Traffic Volume Forecasting Models for Rural Desert Towns

THE PROCESS OF DEVELOPING LINEAR AND MULTIPLICATIVE TRAFFIC VOLUME FORECASTING MODELS FOR DESERT RURAL ROADS IN JORDAN WILL BE DISCUSSED. ONE MODEL WILL BE RECOMMENDED FOR PRACTICAL APPLICATIONS.

BY HASHEM R. AL-MASAEID, TURKI I. AL-SULEIMAN AND MOHAMMED T. OBAIDAT

IN JORDAN, MANY DEVELOPMENT projects have been initiated to improve human and natural resources, especially during the peace era in the Middle East. Some projects are focused on improving desert areas that form more than 88 percent of the Kingdom's area. Although population density in the desert area is very low, decentralization and desert utilization are primary interests to policymakers. As such, the Higher Council for Science and Technology, Amman, Jordan, sponsored a study for improving road networks in the northern-east part of Jordan. Estimation of future traffic volumes on desert roads was one of the major tasks in this project.[1]

The main objective of this research paper is to develop traffic volume forecasting models for rural desert towns in Jordan. Data on traffic volumes and town socioeconomic and demographic characteristics were collected for the purpose of this study. Multiple linear regression analyses were performed to develop statistical traffic volume models that would have practical applications for planners and traffic engineers.

BACKGROUND

Two general approaches can be used to estimate future traffic volumes for rural roads: trend projections and forecasts.[2] In the trend approach, a relationship between historical average daily traffic volumes (ADT) and time (in years) is identified using a linear regression technique. The developed regression line can be extended to obtain the design year ADT. This approach can be applied to individual route or highway segment level. However, in a previous study, this approach had negligible payoff in terms of forecasting accuracy.[3]

In the traffic forecasting approach, a statistical relationship between ADT and a set of explanatory variables is established. Explanatory variables might include town or country demographic and economic characteristics as well as functional classifications of highways. This approach was used to develop elasticity-based traffic forecasting models for rural routes in New York State,[4,5] Indiana[2] and Texas.[6] Multiple linear regression analysis is used to identify explanatory variables that have a significant influence on the ADT. Then, their associated elasticities can be derived. For an equation having the following form:

$$Y_i = \alpha_o + \sum_{j=1}^{n} \alpha_j X_{ij} \qquad (1)$$

where:
Y_i = Value of dependent variable at the ith observation;
X_{ij} = Value of jth independent variable at the ith observation;
α_0 = Constant term;
α_j = Regression coefficient for jth independent variable; and
n = Number of variables.

Elasticities can be estimated as follows:[6]

$$e_j = \alpha_j (\bar{X}_j / \bar{Y}) \qquad (2)$$

where:
e_j = Elasticity of ADT with respect to independent variable X_j;
$\bar{X}_j$ = Overall mean of jth independent variable; and
$\bar{Y}$ = Overall mean of the dependent variable.

METHODOLOGY AND DATA COLLECTION

The study area in the northern part of Jordan encompasses about 48 rural towns. The roads in this region are classified into village, secondary and primary roads. A village road is defined as a road that connects a town/village with a secondary or primary road. In Figure 1, the road network and town locations are shown in the study area. Only one primary road exists in the region and extends from Mafraq City, which is the center of Mafraq district, to Iraq's borders.

Based on a preliminary traffic origin-destination survey conducted in the study area, about 90 percent of vehicles traveled to or from Mafraq City. This finding was expected because cities in Jordan are the main centers of activities, including business, employment, shopping, hospitals, banking, etc. In fact, no primary or secondary roads connect the study area with any city except Mafraq. Therefore, all trips to or from any other city must pass through Mafraq. Thus, the majority of the traffic trips are to or from Mafraq. This finding is important for estimating ADTs related to each town, especially for cities located on the through primary or secondary roads.

Data on daily number of vehicles to or from each town (ADTt) and town socioeconomic and demographic characteristics were collected in the summer of 1995. Coverage and control count stations were distributed in the study area. Count stations were located at intersections of village roads with the primary or secondary roads. For through primary or secondary roads, count stations were sited on both sides of each town. The ADTs were computed by the method presented in Figure 2. If two or more towns are very close, they were considered as one town. The counts were carried out manually to acquire information on traffic flow characteristics, vehicle classification and origin-destination data.

Data on socioeconomic and demographic characteristics of each town were collected through local councils and questionnaires designed and distributed for this purpose. The socioeconomic variables include information on number of persons, number of employees and income per household. The demographic variables included population, number of households per town and car ownership per household. Also, other variables such as number of shops, number of health clinics and distance from each town to Mafraq City were incorporated into the developed database. The statistical characteristics of the collected data are summarized in Table 1.

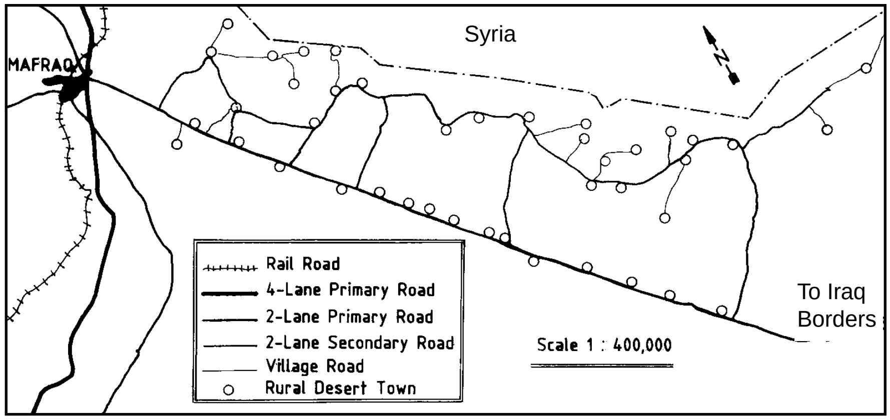


Figure 1. Road network in the northern-east part of Jordan.

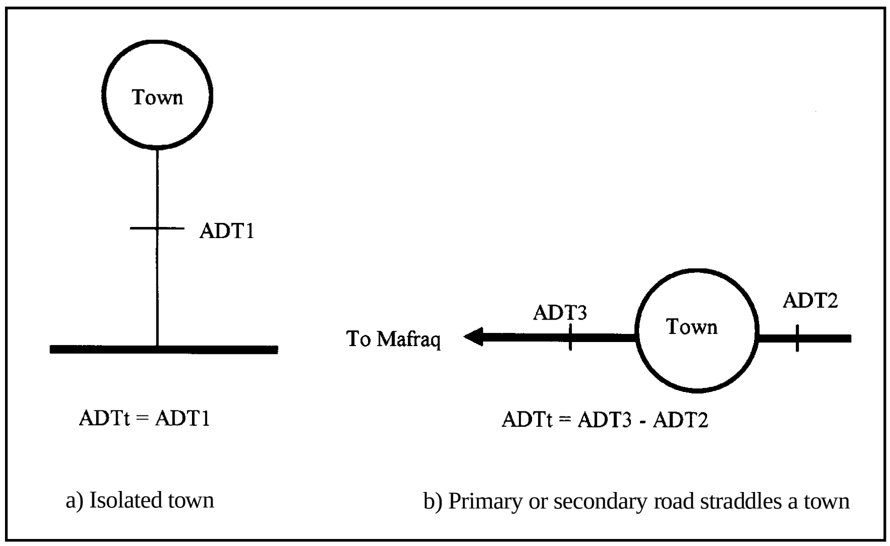


Figure 2. Computation of average daily traffic volume for each town (ADTt).

DEVELOPMENT OF TRAFFIC FORECASTING MODELS

Regression analysis was performed to estimate ADT for roadways in each town. Based on the analysis, two regression models were developed. The first model had a linear form, while the second had a multiplicative form. The first regression equation was found to be as follows:

$$ADTt_i = -323.6+66.8POP+394.4EPH \quad (3)$$

where:

$ADTt_i$ = Average daily traffic volume for a given town;

POP = Town population in thousands; and

EPH = Average number of employees per household.

The statistical characteristics of Equation (3) are noted in Table 2. All regression parameters are statistically significant at the 95 percent confidence level. Also, the coefficient of multiple determination is 0.81. Clearly, the results of this study are compatible with the results of previous forecasting studies in which population and employment levels are the most important predictor variables for estimating ADT on rural roads. Instead of employment, this study used the number of employees per household variable because (*a*) this variable had low correlation with the population variable, and (*b*) it provides more plausible results particularly for towns having large variation in the family sizes. All other included variables were found to have no effect at the specified confidence level.

Variable	Label	Minimum	Mean	Maximum
Town Population, Persons	POP	240	2258	7840
Number of households per town	HPT	36	305.5	890
Average monthly income per household, J.D.*	IPH	120	185	390
Average vehicle ownership per household	VPH	0.31	0.53	0.76
Average employment level per household	EPH	1.0	1.36	1.86
Number of health clinics per town	HU	0.0	1.28	5
Number of shops per town	SU	1.0	13.65	53
Distance from a town to district center (Mafraq), km	DTM	10	39.3	75
Average daily traffic volume for a town	ADTt	84	364.4	924

Table 1. Statistical characteristics of the collected data.

** J.D. = 1.41 US \$*

However, it was anticipated that towns located at far distances from Mafraq City would have lower ADTs, but the results did not confirm this expectation. Generally speaking, this result is consistent with the previous studies in which the average numbers of trips that residents make are not affected by travel distances.[7]

Based on regression Equation (3), the elasticity-based model is as follows:

$$ADTt_f = ADTt_p[1+0.414(\Delta POP)+1.47(\Delta EPH)] \quad (4)$$

where:
$ADTt_f$ = The *ADTt* in future year;
$ADTt_p$ = The *ADTt* in present year;
ΔPOP = The change in population with respect to its present value; and
ΔEPH = The change in employment level with respect to its present value.

The right-hand side of Equation (4) represents the product of the present ADTt and the elasticity portion. Clearly, the elasticity portion of this equation enables the analyst to calculate a traffic growth factor directly.[2]

Although the previous developed model had a high predictability level (i.e., $R^2 = 0.81$) with relatively low values of residuals (all residuals within 2.25 σ), another model in a multiplicative form was developed. The multiplicative regression equation was as follows:

$$ADTt_i = 65.14e^{0.157POP+1.193EPH-0.178HU-1.218(1SU)} \quad (5)$$

where:
HU = The number of health centers (health clinics); and
SU = The number of shops (small shops, supermarkets, etc).

This model and its individual parameters are highly significant. Compared with the linear model in Equation (3), the multiplicative model in Equation (5) had a slightly higher predictability (i.e., $R^2 = 0.84$) and lower residual values (all residuals within 2σ). Despite the fact that the multiplicative form is not common in previous traffic forecasting models, it includes variables that are important at policy levels for remote towns in desert areas. In Equation (5), the increase in the number of health centers would reduce the number of trips especially for medical purposes. Instead of traveling to the district center, the existence of health centers in a town enables residents to get health care locally; consequently, trips for medical purposes would be reduced. Also, an increase in the number of shops would increase the number of trips. This conclusion is logical because an increase in the number of shops would improve the quality of service provided; therefore, they would attract more shopping trips from other adjacent towns.

PRACTICAL APPLICATION

The developed models could be used for estimating future traffic volumes on rural roads that connect desert towns

Table 2. Statistical characteristics of regression Equation (3).

a. Analysis of Variance

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F-Value	Level of α
Model	2	1,222,261.14	611,130.57	67.76	0.0001
Error	29	261,537.17	9,018.52		
Total	31				

b. Regression Analysis

Parameter	Estimate	Standard Error of Estimate	t-Value	Level of α
Intercept	-323.64	95.26	-3.40	0.0020
POP	66.80	8.09	8.25	0.0001
EPH	394.41	71.46	5.52	0.0001

with a major activity center. Normally, the estimated future volumes are required to recommend changes or improvements to the existing road network. To judge which of the developed models is reasonable for this purpose, the models in Equations (3) and (5) should be tested to assess their performance. Except five towns, all other towns in the investigated area were included in the calibration of the models. For each of the five towns, Table 3 shows the actual and estimated ADTs. Table 3 indicates that both models yield comparable results. Probably, the use of a limited number of sites would not provide conclusive results. Although both models in Equations (3) and (5) had reasonable statistical characteristics and provided comparable estimates, the model in Equation (3) is recommended for forecasting purposes because (*a*) it is easy to understand and to implement, (*b*) it includes two explanatory variables that could be easily obtained or estimated, and (*c*) its form is consistent with the previously developed prediction models for rural highways.

Table 3. Comparisons of actual with predicted ADTs.

Site No.	Actual ADTs	Equation (3)		Equation (5)	
		ADTs	% Error	ADTs	% Error
1	436	462	6.0	414	-5.0
2	285	296	3.9	310	8.8
3	563	524	-6.9	585	3.9
4	322	299	-7.1	302	-6.2
5	498	478	-4.0	520	4.4

CONCLUSIONS

An effort was made to develop traffic volume forecasting models for desert rural roads in Jordan that connect desert rural towns with a major activity center such as city district center. Linear and multiplicative models were developed for estimating ADT for each town. Town population and employment levels as well as the number of health clinics and shops were found to be the most important predictive variables. Although both models were reasonable, the linear model is recommended for practical purposes.

ACKNOWLEDGMENT

The major part of the work described in this paper was supported by the Higher Council for Science and Technology through the Deanship of Scientific Research at Jordan University of Science and Technology, Irbid, Jordan. ■

References

1. Al-Masaeid, H.R., and T. Al-Suleiman. “Characteristics of Road Network in the Northern Badia of Jordan.” Rep. No. 37/94. Deanship of Scientific Research, Jordan University of Science and Technology, Irbid, Jordan, 1996.

2. Saha, S.K., and J.D. Fricker. “Traffic Volume Forecasting Methods for Rural State Highways.” Transportation Research Record 1203, TRB, Washington, D.C., USA, 1988, pp. 10–25.

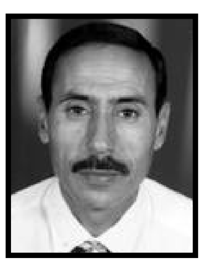
3. Armstrong, J.S. “Forecasting by Extrapolation: Conclusion from 25 Years Research.” *Interfaces,* Vol. 14, No. 6, 1984, pp. 52–56.

4. Neveu, A.J. “Quick Response Procedures to Forecast Rural Traffic.” Transportation Research Record 944, TRB, Washington, D.C., USA, 1982, pp. 47–53.

5. Erlbaum, N.S. “Revised Quick Response Procedure to Forecast Rural Traffic: Revised Methodology and Users Guide.” Rep., Data Service Bureau, New York State DOT, Albany, N.Y., USA, 1990.

6. Stokes, R.W. “Elasticity-Based Rural Traffic Forecasting Models.” *Journal of Transportation Engineering,* ASCE, New York, N.Y., USA, Vol. 121, No. 2, 1995, pp. 234–239.

7. Handy, S. “Regional versus Local Accessibility: Implications for Nonwork Travel.” Transportation Research Record 1400, TRB, Washington, D.C., USA, 1993, pp. 56–66.



HASHEM R. AL-MASAEID, *P.E., is an Associate Professor of civil engineering at Jordan University of Science and Technology. He received a B.S. in civil engineering from Jordan University, Amman, Jordan, and a master’s degree in civil engineering from Yarmouk University, Irbid, Jordan. He has a Ph.D. in transportation engineering from Purdue University. His research interests include traffic and highway engineering.*

TURKI I. AL-SULEIMAN *is an Associate Professor of civil engineering at Jordan University of Science and Technology, Jordan. Where he teaches courses in pavement maintenance and pavement management systems. He received his B.Sc. in civil engineering from Tishreen University, Syria (1980); M.Sc. in transportation engineering, Yarmouk University, Irbid, Jordan (1984); and Ph.D. in transportation engineering, Purdue University, USA (1988). His research interests include highway and traffic engineering, pavement evaluation and maintenance management systems.*

MOHAMMED T. OBAIDAT *is an Assistant Professor of civil engineering at Jordan University of Science and Technology (J.U.S.T.), Jordan, where he teaches courses in photogrammetry, surveying, remote sensing, geographical information system (GIS), advanced mathematics and computer vision. He received the B.Sc. in civil engineering from Yarmouk University, Jordan in 1983. He received his M.Sc. with honors in transportation engineering from J.U.S.T. in 1988. He joined the University of Illinois at Urbana-Champaign, USA, where he received both an M.Sc. and a Ph.D. in photogrammetry and computer vision in 1994. He was awarded the Leica Inc. fellowship, 1992. His research interests include computer vision, photogrammetry, remote sensing, GIS, surveying, transportation engineering and new technologies applicable to civil engineering.*