Quick-Response Procedures to Forecast Rural Traffic

ALFRED J. NEVEU

The development of a quick-response method to forecast traffic volumes at project sites located on the rural highway network is discussed. By using travel data from New York State's continuous count stations in rural locations and various state-, county-, and town-level demographic data, a set of elasticity-based models is derived. These models can forecast future year annual average daily traffic (AADT) as a function of base year AADT modified by various demographic factors. These models are estimated based on the type of service the roadway carries: interurban, urban to rural, and rural to rural. Nomographs and a user's manual that describes a simple seven-step process to use the model were developed and distributed to regional offices throughout New York State.

For highway improvements, the gap between available funds and potential projects is becoming wider as revenues from various sources (including gasoline sales taxes, vehicle registration fees, and driver's license fees) fall because of economic pressure or government-enforced conservation (although the $0.05 gasoline tax increase will ease some of the pressure). Costs of labor and materials are escalating faster than the national rate of inflation. At the same time, compounding the problem, increasing travel demands are placing an even greater burden on the U.S. highway system than in the past, thus worsening an already difficult situation.

These trends mean that the need for construction, rehabilitation, and regular maintenance of the highway network is greater than ever. Each year a large number of such projects, ranging from simple intersection improvements to large-scale facility construction, are identified as candidates for the limited financial resources available. Even in the best of times, not all projects can be funded; now, with reduced monies to fund projects, it is even more imperative that programming decisions be made in the most effective and efficient manner possible.

The selection of projects to be implemented is generally based on some evaluation process in which the costs and benefits of each project are compared. The various evaluation processes consider many factors in weighing each alternative, including safety, noise, air pollution, and energy. Each of these factors is, in turn, based on an estimate of the traffic volume that will use the facility under consideration. Thus the volume estimate determines, to a significant degree, which of the many projects will be implemented.

Travel forecasting methodology is highly advanced at the urban area level. Most large metropolitan areas have developed and implemented a fairly sophisticated set of computer-based travel simulation models based on the traditional four-step process. In a nonurban context, however, this process is not nearly so advanced. With many of the projects competing for the scarce funds coming from nonurban areas, it is important to improve and streamline forecasting procedures for rural travel needs. In this way it would be possible to evaluate many rural projects quickly and accurately, thus providing government officials with better information on which to base their programming decisions.

To fulfill this need, research was initiated by the Transportation Statistics and Analysis Section of the New York State Department of Transportation (NYSDOT) to develop a quick-response procedure to forecast traffic volumes on rural roads. The primary focus of this effort was the design and testing of a simple, fast method to forecast rural traffic volumes. In this paper previous efforts aimed at forecasting rural traffic are examined, the chosen methodology is described, and the results of the analysis are presented. Finally, some of the limitations of the procedure are discussed, and some possible solutions to the limitations are provided.

PAST EXPERIENCE

Little attention has been focused on the topic of forecasting volumes on rural roads. Much of the research that deals with the rural highway system has been in the area of design and construction of low-volume roads, travel to recreation facilities, or rural public transportation. An extensive literature review uncovered only two studies specifically concerned with forecasts of rural traffic volumes.

In 1958 Morf and Houska (1) examined the variation of traffic growth patterns on rural highways. They hypothesized that four factors were responsible for the variations in growth patterns observed on the Illinois rural highway network: geographic location, type and width of pavement, proximity to an urban area, and type of service provided by the roadway. This last factor was subdivided into four categories: interurban, interregional, urban to rural, and rural to rural.

The authors noted that the growth trends in sites close to urban areas were primarily a function of the expansion of the city. Therefore, the remaining analysis focused on rural highways outside the influence of an urban area.

A comparison by geographic location indicated minor differences in growth patterns. Slightly greater traffic increases were noted in northern rather than southern Illinois. Roadways with wider widths had correspondingly greater increases in traffic, but the authors believed that the wider roads were an effect of the volume increases, not a cause of them.

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 increases. Based on these results, the authors projected volume trends on the rural highway network in Illinois for the different road types separately.

The study by Tennant (2) used the land use and traffic generation principle to outline a procedure to estimate rural road traffic in developing counties. By using various economic, social, land use, and travel data from the Mount Kenya region in Kenya, several trip-generation equations were estimated for both urban and rural zones in the study region. The results are almost identical; in both cases employment is a better predictor of trip generation than is vehicle ownership. The correlation coefficients that use either variable in the equation are all in the range of 0.5 to 0.9. Thus even vehicle ownership does a fair job of predicting trips per person. Examining traffic generation from different land uses revealed that 75 percent of the trips were generated by one of three land use types: retail and commercial, government administration, and road transport. Agricultural and residential land use areas did not generate many trips in this region. The author concluded that, obvi-

ously, more detailed research was needed, and, as a first-cut analysis, either vehicle ownership or employment could be used to forecast future rural trip generation.

DEVELOPING THE METHODOLOGY

Current practice at NYSDOT to forecast travel on rural highway links assumes that travel, represented as vehicle miles of travel (VMT), is directly proportional to population (note that these data are from an internal memo from W.S. Caswell to J. Shafer, "VMT Growth Factors for Minor Civil Divisions," January 14, 1975). Travel forecasts for urbanized areas are obtained from the network assignments for each area. In areas outside those geographic boundaries, a different procedure was developed. By using VMT per capita estimates by area from the 1972 National Transportation Study and population estimates for each town and county in the state from the New York State Department of Commerce, annual VMT growth rates by town were derived for the years 1972-1990. These rates were developed by first estimating total VMT for each area by using the VMT per capita data and the population estimates, then calculating the annual growth rates for each area.

Several problems surfaced as these VMT growth rates were used by the Department. First, it was recognized in the beginning that there is not necessarily a correlation between VMT and population. Inaccurate estimates of VMT may result from large amounts of nonresident travel drawn into or through the area. This is especially true in popular recreation areas. Second, although the population in New York state may decline (and did so between 1970 and 1980), the number of households may (and did) rise; thus this procedure would forecast a decline in VMT from 1970 to 1980 when, in actuality, travel was still increasing. Finally, there was no sensitivity to energy price or supply in this method.

Because of these shortcomings, the NYSDOT Transportation Statistics and Analysis Section initiated a research project to develop a procedure sensitive to these factors to forecast rural traffic to be used in the development and evaluation of highway-related projects. This new methodology was designed to meet several criteria. First, the procedure must be simple enough to be used on simple desk-top or hand-held calculators, which are generally available in most planning organization offices. It was believed that a large, cumbersome computer model would be inappropriate in this study. Second, the data used in the procedure must be easily available to the local or regional planner. This includes both historical trends and future predictions. Finally, it was believed that to be of maximum use to the project development staff, the procedure would forecast annual average daily traffic (AADT) at the project site, rather than VMT as was done previously.

An elasticity model formulation was selected as the appropriate model. In this model future year AADT is related to present year AADT and modified by changes in any number of background factors. The general form of the model is as follows:

$$AADT_f = AADT_p \left\{1.0 + e_1 \left[(X_{1,f} - X_{1,p})/X_{1,p}\right] + \ldots\right\} \quad (1)$$

where

$AADT_f$ = AADT in the future year,
$AADT_p$ = AADT in the present year,
$X_{1,f}$ = value of variable X_1 in the future year,
$X_{1,p}$ = value of variable X_1 in the present year,
e_1 = elasticity of AADT with respect to X_1.

The elasticity model was selected for several reasons. 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, a simple linear regression model that relates AADT to the background factors directly was deemed inappropriate. Second, the use of present year AADT to estimate future year AADT (as a sort of pivot point) would reduce the problem of nonresident travel. Finally, the elasticity portion of the model calculates a growth factor directly, so the procedure can be easily transformed into a set of nomographs, thus further simplifying the work required by the user.

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

$$Y = a + a_1 x_1 + a_2 x_2 + \ldots \quad (2)$$

elasticity measures can be estimated by

$$e_i = a_i(\overline{X}_i/\overline{Y}) \quad (3)$$

Thus the background factors that best estimate AADT and their respective elasticities can be derived by using multiple linear regression.

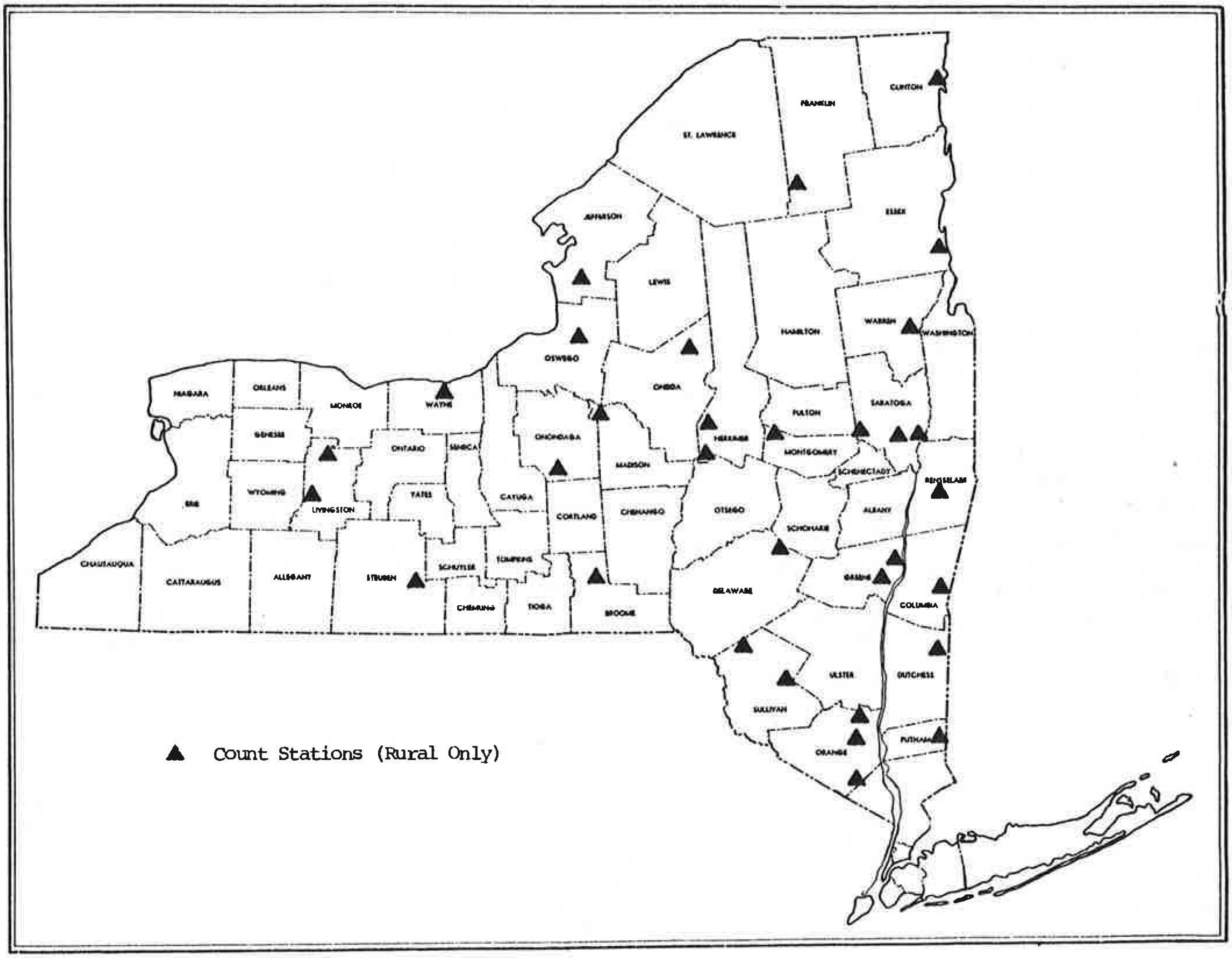
Data for the estimation of the background factors and elasticities came from a variety of sources. The AADT values were obtained from the continuous count program at NYSDOT. Only those stations classified as rural in nature were selected for use in the study. This yielded a total of 32 stations throughout the state (Figure 1). By using the town and county in which the station is located, the various background factors were collected. Information at the state, county, or town level was obtained from a variety of demographic factors, including population, households, automobile ownership, and employment. Some of these data were collected at more than one level of detail. A summary of the background factors collected at each level is as follows:

1. Town level--population, housing units, and households;
2. County level--population, housing units, households, automobile registrations, employment, labor force, personal income, and income per capita; and
3. State level--gasoline sales.

These data were collected for several years (1974-1978) and yielded a total of 5 observations for each station and 160 observations overall. These years were chosen to avoid any complications introduced by the energy emergency situations experienced during the past decade. Although the first energy crisis did encompass the early months of 1974, it was believed that the emergency had eased enough so that yearly totals for the variables would not be significantly affected.

The equations developed to uncover the most important background factors and to estimate their elasticities related each year's AADT for each station to the corresponding year's data for the background variables for that station's location. By using the results from the earlier study in Illinois (1), three different classes of roads were examined separately. These road classes were based on the type of service the road provides. By using functional class as the determinant, the three service types were Interstates (representing interurban and interregional service), principal arterials (repre-

Figure 1. Rural continuous count stations.



senting rural-to-urban service), and minor arterials and major collectors (representing rural-to-rural service). Thus three sets of elasticities and three forecasting models were derived.

Several regression analyses were performed by using a stepwise linear regression program. In the initial runs, one of the income variables was entered into the model. However, future values for either of those income variables are difficult to forecast, especially in an economy that is undergoing such rapid changes. Given the earlier criterion for using variables that are easily available and simple to forecast, all further analyses eliminated any income variables from consideration.

In addition, throughout the remainder of the analyses, town or county housing units appeared in many of the equations. In this case, although the relationship has statistical significance, the causal relationship to travel must be questioned. It was believed that households (sometimes defined as occupied housing units) were a better determinant of travel. Therefore, whenever housing units at any level entered the equations, the corresponding household value was substituted. This resulted in extremely small reductions in explanatory power of the models, but the models had a much better causal foundation.

The final regression equations, along with the R^2 values, t-statistics, and elasticities are as follows. For Interstates,

$$\text{AADT} = -1097.870 + 0.051 \text{ county automobiles} + 9.042 \text{ town households} \tag{4}$$

$$R^2 = 0.65 \quad t = 2.49 \quad t = 6.86$$
$$F = 25.13 \quad e = 0.228 \quad e = 0.832$$

For principal arterials,

$$\text{AADT} = -3013.145 + 0.125 \text{ county households} + 0.866 \text{ town population} \tag{5}$$

$$R^2 = 0.77 \quad t = 4.98 \quad t = 7.27$$
$$F = 45.75 \quad e = 0.572 \quad e = 0.760$$

For minor arterials and major collectors,

$$\text{AADT} = 2867.129 + 0.619 \text{ town households} \tag{6}$$

$$R^2 = 0.20 \quad t = 4.95$$
$$F = 24.52 \quad e = 0.314$$

Each of the models are relatively simple, with only one or two variables in each. The equations use variables that are easily available to local planners from a variety of sources for both historical and future trends. Each of the variables is signif-

icant at the 95 percent confidence level, and all function in the proper direction; i.e., as the variables increase, travel increases. Equations 4 and 5 explain much more of the variance than Equation 6, but this is an expected result. The last type of rural road is much more abundant and serves many more purposes than the other, more specialized, types of roads. Therefore, it is expected that there would be much more variability in the data and much less explanatory power in a simple model. This variability is probably caused by local factors below the town level. Large traffic generators such as malls, drive-in fast food restaurants, or schools in the proximity of the counting station are examples of such a local effect.

There are several items of interest in Equations 4-6. First, in only one equation does a population variable enter, whereas a household variable is in every equation. This supports the contention that households, not population, are a better determinant of travel. This is especially significant because the previous procedure at NYSDOT relied exclusively on population as the determinant of future traffic volumes. Second, it is interesting to note that the energy variable did not enter any of the equations. In fact, its correlation with AADT was extremely small. This variable was a statewide value, whereas the rest of the data was of a finer detail. Unfortunately, more detailed information on fuel supply was not available. Perhaps with more detailed data energy factors may become significant in these equations.

By using the elasticities derived from the regression equations, it is now possible to complete the development of the forecasting model by substituting those elasticities into Equation 1. This model is presented in Equations 7-9. For Interstates,

$$\mathrm{AADT_f} = \mathrm{AADT_p}\ [1 + 0.228\ (\%\Delta\ \text{county automobiles}) + 0.832\ (\%\Delta\ \text{town households})] \qquad (7)$$

For principal arterials,

$$\mathrm{AADT_f} = \mathrm{AADT_p}\ [1 + 0.572\ (\%\Delta\ \text{county households}) + 0.670\ (\%\Delta\ \text{town population})] \qquad (8)$$

For minor arterials and major collectors,

$$\mathrm{AADT_f} = \mathrm{AADT_p}\ [1 + 0.314\ (\%\Delta\ \text{town households}) \qquad (9)$$

To make the procedure even easier to use, nomographs were developed to provide faster estimates of the growth factor (called Z), that portion of the equation encompassing only the elasticities $(1 + e_1\ \Delta\%X_1 + \ldots)$. These nomographs are shown in Figures 2-4, along with example calculations demonstrating their use.

To use these nomographs, the user needs to compute the percentage change in the appropriate variables at the project site from the base year to the horizon year. By using Figure 2 (Interstates) as an example, the variables would be county automobile registrations and town households. The intersection of those lines in the graph yields the growth factor. In the example, a 35 percent change in county

Figure 2. Interstate nomograph.

INTERSTATES

Given: AADT (1980) = 25,600

County Autos, 1980 = 52,000

County Autos, 1990 = 69,160

Town HH, 1980 = 2,200

Town HH, 1990 = 2,620

$$\%\Delta\ \text{County Autos} = \frac{69{,}160 - 52{,}000}{52{,}000} = 33\%$$

$$\%\Delta\ \text{Town HH} = \frac{2{,}620 - 2{,}200}{2{,}200} = 19\%$$

From the nomograph = Z = 1.23

AADT (1990) = Z x AADT(1980)

= 1.23 x 25,600

= 31,488

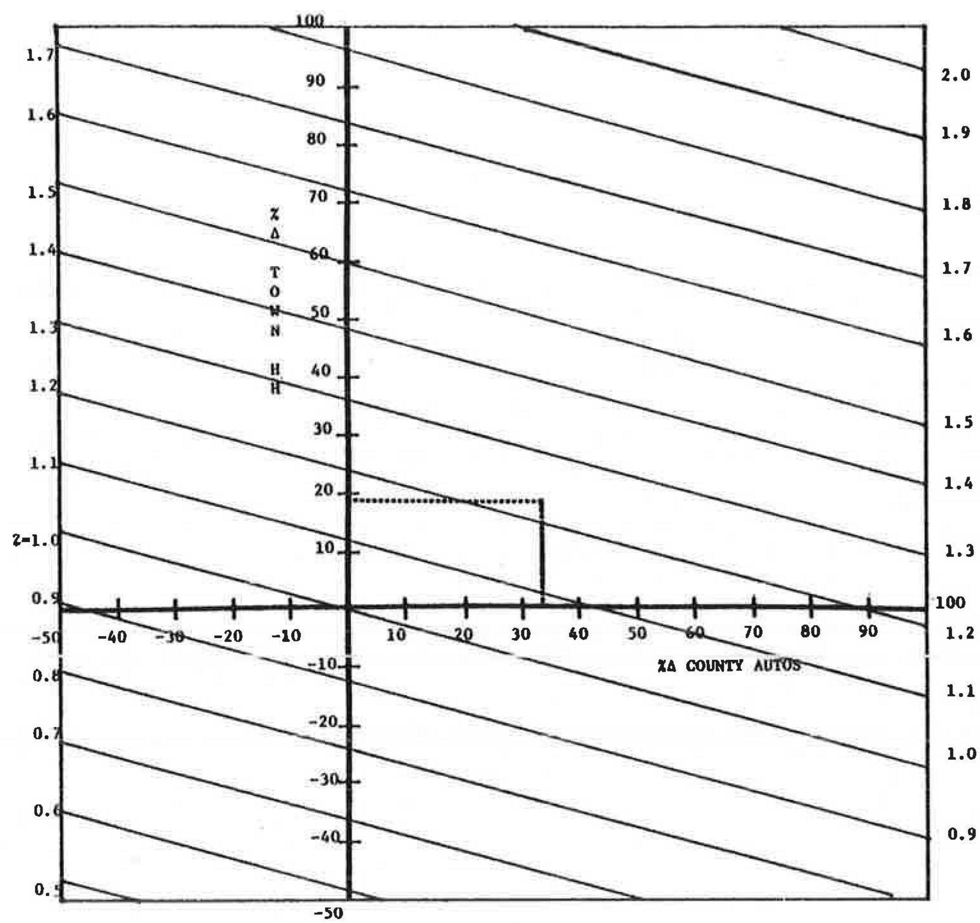


Figure 3. Principal arterial nomograph.

PRINCIPAL ARTERIALS

Given: AADT (1980) = 7,800

Town POP, 1980 = 5,700

Town POP, 1990 = 8,720

County HH, 1980 = 15,500

County HH, 1990 = 24,500

$$\%\Delta \text{ Town POP} = \frac{8{,}720 - 5{,}700}{5{,}700}$$

= 53%

$$\%\Delta \text{ County HH} = \frac{24{,}500 - 15{,}500}{15{,}500}$$

= 58%

From the nomograph, Z = 1.73

AADT (1990) = Z x AADT(1980)

= 1.73 x 7,800

= 13,494

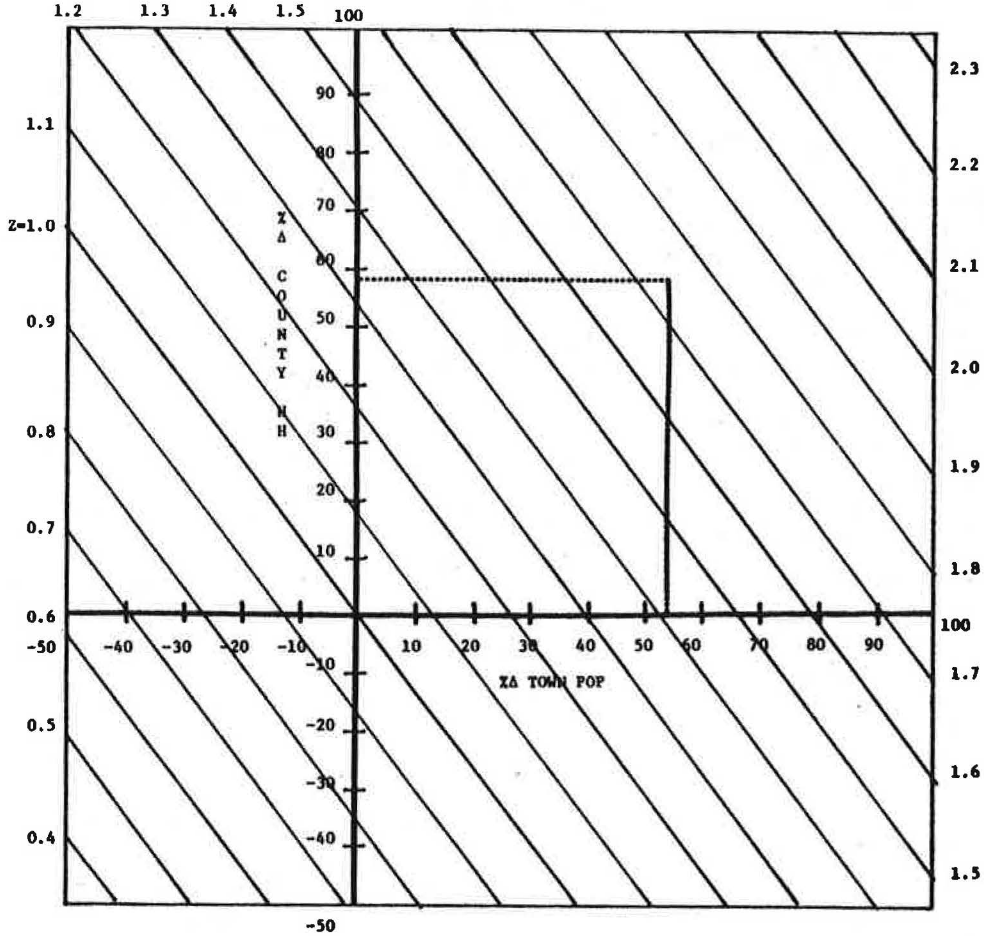


Figure 4. Minor arterial or major collector nomograph.

MINOR ARTERIALS & MAJOR COLLECTORS

Given: AADT (1980) = 1,500

Town HH, 1980 = 1,750

Town HH, 1990 = 2,485

$$\%\Delta \text{ Town HH} = \frac{2{,}485 - 1{,}750}{1{,}750}$$

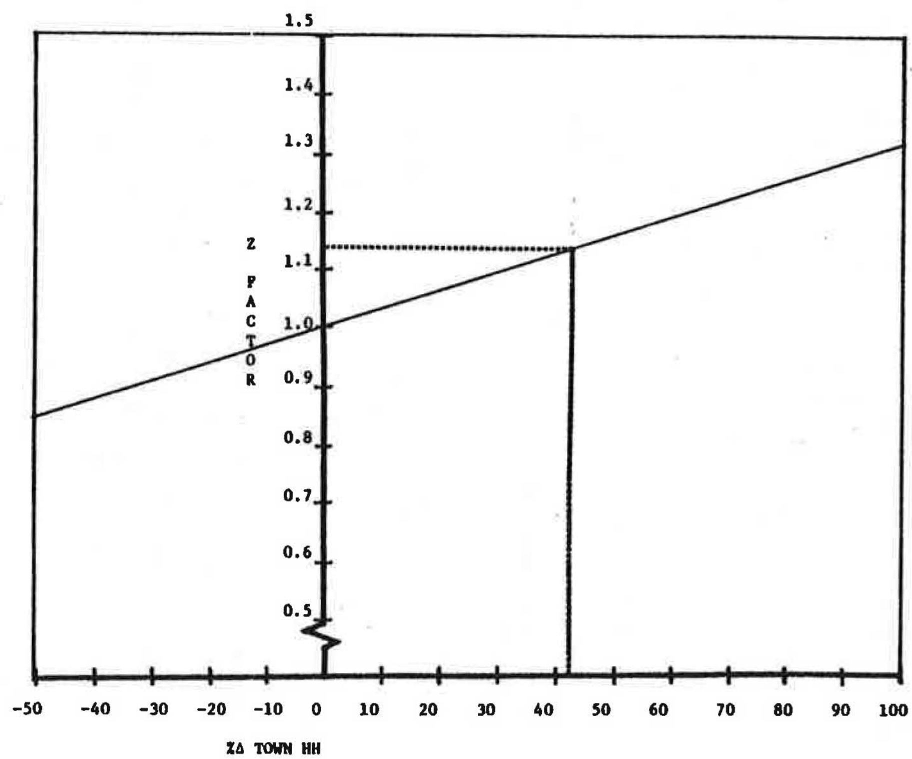
= 42%

From the nomograph, Z = 1.13

AADT (1990) = Z x AADT(1980)

= 1.13 x 1,500

= 1,695



automobile registrations and a 20 percent change in town households give a growth factor of approximately 1.23, which implies a 23 percent growth in traffic from the present to the future year.

These models satisfy all of the criteria specified earlier. The procedure is easily used by anyone with a hand-held calculator; no large computer system is necessary. With the nomographs, the forecasting procedure becomes even easier to use. The data needed to predict rural traffic volumes with these models are readily available at the local and regional levels. Historical trends for population and households are found in census publications, and automobile registration data are generally available from either the state transportation or motor vehicle departments. In addition, recent work at NYSDOT has been directed toward compiling a reference directory for gathering transportation and energy data at all levels of detail (3). This directory provides guidelines and suggestions for collecting this type of information at the local, regional, and state levels.

To use the forecasting procedure, a simple seven-step outline was developed:

1. Determine functional class of roadway,
2. Determine town and county of roadway,
3. Collect base year AADT,
4. Collect base and horizon year data for required variables,
5. Calculate percentage change for each variable,
6. Calculate (or use nomograph to estimate) Z factor, and
7. Calculate horizon year AADT.

The user's manual that describes this procedure was developed and distributed to the regional offices of NYSDOT (4). This manual included step-by-step instructions for using the procedure, the nomographs, an example calculation, and the necessary data to use the methodology.

TESTING THE METHODOLOGY

A sample of 100 sections from the state highway system were selected to test this procedure. These sections were selected because they were proportional to the total number of sections for each of the three service types, and each section had a traffic count performed in 1975 and 1980. By using the appropriate town and county values for the background variables, forecasts of AADT for 1980, based on 1975 AADTs, were computed and compared with the actual 1980 AADTs for each section.

The results indicated that the models performed satisfactorily.

Roadway	Avg Forecast Error (%)	Avg AADT
Interstates	-4.54	12,180
Principal arterials	14.49	5,415
Minor arterials and major collectors	6.93	3,865

The larger errors (for principal arterials, and minor arterials and major collectors) are associated with the smaller values of AADT. Errors of these sizes will not have a large impact on any design decisions.

The models overestimate future AADT on most of these sections, but it must be remembered that in the 1975-1980 time period an energy shortage caused a drop in travel of 5 percent or more. Therefore, the estimate of future AADT should be high. By adjusting the forecasts to account for the 1979 fuel shortage, the models would perform even better.

APPLICATIONS

There are many potential uses for the rural travel forecasting model. Several possible applications are presented in this section, and these deal primarily with the project development process, which is the main task for many state highway agencies.

The most obvious and direct use of this procedure is for the estimation of the benefits for specific highway system improvements. These projects can range from relatively simple road widenings to large-scale reconstruction of highway sections. The procedure estimates future traffic volumes reasonably quickly and accurately, and thus allows the analyst to examine many alternative projects with minimal expenditures of time and money.

A second, related application would be as an aid in the selection of the appropriate design for a project. Answers to questions such as the number of lanes and type of traffic control required are also determined by the volumes on that highway segment. The engineer can gain some insight into the future needs of the area in order to scale the project to meet those criteria.

The final application for the rural traffic forecasting model is the use of the procedure as a guide in the identification of potential problem segments of the state highway system (at least the rural portion). Because the model is based on town- and county-level variables, it is possible to identify the towns and counties where traffic growth will be the greatest and to focus on these areas for more detailed examination. This will be of great assistance in helping the planner estimate where the future problems will be. As a corollary to this use, it is possible to key the traffic counting program to this information by concentrating on the areas that show rapid growth (or decline) and by eliminating frequent counts in the areas that show a stable situation. As the available funds for all phases of highway work decline, this could be one of several ways to reduce the cost of the traffic count program without sacrificing much of its information.

PROBLEMS AND LIMITATIONS

Perhaps the most serious problem with the procedure is one that is common to all forecasting tools: the accuracy of the model is determined to a large degree by the accuracy of the inputs, especially for future values of the background variables. The state provides a set of forecasts for county population and households for 5-year intervals, but there is little information available for the other variables required in the procedure. Thus the question is how to estimate future values for county automobile registrations and town populations and households.

There are several ways to obtain future year estimates of the number of automobiles registered in the county. The first and most obvious way is to check with the state departments of transportation or motor vehicles to see if they have some forecasts of that sort. If that fails, or the local planner wishes to check those forecasts, there are other ways to forecast future automobile registrations. The easiest is to calculate the average annual growth rate from the historical data (in this case, 1973-1980 data), and assume an increasing, decreasing, or constant rate for the future. This method does not incorporate any concern about reaching a saturation point, but it may be reflected by altering the projected growth rate. Another way, which accounts for the saturation problem, is to examine the trend of historical automobiles per person in the county, and then carry that trend out to the fu-

ture until this value reaches a predefined saturation point. Then, by multiplying this trend by the county population, estimates of future year county automobile registrations are developed.

The various ways to obtain future values for both town population and households are virtually identical, and will be considered together. These methods also parallel the ones used to estimate county automobile registrations in the future. The first and simplest way is to calculate an average annual growth rate for the town and carry it over into the future. Of course, the analyst can adjust this rate to more closely reflect the local situation. This method, however, does not guarantee that the sum of the town values will equal the county total (provided already) for a given year. This is not a real problem for localized projects, but it could prove to be a significant error in larger undertakings. Therefore, a somewhat more complex way may be considered. In this method, the town's proportion of the county total is calculated for two points in time. Depending on the difference between them, it may be assumed that the town's proportion increases, decreases, or remains constant out to the horizon year. Although these procedures are not elegant, they do provide several options for the local analyst to use to meet the data requirements of the rural travel forecasting models.

One other major problem encountered while using this new forecasting tool deals with the applicability of the model in various areas. How does the analyst decide that the project area is rural enough for the model? Obviously, the model should not be used to estimate future traffic volumes in the central city, but what about the rest of the areas? It is difficult to develop guidelines to assist in this decision. Perhaps the best advice to give here is to use this model in conjunction with any other travel forecasts (e.g., from the assignment network in the fringe of the urbanized area) that deal with the same area. If no other forecast exists, then the area may be assumed to be adequately represented by this model. As experience is gained in the use of this procedure, better guidelines may be developed.

Finally, the model formulation assumes that the elasticities are constant over time, but the regression derivations do not ensure this. Historically, travel has been growing at a fairly constant rate for many years. After the interruptions caused by the two fuel shortages, travel growth resumed that rate in a short time. Therefore, it was believed that assuming constant elasticities would not introduce any substantial errors.

In addition, a log-linear form to estimate the elasticities, which ensures constant elasticities, was tested. The form of the equation is

$$Y = a_0 + a_1 \ln X_1 + a_2 \ln X_2 + \ldots \quad (10)$$

where a_1, a_2, . . . are the elasticities. The results were not significantly different from the original models (as shown in the following table), and this provides further evidence to support the assumption of constant elasticities from the linear regression formulation.

Roadway	Elasticities Linear	Elasticities Log-Linear
Interstates	-4.54	9.98
Principal arterials	14.49	13.19
Minor arterials and major collectors	6.94	6.50

Overall, few problems have been identified during the initial uses of these models. The problems previously identified were the only significant ones experienced to date. As local planners begin to use this procedure more often, some of the subtler shortcomings may surface, but they are not expected to be major concerns. It must be kept in mind that the end use for the forecasted volumes is the design of rural highway projects. These volumes are generally low enough so that large errors (on the order of 20 to 50 percent) will not cause a significant change in the design criteria.

Finally, it is important to note here that this model is not intended to be the perfect forecasting tool, if such a thing could ever exist. Rather, it is to be used by the analyst as one way, among many, to estimate future travel on the rural highway system. The user is expected to weigh the results in terms of the local situation, and adjust them according to his judgment of the specific area and application.

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