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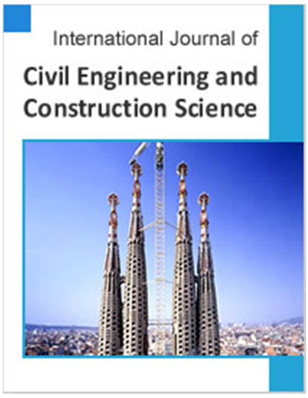

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Trip Generation Model for Makurdi Metropolis, Benue State

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Abstract
Trip generation models help planners anticipate where transportation services will be in the future and it is a fundamental operation within any urban transport planning system. Increase rate of urbanization have increased the population of Makurdi and commercial activities in the city. This have made Land prices and rental rates to escalate in the city centers, which force establishments and housing to move to the city peripherals and thus further increasing everyday commuting. Trip generation and distribution model of Makurdi metropolis was developed for the base year (2015) and this model was used to forecast travel demand in origin-destination trip matrices for the horizon year (2025). The study area was divided into nine zones (according to the council ward of Makurdi) to facilitate collection of data. Data on intra-city travel characteristics were collected through questionnaire distribution, National Population Commission, Ministry of Land and Survey Board. The analysis of data were done with the aid of computer software such as Microsoft excel and SPSS. A mathematical model was developed and the result shows that that the total number of trips made in each trip length segment increased for the horizon year (2025) as compared to the base year (2015), this was due to increase in population of trip makers in each trip length segment in year 2025. It was also found that 5 minute trips have the highest number of trips which are the intra-zonal trips and 10 minute trips have the highest percentage increase of 45.75%.

1. Introduction

The basic purpose of transportation planning and management identify where transportation demand and supply will be in the future. A thorough understanding of existing travel pattern is necessary for identifying and analyzing existing traffic related problems. Detailed data on current travel pattern and traffic volumes are needed for developing travel forecasting/prediction models. The prediction of future travel demand is an essential task of the long-range transportation planning process for determining strategies for accommodating future needs. These strategies may include land use policies, pricing programs and expansion of transportation supply-highway and transit service [1].

Trip generation is the first step of the four-step modelling procedure. It is a very important step since it sets up not only the frame work for the following tasks but also some of the controlling values such as the total number of trips generated in the study area by location and trip purpose. The commonly used units for trip generation analysis usually include a household, a dwelling unit (DU) and a business establishment. However, the results of a trip generation analysis for a study area are aggregated based on larger area as traffic zone [2].

These trips are predicted on either the household or individual level within each travel analysis zones (TAZs) and are defined by trip purpose [3]. Observed travel information gathered by travel surveys and other sources are used to generate the predictions from the regression and cross-classification models [4]. Productions and attractions are forecasted separately and are not equal within the analysis zone because they come from different data sources and are estimated by different prediction methods. Adjustments that constrain the attractions to equal the productions must be made to balance these discrepancies. The final results of this step are the so called "trip ends" for each TAZ [5].

As stated above, trip generation is utilized to predict the total number of trips into and out of each TAZ. The trips generated include both departure and arrival trips. These trip ends are commonly referred to as productions (trip origins) and attractions (trip destinations). Productions and attractions are forecasted separately and are not equal within the analysis zone because they come from different data sources and are estimated by different prediction methods. Data on trip attraction by location are often more difficult to collect depending on trip purpose [6]. Variables that have often been used for predicting trip attractions include employment level and densities, value of land, residential density and location accessibility [7].

The second step of the trip-based model is trip distribution. The purpose of this step is to connect the trip ends determined in trip generation, resulting in a matrix comprised of origin-to-destination trip volumes to and from each TAZ. The most common approach to predict the origin and destination zones is a spatial interaction (SI) mode such as the gravity model. This model is derived from Newtons Law of Gravity and uses the following equation [8].

For modelling 'Link Impedance' can be expressed as distance but travel time or apparent costs are usually better measures. Arbitrary units that are functions of impedance factors may be more convenient than actual measurable quantities for modelling purposes. Such factors can be determined by calibration of some distribution function such as a Gravity Model with a known distribution pattern obtained from an origin - destination survey [9].

1.1. Description of the Study Area

Makurdi town is made up largely of people who engage in civil service duties, commercial activities and agrarian peasantry. The town is a built up area with the highest concentration of people in high level and Wadata. Dense population also exists in some low-lying parts of the town such as Wurukum [10]. The study area is divided into nine traffic analysis zones (TAZ) based on the council ward of the town as shown below.

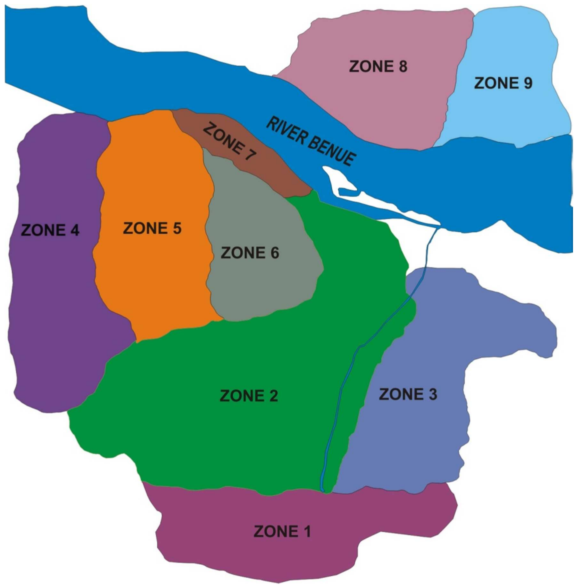

Figure 1. *Map of Makurdi Showing the Nine Zone of the Study Area.*

1.2. Aim and Objectives

The aim of this research is to develop trip generation model for transportation demand in Makurdi.

The objectives of this study are to:

i. collect data on trip characteristics in the study area

ii. fit the data to trip generation and trip distribution

2. Methodology

2.1. Source of Data

Primary and secondary data were used for this study. Inventory of existing geographical and socio-economic activity such as average income of the zones, total number of people employed and travel time were collected from questionnaire distribution while total population of the zones was collected from National Population Commission [11]. Inventory of existing land use such as value of land was collected from State Land and Survey Board

2.2. Sample Size and Growth Rate

The study area was divided into nine (9) different sampling zones and the recommended sample sizes are shown in table 1 and the growth rates of independent variables are shown in table 2

Table 1. *Sample Size.*

Population of Study Area	Sample Size
Under 50,000	20% (1 in 5)
50,000 to 150,000	12 ½% (1 in 8)
150,000 to 300,000	10% (1 in 10)
300,000 to 500,000	6.67% (1 in 15)
500,000 to 1,000,000	5% (1 in 5)
Over 1,000,000	4% (1 in 25)

Source: (field data)

Table 2. *Growth Rates of Different Variables After 10 Years.*

Variable	Growth Rate (%)
Population	3.2
Income	4.1
Value of Land	32
Employment	2.3

Using 2006 population figure of 300377 and table 2, the projected population of Makurdi in 2015 was estimated to be 398275. The estimation was based on equation (1) [12]

$$P = P_0(1 + r)^n \quad (1)$$

Where:

n = number of year of projection

r = growth rate

P_0 = population size at time zero

P = projected population at a time n year later

Considering the projected population a sample size of 1 in 15 (6.67%) was adopted.

Table 3. *Number of Households in Different Zones.*

Zones	Number of Households	Number of Households Interviewed
1	6706	447
2	18971	1265
3	19909	1328
4	9525	635
5	7108	474
6	6686	446
7	6930	462
8	4753	317
9	6260	418
Total	86848	5793

Source: Field Data

Using table 1 and the equation (2) below, tables 4 and 5 were developed.

$$Population\ After\ 10\ Years = Existing\ Population(1 + 0.032)^{10} \quad (2)$$

Table 4. *Variables Used for Regression Equation of Trip Generation.*

TAZ	Existing			After 10 Years	
	TP (X1)	AI (X2)	TT/D (Y)	TP (X1)	AI (X2)
Zone 1	24625	17988	27011	33742	26884
Zone 2	69663	50891	76412	95456	76058
Zone 3	72169	62424	87429	98889	93295
Zone 4	59580	51605	61566	81639	77125
Zone 5	35447	30704	36629	48571	45888
Zone 6	33339	28878	37878	45683	43159
Zone 7	34557	29934	39262	47351	44738
Zone 8	29928	25466	30286	41009	38059
Zone 9	39417	33539	39889	54010	50125

TP = Total Population, AI = Average Income, TT/D = Total Trip Per Day

Source: Field Data

Table 5. *Variables Used for Regression Equation of Trip Attraction.*

TAZ	Existing			After 10 Years	
	TE (X1)	VL (Million) (X2)	DWTA (Y)	TE (X1)	LP (Million) (X2)
Zone 1	6727	3.5	7094	8445	4.7
Zone 2	19031	8.5	20069	23890	11.42
Zone 3	23344	2.7	28940	29304	3.6
Zone 4	19298	1.8	15040	24225	2.4
Zone 5	11482	3.6	8948	14414	4.8
Zone 6	10799	7.5	8288	13556	10.1
Zone 7	11194	2.9	9352	14052	3.9
Zone 8	9523	1.9	8169	11954	2.6
Zone 9	12542	2.5	10759	15744	3.4

TE = Total Employment, VL = Value of Land, DWTA = Daily Work Trip Attraction

Source: Field Data

Table 6. *Cost Matrix Table (C_{ij}) in Terms of Time.*

O-D/Zone	1	2	3	4	5	6	7	8	9
1	5	11	14	20	18	16	21	27	30
2	10	5	16	18	16	12	18	23	26
3	12	14	5	25	21	19	23	24	17
4	19	17	23	5	12	16	19	26	29
5	17	15	22	12	5	10	15	22	28
6	16	12	20	15	10	5	9	16	22
7	20	17	25	18	14	9	5	12	18
8	27	23	26	25	21	16	12	5	11
9	30	25	18	28	27	21	18	11	5

Source: Field Data

3. Result

3.1. Trip Generation

Trip generation and attraction model was developed in equation (3) and (4):

$$Y_{generation} = -4166 + 1.00542x_1 + 0.2202x_2 \quad (3)$$

$$Y_{attraction} = -4473.798 + 1.244a_1 + 81.178a_2 \quad (4)$$

Where:

x_1 = Total Population

x_2 = Income of Household

a_1 = Total Employment

a_2 = Value of Land

$Y_{Generation}$ = Total Trip per Day

$Y_{Attraction}$ = Total Daily Work Trip

Tables 7, 8, 9 and 10 show the model summary and coefficient for trip generation and attraction

Table 7. *Model Summary for Trip Generation.*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.988	0.976	0.968	3809.028

a. Predictors: (Constant), IC (X2), TP (X1)

Table 8. *Model Coefficients for Trip Generation.*

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
	(Constant)	-4166.72	3618.441		-1.152	0.293
1	TP (X1)	1.005	0.376	0.84	2.674	0.037
	AI (X2)	0.22	0.46	0.15	0.479	0.649

a. Dependent Variable: TT/D (Y)

Table 9. *Model Summary for Trip Attraction.*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.988[a]	.976	.968	3809.028

a. Predictors: (Constant), VL (X2), TE (X1)

Table 10. *Model Coefficients for Trip Attraction.*

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
	(Constant)	-4166.72	3618.441		-1.152	0.293
1	TE (X1)	1.005	0.376	0.84	2.674	0.037
	VL (X2)	0.22	0.46	0.15	0.479	0.649

a. Dependent Variable: DWTA (Y)

3.2. Horizon Year (2025) Trip Generation and Attraction

Using these regression equations, horizon year trips for both trip generation and attraction after 10 years were calculated as shown in table 11

$$\text{Trip Generation} = x_0 + (x_1 \text{ x Horizon Year Population}) + (x_2 \text{x Horizon Year household}) \quad (5)$$

$$\text{Trip Attraction} = a_0 + (a_1 \text{ x Horizon Year Employment}) + (a_2 \text{ x Horizon Year Value of Land}) \quad (6)$$

Table 11 shows the total trip generation and attraction for base year and horizon year

Table 11. *Total Trip Production and Attraction for Base and Horizon Year.*

TAZ	Base Year (2015)		Horizon Year (2025)	
	Generation (Pi)	Attraction (Aj)	Generation (Pi)	Attraction (Aj)
	TT/P/D	TT/P/D	TT/P/D	TT/P/D
Zone 1	24552	4179	35677	6413
Zone 2	77079	19891	108553	26172
Zone 3	82138	24785	115800	32273
Zone 4	67098	19679	94896	25857
Zone 5	38233	10102	54771	13789
Zone 6	35711	9569	51267	13210
Zone 7	37168	9687	53291	13323
Zone 8	31531	7527	45444	10608
Zone 9	42848	11331	61172	15388
TOTAL	436358	116750	620871	157033

TT/P/D = Total Trip Per Person Per Day

3.3. Trip Distribution

From table 11 it was found that the total trip production and total trip attraction was not equal. But from the theory of trip distribution model, the total trip attraction/destination must be equal to total trip generation and also the trip generation is considered to be exact. For this reason the trip attraction for different zones was multiplied by an adjustment factor as shown below:

$$Adjustment\ Factor\ for\ Base\ Year = \frac{Total\ Base\ Year\ Generation}{Total\ Base\ year\ Attraction} = 3.738$$

$$Adjustment\ Factor\ for\ Horizon\ Year = \frac{Total\ Horizon\ Year\ Generation}{Total\ Horizon\ Year\ Attraction} = 3.954$$

$$Adjusted\ Trip\ Attraction = Adjusted\ Factor\ x\ Trip\ Attraction\ of\ any\ Zone \quad (7)$$

Table 12 show the adjusted total trip generated and attracted for base and horizon year

Table 12. *Adjusted Total Trip Generation and Attraction for Base and Horizon Year.*

TAZ	Base Year (2015)		Horizon Year (2025)	
	Generation (Pi)	Attraction (Aj)	Generation (Pi)	Attraction (Aj)
	TT/P/D	TT/P/D	TT/P/D	TT/P/D
Zone 1	24552	15619	6413	25355
Zone 2	77079	74343	26172	103478
Zone 3	82138	92635	32273	127600
Zone 4	67098	73551	25857	102232
Zone 5	38233	37757	13789	54518
Zone 6	35711	35765	13210	52229
Zone 7	37168	36206	13323	52676
Zone 8	31531	28132	10608	41941
Zone 9	42848	42350	15388	60840
TOTAL	436358	436358	620871	620871

TT/P/D = Total Trip per Person per Day

$$\text{Impedance Factor} = e^{-\beta C_{ij}} \quad (8)$$

The impedance factor in Table 13 was calculated using equation 8

Table 13. *Impedance Factor Table.*

O-D/Zone	1	2	3	4	5	6	7	8	9
1	0.6065	0.3329	0.2466	0.1353	0.1653	0.2019	0.1225	0.0672	0.0498
2	0.3679	0.6065	0.2019	0.1653	0.2019	0.3012	0.1653	0.1003	0.0743
3	0.3012	0.2466	0.6065	0.0821	0.1225	0.1496	0.1003	0.0907	0.1827
4	0.1496	0.1827	0.1003	0.6065	0.3012	0.2019	0.1496	0.0743	0.055
5	0.1827	0.2231	0.1108	0.3012	0.6065	0.3679	0.2231	0.1108	0.0608
6	0.2019	0.3012	0.1353	0.2231	0.3679	0.6065	0.4066	0.2019	0.3012
7	0.1353	0.1827	0.0821	0.1653	0.2466	0.4066	0.6065	0.3012	0.1653
8	0.0672	0.1003	0.0743	0.0821	0.1225	0.2019	0.3012	0.6065	0.3329
9	0.0498	0.0821	0.1653	0.0608	0.0672	0.1225	0.1653	0.3329	0.6065

Trip for each zone to different zones was calculated using equation 9

$$T_{ij} = \frac{P_i A_{jk} F_{ij} K_{ij}}{\sum_{j=1}^{9} A_{jk} F_{ij} K_{ij}} \quad (9)$$

Where:

T_{ij} = Number of trips produced in zone i and attracted to zone j

P_i = Number of trips produced in zone i

A_j = Number of trips attracted to zone j

F_{ij} = Generalize cost function of travel from i to j

K_{ij} = Zone-to-zone adjustment factor

Tables 15 and 16 shows the trip interchange for the first iteration

Table 14. *Trip Interchange for Base Year – Iteration One.*

T_{ij} Iteration One										Target O_i
O – D/Zone	1	2	3	4	5	6	7	8	9	$\sum O_i$
1	2616	6834	6308	2748	1723	1994	1225	522	582	24552
2	3953	31018	12866	8364	5244	7411	4117	1941	2165	77079
3	3540	13795	42277	4544	3480	4026	2733	1920	5822	82138
4	1596	9276	6345	30465	7767	4932	3699	1427	1591	67098
5	1073	6236	3859	8330	8610	4947	3037	1172	968	38233
6	914	6489	3632	4755	4026	6286	4266	1646	3697	35711
7	812	5218	2922	4671	3577	5587	8436	3255	2689	37168
8	439	3121	2881	2527	1936	3022	4564	7141	5900	31531
9	447	3505	8793	2568	1457	2516	3437	5378	14749	42848
Total $\sum D_j$	15389	85493	89883	68972	37820	40720	35514	24402	38164	
Target $\sum D_j$	15619	74343	92635	73551	37757	35765	36206	28132	42350	463353

Table 15. *Trip Interchange for Horizon Year – Iteration One.*

Tij Iteration One										**Target O_i**
O – D/Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**$\sum O_i$**
1	4321	9679	8841	3886	2532	2963	1813	792	851	35677
2	6372	42868	17597	11543	7519	10745	5948	2873	3088	108553
3	5756	19234	58332	6326	5034	5889	3982	2867	8378	115800
4	2593	12925	8749	42388	11226	7209	5387	2130	2288	94896
5	1749	8719	5339	11629	12487	7257	4438	1755	1397	54771
6	1489	9063	5020	6632	5832	9211	6228	2462	5329	51267
7	1315	7247	4016	6478	5153	8140	12246	4842	3855	53291
8	712	4338	3962	3508	2791	4407	6631	10631	8465	45444
9	724	4871	12093	3564	2100	3668	4992	8005	21155	61172
Total $\sum D_j$	24876	116992	121801	90089	52132	56943	49141	34334	51514	
Target $\sum D_j$	25355	103478	127600	102232	54518	52229	52676	41941	60840	620871

From tables 15 and 16 it was found that the total trip generated after the distribution, match with the corresponding target values, but the total trip attractions do not equal the target attractions. Further iterations were carried out using Microsoft excel program. The final-destination matrices for trip distribution among different zones for the base and horizon year were obtained as shown in tables 16 and 17

Table 16. *Adjusted Trip Distribution for Different Zones (Base Year).*

Tij Iteration One										**Target O_i**
O – D/Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**$\sum O_i$**
1	2691	6011	6681	3012	1760	1792	1290	633	683	24552
2	4158	27894	13933	9373	5476	6810	4433	2407	2595	77079
3	3530	11761	43403	4827	3446	3507	2789	2257	6618	82138
4	1579	7846	6464	32112	7629	4263	3746	1665	1794	67098
5	1088	5405	4028	8996	8665	4381	3151	1401	1119	38233
6	925	5616	3786	5129	4046	5559	4421	1964	4265	35711
7	811	4454	3003	4968	3546	4873	8622	3831	3061	37168
8	418	2538	2821	2561	1828	2512	4445	8009	6399	31531
9	420	2819	8517	2574	1361	2068	3309	5964	15816	42848
Total $\sum D_j$	15619	74343	92635	73551	37757	35765	36206	28132	42350	463353
Target $\sum D_j$	15619	74343	92635	73551	37757	35765	36206	28132	42350	463353

Table 17. *Adjusted Trip Distribution for Different Zones (Horizon Year).*

Tij Iteration One										**Target Oi**
O – D/Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**$\sum O_i$**
1	4436	8518	9353	4254	2583	2662	1910	962	999	35677
2	6686	38555	19024	12912	7837	9867	6403	3566	3704	108553
3	5732	16416	59843	6716	4979	5132	4068	3377	9537	115800
4	2563	10951	8911	44671	11024	6236	5464	2491	2585	94896
5	1771	7565	5569	12551	12558	6429	4610	2101	1617	54771
6	1504	7848	5225	7143	5853	8143	6455	2942	6154	51267
7	1310	6186	4120	6877	5098	7094	12513	5704	4389	53291
8	675	3525	3870	3545	2629	3656	6450	11920	9174	45444
9	679	3915	11684	3563	1957	3010	4803	8879	22681	61172
Total $\sum D_j$	25355	103478	127600	102232	54518	52229	52676	41941	60840	620871
Target $\sum D_j$	25355	103478	127600	102232	54518	52229	52676	41941	60840	620871

Figure 2 shows that the total number of trips made in each trip length segment increased for the horizon year (2025) as compared to the base year (2015).

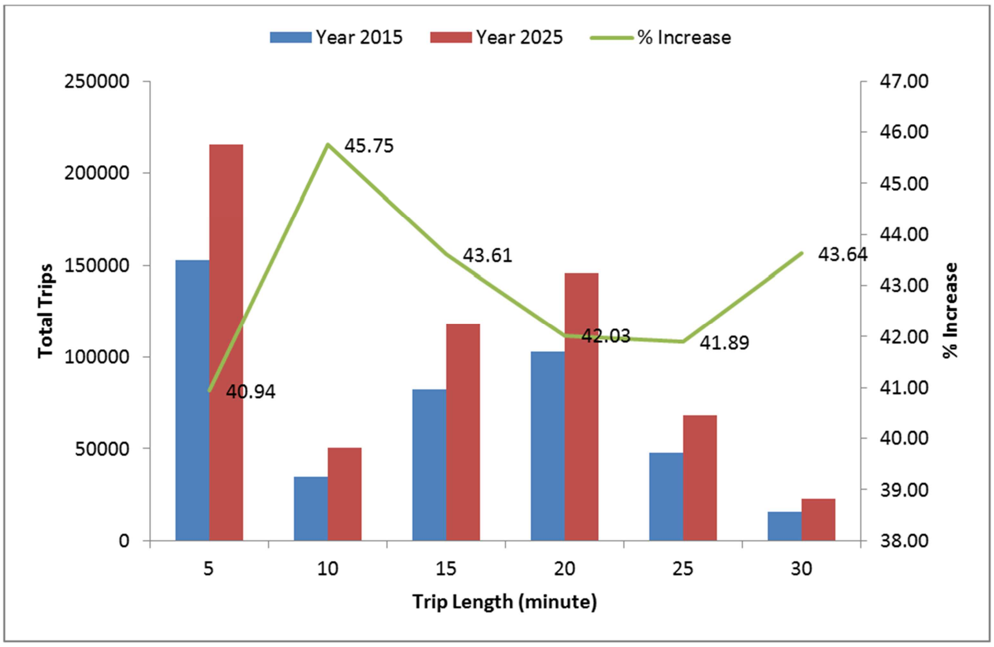

Figure 2. *Percentage Increase in Each Trip Length Segment.*

4. Discussion of Result

4.1. Over All Model Fit

The trip generation and attraction model in table 7 and 8 show that the positive sign of the coefficients of total population, income of household, total employment and value of land have increasing effect on the total trip generated in the zones. i.e. the higher the population the higher the trip generated. Also, the negative sign of the constant was due to the skewness of the independent variables (income and value of land). This was due to the fact that the income of employees in Makurdi is not spread within the nine zones (negative skew). This was confirmed in the annual abstract, 2012 which state that 70% of the population of Makurdi were low income earners. The value of land (land price) was also not spread within the nine zones i.e. the price of land in all the zones have little difference. Overall model fit for trip generation and attraction was deemed good. The R^2 value for trip generation was 0.988 and that for attraction was 0.879 which implies that 98.8% and 87.9% of the variance of the dependent variable can be explained by the model.

4.2. Validity Tests

Using 95% confidence level (5% significant), the test of significance showed that the coefficient of total population and total employment were significant while the constant terms and the coefficients of income of household and value of land were not significant.

4.3. Trip Length Segment

Figure 2 shows that the total number of trips made in each trip length segment increased for the horizon year (2025) as compared to the base year (2015), this was due to increase in population of trip makers in each trip length segment in year 2025. It was also found that 5 minute trips have the highest number of trips which are the intra-zonal trips and 10 minute trips have the highest percentage increase of 45.75%.

5. Conclusion

Trip generation model of Makurdi was developed for the base year (2015) which was used to forecast travel demand in origin-destination trip matrices for the horizon year (2025). Based on the results of the analysis carried out it was found the total population and total employment was significant while the constant terms and the coefficients of income of household and value of land were not significant for the trip generation model. Also from the trip distribution model, it was found that 5 minute trips have the highest number of trips which are the intra-zonal trips and 10 minute trips have the highest percentage increase of 45.75%.

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