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# Public Roads

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Sections of Seattle Freeway, IS–5, under construction, Seattle, Wash., Mt. Rainier in background. When completed in late 1966, the Seattle Freeway will unite many communities and is expected to serve more people than any other highway in the Pacific Northwest.

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# IN THIS ISSUE



**U.S. DEPARTMENT OF COMMERCE**
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**BUREAU OF PUBLIC ROADS**
**REX M. WHITTON, Administrator**

# Test of Some First Generation Residential Land Use Models

BY THE
OFFICE OF PLANNING
BUREAU OF PUBLIC ROADS

Reported by [1] CARL N. SWERDLOFF and JOSEPH R. STOWERS,
Supervisory Highway Research Engineers,
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*The relative accuracy of forecasting land use by five residential land use simulation models was tested in the study discussed in this article. Explicit model statements and descriptions of the procedures used in calibrating the forecasts are given. All conditions for the test models were held constant except the interrelations among variables, so that differences among the forecasts would be caused only by inherent differences in the models themselves. Results of the study reported here cannot be considered definitive because of the differences in amount of information required and the differences in the degree to which the models were fitted to data. Also, the study represents only one of many possible test conditions.*

*Some conclusions useful to small metropolitan areas, lacking resources for development of new models and refinement of existing models, can be drawn from the study results. Simple, nonbehavioral residential land use forecasting models were shown to be sufficiently accurate for metropolitan areas of 100,000 population or more. The models also were effective in forecasting for geographic units having a population of about 2,000, although results for smaller areas were not accurate. In the evaluation none of the five forecasting models was superior; use of any one of the models for urban planning would be preferable to forecasting without a model.*

## Introduction

A COMPARATIVE evaluation of five operational residential land use forecasting techniques, four of which have been used previously in urban transportation planning studies, is discussed in this article. The techniques are representative of the earliest efforts in the development of operational urban activity simulation models and serve, either in the original or modified form, many transportation planning organizations. The more complex and accurate urban activity simulation models, currently under development, often draw upon fundamental concepts that originated with or were adapted to early techniques. Improvements being introduced in these second generation models include more complex statistical estimating procedures, the stratification of residential locators into distinct groups, and the incorporation of behavioral relationships in model formulation. Although newer techniques may require several years of research, evaluation, and refinement before they become fully operational, the less sophisticated techniques evaluated here would be useful to small metropolitan areas lacking resources for developmental research.

The primary objective of the research discussed in this article was to compare the relative accuracy of the existing techniques through a series of after the fact tests, in which all conditions were constant except the interrelationships among variables, so that differences in forecasts would be a function only of inherent differences in models. However, the results of this study cannot be interpreted as definitive statements for several reasons. First, the tests are not all of the same class. Some are forecasts, others data fitting problems that involve fitting different numbers of parameters. Second, more information is used in some than in others. Third, the results represent a sample of one of a large universe of possible test conditions; entirely different results might be obtained if these models were used on different data in other cities, for different time periods, by other forecasters.

## Conclusions and Findings

- Simple, nonbehavioral residential land use forecasting models are sufficiently accurate for use in small metropolitan areas having populations of 100,000 or more. The analysis of the spatial structure and growth pattern of Greensboro, N.C., confirms the belief that analytical planning would be helpful in the development of such urban areas.

- Land use forecasting with simple first generation models produced reasonably accurate results for levels of geographic organization where the average area unit contained a population of about 2,000. Efforts to forecast growth for much smaller areas may prove unjustified. At zone levels of about 300 population, these models appeared to offer little or no assistance in forecasting land use.

- Differences in accuracy among the five forecasting models were not large enough to warrant a strong recommendation for any one model in preference to another. Use of any one of the models seems preferable to forecasting land use without analytical techniques.

- The accessibility model produced the most accurate forecast, of methods used, without calibration to time series data. Errors in fitting were insensitive to small changes in the exponent of accessibility.

- Although five or more parameters were used in the regression model equations, none of the multiple linear regression models were better than the two variable fitted models.

- Multiple regression models possess drawbacks. If the dependent variable is expressed as an extensive quantity, such as an increase in dwelling units, measured relations with independent variables will be influenced by peculiarities of area definition and size, and they might not conform to logical hypotheses regarding the land development process. Nonlinear transformations on the dependent variable, such as logarithms or fractional power functions, are unsatisfactory. The use of least squares calculations tends to bias the parameter estimates to produce good fits to small independent variables and poor fits to large ones. Expression of the dependent variable as an intensive quantity, such as dwelling unit increase per unit of geographic area, may be the most satisfactory operational solution except that relations actually nonlinear may not be represented properly. This might be corrected by treating certain independent variables as sets of dummy variables.

- Although the two intervening opportunities models performed satisfactorily, possible improvement might be obtained by allocating growth from all major centers of employment rather than from a single point, the CBD. In addition, each of the two models plots as a straight line plot on different semilogarithimic coordinates. This linear relationship was found not to hold true for the entire study area of Greensboro. Apparently the hypotheses are valid, but separate functions may be necessary for the established inner city area and the developing suburban area.

[1] Presented at the 46th annual meeting of the Highway Research Board, Washington, D.C., Jan. 1966.

• The C.A.T.S. forecasting model differs from the other models: It forces the analyst to become intimately familiar with the study area before attempting to make a forecast. This is a strong feature. The graphic analyses that the method is based on represent descriptions of the key spatial relations of a metropolitan area, even for small areas. The methods of analysis are useful regardless of the forecasting technique used. They can serve as a check on the reasonableness of forecasts made by less subjective models.

However, as applied in the study reported in this article, the method is time-consuming; it requires considerable handwork and far more data manipulation. The method is less adaptable to the computer and would be cumbersome for testing alternative land use policies or for recursive use in combination with submodels.

• The five models tested are not representative of the type and number of current land use forecasting models. They represent the initial models but lack the sophistication and elegance of more recent model developments. These are descriptive models and do not involve either the behavior of decision makers or have any theoretical content. It is highly probable that the key to increased forecasting accuracy for small subareas is in the ability of the analyst to simulate the decision process for subpopulations of the area.

## General Procedures

The five residential land use forecasting procedures are each variants of work done by others. The only innovations introduced during the study were simplifications and modifications made for particular conditions. In any realistic planning application, more care would have to be given to the particular forecasting tool used. Trends would be more carefully analyzed, the forecasters would be more familiar with the area being studied, and output of models would be scrutinized and modified as judgment indicated. In the research reported here the models were applied crudely and the immediate output was accepted. The techniques were: (1) The density-saturation gradient model; (2) accessibility model; (3) regression model; and (4) two intervening opportunities models.

The density saturation gradient model (DSGM) is a simplification of the approach used for the *Chicago Area Transportation Study* (C.A.T.S.) (*1*).[2] Of the five models, the DSGM is the least computer oriented, it is more demanding of subjective inputs, and, therefore, it is the least suitable for objective comparison with other forecasting procedures. The DSGM method is based on the regularity of the decline in density and percentage of saturation with distance from the central business district (CBD) and the stability of these relations through time.

The accessibility model is based upon a concept formulated by Walter Hansen (*2*). Growth in a particular area is hypothesized to be related to two factors: The accessibility of the area to some regional activity distribution, and the amount of land available in the area for development. The accessibility of an area is an index representing the closeness of the area to all other activity in the region. All areas compete for the aggregate growth and share in the growth in proportion to their comparative accessibility positions weighted by their capability to accommodate development as measured by vacant, usable land.

The multiple linear regression model is a popular approach because of its operational simplicity and because several variables can be incorporated (*3*). The proportion of total regional growth in a particular area is assumed to be related to the magnitude of several variables that in some manner are measures of geographic desirability. The procedure is to determine those variables and their weights that in linear combination can be related to the growth observed over a past time period. These independent variables and their weights (regression coefficients), in linear combination (the regression equation), then can be applied to the individual analysis areas to forecast the magnitude of growth, which is the dependent variable.

Although more commonly applied to the problem of trip distribution, the intervening opportunities models can be used to simulate the distribution of urban activity. Two separate and distinct models were applied in this study, based upon the general idea that the probability of an opportunity being accepted decreases as some function of the number of opportunities ranked closer to a central distributing point. The Stouffer formulation was originally applied to intra-urban migration (*4*). A related formulation has more recently been investigated as a trip distribution technique (*5*). Schneider's formulation was originally applied to trip distribution (*6*) and is currently being used in distributing urban activity(*7*).

The test area used for all the work in the study reported here was Greensboro, N.C. This city was chosen primarily because a rather extensive information file on a small area basis for two time periods (1948 and 1960) was available. Also, it was believed that Greensboro was representative of the kind and size city for which forecasting techniques of the kind being examined would still be appropriate after the development of more sophisticated models in the large metropolitan areas.

The data utilized in the study were made available by Prof. F. S. Chapin, Jr., of the University of North Carolina and Mr. A. M. Voorhees of Alan M. Voorhees and Associates. The data obtained from the University of North Carolina contained information for the Greensboro area coded to 3,980 grid cells, each one a 1,000 feet square, for a circular area of about a 7-mile radius. These data included quantitative measures of land use; population; residential density; proximity to different activities and the CBD; and some environmental measures that are listed completely in a monograph on *Factors Influencing Land Development* by F. S. Chapin, Jr., and S. F. Weiss, University of North Carolina, April 1962. Most of these data were availab at the grid level for two time periods, 19 and 1960.

The data supplied by Alan M. Voorhe and Associates included 1960 populatio employment, accessibility to shopping, a accessibility to employment, for about 2 zones. Accessibility measures were comput from zone-to-zone traveltimes over the hig way network.

### Problems encountered

Problems were encountered in combini the data from these two sources in a for suitable for testing the models. A princip difficulty was the aggregation of grids zones. Because it was desirable to work a level of aggregation more typical of tran portation studies, new zone boundari following grid lines approximating the irregul old zone boundaries had to be defined. important error was introduced as on accessibility scores from the original zo file were used in subsequent analyses. extensive quantities used were grid aggregat

Consideration of all data sources and t purpose of the study led to the decision use dwelling units as the items to be p dicted. However, another problem w encountered as data were not directly ava able. Estimates were made and differe checks applied by using the 1948 land ar the 1948 USGS map for suburban areas, t 1950 Census block statistics for the cent city and the 1960 land area and dwelli unit densities.

A third problem was the estimation accessibility measures for 1960 for cert zones at the fringe. The area covered by t zone file did not extend to the boundaries the grid coverage area in all directio Rather than eliminate this area entire estimates of accessibility measures were ma for about half of the outer ring of zones examining contours of isoaccessibility lin which follow fairly regular patterns in t fringe areas.

## Model Description And Methodolo

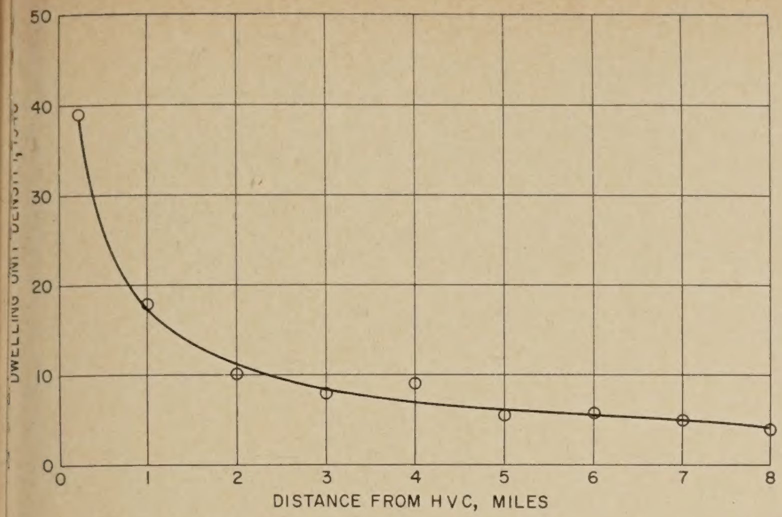
Explicit model statements and descriptio of the procedures used in calibrating or fo casting for each of the five methods discussed here.

### Density-saturation gradient model

The DSGM is the least formally structur forecasting procedure of the five. No form theoretical statements or mathematical h potheses are required, although the staff the C.A.T.S. has presented excellent c ceptual explanations of its empirical findi and rationale for their projections ( Theoretical development, however, was r essential to the purpose of the resear reported in this article.

Certain limitations for application of t DSGM to the Greensboro area existed pr to the testing. The only known previo application of this technique was for t Chicago area. Some initial fear existed th

[2] References identified by italic numbers in parentheses are listed on page 109.




'igure 1.—*Dwelling unit density by distance bands for 1948.*

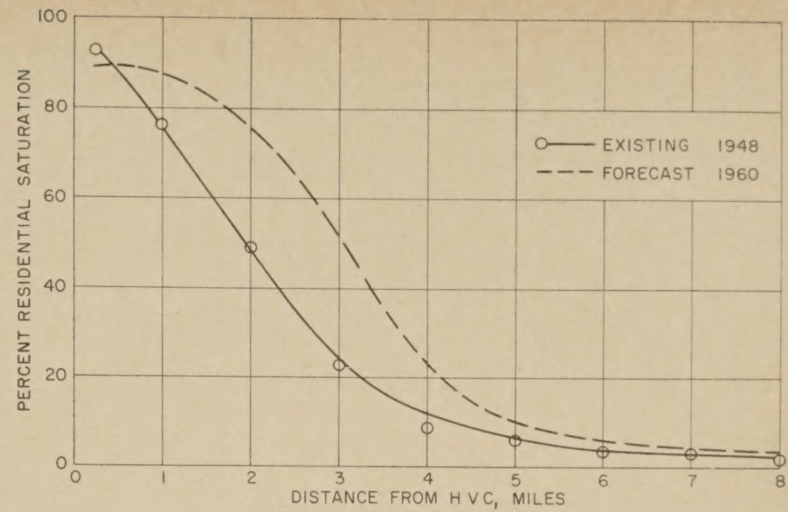



*Figure 2.—1960 forecast of percentage of residential saturation by distance bands.*

he regularities in activity distribution around he central place, which is axiomatic to the 1ethod, would not be manifest for a city the ize of Greensboro. The declines in density nd percent capacity are the result of the peration of the competitive land market, a 1echanism that might not exert a dominating nfluence upon spatial organization in a city f Greensboro's size. However, these fears vere unwarranted and, in fact, the distribuion of residential activity was markedly tructured around the CBD.

### 'wo trials

Two semi-independent forecast trials by he DSGM were made to determine the ensitivity of the results to variations in the ritical assumptions made. The forecasts vere distinct in that the first trial was made ising airline distance from the high value corner (HVC) as the key spatial variable. The HVC is a point representative of the hypothetical activity center of the CBD. Traveltime to the HVC was used in the second rial.

The relation between the 1948 dwelling unit density and the airline distance from the HVC are shown by data in figure 1. Each point on the plot represents the gross residential density (street area included) for a ring around the HVC. With the exception of the first or CBD ring, each ring was determined by the boundaries of zones whose centroids fell within plus or minus one-half mile of the nominal distance of the ring from the HVC. The plot of the data shows a decline in residential densities with distance from downtown Greensboro in 1948. This decline was encouraging because the reliability of the DSGM depends on the strength and stability of this relation.

The DSGM depends equally upon the correlation between distance and percent saturation. To compute the latter, residential capacity must be defined. Capacity is defined mathematically as existing dwelling units plus the product of vacant available, suitable land, and expected residential density. A decision had to be made as to the density values to be used in the computation. Theoretically the density values should be the anticipated average density at which all future residential development will occur. Thus density should be developed from an intensive analysis of trends in residential density patterns and zoning policies. For purposes of the study, however, future densities for each zone were assumed to be those shown by the smooth hand-fitted curve developed for figure 1. Before acceptance of density data shown by this single curve, gradients were plotted for each of five sectors. Although this plotting showed less than regular relationships, no significant variation in density gradients was noted between sectors.

Figures for vacant, suitable land for residential development were estimated by subtracting those for marginal land and land zoned for nonresidential uses from the amount of 1948 nonurban land. A systematic, but subjective procedure was used in the treatment of zoning: Land use was weighted by factors ranging from zero for grids zoned only for industrial use to 1.0 for grids zoned only for residential use; land use in grids zoned for mixed uses and other nonindustrial uses was weighted subjectively on a scale from zero to unity.

### Saturation density

Having computed future residential development densities and vacant available land, it was possible to compute both the residential saturations in dwelling units and the existing percentage of saturation for each distance ring from the HVC. The resultant percentage from the division of saturation into 1948 dwelling units was used to construct the percentage of saturation gradient. The residential saturation plot, shown in figure 2, conforms to that expected for an urban area. The distinct and sharp transition between the 3½- and 4½-mile points indicates a transition in the character of the area used for the study from urban to mostly rural. The almost negligible slope of the curve beyond the 4½-mile point indicates agricultural development and the absence of strong competition for location close to central Greensboro.

The 1960 projection of the percentage of residential saturation is also shown in figure 2. The 1948 percentages of saturation gradients also were plotted by sector; as for the density gradient some scattering of points was noticeable but this scattering was not sufficient to require using sector specific gradients. The 1960 projection is the most critical and subjective step in the forecasting process. The only restraint used in developing the projected curve was to assure that the area under the curve would reflect the projected regional growth. The number of dwelling units in the study area increased from 27,191 to 41,250 in the 1948 to 1960 period, a growth of 52 percent.

Many different procedures can be used to establish an acceptable projection of the percentage of saturation gradient. It was, however, considered useful to develop the overall scale—the area under the final curve that would be commensurate with the requirement for projection of the regional population. As a first approximation, each ordinate rate was raised a distance equivalent to 52 percent of the 1948 rate. The resultant curve then approximated the forecast condition under the assumption of uniform growth over the entire region. General criteria were then introduced to modify the first approximation of the shape of the gradient in 1960. These were that: (1) The bulk of the residential growth would occur in the 2-, 3-, and 4-mile rings; (2) the inner ring would suffer a slight decline; (3) the shape of the gradient would tend to bow out in the 1- to 3-mile range; (4) the sharp transition in slope of the 1948 saturation gradient, observed at about the 4- to 5-mile point, would become less abrupt for 1960; and (5) the land use for areas 5 miles and beyond would show some exurban growth, but the general flat slope would remain.

### Dwelling unit growth

Relatively few attempts were necessary before a solution was obtained that was of satisfactory shape and that conformed to the actual 1948–60 increase in total dwelling units. The forecast dwelling unit totals by analysis

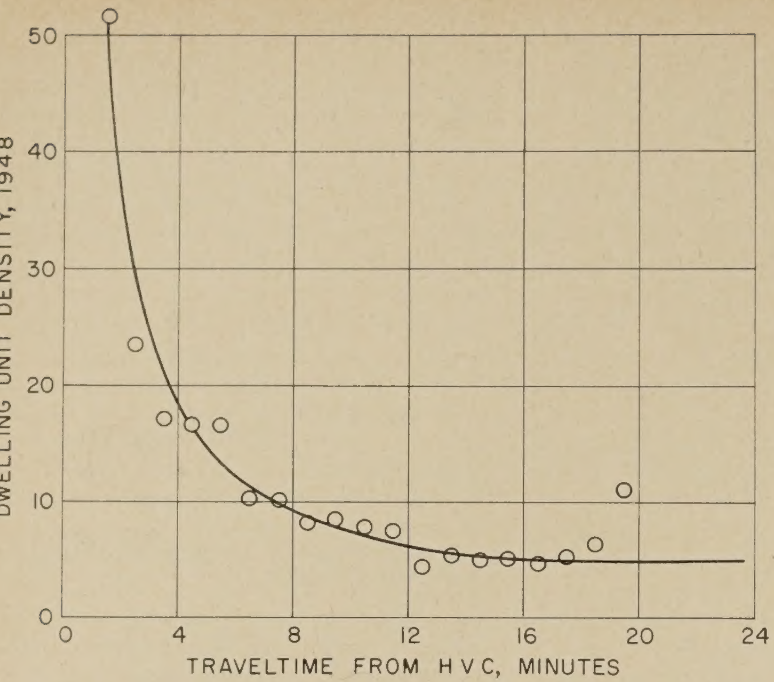



*Figure 3.—Dwelling unit density by time bands for 1948.*

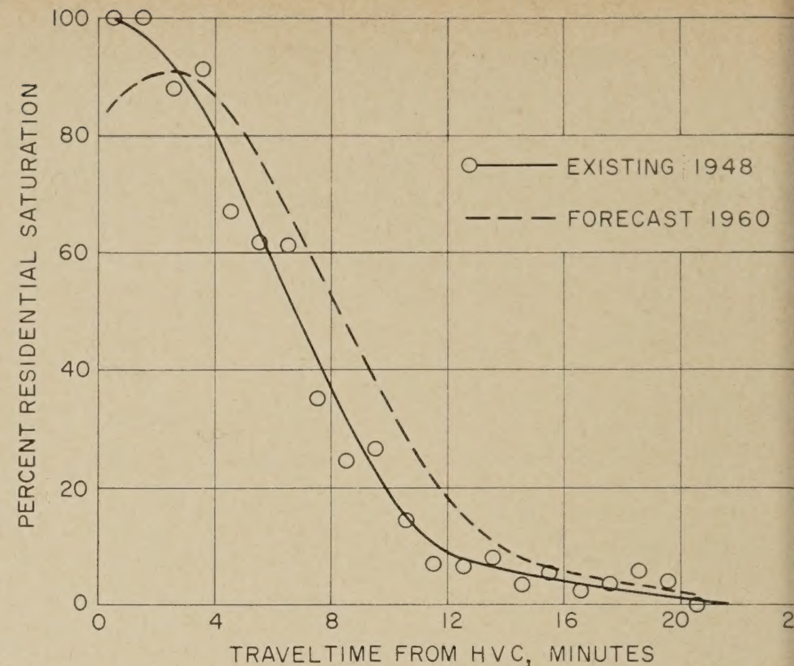



*Figure 4.—1960 forecast of percentage of residential saturation by time bands.*

ring were established by multiplying the appropriate ordinate figure (fig. 2) from the forecast percentage of saturation gradient by the ring saturation quantities.

The projected growth of each ring was distributed to zones in a two-step process following the logic of the C.A.T.S. The distribution of projected growth to districts (defined by ring-sector boundaries) was handicapped by a lack of historical data. Ideally the trends in land use composition and growth rates between sectors should be studied in detail. For trial one, however, the simple assumption was made that sectors would share growth in proportion to available residential capacity. The final distribution to zones was based on a systematic but subjective linear weighting of the following factors: (1) Distance to convenience shopping; (2) available residential capacity; (3) distance to the major street system; (4) percentage of industrial development in the zone; and (5) percentage of residential development in the zone.

Trial two was conducted independently of trial one and differed from it in two ways. First, traveltime to the HVC was substituted for airline distance as the major independent variable. Zones were grouped into 1-minute interval rings for all analyses. Second, ring growth was allocated to sectors—that is, the district-level forecast—in proportion to the product of each sector's available residential capacity and the number of existing (1948) dwelling units. The same processes for trial two as for trial one were used in estimating density and holding capacity, in establishing sector definitions, and in allocating growth from districts to zones.

Figure 3 shows the dwelling unit density gradient as determined from the ring analysis in trial two: The general shape of the curve is the same as that for trial one. The curves for percentage of saturation of dwelling unit density calculated for the 1948 base period and the 1960 forecast are shown in figure 4. The 1960 gradient shape is similar to the shape for trial one except for a slight decrease in the growth allocated to the inner rings, which caused a lessening in the bowing effect and in the slope of the gradient in the intermediate areas. Forecast results are discussed after the other models have been described.

### *Accessibility Model*

The generalized form of the accessibility model is

$$G_i = G_t \frac{A_i^a V_i}{\sum_i A_i^a V_i} \qquad (1)$$

Where,

$G_i$ = Forecast growth for zone $i$.

$G_t$ = Total regional growth $= \sum_i G_i$.

$A_i$ = Accessibility index for zone $i$.

$V_i$ = Vacant available land in zone $i$.

$a$ = Empirically determined exponent.

The computation of the accessibility index traditionally is

$$A_i = \sum_j \frac{E_j}{(T_{ij})^b} \qquad (2)$$

Where

$E_j$ = Measure of activity in zone $j$.

$(T_{ij})$ = Traveltime from zone $i$ to zone $j$.

$b$ = An empirically determined exponent.

However, friction factors developed by Voorhees in the gravity model calibration were used in the computation of accessibility for the research reported here, as

$$A_i = \sum_j E_j (F_{ij}) \qquad (3)$$

$(F_{ij})$ is the friction of time separation of zones $(T_{ij})$ minutes apart. The $(F_{ij})$ values are approximately proportional to the actual number of trips $(T_{ij})$ minutes long per trip end in each pair of zones $(T_{ij})$ minutes apart. In practice the computation of $(F_{ij})$ is complicated by a desire to have the $(F_{ij})$ result form a smooth monotonic relation to $(T_{ij})$ while maintaining approximate equality between the resultant mean trip length.

By using the foregoing explanation of the model, only the parameter for the empirically derived exponent, $a$, had to be determined. Two methods could be used: (1) Results from studies in other cities could be used to forecast 1960 zonal growth for an independent test of the model or (2) by calibration to actual changes in dwelling units from 1948 to 1960. Both methods were used to establish this parameter and the results are discussed after the description of other models. A value of 2 was assumed for parameter $a$ in the first method; Hansen (*2*) had established that $a = 2.7$ was the optimum value for this parameter in the Washington, D.C., area. The assumption that accessibility would have less influence in shaping growth in a smaller city was substantiated by the results obtained when fitting values for $a$. Methods used in fitting $a$ to the 1948–60 data are described at the end of this article.

### *Regression*

Expressing the dependent variable of the multiple regression formulation as a function of the 1948–60 growth rather than as a function of the absolute amount of cumulative development at a single point in time was considered desirable. This function of growth was used to maintain comparability with the dependent variables of the other models and to conform to the standard practice of transportation planning models (*8*). As pointed out by the Traffic Research Corporation greater accuracy is expected for relatively short-range forecasts when predicting increments of growth (*9*).

By using change in dwelling units or some function thereof as the dependent variable, an independent forecast to check against the 1960 ata could not be obtained. The equation parameters had to be estimated from the full 1948–60 data files. Therefore, in contrast to the other four methods, accuracy results for the regression model of land use forecasts are shown only for a fitted model and not a forecast. Dwelling unit data for a third point in time would be required to test the forecasting reliability of the calibrated regression equation.

The regression approach differs from the other models used in the study in two ways: Many independent variables as opposed to one or two may be incorporated; and variables are related to growth only in linearly weighted combination, but they may be transformed prior to regression. The latter restraint is imposed by the standard regression program. The BIMD 34 stepwise multiple regression program developed by the UCLA Bio Medical Center for the IBM 7090/7094 was used in this work. Nonlinear regression equations may be developed, but different normal equations must be solved and standard regression programs cannot be used.

**Equations developed**

Many equations were developed for testing different hypotheses regarding the functional relation between variables. Forty-four independent variables plus selected nonlinear transformations were examined. These included measures of zone size and amount of land in different uses; accessibility to employment; time and distance to HVC; zonal employment, total and by major type; 1948 densities; vacant available land; zoning protection; land value; and proportion of total land and developed land in each major use. Four definitions of the dependent variable tested were the increase in dwelling units (D.U.), the log D.U., the D.U. per unit of available land (D.U./L.), and the log D.U./L.

Logarithimic transformations were used to test hypotheses for exponential relations, as expressed in the accessibility model. The growth-per-unit-of-available-land transformations were used to remove measures of zone size from the equations, thereby avoiding distorted relations caused by peculiarities of area definitions.

The equation accepted after all trials was:

$$Y=-2.3+0.061X_1+0.00066X_2+1.1X_3 -0.11X_4-0.0073X_5 \qquad (4)$$

Where,

$Y$ = Logarithm of growth in dwelling units per unit of vacant land for 1948–60.

$X_1$ = Zoning protection in 1948.

$X_2$ = Percentage of total land area in residential use in 1948.

$X_3$ = Logarithm of accessibility to employment in 1960.

$X_4$ = Dwelling unit density in 1948.

$X_5$ = Percent of total land in industrial use in 1948.

The coefficient of correlation is 0.61. The $t$ and $\beta$ (standardized regression coefficient) values are shown in table 1 for each of the independent variables in the equation. Regression coefficients are significantly different

**Table 1.—Relative significance and explanatory power of variables in regression equation**

| | $t$ | $\beta$ |
|---|---|---|
| Log accessibility to employment in 1960 | 4.30 | 0.321 |
| Zoning Code, 1948 | 2.89 | .213 |
| Percentage of total land in residential use, 1948 | 2.70 | .187 |
| Dwelling unit density, 1948 | 3.28 | .177 |
| Percentage of urban land in industrial use, 1948 | 2.98 | .159 |

from zero, with 95 percent of confidence. The transformed accessibility variable has the greatest $\beta$ value and exhibits the most influence upon the estimate of the dependent variable. The percentage of industrial urban land has the lowest $\beta$ value and, therefore, contributes least to the total equation estimate.

**Dwelling unit density**

The contribution of each independent variable to the equation is discussed in the following paragraphs. The zoning code was a rating from 0 to 9, where a high rate indicated zoning control close to a single family residential area, and a low rate indicated marginal to no zoning control. The positive relation reflects the positive environmental influence of strict residential zoning policy. The positive contribution of percentage of residential development is a measure of residential clustering. Slow growth or decline in the residential density in old city areas coupled with the rapid increase in fringe and newly settled areas accounts for the negative coefficient for dwelling unit density. The negative contribution of percentage of industrial land use reflects an environmental restraint on new residential development. The positive contribution of accessibility is self-explanatory.

Logarithmic and intensity unit estimation introduced operational difficulties. The estimating equation could neither accept negative rates for the dependent variable nor estimate zonal decline. Therefore zones that suffered dwelling unit decline over the calibration period were considered to have shown no change. Several zones had a dwelling unit growth but had no vacant land available in 1948. Without adjustment the growth intensity value is infinite. Therefore, large arbitrary growth intensity rates were substituted. Unlike other models, there is no built-in provision to assure that the accumulated zonal estimates obtained from the regression equation solution will equal the actual total regional growth. All regression estimates had to be factored up to sum to the actual regional growth.

## *Two Intervening Opportunities Models*

The two opportunities models tested were based on different initial assumptions and had dissimilar mathematical forms. Nevertheless, both models can be reduced to a simple general hypothesis that the probability of acceptance for development of a suitable residential opportunity (a unit of available capacity) is a monotonically decreasing function of the number of intervening opportunities. These opportunities were ranked by time from the HVC. Improvement in these models could perhaps be made by allocating increments of growth from all major centers of employment in proportion to the amount of employment in each center. This would make the test of the intervening opportunities models more comparable to the accessibility model procedure.

**Stouffer model**

The Stouffer model is defined as:

$$g_p=\frac{ko_p}{o} \qquad (5)$$

Where,

$g_p$ = Dwelling units forecast to be located in a particular area, $p$.

$o_p$ = Opportunities in interval $p$.

$o$ = Opportunities from central point through interval $p$.

$k$ = Constant of proportionality to assure that the total number of dwellings located equals the actual total growth.

As stated, the Stouffer model can be applied without assuming any values for parameters. However, the operation requires that the study area be structured into a number of discrete geographic units which are ranked from a central distribution point, the HVC in the research discussed here. One method of totaling areas, according to Strodtbeck (*10*), is to delineate a small number of rings containing approximately equal numbers of opportunities. For the initial application of the Stouffer model to the allocation of residential growth, the Greensboro study area was divided into 10 rings; each ring was composed of a number of zones and an approximately equal number of opportunities. Zones were assigned to rings according to their ranking in time from the HVC. By direct substitution in the formula, it was possible to determine $g_p$, the forecast number of dwellings in ring $p$. The ring forecasts were then proportioned among the constituent zones on the basis of opportunities.

To explain the fitting of the Stouffer equation to 1948–60 data the equation must be converted into its continuous differential form, as follows:

$$d(G_p)=\frac{kd(o)}{o} \qquad (6)$$

By integrating:

$$G_p=k{\cdot}ln o+C \qquad (7)$$

Where,

$G_p$ = Dwellings allocated to all opportunities from the central point up to and including opportunity interval $p$.

$d(G_p)$ = Dwellings allocated to opportunity interval $p$.

$o$ = As defined in equation 5.

$d(o)$ = Opportunities in interval $p$.

$C$ = Constant of integration.

This equation plots as a straight line of slope $k$, where the ordinate, total allocated dwellings, is in linear form; and where the abscissa, total accumulated opportunities, is a logarithmic scale. As a test of the appropriateness of the Stouffer model in describing the spatial distribution of residential growth in Greensboro, the actual accumulated zonal dwelling unit growth 1948–60 was plotted against accumulated 1948 opportunities. Zones were ranked by traveltime to the HVC. The straight line plot of figure 5 tends to confirm the validity of the Stouffer model. Because a single straight line could not be adequately fitted to the points, two distinct straight lines were necessary. The two lines were hand fitted, the 1960 growth estimates were made to the individual zones from the straight lines, and the error was computed. These results and those computed from the initial, noncalibrated test of the Stouffer model are discussed later with the results of the other four models.

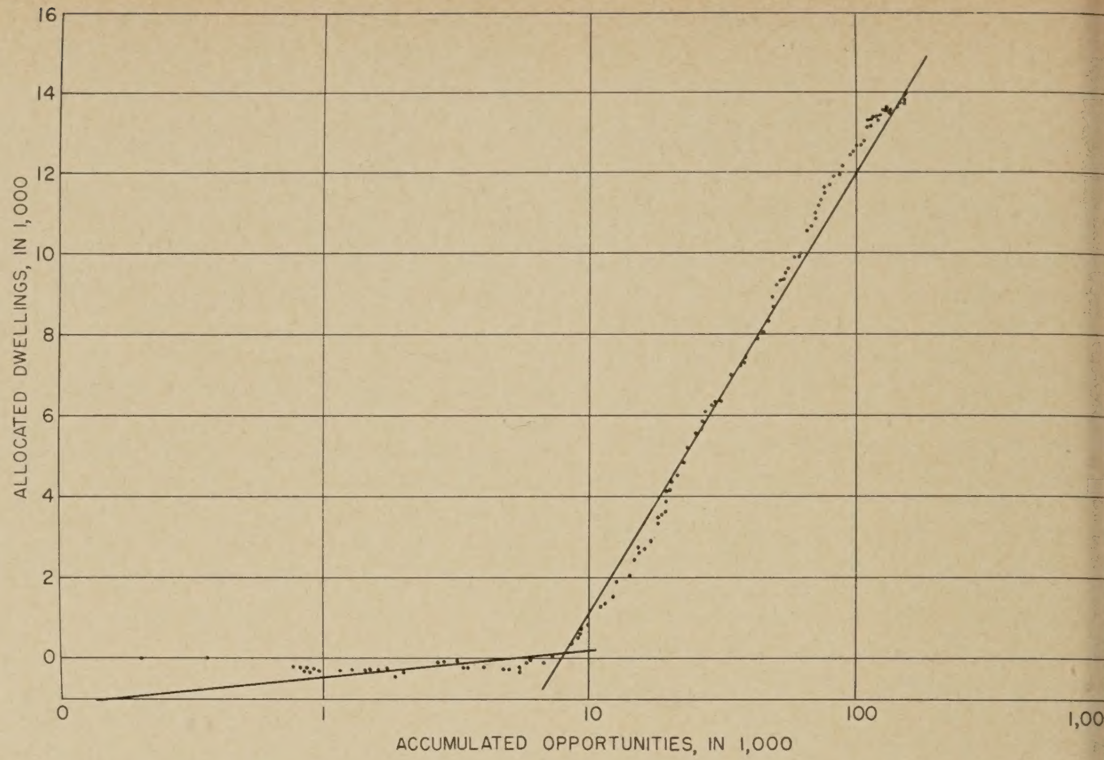



*Figure 5.—Test of Stouffer model.*

**Schneider model**

As applied to the distribution of residential growth, the Schneider model is:

$$d(G_p)=g_t[(e^{-\ell o})-e^{-\ell(o+o_p)}] \qquad (8)$$

Where,

$G_p$= Locations in opportunity interval from the central point up to interval $p$.

$d(G_p)$= Locations in opportunity level $p$.

$g_t$= Total growth to be allocated.

$\ell$= Model parameter expressing probability of an opportunity being accepted for location.

$o$= Opportunities from the central point up to interval $p$.

$o_p$= Opportunities in interval $p$.

The parameter $\ell$ must be stipulated to apply to this model. The first trial of the model for a 1960 forecast was completed without the 1948–60 data. The value of $\ell$ was estimated from the assumption that the actual dwelling unit increase within the study boundaries was 99 percent of the aggregate Greensboro oriented growth. The resultant $\ell$ was $12.76\times10^{-6}$. This theoretical model is based on a distribution to an unbounded area. Application to a finite area requires specification of the number of accepted opportunities outside the boundary or the percentage of accepted opportunities up to the boundary.

For an explanation of the fitting of the Schneider model to 1948–60 data, the equation can be restated after integration as

$$G_p=g_t[1-e^{-\ell o}] \qquad (9)$$

Subtracting $g_t$ from both sides and rearranging

$$g_t-G_p=g_t e^{-\ell o} \qquad (10)$$

or

$$ln(g_t-G_p)=l_n g_t-\ell o \qquad (11)$$

This relation plots as a straight line where the ordinate $(g_t-G_p)$, is in logarithmic scale and the abscissa, total accumulated opportunities from the central point $(o)$, is in linear scale. The slope is $\ell$ and the intercept $g_t$.

The Schneider model effectively replicated the spatial distribution of residential growth in Greensboro. Therefore, plotting the actual quantity $(g_t-G_p)$ against accumulated opportunities $(o)$ in semilogarithmic forms yielded linear relations, as shown in figure 6.

**Straight line segments**

As with the Stouffer model, the Greensboro data plot as two distinct straight line segments rather than one, as required by the initial model formulation. The zones comprising the transition area between the two straight line segments (fig. 6) are the same ones as those at the juncture of the two line segments for the Stouffer model (fig. 5). The fitted line slopes can be loosely compared to the short and long trip $\ell$'s, which are standard practice in applying the Schneider model as a trip distribution model. The slope for the central city line segment is $1.707\times10^{-6}$, and for the outer suburban area it is $10.9\times10^{-6}$.

As shown in figures 5 and 6, the distribution of residential growth in Greensboro from 1948 to 1960 did not adequately conform to results of either of the intervening opportunities models for the complete range of opportunities. However, the data plot as two straight lines, as shown in both figures. The transition points in the vicinity of the intersection of the fitted straight lines in both figures are for the same data points and represent the same zones. Although a detailed examination of these zones has not been attempted, it seems that they approximate a transition ring in Greensboro that separates the inner city, marginal growth area from the suburban, rapid expansion area. This band encircles the HVC at a radius of 1½ to 2 miles. In 1948 Greensboro had a leveling off in the percent saturation gradient at 3½ to 4½ miles fro[m] the HVC. The area circumscribed by th[e] transition band was probably characteristic [o] areas in most cities that are old, perhap[s] show signs of blight, and have little availabl[e] residential capacity.

The inner area straight line slopes drawn t[o] the two plots are both very close to th[e] horizontal. However, steep slopes represen[t] the suburban areas. Viewing the opportunit[y] surface from the HVC according to either [of] the two plots, a hypothetical locator assess[es] himself a greater penalty in passing up subu[r]ban opportunities than inner city opportun[i]ties. The significantly lower slopes on th[e] plots indicate that the inner city opportuniti[es] are a less desirable subset of the total; ther[e]fore a lower probability exists for acceptan[ce] of individual opportunities. Perhaps tho[se] making location choices from the inner cit[y] opportunity subset are responsive more to th[e] individual living qualities of the opportuniti[es] other than to their accessibility. The inn[er] city opportunities may be considered to ha[ve] homogeneous access whereas the suburba[n] subset of opportunities are differentiated b[y] access.

**Stability**

Of a purely forecasting interest is th[e] question of the stability of the linear relatio[n] shown in figures 5 and 6—do the slopes rema[in] more or less constant over time and how do[es] the transition area behave in relation to th[e] total opportunity surface. A speculation ma[y] be made that the straight line relation fitte[d] to the data will hold and that the diffusion [in] residential location in the past is merely [a] reflection of the diffusion in the opportunit[y] surface. A physical dispersion outwar[d] caused by the filling in of less distant are[as] would occur rather than an alteration in th[e] location function. But, it is possible th[at] rough time the slopes of the plots may be ıttening out, which is symptomatic of a ciety less restrained by the impedance of avel. Clearly, answers to such speculations e required before the applicability of the ted lines to forecasting to a future time oint can be estimated.

## *Interpretation of Results*

The results obtained by testing the five sidential land use forecasting techniques and ıe actual change in residential structure of ıe Greensboro area are presented in the ıllowing paragraphs. The outcome of the ial forecasts are diagnosed by comparisons ith actual growth and some conclusions have een made.

### aive model

The single accuracy measure that was ılculated for all trial forecasts was the sum f the squares of the dwelling unit forecasting rror. The accuracy measures were computed ɔr the sectors, rings, districts, and zones. A ixth forecast was made using the naive ssumption of equal growth for all zones. The computed error sum of squares, which will e referred to as the naive model, is (n-1) imes the variance in actual zonal residential rowth. The naive model served as a bench nark in evaluating the results of the five echniques.

### ime and distance

The computed error sum of squares for all f the forecasts and calibrations at each level f aggregation is shown in table 2. For complete comparisons, the results of zone level orecasts for each of the models, except the DSGM model, have been collected to districts ınd rings defined by both time and distance rom the HVC. Trial one of the DSGM was ɔased on analysis at the district level defined y distance from the HVC. Trial two of the DSGM was based on analysis at the district evel defined by time to HVC.

The error measurements shown in table 2 ıre an index that can be used to compare results for the same level. However, comparisons between data in the different columns are meaningless as different numbers of areas and different variances from mean growth rates are involved at different geographic levels. Comparisons between forecast techniques as well as between geographic analysis levels can be made from the ratio of all errors to errors obtained in forecasts with the naive model, as shown in table 3.

### Zone level results

Forecasting results with all five models were poor at the zone level. Sometimes results from the naive model, assuming equal growth for all zones, exceeded the accuracy of other forecasts. Discouraging zone level results obtained with the DSGM indicated poor choice of criteria by the authors in distributing growth from districts to zones. Accurate use of the DSGM model requires historical data that were not available and

**Table 2.—Error sum of squares for all trials** [1]

| Model | Zone | Districts | | Rings | | Sector |
|---|---|---|---|---|---|---|
| | | Distance ring | Time ring | Distance | Time | |
| DSGM: | | | | | | |
| Trial 1 | 2.33 | 6.97 | ------ | 8.36 | ------ | 9.69 |
| Trial 2 | 2.41 | ------ | 4.43 | ------ | 4.07 | 3.02 |
| Accessibility: | | | | | | |
| Forecast | 1.80 | 4.16 | 2.84 | 3.25 | 2.33 | 4.58 |
| Fitted | 1.79 | 3.98 | 2.76 | 2.18 | 1.99 | 4.46 |
| Regression: | | | | | | |
| Fitted | 1.85 | 4.71 | 3.14 | 5.16 | 2.84 | 3.71 |
| Stouffer: | | | | | | |
| Forecast | 2.21 | 6.45 | 4.22 | 5.57 | 3.48 | 11.25 |
| Fitted | 1.91 | 4.72 | 3.07 | 2.42 | 1.46 | 8.84 |
| Schneider: | | | | | | |
| Forecast | 2.07 | 6.16 | 4.13 | 4.10 | 3.38 | 13.92 |
| Fitted | 1.95 | 4.65 | 3.08 | 1.91 | 1.65 | 10.18 |
| Naive | 2.20 | 7.66 | 5.22 | 20.64 | 10.54 | 16.18 |

[1] All results have been multiplied by $10^{-6}$.

intimate familiarity with the area, which the authors lacked. The DSGM model cannot be blamed for the results obtained in the research reported here.

A substantial amount of the error at the fine detailed zone level can be attributed to inaccuracies in data, such as assumptions made in certain estimates, incompatibility of merged files, definition differences between time periods, etc. However, other factors also contributed to inaccurate forecasts. The average zone contained 109 dwelling units in 1948 and the number of dwelling units had increased to only 165 by 1960. These figures were too small to obtain a reliable prediction with any model. Obviously, differences in land use between zones at this level

**Table 3.—Ratio of all errors to naive model error**

| Model | Zone | Districts | | Rings | | Sector |
|---|---|---|---|---|---|---|
| | | Distance ring | Time ring | Distance | Time | |
| DSGM: | | | | | | |
| Trial 1 | 1.06 | 0.91 | ------ | 0.41 | ------ | 0.60 |
| Trial 2 | 1.10 | ------ | 0.85 | ------ | 0.39 | .19 |
| Accessibility: | | | | | | |
| Forecast | .82 | .54 | .54 | .16 | .22 | .28 |
| Fitted | .81 | .52 | .53 | .11 | .19 | .28 |
| Regression: | | | | | | |
| Fitted | .84 | .62 | .60 | .25 | .27 | .23 |
| Stouffer: | | | | | | |
| Forecast | 1.01 | .84 | .81 | .27 | .33 | .70 |
| Fitted | .87 | .62 | .59 | .12 | .14 | .54 |
| Schneider: | | | | | | |
| Forecast | .94 | .80 | .79 | .20 | .32 | .86 |
| Fitted | .89 | .61 | .59 | .09 | .15 | .63 |
| Naive | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

were primarily the result of random variations that could not be reflected by the models. The districts represented a more reasonable level of detail at which to compare the accuracy of forecasts. For comparison with transportation study practices, the average district—defined by distance rings—used in the study could be expected to have about 8,000 person trip ends in 1948—about 660 dwelling units with 3.2 persons per dwelling and four trip ends produced per person.

### Accessibility model accuracy

The relative accuracy of the accessibility model forecasts at different levels in relation to the size of the rates being forecast are shown in table 4. The root mean square

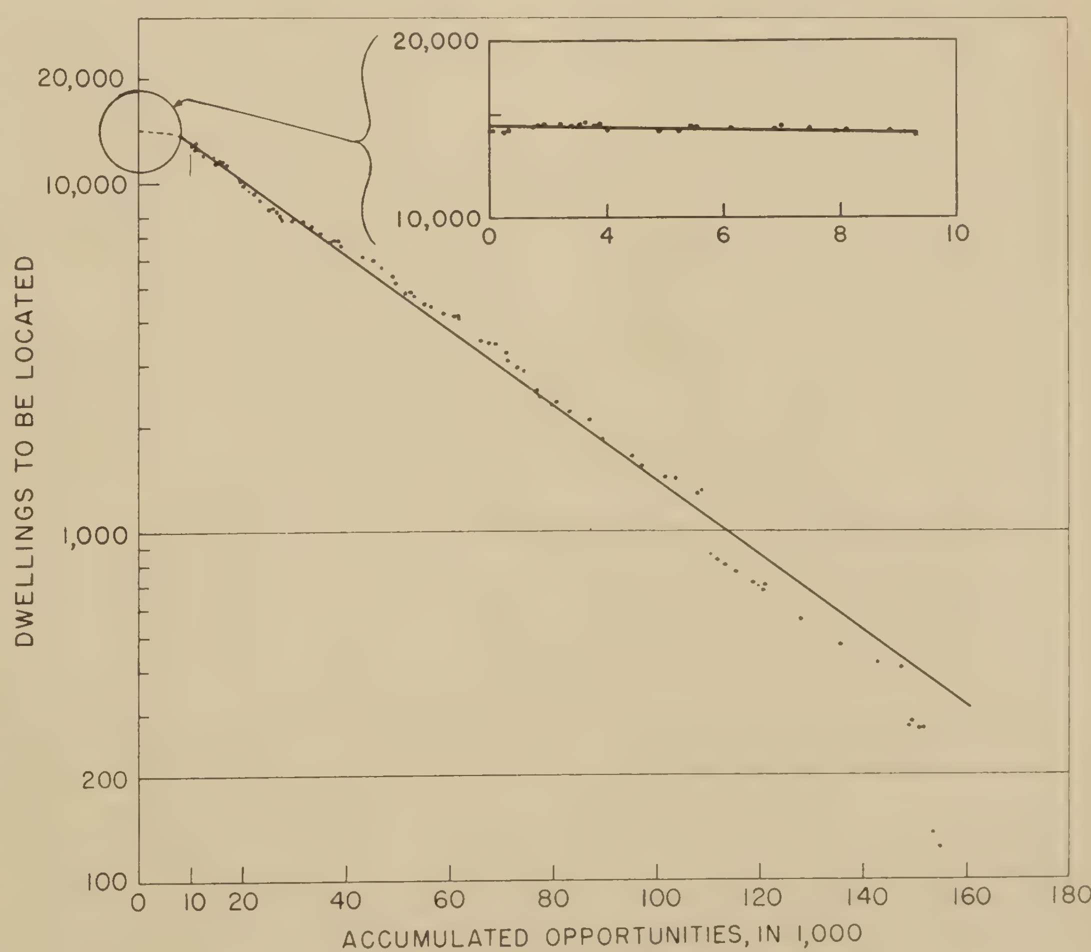



*Figure 6.—Test of Schneider model.*

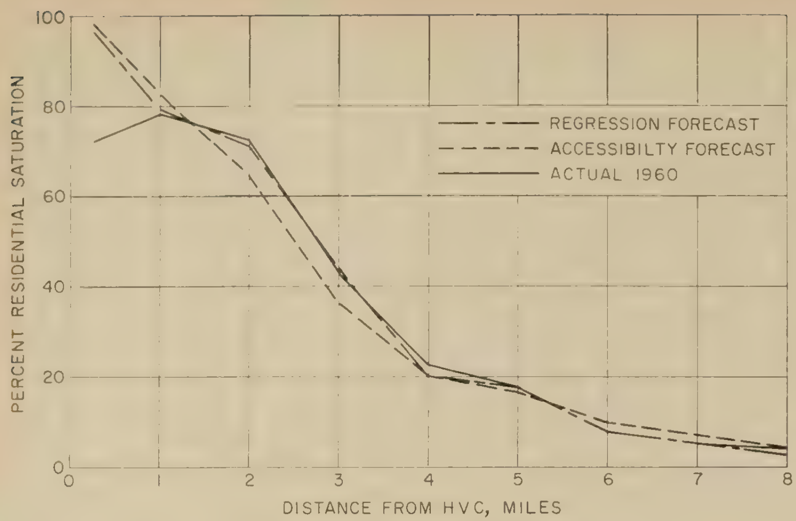



*Figure 7.—Comparison of 1960 and 1948 dwelling unit densities by distance bands.*

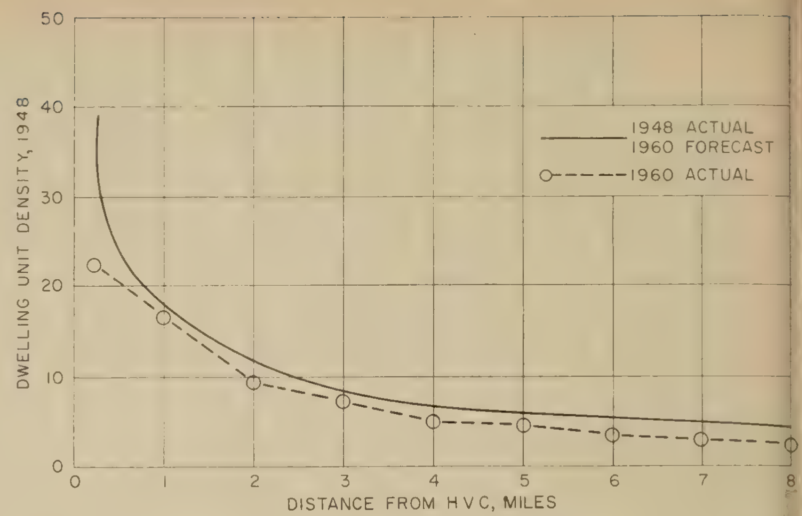



*Figure 9.—Regression model and accessibility model forecast compared with actual 1960 percentage of residential saturation*

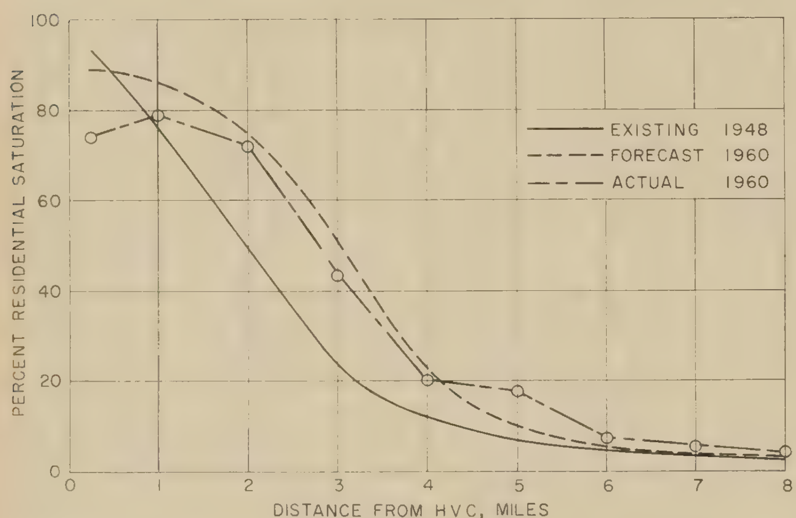



*Figure 8.—Density-saturation gradient model forecast compared with actual 1960 and 1948 percentage of residential saturation.*

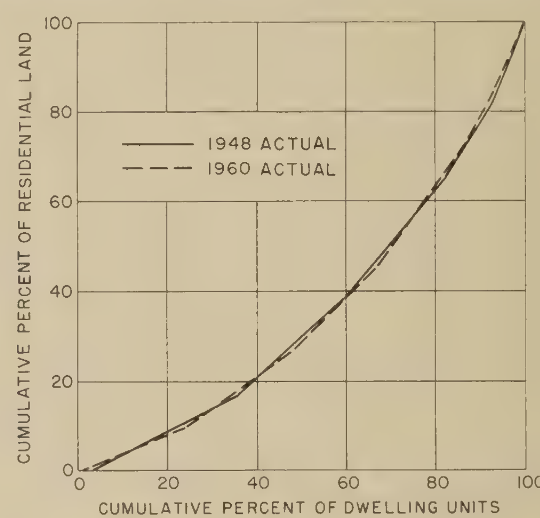



*Figure 10.—Cumulative percentage of residential land and dwelling units for 1948 and 1960 from the core area.*

**Table 4.—RMSE of accessibility model related to actual growth**

| | Zones | District, distance bands | Rings, distance bands |
|---|---|---|---|
| RMSE, $\sqrt{\frac{S.S}{n}}$ | 85 | 381 | 600 |
| Dwelling units: | | | |
| Average per area, 1960 | 165 | 1,006 | 4,580 |
| Average growth per area, 1948–1960 | 56 | 342 | 1,560 |
| Total number of areas | 249 | 41 | 9 |

**Table 5.—Results of three versions of linear regression on transformed accessibility model**

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Accessibility exponent, $b$ | 3.52 | 1.63 | 2.29 |
| Log, $a$ | −8.0 | −3.2 | −4.9 |
| Vacant land exponent, $c$ | 1.51 | 1 | 1 |
| Sums of squares of error [1] | 2.21 | 1.89 | 1.78 |

[1] Results have been multiplied by $10^{-6}$.

error (RMSE) is used as the measure of error as it can be compared to the size of the forecasts: About two-thirds of the errors being within 1 RMSE. The RMSE was roughly half the average number of dwelling units per zone for 1960, and about a third the average number of dwelling units per district for 1960. These accuracies must be considered in relation to the overall growth rate of 52 percent. The ratios of the RMSE's to the 1960 results could be expected to be nearly cut in half if the overall growth rate were half as large. As shown in table 3, at most levels the accessibility model provided substantially better results than other unfitted models but the results from the fitted Stouffer and Schneider models were comparable to those obtained from the fitted accessibility model. Addition of several explanatory variables did not improve the accuracy of the linear regression model.

Results at the sector level are important because of their implication for forecasting radial corridor movements. The intervening opportunities models produced comparatively poor results here, perhaps because these models were not made sensitive to the distribution of employment as were the accessibility regression models.

For trial one of the DSGM, relative growt was assumed by sectors in proportion t available capacity—a weak assumption whe judged by the error of trial two. Residenti character is important for attracting addition growth at all levels: Between sectors, a demonstrated by comparison of the tw DSGM trials, and at the zone level, a demonstrated by the statistical significanc of residential land in the regression analysi

### Growth patterns

All 1960 density forecasts were based on th assumption that development in any zo would occur at the density indicated by smooth line drawn through the 1948 densit points with reference to distance or time fro the HVC. The actual 1960 density-distanc gradient is compared with that for 1948 i figure 7. There was a uniform decrease i density at all distances, except for the co area where the decrease was substantia This difference undoubtedly accounts f some error in the core area forecasts th required estimates of 1960 density for th DSGM and the intervening opportuniti models.

The actual 1960 and 1948 percentage saturation gradients are given in figure

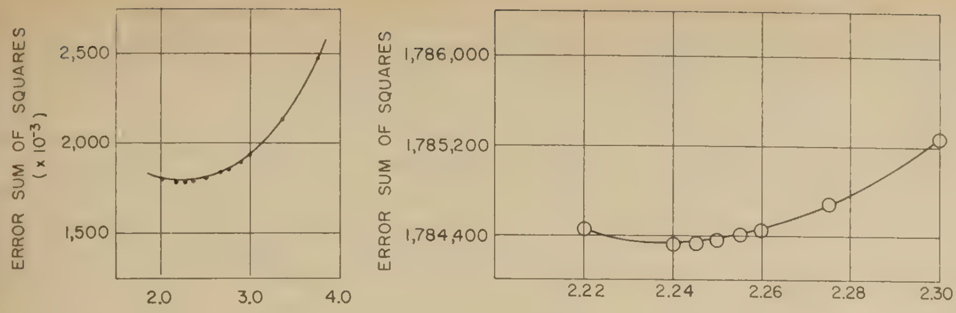



***Figure 11.—Accessibility model sum of squares of error for a range of exponents.***

long with the forecast curve used for trial ne of the density-saturation gradient method. The actual 1960 curve is not as smooth as the 948 curve as the plot represents the percentage of 1948 capacity rather than 1960 apacity. The most significant errors in the orecast seem to have been the result of a arge decline in the density at the core and he growth in relatively remote parts of the rea as rings 5 and 6 indicate. However, the general shape of the forecast curve is appropriate.

Figure 9 shows the density-distance results obtained from the accessibility and regression nodels. Agreement with the actual 1960 gradient is very good, except for the obvious nability of these models as used in the research to predict dwelling unit decreases n the core area.

Plots shown in figure 10 reflect the changes n the residential density structure from 1948 to 1960. The cumulative percentage of total regional dwellings was plotted against the cumulative percentage of total residential land area on the HVC ring level basis. Percentages proceed outwards from the core ring. Plots for the actual conditions in both 1948 and 1960 are shown. If smooth curves were drawn the slope at any point would represent the inverse marginal dwelling unit density. A diagonal line drawn on figure 10 would represent uniform residential density for the entire study area. The bowing of each of the curves below the diagonal indicates the decline in density outwards from the HVC. If there were a decline in the inner area densities and an increase in the dwelling unit density in the outer rings, the total area would be approaching a state of uniform density, and the curve would shift toward the diagonal. But, if the difference between inner and outer area densities was to increase substantially, there would be a shifting of the plot down and to the right. The overall increase in residential density of 52 percent from 1948 to 1960 indicates a rather minute change in the density structure of the study area.

Although the two plots in figure 10 appear to coincide almost exactly, they do not indicate an absence of change in the geographic distribution of dwelling units from 1948 to 1960. That is, inasmuch as the majority of residential growth occurred in the suburban rings, the dwelling units in the inner rings in 1960 represent a smaller part of the total area dwelling units than in 1948 and they occupy a smaller part of the available residential land.

It is unknown whether similar plots for other urban areas have the consistency of the Greensboro area plots. If this is determined to be so, such plots could be helpful in making residential land use forecasts.

## *Calibration of Accessibility Model*

Two procedures used to estimate the best exponent of accessibility were linear regression on transformed variables and an iterative, nonlinear least squares fit of the untransformed dependent variable. Both are reported here as the differences in results may be of interest.

### Linear regression on transformed variables

Three transformed equations of the accessibility model also were tested; they are

$$\log G_i = \log a + b \log V_i + c \log A_i$$

or, in nonlogarithmic form

$$G_i = a(V_i)^b(A_i)^c \qquad (12)$$

$$\log \frac{G_i}{V_i} = \log a + b \log A_i$$

or, in nonlogarithmic form

$$G_i = a(V_i)(A_i)^b \qquad (13)$$

$$\log G_i - \log V_i = \log a + b \log A_i \qquad (14)$$

The nonlogarithmic form for equation 14 is the same as for equation 12. The nonlogarithmic forms of (12) and (13) are essentially the same as the standard form of the accessibility model. They would be identical if they contained the condition that

$$a = \frac{G_T}{\sum V_i (A_i)^b} \qquad (15)$$

As a standard regression program was used, this condition might be violated and equation estimates must be factored to sum to actual total growth. This holds for all three of the transformed versions of the model.

Equation 12 also expresses vacant land as a power function in contrast to its linear form in the standard formula. The basic problem, however, is that the least squares criterion is different for each equation (the minimization of unexplained variance in the dependent variable) as the dependent variable is different for each. None is the correct criterion. The log transformed equation tends to produce a bias toward better fits for the smaller values of the untransformed dependent variable.

The results of the three versions of the accessibility model are summarized in table 5. Because of the fairly large variation in the accessibility exponent, as well as in the error term, the authors are skeptical of regression on transformed dependent variables.

### Nonlinear least squares fit of exponent

A routine was programed to iterate the true least squares solution for the standard accessibility model

$$G_i = G_T \frac{(A_i)(V_i)^b}{\sum_i A_i (V_i)^b}$$

Results are shown in a plot of the sums of squares of error in reference to a range of exponents in figure 11. A smooth curve with a minimum sum of squares at $b = 2.24$ is shown. The right part of figure 11 is a blowup of the critical area of the plot shown on the left. These results can be compared with the $b$ value of 2.7 reported by Hansen (*2*) for Washington, D.C.

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235–196—66——2

# State Highway Patrol Functions and Financin

*BY THE*
*OFFICE OF PLANNING*
*BUREAU OF PUBLIC ROADS*

**Reported by [1, 2] EDWARD A. GLADSTONE a**
**THOMAS W. COOPER, Financial Economis**
**Highway Statistics Divisi**

***The primary purpose of the study reported in this article was to investigate the method used by each State for law enforcement agency financing. The organizational structure, statutory authority, scope of responsibility, and method of financing that is used in each of the States was examined in order to establish a basis for comparing their methods of financing. The agency structures and methods of financing vary among the States; but the problems arising from increased highway mileage and traffic are generally shared throughout the States. Increased highway mileage and traffic have forced law enforcement agencies to take on additional functions that in turn generate an increased need for manpower and revenue.***

***The Bureau of Public Roads has determined that the most reasonable and usable method for financing the varied police functions in all the States would be to support traffic-related functions from highway-user revenues and nontraffic-related functions from general funds. It is believed that this plan would provide adequate finances for the additional manpower required to meet the growing needs of traffic and traffic safety. Some States have adopted the plan indicated by the Bureau of Public Roads. In other States, however, application of this plan is complicated by the problem of determining which functions are traffic-related and which are nontraffic-related. Another difficulty arises in determining the type of highway-user tax to be used to support traffic functions. In deciding these issues, the States have developed individual plans and legislation to provide for their law enforcement agencies.***

***The problem of law enforcement agency financing is not resolved, however. The need for additional manpower and finances continues to increase; the emphasis on traffic safety expressed by all State officials indicates that the problems of traffic law enforcement and its financing remain major issues.***

## *Introduction*

THIS ARTICLE is a report on a study of State highway law enforcement agency financing. A structural examination was made of law enforcement agencies including agency organization, status within the State government organization, present statutory powers, and functions performed, in 49 States (Hawaii was not included). In all States, traffic patrol functions include law enforcement and public service. But, the specific structures, functions, and methods of financing the traffic patrol agencies are different. Comparative analyses of the agencies were made to measure the relative adequacy of the patrols in the individual States.

Since 1921, the Bureau of Public Roads has annually compiled and published highway finance statistics; since 1925, it has identified receipts and expenditures relative to highway policing. These statistics have been continually improved, expanded, and refined so that today law enforcement agency finances can be thoroughly documented. However, costs of law enforcement cannot as yet be assigned to precise functions. In some States the costs of routine traffic supervision cannot be separated from costs of driver and safety education, vehicle size and weight enforcement, and other functions; some State agencies are responsible for enforcing criminal laws as well as traffic laws, and the costs of each may not be identifiable. Nevertheless, findings from this study should be useful to police organizations, public authorities, and legislative bodies in measuring the needs and accomplishments of the patrol agencies, as well as suggesting equitable financing plans, that appropriately reflect the functions of the agencies.

## *Background*

Most of the Governors of the 47 State legislatures meeting in 1965, voiced concern for the safety of the motoring public, and the importance of the State police organization enforcement of traffic and safety laws. In State after State, the Governor's message emphasized the need for additional highway patrol troops to curb highway accidents and fatalities. Governors, legislative committees, and safety agencies, in at least 30 States requested increased patrol strength. Collectively, 21 States requested that nearly 3,800 troopers be added to the patrol strength during the next 1 to 4 years. As of mid-1965, the States have requested a 23 percent increase in patrol strength. Although reques probably will not receive full legislati approval in many States, they are an indic tion of State concern for combating acciden and fatalities.

Governor George Romney of Michig pointed to some significant statistics in h Special Message on Traffic Safety to the 19 legislature. He labeled the 2,125 death 145,000 injuries, and 285,000 reported ac dents of 1964 the "Michigan Massacre it caused an estimated economic cost of least $380 million to Michigan and its citizen or more than $1 million a day. Statisti adapted from the Governor's report sho that the rate of increase of traffic misha between 1962 and 1964 in Michigan w considerably larger than the increase in v hicles or travel. Traffic deaths increase 35 percent from 1962 to 1964; traffic injur 34 percent; property damage accidents, percent; economic losses, 33 percent; vehic registration, 10 percent; licensed drive 5 percent; vehicle-miles of travel, 13 percen

Governor Romney's Special Commissi on Traffic Safety concluded that legislatio manpower, and financial and public suppo were inadequate to keep pace with the moun ing problem. This Commission typifies t concern of State governments in the mi 1960's for highway safety and the necessi for adequate law enforcement practices a policies for reducing accidents.

## *Conclusions*

State traffic law enforcement agencies ha gained many new functions over the year But, the delegation of responsibility for add tional functions, lack of manpower, and t method of financial support for the new fun tions have been problems.

These problems are exemplified with respe to toll roads. The toll road capacity provide many services and aids to motoris has been publicized, but the scope and mea for providing the services have not bee resolved. At present the police agenci are not equipped with the manpower provide motorist aids. Recruitment woul not be difficult, but additional manpow costs cannot be covered in all States und their present method of financing. Inform tion from the questionnaires received fro all the States shows that police agencies woul require a total of 56 percent increase in perso nel by 1969; based on current costs, th increase would require revenues of more tha $450 million in 1969.

The majority of the traffic law enforceme agencies are supported from highway-us

[1] Presented at the 45th annual meeting of the Highway Research Board, Washington, D.C., Jan. 1966.

[2] The assistance of the State law enforcement agencies, as members of the International Association of Chiefs of Police, especially William Franey, Director, and his staff of the Highway Safety Division, is acknowledged. The State law enforcement agencies responded to a questionnaire designed jointly by the authors and IACP staff members and circulated by IACP.

enues either through direct allocations in highway-user taxes or indirectly through eral fund appropriations. The support traffic-related functions from highway-user enues is recognized by the Bureau of blic Roads as a proper highway expend-re. Therefore, it would seem reasonable t highway-user revenues would support ffic-related functions and general funds uld support nontraffic-related functions. ne States have already adopted this plan financing.

Adequate financing of highway patrols is o related to safety. The increased mileage divided highways is followed by increased ffic accidents and fatalities each year. hough there is no conclusive evidence that reased patrol strength or functions would luce accidents, the requests by Governors l legislators for additional personnel indi-e a belief that such a correlation exists.

### *Origins and Development*

The law enforcement arm of the States gan nearly 150 years ago with the first rder patrols. Traditionally, the responsi-ity for law enforcement in our general ucture of self-government has been con-ntrated at the local level. With few ex-ptions this practice, which dates back to rly British institutions, shaped our law forcement procedures until the 20th century. he first State law enforcement agency was e Texas Rangers, formed in 1835 to patrol e Mexican border. Arizona and New exico also formed State border patrols in e early 1900's, but they were soon abolished cause of political involvement.

The first State police force or constabulary, it was initially called, was formed in assachusetts in 1865. This agency was eated primarily to suppress commercialized ce, but it was granted general police powers roughout the State. In 1879, this agency as absorbed into the Massachusetts District olice, a State detective unit. Its new duties cluded investigating fires, enforcing fish ws, and inspecting boilers and buildings. his agency was absorbed into the Depart-ent of Public Safety in 1920.

In 1903 the Connecticut State Police was atterned after the Massachusetts District olice and was chiefly responsible for enforcing quor and gambling laws. In 1905, the ennsylvania State Constabulary was or-anized, and this organization marked the eginning of a new era in rural police ad-inistration. From the beginning, it operated a mounted and uniformed body having a idely distributed system of troop head-uarters and substations as a base of opera-ons. This provided a continuous patrol roughout the rural areas. Broad ad-ninistrative powers were granted the Superin-endent of State Police, who was responsible nly to the Governor. In 1917, New York rganized a State police force.

When the Nation was comprised of widely eparated municipalities, local law enforce-ent was adequate. But, as society became ore mobile and population increased, a entralized mechanism became necessary if law and order were to prevail. In some areas sheriffs and constables became unable to cope with crime and were reluctant to enforce unpopular State laws; waste, mismanagement, and political influence caused the municipal police function to deteriorate. There was a need for uniformity of State law enforcement methods; and there was a lack of coordination of activities in an era of mobile crime.

Governor Arthur M. Hyde expressed the gravity of the situation in his message to the 52d Missouri General Assembly in 1923. He stated that, "Nowhere is there any effective agency for enforcement of law and maintenance of order except the National Guard. The State owes an inescapable duty to the public to preserve peace and order. . . . No law can be enforced without the cooperation of three officials—sheriff, prosecuting attorney, and court. When one of these three fails, anarchy results.

". . . No power exists whereby the State can send any of its officials into the county to assist in preserving peace and order. Unless the emergency is grave enough to warrant sending the National Guard, the State and the people are helpless.

". . . The best machinery for law enforcement by State authority yet devised is a State police force. A State constabulary is the remedy, so far as remedy exists in the powers of government against lawlessness."

### *State Police Forces*

Police facilities were greatly improved during the 20-year period from 1919 to 1939 by the creation of State police forces in 46 States. Paralleling this action was the increased use of automobiles, which created the need for motor-vehicle and traffic law enforcement agencies. But, combining the functions of traffic law enforcement with criminal law enforcement caused much controversy. Local governments were reluctant to relinquish general police powers to a central agency. Labor unions were opposed to a strong central police force because of the alleged strike-breaking activities of the Keystone Police in Pennsylvania.

From the controversy two separate types of police departments evolved; one had broad police powers, the other had only highway law enforcement power. The distinction is expressed in a statement from *The Book of the States*, 1962–63 edition, page 437, published by the Council of State Governments:

". . . The State police enforce all laws, including traffic laws and regulations and their enforcement arms reach into every corner of the State. . . . The duties of most State highway patrols, important though they are, are restricted almost entirely to enforcement of traffic laws and regulations and to carrying out highway accident-prevention programs. . . ."

The separation of highway law enforcement and general criminal law enforcement remained a controversy. Local officials in many States opposed centralization of police function and allowed the new highway agencies only limited power. Against this, it was argued that a general police force should be given sufficient authority to combat crime in general as highway patrolling played a major role in the apprehension of criminals. In Texas and Pennsylvania parallel agencies were created to enforce criminal laws and motor-vehicle laws. However, the separate agencies were subsequently consolidated. In other States that have highway patrols, the local government retains general police power.

Initial traffic enforcement legislation in some States did not create a police organization, but merely authorized the appointment of individuals to patrol the highways. These patrolmen enforced traffic laws, motor-vehicle regulations, and sometimes all State laws. In time, the State legislatures became interested in general policing and many of the traffic patrol agencies of the 1920's and 1930's were reorganized as State Police. By 1941, 35 State Police agencies were authorized to enforce all State laws; 13 organizations had limited powers.

### *Legislative Restrictions*

Broad police powers, however, were still subject to legislative restrictions. Enabling legislation in many States denied patrolmen jurisdiction in criminal investigation or authority to search and seize. Patrolmen were only permitted to take weapons from arrested persons; the case was then referred to duly authorized peace officers. The legislature also restricted law enforcement agencies through control of funds. The general fund and highway-user revenues that supported the law enforcement agencies were tightly controlled by the legislature.

Legislative control of highway patrol activities through control of revenue was exercised in Missouri. Initially the Highway patrol in that State had only highway and motor-vehicle law enforcement powers. Later, broad police powers were granted and exercised. The constitutionality of these broad powers was challenged by the State's Attorney. The Missouri Constitution provided that highway moneys should be used for highway purposes only. Because the Highway patrol was supported entirely by these moneys, general police powers for the Highway patrol were considered unconstitutional. A subsequent legislature authorized that the State general fund pay 10 percent of the Highway patrol budget, thereby limiting the general policing activities of the Missouri Highway Patrol to 10 percent of its activities.

Agencies also are restricted to highway authority on the premise that traffic enforcement has little need for detective or central investigation powers. However, the Highway patrol is expected to perform certain duties of a nonhighway nature such as the investigation of crimes originating on the highway; arrest of criminals committing crimes in the presence of a patrolman; apprehension of criminals using highways for escape; and aid to local peace officers or the Governor on request. But, these nontraffic functions are generally confined to rural areas.

Changing needs made periodic reexaminations of existing statutes necessary. As the volume of traffic increased, traffic enforcement agencies were forced to expand numerically and to assume broader regulatory functions. By 1941, 25 police departments were reorganized as independent organizations. The remaining 23 State agencies were subsidiary units of such departments as public safety, highway, motor-vehicles, law enforcement, and public works and revenue.

### *Highway Police Organization*

Today's highway police organization has expanded in form, organization, and purpose, and the trend continues toward the granting of broad police powers. Broad police powers have been granted to State police agencies in 43 of the 49 States covered in the study reported in this article; the police powers of only 6 agencies are limited to highway-related functions. However, the trend toward the creation of independent agencies has been reversed; only 19 of the 49 States have in pendent agencies. This includes New Y and Rhode Island, where the State police divisions of the executive departments, have independent status; and West Virgi where the department of public safety and State police are the same organization. the other 30 States, police agencies are s divisions of a department of public safe highway department, motor vehicle depa ment, highway safety department, departm

**Table 1.—Statutory provisions governing creation and financial support of law enforcement agencies**

| State | Primary agency | Citation creating agencies | Source of funds | Citation apportioning or appropriating operating funds |
|---|---|---|---|---|
| Alabama | Department of Public Safety. | Title 36; Sec. 58(54). | Motor vehicle fees. | Title 36; Sec. 58(61), 53. |
| Alaska | Department of Public Safety. | Sec. 44.41.010 (AS). | General fund. | Ch. 167, Laws of 1961. |
| Arizona [1] | Highway Patrol Division. | Sec. 28.231-A (ARS). | Highway-user revenues. | Sec. 28-231D. |
| Arkansas | Department of State Police. | Sec. 42-402 (1947 Stat.). | Driver license fees and general funds. | Title 76-309.3(c)(a). |
| California [1] | Department of Highway Patrol. | Sec. 13975, Gov. (WCAC). | Motor vehicle fees. | Ch. 3, Sec. 42.271(b). |
| Colorado | State Highway Patrol. | Sec. 120-10-1 (CRS, 1953). | Highway-user revenues. | Sec. 120-10-23. |
| Connecticut | State Police Department. | Title 29; Ch. 529, Sec. 29-4 (GSA). | Highway-user revenues and general funds. | Title 14; Ch. 246, Sec. 14-156. |
| Delaware [1] | State Police Division. | Ch. 83, Sec. 8301, Title 11 (DCA). | General fund. | Title II; Sec. 8303. |
| Florida | Department of Public Safety. | Sec. 321.01 (FSA). | General fund. | Sec. 321.09. |
| Georgia | Department of Public Safety. | Ch. 92A-105 (GCA). | Driver license fees through general fund. | Ch. 92A-120. |
| Hawaii [2] | | | | |
| Idaho | Department of Law Enforcement. | Sec. 19.4801 (IC). | Highway-user revenues. | Sec. 19.4811. |
| Illinois | Department of Public Safety. | Ch. 121, Sec. 307.1 Supp. (IAS). | Motor vehicle fees. | Statute 127, Sec. 144.3. |
| Indiana | State Police Department. | Ch. 8, Sec. 47-846 (BIS). | Highway-user revenues and general funds. | Title 36-2817. |
| Iowa | Department of Public Safety. | Sec. 80.1 (ICA). | General fund. | Sec. 80.8; Ch. 1, Sec. 51, Laws of 1963. |
| Kansas | State Highway Patrol. | Ch 74, Art. 20a01 (GS-1949). | Highway-user revenues. | Ch. 68-416a. |
| Kentucky | Department of Public Safety. | Ch. 17, Sec. 010 (KRS). | Highway-user revenues and general funds. | Ch. 3, Laws of 1962. |
| Louisiana | Department of Public Safety. | Sec. 40:1301 (WLRS). | Driver license fees and general funds. | Ch. 2, Sec. 32.412 and 426; Ch. 75, Laws of 1962. |
| Maine | State Police Department. | Ch. 15, Sec. 1 (RS-1954). | Highway-user revenues and general funds. | Ch. 23, Sec. 133. |
| Maryland | Department of State Police. | Art. 88B, Sec. 3 (ACM-1957). | Motor vehicle revenues and general funds. | Art. 66.5, Sec. 341. |
| Massachusetts | Department of Public Safety. | Ch. 22, Sec. 1 (GLA). | Highway-user revenues and general funds. | Ch. 22, Sec. 9B. |
| Michigan | State Police Department. | Ch. 24, Sec. 4.432 (SA). | General fund. | Ch. 193, Sec. 1, Laws of 1961. |
| Minnesota [1] | Highway Patrol. | Sec. 161.47 (MSA). | Highway-user revenues. | Sec. 161.47, Subd. 5. |
| Mississippi | Department of Public Safety. | Title 30; Ch. 2, Sec. 8078 (MC-1942). | Motor vehicle fees through general fund. | Title 30; Ch. 2, Sec. 8120.5. |
| Missouri | State Highway Patrol. | Title 5; Sec. 43.020 (VAS). | Highway-user revenues and general funds. | Title 5; Sec. 43.100 and 43.180. |
| Montana | State Highway Patrol. | Title 31-101 (RSM-1947). | Driver license fees and general funds. | Title 31-105 and 31-210. |
| Nebraska [1] | Law Enforcement and Safety Patrol. | Title 60.431 (RSN-1943). | General fund. | Ch. 330, Laws of 1963. |
| Nevada [1] | Highway Patrol Division. | Ch. 481.130 (NRS). | Highway-user revenues and general funds.[3] | Ch. 481.083 and 48:150. |
| New Hampshire | Department of Safety. | Ch. 106.A:1 (NHRSA-1955). | Highway-user revenues and general funds. | Ch. 6.12. |
| New Jersey | Department of Law and Public Safety. | Ch. 52.17B-3 (NJSA). | General fund. | Ch. 52.9H-2. |
| New Mexico | State Police Department. | Ch. 39, Article 2, Sec. 2, (NMS-1953). | Driver license fees through general fund. | Ch. 39.2-22. |
| New York | Division of State Police. | Executive Law, Sec. 210. | General fund. | Ch. 147, Laws of 1964. |
| North Carolina [1] | State Highway Patrol. | Ch. 20-1 (GSNC). | Highway-user revenues. | Ch. 20-194. |
| North Dakota | State Highway Patrol. | Ch. 39-03-02 (NDRC-1943). | Motor vehicle fees and general funds. | Ch. 39-03-08 and -16. |
| Ohio | Department of Highway Safety. | Ch. 5503.01 (ORCS). | Motor fuel tax and motor vehicle fees. | Ch. 4501.6. |
| Oklahoma | Department of Public Safety. | Title 47; Ch. 2, Sec. 103 (OSA). | Driver license fees and general funds. | Title 47, Sec. 6-101, 14-116, 22.2; Ch. 29[...] Laws of 1963. |
| Oregon | State Police Department. | Title 18; Sec. 181.020 (ORS). | Highway-user revenues through general fund. | Ch. 181.040. |
| Pennsylvania | State Police Department. | Title 71; Sec. 65 (P-P). | Highway-user revenues through general fund. | Title 72; Sec. 3563a. |
| Rhode Island | Division of State Police. | Title 42; Ch. 28, Sec. 2 (GLRI) 1956. | General fund appropriation. | Sec. 42-28-32. |
| South Carolina [1] | Law Enforcement Division. | Sec. 46-851 (CLSC-1962). | Highway-user revenues. | Sec. 33-287. |
| South Dakota [1] | Motor Patrol. | Sec. 44.06.03 (SDC-1939). | Highway-user revenues. | Sec. 44.06.06. |
| Tennessee | Department of Safety. | Sec. 4.320 (TCA). | Motor vehicle fees through general fund. | Sec. 4.711. |
| Texas | Department of Public Safety. | Art. 4413 (VCS). | Highway-user revenues. | Arts. 6687b(15), 6701d(141), 4413(26). |
| Utah | Department of Public Safety. | Title 41-13-1; (VAC-1953). | Motor fuel tax and motor vehicle fees. | Title 41-13-4. |
| Vermont | Department of Public Safety. | Ch. 111, Sec. 1811 (VSA). | Highway-user revenues and general funds. | Ch. 252, Part III, Laws of 1961. |
| Virginia | Department of State Police. | Title 52; Ch. 1, Sec. 52-1 (CV-1950). | Motor vehicle fees. | Title 46.1; Sec. 167(c,2). |
| Washington | State Patrol Department. | Ch. 43, Sec. 43.010 (RCW). | Driver license fees and motor-vehicle fees. | Ch. 46.68.30 and .40. |
| West Virginia | Department of Public Safety. | Sec. 1237 (WVC-1961). | Learner's permit fees and general funds.[4] | Sec. 1721(213); Ch. 12, account 570, Laws of 1963. |
| Wisconsin [1] | Enforcement Division. | Ch. 110.01 (WWSA). | Motor vehicle fees. | Ch. 20.560(73). |
| Wyoming [1] | Highway Patrol. | Title 31; Ch. 2, Sec. 31.7 (WS-1957). | Highway-user revenues. | Sec. 31-11. |

[1] Although these are secondary agencies, they represent the primary State agency responsible for law enforcement. In these States, the parent department is concerned primarily w activities other than police work.
[2] Hawaii has no State police organization; each island has its own police department.
[3] The nonhighway activities of the highway patrol, when authorized by the Governor, are supported by the general fund.
[4] Learner's permit fees are deposited in the general fund to the credit of the State police.

law enforcement, department of safety, de-tment of law and public safety, or highway nsportation agency. The agency having law enforcement function in each State is ed in table 1.

Since 1941 changes have occurred in the ganization of police agencies. The number subordinate organizations has only in-ased by 5, but 12 subordinate agencies and independent agencies have reorganized. ne of the reorganized agencies were placed ler different departments; three became in-pendent. Of the eight independent agencies t reorganized, six became units within the hway department; and one became a unit hin the department of motor vehicles.

## *Agency Organization*

Although the organizations of many police encies have comparable status within the ate government, their internal structures e not alike; most of the structural differences n be explained by the differences in func-ons. For example, Pennsylvania and Mary-nd operate as State police organizations; w Jersey and Texas, as departments of blic safety; and Missouri and Washington, highway patrols.

## *Broad Police Powers*

The Pennsylvania State Police organization s six bureaus and a field division of troops. e Technical and Staff Services Bureaus are nder the chief of staff and provide adminis-ative services for the organization; the aining and Staff Inspection Bureaus are nder the commissioner; and the Detective d Traffic Bureaus are under the deputy mmissioner and form a line operation with e field division troops. The field division nsists of 15 substations each containing ime, staff, and traffic units. The internal ructure is a recent development; the primary nctions of the police have been set apart om supporting services to ensure the most ficient operation.

The Maryland State Police organization is vided into a headquarters office of super-tendent, executive officer, and adjutant, who pervise eight divisions. An intelligence unit the same organizational level reports to the perintendent in the headquarters unit. The ght divisions are: Training-personnel; Inves-gation; Quartermaster; Communications; ccident Records; Medical; Finance; and perations.

The New Jersey State Police is one of seven ivisions of the Department of Law and Public afety. The police organization is divided nto three major categories of responsibility. ive police commands form the field operations nd report to the superintendent. A deputy uperintendent supervises administrative ac-ivities; an executive officer directs operations ommunications activities; and an investiga-ion officer directs criminal investigation and lentification activities.

The Texas Department of Public Safety dministered by the Public Safety Commission hrough a director and assistant director has headquarters unit composed of four major livisions, each headed by a chief; seven special service sections; and the Rangers. Also, six regional commands are organized as counterparts of the headquarters structure and have direction and identification as: Supervisor, Communications; Technicians, Crime Laboratory; Adjutant, Office Services; Sergeant, Safety Education; Captain, Driver License; Captain, Highway Patrol (may be more than one district); Captain, License and Weight; Captain, Motor Vehicle Inspection. Each regional commander reports to the director.

The Pennsylvania, Maryland, New Jersey, and Texas agencies are responsible for the enforcement of both criminal and traffic law. But the Missouri and Washington organizations are structured primarily for traffic activities.

### Traffic law enforcement

In Missouri, the State Highway Patrol headquarters unit is divided into six divisions that report to an assistant superintendent. Nine patrol troops in a field operations unit are under the direction of two field supervisors, who also report to the assistant superintendent.

The Washington State Highway Patrol has many divisions. A chief directs the Investigative and the Finance and Budget Divisions; an assistant chief supervises six divisions; an administrative officer directs seven divisions; a staff inspector supervises field forces in seven districts, a Program and Planning Division, and a General Maintenance Division.

## *The Police Function*

A tendency seems to exist to organize the police into functional units for criminal law enforcement, traffic law enforcement, training, communications, and so on. Traffic supervision and crime repression are the major functions; the former is carried out in every State police agency, the latter in most agencies. Related functions are organized as divisions within the agency. The agencies are staffed by both uniformed and civilian personnel. The uniformed or sworn personnel, designated as peace officers, troopers, patrolmen, etc., have authority to apprehend and arrest. The civilian personnel perform clerical tasks and in many States operate communication networks.

Traffic supervision is the primary function in each agency and requires the major part of each State patrolman's time. Traffic supervision includes the enforcement of traffic laws, supervision and direction of traffic, and the investigation of accidents. Within the framework of enforcing traffic laws, the patrolman must (1) observe all vehicle use and users, roadway and vehicle conditions, and deter would-be traffic law violators; (2) detect pertinent defects in individual behavior, vehicle equipment, or highway condition; (3) initiate appropriate action to prevent such defects from causing accidents or delays, remedy the defects, or discourage repetition of dangerous or prohibited acts; (4) investigate complaints of traffic law violations; (5) record and report all activity; and (6) assist the courts during adjudication of traffic violations.

In supervising and directing traffic the patrolman (1) provides information that will help people to reach their destinations and to comply with traffic laws and regulations; (2) indicates to drivers what is desired and expected of them, particularly when and how to move in congested areas; (3) takes emergency action to direct flow of traffic when signals or controls prove to be inadequate; and (4) provides assistance by escort, as authorized.

### Support functions

When investigating accidents, the patrolman is required to (1) take action to prevent aggravation of the damage and injury; (2) and obtain information on the circumstances of the accident, determine the specific violation of law, and record and report all information.

Several essential supporting functions, performed at a technical or supervisory level, implement the basic traffic functions. They include (1) maintaining records; (2) compiling data on needed corrective action; (3) preparing special studies or reports; (4) coordinating plans and activities with official agencies and support groups; (5) supplying laboratory and technical aids; and providing incidental services to motorists. Cooperative functions are also performed by the police in conjunction with other agencies. Safety education, driver examination, driver record maintenance, vehicle inspection, vehicle weighing, equipment regulation, bicycle inspection and regulation, and suspension and revocation notification are considered cooperative functions.

Many States have the automobile theft investigation and recovery function located within the activities of the police agency. It is usually classified under the criminal investigation rather than traffic function. Agencies with broad police powers have criminal law enforcement functions that are generally assigned to a detective bureau, indentification bureau, and a crime laboratory. There are other miscellaneous functions that are assigned to only a few police agencies. They cover such activities as fire prevention and investigation; firearms regulation; livestock inspection, theft, and patrol; boat registration; liquor control; fish and game law enforcement; building and boiler inspection; underwater recovery; inspecting migrant workers' homes, boarding homes, and nursing homes; and civil defense. Supporting activities that are essential to the efficient operation of the organization include personnel, finance, quartermaster, planning, maintenance, special services, internal inspection, training, and communication.

### Traffic function time

The amount of time devoted to traffic- and nontraffic-related functions varies among agencies. A composite distribution, summarized in table 2, was made based on percentages supplied from a questionnaire sent to each State police agency. Of primary interest was the time spent on basic traffic supervision. In agencies that are subordinate units of a department of public safety, about 47 percent of the total activity of both uniformed and civilian personnel was devoted to

**Table 2.—Distribution of organization functions—uniformed and nonuniformed**

| | Traffic functions | Traffic-related functions | Other functions |
|---|---|---|---|
| ALL PERSONNEL | | | |
| Subordinate agencies: | *Percent* | *Percent* | *Percent* |
| Departments of public safety | 46.8 | 42.4 | 10.8 |
| Highway, motor vehicle, and other | 64.0 | 30.2 | 5.8 |
| Independent agencies: | | | |
| State police | 47.4 | 26.7 | 25.9 |
| Highway patrol | 51.0 | 46.2 | 2.8 |
| UNIFORMED PERSONNEL | | | |
| Subordinate agencies: | | | |
| Departments of public safety | 68.0 | 22.0 | 10.0 |
| Highway, motor vehicle, and other | 75.0 | 20.7 | 4.3 |
| Independent agencies: | | | |
| State police | 58.5 | 20.3 | 21.2 |
| Highway patrol | 72.1 | 24.8 | 3.1 |

traffic supervision; in agencies that are subordinate units of highway and motor vehicle departments about 64 percent was spent; in independent State police agencies 47 percent was spent; and in independent highway patrols 51 percent was spent. Where agency activity was confined to sworn uniformed personnel, averages were higher. Traffic supervision occupied 68 percent of the total activity in department of public safety agencies compared to 75 percent in subordinate police agencies, 59 percent in State police agencies, and 72 percent in highway patrols.

Information from the questionnaire showed an average workweek of 48 hours for uniformed personnel and 40 hours for civilians. The data also were used to determine the time spent on agency functions by highway patrolmen. Criminal investigation and its supporting functions were not considered. The patrolman spends 40 hours a week in the performance of basic traffic functions, including traffic surveillance, accident investigation, auto theft and recovery, and court appearances; 1 hour in compiling records and statistics and in police laboratory work; 4 hours in driver licensing, truck weighing, motor-vehicle and school bus inspection, and safety education; and 3 hours in communications, personnel, training, and special services required within the internal structure of the organization.

### *Manpower*

Each State police agency was also asked to report its personnel strength for three periods of time. Civilian and sworn uniformed personnel were considered separately. As of July 1, 1959, there were 22,864 sworn uniformed personnel and 7,981 civilians or a total force of 30,845 persons engaged in State police activities. By July 1, 1964, the number had increased to 26,784 sworn uniformed personnel and 9,968 civilians, a total force of 36,752. The sworn uniformed personnel increased 3,920 or 17 percent and

**Table 3.—Sworn uniformed and civilian personnel for 1940 and 1964** [1]

| State | Sworn uniformed personnel | | Civilian personnel | | Total | |
|---|---|---|---|---|---|---|
| | 1940 | 1964 | 1940 | 1964 | 1940 | 1964 |
| Alabama | 134 | 561 | 27 | 204 | 161 | 765 |
| Alaska | ---------- | 101 | ---------- | 46 | ---------- | 147 |
| Arizona | 41 | 319 | 10 | 66 | 51 | 385 |
| Arkansas | 61 | 218 | 7 | 60 | 68 | 278 |
| California | 719 | 2,795 | 197 | 907 | 916 | 3,702 |
| Colorado | 116 | 332 | 16 | 141 | 132 | 473 |
| Connecticut | 225 | 502 | 85 | 201 | 310 | 703 |
| Delaware | 92 | 221 | 15 | 53 | 107 | 274 |
| Florida | 60 | 614 | 4 | 596 | 64 | 1,210 |
| Georgia | 168 | 420 | 12 | 326 | 180 | 746 |
| Hawaii [2] | | | | | | |
| Idaho | 40 | 140 | 46 | 27 | 86 | 167 |
| Illinois | 350 | 1,145 | 127 | 525 | 477 | 1,670 |
| Indiana | 221 | 651 | 85 | 232 | 306 | 883 |
| Iowa | 128 | 285 | ---------- | 82 | 128 | 367 |
| Kansas | 67 | 223 | 5 | 80 | 72 | 303 |
| Kentucky | 113 | 457 | 10 | 198 | 123 | 655 |
| Louisiana | 439 | 554 | 26 | 491 | 465 | 1,045 |
| Maine | 109 | 244 | 11 | 47 | 120 | 291 |
| Maryland | 104 | 733 | 34 | 249 | 138 | 982 |
| Massachusetts | 323 | 614 | 105 | 164 | 428 | 778 |
| Michigan | 443 | 1,170 | 131 | 305 | 574 | 1,475 |
| Minnesota | 125 | 377 | 13 | 86 | 138 | 463 |
| Mississippi | 85 | 378 | 18 | 118 | 103 | 496 |
| Missouri | 175 | 505 | 48 | 440 | 223 | 945 |
| Montana | 71 | 143 | 9 | 66 | 80 | 209 |
| Nebraska | 67 | 225 | 3 | 45 | 70 | 270 |
| Nevada | 11 | 50 | 3 | 16 | 14 | 66 |
| New Hampshire | 52 | 126 | 12 | 17 | 64 | 143 |
| New Jersey | 319 | 996 | 70 | 242 | 389 | 1,238 |
| New Mexico | 42 | 204 | 4 | 66 | 46 | 270 |
| New York | 895 | 2,464 | 34 | 282 | 929 | 2,746 |
| North Carolina | 188 | 648 | 41 | 185 | 229 | 833 |
| North Dakota | 13 | 80 | 5 | 6 | 18 | 86 |
| Ohio | 200 | 855 | 60 | 409 | 260 | 1,264 |
| Oklahoma | 125 | 348 | 18 | 253 | 143 | 601 |
| Oregon | 168 | 535 | 17 | 91 | 185 | 626 |
| Pennsylvania | 1,516 | 2,015 | 141 | 312 | 1,657 | 2,327 |
| Rhode Island | 71 | 119 | 10 | 21 | 81 | 140 |
| South Carolina | 154 | 460 | 25 | 2 | 179 | 462 |
| South Dakota | 17 | 88 | ---------- | 36 | 17 | 124 |
| Tennessee | 100 | 518 | 32 | 200 | 132 | 718 |
| Texas | 340 | 1,398 | 98 | 1,014 | 438 | 2,412 |
| Utah | 50 | 152 | 6 | 41 | 56 | 193 |
| Vermont | 37 | 111 | 26 | 53 | 63 | 164 |
| Virginia | 178 | 745 | 42 | 304 | 220 | 1,049 |
| Washington | 167 | 369 | 50 | 380 | 217 | 749 |
| West Virginia | 218 | 279 | 32 | 85 | 250 | 364 |
| Wisconsin | 45 | 222 | 2 | 187 | 47 | 409 |
| Wyoming | 15 | 75 | 1 | 11 | 16 | 86 |
| TOTAL | 9,397 | 26,784 | 1,773 | 9,968 | 11,170 | 36,752 |

[1] Source of the 1940 data, *State and Provincial Police*, by David Geeting Monroe, p. 9.
[2] Hawaii has no State police organiza tion; each island has its own police department.

the civilian strength 1,987 or approximately 25 percent. The total strength of the police agencies increased 5,907 or 19 percent.

Estimates by each agency show that 57,444 persons including 44,210 sworn uniformed personnel and 13,234 civilians will be needed to provide adequate traffic supervision and perform the other agency functions by July 1, 1969. This is an increase of 17,417 troopers or 65 percent, 3,582 civilians or 33 percent, and a total increase of 20,699 or 56 percent. The growth of police agencies over the 25 years from 1940 to 1964 is shown in table 3. The increase of 25,582 in police manpower during this 25-year period is compared to an expected increase of 20,699 during the 5-year period 1964–69.

Questionnaire responses showed that 29 State agencies were responsible for patrolling State highways within incorporated municipalities. Of those agencies, five patrolled the highways upon request of local governments; five confined urban patrol to the Interstate System; four patrolled small cities and towns; four patrolled where no local police force was maintained; and the remaining State patrols gave no explanation for patrolling these highways. Most State patrol agencies devoted less than 5 percent of their total activity to patrolling municipal areas; six States devoted 5 to 10 percent to incorporated areas.

County roads in 41 States are patrolled by the State agency. In addition, county or township patrols operate in 39 States. Out of 3,054 counties, 773 road patrols and 320 township road patrols are operated. Eight States have road patrols in each county; 10 States have no local county road patrols. Separate patrols for the free sections of the Interstate System exist in only five States. However, as more mileage is opened to traffic and motorist needs increase, the need for these patrols should also increase.

### *Statutory Authority*

The statutory provision for the creation l financial support of law enforcement ncies in each State is listed in table 1.

**od roads amendments**

Presently 29 State constitutions have good ds amendments that earmark highway-r taxes for highway purposes. A model endment published in *Good Roads Amendnts* by the National Highway Users Conence, Inc. in 1965 proposed that: "No nies derived from fees, excises, or license es relating to registration, operation, or of vehicles on the public highways, or fuels used for the propulsion of such veles, shall be expended for other than cost administering laws under which such monies derived, statutory refunds and adjustnts provided therein, payment of highway ligations, cost of construction, reconstrucn, maintenance and repair of public highys and bridges, and expense of State forcement of traffic laws." Such amendnts are designed to prevent future legisures and special interest groups from erting road-user taxes to other than hway purposes.

Constitutions in 29 States include good ads amendments. Funds are specified for otor-vehicle and traffic law enforcement in State constitutions. These States allocate ghway-user funds directly, with the excepon of Alabama and Oregon, where tax venues are appropriated to the enforcement encies from the State general funds.

Six State amendments provide that highway nds support traffic supervision or traffic fety. In this group Idaho, New Hampshire, uth Dakota, and Colorado support law forcement agencies by direct allocations. Pennsylvania, moneys are appropriated om the special motor license fund, to the neral fund, and then reappropriated to the licing agency. Though receipts pass rough the general fund they are specifically signated for the highway patrol agency. Iowa, the good roads amendment does not ovide for the support of the highway patrol om highway revenue. However, operator d chauffeur license fees deposited in the neral fund provide substantial support for e highway patrol.

In 10 States, the amendments do not include affic enforcement as a highway cost. Within is group Kansas and Minnesota have nendments that earmark highway funds for ighway purposes. Kansas legislation proides highway fund support for a traffic atrol; Minnesota allows the highway patrol be placed under any agency as long as atrol functions remain the same and patrolng costs can be covered by highway revenues. Florida and Georgia, road-use moneys pply only to motor-fuel tax receipts, and in lorida only to two-sevenths of the receipts. The Florida Department of Public Safety is upported by the general fund; but, driver cense fees deposited in the general fund are onsidered support for the highway patrol gency. The Georgia Department of Public afety is also supported by driver license fees that are deposited in the general fund. However, in Georgia the department has first claim to these funds. In Louisiana driver license fees are credited directly to the law enforcement agency.

Prior to April 1, 1963, Michigan's amendment restricted motor-fuel and vehicle registration revenues to highway construction, maintenance, and administration. State police functions were not supported from these revenues. On April 1, 1963, the State constitution was changed to provide highway revenues for highway purposes, as defined by law. Governor Romney subsequently recommended the use of highway funds for the freeway patrol. The Michigan amendment does not specifically cover fees on operators' licenses; the fees are deposited in the general fund where they are drawn upon to support, in part, the State police.

**General funds**

The traffic enforcement agencies in Montana, North Dakota, and West Virginia are financed principally from the State general fund. Their amendments do not provide for traffic law enforcement as a highway cost element. In Montana and North Dakota, revenue from operators' license fees is not subject to the purview of the amendment; these revenues are deposited in the State general fund, from which appropriations are made for enforcement agencies. Nevada's good roads amendment includes administration as well as construction and maintenance as authorized highway expenditures. The legislature determined that Motor Vehicle Department costs should be considered administrative costs. Consequently, the Nevada State Highway Patrol, as a division of the Motor Vehicle Department, is financed entirely from highway funds. Generally, in States where constitutional amendments do not provide highway moneys for law enforcement, there is little the legislatures can do in assigning such moneys to cover highway police activities.

Although 21 States have no consitutional good roads amendments, in practice, most apply road-user tax revenues exclusively to highway purposes. Five of these States operate on a one-fund basis whereby all State revenues are deposited in a general fund from which highway appropriations are paid. Therefore, road-user revenues in these States support policing and other highway activities to the extent that revenues equal appropriations for highway and related purposes. In 11 of the States, road-user revenues are allocated directly for support of the traffic enforcement agencies. In the remaining five States, the agencies are supported almost entirely from general fund appropriations. In four of these five States, operator license and road-user revenues placed in the general fund partially or entirely equal the amount expended by police agencies.

In summary, the costs of enforcing State traffic and motor-vehicle laws is clearly recognized as a highway expense by 21 of the 29 States having good roads amendments; by 11 of the remaining 21 States; and by many national organizations associated with roads and motor-vehicles. This interpretation is shared by the Federal Government, as explained in the following paragraph.

### *The Federal Interpretation*

The Bureau of Public Roads has for many years considered highway policing an essential and important highway activity, and it has ruled that expenditures for that purpose are fully consistent with the policy statement in the Hayden-Cartweight Act, 48 Stat. 993 (1934). The act states that it is unfair and unjust to tax motor-vehicle transportation unless the proceeds of such taxation are applied for construction, improvement, and maintenance of highways and administrative expenses in connection therewith. The terms of the ruling were defined by the Administrator of the Bureau of Public Roads through the General Counsel. Administrative expenses, were interpreted to include not only the administration of highway construction and maintenance but also the enforcement of motor-vehicle and traffic laws.

### *Policing Toll Roads*

Traffic patrol functions on public toll roads can be effectively analyzed and measured because such roads consist of a known mileage and carry known volumes and types of traffic. The special services provided on toll roads, however, are not necessarily applicable to tax supported freeways such as the Interstate System. The major toll roads are generally patrolled by personnel from State police agencies; however 15 toll roads have permanently assigned detachments. Established patrol units are supported entirely from toll revenues paid by the road users. The initial cost of permanent toll road patrols is usually appropriated from the parent law enforcement agency, subject to reimbursement by the toll road authority.

Available data showed that more than $11 million was spent for policing on 19 major toll roads during 1964. These funds were almost entirely devoted to traffic law enforcement; criminal investigation represented only a minor expense. The traffic law enforcement function included maintenance of an orderly flow of traffic as well as motorist assists. Motorist assists, necessary because of widely separated interchanges and service centers on toll roads, is provided by State police and service crews commissioned by toll road authorities.

Although maintenance and emergency service vehicles are available, the patrol is usually the first to provide aid. The patrolman will manage minor emergencies himself, but obtains assistance for serious situations. Some aids given motorists are: gas; tire changes; service calls; mechanical aid; fire extinguishing; information; parking and U-turn permits; checks on sleeping drivers; person, property, and message relays; special escort services; removal of objects from road; collection of unpaid tolls; checks on abandoned vehicles; removal of hitchhikers;

**Table 4.—Statistics on highway patrols, 1964**

| Toll facility | Uniformed personnel | Road mileage | Expenditures | Annual vehicle-miles of travel | Motorist assists | Assists per trooper | Assists per million vehicle-miles of travel |
|---|---|---|---|---|---|---|---|
| | *Number* | *Miles* | *Thousands* | *Millions of miles* | *Number* | *Number* | *Number* |
| Indiana Turnpike | 46 | 157 | $556 | 612 | 22,018 | 4,786 | 36 |
| Kansas Turnpike | 23 | 237 | 303 | 341 | 14,855 | 6,459 | 44 |
| New Jersey Turnpike | 104 | 134 | 1,371 | 1,753 | 63,298 | 6,086 | 36 |
| Garden State Parkway | 98 | 175 | 966 | 1,552 | 33,586 | 3,427 | 22 |
| New York Thruway | 211 | 561 | 2,580 | 3,006 | [1] 39,151 | 1,855 | 13 |
| Ohio Turnpike | 90 | 241 | 1,029 | 1,147 | 18,736 | 2,082 | 16 |
| Dallas-Fort Worth Turnpike | 13 | 30 | 137 | 197 | 13,097 | 10,074 | 66 |
| Richmond-Petersburg Turnpike | 19 | 35 | 193 | 213 | 8,523 | 4,486 | 40 |
| West Virginia Turnpike | 16 | 86 | 171 | 115 | 7,393 | 4,621 | 64 |
| TOTAL | 620 | 1,656 | 7,306 | 8,936 | 220,657 | ---------- | ---------- |

[1] Number of motorists with disabled vehicles aided by the Thruway patrol; an additional 46,101 motorists were assisted by Thruway emergency service crews.

**Table 5.—Activity statistics on some toll road highway patrols, 1964**

| Toll facility | Miles patrolled (thousands) | Motorist assists | Traffic arrests | Warnings issued | Assists per thousand miles of patrol | Arrests per thousand miles of patrol | Warnings per thousand miles of patrol |
|---|---|---|---|---|---|---|---|
| Kansas Turnpike | 1,371 | 14,855 | 2,139 | 1,614 | 11 | 2 | 1 |
| New Jersey Turnpike | 3,349 | 63,298 | 33,695 | 22,639 | 19 | 10 | 7 |
| Garden State Parkway | 3,400 | 33,586 | 15,856 | 20,770 | 10 | 5 | 6 |
| New York Thruway | 8,346 | 39,151 | 57,838 | 31,299 | 5 | 7 | 4 |
| TOTAL | 16,466 | 150,890 | 109,528 | 76,322 | ---- | ---- | ---- |

**Table 6.—Historical summary of expendi tures for traffic law enforcement an related activities [1]**

[*Millions of dollars*]

| Years | Traffic law enforcement: Toll roads only | Traffic law enforcement: All roads | Safety education | Size and weight enforcement | Total |
|---|---|---|---|---|---|
| 1946 [2] | ------ | ------ | ------ | ------ | 41.3 |
| 1947 [2] | ------ | ------ | ------ | ------ | 45.9 |
| 1948 [2] | ------ | ------ | ------ | ------ | 63.3 |
| 1949 | ------ | 67.8 | 1.3 | 1.1 | 70.2 |
| 1950 | ------ | 74.7 | 1.5 | 1.4 | 77.6 |
| 1951 | 0.2 | 86.2 | 2.6 | 2.4 | 91.2 |
| 1952 | .6 | 89.2 | 3.8 | 2.5 | 95.5 |
| 1953 | 1.2 | 105.2 | 4.3 | 3.1 | 112.6 |
| 1954 | 1.8 | 115.7 | 4.7 | 3.2 | 123.6 |
| 1955 | 3.4 | 124.4 | 6.3 | 4.8 | 135.5 |
| 1956 | 4.7 | 139.0 | 7.4 | 5.2 | 151.6 |
| 1957 | 6.2 | 162.1 | 9.3 | 6.9 | 178.3 |
| 1958 | 7.5 | 183.3 | 10.0 | 9.0 | 202.3 |
| 1959 | 7.8 | 192.3 | 14.4 | 9.0 | 215.7 |
| 1960 | 8.6 | 208.9 | 15.9 | 10.4 | 235.2 |
| 1961 | 10.0 | 223.6 | 18.8 | 11.0 | 253.4 |
| 1962 | 10.5 | 235.5 | 24.9 | 12.8 | 273.2 |
| 1963 | 10.8 | 246.8 | 33.3 | 14.1 | 294.2 |
| 1964 | 12.0 | 263.1 | 48.4 | 15.3 | 326.8 |

[1] Includes expenditures by State highway departmen and other State agencies for traffic related activities.
[2] No breakdown available.

traffic direction; first aid; oversize vehicle fee collection.

Data is limited for comparing services on toll and toll-free highways. New Jersey, however, does furnish such information. A comparison of New Jersey State Police operations on toll (New Jersey Turnpike and Garden State Parkway) and nontoll roads during 1964 shows that in terms of the miles traveled on patrol, the incidence of vehicle arrests was higher on free roads and the number of motorist assists was considerably lower. A review indicates that 52 percent of the total functions of the patrols on toll roads in New Jersey were devoted to motorist assists in 1964, as compared to less than 1 percent for the other patrols. In contrast, arrests and traffic investigations accounted for only 32 percent of the patrol function on toll roads and 49 percent on nontoll roads.

Comparative data for patrol functions are not available for all major toll roads; however, comparisons can be made from information on specific toll roads as shown in tables 4 and 5. Table 4 contains information on personnel, road mileage, patrol expenditures, vehicle-miles of travel, and motorist assists by road patrols for nine of the Nation's major toll roads in 1964. Patrol expenditures averaged about $12,000 per man. Assists averaged 3,559 per trooper or in terms of travel, 25 motorists required assistance for every 1 million miles of travel.

A breakdown of motorist assists was obtained for a few toll facilities. It is estimated that 39 percent of the motorist assists involved mechanical failure; 20 percent involved tire failures; and 14 percent involved vehicles that ran out of fuel. The remaining 27 percent covered the other services performed by toll road patrols for the motoring public, such as message relays, special permits, special escorts, and first aid.

Table 5 charts three types of activity performed by toll road patrols in terms of the mileage patrolled on four roads. In addition to motorist assists, averages were computed for traffic arrests and warnings. Totaled, for every thousand miles of patrol, the trooper averaged nine motorist assists, seven traffic arrests, and five warnings.

### *Motorist Assists*

If motorist assists are necessary on nontoll freeways, the question arises as to whether such assistance should be given by the State police or another highway agency. Governor Romney of Michigan stated, in a special legislative message on traffic safety, January 16, 1964, that, ". . . freeways must be patrolled for the supervision, protection, and assistance of our motorists." He referred to the fact that fewer traffic violations occur on freeways, although traffic supervision and police protection is still required in order to maintain an orderly and safe flow of traffic. Governor Romney pointed out that ". . . assistance to motorists, while incidental to the performance of regular police duties, is closely related to the basic police function of public protection."

In July 1962, there were 100 State troope assigned to patrol Michigan freeways. How ever, a ruling of the Michigan Civil Servic Commission limited troopers to a 48-hour wee and freeway patrolling was discontinued fo lack of manpower. The scheduling of free way patrols was shifted from headquarters t local post commands. The net result was sharp reduction in freeway patrols. But, th need did not disappear. The State Highwa Commissioner initiated freeway service fo stranded motorists on a limited scale and th Michigan Department of State Highway planned to expand the aiding of motorists t include the entire 1,000-mile freeway syster at an estimated annual cost of $943,00 Governor Romney disapproved of the dupl cation of service by two organizations, and th attorney general subsequently ruled tha motorist assistance by the Department o State Highways was illegal.

The Governor recommended an appropria tion of $1,303,300 to finance a 130-troope freeway patrol for fiscal year 1964–65. Aid t stranded motorists was to be a patrol duty It was further recommended that suppor come from motor vehicle taxes rather than th general fund. At the time of this study, i was not known whether these recommenda tions became law.

Toll road authorities have a freer hand i authorizing services such as motorist assist and covering the costs incurred with use charges (tolls). But State highway depart ments and police departments, one of whic must ultimately provide these aids, have th problem of balancing the costs of such serv ices against the need for funds for oth highway and traffic-related functions. Eve where charges are levied for these aids it i not known whether revenue raised cover costs incurred.

## Table 7.—Police agency disbursements for traffic and related functions, 1964

[Thousands of dollars]

| State | Traffic supervision [1] | Safety education | Size and weight enforcement | Driver license examination | Motor vehicle inspection | Communications | Training | Administration and supporting services [2] | Total traffic-related disbursements | Nontraffic-related activities | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama | 2,447 | 1,311 | -------- | 802 | -------- | -------- | -------- | -------- | 4,560 | 189 | 4,749 |
| Alaska | 657 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 657 | -------- | 657 |
| Arizona | 4,910 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 4,910 | -------- | 4,910 |
| Arkansas | 1,282 | 263 | -------- | 58 | -------- | -------- | -------- | -------- | 1,603 | 375 | 1,978 |
| California | 31,729 | 1,339 | 1,556 | -------- | -------- | 2,056 | 1,572 | 4,959 | 43,211 | -------- | 43,211 |
| Colorado | 3,854 | 5 | -------- | -------- | -------- | 328 | -------- | 427 | 4,614 | -------- | 4,614 |
| Connecticut | 3,525 | 161 | -------- | -------- | -------- | 344 | -------- | 439 | 4,469 | -------- | 4,469 |
| Delaware | 1,449 | 26 | -------- | -------- | -------- | -------- | -------- | -------- | 1,475 | -------- | 1,475 |
| Florida | 4,713 | -------- | -------- | 1,469 | -------- | 90 | -------- | 2,401 | 8,673 | -------- | 8,673 |
| Georgia | 3,851 | -------- | -------- | 958 | -------- | -------- | -------- | -------- | 4,809 | 1,366 | 6,175 |
| Hawaii [3] | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| Idaho | 1,102 | 72 | 434 | -------- | -------- | -------- | -------- | -------- | 1,608 | -------- | 1,608 |
| Illinois | 12,448 | 244 | 684 | -------- | -------- | -------- | -------- | -------- | 13,376 | 612 | 13,988 |
| Indiana | 4,556 | 736 | 185 | -------- | -------- | -------- | -------- | 1,428 | 6,905 | -------- | 6,905 |
| Iowa | 3,022 | -------- | -------- | 417 | -------- | -------- | -------- | -------- | 3,439 | -------- | 3,439 |
| Kansas | 2,896 | -------- | -------- | -------- | -------- | -------- | -------- | 27 | 2,923 | -------- | 2,923 |
| Kentucky | 5,191 | 195 | -------- | 189 | -------- | -------- | -------- | -------- | 5,575 | -------- | 5,575 |
| Louisiana | 4,523 | 69 | 135 | 1,799 | 310 | -------- | -------- | 365 | 7,201 | -------- | 7,201 |
| Maine | 1,881 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 1,881 | -------- | 1,881 |
| Maryland | 5,036 | -------- | -------- | -------- | -------- | 355 | 181 | 2,772 | 8,344 | 359 | 8,703 |
| Massachusetts | 5,838 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 5,838 | -------- | 5,838 |
| Michigan | 7,096 | 286 | -------- | -------- | -------- | 369 | 87 | 1,142 | 8,980 | -------- | 8,980 |
| Minnesota | 5,214 | -------- | 41 | -------- | -------- | -------- | -------- | -------- | 5,255 | -------- | 5,255 |
| Mississippi | 3,179 | 121 | -------- | 309 | 93 | 332 | -------- | 787 | 4,821 | -------- | 4,821 |
| Missouri | 5,900 | 175 | 595 | 642 | -------- | -------- | -------- | 154 | 7,466 | -------- | 7,466 |
| Montana | 1,069 | -------- | -------- | 410 | -------- | -------- | -------- | 302 | 1,781 | -------- | 1,781 |
| Nebraska | 1,122 | 29 | -------- | -------- | -------- | 110 | 8 | 772 | 2,041 | -------- | 2,041 |
| Nevada | 637 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 637 | -------- | 637 |
| New Hampshire | 1,147 | 80 | -------- | -------- | -------- | 63 | -------- | 67 | 1,357 | -------- | 1,357 |
| New Jersey | 8,506 | -------- | 121 | -------- | -------- | -------- | -------- | -------- | 8,627 | -------- | 8,627 |
| New Mexico | 2,341 | 25 | -------- | 14 | -------- | 262 | 32 | 37 | 2,711 | -------- | 2,711 |
| New York | 19,345 | -------- | -------- | -------- | 387 | -------- | -------- | -------- | 19,732 | -------- | 19,732 |
| North Carolina | 6,117 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 6,117 | -------- | 6,117 |
| North Dakota | 709 | 15 | -------- | 37 | -------- | -------- | -------- | -------- | 761 | -------- | 761 |
| Ohio | 10,092 | 155 | -------- | 945 | -------- | -------- | -------- | 765 | 11,957 | -------- | 11,957 |
| Oklahoma | 2,941 | -------- | 236 | 372 | -------- | 246 | -------- | 47 | 3,842 | -------- | 3,842 |
| Oregon | 3,199 | -------- | -------- | -------- | -------- | 34 | -------- | 356 | 3,589 | -------- | 3,589 |
| Pennsylvania | 17,121 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 17,121 | -------- | 17,121 |
| Rhode Island | 788 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | 788 | -------- | 788 |
| South Carolina | 3,314 | -------- | 87 | 373 | -------- | -------- | -------- | -------- | 3,774 | -------- | 3,774 |
| South Dakota | 996 | 45 | 116 | -------- | -------- | -------- | -------- | 24 | 1,181 | -------- | 1,181 |
| Tennessee | 3,452 | 90 | -------- | 480 | -------- | 77 | 6 | 787 | 4,892 | -------- | 4,892 |
| Texas | 6,597 | 194 | 750 | 2,853 | 668 | -------- | -------- | -------- | 11,062 | -------- | 11,062 |
| Utah | 1,663 | 23 | 375 | 373 | -------- | -------- | -------- | -------- | 2,434 | -------- | 2,434 |
| Vermont | 795 | 23 | 21 | -------- | -------- | 24 | -------- | 169 | 1,032 | -------- | 1,032 |
| Virginia | 6,077 | 167 | -------- | -------- | -------- | 835 | 250 | 1,058 | 8,387 | -------- | 8,387 |
| Washington | 3,663 | 270 | 654 | 808 | -------- | 1,108 | 79 | 1,105 | 7,687 | 694 | 8,381 |
| West Virginia | 1,588 | -------- | -------- | -------- | 97 | -------- | -------- | -------- | 1,685 | -------- | 1,685 |
| Wisconsin | 1,786 | -------- | 371 | -------- | -------- | 487 | 73 | 995 | 3,712 | -------- | 3,712 |
| Wyoming | 860 | 23 | -------- | -------- | -------- | -------- | -------- | -------- | 883 | -------- | 883 |
| TOTAL | 232,224 | 6,142 | 6,361 | 13,308 | 1,555 | 7,120 | 2,288 | 21,385 | 290,383 | 3,595 | 293,978 |

[1] Includes all costs of the agency when itemized expenditures were not available.
[2] Includes safety responsibility and pension funds.
[3] Not included in police study.

### *Police Financing*

A study of the financing of State law enforcement agencies is complicated by the variety of organizational structures and the diversity of functions performed. Moreover, many agencies keep financial accounts on an object basis, that is, salaries, supplies, equipment purchases, and so on, rather than on a functional or activity basis. Where the parent or primary department has a division structure and funds are accounted for on a division basis, the costs of the patrol usually can be identified. But, costs for traffic supervision, traffic-related functions, or general law enforcement are not easily distinguished. The related functions are not the same in all States, and allocations of funds to the functions often are not specifically recorded. Therefore, estimated assignments were made on the basis of personnel man-hours, activity reports, and the like.

### *Annual Expenditures*

For the study reported here, law enforcement expenditures were derived from statistics published by the Bureau of Public Roads. The Bureau has compiled annual highway statistics since 1921 and has identified expenditures for law enforcement beginning in 1925. In that year California, Maine, and Pennsylvania reported expenditures for law enforcement activities totaling \$924,000. By 1934, with 34 States reporting, expenditures totaled \$8,800,000. In 1941, police expenditures reached \$29,400,000 for 47 States; and by 1950, with all States reporting, expenditures were \$77,600,000. The postwar boom in vehicle ownership, travel, and highway construction led to rapid increases in outlays for patrol operations; they doubled by 1956 to \$151,600,000 and doubled again by 1964 to \$326,800,000. As shown in table 6 expenditures for law enforcement have increased steadily since 1946.

Since 1949, the Public Roads statistics have identified traffic law enforcement, safety education, and vehicle size and weight enforcement as the major areas of law enforcement expenditure. However, because Public Roads classifies expenditures without regard to the expending agency, the expenditures given in table 7 are not necessarily limited to police agencies. Costs of certain services related to the general area of policing and safety are included in Public Roads statistical summaries even though they were not incurred by the police agencies. For example, inspection of motor vehicles may be done by patrolmen, employees of motor vehicle departments, or private garages; but the public cost is considered a law enforcement expense by the Bureau of Public Roads.

In using the Public Roads statistics, the method of accounting should be known. The only concern is with highway or traffic related functions, consequently, the financial reports published by Public Roads do not include any allocations and expenditures of funds for nontraffic-related functions except those financed by highway-user revenues. These expenditures are not recorded as a police cost, but as nonhighway expenditures of highway-user revenues.

As shown in table 1, the two major sources of revenue for police functions are highway-user taxes and general funds. Highway-user taxes are those levied on owners and operators of motor-vehicles for their use of the public highways. These taxes are primarily motor-fuel taxes, registration fees, operators' licenses, and other fees allied with the ownership and operation of motor-vehicles. Also included are fines and penalties for registration violations and vehicle size and weight violations. In each State, financial support for the police agency is determined by the legislature. Finances may come from highway-user revenues, general fund revenues, or a combination of both.

### *Highway-user Revenue*

Twenty-one State police agencies receive their entire support from highway-user revenues. In some agencies these moneys are allocated from a readily identified source. For example, in Ohio, the Department of Highway Safety gets an appropriation from motor-fuel tax collections and operator and chauffeur license fees. In other agencies the source of funds is not known. In Arizona, the Highway Patrol receives an appropriation from the State Highway Fund, which contains revenue from various highway-user taxes. Of these 21 States, 16 have subordinate agencies. The subordinate agencies include six departments of public safety, five highway departments, three motor vehicle departments, and two other departments. Five States have independent agencies that include two State police and three highway patrols.

#### General fund revenue

General fund appropriations support State police agencies in 16 States. Taxes, fees, and often highway-user revenues are deposited in the State general fund. The Bureau of Public Roads considers that the general fund appropriation by the police agency was derived from highway-user revenues to the extent that the user revenues do not exceed the appropriation.

In Alabama, Georgia, Mississippi, New Mexico, Oregon, and Pennsylvania, certain highway-user revenues are deposited into the State general fund or into a special fund created within the general fund. These revenues are appropriated by the legislature for police support or are used to reimburse the general fund for moneys previously allocated for police support. The basic difference between these States and the other 10 State agencies supported by general fund appropriations is that the source of financial support for police activities is identified as highway-user revenues. Eight of the 16 State agencies in this group are departments of public safety, two are highway departments, and six are independent State police agencies.

**Table 8.—Police agency receipts for traffic and related functions, 1964**

[*Thousands of dollars*]

| State | Imposts on highway users | | | Tolls | Total highway-user revenues | General fund appropriations | Miscellaneous receipts | Total receipts |
|---|---|---|---|---|---|---|---|---|
| | Dedicated revenues | | Commingled highway-user revenues | | | | | |
| | Motor-fuel taxes | Motor vehicle revenues | | | | | | |
| Alabama | ------ | ------ | ------ | ------ | ------ | 4,868 | 596 | 5,464 |
| Alaska | ------ | ------ | ------ | ------ | ------ | 657 | ------ | 657 |
| Arizona | ------ | ------ | 6,519 | ------ | 6,519 | ------ | ------ | 6,519 |
| Arkansas | ------ | 1,810 | ------ | ------ | 1,810 | ------ | ------ | 1,810 |
| California | ------ | 43,211 | ------ | ------ | 43,211 | ------ | ------ | 43,211 |
| Colorado | ------ | ------ | 4,505 | ------ | 4,505 | ------ | 109 | 4,614 |
| Connecticut | ------ | ------ | 4,469 | ------ | 4,469 | ------ | ------ | 4,469 |
| Delaware | ------ | ------ | ------ | 153 | 153 | 1,388 | ------ | 1,541 |
| Florida | ------ | ------ | ------ | 619 | 619 | 8,054 | ------ | 8,673 |
| Georgia | ------ | ------ | ------ | ------ | ------ | 5,943 | ------ | 5,943 |
| Hawaii [1] | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| Idaho | ------ | ------ | 1,608 | ------ | 1,608 | ------ | ------ | 1,608 |
| Illinois | ------ | 13,450 | ------ | 538 | 13,988 | ------ | ------ | 13,988 |
| Indiana | ------ | ------ | 5,796 | 556 | 6,352 | 553 | ------ | 6,905 |
| Iowa | ------ | ------ | ------ | ------ | ------ | 3,439 | ------ | 3,439 |
| Kansas | ------ | ------ | 1,274 | 303 | 1,577 | ------ | ------ | 1,577 |
| Kentucky | ------ | ------ | 3,652 | 101 | 3,753 | 1,822 | ------ | 5,575 |
| Louisiana | ------ | 2,879 | 159 | 2 | 3,040 | 4,158 | ------ | 7,198 |
| Maine | ------ | ------ | 1,490 | 12 | 1,502 | 117 | 32 | 1,651 |
| Maryland | ------ | 8,521 | ------ | 182 | 8,703 | ------ | ------ | 8,703 |
| Massachusetts | ------ | ------ | 5,310 | 528 | 5,838 | ------ | ------ | 5,838 |
| Michigan | ------ | ------ | ------ | ------ | ------ | 8,980 | ------ | 8,980 |
| Minnesota | ------ | ------ | 5,255 | ------ | 5,255 | ------ | ------ | 5,255 |
| Mississippi | ------ | ------ | ------ | ------ | ------ | 5,697 | ------ | 5,697 |
| Missouri | ------ | ------ | 7,466 | ------ | 7,466 | ------ | ------ | 7,466 |
| Montana | ------ | 126 | ------ | ------ | 126 | 1,655 | ------ | 1,781 |
| Nebraska | ------ | ------ | ------ | ------ | ------ | 2,041 | ------ | 2,041 |
| Nevada | ------ | ------ | 1,230 | ------ | 1,230 | ------ | ------ | 1,230 |
| New Hampshire | ------ | ------ | 1,133 | 104 | 1,237 | ------ | 44 | 1,281 |
| New Jersey | ------ | ------ | ------ | 2,439 | 2,439 | 6,188 | ------ | 8,627 |
| New Mexico | ------ | ------ | ------ | ------ | ------ | 2,711 | ------ | 2,711 |
| New York | ------ | ------ | ------ | 2,615 | 2,615 | 17,117 | ------ | 19,732 |
| North Carolina | ------ | ------ | 6,117 | ------ | 6,117 | ------ | ------ | 6,117 |
| North Dakota [2] | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| Ohio | 9,121 | 1,807 | ------ | 1,029 | 11,957 | ------ | ------ | 11,957 |
| Oklahoma | ------ | 522 | ------ | 262 | 784 | 3,058 | ------ | 3,842 |
| Oregon | ------ | ------ | ------ | ------ | ------ | 3,589 | ------ | 3,589 |
| Pennsylvania | ------ | ------ | ------ | 2,117 | 2,117 | 15,004 | ------ | 17,121 |
| Rhode Island | ------ | ------ | ------ | ------ | ------ | 788 | ------ | 788 |
| South Carolina | ------ | ------ | 3,774 | ------ | 3,774 | ------ | ------ | 3,774 |
| South Dakota | ------ | ------ | 1,181 | ------ | 1,181 | ------ | ------ | 1,181 |
| Tennessee | ------ | ------ | ------ | ------ | ------ | 4,044 | 848 | 4,892 |
| Texas | ------ | 3,521 | 7,404 | 137 | 11,062 | ------ | ------ | 11,062 |
| Utah | 1,854 | 666 | ------ | ------ | 2,520 | ------ | ------ | 2,520 |
| Vermont | ------ | ------ | 713 | ------ | 713 | 319 | ------ | 1,032 |
| Virginia | ------ | 7,945 | ------ | 226 | 8,171 | ------ | 188 | 8,359 |
| Washington | ------ | 8,745 | ------ | ------ | 8,745 | ------ | 26 | 8,771 |
| West Virginia | ------ | 97 | ------ | 171 | 268 | 1,417 | ------ | 1,685 |
| Wisconsin | ------ | 3,712 | ------ | ------ | 3,712 | ------ | ------ | 3,712 |
| Wyoming | ------ | ------ | 883 | ------ | 883 | ------ | ------ | 883 |
| TOTAL | 10,975 | 97,012 | 69,938 | 12,094 | 190,019 | 103,607 | 1,843 | 295,469 |

[1] Not included in police study.
[2] 1964 expenditures were supported by general funds appropriated in 1963.

#### User and general revenues

The third method of financial support for police functions is the allocation of both highway-user and general fund revenues; 12 States use this method. In Montana and North Dakota, highway-user revenue is a small percentage of the total income. Part of the driver license fees in Montana is allocated to the police retirement fund; the North Dakota highway patrol receives a small part of the registration and other related fees for its safety program. The Maryland State Police, as a result of recent legislation, is limited to an annual appropriation of $8,250,000, paid from motor-vehicle fees. Expenditures in excess of this amount are paid from the general fund.

In five States, the amounts paid from highway-user revenues and general fund revenues are based on percentages established l law: Missouri, 90-percent highway funds, 1 percent general funds; Connecticut, Indiar and Maine, 75-percent highway funds, 2 percent general funds; Vermont, 50-perce highway funds, 50-percent general func The primary purpose for the appropriation both revenues is to support traffic-relat functions with highway funds, and nontraf or criminal-related functions with gener funds.

In Oklahoma, the Department of Pub Safety receives the first $112,500 collected the registration of commercial vehicles a the same amount on overweight fees; in adc tion, 10 percent of the net receipts from driv license fees is allotted to the pension fur Remaining support comes from the gener fund. In Kentucky, the Department of Pu

Safety has received the bulk of its support from highway-user revenues deposited in the road fund. As a result of the appropriation as passed by the 1964 General Assembly, the major source of financial support for the Kentucky Department of Public Safety was shifted from the road fund to the general fund. For fiscal year 1964–65, the general fund appropriation amounted to 56 percent of the total appropriation; for fiscal year, 1965–66, the appropriation reached 88 percent. In Louisiana, support comes from several user revenue sources and an annual general fund appropriation. In West Virginia, the Motor Vehicle Inspection Division of the State Police is self-supporting; remaining State Police support comes from the general fund.

Of the States receiving allocations from both highway-user and general fund revenues, four State agencies are subordinates of the departments of public safety, five are independent State police, and three are independent highway patrols.

The growth of expenditures for traffic-related activities from 1946 to 1964 are divided into the three basic categories in table 6. These figures include size and weight enforcement and safety education expenses for other than traffic law enforcement agencies. For example, many highway departments perform the function of weighing vehicles and operating the port of entry stations; their expenditures in this area accounted for 60 percent of the total expenditures in 1964.

In the field of safety education, the increased spending is attributable to the current trend of financing student driver training programs with highway-user revenues and other State moneys. By the close of 1964, 24 State legislatures provided for the financial support for driver training programs. These programs accounted for 52 percent of the total expenditure shown in table 6 for safety education. Motor vehicle and State agencies provided 28 percent of the total safety education programs.

**Receipts and disbursements**

Disbursements by function and receipts by source of funds of State police agencies are shown in tables 7 and 8, respectively. Any differences between receipts and disbursements are the result of fund balances omitted from the tables. In table 8 receipts include toll revenues and minor miscellaneous income. In the summary columns net contributions to police agencies were considered to have been derived specifically from user revenues and miscellaneous funds and not from the total general fund. To compile figures for table 7, adjustments were made in the 1964 figures shown in table 6; expenditures for administrative functions performed by police agencies were added. The table of disbursements itemizes some functions performed by police agencies. However, every function may not be performed by every State police agency; some come under the jurisdiction of another agency.

A summary of police function financing shows that 94.2 percent of revenue allocated for traffic-related police functions was derived for highway-user revenues, 5.2 percent from miscellaneous receipts. Police function allocations from the highway-user revenues were \$278.4 million with \$3.6 million or 1.3 percent expended for nonhighway purposes. Total 1964 disbursements of highway-user revenues amounted to \$6.3 billion with \$625.7 million or 9.9 percent expended for nonhighway purposes.

## *Special Fees for Special Services*

In some States fees are charged for special services provided by the police agency. Such services include motor vehicle inspection and driver license examinations. Of the 20 State police agencies that require periodic inspection, 5 reported this service as a separate expenditure. In each of the 5 States, except New York, the fee collected for issuing inspection stickers is allocated to the police agency. Driver license examinations are conducted by the police agency in 22 States. Examination costs and related administrative costs are shown in table 7 for 19 of these States; 3 States, Alaska, Pennsylvania, and West Virginia, did not identify these costs. In 6 of the 22 States, part or all of the revenues collected from operator and chauffeur licenses is allocated directly to the police agency. In one State, the amount allocated from these fees is used to support the Driver License Division of the Department of Public Safety, which conducts the driver examinations. In 15 States, revenue from these fees is deposited in the fund that supports the police agencies. The operator and chauffeur license fees also support driver training programs in 11 States, although such programs are not a primary function of the agency.

Police agencies in many States support traffic-related activities with highway-user revenues and nontraffic-related activities with general funds. Assuming that this method of financing is the most acceptable, the problem remains to determine the type of highway-user tax to be used for support of traffic-related functions. In 1964, Prof. Robert G. Hennes of the University of Washington, in *Memorandum on Patrol Financing*, reported his study of the problem in the financing of the Washington State Patrol.

Following the practice of allocating costs in proportion to the benefits received, Professor Hennes first estimated the percentage of patrol costs incurred for highway functions and second the percentage of patrol costs incurred for related functions. Using data from a previous study, he determined that 51 percent of the patrol's time was spent on traffic patrol, and that the remainder was equally divided between traffic-related functions and functions more closely related to the number of vehicles than to the distance they traveled, such as vehicle inspection, licensing, weight control, and so on. The separation of the total functions into these components provided the basis for assigning financial support. The traffic-related costs, constituting about 75 percent of the patrol's highway-related function costs, was to be collected from road-users in proportion to vehicle-miles traveled. Fees would be allocated to each vehicle class by multiplying the number registered by the miles traveled, and converting the result into the percentage of total miles traveled for each vehicle class.

Weight control expenditures would be computed from the remaining 25 percent of the patrol's highway-related function costs and then apportioned to commercial vehicles in relation to their use of the highway. Remaining expenditures would be allocated to the three classes of vehicles at a set fee. Nonhighway costs would be financed from general fund contributions, if possible. Professor Hennes believed that the heavy truck-over-10-ton, should support about three times as much of the highway patrol budget as an automobile or light truck. But this apportionment of costs would have little effect because the number of vehicles in this class is small. Hennes also suggested that police activity might be further supported by gas tax instead of the vehicle license fee, as this revenue increases with the amount of travel, as does patrol activities.

# NEW PUBLICATIONS

### *Freeways to Urban Development*

*Freeways to Urban Development, A new concept for joint development,* explains and illustrates in leaflet form a new Bureau of Public Roads concept for joint urban freeway and urban development. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 15 cents a copy.

The Public Roads concept is presented in response to President Johnson's call for imaginative thinking in meeting the growing demands of the Nation's cities. Joint development offers a way for city planners to surmount the limitations of money, space, and time, and provide housing, parks, and other community facilities simultaneously with the construction of freeways. The concept is based on the economics of land acquisition and use. Bureau of Public Roads studies indicate that in some urban situations the cost of acquiring whole blocks or squares of property would be comparable to or only slightly higher than the cost of acquiring freeway rights-of-way including payment for severance damages or the remainder where only part of the property is acquired. Thus, a city could acquire land on the route of a planned freeway, sell freeway space to the highway department, and still retain land for urban development at a fraction of the cost of acquiring it alone.

The space alongside, over, and under the freeway could be used to meet any of the city's redevelopment needs. Constructi of the freeway could be coordinated wi other development so that new replaceme housing and buildings would be available f those displaced as construction progresse those displaced could be given priority f space in the new facilities.

As a massive nationwide freeway constru tion program is now underway, there is a immediate opportunity for joint urban d velopment. The Bureau of Public Roads ready to work with the Nation's citie through State highway departments ar other Federal agencies to achieve maximu use of the scarce urban land that is need for highway transportation.



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**EPORTS TO CONGRESS**

'ederal Role in Highway Safety, House Document No. 93 (1959). 60 cents.

Iighway Cost Allocation Study:
Final Report, Parts I–V, House Document No. 54 (1961). 70 cents.
Supplementary Report, House Document No. 124 (1965). $1.00.

Iaximum Desirable Dimensions and Weights of Vehicles Operated on the Federal-Aid Systems, House Document No. 354 (1964). 45 cents.

'he 1965 Interstate System Cost Estimate, House Document No. 42 (1965). 20 cents.

**UBLICATIONS**

A Quarter Century of Financing Municipal Highways, 1937–61, $1.00.

Accidents on Main Rural Highways—Related to Speed, Driver, and Vehicle (1964). 35 cents.

Aggregate Gradation for Highways: Simplification, Standardization, and Uniform Application, and A New Graphical Evaluation Chart (1962). 25 cents.

America's Lifelines—Federal Aid for Highways (1966). 20 cents.

'alibrating and Testing a Gravity Model for Any Size Urban Area (1965). $1.00.

'apacity Charts for the Hydraulic Design of Highway Culverts (Hydraulic Engineering Circular, No. 10) (1965). 65 cents.

'lassification of Motor Vehicles, 1956–57 (1960). 75 cents.

Design Charts for Open-Channel Flow (1961). 70 cents.

Design of Roadside Drainage Channels (1965). 40 cents.

Federal Laws, Regulations, and Other Material Relating to Highways (1966). $1.50.

Freeways to Urban Development, A new concept for joint development (1966). 15 cents.

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Highway Finance 1921–62 (a statistical review by the Office of Planning, Highway Statistics Division) (1964). 15 cents.

Highway Planning Map Manual (1963). $1.00.

Highway Planning Technical Reports—Creating, Organizing, and Reporting Highway Needs Studies (1964). 15 cents.

Highway Research and Development Studies, Using Federal Aid Research and Planning Funds (1964). $1.00.

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Highway Research and Development Studies, Using Federal-Aid Research and Planning Funds (May 1965). 75 cents.

Highway Statistics (published annually since 1945):
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Highway Transportation Criteria in Zoning Law *and* Police Power and Planning Controls for Arterial Streets (1960). 35 cents.

Highways to Beauty (1966). 20 cents.

Highways and Economic and Social Changes (1964). $1.25.

Increasing the Traffic-Carrying Capability of Urban Arterial Streets: The Wisconsin Avenue Study (1962). Out of print. Appendix, 70 cents.

Interstate System Route Log and Finder List (1963). 10 cents.

Labor Compliance Manual for Direct Federal and Federal-Aid Construction, 2d ed. (1965). $1.75.

Landslide Investigations (1961). 30 cents.

Manual for Highway Severance Damage Studies (1961). $1.00.

Manual on Uniform Traffic Control Devices for Streets and Highways (1961). $2.00.
Part V—Traffic Controls for Highway Construction and Maintenance Operations (1963). 25 cents.

Opportunities for Young Engineers in the Bureau of Public Roads (1965). 30 cents.

Reinforced Concrete Pipe Culverts—Criteria for Structural Design and Installation (1963). 30 cents.

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Selected Bibliography on Highway Finance (1951). 60 cents.

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Standard Plans for Highway Bridges (1962):
Vol. I—Concrete Superstructures. $1.00.
Vol. II—Structural Steel Superstructures. $1.00.
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Vol. IV—Typical Continuous Bridges. $1.00.
Vol. V—Typical Pedestrian Bridges. $1.75.

Standard Traffic Control Signs Chart (as defined in the Manual on Uniform Traffic Control Devices for Streets and Highways) 22 x 34, 20 cents—100 for $15.00. 11 x 17, 10 cents—100 for $5.00.

The Identification of Rock Types (revised edition, 1960). 20 cents.

The Role of Economic Studies in Urban Transportation Planning (1965). 45 cents.

Traffic Assignment and Distribution for Small Urban Areas (1965). $1.00.

Traffic Assignment Manual (1964). $1.50.

Traffic Safety Services, Directory of National Organizations (1963). 15 cents.

Transition Curves for Highways (1940). $1.75.

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