Evaluation of Three Inexpensive Travel Demand Models for Small Urban Areas

C. J. KHISTY AND M. Y. RAHI

Conventional urban travel demand models, which are data-hungry, costly, and mainly meant for use in large cities and metropolitan areas, are not suitable for small urban areas with a population of 500,000 or less. These small urban areas generally lack the staff, expertise, and budget to operate the conventional models. Three simplified travel demand models are evaluated that are suitable for small urban areas and make use of routinely collected ground counts. These three models are applied in a common setting to the City of Pullman (1980 population 23,579) in the State of Washington. Socioeconomic data and routinely collected ground counts for 1970 were used as inputs to run the models, and the outputs (travel forecasts) were compared with 1980 ground counts, to determine their forecasting capability. All three models tested performed very well. The RMS error ranges between 9 and 15 percent, and the link volume forecasting capability for most of the links ranges between 10 to 15 percent of the observed volumes. Contacts with selected planning organizations in the State of Washington reveal that such methods will be useful in small urban areas, considering their staff, expertise, time and budget limitations. Currently, these small urban areas use unproven heuristic methods. The models described in this paper will considerably help small urban areas to forecast travel demands, using routinely collected traffic ground counts and socioeconomic data, with confidence.

A primary purpose of the transportation planning process is to generate information useful to decision makers on the consequences of alternative transportation-related actions (*1*). The objective of this process is to provide information necessary for making decisions on when and where improvements should be made in the transportation system, thus satisfying travel demands and promoting land development patterns that are in keeping with community goals and objectives (*2*). Much of the attention of transportation planners and policy makers in the past has concentrated on the problems of metropolitan areas. In recent years, however there has been a greater awareness of transportation problems in small urban areas. Small urban areas, generally those with populations under 50,000, have somewhat different transportation planning needs as compared to large metropolitan areas. These needs require planning techniques that are less data hungry, less costly, and less time consuming.

This paper addresses the transportation planning needs of small urban areas with populations under 50,000. Nationwide, these small urban areas with populations between 2,500 and 50,000 have been gaining in their population share, as indicated in Table 1 (*3*). These population changes suggest a need for a renewed focus on the transportation planning requirements of small urban areas.

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One of the most important pieces of information for making decisions regarding transportation improvements is the horizon-year traffic volumes on the major links of a city's transportation network. It is customary for most cities and counties to collect traffic counts on their street system on a routine basis. This data base, consisting of base-year ground counts, can be put to good use in forecasting horizon-year traffic flows. Some inexpensive techniques for forecasting travel demands have been developed in recent years, using routinely collected ground counts and socioeconomic data. However, they have, to date, not been evaluated and tested in a common setting.

This paper describes, discusses, and evaluates inexpensive travel demand models using routinely collected ground counts. In a report (*4*) prepared for the Washington State Department of Transportation, several methods were examined of which four were found to be promising. Three of these four models are applied in a common setting to the City of Pullman (1980 population 23,579) in the State of Washington. Socioeconomic data and routinely collected ground counts for 1970 were used as inputs to run the models, and the outputs (link forecasts) were compared with 1980 ground counts to determine their forecasting capability. The reason for comparing only three of the four promising models is that the three evaluated in this paper are "calibrated" using the base-year traffic counts, while the fourth procedure (FHWA's Synthetic Traffic Simulation Method) is not "calibrated" or adjusted using the base-year traffic counts.

OVERVIEW

Travel demand models using routinely collected ground counts are a comparatively recent endeavor. The development of a travel demand forecasting model based on base-year traffic ground counts was first initiated as recently as 1972 (*5*). In these models, the link traffic volumes in the base year are used for calibration; the horizon-year socioeconomic variables and base-year calibrated models are then used to predict the traffic volumes in selected links of the network for the horizon year (Figure 1).

The transportation characteristics of small urban areas as well as their prevailing transportation problems have been described in a U.S. Department of Transportation (USDOT) document (*6*). As seen in Table 1, the proportion of total population living in small urban areas increased from 28.7 percent in 1950 to 39.6 percent in 1980. These population

TABLE 1 POPULATION SHARE OF COMMUNITIES OF DIFFERENT SIZES IN THE UNITED STATES (3)

Size of Areas	% of Total Population			
	1950	1960	1970	1980
Large Urban Areas 50,000+	35.3	36.2	35.9	34.1
Small Urban Areas 2,500 − 50,000	28.7	33.7	37.7	39.6
Rural Areas Less than 2,500	36.0	30.1	26.4	26.3

changes have generated an awareness of the transportation problems of these areas, which were all too frequently overlooked in the past. For instance, the existing transportation systems must accommodate new land use developments and handle the local traffic impacts resulting from the development of new activity centers such as shopping centers, industrial parks, etc., which were not too common in the past. This trend demands the development of planning tools and methodologies suitable for use in such communities.

Unfortunately, the growth of population and the subsequent demand for transportation facilities and services in small urban areas have not induced a proportional growth in the planning staff, budget, and other resources in these areas. As a result, most of these communities lack the resources necessary to run sophisticated conventional transportation models to make appropriate decisions. Most recently, in a survey conducted in the State of Washington, a selected number of county and regional planning councils, conferences, and commissions representing small- and medium-size urban areas were requested to express their experiences in forecasting travel demands in their study areas. In their responses, most of them indicated that the conventional models are inappropriate for use and that simplified, easy-to-understand, and inexpensive travel demand models would be useful, if available. They also mentioned that the lack of qualified staff, expertise, time constraints, and a limited budget often added to their problems (*4*).

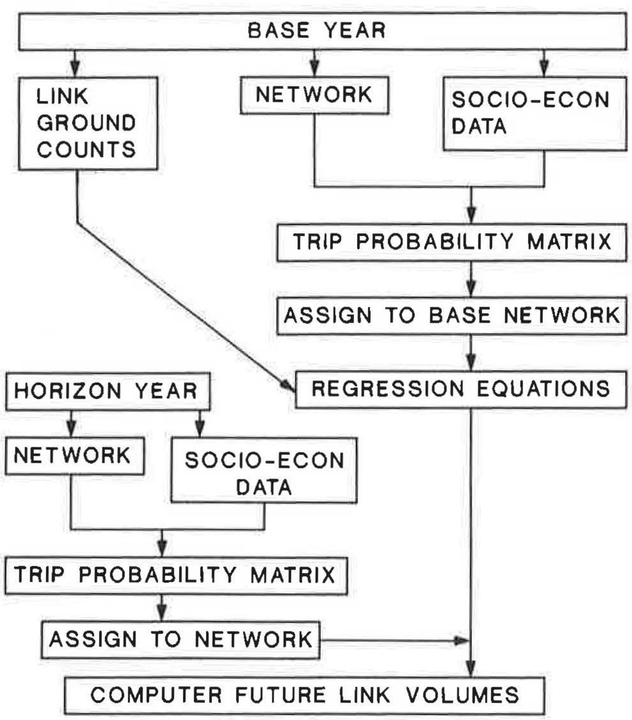

FIGURE 1 Flow chart of a travel demand model based on ground counts.

DESCRIPTION OF THE MODELS

It is customary for most cities and counties, including small urban areas, to collect traffic counts on their street system on a routine basis. For most small urban areas these counts serve the purpose of comparing and validating the estimates of the link volumes forecasted by some heuristic methods. Since these data are readily available in any small urban area, it was felt that demand models that make use of these data as basic inputs in travel forecasting would be the best choice for the small urban area planner. Several such models have been identified, of which four have been found applicable for small urban areas (*4*). These four models can be easily applied to small urban areas, because the input requirement of these models, besides link ground counts, is minimal. Moreover, the computational resources and expertise needed to run these models are also within the capability of the small urban area planner.

The four models identified as applicable for small urban areas are:

1. Low's model;
2. FHWA's Synthetic Traffic Simulation Method;
3. Neumann et al.'s technique; and
4. Khisty-AlZahrani's model.

A brief description of each of these models follows.

Low's Model

In this model, traffic volumes are determined one link at a time, primarily as a function of the relative probability that one link will be used in preference to another (5). Interzonal trip probabilities are assigned to the network, using traffic assignment procedures, to produce estimated trip probabilities on a link-by-link basis. Regression equations are developed to relate the counted link volumes to assigned trip probabilities and other link characteristics. These equations are then used to estimate link volumes for the horizon year, after determining and assigning new interzonal trip probabilities to reflect those conditions. The procedure was applied as a volume forecasting model for a metropolitan area in West Virginia. Hogberg (7) as well as Smith and McFarlane (8) evaluated the model by applying it to various small urban areas.

Some theoretical limitations have been pointed out in Low's model. In contrast to the conventional urban transportation demand (UTD) models, it does not exhibit model stability over time because of incorrect specifications. One misspecification is in representing trip productions and attractions by only production and attraction characteristics. The result is that the changes in the trip-making propensity of the study area population over time are not included in the model. For example, the population of an urban area could remain stable over time, but the number of trips could increase dramatically because of increases in, say, auto ownership.

A step-by-step procedure of the model follows:

1. Estimate trip productions and attractions for the zones. For work trips, zonal productions P_i equals the number of workers living in zone i, and zonal attractions A_j equals the number of employments located at zone j. This has to be done for both base year and horizon year.
2. Calculate f_{ij} (friction factors between zones i and j) using the equation:

$$f_{ij} = P_i A_j t_{ij}^{-2}$$

where t_{ij} is the travel time between zones i and j.

3. Assign f_{ij} (friction factors) to the network by all-or-nothing technique.
4. Develop regression equation, using the available link counts, as follows:

$$V^{kl} = a + b \sum P_{ij}^{kl} f_{ij}$$

where V^{kl} is the base year traffic volume on link $k - l$; P_{ij}^{kl} is equal to 1 if trips between $i - j$ is found on link $k - l$, 0 otherwise; and a and b are calibrated constants.

5. Estimate the horizon year link volumes using the regression equation and the assigned horizon year f_{ij} values.

FHWA's Synthetic Traffic Simulation Method

This simulation procedure has essentially the same components as that of the conventional transportation planning process, namely, trip generation, distribution, and assignment (9). Modal choice is not considered since the role of mass transit is relatively minor in most small urban areas. The basis of the approach is the borrowing of information and experiences from other studies to develop trip generation and trip distribution models. By borrowing travel relationships, the home interview survey and much of the data editing and analyses are eliminated. This elimination results both in reduced costs and in great time savings. Small cities are defined as those having less than 100,000 population.

The process begins by collecting standard socioeconomic and traffic count data. An internal origin and destination survey is eliminated. The highway network and appropriate zones are coded. Trip generation relationships (cross-classification trip rates or equations) are selected from other cities of similar size and characteristics. Productions and attractions for each trip purpose by zone are computed. These results are checked for reasonableness by the use of selected control zones, comparison of estimated vehicle-miles of travel (VMT) with actual VMT, and comparison of trip rates per dwelling unit (DU) and per capita with other similar studies. The productions and attractions are distributed by purpose using the gravity model and friction factors transferred from other transportation studies. The resulting trip length frequencies for each trip purpose are checked for reasonableness by comparison with the frequency curves from similar urban areas. The trip assignment is then made to the existing network. Gross checks and fine tuning are done to adjust the model.

Several small urban areas have successfully used the approach, achieving satisfactory reproduction of travel patterns. With reasonable care, the procedure should produce results which are good enough to be used in making decisions regarding future transportation plans and for the evaluation of the current system adequacy. Experienced transportation planning personnel and data analysts are needed to apply the method. Standard socioeconomic data, traffic counts (standard cordon, central business district cordon, screenline crossings, etc.), and highway network details are needed, as well as a comprehensive knowledge of models, procedures, and results of similar transportation studies.

The merits of the procedure lie in the large savings in cost, time, and effort, due to the elimination of the internal survey and minimal data editing and analysis. The limitations, however, include dependence on other transportation studies of similar dimensions, which may be difficult to come by. Inaccuracies from borrowed relationships may also be carried over. On the face of what has been stated here, this procedure is not as simple and efficient as it sounds. The saving in time and money lies in transferring rates from other studies.

A step-by-step procedure of the model follows:

1. Borrow trip rates for zonal production and attraction from other studies.
2. Apply the gravity model to distribute the zonal productions and attractions. The friction factors can be borrowed from NCHRP 187 (10).
3. Assign distributed trips to the network.

This model is not evaluated in this paper along with the others for reasons mentioned before.

Neumann et al.'s Technique

The model directly estimates areawide, all-purpose trip production rates (11). The method distributes and assigns zonal socioeconomic variables (autos, dwelling units, and population) directly to the study area network. External trips are deducted from the total ground counts to obtain the internal trips of the area. These ground counts are entered into a linear regression model as the dependent variables, and the assigned socioeconomic variables are entered as the independent variables. The resulting regression coefficients are the estimates of the areawide, all-purpose trip production rates.

The method is sensitive to the friction factor curves used in the trip distribution step. The methodology was tested in Lynchburg, Va. (1970 SMSA population 146,000), and Lexington, Ky. (1970 SMSA population 295,000). Estimated production rates obtained were within 96 percent of true rates. It produces accurate results and can be used in verifying borrowed production rates in the synthetic procedures. Since the method is sensitive to the accuracy of the friction factors utilized, a large proportion of the count stations should be located outside the central business district (CBD). In addition, data must be available on external-external and external-internal trip volumes for the city. This suggests that the methodology might find application in cities where the resources are sufficient to conduct external surveys. If a coded network is already available, the effort required for analysis could involve about three man-days, and the cost of data collection would be negligible.

A step-by-step procedure of the technique is shown below:

1. Assign base year socioeconomic variables directly to the network. The socioeconomic variable available for application can be the zonal population. The gravity model is used to distribute the variables. The zonal population and employment (as attraction) for base year are used for this purpose. The friction factors for the model are borrowed from NCHRP 187 (*10*). Using the travel time matrix, the gravity model is applied to distribute the socioeconomic variable. Assignment of this matrix gives the link totals for the socioeconomic variable (population).

2. Develop regression equation. The available link counts are used as the dependent variable while the corresponding link totals for population are used as independent variable for regression analysis. The following regression equation results:

$$V^{kl} = a + b \sum P^{kl} X_p^{kl}$$

where V^{kl} is the base year traffic volume on link $k - l$, a and b are the calibrated constants, and X_p^{kl} is the contribution of socioeconomic variable p to link $(k - l)$, and P^{kl} is either 1 (if link is contributed by p) or 0 (otherwise). Constant b is the areawide trip rate per person.

3. Assign socioeconomic variables for the horizon year. The horizon-year zonal population and employment are used to distribute the socioeconomic variable in the horizon year. The same set of friction factors are used in the gravity model. When the socioeconomic variable is assigned to the network it gives the link totals for the horizon year. These totals are used in the regression equation developed from the base-year data to estimate the horizon-year link volumes.

Khisty-AlZahrani's Model

This is an internal volume forecasting (IVF) model based on Low's model (*12*). The model incorporates improvements suggested by Smith and McFarlane (*8*). To eliminate the errors in Low's model, the model recommends replacing the zonal production and attraction characteristics with direct estimates of trip productions and attractions, and including origin zone accessibility in the denominator of the probability factor. The production and attraction variables and the friction factors are modified in this model as follows:

1. The production zone variable (P_i) is replaced by ER_i, the number of employees residing in zone i.
2. The attraction zone variable (A_j) is replaced by EW_j, the number of employees working in zone j.
3. The friction factor values $[F(C_{ij})]$ are calculated in a manner similar to that used in trip distribution models. $F(C_{ij})$ is an indirect indicator of the cost of travel (t_{ij}) between zones i and j

$$F(C_{ij}) = \exp(-0.10t_{ij})$$

The second theoretical limitation is avoided simply by dividing the attraction term EW_j at the destination by the total attractions of the study area, $\Sigma_j EW_j$.

The model was applied to the City of Spokane, Wash. (1980 population 171,300). The 1970 data were used to calibrate the model. The calibrated model was used to forecast the traffic volume for the horizon year 1980. It was assumed that the major street network would not change significantly between the base year and the horizon year. The only data that were necessary for the application of the model were the two variables ER_i and EW_j for 1980, which were obtained exogeneously. These values as well as the friction factor matrix were used to obtain the horizon-year trip interchange indices matrix. External-external and external-internal volumes on the links were obtained from suggestions provided in NCHRP 187 (*10*).

A comparison of the model with Low's original model indicated that the model output gave somewhat better results. Also, a comparison of the observed and the estimated horizon-year link volumes was made. Although the actual to estimated volumes for the horizon year ranged from 0.93 to 1.27, most volume groups were within 10 percent of the actual volumes.

Because network configuration and census data are generally available, the effort required to work the model for a small- or medium-sized city might involve 10 to 15 man-days. The model combines several conventional submodels into one process, and the output in terms of traffic volumes can be statistically described and tested. The model is quick, reliable, and transparent for forecasting travel in small urban areas.

A step-by-step procedure of the model follows:

1. Determine the number of workers residing in (labor force) and number of jobs available at each zone of the area under study.
2. Calculate values of the trip interchange index I_{ij} according to the formula:

$$I_{ij} = ER_i \frac{EW_j}{\Sigma\, EW_j} F(C_{ij})$$

where

ER_i = number of workers residing in zone i,
EW_j = number of jobs available at zone j,

$F(C_{ij}) = e^{-0.1t_{ij}}$ = friction factor between zones i and j, and
t_{ij} = travel time between zones i and j.

I_{ij} values are calculated for all the interchanges for both the base year and the horizon year.

3. Assign the I_{ij} values to the network. The all-or-nothing assignment is used to calculate the sum of the values of $P_{ij}^{kl}I_{ij}$ for each link. P_{ij}^{kl} values are equal to either 1 (if the trips between $i - j$ is found on link $k - l$), or 0 (if it is not).

4. Develop regression equation. Using link counts as the dependent variable $\Sigma P_{ij}^{kl}I_{ij}$ as the independent variable in the regression, the following equation is developed for use in the horizon year:

$$V^{kl} = a + b \sum P_{ij}^{kl} I_{ij}$$

where V^{kl} is the base year volume on link $k - l$, and a and b are calibrated constants.

5. Calculate horizon-year $\Sigma P_{ij}^{kl}I_{ij}$ and forecast for link volumes. The horizon-year values of I_{ij} are assigned to the network, and the values of $\Sigma P_{ij}^{kl}I_{ij}$ are calculated for all the links in the horizon year. These values are used in the regression equation developed from the base-year data to obtain the forecast-year link volumes.

APPLICATION OF THE MODELS

Three of the four models described in the previous section were selected for application in a common setting, because they emerged as the most promising techniques out of a total of 13 techniques considered for use in small urban areas (*4*). The criteria used to screen these techniques out of the currently available techniques were the following:

1. amount and type of data required;
2. transparency of the methodology used (i.e., absence of "black-box" effect);
3. simplicity in application;
4. ease of updating;
5. use of ground counts;
6. avoidance of large-memory computers;
7. use of hand-held calculators and/or personal computers;
8. cost of running the models;
9. time required in application; and
10. expertise required to run the models.

These ten criteria provide a rough measure of the suitability and applicability of the models for small cities. Table 2 shows applicability scores of these models. The application of the three models in a common setting was considered important, because the result of this experiment would provide a comparative evaluation of the models in terms of their performance, i.e., ease of their application, resource and time requirements, and accuracy. The City of Pullman in the State of Washington was chosen as a suitable free-standing small urban area for this evaluation. The city had a 1970 population of 20,509, which grew to 23,579 in 1980. Ground counts were available for this city for both the 1970 and the 1980 transportation network. The socioeconomic data required by the models were also available from the census records of 1970 and of 1980. The 1970 data were used to obtain the forecasted trips and these were compared to the actual 1980 ground counts. In the following sections, the data collection methodology and the performance of the models are described.

TABLE 2 APPLICABILITY SCORES OF THE METHODS [RANGE: 0 (BAD) TO 5 (GOOD)]

	Criteria										
	Data Required	Transparency	Simplicity	Ease of Updating	Use of Counts	Computer Required	Calculators/PC	Cost of Running	Time Required	Expertise Needed	
Model	1	2	3	4	5	6	7	8	9	10	Total
Low	4	1	3	0	5	4	4	5	5	4	33
FHWA	4	4	4	4	2	3	2	3	4	3	33
Neumann	4	4	2	3	4	3	3	4	4	3	34
Khisty-AlZahrani	4	4	3	4	5	4	4	5	4	3	40

DATA COLLECTION FOR THE MODELS

The minimum data needed by each of the three models are basically same. Data for both the base year and the horizon year were needed to apply the models and test their performances. The common set of data collected for the City of Pullman included:

- transportation networks for both base year (1970) and the horizon year (1980), showing the zones of origin and destination of trips along with travel times on the links,
- traffic counts on the links of the network, for both base year and the horizon year,
- population of each of the planning zones, for both base year and the horizon year, and
- employment data at each of the planning zones, for both base year and the horizon year.

The transportation network did not change significantly between the base year (1970) and the horizon year (1980) in the City of Pullman. The population and employment data for the city, obtained from the Bureau of Census by census tracts (CT), enumeration districts (ED), and small census districts (CD), were used in demarcating five planning zones. Zonal population and employment data were derived for both the base and the horizon years. These zones, along with the transportation network, are shown in Figure 2. For this analysis, the transportation network consisted of five planning zones, eleven major links and ten major nodes. There were also four external zones that contributed traffic to the link volumes on the major links.

The one census record that was easily accessible and useful was the Summary Tape File (STF) 3A. In particular, the data coded at Summary Level 15 in the STF 3A were sufficiently good for deriving zonal data. Although the zonal population data were readily available for both the base year and the horizon year, this was not the case for zonal employment opportunities data.

As mentioned earlier, the ground counts on the links of the transportation network of the city were readily available from the city engineering department. These data were recorded link-by-link in two city traffic study reports, one conducted around 1970 and the other around 1980. These reports provided road-link inventories as well.

Because travel demand forecasting models described here depend on exogeneous information on external trips, and their appropriate assignment to the internal network of the city, it was essential to seek an appropriate method to accomplish the external trips assignment on the network of the small urban area. The City of Pullman has four external neighboring communities, and traffic cordon counts in these neighborhoods were available in the traffic studies. Therefore, the methodology described in NCHRP 187 (*10*) to account for external trips was adopted. However, extreme care had to be

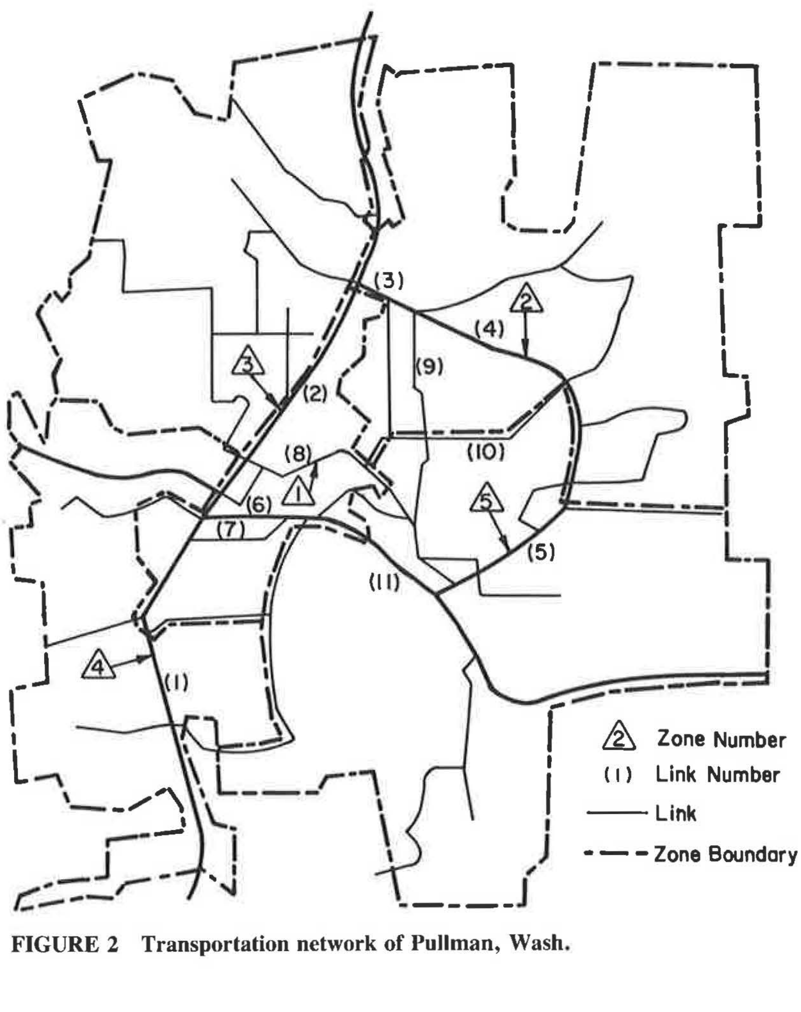

FIGURE 2 Transportation network of Pullman, Wash.

taken in assigning the external trips on the internal networks, although for most small urban areas, this task should not be a tedious exercise.

PERFORMANCE OF THE MODELS

All three models performed sufficiently well, although individual performance varied. All the models were first calibrated using the 1970 socioeconomic and transportation ground count data. This calibration yielded regression equations that could be used to forecast the horizon year (1980) link volumes. For the calibrated models, the goodness-of-fit of the regression equations was justified by the coefficient of determination (R^2) value and the Student's t-test. These values are shown in Table 3. The values appear to be quite reasonable, since the R^2 values are all above 0.80 and t_0 exceeds the threshold t of 3.25 at 99 percent confidence level with nine degrees of freedom.

After the horizon-year link volumes were forecasted by each of the models, they were compared with the actual 1980 traffic volumes of the corresponding links. Another set of regression equations was developed to relate the 1970 actual traffic volumes to the 1980 estimated traffic volumes of the corresponding links, so that the link volumes of minor street links (which were not used in the model calibration step) could also be forecasted. Once again, the goodness-of-fit of these equations was tested for validity. These values are shown in Table 4. The R^2 values range from 0.65 to 0.76, while t_0 once again exceed the threshold t of 3.25 at 99 percent confidence level with nine degrees of freedom.

Finally, for the comparison of the link volumes estimated by each of the models with those observed on the corresponding links, the root mean square (RMS) error and the percent RMS error values of each of the models were calculated and compared. The Percent Root Mean Square Error (% RMS) is defined as the ratio of the RMS error to the mean of the observed output variables. The RMS error, known as standard error, is the standard deviation of the sampling distribution. These are given as:

$$\text{RMS error} = [\Sigma(V_0^{kl} - V_e^{kl})^2/(N - 2)]^{1/2}$$

TABLE 3 GOODNESS-OF-FIT OF MODEL CALIBRATION

Model	R^2	t-test
Low	0.82	$t_0 = 6.29 > t_{9,.005} = 3.25$
Neumann	0.80	$t_0 = 5.94 > t_{9,.005} = 3.25$
Khisty	0.86	$t_0 = 7.50 > t_{9,.005} = 3.25$

TABLE 4 GOODNESS-OF-FIT OF MODEL FORECASTING

Model	R^2	t-test
Low	0.76	$t_0 = 5.38 > t_{9,.005} = 3.25$
Neumann	0.65	$t_0 = 4.05 > t_{9,.005} = 3.25$
Khisty	0.76	$t_0 = 5.31 > t_{9,.005} = 3.25$

and

$$\% \text{ RMS Error} = \frac{\text{RMS Error}}{V_{\bar{o}}} \times 100$$

where V_o^{kl} is the observed volume on link $k - l$, V_e^{kl} is the estimated volume on link $k - l$, N is the number of links, and $V_{\bar{o}}$ is the arithmetic mean of the observed link volumes. These values gave an individual performance of the models. The results of these evaluations are shown in Table 5. The range between 9 and 15 percent appears to be most satisfactory.

For a critical examination of the performance of the models, the ratios of the 1980 observed to estimated link volumes (V_o/V_e) are tabulated for each of the models in Table 6. The range of V_o/V_e is 0.76 to 1.11 for the Low model, 0.82 to 1.17 for the Neumann technique, and 0.81 to 1.09 for the Khisty-AlZahrani model. Low's model generally estimated link volumes lower than observed, with half the links within 10 percent of actual volumes. Neumann's model fared about the same, while the Khisty-AlZahrani model produced most of the link volumes within 10 percent of the actual volumes. In Figures 3 through 5, the observed 1980 link volumes are plotted against the corresponding link volumes estimated by each of the models. While all three models perform well, the performance of the Khisty-AlZahrani is good from all aspects.

TABLE 5 EVALUATION OF THE MODEL ESTIMATES

Model	RMS Error	% RMS Error
Low	1693.85303	15.04043
Neumann	1542.41626	13.69575
Khisty	1063.20752	9.44066

TABLE 6 RATIOS OF OBSERVED TO ESTIMATED VOLUMES (V_o/V_e), BY LINK, FOR THE THREE MODELS

Link No.	Low	Neumann	Khisty
1	0.929	1.098	1.039
2	0.784	0.938	0.888
3	0.980	1.171	1.086
4	0.837	0.968	0.919
5	1.114	1.073	1.075
6	0.905	0.821	0.907
7	0.804	0.837	0.883
8	0.812	0.868	0.905
9	0.764	0.769	0.805
10	1.046	1.049	1.094
11	0.924	0.847	0.909

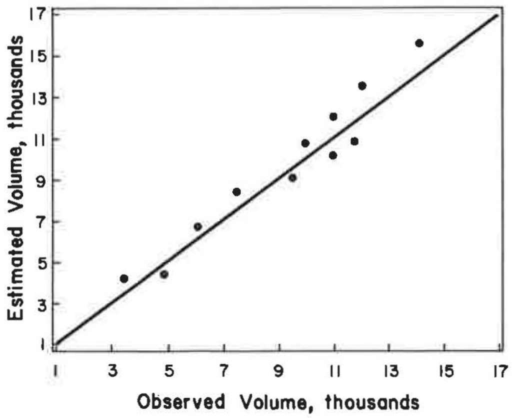

FIGURE 3 Performance of Khisty-AlZahrani model.

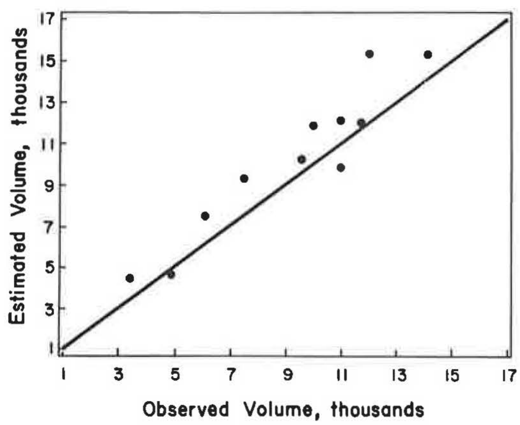

FIGURE 4 Performance of Low model.

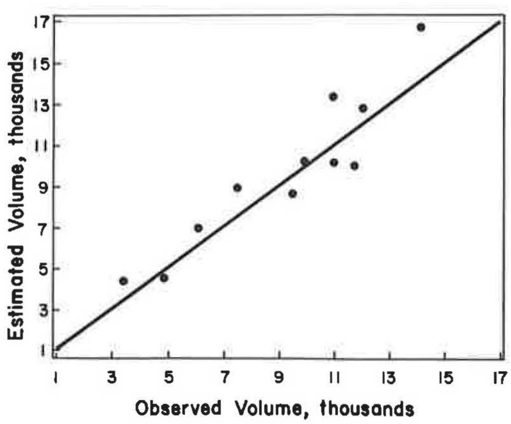

FIGURE 5 Performance of Neumann technique.

DISCUSSION OF RESULTS

The intention of this evaluation was not to proclaim a winner. Any of the three models can be easily applied in any small urban area setting with a population less than 50,000. The techniques can also be applied to larger urban areas.

These models would be particularly useful to transportation planners at the regional and local levels who are concerned with the planning and operation of transportation facilities and services in small cities or urban areas, especially those that are free-standing in rural regions but also those that are extensions of large metropolitan areas. The use of these models will result in considerable savings in time, money, and manpower, besides enabling decision makers to examine a variety of alternative plans reflecting broad policy. The use of these models can be highly recommended for modeling small urban areas, where transportation system management analysis is needed but qualified full-time transportation planners are not available on the planning staff. Caution, however, needs to be exercised regarding:

- the choice of socioeconomic variables (more experience needs to be gained from further application of the models in cities of varying sizes);
- the application of the models to cities having high percentage of mass-transit patronage;
- the fact that the outputs from these models are in terms of trips for all purposes (home-based, nonhome-based, and other trips could possibly be worked out with additional data);
- the exclusion of external-external, external-internal, and internal-external trips (count stations located on the cordon line would be most helpful in dealing with the forecast of such trips); and
- the use of this type of model for crucial policy options (the model is sensitive only to network changes).

CONCLUSION

Since the transportation characteristics, problems, and needs of small urban areas are quite different from large urban areas, special attention must be given in selecting techniques or models to forecast the demand for transportation facilities and services. The fact that these small urban areas generally lack the staff, expertise, and budget to operate the conventional models must be taken into account. Three inexpensive travel demand models discussed in this paper show sufficient promise in their performance to warrant adoption. All these models advantageously use traffic ground counts, an important input which is routinely collected by small urban areas and readily available to the traffic planner. The choice of adopting any one of these models should depend on the individual traffic planner, and on manpower and time availability.

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Publication of this paper sponsored by Committee on Transportation Planning Needs and Requirements of Small and Medium-Sized Communities.