Traffic Volume Forecasting Model by using Elasticity Method and Exponential Smooth Model for Main National Roads of Rwanda

Mathieu Ntakiyemungu[1*] and Hang Zhang[2]

[1]Masters Candidate at Wuhan University of Technology.
Major: Highway and Railway engineering.

[2]School of Transportation,Wuhan University of Technology
Wuhan, Hubei,430063,China.

[*]*Corresponding author's email: ntakmatnty [AT] gmail.com*

ABSTRACT---- ***The accuracy in traffic forecasting helps the planners to have a good plan about the highways as the forecasting volume has been recognized as one of the factors that involve in the analysis of highway planning, reconstruction, new construction as well as maintenance. This paper presents the models to forecast the selected main roads in Rwanda by comparing two methods: elastic method and exponential smooth model. This study shows that the traffic forecasting by using exponential smooth model can overestimate and doesn't consider the demographic as well as economic variables and shows that the elastic model is a best method to estimate and forecast the traffic volume as it combines the demographic data as well as the economic ones but the rate is slow. The best estimate is the combination of the two methods.***

Keywords--- Elasticity method, traffic forecasting, smooth, national roads, Rwanda.

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1. INTRODUCTION

Traffic volume is very important in highway design. The forecasting volume has been recognized as one of the factors that involve in the analysis of highway planning, reconstruction ,new construction as well as maintenance. Rwanda as the country where the economy is growing rapidly need to have a good method to forecasting the traffic volume which can help in highway planning. D.Fricker and K.Saha(196) said that developing future traffic estimates is not an exact science, dependent as it is on so many hard-to-predict variables. Traffic forecasting procedures must be reasonably easy and economical to carry out, be sensitive to a wide range of policy issues and alternatives, and produce Information useful to decision-makers in a form that does not require extensive training to understand.

In rural areas, when assignment-based models do not exist or are not practical to apply, traffic estimates are generally made by expanding present traffic into the future based on projections of population, employment, vehicle registration, land-use data, or other parameters

Armstrong(1984,1986), in his studies of forecasting, concluded that sophisticated extrapolation techniques have had a negligible payoff for accuracy. In forecasting more sophisticated methods are generally more difficult to understand, and they cost more to develop, maintain, and implement. He proposed that complexities should be avoided unless absolutely necessary. So, simple methods, which are easily understood, have been undertaken to develop traffic growth factor models in this study.

Mckay, in his work with Cook County and the City of Chicago he said that the relation between population and highway traffic indicates the necessity of considering population trends in the formulation of a highway Improvement program. The prediction of expected future traffic on the projection of the trend of motor vehicle registration Is a reasonably accurate Indication of future highway traffic.

Many researchers like Zhao (2011) showed that the factors affecting the traffic volume: demographic factors(population, employment, household, private car ownership, female participation in the work force), fuel price, new or improved roads, income, public transport service level.

ALFRED NEVEU(1983) in his research concluded that the only factor that had an appreciable effect on traffic growth rates was the characteristic of type of service. Highways with the greatest percentage of interurban or interregional service generally had the largest increases in travel. Roads that served largely urban-to-rural or rural-to-urban travel had the smallest increase.

The data used to estimate came from different sources. TheAADT(annual average daily traffic) were given by RTDA(Rwanda Transport and Development Authority) and other factors were given by NISR(National Institute of Statistic of Rwanda). All used data were at national level because the chosen roads are national roads.

1.1. Elasticity model

The elasticity of demand with respect to a certain variable, such as travel cost, is defined as the rate of change of demand with respect to that variable, normalized by the current levels of demand and the variable in question. Elasticity is thus a measure of the sensitivity to change in system conditions (Meyer and Miller, 2001).

The elasticity method mainly relates traffic growth to changes in the related economic (such as percapita income, population and GDP) and demographic (such as population, household, etc) factors**.**

Advantages: The elasticity modelConsider demographic and cost factors, show the impact on land use and travel frequency of improving the traffic conditions; discuss the induced traffic with time effect (He and Zhao)

Disadvantages: High accurate requirement of data collection; calculation error exists in wrong data collection (He and Zhao)

1.2. Exponential smoothing method

With exponential smoothing the idea is that the most recent observations will usually provide the best guide as to the future, so we want a weighting scheme that has decreasing weights as the observations get older. The choice of the smoothing constant is important in determining the operating characteristics of exponential smoothing(Eva and Oskar). The smaller the value of α, the slower the response. Larger values of αcause the smoothed value to react quickly not only to real changes but also random fluctuations (MONTGOMERY,1990). Simple exponential smoothing model is only good for non-seasonal patterns with approximately zero-trend and for short-term forecasting because if we extend past the next period, the forecasted value for that period has to be used as a surrogate for the actual demand for any forecast past the next period

2. OTHER METHOD

2.1. Forecasting using growth rate based on past traffic data

M Kamplimath, M.Varuna, V. Kumar, Y.Bhargav said that the traffic volume can be estimated by using the past traffic data collected in different years, for the case of Rwanda this cannot be accurate because there is no enough available historical data and also the past traffic data do not show any definite trend, one should not be guided by past traffic data for deriving forecasted traffic volume.

2.2. Forecasting using vehicle registration data

M Kamplimath, M.Varuna, V. Kumar, Y.Bhargav said that the traffic volume can be forecasted by using vehicle registration. Such an assumption may not be correct, unless the area of influence is well defined and the general development pattern of influence area remains same.

3. DELOPPING METHEDOLOGY

In order to facilitate the planners in the ministry of infrastructure this paper try to develop the model that is simple to use like hand-held calculation and also the data to be used must be easily available in most planning offices. This includes both historical trends and future predictions.

This paper presents two methods:

- first the elastic based model was developed cause Elasticity model Consider demographic

and cost factors, show the impact on land use and travel frequency of improving the traffic conditions; discuss the induced traffic with time effect(HE and Zhao, 2013)

And also the elasticity model was used because it was believed that the range of volumes over which the model would be applied would be much greater than that available in the calibration

data set, some research showed that a simple linear regression model that relates AADT to the background factor directly is inappropriate. second, the use of present year AADT to estimate future year M (as a sort of pivot point) would reduce the problem of nonresident travel. Neveu(1983) suggest that the elasticity portion of the model calculate a growth factor directly, so the procedure can be easily transformed into a set of nomography, thus further simplifying the work required by the user.

In the model(Neveu ,1983) chosen the AADT is related to to present year AADT and modified by the changes in any number of background factors.So the general form of the model is as follows:

$$AADT_f = AADT_p \left\{ 1.0 + \sum_i^n e_i \left[\frac{X_{i,f} - X_{i,p}}{X_{i,p}} \right] \right\} \quad (1)$$

$AADT_f$ = in future year,
$AADT_p$ =in present year,
P
$X_{i,f}$ = value of variable x in the future year,

$X_{i,p}$= value of variable x, in the present year,

e_i = elasticity of AADT with respect to x ,
n =number of associated variables.

The elasticities and the appropriate background factors are derived from a linear equation that relates AADT to a variety of the factors. It can be shown mathematically that, given an equation of the form:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots \quad (2)$$

Elasticity measures can be estimated by:

$$e_i = a_i \left(\frac{\bar{X}_i}{\bar{Y}} \right) \quad (3)$$

Where $\bar{Y}$:Average depend variable
$\bar{X}_i$: average independent variables
Thus, using multiple linear regressions, the background factors that best estimate AADT and their respective elasticities can be derived.

The registered vehicles from 2013 have been estimated by using three index smooth model or Brown's Quadratic Exponential Smoothing Method(HE and ZHAO,2013).
Where: α= smooth constant and is 0>α>1
T=Forecast period and,

By taking α=0.5 and using equation (6), $Y_{t+T} = 124340 + 19839.65T + 1611.95T^2$ (4)

Following are background factors for developing the model:Population, households, vehicle ownership, GPD, employment, CPI, income. Refer to table 1&2

Table 1: Rwanda National Population Projection 2007-2022

YEAR	MEDIUM			LOW			HIGH		
	TOTAL	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	MALE	FEMALE
2007	9,556,669	4,597,277	4,959,393	9,556,669	4,597,277	4,959,393	9,556,669	4,597,277	4,959,393
2008	9,831,501	4,736,104	5,095,397	9,822,186	4,731,386	5,090,800	9,834,124	4,737,433	5,096,691
2009	10,117,029	4,880,233	5,236,796	10,088,891	4,866,000	5,222,890	10,124,927	4,884,228	5,240,699
2010	10,412,820	5,029,450	5,383,371	10,355,902	5,000,683	5,355,219	10,428,754	5,037,503	5,391,252
2011	10,718,379	5,183,505	5,534,874	10,622,222	5,134,936	5,487,286	10,745,236	5,197,070	5,548,166
2012	11,033,141	5,342,112	5,691,029	10,886,790	5,268,224	5,618,566	11,073,944	5,362,712	5,711,232
2013	11,355,940	5,504,823	5,851,118	11,148,087	5,399,922	5,748,166	11,414,031	5,534,141	5,879,890
2014	11,686,013	5,671,262	6,014,751	11,404,881	5,529,415	5,875,466	11,764,863	5,711,047	6,053,816
2015	12,022,635	5,841,011	6,181,624	11,655,990	5,656,058	5,999,932	12,125,840	5,893,074	6,232,766
2016	12,365,180	6,013,754	6,351,427	11,912,094	5,785,266	6,126,828	12,496,460	6,079,969	6,416,491
2017	12,713,052	6,189,185	6,523,867	12,172,222	5,916,517	6,255,705	12,876,243	6,271,487	6,604,756
2018	13,084,188	6,376,440	6,707,748	12,436,438	6,049,867	6,386,571	13,265,836	6,467,991	6,797,845
2019	13,459,227	6,565,654	6,893,573	12,703,981	6,184,924	6,519,057	13,664,744	6,669,229	6,995,516
2020	13,838,421	6,756,987	7,081,434	12,974,095	6,321,300	6,652,795	14,072,509	6,874,964	7,197,544
2021	14,221,792	6,950,451	7,271,341	13,245,866	6,458,528	6,787,339	14,488,685	7,084,972	7,403,713
2022	14,591,018	7,136,748	7,454,270	13,518,555	6,596,228	6,922,327	14,912,874	7,299,049	7,613,825

Source: National Institute of Statistics of Rwanda , July 2009

Table 2: Background factors

year	X1(number)	X2(numb)	X3(numb)	X4(numb)	X5($)	X6	X7(billions)
2007	9556669	2222482	57918				
2008	9834124	2286396	71306	8258460	461	91.4	2555
2009	10124927	2354635	80019		499	101.4	2904
2010	10412826	2425588	88621	8757187	519	103.77	3250
2011	10745236	2498893	105324		570	109.63	3795
2012	11073944	2575336	124938		620		
2013	11414031	2654426	145791	9121341	644	121.52	4885
2014	11764863	2736015	169568				
2015	12,125,840	2887105	198367				
2016	12,496,460	2975348	229490				
2017	12,876,243	3065773	263830				
2018	13,265,836	3158533	301409				

SOURCE: National Institute of Statistics for Rwanda (NISR), year book 2012 and Rwanda population projection 2022

Note: the values of X3 from 2013 up to 2018 have been estimated by using equation (6)

X1=population
X2=households
X3=vehicle registration
X4=Employment
X5=GDP per Capita
X6=CPI(consumer price index)
X7=Income

This paper was limited on the selected main national roads with their AADT. Refer to table 3:

Table 3: National rods and their respective AADT

ROAD ID	AADT(vehicle/day)		
	Year		
	2008	2010	2013
RN1 Kigali-Butare-Akanyaru (157 Km)	1672	1595	5,210
RN 2 Kigali-Gatuna (77.7 km)	984	1362	3,030
RN3 Kigali-Kayonza-Rusumo (166.1 km)	1138	1471	3,009
RN 4 Kigali-Ruhengeri-Gisenyi (149.6 Km)	1827	1504	2,121

Source: Rwanda Transport and Development Agency

- Secondly the exponential smooth method was developed as follows:

Brown's Linear Exponential Smoothing Method with Single Parameter

Brown's linear exponential smoothing method with single parameter is used wheresome data shows linearly declining or rising trendand can be applied to the data which has a significant trend, estimations are always remains lower than actual values(HE and ZHAO, 2013).The formula is as follow:

$$y_t^{(1)} = \alpha y_t + (1-\alpha) y_{t-1}^{(1)}$$
$$y_t^{(2)} = \alpha y_t^{(1)} + (1-\alpha) y_{t-1}^{(2)} \quad (5)$$
$$a_t = 2y_t^{(1)} - y_{t-1}^{(2)}$$

Three Index Smooth Model or Brown's Quadratic Exponential Smoothing Method

When the time series are curved shape (quadratic, third order or more) and when the information and data have continued to grow or down along one curveBrown's quadratic exponential smoothing technique is suitable for estimation. Third parameter is added to the model. The equations for quadratic exponential smoothing are below

$$y_t^{(1)} = \alpha y_t + (1-\alpha) y_{t-1}^{(1)}$$
$$y_t^{(2)} = \alpha y_t^{(1)} (1-\alpha) y_{t-1}^{(2)}$$
$$y_t^{(3)} = \alpha y_t^{(2)} + (1-\alpha) y_{t-1}^{(3)}$$
$$a_t = 3y_t^{(1)} - 3y_t^{(2)} + y_t^{(3)} \quad (6)$$
$$b_t = \frac{\alpha}{2(1-\alpha)^2}\left[(6-5\alpha) y_t^{(1)} - 2(5-4\alpha) y_t^{(2)} + (4-3\alpha) y_t^{(3)}\right]$$
$$c_t = \frac{\alpha^2}{(1-\alpha)^2}\left(y_t^{(1)} - 2y_t^{(2)} + y_t^{(3)}\right)$$
$$Y_{t+T} = a_t + b_t T + \frac{1}{2} c_t T^2$$

4.ANALYSIS

Due to a rapid change of economic of Rwanda it is difficult to forecast the GPD,CPI, income , so the final variables entered in the analysis are only population, households ,employment and vehicle ownership.

Several regression analyses were performed by using SPSS and MINITAB softwares. The predictors are very correlated each other, the collection was made firstly by removing the employment variable because it is difficult to find the real record of employment, and so later using the Best subset method by Minitab software seems to be difficult to find the bests fitted coefficients, so by using the least square method we could estimate the coefficients. The methods are described below:

The model is a system of n equations that can be expressed in matrix notation as

$$Y = X\beta$$

Where

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ . \\ y_n \end{bmatrix} \quad X = \begin{pmatrix} 1 & x_{11}\dots & x_{1k} \\ . & . & . \\ . & . & . \\ . & . & . \\ 1 & x_{n1}\dots. & x_{nk} \end{pmatrix} \quad \beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ . \\ . \\ . \\ \beta_k \end{bmatrix}$$

So the least squares estimate of β is

$$\beta = \left(X^T X\right)^{-1} X^T Y \quad (7)$$

Table 4: Correlation Matrix

	y	X1	X2	X3	X4	X5	X6	X7
y	1							
X1	0.893926	1						
X2	0.85338	0.996508	1					
X3	0.921006	0.997913	0.989036	1				
X4	0.987259	0.811218	0.75956	0.847287	1			
X5	0.905216	0.999666	0.994016	0.999249	0.826065	1		
X6	0.96981	0.976241	0.954739	0.988197	0.918651	0.981517	1	
X7	0.992777	0.941244	0.909758	0.96109	0.961038	0.949662	0.992062	1

The final regression equations were made and are as follows:

RN1: $Y_1 = 5341.6\text{-}0.00016X_2$ (8)

e_2=1.36

RN2:

$$Y_2 = 3088.94\text{-}0.00093X_2 + 0.00021X_3 \quad (9)$$

e_2=1.23 e_3=0.01

RN3:

$$Y_3 = 3063.41\text{-}0.00085X_2 + 0.00018X_3 \quad (10)$$

e_2=1.09 e_3=0.01

RN4:

$$Y_4 = 2144.82\text{-}0.00014X_2 + 0.00013X_3 \quad (11)$$

e_2=0.18 e_3= 0.006

By using the elasticities derived from the regression equation, it is now possible to complete the development the forecasting model b substituting those elasticities into the above equations . Thismodel is presented in the following equations:

For RN1

$$AADT_f = AADT_p \{1.0 + 1.36(\%\Delta \text{ country households})\} \quad (12)$$

For RN2

$$AADT_f = AADT_p \{1.0 + 1.23(\%\Delta \text{ country households}) + 0.01\ (\%\Delta \text{ counry vehicles})\} \quad (13)$$

For RN3

$$AADT_f = AADT_p \{1.0 + 1.09(\%\Delta \text{ country households}) + 0.01\ (\%\Delta \text{ counry vehicles})\} \quad (14)$$

For RN4

$$AADT_f = AADT_p \{1.0 + 0.18(\%\Delta \text{ country households}) + 0.006\ (\%\Delta \text{ counry vehicles})\} \quad (15)$$

Table 5: Actual vs Forecasted AADT

ROAD ID	AADT(vehicle/day)								
	2008			2010			2013		
	actual	fore casted	Error (%)	actual	fore casted	Error (%)	actual	fore casted	Error (%)
RN1	1672	1738	3.9	1595	1660	4.07	5210	5420	4.03
RN 2	984	1021	3.76	1362	1414	3.81	3144	2937	3.76
RN3	1138	1177	3.42	1471	1519	3.23	3009	3018	3.27
RN 4	1827	1830	0.0016	1504	1507	0.0026	2121	2125	0.0018

By choosing α=0.5, and use brown's linear exponential smoothing method with single parameter

thefinal fomulas for the selected national roads are as follow:

For RN1, $Y_{t+T} = 4306.38 + 884.63T$ (16)

For RN2, $Y_{t+T} = 2613 + 511.5T$ (17)

For RN3, $Y_{t+T} = 2624.5 + 467.75T$ (18)

For RN4, $Y_{t+T} = 1966.7 + 73.5T$ (19)

Table 6: Forecasted AADT

	year	RN1	RN2	RN3	RN4
EM	2014	5428	3150	3115	2133
	2015	5832	3368	3308	2156
	2016	6067	3498	3423	2168
	2017	6039	3632	3542	2181
	2018	6427	3771	3664	2194
ESM	2014	5191	3125	3093	2041
	2015	6076	3636	3560	2114
	2016	6961	4148	4028	2188
	2017	7845	4659	4496	2261
	2018	8730	5171	4964	2334

EM: Elastic Method, ESM: Exponential Smooth Method

5. RECOMMENDATIONS AND LIMITATION

1. Those models were developed by using few data; they must be used for a short term planning.

2. In developing those models the data used were at national level, they must be used only on national roads.

3. Lack of more data may results on questionable results, so it is recommended to revise those model incase more data are available.

4. It is recommended to do another study where the variables such as: employment, GPD, income fuel consumption etc, are included.

5. A further study must be carried out by considering the population and household of the region where the road pass.

6. An installation of automatic count is needed in order to know the real AADT for every year.

6. CONCLUSION

The following are the conclusion from this study:

1. This study shows that the elastic model is a best method to estimate and forecast the traffic volume as it combines the demographic data as well as the economic ones but the rate is slow.

2. The variables: households, vehicle registration and population are the most variables that influence the traffic volume for the case of Rwanda.

3. This study shows that the traffic forecasting by using exponential smooth model can overestimate and doesn't consider the demographic as well as economic variables. The best estimate is the combination of the two methods

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