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Modelling of Turning Traffic Volume In Ibadan, Nigeria using Linear and Hybrid Furness-Fratar Techniques

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Abstract: Estimation for inflow and outflow traffic volumes are often carried out manually and electronically. These are used for road design planning and management. The time, labour and financial demand are often high and needed serious consideration. This has thus formed the basis of this work. objective of this work is directed at reducing the time, labour and financial demand associated with traffic volume count. Two new traffic models namely linear lagragian and hybrid furness-fratar models were developed. The models were used to investigate an intersection with five legs at Ibadan, Nigeria. The predicted traffic volume when one of the legs was treated as unknown was compared with the field values. Thereafter turning traffic volumes estimate for all the legs was carried out using furness model.

The model estimates using linear lagragian showed that estimate of leg with least traffic volume are closer to the field values than when legs with high traffic volume were considered. The hybrid furness-fratar model did not give a clearly defined pattern The U- turn traffic volumes for all the legs were less than 0.05 % when compared with the outflow volume. This suggests that U-turn is very unusual at this intersection and should be taken into consideration at any future development.

Keywords: *Traffic, Turning volume, Furness model, Fratar Model, Hybrid Model*

I. INTRODUCTION

In Nigeria, road transportation is the dominant form of transportation[1]. As such increasing attention is being required for its management. The demand of traffic engineer is to majorly improve on the efficiency of an existing system rather than to build new higher capacity roads[2]. There were considerable efforts in the development of traffic theories in 1905's.. Some of the seminal works of that period include the works by Newell[3], Webster[4], Edie and Foote[5], Chandler et al[6] and other papers by Herman et al[7]. Turning traffic volumes are important part of the analysis of any intersection, to measure turning traffic volumes, vehicles must be tracked through the intersection from their approach leg to their exit leg. Turning traffic volumes are important part of the analysis of any intersection, to measure turning traffic volumes, vehicles must be tracked through the intersection from their approach leg to their exit leg. Michael et al[8] evaluated that an alternative to directly measuring turning movement volumes through field observations is to estimate them. Bell[9]; Cremer and Keller[10]; Nihan and Davis[11][11]earlier described some turning movement estimation procedures. Adebisi[12] used published algorithms to improve manually counted turning traffic volume at road junctions. Notable models such as furness and fratar models have been developed for estimation of turning traffic volume. These models which can be used to predict reliably turnings at intersections require complete inflow and outflow volumes at each leg of the intersection. Shiliang et.al[13] discussed Markov Chain approach of estimating traffic volume in cases there are missed days. For a city like Ibadan, there may be one leg without information about the inflow and outflow traffic volume. In the light of this, there is the need to develop suitable turning traffic model for cases when there are missing or incomplete information of a leg in an intersection

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II. DESCRIPTION OF STUDY AREA SELECTED INTERSECTIONS

The models to be developed are expected to be used to carry out traffic study in the city of Ibadan, Nigeria. Ibadan, city in southwestern Nigeria, capital of Oyo State, located about 110 km (about 70 mi) northeast of Lagos. Ibadan is a major transit point between the coast and areas to the north. The city is on the railroad line linking Lagos with Kano and is well connected by road to other cities in the region

III. MULTI-LEG INTERSECTION

This is a converging point for vehicles coming from the northern and eastern parts of the country and as well as from Lagos, the largest commercial city in Nigeria. A sketch of the intersection is shown in Figure 2

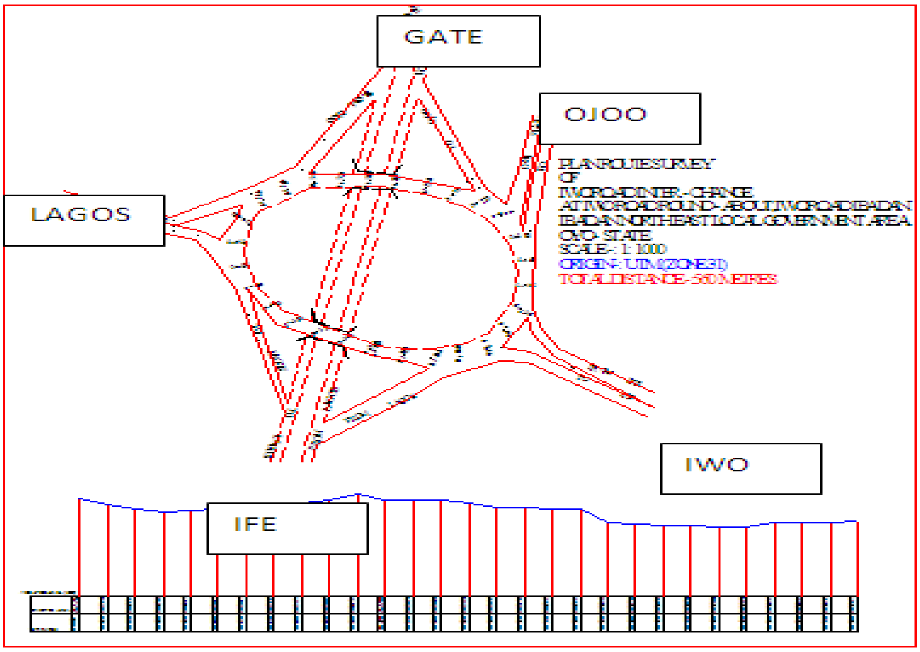

Fig. 1: A Multi Leg Intersection at Iwo road, Ibadan.

Development of Linear and Hybrid Model of Fratar and Furness

Given a junction with m-legs the inflow and outflow then x_1, x_2………………x_m are outflow from each of the legs while x_{n+1+}, x_{n+2+}……………….x_{2m} are inflow from each of the legs.
Assuming that t_{ij} is the turning traffic volume from leg i to leg j, then the turnings at the junction can be estimated using the furness model stated below.
The Fratar turning traffic equation can be written as

$$t_{ij}^{\ n} = t_{ij}^{n-1} G_i^{n-1} G_j^{n-1} \quad \text{---(1)}$$

This equation is recast as

$$t_{ij}^{\ n} = \frac{O_i D_j}{\sum_{k=1}^{m} r_k D_k} t_{ij}^{n-1} = W_{ij} t_{ij}^{n-1} \quad \text{------------(2)}$$

O_i = inflow into a leg i
D_i = outflow from a leg i

$$\text{where} \quad W_{ij} = \frac{O_i D_j}{\sum_{k=1}^{m} r_k D_k} \quad \text{-------------------------------------(3)}$$

Let $O_i = \sum_{k=1}^{2m} a_k x_k$ where a_k = 1 if k=i otherwise a_k =0

and $D_j = \sum_{k=1}^{2m} b_k x_k$ where b_k = 1 if k=j+m otherwise b_k =0

By setting c_i =0 for i=1, m
and $c_i = r_j$ for i=m+1, 2m with j =i-m

Then $\sum_{k}^{m} r_k D_k = \sum_{k=1}^{2m} c_l x_l$

Note that for a leg i in the intersection, the inflow is now being represented as an unknown x_i while the outflow is represented by x_{i+m}

Eqns (5) can thus be rewritten as $W_{ij} = \dfrac{\sum_{k=1}^{2m} a_k x_k \sum_{k=1}^{2m} b_k x_k}{\sum_{k=1}^{2m} c_k x_k}$ -------------------------(4)

An aggregate objective function can be written as $F = \sum_{i=1}^{m}\sum_{j=1}^{m} W_{ij}$

The Furness equation for turning volume are given as

$$t_{ij}^{\ n} = \frac{t_{ij}^{\ n-1} O_i}{\sum_{j=1}^{m} t_{ji}^{n-1}} \quad \text{--(5)}$$

$$t_{ij}^{\ n+1} = \frac{t_{ij}^{\ n} D_j}{\sum_{j=1}^{m} t_{ij}^{n}} \quad \text{--(6)}$$

Eqns.(5) and (6) can be combined and also recast as

$$t_{ij}^{\ n+1} = \frac{D_j}{\sum_{k=1}^{m} r_{kj} O_k} t_{ij}^{n} = V_i\, t_{ij}^{n} \quad \text{------------------------(7)}$$

In this case $V_i = \dfrac{\sum_{k=1}^{2m} a_k x_k}{\sum_{k=1}^{2m} b_k x_k}$ -------------------------(8)

For this case an objective function R can be defined as

$$R = \sum_{i=1}^{m} V_i$$

For leg j with known inflow O_j and outflow D_j, two constraint equations can be written as

$G_{io} = x_j - O_j$ ---(9)

$G_{id} = x_{j+m} - D_j$ ---(10)

If there are m-1 legs with known inflow and outflow values then aggregate constraint equations can be written as

$$G_a = \sum_{j=1}^{m-1} x_j - O_j \quad \text{---(11)}$$

$$G_b = \sum_{j=1}^{m-1} x_{j+m} - D_j \quad \text{---(12)}$$

If it assumed that there is no traffic accumulation at the junction then
(sum of known inflow into a junction) = (sum of known outflow into a junction)
Additional constraint equation for the leg m with unknown inflow and outflow can be written as

$$G_c = x_m - x_{2m} + \sum_{j=1}^{m-1} x_j - \sum_{j=1}^{m-1} x_{j+m} \quad \text{---(13)}$$

A Linear Lagragrian function can then be written as

$L_1 = R + \lambda\,(G_a + G_b + G_c)$ -- (14)

λ is a Lagragian multiplier
$X = (X) - H^{1}\Delta L_1$ ---(15)
where H=Hessian matrix

An hybrid Lagragian function can also be written as
$L_2 = F^4 + R^4 + \lambda\,(G_a + G_b + G_c)$ --- (16)

With the unknown inflow and outflow values for a leg in the junction determined, the normal Furness turning traffic equations can then used to estimate the turning traffic volumes for all the legs.
Two models were developed using L_1 and L_2 Lagragians functions and with the same constraints equations to evaluate the inflow and outflow traffic volumes at an unknown leg.

IV. FIELD STUDY

Traffic count was carried out at the selected intersection in the city. The inflow and outflow traffic volume was determine for all classes of vehicles. The study was carried out for seven days. Thereafter the average daily traffic(ADT) for inflow and outflow for each of the legs of the intersection was determined.

V. RESULTS AND DISCUSSIONS

Each of the models was tested on a selected 5 leg intersection by stepping down one leg after the other and subsequently comparing the model values for inflow and outflow with the obtained field values. The results for Model 1 (using Hybrid Lagragian function) are presented in Tables 1-10, while Tables 11-20 are the results for Model 2(Linear Lagragian function). Results from Model 2 showed a decreasing value of error estimates with decreasing values of inflow and outflow traffic volumes at unknown leg. However Model 1 results did not give a clearly defined pattern. It appears that Model 2 gives better estimate of unknown leg traffic volume with least traffic volume in the intersection. Since Model 1 still yielded converging results, it may be used at an intersection, by initially carrying out some trials which can be used to estimate the correction factor required. Turning traffic volumes estimates suggested that the incidence of U-turns are much unlikely in the intersection. In any case the intersection has a large radius which may make U-turns unnecessary.

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Table 1: Inflow and OutFlow Values for Field and Hybrid Model with Gate leg Unknown

	A:(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	29785	29785	.00	14418	14418	.00
Leg 3	2873	2873	.00	3469	3469	.00
Leg 4	4537	4537	.00	4283	4283	.00
Leg 5	13834	6587	-1.10	13842	11214	-.23

Table 2: Turning Estimate with Gate Leg Unknown with Hybrid Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	379	19302	1309	1024	7618	.01
leg 2	7696	289	208	1656	4105	.02
leg 3	568	2882	3	636	757	.00
leg 4	1801	238	286	40	984	.01
leg 5	1617	7073	1067	1180	371	.03

Key
Leg 1-lagos
Leg 2-ife
Leg 3-ojoo
Leg 4-iwo
Leg 5-gate

Table 3: Inflow and OutFlow Values for Field and Hybrid Model with Iwo leg Unknown

	A:(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	29785	29785	.00	14418	14418	.00
Leg 3	2873	2873	.00	3469	3469	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	14888	4537	-2.28	14836	4283	-2.46

Table 4: Turning Estimate with Iwo Leg Unknown with Hybrid Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	303	18740	1102	1439	7339	.01
leg 2	6151	281	175	2328	3955	.02
leg 3	454	2798	3	895	729	.00
leg 4	3768	606	630	147	2482	.02
leg 5	1385	7360	963	1778	383	.03

Key
Leg 1-lagos
Leg 2-ife
Leg 3-ojoo
Leg 4-gate
Leg 5-iwo

Table 5: Inflow and OutFlow Values for Field and Hybrid Model with Ojoo leg Unknown

	A:(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	29785	29785	.00	14418	14418	.00
Leg 3	4537	4537	.00	4283	4283	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	15131	2873	-4.27	15098	3469	-3.35

Table 6: Turning Estimate with Ojoo Leg Unknown with Hybrid Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	300	18258	1730	1388	7371	.01
leg 2	6085	273	275	2246	3972	.02
leg 3	555	3366	6	1065	904	.00
leg 4	3727	590	989	142	2493	.02
leg 5	1394	7298	1538	1746	392	.03

Key
Leg 1-lagos
Leg 2-ife
Leg 3-iwo
Leg 4-gate
Leg 5-ojoo

Table 7: Inflow and OutFlow Values for Field and Hybrid Model with Ife leg Unknown

	A:(in(model))	B(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	2873	2873	.00	3469	3469	.00
Leg 3	4537	4537	.00	4283	4283	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	7866	29785	.74	7680	14418	.47

Table 8: Turning Estimate with Ife Leg Unknown with Hybrid Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	1044	3938	4286	4434	9489	.04
leg 2	2149	6	69	727	518	.00
leg 3	1143	429	8	2013	688	.00
leg 4	7574	74	1429	265	1872	.02
leg 5	2286	741	1793	2624	237	.03

Key
Leg 1-lagos
Leg 2-ojoo
Leg 3-iwo
Leg 4-gate
Leg 5-ife

Table 9: Inflow and OutFlow Values for Field and Hybrid Model with Lagos leg Unknown

	A:(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	29785	29785	.00	14418	14418	.00
Leg 2	2873	2873	.00	3469	3469	.00
Leg 3	4537	4537	.00	4283	4283	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	12474	12061	-.03	12553	23190	.46

Table 10: Turning Estimate with Lagos Leg Unknown

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	1501	1675	1769	1818	8409	.10
leg 2	3818	3	35	368	567	.00
leg 3	2619	291	5	1315	971	.00
leg 4	12803	37	693	128	1949	.01
leg 5	9043	866	2035	2958	578	.04

Key
Leg 1-ife
Leg 2-ojoo
Leg 3-iwo
Leg 4-gate
Leg 5-lagos

Table 11: Inflow and OutFlow Values for Field and Linear Model with Gate leg Unknown

	A(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	29785	29785	.00	14418	14418	.00
Leg 3	2873	2873	.00	3469	3469	.00
Leg 4	4537	4537	.00	4283	4283	.00
Leg 5	**1693**	**6587**	**.74**	**1701**	**11214**	**.85**

Table 12: Turning Estimate with Gate Leg Unknown with Linear Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	429	24381	1941	1327	955	.01
leg 2	8722	365	309	2146	515	.03
leg 3	644	3640	5	825	95	.00
leg 4	2040	301	424	52	123	.02
leg 5	**225**	**1098**	**194**	**188**	**6**	**.00**

Key
Leg 1-lagos
Leg 2-ife
Leg 3-ojoo
Leg 4-iwo
Leg 5-gate

Table 13: Inflow and OutFlow Values for Field and Linear Model with Iwo leg Unknown

	A(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	29785	29785	.00	14418	14418	.00
Leg 3	2873	2873	.00	3469	3469	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	**1936**	**4537**	**.57**	**1883**	**4283**	**.56**

Table 14: Turning Estimate with Iwo Leg Unknown with Linear Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	272	19342	1261	1524	790	.01
leg 2	8949	469	324	3987	689	.03
leg 3	328	2316	3	760	63	.00
leg 4	7368	1359	1567	339	581	.03
leg 5	198	1206	175	299	7	.00

Key
Leg 1-lagos
Leg 2-ife
Leg 3-ojoo
Leg 4-gate
Leg 5-iwo

Table 15: Inflow and OutFlow Values for Field and Linear Model with Ojoo leg Unknown

	A:(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	29785	29785	.00	14418	14418	.00
Leg 3	4537	4537	.00	4283	4283	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	**1935**	**2873**	**.33**	**1902**	**3469**	**.45**

Table 16: Turning Estimate with Ojoo Leg Unknown with Linear Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	268	18711	1979	1455	777	.01
leg 2	8912	458	515	3848	684	.03
leg 3	412	2860	5	926	79	.00
leg 4	6824	1236	2312	304	537	.03
leg 5	192	1151	271	282	6	.00

Key
Leg 1-lagos
Leg 2-ife
Leg 3-iwo
Leg 4-gate
Leg 5-ojoo

Table 17: Inflow and OutFlow Values for Field and Linear Model with Ife leg Unknown

	A (in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	12061	12061	.00	23190	23190	.00
Leg 2	2873	2873	.00	3469	3469	.00
Leg 3	4537	4537	.00	4283	4283	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	**1114**	**29785**	**.96**	**928**	**14418**	**.94**

Table 18: Turning Estimate with Ife Leg Unknown with Linear Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
leg 1	2398	4820	6453	7862	1657	.10
leg 2	2664	4	56	696	49	.00
leg 3	1642	328	8	2230	75	.00
leg 4	9547	50	1180	257	179	.02
leg 5	**360**	**62**	**185**	**319**	**3**	.00

Key
Leg 1-lagos
Leg 2-ojoo
Leg 3-iwo
Leg 4-gate
Leg 5-ife

Table 19: Inflow and OutFlow Values for Field and Linear Model with Lagos leg Unknown

	A:(in(model))	B:(in(field))	(B-A)/B	D:(out(model))	E:(out(field))	(E-D)/E
Leg 1	29785	29785	.00	14418	14418	.00
Leg 2	2873	2873	.00	3469	3469	.00
Leg 3	4537	4537	.00	4283	4283	.00
Leg 4	6587	6587	.00	11214	11214	.00
Leg 5	**1179**	**12061**	**.90**	**1258**	**23190**	**.95**

Table 20: Turning Estimate with Lagos Leg Unknown with Linear Model

	leg 1	leg 2	leg 3	leg 4	leg 5	% uturn
Leg 1	3013	2480	3382	3777	921	.22
Leg 2	5054	3	44	505	41	.00
Leg 3	3448	283	7	1792	70	.00
Leg 4	17281	37	891	178	144	.01
Leg 5	989	70	212	335	3	.00

Key
Leg 1-ife
Leg 2-ojoo
Leg 3-iwo
Leg 4-gate
Leg 5-lagos