips had the highest percentage increase of 45.75 %.

3. Materials and methods

Gboko town is the headquarters of Gboko Local Government Area (LGA) in Benue State, North-Central, Nigeria. Gboko town is located between latitude 7° 18' 17''N and 7° 23' 37''N and longitude 8° 47' 07''E and 8° 51' 47''E (Iorkua et al., 2019). It is bordered to the North by Tarka and Buruku LGAs, to the South by Konshisha LGA, to the West by Gwer LGA and to the South – East by Ushongo LGA. Gboko town is developed with streets that connect one part of the town and the others however; most of the streets are worn away while some are completely cut off by gully erosion.

The town is known for farming, commerce and civil service. The people of the area are mainly farmers that cultivate vegetables and other perishable food products. The farmers produce crops like yam, cassava, rice, soya beans, millet, potatoes, guinea corn, benniseed, maize and groundnuts. Many trips are generated from activity centres spatially separated in the town due to the desire to meet human social needs. The population of Gboko town was estimated at 384,265 persons in 2019 (NPC, 2006) and was projected to reach 666,315 persons (133,263 households) in 2035.

The population of Gboko town was organised into 13 prominent neighbourhoods namely Gboko central, Adekaa, Abagu, Agadam, Genger, GRA, Gboko north, Buter, Gboko east, Gboko south, Ankyenge, Gboko west and Agase. The prominent neighbourhoods of Gboko town were further divided into 22 TAZ for the purpose of this research based on homogeneous characteristics of residents. Gboko town is also made of streets that connect one part of the town and the others however; most of the streets are worn away while some are completely cut off by gully erosion. This is common in the eastern part of Gboko town where there are many streams associated with stream bank erosion (Iorkua et al., 2019).

The economic base of the town depends on farming, commerce and civil service. The people of the area are mainly farmers that cultivate vegetables and other perishable food products. The farmers produce crops like yam, cassava, rice, soya beans, millet, potatoes, guinea corn, benniseed, maize and groundnuts. Gboko produces over 40 % of the state's soya bean yield.

The study adopted survey method using a multi-stage framework that covers survey and measurements. Population of the study entails households in Gboko town, Benue State and the town being one of the higher order towns in the state was purposefully sampled due to its capability to generate intense traffic. The study relied on both primary and secondary source of data. The primary source of data consisted of structured questionnaire and travel dairy to collect information on journeys in the study area.

The population of Gboko town had 384,265 persons as estimated in 2019. The household heads was the basis of questionnaire administration in the study area. To obtain the sample size for the study, the Research Advisors' required sample size table (template) attached as in Appendix I (The Research Advisors, 2006) was consulted. Consequently, the template showed minimum sample size of 384 household heads that was drawn at 5 % confidence level with 0.05 % degree of accuracy (margin error) for study. However, the study sampled 457 heads of households to accommodate anticipated cases of non-response that may affect the validity of the results.

A total of 457 questionnaires were distributed to household heads that have homogeneous socio-economic characteristics in 22 traffic analysis zones based on population of each TAZ through a multistage random sampling procedure. However, 440 completed questionnaires were returned for data analysis. Adequate copies of travel diaries were also made available to sampled households to collect information on journeys between 16th October, 2019 and 27th February, 2020.

The completed household travel survey questionnaire was coded into computer for analysis. In order to have confidence in the data collected from a sample population, post-evaluation validity methods were done with an intention to indirectly examine the quality of data collection. Two validation tests for consistency of the data were performed after the data entry stage; (i) validation was done by choosing a computer check on the variables (proactive bug finding). For instance, if the person indicates some high unrealistic values like 1500 schools in a TAZ; and (ii) logical check was done for the internal consistency of the data (import/export data migration). For example, if a respondent whose income is less than ₦10,000.00 per month, he/she cannot claim to spend more than ₦9,000.00 per week on car maintenance/fuel. The questionnaire that failed to pass validation tests was treated as outliers, and removed to ensure correctness of the data for modelling.

Trip generation uses characteristics of the transportation network and regional demographics to generate and distribute the trip ends from specific origins to destinations amongst the traffic analysis zones (TAZ). Trip generation analysis in Gboko town started with the use of information collected from households using questionnaire and travel diary. The town was demarcated into 22 TAZ based on similar socioeconomic characteristics of residents, while the boundaries were determined with regards to political, man-made and natural features like roads and streams.

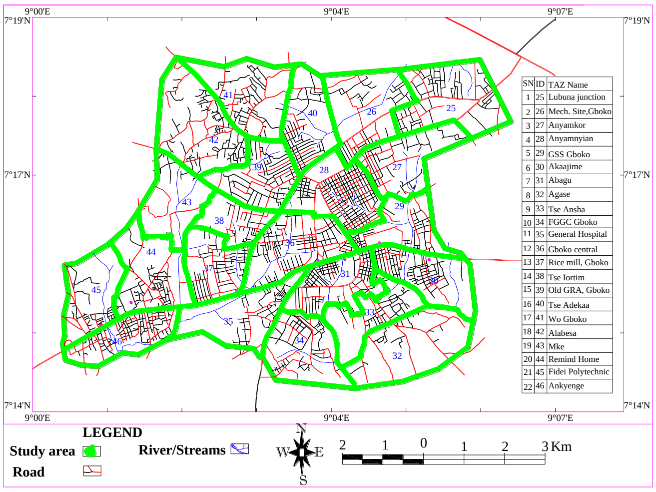

Figure 1: Gboko study Area
Source: Author's Fieldwork (2020).

4. Results and discussion

The predicted trips were aggregated within each travel analysis zone (TAZ) and were defined by trip purpose.

Since it was cumbersome to distribute trip generation between activity centres like home, school, shop, stadium and event centre namely home based work, home based education, home based shop, home based social, home based other and non-home-based collected in the area.

However, work trip had the greatest number of trips for productions and was proxy for trip distribution as in Table 1. Similarly, work trip had the greatest number of trips for attractions and was proxy for trip distribution as in Table 2.

Observed travel information gathered through travel surveys and other sources were used to generate predictions from the regression models. Productions and attractions were forecasted separately and were found not to be equal within each of the analysis zone because they came from different data sources as trip ends. The discrepancies were balanced to make attractions to equal the productions for Gboko town as in Table 3. The trip balancing process ensures that unbalanced trip productions ends are equal to trip attractions ends in the calculated model. Trip attractions for Home Based Work are balanced to Home Based Work productions due to a higher level of confidence in household data that produces trips in the TAZ using the Control Factor (CF). The CF for trip productions is the ratio of adjusted trip productions to adjusted trip attractions.

Table 1: Trip Production by Purpose in the Study Area

TAZ	Work	Shop	Rec	Educ.	Other	NHB	Prod.
Lubuna Junction	10630	4723	1611	4942	1283	0	23189
Mechanic site	7632	5284	1852	4238	1223	1970	22199
Anymkor	9935	5842	1633	3969	1405	1152	23936
Anyamnyian	13100	4621	1486	5124	1258	1005	26594
GSS Gboko	10160	4478	1584	4770	1356	1637	23985
Akaajime	9159	5805	2415	4096	1554	1301	24330
Abagu	10891	5052	1568	5144	0	1987	24642
Agase	8055	4339	0	4096	2285	0	18775
Tse Ansha	7944	4096	0	3464	0	1179	16683
Fed. Govt. Girls' Coll.	9984	4871	2100	3156	1872	1093	23076
General Hospital	10533	4044	0	5557	1406	1153	22693
Gboko central	11197	6073	1849	5030	0	1368	25517
Rice mill, Gboko	8276	6184	0	4286	0	0	18746
Tse Iortim	9183	5399	2273	4168	1433	2180	24636
GRA, Gboko	13355	4415	2076	5227	1848	0	26921
Tse Adekaa	8106	3775	0	4432	2622	2469	21404
Wo Gboko	10353	4945	2461	4513	1574	0	23846
Albesa	10095	4630	1927	5264	1260	0	23176
Mke	6910	4848	0	3618	0	0	15376
Remind Home	10641	4577	2326	5185	1247	0	23976
Fidei Polytechnic	8300	5341	0	4582	0	0	18223
Ankyenge	12011	4330	2505	4815	1185	0	24846
Total	**216450**	**107672**	**29666**	**99676**	**24811**	**18494**	**496769**

Table 2: Trip Attractions by Purpose in the Study Area

TAZ	Work	Shop	Rec	Educ.	Other	NHB	Attr.
Lubuna Junction	12004	8907	3089	5551	2361	0	31912
Mechanic site	4056	9468	3330	4847	2301	2714	26716
Anymkor	9746	10026	3111	4578	5483	1896	34840
Anyamnyian	15595	8805	2964	5733	2336	1749	37182
GSS Gboko	9905	8662	3062	5379	2434	2381	31823

Akaajime	9684	9989	3893	4705	2632	2045	32948
Abagu	14456	9236	3046	5753	0	2731	35222
Agase	5694	8523	0	4705	5363	0	24285
Tse Ansha	7347	8280	0	4073	0	1923	21623
Fed. Govt. Girls' Coll.	8186	9055	3578	3765	4950	1837	31371
General Hospital	9148	8228	0	6166	5424	1897	30863
Gboko central	15393	10257	3327	5639	0	2112	36728
Rice mill, Gboko	9144	10368	0	4895	0	0	24407
Tse Iortim	10983	9583	3751	4777	2511	2924	34529
GRA, Gboko	8862	8599	3554	5836	2926	0	29777
Tse Adekaa	5972	7959	0	5041	6700	3213	28885
Wo Gboko	7817	9129	4939	5122	2652	0	29659
Albesa	14960	8814	3405	5873	3338	0	36390
Mke	4823	9032	0	4227	0	3106	21188
Remind Home	12153	8761	3804	5794	2325	0	32837
Fidei Polytechnic	7992	9525	0	5191	0	0	22708
Ankyenge	12530	8514	3983	5424	2263	1745	34459
Total	**216450**	**199720**	**52836**	**113074**	**55999**	**32273**	**670352**

Table 3: Multiple Regression Data for Trip Production and Attraction in Gboko Town

TAZ	TAZ Name	Trip Prod.	Pop.	Income	Veh. owned	Trip Attr	Land price	Job loc.	No. of Workers
25	Lubuna junction	10621	20525	42653	26	24350	1760870	283	60
26	Mech. Site,Gboko	9453	15005	43820	20	12653	1868421	322	36
27	Anyamkor	9645	14195	44735	22	13958	1617647	246	42
28	Anyamnyian	12500	30210	52615	41	21690	2700000	266	96
29	GSS Gboko	9315	15730	56320	20	11860	1921053	257	46
30	Akaajime	8650	23245	30650	15	10565	2140000	315	46
31	Abagu	9487	21880	48700	26	23856	2615385	353	86
32	Agase	7825	9480	38508	9	10563	2409091	138	20
33	Tse Ansha	6420	11020	32638	9	11438	1961538	154	28
34	Fed. Govt. Girls' Coll.	9180	16005	57345	18	12649	1973684	207	34
35	General Hospital	10438	15370	58105	23	11745	1611111	174	38
36	Gboko central	10935	27180	39562	29	22438	2928571	354	96
37	Rice mill, Gboko	9738	12525	40670	9	12700	1833333	186	40
38	Tse Iortim	8450	12375	55350	13	15483	2900000	180	64
39	Old GRA, Gboko	13912	21800	59820	45	13845	3192308	298	50
40	Tse Adekaa	9560	7560	46590	8	9354	1722222	77	16
41	Wo Gboko	11823	21525	60250	18	11690	2227273	161	34
42	Alabesa	12750	19160	38500	23	22905	1934783	259	84
43	Mke	6539	6055	32412	2	6855	1785714	76	8
44	Remind Home, Gboko	10460	21260	34917	28	14769	2060000	280	64
45	Fidei Polytechnic	8645	13885	35800	10	11705	1911765	201	32
46	Ankyenge	12605	28275	38967	36	23845	1984848	294	66

4.1. Determination of household trip generation in Gboko town

The determination of the household trip making pattern commenced with the trip generation model that was used in the trip distribution stage. The explanatory factors like population, income, and car ownership that were aggregated at TAZ level in Gboko town. The variables as in Table 3 were regressed to derive production regression equation, while land price, job locations and number of workers were used to derive attraction equations.

The variables were used in computer based SPSS environment that yielded production equation (Y_{prod} =

5348.098 + 0.050 × Pop - 0.032 × Hinc + 111.171 × Veh.own + error ; r = 0.852, r^2 = 0.726; assumed work production trip rate = 3.64 trips/person/day)
where;
prod = Productions,
Pop = Population,
Hinc = Household income, and
Veh.own = Vehicle ownership.
Then attraction equation (Y_{attr} = 9352.565 - 0.002 × Land val + 1.588 × Job loc + 209.689 × No. of workers + error; r = 0.897, r^2 = 0.804; assumed work attraction trip rate = 5.73 trips/person/day).
where;
attr = Attraction,
Land val = Land value,
Job loc = Job location, and
No. of workers = Number of workers.
The regression equations for productions and attractions were significant at 5 % level, and best fit of data.

The initial base year trip productions and attractions were adjusted using production and attraction regression equations to cross-checked over or under reported trip productions and attractions in each traffic analysis zone in Gboko town. The horizon year trip productions and attractions in Gboko town were calculated using assumed work attraction trip rates and were balanced as in Table 4.

Trip distribution modelling started after the regularisation process (necessary base year adjustments and horizon year projections) with the view to connect the trip ends (productions and attractions) determined in the trip generation stage. The gravity model was used in conjunction with friction factors (impedance factor values) to predict trip volumes to and from each TAZ, resulting in a matrix of origin-to-destination (O-D). Friction factors were expressed as travel time costs rather than linear distance and monetary costs in this study. The reason being that it was easier to quantify cost in terms of time spent from origin to destination as compared to linear distance measurements or fluctuating value of money incurred as fare from origin to destination.

The actual travel time between each TAZ was calibrated into impedance factor values making it more convenient measurable quantities for modelling purposes as in Table 5.

Table 4: Balancing Productions and attractions in Gboko Town

TAZ Name N = 22	TAZ ID	2019 Unbalanced		2035 Unbalanced		2019 Balanced		2035 Balanced	
		Prod	**Attr**	**Prod**	**Attr**	**Prod**	**Attr**	**Prod**	**Attr**
Lubuna junction	25	10630	18862	38693	68658	10630	12004	38693	43603
Mech. Site,Gboko	26	7632	6373	27780	23198	7632	4056	27780	14733
Anyamkor	27	9935	15315	36163	55747	9935	9746	36163	35404
Anyamnyian	28	13100	24505	47684	89198	13100	15595	47684	56648
GSS Gboko	29	10160	15564	36982	56653	10160	9905	36982	35979
Akaajime	30	9159	15218	33339	55394	9159	9684	33339	35180
Abagu	31	10891	22716	39643	82686	10891	14456	39643	52512
Agase	32	8055	8947	29320	32567	8055	5694	29320	20682
Tse Ansha	33	7944	11545	7944	11545	7944	7347	7944	7332
FGGC, Gboko	34	9984	12863	36342	46821	9984	8186	36342	29735
General Hospital	35	10533	14375	38340	52325	10533	9148	38340	33230
Gboko central	36	11197	24188	40757	88044	11197	15393	40757	55915
Rice mill, Gboko	37	8276	14369	30125	52303	8276	9144	30125	33216
Tse Iortim	38	9183	17259	33426	62823	9183	10983	33426	39898
Old GRA, Gboko	39	13355	13926	48612	50691	13355	8862	48612	32193
Tse Adekaa	40	8106	9385	29506	34161	8106	5972	29506	21695
Wo Gboko	41	10353	12283	37685	44710	10353	7817	37685	28394
Alabesa	42	10095	23508	36746	85569	10095	14960	36746	54343
Mke	43	6910	7579	25152	27588	6910	4823	25152	17521
Remind Home	44	10641	19097	38733	69513	10641	12153	38733	44146
Fidei Polytechnic	45	8300	12558	30212	45711	8300	7992	30212	29030
Ankyenge	46	12011	19689	43720	71668	12011	12530	43720	45515
`		**216450**	**340124**	**766904**	**1207573**	**216450**	**216450**	**766904**	**766904**

Base year Control Factor = adjusted 2019 productions/2019 adjusted attractions
= 0.6363856
Horizon year Control Factor = adjusted 2035 productions/2035 adjusted attractions
= 0.6350788

Source: Author's Fieldwork (2020)

Table 5: Friction Factors (Impedance Factor Values) in Gboko Town

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	
25	0.5613	0.3151	0.0788	0.2228	0.1768	0.1404	0.2228	0.0884	0.0702	0.0442	0.0496	0.0394	0.0313	0.0702	0.1114	0.1576	0.0625	0.0993	0.0496	0.0124	0.0055	0.0035	2.6131
26	0.3151	0.5613	0.3151	0.3151	0.2807	0.1985	0.2501	0.0993	0.1251	0.1114	0.1576	0.1985	0.0993	0.1114	0.2228	0.3536	0.1768	0.1251	0.0788	0.0496	0.0139	0.0078	4.1669
27	0.0884	0.3969	0.5613	0.3536	0.3536	0.2228	0.3151	0.1404	0.1576	0.1404	0.1985	0.2501	0.1404	0.1576	0.2807	0.3969	0.2228	0.1576	0.0993	0.0702	0.0442	0.0394	4.7878
28	0.2228	0.3536	0.3969	0.5613	0.3536	0.2807	0.3536	0.1251	0.0993	0.0884	0.2501	0.1768	0.1404	0.2228	0.3969	0.3151	0.2807	0.1985	0.1404	0.1251	0.0788	0.0702	5.2311
29	0.1768	0.2807	0.3151	0.3536	0.5613	0.3151	0.3536	0.7072	0.1404	0.1768	0.3536	0.3151	0.3969	0.3536	0.3969	0.2501	0.2228	0.2501	0.2807	0.2501	0.1576	0.1404	6.7485
30	0.1404	0.1985	0.2228	0.2807	0.3151	0.5613	0.2807	0.1576	0.1251	0.0788	0.0884	0.0702	0.0442	0.1251	0.1985	0.2807	0.1114	0.1768	0.0884	0.0557	0.0702	0.0625	3.7331
31	0.1576	0.7072	0.3151	0.3536	0.3536	0.2807	0.5613	0.3536	0.3536	0.2807	0.1985	0.2228	0.1251	0.3151	0.3969	0.3536	0.3151	0.3969	0.2807	0.2228	0.0788	0.0702	6.6935
32	0.0884	0.1114	0.1404	0.1251	0.2501	0.1576	0.3536	0.5613	0.3969	0.2501	0.1985	0.2501	0.1404	0.3536	0.3969	0.3969	0.3536	0.3536	0.3151	0.1985	0.0557	0.0442	5.4920
33	0.0702	0.1251	0.1576	0.0993	0.1985	0.1251	0.3536	0.3969	0.5613	0.3536	0.3536	0.3151	0.3151	0.2501	0.1985	0.1576	0.1404	0.1768	0.1576	0.1251	0.0993	0.0788	4.8092
34	0.0442	0.1114	0.1404	0.2501	0.1768	0.0788	0.2807	0.2501	0.3536	0.5613	0.3969	0.3151	0.2501	0.2807	0.3151	0.2501	0.1985	0.1576	0.1768	0.1576	0.1251	0.0993	4.9703
35	0.0496	0.1576	0.1985	0.2501	0.3536	0.0884	0.2807	0.2807	0.3536	0.3536	0.5613	0.3969	0.2807	0.2501	0.2807	0.1985	0.1251	0.1404	0.1576	0.1251	0.0993	0.0884	5.0705
36	0.0394	0.1985	0.2501	0.1768	0.3151	0.0702	0.2228	0.2501	0.3151	0.3151	0.3969	0.5613	0.2228	0.2501	0.2807	0.1114	0.0788	0.0625	0.0993	0.1404	0.0394	0.0351	4.4319
37	0.0313	0.0993	0.1404	0.2228	0.4455	0.0442	0.1251	0.1404	0.2807	0.2501	0.1985	0.2228	0.5613	0.3969	0.3536	0.2807	0.2228	0.2501	0.2807	0.1985	0.1576	0.1251	5.0284
38	0.0702	0.1114	0.1576	0.2228	0.3536	0.1251	0.3151	0.3536	0.7072	0.2807	0.2501	0.2501	0.3969	0.5613	0.3969	0.2807	0.1985	0.2228	0.3536	0.2501	0.1985	0.1768	6.2336
39	0.1114	0.2228	0.2807	0.3969	0.3969	0.1985	0.3969	0.3536	0.1404	0.3151	0.1985	0.2807	0.3536	0.3969	0.5613	0.3151	0.2228	0.1985	0.2501	0.1768	0.1404	0.1251	6.0330
40	0.1576	0.3536	0.3969	0.3151	0.2501	0.2807	0.3536	0.3969	0.1576	0.7072	0.1985	0.1576	0.2807	0.2807	0.3151	0.5613	0.3969	0.3536	0.2807	0.2228	0.1768	0.1576	6.7516
41	0.0625	0.1768	0.2228	0.2807	0.2228	0.1114	0.3151	0.3536	0.1404	0.1985	0.1251	0.0788	0.2228	0.1985	0.2228	0.3969	0.5613	0.3969	0.3536	0.2807	0.2228	0.1985	5.3433
42	0.0496	0.1251	0.1576	0.1985	0.2501	0.1768	0.3969	0.4455	0.1768	0.1576	0.1404	0.0625	0.2501	0.2228	0.1985	0.3536	0.3969	0.5613	0.3969	0.3151	0.1985	0.1768	5.4079
43	0.0496	0.0884	0.0993	0.1404	0.2807	0.0884	0.2807	0.3151	0.1576	0.1768	0.1576	0.0993	0.2807	0.3536	0.2501	0.2807	0.3536	0.3969	0.5613	0.3536	0.2807	0.2501	5.2952
44	0.0176	0.0496	0.0702	0.1251	0.2501	0.0557	0.2228	0.1985	0.1251	0.1576	0.1251	0.1404	0.1985	0.2501	0.1768	0.2228	0.2807	0.3151	0.3536	0.5613	0.3969	0.3536	4.6472
45	0.0088	0.0351	0.0442	0.0788	0.1576	0.0394	0.0788	0.0557	0.0993	0.1251	0.0993	0.0394	0.1576	0.1985	0.1404	0.1768	0.2228	0.1985	0.2807	0.3969	0.5613	0.3969	3.5919
46	0.0031	0.0055	0.0993	0.0702	0.1404	0.0351	0.0702	0.0442	0.0788	0.0993	0.0884	0.0351	0.1251	0.1768	0.1251	0.1576	0.1985	0.1768	0.2501	0.3536	0.3969	0.5613	3.2914
	2.5159	**4.7849**	**4.7611**	**5.3934**	**6.4366**	**3.6749**	**6.3838**	**6.0678**	**5.1157**	**5.2224**	**4.7850**	**4.4781**	**5.0140**	**5.7765**	**6.2166**	**6.2483**	**5.3433**	**5.3657**	**5.2856**	**4.6420**	**3.5982**	**3.2616**	**110.3714**

Source: Author's Fieldwork (2020)

4.2. Trip distribution in Gboko town

The balanced productions and attractions were arranged or distributed with productions on column axis and attractions on row axis to form Production/Attraction (P/A) matrix for intra and inter zonal trips. The trip productions and attractions were mere trip ends that have no systematic arrangement among the various TAZ. At this stage, the application of gravity equation in conjunction with calibrated impedance factor values resulted into the trip ends systematic arrangement of trips from zone to zone (inter-zone) and within the zone itself (intra-zone) as in Table 6.

Trip productions (row totals) and attractions (column totals) of each TAZ in Table 6 were not equal therefore, Equation 8 was applied to adjust base year trips.

Iteration of base year adjusted trips interchanges continued until the third iteration that the base year trips were balanced as in Table 7.

Horizon year trips were similarly distributed starting with the balanced 2035 productions and attractions arranged on column axis and row axis. The production and attraction (P/A) matrix had blank cells for intra and inter zonal trips. The trip ends attractions were arranged as column totals and trip ends productions as row totals of each TAZ in the horizon year. The Equation 4 was also applied as in Table 8 to distribute trips among the zones resulting into horizon O-D matrix in Gboko town.

Hence horizon trip interchanges for productions and attractions were not equal, iteration of horizon year trips interchanges using Equation 8 continued to adjust trips until it was at the third iteration that the horizon year trips were balanced as in Table 9.

Table 6: Base Year Trip Interchange in Gboko Town

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	P
25	1101	618	155	437	347	275	437	173	138	87	97	77	61	138	218	309	123	195	97	24	11	67	5185
26	618	1101	618	618	550	389	490	195	245	218	309	389	195	218	437	693	347	245	155	97	27	29	8183
27	173	778	1101	693	693	437	618	275	309	275	389	490	275	309	550	778	437	309	195	138	87	77	9386
28	437	693	778	1101	693	550	693	245	195	173	490	347	275	437	778	618	550	389	275	245	155	138	10255
29	347	550	618	693	1101	618	693	1387	275	347	693	618	778	693	778	490	437	490	550	490	309	275	13230
30	275	389	437	550	618	1101	550	309	245	155	173	138	87	245	389	550	218	347	173	109	138	123	7319
31	309	1387	618	693	693	550	1101	693	693	550	389	437	245	618	778	693	618	778	550	437	155	138	13123
32	173	218	275	245	490	309	693	1101	778	490	389	490	275	693	778	778	693	693	618	389	109	87	10764
33	138	245	309	195	389	245	693	778	1101	693	693	618	618	490	389	309	275	347	309	245	195	155	9429
34	87	218	275	490	347	155	550	490	693	1101	778	618	490	550	618	490	389	309	347	309	245	195	9744
35	97	309	389	490	693	173	550	550	693	693	1101	778	550	490	550	389	245	275	309	245	195	173	9937
36	77	389	490	347	618	138	437	490	618	618	778	1101	437	490	550	218	155	123	195	275	77	69	8690
37	61	195	275	437	874	87	245	275	550	490	389	437	1101	778	693	550	437	490	550	389	309	245	9857
38	138	218	309	437	693	245	618	693	1387	550	490	490	778	1101	778	550	389	437	693	490	389	347	12220
39	218	437	550	778	778	389	778	693	275	618	389	550	693	778	1101	618	437	389	490	347	275	245	11826
40	309	693	778	618	490	550	693	778	309	1387	389	309	550	550	618	1101	778	693	550	437	347	309	13236
41	123	347	437	550	437	218	618	693	275	389	245	155	437	389	437	778	1101	778	693	550	437	389	10476
42	97	245	309	389	490	347	778	874	347	309	275	123	490	437	389	693	778	1101	778	618	389	347	10603
43	97	173	195	275	550	173	550	618	309	347	309	195	550	693	490	550	693	778	1101	693	550	490	10379
44	35	97	138	245	490	109	437	389	245	309	245	275	389	490	347	437	550	618	693	1101	778	693	9110
45	17	69	87	155	309	77	155	109	195	245	195	77	309	389	275	347	437	389	550	778	1101	778	7043
46	6	11	195	138	275	69	138	87	155	195	173	69	245	347	245	309	389	347	490	693	778	1101	6455
A	4933	9380	9336	10574	12618	7204	12515	11895	10030	10239	9378	8781	9828	11323	12186	12248	10476	10520	10361	9099	7056	6470	216450

Source: Author's Fieldwork (2020)

Table 7: Base Year Adjusted Trip Interchange in Gboko Town (Third Iteration)

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	P
25	4095	455	276	1080	468	630	875	152	183	126	164	232	101	238	280	264	162	491	80	53	20	205	10630
26	1232	433	591	817	397	476	525	92	172	166	278	629	173	200	296	318	244	332	69	118	27	47	7632
27	403	360	1237	1076	584	628	778	152	256	250	410	930	288	333	436	416	360	489	102	198	101	148	9935
28	1161	365	994	1944	667	898	992	154	183	177	590	748	326	536	703	378	517	700	162	397	207	301	13100
29	580	181	496	771	665	635	626	551	162	225	524	840	583	534	441	188	259	555	205	501	260	378	10160
30	713	199	544	948	581	1753	769	188	228	156	203	290	100	293	342	328	200	611	99	173	180	261	9159
31	578	513	555	862	471	630	1110	308	458	399	329	664	206	533	494	298	409	986	229	501	145	213	10891
32	299	75	229	280	306	327	647	450	476	330	305	688	213	555	457	310	424	813	239	412	96	124	8055
33	256	90	276	242	263	280	694	343	724	500	585	935	517	421	246	132	180	435	129	278	181	237	7944
34	196	98	297	732	284	214	666	261	551	958	790	1128	495	573	471	253	309	471	174	425	277	361	9984
35	225	140	430	748	577	244	682	299	563	618	1146	1454	568	521	430	204	200	429	158	344	225	328	10533
36	211	211	647	632	612	232	645	317	598	655	963	2449	536	620	512	137	149	229	120	461	105	156	11197
37	114	73	248	543	592	101	247	121	364	356	329	664	925	674	440	237	288	622	229	444	290	375	8276
38	232	73	249	489	423	253	561	277	826	359	373	669	588	857	444	213	231	498	260	504	324	480	9183
39	538	213	652	1275	695	590	1034	405	241	590	434	1103	766	888	923	350	381	649	266	523	341	498	13355
40	425	188	513	563	244	464	513	252	155	738	242	344	339	349	288	346	377	644	169	366	239	348	8106
41	272	151	464	806	350	296	735	363	216	333	245	277	433	397	327	395	857	1164	342	741	484	705	10353
42	204	100	312	544	372	449	881	435	259	252	262	210	463	425	277	335	576	1569	365	793	410	602	10095
43	123	50	138	270	295	157	438	216	161	203	216	250	368	472	246	187	362	778	363	626	407	584	6910
44	84	47	160	392	428	161	568	222	209	293	266	538	421	552	283	235	467	1011	373	1620	939	1372	10641
45	41	33	99	249	270	114	200	62	164	228	211	149	336	431	224	191	371	632	295	1142	1324	1534	8300
46	22	8	339	332	361	152	270	74	198	274	283	202	399	581	302	257	494	852	395	1533	1410	3273	12011
A	12004	4056	9746	15595	9905	9684	14456	5694	7347	8186	9148	15393	9144	10983	8862	5972	7817	14960	4823	12153	7992	12530	**216450**

Source: Author's Fieldwork (2020)

Table 8: Horizon Year Trip Interchange in Gboko Town

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	P
25	3900	2189	548	1548	1228	975	1548	614	488	307	345	274	217	488	774	1095	434	690	345	86	38	80	18211
26	2189	3900	2189	2189	1950	1379	1738	690	869	774	1095	1379	690	774	1548	2457	1228	869	548	345	97	54	28951
27	614	2758	3900	2457	2457	1548	2189	975	1095	975	1379	1738	975	1095	1950	2758	1548	1095	690	488	307	274	33265
28	1548	2457	2758	3900	2457	1950	2457	869	690	614	1738	1228	975	1548	2758	2189	1950	1379	975	869	548	488	36345
29	1228	1950	2189	2457	3900	2189	2457	4914	975	1228	2457	2189	2758	2457	2758	1738	1548	1738	1950	1738	1095	975	46888
30	975	1379	1548	1950	2189	3900	1950	1095	869	548	614	488	307	869	1379	1950	774	1228	614	387	488	434	25935
31	1095	4914	2189	2457	2457	1950	3900	2457	2457	1950	1379	1548	869	2189	2758	2457	2189	2758	1950	1548	548	488	46507
32	614	774	975	869	1738	1095	2457	3900	2758	1738	1379	1738	975	2457	2758	2758	2457	2457	2189	1379	387	307	38159
33	488	869	1095	690	1379	869	2457	2758	3900	2457	2457	2189	2189	1738	1379	1095	975	1228	1095	869	690	548	33414
34	307	774	975	1738	1228	548	1950	1738	2457	3900	2758	2189	1738	1950	2189	1738	1379	1095	1228	1095	869	690	34533
35	345	1095	1379	1738	2457	614	1950	1950	2457	2457	3900	2758	1950	1738	1950	1379	869	975	1095	869	690	614	35229
36	274	1379	1738	1228	2189	488	1548	1738	2189	2189	2758	3900	1548	1738	1950	774	548	434	690	975	274	244	30793
37	217	690	975	1548	3095	307	869	975	1950	1738	1379	1548	3900	2758	2457	1950	1548	1738	1950	1379	1095	869	34935
38	488	774	1095	1548	2457	869	2189	2457	4914	1950	1738	1738	2758	3900	2758	1950	1379	1548	2457	1738	1379	1228	43312
39	774	1548	1950	2758	2758	1379	2758	2457	975	2189	1379	1950	2457	2758	3900	2189	1548	1379	1738	1228	975	869	41916
40	1095	2457	2758	2189	1738	1950	2457	2758	1095	4914	1379	1095	1950	1950	2189	3900	2758	2457	1950	1548	1228	1095	46910
41	434	1228	1548	1950	1548	774	2189	2457	975	1379	869	548	1548	1379	1548	2758	3900	2758	2457	1950	1548	1379	37124
42	345	869	1095	1379	1738	1228	2758	3095	1228	1095	975	434	1738	1548	1379	2457	2758	3900	2758	2189	1379	1228	37573
43	345	614	690	975	1950	614	1950	2189	1095	1228	1095	690	1950	2457	1738	1950	2457	2758	3900	2457	1950	1738	36790
44	122	345	488	869	1738	387	1548	1379	869	1095	869	975	1379	1738	1228	1548	1950	2189	2457	3900	2758	2457	32288
45	61	244	307	548	1095	274	548	387	690	869	690	274	1095	1379	975	1228	1548	1379	1950	2758	3900	2758	24957
46	22	38	690	488	975	244	488	307	548	690	614	244	869	1228	869	1095	1379	1228	1738	2457	2758	3900	22869
A	17480	33245	33079	37473	44721	25531	44355	42159	35543	36284	33246	31114	34835	40136	43192	43413	37124	37280	36724	32252	25001	22717	**766904**

Source: Author's Fieldwork (2020)

Table 9: Horizon Year Adjusted Trips (Third Iteration)

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	P
25	15284	1708	1041	4017	1749	2379	3342	587	197	482	630	899	391	891	1034	984	597	1839	301	204	74	63	38693
26	4483	1592	2170	2969	1451	1760	1961	345	181	632	1045	2365	649	740	1081	1154	886	1211	249	427	98	331	27780
27	1502	1343	4621	3982	2185	2362	2952	583	276	952	1574	3562	1096	1249	1626	1550	1333	1823	375	722	370	125	36163
28	4265	1347	3678	7119	2460	3350	3728	584	195	675	2233	2831	1233	1988	2593	1385	1891	2588	599	1443	746	753	47684
29	2106	657	1815	2791	2429	2340	2321	2061	170	839	1964	3141	2169	1962	1612	690	935	2027	743	1799	927	1484	36982
30	2550	718	1958	3379	2080	6355	2810	700	234	572	749	1069	370	1060	1231	1169	714	2185	358	607	632	1839	33339
31	2122	1897	2053	3154	1732	2356	4163	1164	488	1507	1246	2511	774	1976	1822	1092	1493	3636	836	1811	523	1287	39643
32	1106	277	849	1036	1135	1226	2432	1714	510	1246	1154	2614	803	2057	1692	1137	1555	3006	874	1496	343	1058	29320
33	258	91	280	241	264	285	714	356	211	518	604	967	530	428	248	133	181	441	128	276	180	610	7944
34	749	376	1153	2810	1089	833	2622	1038	614	3800	3139	4474	1945	2219	1822	974	1186	1819	667	1610	1047	356	36342
35	822	520	1590	2743	2127	911	2558	1136	600	2334	4331	5496	2131	1930	1582	752	730	1576	580	1248	811	1832	38340
36	768	770	2358	2278	2228	852	2390	1192	630	2447	3605	9149	1989	2269	1861	498	540	829	431	1651	379	1643	40757
37	435	275	948	2056	2255	387	959	477	402	1389	1288	2600	3589	2579	1680	896	1092	2372	870	1670	1085	821	30125
38	889	280	968	1869	1629	988	2197	1100	919	1419	1477	2651	2306	3313	1714	814	887	1920	995	1913	1242	1936	33426
39	1938	771	2363	4573	2508	2152	3802	1504	250	2186	1610	4084	2822	3218	3329	1257	1363	2350	966	1852	1205	2509	48612
40	1488	666	1814	1970	857	1651	1841	917	154	2668	874	1248	1217	1234	1016	1217	1320	2274	591	1269	824	2396	29506
41	1016	571	1754	3024	1315	1129	2823	1406	233	1287	948	1074	1662	1503	1237	1481	3214	4393	1277	2755	1788	1795	37685
42	727	364	1117	1926	1331	1613	3200	1597	264	920	959	765	1681	1521	990	1188	2047	5593	1294	2785	1434	3430	36746
43	513	180	495	959	1052	567	1595	792	166	727	756	858	1326	1698	881	663	1283	2783	1287	2200	1428	2943	25152
44	321	181	628	1521	1667	638	2250	888	235	1154	1069	2153	1669	2138	1105	937	1812	3933	1444	6217	3595	3178	38733
45	146	117	357	872	956	410	730	228	169	832	778	550	1206	1542	800	676	1309	2253	1040	3997	4623	6621	30212
46	115	32	1394	1359	1480	636	1122	313	234	1149	1197	854	1658	2383	1237	1048	2026	3492	1616	6194	5676	8505	43720
A	43603	14733	35404	56648	35979	35180	52512	20682	7332	29735	33230	55915	33216	39898	32193	21695	28394	54343	17521	44146	29030	45515	**766904**

Source: Author's Fieldwork (2020)

4.3. Household Trips Pattern in Gboko Town

Trip length frequency of each trip segment was the determinant of household trip pattern in Gboko town. Trip length segment was the determinant factor to assess household trip patterns in Gboko town. It was used to compare the increase in number of projected trips for the horizon year (2035) with the base year (2019) in Gboko town as in Table 10.

Table 10 shows that 25-minutes trips were dormant in Gboko town with 17.01 % annual increase. Although 5-minute trips accounted for 12.99 %, long duration travels between 40-minutes and above recorded 35.92 %. This implied that it does not take much time for people to reach their destinations in Gboko town despite the large expanse of the town. Although the trips have short length that make commuters candidates for walking and bicycling (use of non-motorised mode of transport), a substantial share of these trips could be done on cars.

From the result of the analysis, population, household income and vehicle ownership were significant attributes to trip production, while land value, job location and number of workers were significant for trip attractions in Gboko town. This agrees with (Nwafor, et al., 2018; Solanke, 2014; Solanke, 2015) that the population, number of workers in household and income contributes significantly and overwhelmingly to the household trip generation.

These attributes enabled trip generation and attraction in the town. It was also found that 25-minute trips were dormant in Gboko town with a 17.01 % annual increase. The suggestion of the results of the study is that 25-minutes travel journeys would be more when compared to other trip length frequencies in the study area. This means, it would take much longer time and distance for people to reach their destination in Gboko town due to large expanse of the town, deficiency of public transit facilities and poor infrastructure. Also the more the trip length, the longer the distance a commuter has to cover.

Table 10: Trip length segment for Gboko town

	2019 Trips	2035 Trips	Change in Trips	16-yr.% change	1-yr % change
5 min	33021	101655	68634	207.85	12.99
10 min	66500	246146	179646	270.14	16.88
15 min	73083	263751	190668	260.89	16.31
20 min	29105	102309	73204	251.52	15.72
25 min	9504	35363	25859	272.09	17.01
30 min	3564	12867	9303	261.03	16.31
35 min	738	2114	1376	186.45	11.65
40 min	734	2096	1362	185.56	11.60
45 min	116	383	267	230.17	14.39

50 min	85	220	135	158.82	9.93
	216450	**766904**			

Source: Author's Fieldwork (2020)

5. Conclusion

Trip generation and distribution models for Gboko town were developed for the base year (2019) and were used to forecast travel demand in origin-destination trip matrices for the horizon year (2035). These models provided accurate scenarios of the current travel pattern in the town and aided in forecasting the future travel situations in the study area.

The study recommended that urban transportation policies should encourage the provision and use of walking, bicycles, and public transit buses. The government should provide incentives to motivate public transit users, and there should be an improvement in the road network system, as such measures would reduce the frequency of trips in the town.

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