SIMPLIFIED PROCEDURE FOR MAJOR THOROUGHFARE PLANNING IN SMALL URBAN AREAS

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The purpose of the research project was to develop a simplified procedure for major thoroughfare planning in small urban areas. Previously developed corridor growth factor models for developing future estimates of internal traffic in small urban areas were tested, modified, and refined. Lafayette, Indiana, data were used. Regression models to provide data usually obtained by use of external cordon surveys were developed. External survey reports from 36 cities in 14 states, ranging in population from 10,000 to 90,000, provided most of the data used. Alternate procedures for providing the external survey information, based on use of historical data from the subject city, were also developed. The completed procedure provides forecast traffic volumes within the accuracy necessary for major thoroughfare planning in small urban areas at low cost and with a level of sophistication that will permit application by personnel usually available in small communities. The feasibility of the complete procedure for providing the required traffic volume for major thoroughfare planning in small urban areas was demonstrated in Columbus, Indiana.

•THE continuing planning process developed as provided by the Federal-Aid Highway Act of 1962 was somewhat precise and detailed in the stated requirements. A complete land-use inventory, an inventory of existing physical facilities, an inventory of population and economic information, a review of existing zoning and subdivision regulation ordinances, an inventory of parking facilities and use, and a complete inventory and study of all other aspects pertaining to or connected with existing traffic were required. The manner in which the detailed inventories would be obtained was carefully outlined. A home-interview origin-destination survey and an external cordon survey were specifically required. With the information from the external survey and other collected data, forecasts of future traffic volumes were made, and total future trip generation by traffic zone within the study area was determined. Through the use of computers, these future trips are distributed among the various traffic zones, and finally the total trips between zones are assigned to a mathematical representation of the major arterial network. Through this process, the planners are able to determine the segments of the transportation system requiring either improvement or further planning for development of complete new segments to handle forecast traffic for the target year. This is accomplished by comparing the assigned traffic to the existing capacity of the individual segments of the system.

Techniques specifically designed to accomplish the same study objectives for the small urban areas as for the large areas have not been developed and tested. In general, especially in studies of areas having a population range of 25,000 to 50,000, it has been the practice to use the same procedures as used in the large-area studies. This, of course, means that, in small urban areas, a much higher overall sample percentage is necessary for the home-interview origin-destination survey. In addition, a highly qualified staff, consisting of professional and technical personnel, is needed to successfully complete a transportation study. The required professional staff for a small urban area will be almost as large as a staff for a large urban area. The end result is that, even if a competent staff were available to complete a transportation study for a small urban area, the cost will be much higher on a per capita basis than for a large urban area.

An additional major disadvantage of the detailed procedures followed in large areas is the length of time required to complete such a comprehensive study. The initial data collection phase of a study will usually require a minimum of 2 years when using established procedures in any urban area. In addition, the maximum benefits are derived from such studies only if they are reviewed and updated every 5 years as a minimum.

In small urban areas of 5,000 to 50,000 population, there are always many existing minor transportation problems. These will become greater as the area grows and automobile registrations increase. These problems can be alleviated by proper planning in the majority of cases even though such planning is not currently required by federal legislation.

For the purposes of this study, a small urban area will be defined as a geographically separate urban area. The size will be limited to less than 100,000 population. Public transportation in such areas usually is nonexistent or, at best, accommodates only a small portion of the population; therefore, study procedures for this area will not be included. This is not to imply that small urban areas can ignore the need to plan for a proper transit system.

A simplified planning procedure for major thoroughfare planning, developed and designed specifically to satisfy the requirements of small urban areas, is needed. The procedure must be easily applied by the type of personnel usually available at the municipal level of government, require a small budget, and produce results with the degree of accuracy necessary for sound thoroughfare planning.

Utilization of existing city personnel would accomplish a multipurpose objective. First, the completion of the study by local personnel would enhance the possibility of developing the all-important continual planning process. Second, this type of procedure would permit maximum efficiency and economy, allowing city personnel to complete the required data collection during normal slack periods in their regular routine. Third, and possibly most important, the involved personnel will gain an overall knowledge of the community and its traffic and transportation problems. The problem was approached with the preceding criteria as a guide.

French's (3) recently completed research study utilized data that are readily available in small areas in order to develop simple models for deriving internal-internal traffic volumes on arterial streets in small urban areas. In his models, French used only three independent variables that required collection of data: dwelling units, retail employment, and total employment per corridor. The procedure also required delineating traffic corridors, establishing the limits of the central business district (CBD) and its environments, and determining an external cordon line. The existing traffic volumes at each intersection of a major arterial with the corridor boundary were also required. All of the required information for the preceding models is readily available in all areas or easily obtainable from uncontrolled aerial photography.

CONCEPTUALIZATION OF PROBLEM

In the large urban areas, the sheer magnitude of the component parts of the transportation system and interactions of the many attracting forces or traffic generators make the problem impossible for the planners to mentally visualize. As a result, a step-by-step planning process is required that includes computerized data collection, assimilation, and summarization. In this manner, the individual components may each be carefully analyzed separately and then combined in any selected manner for analysis of alternate systems. However, this procedure is costly and is not necessary for transportation planning in smaller urban areas.

A majority of small urban areas in this country have experienced a modified sector and concentric circle growth pattern. The CBD remains the major traffic generator in the community, and traffic corridors radiate outward from this center. If major shopping centers exist, they are usually located on the radial arterial streets and are small compared to the size of centers in the central area; therefore, their influence is subsidiary to that of the central area.

The traffic corridor concept of thoroughfare planning is not new. In fact, many transportation planners still feel that this approach to the solution of the problem of providing an adequate transportation system is superior to a zone-by-zone analysis—even in this day of third-generation computers. Using the corridor technique requires that both the capacity of the available thoroughfares and the forecast traffic volumes be determined by corridor. The traffic corridor concept is accepted in principle by all planners who utilize computer capacity-restrained-traffic assignment packages in transportation planning. This particular theory of assignment provides for a reduction in link speed when the assigned volume reaches a predetermined level, with this level being based on the level-of-service concept of capacity. The reduction in link speed forces computation of new zone-to-zone minimum paths or trees and new assignment of trips. This effectively distributes trips over a number of arterial streets serving the same basic traffic movement and provides in essence a corridor assignment. In many cases, the reasons for traveler preference for one arterial over another in a corridor may be a slight travel-time difference or some other factor that can be readily rectified or that no longer exists as volumes increase.

Future demand traffic volumes are necessary for each corridor to permit planning for improvements to handle the demand within the time constraint established. French proposed that this future traffic volume could be obtained by multiplying the existing traffic volumes by a growth factor (3). The growth factor was based on growth of the "activities" in the corridor. Comparison of the street capacities to forecast volumes can then provide an estimate of system deficiencies.

STUDY PROCEDURE

The entire procedure is based on the assumption that the existing travel patterns in the community will remain stable over time. This is considered a reasonable assumption. It can be noted that, even in the very large cities, the basic travel patterns remain substantially the same except for circuitous travel over routes provided by controlled-access facilities that tend to encourage such travel. In the small cities, the growth is usually an extension along present patterns. To disrupt or change the basic travel patterns in a small city requires the elimination of a large portion of the existing street network. This is not likely to occur.

The procedure developed considers external and internal traffic separately, and each will be discussed separately here.

CORRIDOR IDENTIFICATION

A corridor may be defined as an area between traffic divides. It represents the area producing trips served by the one or more basically parallel major streets in the area. The orientation of the corridor in small urban areas would be basically oriented toward the central area because of its predominance as a generator. With a knowledge of the local travel habits, supplemented by aerial photographs, street classifications, land-use maps, and a traffic volume map, the corridor limits may be determined. The corridor boundary should be equidistant between arterials unless physical constraints dictate otherwise. Corridors may overlap with separate corridors identified on circumferential or cross routes.

To select corridors first requires delineation of the central area. This central area would include the CBD "core" and would generally include the "frame" of the CBD. Specifically, the central area would begin at the point where radial corridors and the arterial streets serving the corridors merge and lose their individual identity. Usually the merging movement would be served by cross routes bordering the CBD, providing for dispersal of traffic to the scattered destinations.

Traffic entering small cities is composed of varying percentages of external-internal and external-external traffic. Generally, the composition and magnitude of this traffic are determined by an external cordon survey.

It was determined that there are five different items in external traffic information that require procedures to be developed for application in the planning. These are as follows:

1. Method of forecasting total external traffic volumes,
2. Method of allocating the total external traffic to each external cordon crossing,
3. Method of determining the amount of the forecast total external traffic that is external-internal traffic volume,
4. Method of allocating the external-internal traffic volumes to each external cordon station, and
5. Method of determining the amount of the total external-internal traffic volume that is the external-internal traffic destined to the central area.

There are two separate feasible procedures for determining the total external traffic and the components of external-external and external-internal traffic necessary for the simplified procedure for major thoroughfare planning. The procedure will be selected on the basis of the availability of the following information:

1. Previous external cordon survey study for the area, or
2. Traffic volumes from a past year at each cordon station.

TRAFFIC COMPUTATIONS: EXTERNAL REPORT AVAILABLE

Total External Crossings

With an external survey report available the procedure is greatly simplified. A growth factor based on the increase in vehicle registration should be adequate for forecasting. A calibration period using a growth factor based on 5 to 10 years should provide a check on the accuracy of the procedure. This assumption was tested by using 15 cities in Indiana for a data set (Table 1). Traffic volumes on an external cordon around each city were obtained for two points in time that were not less than 5 and preferably 10 to 20 years apart. The cordon line was established at a point that included the urban area for both years and where an Indiana count station was located. A regression analysis was made using as the independent variable the base year total external traffic volumes multiplied by a growth factor representing the increase in county vehicle registration for the period between the two points. The observed total external traffic volume for the later year was used as the dependent variable. The results of the regression analysis were an R^2 of 0.96 with a standard error of estimate of 3.734.

Allocation of Total External Volumes Among Cordon Stations

A model for allocating total external traffic between stations was developed; eight cities with external survey reports available for two points in time were used for the investigation. Data from a total of 72 external cordon crossings in the eight cities were used in a simple regression procedure. This technique for establishing the correlation between the variables was selected because of its simplicity and adequacy. A statistical test was made that showed that the percentage of the total traffic crossing at each of the external cordon stations remains constant over time. As a test, the percentages of total traffic crossing at each station from the base year reports were used for the dependent or response variable, and the percentages of total traffic crossing at each station in the later reports were used for the independent variable. Values for stations in each city were computed in addition to a regression on a combined sample of all 72 crossings in the eight cities. The results of the analysis were examined to evaluate the comparison. Two null hypotheses were tested in each model as follows: $H:B_0 = 0$ and $H:B_1 = 1.00$.

The first hypothesis tests that the intercept value is equal to zero. The second hypothesis tests that the regression coefficient is equal to 1.00. In all models, neither hypothesis could be rejected at the 5 percent level. The results of the analysis were an R^2 of 0.94 and a standard error of estimate of 2.70.

Split Between External-External and External-Internal Traffic Volumes

When a past external survey is available, the percentages of the total external-internal cordon crossings at each station are probably the best estimate of the percentage of the total external-internal cordon crossings for the study year; however, a procedure to provide this information where a report is not available will be presented later. A regression technique was used to test the assumption that the percentage of the external-internal traffic crossing the external cordon at each cordon station was the same as the percentage of the total external traffic crossing at that same station. Twenty-seven survey reports were used for this phase of the investigation consisting of 232 independent cordon crossing stations. Values were computed for data for each city in addition to the regression on the combined sample. For this regression analysis, the percentage of the total external cordon crossings at each cordon station was used as the dependent or response variable. The percentage of the total external-internal traffic at each cordon crossing was used as the independent variable. Table 2 gives the cities used in this analysis.

External-Internal Volume

The split of the total external traffic volume into the two components, external-external and external-internal traffic volumes, is required for the simplified planning procedure. If a previous external cordon survey has been completed, the percentage of split at each station then provides the best estimate of the present split.

External-Internal Traffic to CBD

The final step necessary to provide a complete package for the simplified planning procedure is to determine a means of establishing the percentage at each external cordon station of the external-internal trips that are destined to the central area or to the screen line where the radial corridors merge and lose identity. Employment has been shown to be a very strong trip indicator in other studies, and a simplified distribution method using employment (but not requiring computer iterations for application) was developed.

Eleven study reports containing detailed employment data and trip information by traffic zones were utilized as the data source for this phase of the investigation. Cities included are given in Table 3. Identification of a central area was initially required. For this study, the central area was defined as the CBD and the contiguous traffic zones where the total employment exceeded the number of residents.

The response variable of the regression analysis was the percentage of external-internal trips destined to the central area. The independent variable was the percentage of the total employment in the central area. The R^2 was 0.75, the regression coefficient was 0.95, the standard error of the estimate was 4.60 percent, and the intercept value was 1.11. The assumption that the percentage of the total external-internal trips with origins and destinations in the central area is the same as the percentage of the total study area employment used in the central area was considered valid.

TRAFFIC COMPUTATIONS: EXTERNAL REPORT NOT AVAILABLE

If an external survey report is not available, but traffic volumes from a past year are available at each cordon station, the following procedure should provide information adequate for planning purposes.

Total External Crossings

The procedure for total external crossings is identical to that previously specified when an external report is available. The growth factor based on the increase in vehicle registration is used, but, once again, a calibration period is used as a check on the procedure. If the calibration is not acceptable, an alternate technique using a regression equation for forecasting the future year's total external cordon crossings is used.

Allocation of Total External Volumes Among Cordon Stations

Distribution of total external volumes among cordon stations follows the procedure previously outlined.

Table 1. Growth factor based on county vehicle registration increase.

City	Population (× 10^3)	Base Year	Base Year Total External Crossing	Vehicle Registration Growth Factor	Present Year Used	Present Year Total External Crossing	Forecast Total External Crossing	Error	Percentage of Error
Kokomo	43.3	1956	31,435	1.72	1968	49,461	54,068	4,607	9.3
Marion	40.0	1958	45,405	1.36	1966	45,375	45,302	-73	-0.2
Elkhart	42.4	1959	50,446	1.33	1967	63,707	67,093	3,386	5.3
Goshen	14.6	1959	28,353	1.33	1967	42,378	37,709	-4,669	11.0
Anderson	69.9	1959	42,378	1.50	1969	63,579	63,567	-12	0.0
Columbus	31.4	1959	31,233	1.64	1971	52,586	51,222	-1,364	-2.6
Bloomington	43.2	1960	32,016	1.76	1970	52,835	56,348	3,513	6.6
Wabash	13.3	1965	27,222	1.11	1970	27,435	30,216	2,781	10.1
Seymour	13.1	1963	27,186	1.27	1968	32,786	34,526	1,740	5.3
Connersville	17.5	1957	18,648	1.37	1970	27,762	25,547	-2,215	-8.0
Lafayette	64.0	1952	41,827	1.90[a]	1970	71,278	76,120	-4,842	6.8
South Bend	122.8	1958	64,500	1.36[a]	1968	88,798	89,400	602	0.7
Muncie	68.1	1957	46,695	1.55	1970	75,798	72,377	-3,421	-4.5
Vincennes	19.7	1953	34,212	1.55	1970	43,947	53,029	9,082	20.7
Logansport	19.1	1952	24,419	1.61	1970	34,786	39,315	4,529	13.0

[a]Growth in vehicle registration for Indiana for cross-state route.

Table 2. External volume and external-internal volume.

City	Sample Size	Intercept Value	Regression Coefficient	Standard Error of Estimate	F-Value	R^2
Independence, Kansas	10	0.02	1.00	1.14	719.54	0.99
Big Rapids, Michigan	6	-4.36	1.26	2.42	206.11	0.98
Richmond, Kentucky	7	-5.28	1.38	3.27	90.08	0.95
Campbellsville, Kentucky	8	-0.81	1.07	0.92	274.06	0.98
Bonham, Texas	6	-1.23	1.07	3.60	36.7	0.90
Center, Texas	8	0.48	0.96	1.83	21.54	0.78
New Castle, Pennsylvania	12	-0.00	1.00	1.57	87.72	0.90
Vincennes, Indiana	13	-0.03	1.01	2.54	113.44	0.91
Bay City, Michigan	6	-3.54	1.21	5.14	9.71	0.71
Ann Arbor, Michigan	5	2.65	0.87	4.71	32.74	0.92
Bowling Green, Kentucky	10	-2.20	1.22	2.48	140.91	0.95
Junction City, Kansas	11	1.48	0.84	3.76	134.93	0.94
Brownwood, Texas	9	-0.98	1.09	1.27	510.60	0.99
Somerset, Kentucky	9	-1.35	1.12	0.91	997.01	0.99
Childress, Texas	7	-3.92	1.27	2.68	165.96	0.97
Bay City, Texas	7	-0.21	1.02	1.27	651.34	0.99
Athens, Texas	9	-0.60	1.05	1.00	380.05	0.98
Caruthersville, Missouri	4	2.56	0.90	2.63	188.59	0.99
Hannibal, Missouri	9	-0.68	1.06	1.36	440.44	0.98
Commerce, Texas	6	-0.88	1.05	2.19	113.80	0.97
Blytheville, Arkansas	8	-0.09	1.01	0.39	4,507.47	1.00
Borger, Texas	6	1.53	0.91	1.18	347.64	0.99
Cynthiana, Kentucky	6	-0.69	1.04	3.09	80.51	0.95
Kinston, North Carolina	13	-0.05	1.01	1.93	85.50	0.89
Charlottesville, Virginia	11	-0.58	1.06	1.21	391.43	0.98
Pulaski, Virginia	10	-0.00	1.00	0.44	5,408.23	1.00
Martinsville, Virginia	16	0.02	1.00	2.37	73.98	0.84
Combined set	232	-0.16	1.01	2.33	4,193.07	0.95

External-External Volume

The total external-external cordon vehicle crossings are forecast using regression modeling and Eq. 1:

$$Y_2 = 4.28 + 0.035\,(X_1) + 0.066\,(X_2) - 0.064\,(X_3) \tag{1}$$

where

Y_2 = total external-external cordon crossings (in thousands),
X_1 = population of the cities larger than subject city within a 25-mile radius of the city center (in thousands),
X_2 = county population density (in population/square mile), and
X_3 = population of the cities smaller than subject city within a 25-mile radius of the city center (in thousands).

The summary table is as follows:

Variable	R	R^2	Increase in R^2	F-Value to Add or Remove
X_1	0.73	0.53	0.53	37.96
X_2	0.82	0.68	0.15	15.27
X_3	0.86	0.74	0.06	7.10

The analysis of variance is as follows:

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value
Regression	3	1,339.08	446.36	29.69
Residual	32	481.16	15.04	
Total	35	1,820.24		

The standard error of the estimate was 3.88.

The allocation of the total external-external trips to each cordon station is assumed to be the same percentage as the traffic distribution for the present year.

External-Internal Volume

The methodology is the same as previously specified when an external report is available. The external-internal volume at each cordon station is found through subtraction of the external-external volumes from the station's total external volume.

External-Internal Traffic to CBD

The method used is the same as that previously stated. The percentage of the external-internal trips that are destined to the CBD is the same ratio as CBD employment is to total study area employment. The remaining external-internal traffic is assumed to be distributed to all study zones from each cordon station. The individual flows will normally be small.

ALTERNATE TECHNIQUE

If for the study year the actual traffic volumes at the cordon checkpoints along the corridors do not agree (within reasonable limits) with values provided through this methodology, an alternate technique is proposed. The external trip information can be developed by regression modeling.

Regression analysis, using cross products of certain combinations of the variables, determined from plots, was employed as a means of investigating the interactions. Possible combinations of independent variables versus each of the response variables were plotted. Those combinations of variables that indicated an intersection within the limits of the response variable being investigated, if they met the additional criteria stated previously, were then entered into the stepwise regression program by use of the transgeneration option.

External survey reports from 77 cities in 19 different states were obtained for the original data set. The reports were made available by the state highway departments in each of the states.

A total of 20 independent variables, both quantitative and qualitative, were available in the development of the final regression models for this study. Of these 20, 3 were dummy variables used to represent qualitative factors. The same independent variables were used in developing two models regressing on two different response variables during the model development. The response variables were the total external and total external-external cordon crossings. The cities included in the data set are given in Table 4.

As a result of the regression analysis, a model for predicting total external cordon vehicle crossings (for an inference space of 10,000 to 100,000 population) is given as Eq. 2:

$$Y_1 = 28.55 + 0.068 (X_1) + 0.00009 (X_2) - 369.8 (X_3) + 78.3 (X_4) \qquad (2)$$

where

Y_1 = total external cordon crossings (in thousands),
X_1 = county population density (in population/square mile),
X_2 = county area multiplied by population of the cities larger than subject city within a 25-mile radius of the city center (population × square miles),
X_3 = reciprocal of the total study area population, and
X_4 = reciprocal of the total study area employment.

The summary table is as follows:

Variable	R	R^2	Increase in R^2	F-Value to Add or Remove
X_1	0.66	0.43	0.43	25.68
X_2	0.75	0.57	0.14	10.47
X_3	0.81	0.65	0.08	7.39
X_4	0.85	0.72	0.07	8.13

The analysis of variance is as follows:

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value
Regression	4	4,519.11	1,129.78	20.10
Residual	31	1,742.47	56.21	
Total	35	6,261.58		

The standard error of the estimate was 7.50.

INTERNAL TRAFFIC

Developing a Growth Factor

A growth factor for each corridor must be established to forecast growth of internal traffic. The factor must adequately represent the growth of all "activities" in the corridor. Corridors commonly contain an agglomeration of land uses, each having a different trip generation rate; therefore, a method of weighting these rates is necessary. The growth factor must reflect the increase, present to target year, of each land use.

The method established to handle the weighting of trip attractiveness of various land uses was to use the percentage of total linked trips by linked-trip purpose. This information was obtained from a review of available origin-destination study reports. Trip purpose may be related to land uses or other parameters to obtain a relative trip attractiveness. Linked-trip purpose percentages for automobile driver trips for various sized cities indicate that the percentages are similar for all sizes of cities.

Parameters that are easily measured and capable of being forecast are needed to indicate trip purposes. The acres of each type of land have been used in many studies for this purpose, but there are problems inherent with this parameter, such as varying densities of development, that make it undesirable.

The total number of employees within the unit of study is a good indicator of work and business trips. This information is available from several sources and is usually listed by business establishments and can be forecast satisfactorily.

Home trips can be determined by using the number of dwelling units per corridor.

Shopping trips may be determined by using the total number of retail employees. The number of retail employees by corridor can be obtained easiest concurrently with collection of the number of total employees necessary for work trips.

Social-recreation trips to clubs, theaters, residential areas, and so forth are difficult to represent with any single parameter because of their diversity. The three parameters used for work and business, home, and shopping trips can be assumed to represent these trips without a separate parameter.

Previous research has indicated that these three parameters adequately represent total trips. This project therefore used total employees to represent work and business-linked trips by corridor, the number of retail employees were used for shopping-linked trips, and the number of dwelling units were used for home-linked trips and other trips to residential areas.

The procedure established relative trip production rates for the three parameters in the study area in the following manner. The relative average trip production rate per employee is established by dividing the percentage of the total trips to be represented by that parameter by the total number of employees in the study area. The same procedure would be followed for the remaining parameters. These rates are assumed to remain constant over time and are used in both the base and target years.

The procedure for developing a growth rate by corridor was as follows:

1. The relative trip rates by each parameter are multiplied by the quantity of the parameter in the corridor for the base year, and the products are totaled;
2. The procedure is repeated for the target year using forecast quantities of the parameters;
3. The ratio of the target year sum to the base year sum is the corridor growth factor; and
4. The corridor growth factor multiplied by the base year traffic volume in the corridor gives the forecast or design volume for the corridor.

Plan Evaluation

The evaluation procedures for alternate plans are well documented by many references such as the National Committee on Urban Transportation (1). The evaluation is simplified because the extent to which mass transit vehicles will contribute to congestion or its relief is minor in small urban areas. Furthermore, freeway networks are seldom warranted; therefore, improvements to the existing system are the primary solution to traffic problems. The street-capacity calculations themselves should provide clues as to where additional needed capacity can be provided with minimum expenditures. The Policy and Procedure Memorandum 21-18, U.S. Department of Transportation, Federal Highway Administration, dated May 13, 1971, for the TOPICS program provides a good guide for methods of upgrading existing facilities.

All traffic assignment procedures require engineering judgment. This proposed simplified procedure requires the same judgment in its application. There will be only a few existing parallel arterial streets to handle the corridor traffic, and it can be assumed that traffic can be divided between these streets. Major arterials should always have four moving lanes. This should be sufficient, in most cases, to handle arterial traffic in small urban areas. It should be remembered that reevaluation of the plan will be simple under the proposed procedure; therefore, it can be easily and quickly repeated whenever any substantial variations in forecast traffic volumes are noted.

The usual procedure for major thoroughfare planning is to make an overall 20-year forecast with 5-year step or incremental forecasts to provide information for establishing project construction priorities and for capital improvement programs. The simplified procedure should not be an exception to this procedure; quite the contrary, this is one of the strong points of the method. Simplicity and minimum personnel requirements permit reevaluation on short notice as area development dictates. When unexpected new development occurs, a reevaluation can be quickly accomplished to check proposed plans and provide information for modifications if necessary. The 5-year incremental forecasts will also preclude errors due to large growth factors.

The "best" plan is that plan that satisfies the people of the community and satisfactorily handles the traffic. The simplified procedure described here can be used to develop adequate information to provide direction to those charged with the responsibility of developing a plan, but it is not intended as "the" cookbook solution. Judgment and assistance of those in the area are not only helpful but an absolute necessity when developing a plan that will be acceptable to the community it affects.

Data Collection

Data collection is greatly simplified using this procedure. Dwelling unit data and street inventory information are obtained from aerial photographs for the various time periods. Employment data, obtained from state employment offices, are supplemented by some personal contact. Traffic data are usually available from the state, county, or city. Some additional counts may be required. Automobile registrations are available from the state.

Additional information, such as maps, zoning, and land-use data, are usually available from the city; however, some additional data collection may be necessary.

DEMONSTRATION OF PROCEDURE

Proper evaluation of the growth-factor technique of traffic forecasting requires the establishment of standards for acceptance. The standard of acceptance for this project was established as the point where the predicted volume was within the range of accuracy that would allow a planner or designer to determine the correct number of lanes, proper location of improvements, and proper relative construction priorities for improvements to the major thoroughfare system of a small urban area. In reviewing the described procedure, the reader must not lose sight of the basic advantages and design constraints of this procedure. It is simple and economical to use and can be effectively utilized by personnel possessing a minimum of expertise in transportation planning. In short, it is intended to be as simple and inexpensive as possible while still providing the required information.

Major thoroughfare capacities for planning purposes are based on the 1965 Highway Capacity Manual (4). Using the manual, certain ranges of service volumes for the demonstration city were obtained for a thoroughfare assuming the following: level of service, C; population of city, 75,000; peak-hour factor, 0.85; directional split, 60 to 40; peak-hour volume, 10 percent of ADT; G/C, 0.45; lane width, 10 to 12 ft; no parking; and 20 percent turns. Use of these assumptions gives the following capacity ranges for major thoroughfares: four-lane thoroughfare, 12,000 to 15,000 vehicles per day (vpd); four-lane thoroughfare with left-turn lanes, 15,000 to 19,000 vpd; and six-lane thoroughfare, 19,000 to 23,000 vpd.

This indicates that an estimated volume with an error of approximately 4,000 vpd, for volumes under 19,000, will not change the basic design of the street. If the estimated volume forecast during the planning study is a little less than 15,000 vpd for a four-lane street that is 12 ft wide, no improvements will be recommended. If the volume for the target year actually is between 15,000 and 19,000 vpd, then some widening may be needed at critical intersections to incorporate left-turn lanes. At noncritical intersections, additional green time may be available from the cross street to accommodate the additional volumes. It is apparent from these figures that the underestimation of future traffic by 4,000 vpd of volumes below 19,000 would not create a traffic problem for the target year. Overestimation would not involve significant overdesign unless the estimated volume exceeds approximately 19,000 vpd.

The streets on the major thoroughfare system in any urban area should be designed and constructed to four-lane minimum standards according to the recommendations of the National Committee on Urban Transportation. Volumes in the range below the basic capacity of a four-lane facility therefore do not affect the design in any manner.

FEASIBILITY DEMONSTRATION

The city of Columbus, Indiana, was selected as the site to demonstrate the feasibility of the entire package comprising the simplified procedure for major thoroughfare planning in small urban areas.

Study Area

Columbus is a city of approximately 27,000 population. The city is a typical small city that has experienced a steady growth through the years. Because of the location at the junction point of several rivers and other small streams, the growth has been primarily in the north and east portions of the city rather than concentrically as in many communities.

The completion of I-65, providing a connecting route from Indianapolis to Louisville, Kentucky, and also on the route from Chicago to Florida and other southern states, is the only major change in the highway system in the area during the past 20 years.

A number of major industrial plants such as Cummins Engine and Arvin Industries are located in the city. The city has a higher than average ratio of employment to population because of heavy industrialization. The effect of this factor on trip generation characteristics of the community is to produce a higher percentage of external-internal trips than other comparably sized communities. The city administration and the citizens have long recognized the necessity for sound planning of the future. This progressive attitude is positively indicated by numerous studies and resulting reports on all phases of community development. The abundance of basic material to use for data sources may indicate that the estimated cost for the study should be increased when estimating the cost of application in communities with less basic data.

External Cordon

The study area external cordon was established to include the area expected to become developed by 1990. The I-65 route was utilized as the west cordon limit because of the natural screen line it provides.

Clifty Creek was established as the east boundary. The location of the cordon throughout the study area made possible the use of Indiana State Highway Commission count station locations.

Corridors and Major Thoroughfares

The arterial street plan prepared by De Leuw, Cather and Company (2), currently being used as a guide for Columbus, was used to assist in initial street inventory traffic volume counts and corridor identification.

The identification of corridors for Columbus was accomplished by using the arterial street plan, the existing traffic volume flow map, existing land-use map, and information from personnel familiar with the area.

Seven basically radial corridors were established as shown in Figures 1 and 2. Two of these corridors overlap because of the configuration of the streets. Ind-46 is considered a radial route; however, it causes a 90-deg route change in the approach to the central area screen line, dispersing traffic over five closely spaced streets crossing the screen line. This alignment crossed corridor 4, Central Avenue. This does not create a double count because the procedure uses a growth factor, not trip productions.

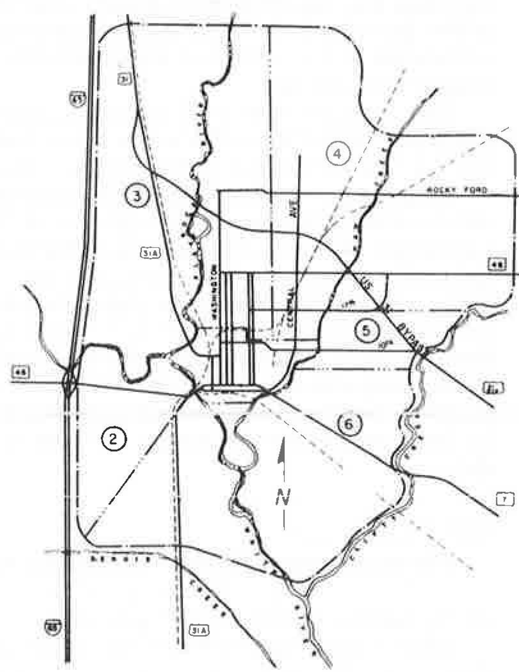
Table 3. External-internal trips and employment.

City	Study Size (× 10^3)	Total Employment	Employment in CBD and Frame Destinations	Percentage of Employment in CBD and Frame Destinations	External-Internal Crossings to CBD and Frame Destinations	Total External-Internal Crossings	Percentage of External-Internal Crossings to CBD and Frame Destinations
Moberly, Missouri	13.4	5,079	2,200	43.3	6,109	14,762	41.6
Henderson, North Carolina	20.4	9,778	2,495	25.5	5,600	20,522	27.3
Lawrenceburg, Tennessee	10.3	5,786	1,546	26.7	2,600	12,322	21.1
Lumberton, North Carolina	20.4	7,166	2,168	30.3	7,400	26,000	28.5
Glasgow, Kentucky	13.0	9,330	2,110	22.6	4,700	15,956	29.5
Franklin, Kentucky	7.3	5,760	1,329	23.1	3,100	10,142	30.6
Cynthiana, Kentucky	6.7	2,900	886	30.6	3,900	11,009	35.4
Frankfort, Kentucky	22.9	16,500	5,415	32.8	5,300	16,287	32.5
Brownsville, Texas	65.0	14,449	5,300	36.7	9,185	25,948	35.4
Champaign-Urbana, Illinois	80.0	33,885	12,898	38.0	8,800	26,714	33.0
Nashville, Tennessee	732.0	142,018	16,800	11.8	8,219	69,199	11.8

Table 4. Populations of cities used in alternate model.

City	City Population (× 10^3)	Study Population (× 10^3)
Moberly, Missouri	13.4	13.4
Lancaster, Ohio	32.9	32.9
Bellefontaine, Ohio	11.3	11.3
Urbana, Ohio	11.2	11.2
Xenia, Ohio	25.4	25.4
Tiffin, Ohio	21.6	21.6
Circleville, Ohio	11.7	11.7
Greenville, Ohio	12.4	12.4
Mount Vernon, Ohio	13.4	13.4
Alpena, Michigan	14.7	17.2
Bay City, Michigan	49.1	82.3
Glasgow, Kentucky	10.9	13.0
Richmond, Kentucky	12.5	12.5
Bowling Green, Kentucky	30.5	33.2
Frankfort, Kentucky	18.0	22.9
Owensboro, Kentucky	42.5	42.5
Elizabethton, Tennessee	10.1	19.7
Henderson, North Carolina	12.7	20.4
Kinston, North Carolina	24.8	49.0
Jacksonville, North Carolina	15.7	30.6
Lumberton, North Carolina	15.3	20.4
Sanford, North Carolina	11.7	16.5
Hays, Kansas	14.0	14.0
Independence, Kansas	11.5	11.5
Pittsburg, Kansas	18.7	18.7
Borger, Texas	13.9	13.9
Bay City, Texas	12.0	12.0
Brownwood, Texas	16.3	16.3
Big Spring, Texas	28.2	28.2
Blytheville, Arkansas	28.3	28.3
Pulaski, Virginia	11.0	13.3
Tuscaloosa, Alabama	61.9	73.2
Gainesville, Georgia	15.4	21.4
Boise, Idaho	75.0	85.3
Billings, Montana	61.6	62.0
Great Falls, Montana	60.0	74.7

Figure 1. Corridors of Columbus.



US-31 Bypass traffic was forecast using a growth factor based on the growth of the entire area from the Tenth Street corridor on the east to the Flatrock River on the west.

Calibration Procedure

The simplified procedure developed recommends the use of two points in time to establish a calibration for the city involved. The project was initiated early in 1971; therefore, 1970 was used for the study year data.

The 1960-to-1970 calibration period for Columbus was selected for several reasons as follows:

1. U.S. Bureau of Census data were available to check dwelling unit counts from aerial photography,
2. Traffic volume counts were available from the Indiana State Highway Commission, and
3. The 10-year period provided a reasonable test of the capabilities of the overall procedure.

A complicating factor that occurred during this period was the construction and opening to traffic of I-65 immediately west of Columbus. The 1963 Columbus arterial plan (2) presented before-and-after volumes throughout the city, providing sufficient information to assess the effect of opening of I-65.

The actual calibration procedure was as follows: 1960 was used as a base year, and growth factors for the external and internal traffic based on the corridors established were computed. After applying the growth factors to the 1960 existing volumes, the resulting forecast 1970 volumes were compared to the observed 1970 volumes. Comparison of the central area screen line volumes within the accuracy necessary for design was considered sufficient to reasonably ensure that the corridors established were satisfactory for planning purposes.

External Traffic

An external traffic growth factor was computed using the increase in total vehicle registration for Bartholomew County for the period 1960 to 1970. The completion and opening to traffic of I-65 just west of the city in late 1962 made direct comparison of 1960-to-1970 external volumes impossible; however, adjustment of the 1960 volumes on US-31 by 30 percent to adjust for the Interstate provides comparable figures. The adjustment factor was provided by information presented in the arterial street plan report (2).

Table 5 gives a comparison of forecast 1970 traffic volumes at external cordon stations (developed by applying a growth factor, based on the increase in total vehicle registration in the county from 1960 to 1970, to the 1960 traffic volumes at each station) and the observed 1970 traffic volumes. The 1960 traffic volumes at the US-31 external station north of the city and US-31 Bypass at Clifty Creek were reduced 30 percent as indicated by the De Leuw, Cather study (2) to adjust for the opening of I-65. The total 1970 forecast external volume was 46,614 vpd as compared to the observed 1970 external volume of 48,683 vpd at the stations. The total error is 2,069 crossings, and, by distributing this among individual stations based on the existing percentages of total external traffic, the maximum error would be 500 crossings. Individual expansions at each station indicate maximum errors of 3,301 vpd at US-31 Bypass at Clifty Creek and 2,790 vpd at US-31 Alternate at Denois Creek. These differences can be attributed to a slight change in traffic patterns occurring subsequent to the opening of I-65. None of the differences was of sufficient magnitude to cause a design change if they were used for a design. However, the future forecast will be based on the 1970 patterns and, therefore, will not reflect these differences because of a slight change in traffic patterns. The growth factor for all external stations was based on the Bartholomew County total vehicle registration increase because I-65 (outside cordon) was considered to be the route selected by cross-state traffic. The comparison thus obtained was considered acceptable, and a growth factor based on county vehicle registration increase was considered acceptable for forecasting external volumes to 1990.

The external-external component of the total external traffic was determined by regression model. The external-external volume thus computed was 9,500 vehicles in 1960 and 10,800 in 1970. This volume was distributed to the external stations using the same percentage as existed for the total external volume.

The percentage of the external-internal traffic to be distributed to the central area was determined by the percentage of total study area employees employed in the central area in 1970. This amounted to 44.3 percent.

Internal Traffic

The internal traffic volume growth factors were computed using the growth of three parameters, dwelling units, total employment, and retail employment, in each of the seven established corridors.

The percentage of the total internal trips to be represented by each of the three parameters of dwelling units, total employment, and retail employment are 50, 35, and 15 respectively. Dwelling unit data by corridor were obtained from aerial photography enlargements (1 in. = 400 ft) for both years. Employment data for both years were obtained from information assimilated and tabulated by the Indiana Employment Securities Division. The base year traffic volumes were obtained primarily from counts made by the Indiana State Highway Commission in 1959, supplemented by information from city files and the arterial street plan report (2). The 1970 counts were from the Commission and City Engineer's Office. Additional counts were provided by city personnel to complete the required information.

The corridor growth factor procedure was used to expand the existing 1960 traffic volumes to 1970 and compared them with the actual observed traffic volumes. The forecast and observed volumes at the central area screen line were compared for each corridor, and additional point volumes were compared on Ind-46 (25th Street) at US-31 Bypass and Washington Street intersections. Table 6 gives the results of this comparison and gives the growth factors used.

The maximum difference between 1970 forecast average daily traffic volumes and 1970 observed volumes was 2,361 in corridor 3, US-31 (N). This is probably due to a slight change in traffic patterns occurring after completion of I-65; however, the difference did not affect the thoroughfare design.

Differences in all other corridors are of such magnitude that designs would have been unaffected. Corridor 7 is one of the major corridors with regard to total traffic magnitude; however, the one-way pairs of Franklin and Lafayette and California and Chestnut, in addition to Washington Street, serve the traffic desiring to enter the central area. Seventeenth Street was not included as an east-west route because of its configuration, which terminates at US-31 Bypass on the east and at a cemetery on the west. It does effectively serve as an overflow or alternate route for Ind-46 and 25th Street for short trips as shown by the existing volumes. The calibration or check period as described here substantiates the corridor identifications and the overall feasibility of the entire procedure with respect to providing adequate accurate design information.

CONCLUSIONS

The completed package for a simplified planning procedure for major thoroughfare planning for small urban areas, using the corridor growth factor technique with synthetically developed external data, provides traffic volumes sufficiently accurate to develop major thoroughfare plans. The methodology fits satisfactorily into the overall planning process, using output from other studies as input to the process. The cost of completing this type of study is a fraction of that required for the home-interview, computer-oriented procedures although the resulting information produced satisfies the same requirements, i.e., design volumes. Detailed cost and time figures were compiled during the feasibility demonstration. After making upward adjustments in these costs to convert from a research environment, the best estimate of the total cost if the study is conducted by city personnel is $15,389.

Specifically, the following conclusions can be drawn from the research:

Figure 2. Columbus radial corridors.

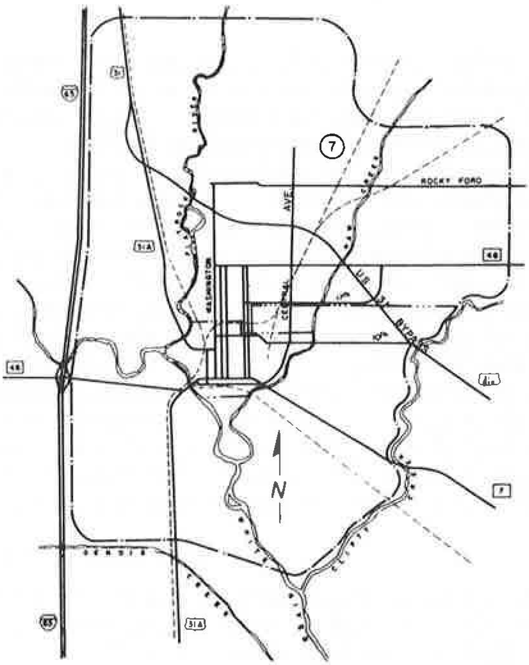


Table 5. External cordon station check for Columbus.

Route	1960 Volume	Growth Factor	Estimated 1970 Volume	Actual 1970 Volume	Error
US-31 (N)[a]	6,858	1.64	11,247	10,399	848
Ind-46 (E)	3,956	1.64	6,488	6,816	-328
US-31 Bypass at Clifty Creek[a]	5,325	1.64	8,733	12,034	-3,301
Ind-7 at Clifty Creek	4,522	1.64	7,416	7,371	45
US-31 Alternate at Denois Creek	3,562	1.64	5,842	3,052	2,790
Ind-46 (W)	4,200	1.64	6,888	9,011	-2,123
			46,614	48,683	

[a]Existing volumes reduced 30 percent to adjust for opening of I-65 (2).

Table 6. Radial corridors of Columbus.

Corridor	Street or Highway	1960 Volume	Internal Volume	Internal Growth Factor	External Volume	External Growth Factor	Estimated 1970 Volume	Actual 1970 Volume	Corridor Error
Direct Route									
1	US-31 Alternate (S)	7,400	5,170	1.63	2,230	1.64	12,084	10,240	1,844
2	Ind-46 (W)	4,793	2,193	2.98	2,600	1.64	10,799	12,861	-2,062
3	US-31 (N)	5,220	0	2.38	5,220	1.64	8,561	6,200	2,361
4	Central Avenue	10,000	10,000	1.31	–	–	13,100	14,495	-1,395
5	Tenth Street	4,100	4,100	1.34	–	–	5,494	5,400	94
6	Ind-7	14,608	11,898	1.21	2,710	1.64	18,841	16,708	2,133
7	Washington	10,800	8,435	1.54	2,365	1.64	16,869	15,974	
	Franklin	2,500	2,500	1.54	–	–	3,850	3,800	
	Lafayette	1,500	1,500	1.54	–	–	2,310	1,700	
	California	2,300	2,300	1.54	–	–	3,542	2,900	
	Chestnut	1,300	1,300	1.54	–	–	2,002	2,500	
		18,400	16,035	1.54	2,365	1.64	28,573	26,874	1,699
Circumferential Route									
	US-31 Bypass at 25th Street	7,700[a]	6,770	1.46	930	1.64	11,025	12,317	-1,292

[a]Reduced volume by 30 percent (2).

1. The corridor growth factor procedure, in combination with synthetically produced external information, can be used as a complete package to determine future traffic demand within the accuracy necessary for major thoroughfare planning in small urban areas. Tests in Columbus substantiated this fact.

2. The three parameters used for the corridor growth factors determination are adequate to indicate corridor traffic volume growth. The data are easy to obtain and easy to forecast. Aerial photography can be used satisfactorily to obtain dwelling unit information, discern growth patterns, and so forth for use with the simplified procedure.

3. With regard to external traffic in small urban areas, the existing distribution of total external cordon traffic volumes among stations may be used as the best estimate of future distribution of the forecast total external volumes. For small urban areas, a growth factor developed by using the county total vehicle registration increase is sufficiently accurate for thoroughfare planning. Regression modeling can be used to provide the total external-external traffic volumes in a small urban area with sufficient accuracy for thoroughfare planning, and this computation does not require use of computers. The best estimate for distribution of external-external traffic volumes among external cordon stations is the existing percentages of total external volumes.

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