LAND USE AND ARTERIAL SPACING IN SUBURBAN AREAS

REPRINTED JANUARY 1980

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
URBAN PLANNING DIVISION

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ABSTRACT

These guidelines provide planners and engineers with a "how to" approach for estimating traffic volumes within corridors and the associated arterial street system requirements. The guidelines also aid in decisions concerning the amount of development an existing arterial street system can support and, thus, provide an indication of how zoning changes impact the street system. In cases where technical resources are limited or quick estimates for alternative development proposals are needed, the guidelines should be particularly useful.

Author: Gruen Associates; National Association of Counties Research Foundation (NACORF); Joyce Curtis and George Schoener
Publication Year: Reprinted January 1980
Sponsor: U.S. DEPARTMENT OF TRANSPORTATION, Federal Highway Administration, Urban Planning Division

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PREFACE

These guidelines provide planners and engineers with a “how to” approach for estimating traffic volumes within corridors and the associated arterial street system requirements. The guidelines also aid in decisions concerning the amount of development an existing arterial street system can support and, thus, provide an indication of how zoning changes impact the street system. In cases where technical resources are limited or quick estimates for alternative development proposals are needed, the guidelines should be particularly useful.

The simplified guidelines are designed primarily for use in suburban areas. In addition, it should be realized that these guidelines are designed to predict arterial street requirements and that an assumption is made that there will be a full supporting local street system for land access.

The guidelines were originally developed by Gruen Associates and documented in a report titled "Simplified Guidelines for Major Street Planning," dated April 1973. The guidelines were subsequently field tested by the National Association of Counties Research Foundation (NACORF). This report has been prepared based on the results of the field testing and recommendations by NACORF, as well as additional analysis by Joyce Curtis and George Schoener of the Federal Highway Administration.

INTRODUCTION

Major streets serve a variety of land uses in urban areas; therefore, the system of urban streets must be closely related to land development patterns if balanced growth is to be achieved. This manual provides simplified guidelines for correlating arterial street systems with local development patterns and densities. These simplified guidelines are designed to be flexible and easily applied. They can help to estimate the required arterial street system size and spacing and may also be applied in reverse to determine the magnitude of development that can be supported by a given street system.

The guidelines are tailored especially for the developing suburban portions of our metropolitan areas, where the growth potentials offer a broad range of planning opportunities. In these areas, the need for simple guidelines may be especially acute due to lack of staff and resources to carry out extensive computer-based transportation planning studies for the subregion.

Urban street systems deserve careful, comprehensive consideration. They represent major public investments and have far-reaching impacts upon our daily urban environment. To project detailed traffic needs, some very complex simulation techniques have been developed in recent years. For some purposes, however, a less sophisticated approach, as reflected by the guidelines in this manual, may be used to good advantage. For an initial ballpark estimate, for an overview analysis of alternative growth strategies, or for an evaluation of street system requirements, the simplified guidelines may be most helpful.

Throughout this manual, the terms region, subregion, and project will be used to describe various geographical areas. Figure 1 illustrates the relationship of these three areas, and this relationship should be borne in mind when applying the guidelines in this manual.

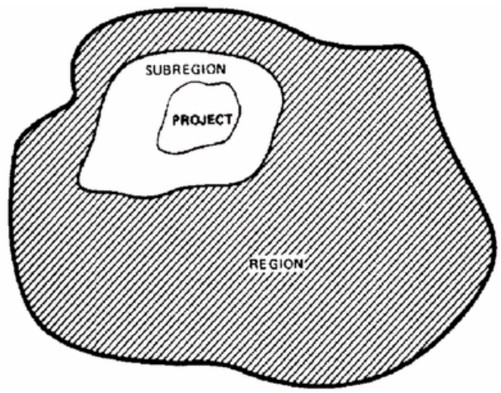


Figure 1. RELATIONSIPS OF REGION, SUBREGION AND PROJECT AREAS

Basis for Guidelines

As the basis for developing the simplified guidelines, it was assumed that the arterial street system and spacing will be determined in accordance with traffic demand. Street capacity tailored to anticipated traffic demand is, therefore, the conceptual foundation underlying these guidelines. In practice, a variety of other important factors often influences the sizing or implementation of major street systems. These include:

- Local governmental policy, practice or code requirements , governing street size and spacing.
- Historical precedent established elsewhere in the urban area, which encourages or requires street system conformity.
- Determination to stimulate or inhibit growth.
- Use of streets to modify traffic demand, e.g., divert through traffic, increase transit use.

In developing these guidelines, it was recognized that traffic demand can be approximated or generalized as a function of land use. This is the basic concept underlying comprehensive urban transportation planning. The concept was extended to help develop the simplified street planning Guidelines for general urban area applications.

The simplified ,guidelines were developed from simulation model analyses of a broad spectrum of land use patterns in conjunction with alternative circulation systems. Actual travel and land use data from various cities and metropolitan areas were incorporated as simulation inputs, and existing urban development conditions were used to validate the guidelines. Analysis was restricted to typical ranges of development patterns for residential and nonresidential developments.

Limitation of Guidelines

The limitations inherent in guidelines of this nature must be clearly recognized. Any picture of complex social interactions in greatly simplified terms must sacrifice a degree of accuracy for the sake of simplicity. Relationships developed for conditions in general will not fit any individual condition precisely. Because all variables influencing travel cannot be accounted for, a number of important assumptions about the character of the land use must be made by the user of the guidelines, not all of which are likely to be completely realized. For these reasons, precision should not be sought in applying the guidelines.

The guideline relationships were developed from simulation of urban areas having continuous major street systems which provide for relatively direct travel to all parts of the area. No major barriers to travel were built into the Guidelines however, some urban and suburban areas will have significant barriers to travel created by topographic or man-made features, each of which may produce a modified travel pattern unique to the area and differing from the travel ,volumes predicted By the guidelines. Changes to the basic travel patterns may either increase or decrease the per mile volumes, depending on whether traffic is squeezed into a narrow corridor or diverted away from a travel barrier. In complex cases involving travel barriers, the basic relationships should be supplemented by analysis of traffic distribution and assignment to evaluate the changes in the basic travel pattern.

Framework of Guidelines

These Guidelines provide a "how to" approach for determining traffic facility needs across a broad spectrum of suburban traffic conditions. They are divided into three basic sections:

1. Street Requirements Based on Residential Density
2. Demographic Service and System Adjustments.
3. Major Generator Volumes and Street Requirements

The section Street Requirements Based on Residential Density provides the basis for estimating street needs under conditions normally encountered in suburban area development. Certain socioeconomic and traffic service assumptions are incorporated which may be refined or amplified by the techniques provided in the following sections.

Within the Demographic, Service and System Adjustments section, adjustment factors are provided for a number of important characteristics which significantly influence tripmaking and street needs. The adjustments are based upon the following suburban characteristics: residential density, level of traffic service, car ownership, transit utilization, residential/nonresidential mix and the proximity of freeways. These adjustments give versatility and allow the results to more fully reflect existing local conditions.

Although most of suburbia generates relatively uniform traffic, certain concentrated developments produce traffic of a much higher intensity. These include: airports, industrial parks, universities, government centers, large office and commercial centers, shopping centers, and high-density residential complexes. The section on Major Generator Volumes and Street Requirements identifies the volumes and additional street requirements for these special generators. These street requirements are added to those resulting from the residential density to assess the combined total impact. Definitions for the special generators to which Charts 8-15 apply may be found in Appendix A. The use of these charts for special generators other than those defined may result in an overestimation or underestimation of actual street requirements.

Figure 2 illustrates the step-by-step procedure for applying the guidelines to estimate arterial street requirements. To determine the magnitude of development a given street system can support, this procedure is applied in reverse.

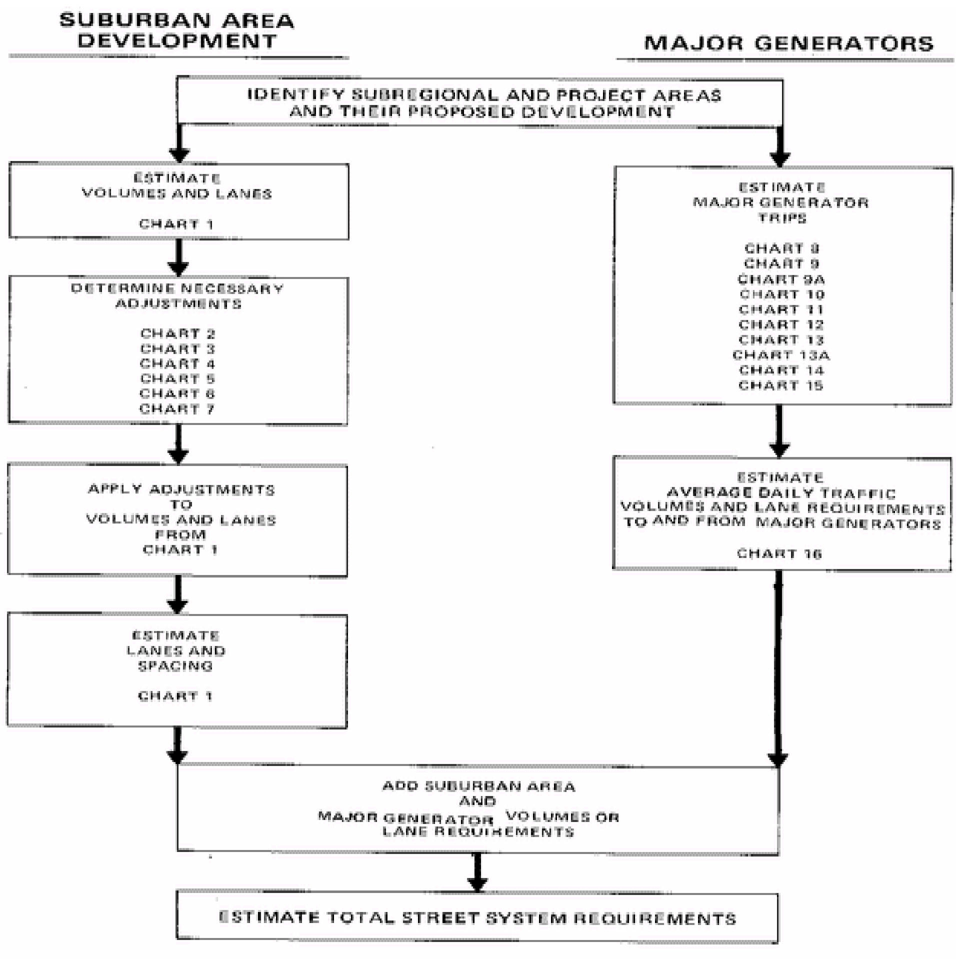


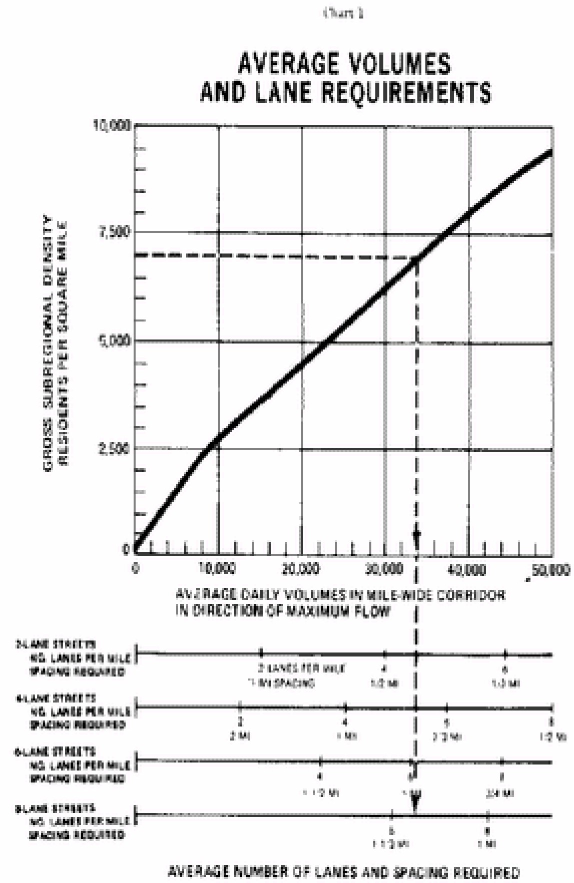
Figure 2. How To Use The Guidelines

STREET REQUIREMENTS BASED ON RESIDENTIAL DENSITY

Chart 1 is used for analysis of land use patterns distributed over a subregional area, considered jointly with the overall development pattern of uniform density in the surrounding region. The minimum development size that can be considered as subregional development is determined primarily by major street system spacing; if an area is so small that it "falls through" the spaces within the major street system and cannot be integrated with the surrounding development pattern, then it is better analyzed by the methods described subsequently for major generators. However, even a small project should be analyzed by the subregional development methods if the project, together with its surrounding development, can be considered as a uniform land use pattern extending over a substantial area.

Example

Given a uniform subregional density of 7,000 residents per square mile, Chart 1 indicates that a daily traffic volume of about 34,000 per mile could be expected and that four to six lanes per mile are required, depending upon the street section. These lanes may be provided by various street combinations, starting from two-lane streets at ½-mile spacing to six-lane streets at 1-mile intervals.



Since the primary direction of flow normally establishes the size of the major street system in both directions, Chart 1 was developed to reflect volumes per mile and street requirements in the direction of maximum flow, or primary direction. Therefore, Chart 1 should be used for estimating primary direction requirements. If predictions of traffic in the secondary direction are to be developed, the degree of directional imbalance and reduction factor should be estimated from local traffic patterns in the immediate area.

DEMOGRAPHIC, SERVICE AND SYSTEM ADJUSTMENTS

This section provides factors for adjusting to various local conditions. The factors are applied to the results obtained from Chart 1; however, this depends on the availability of data for variables which are significantly related to traffic demand. As the number of adjustments increase, the accuracy of the estimates decrease, therefore, the adjustment factors should be used cautiously to attain the best possible accuracy.

Density Patterns

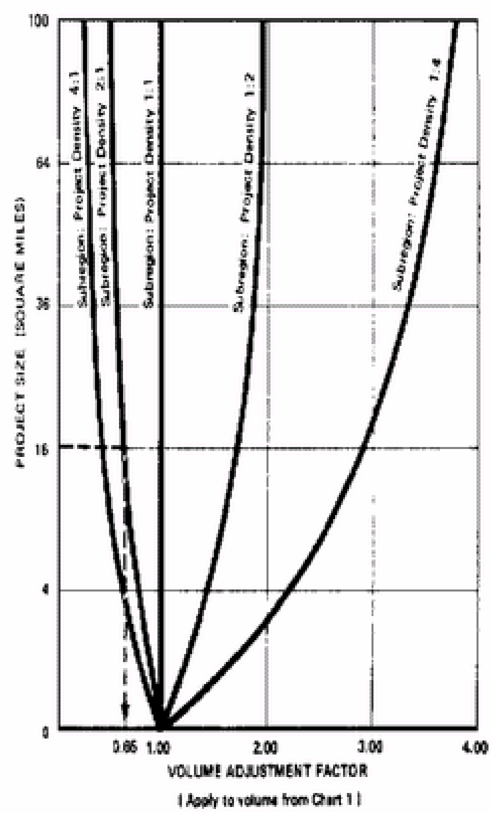
Uniform residential density may not prevail throughout the subregion; therefore, Chart 2 provides adjustments for various non-uniform density combinations. The relative densities of the subregion and the project are expressed as a series of ratios (4:1, 2:1, 1:1, 1:2, 1:4) which are represented by curves on the chart. The chart should be entered with the ratio of subregional area density to project area density and the size of the project in square miles. For other density combinations, adjustment factors may be interpolated between the given curves. The adjustment factor is to be applied to the Chart 1 volumes that were determined using subregional density. It should be noted that the simulation runs used in developing Chart 2 were based on regularly shaped areas, and that as the area becomes more irregularly shaped (i.e., farther from square-shaped), a greater error is introduced in the volume estimate.

Example

Given a 4-mile by 4-mile project with a residential density of 3,500 residents per square mile located in a subregion having 7,000 residents per square mile, Chart 2 gives an adjustment factor of 0.65. When this factor is applied to the volume obtained from Chart 1 (34,000 per mile), a modified volume of 22,100 is obtained.

Chart 2

ADJUSTMENT FACTOR FOR DENSITY AND PROJECT SIZE



Level of Traffic Service

The charts in this manual are based on Level of Traffic Service “C.” If other levels of service are desired, the adjustment factors in Chart 3 may be applied. The factors were calculated based on Highway Capacity Manual* service volumes for four-lane arterial streets with peak period parking prohibited. Because the adjustment factors for the various street sections do not vary by more than 5 percent, these same adjustment factors may be applied for other street sections (i.e., two-lane, six-lane, eight-lane).

Example

Given an arterial street with a Level of Service "B," Chart 3 gives an adjustment factor of 1.09. This adjustment factor, when applied to the volume from Chart 1 (34,000 per mile), results in a modified volume of 37,060 per mile.

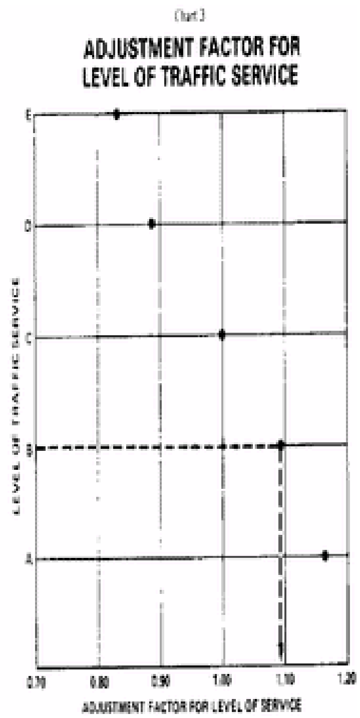


Figure 3 illustrates the six level of service. Under Level of Service “A,” the approach to the intersection is quite open, turning movements are easily made, and nearly all drivers find freedom of operation.

At Level of Service “B,” operating speeds are just at the point where some restriction due to traffic conditions is occurring. Drivers can pick their lanes and select their speeds with reasonable freedom.

Level of Service “C” reflects a high volume, stable flow throughout the network and is typically associated with urban design practice. Most drivers feel somewhat restricted.

At Level of Service “D” unstable flow is approached. Tolerable operating speeds are being maintained although fluctuations in volume and flow restrictions frequently cause substantial drops in operating speeds.

Level of Service “E” represents the most vehicles that any particular intersection can accommodate. There may be long queues of vehicles waiting upstream of the intersection and delays may be great.

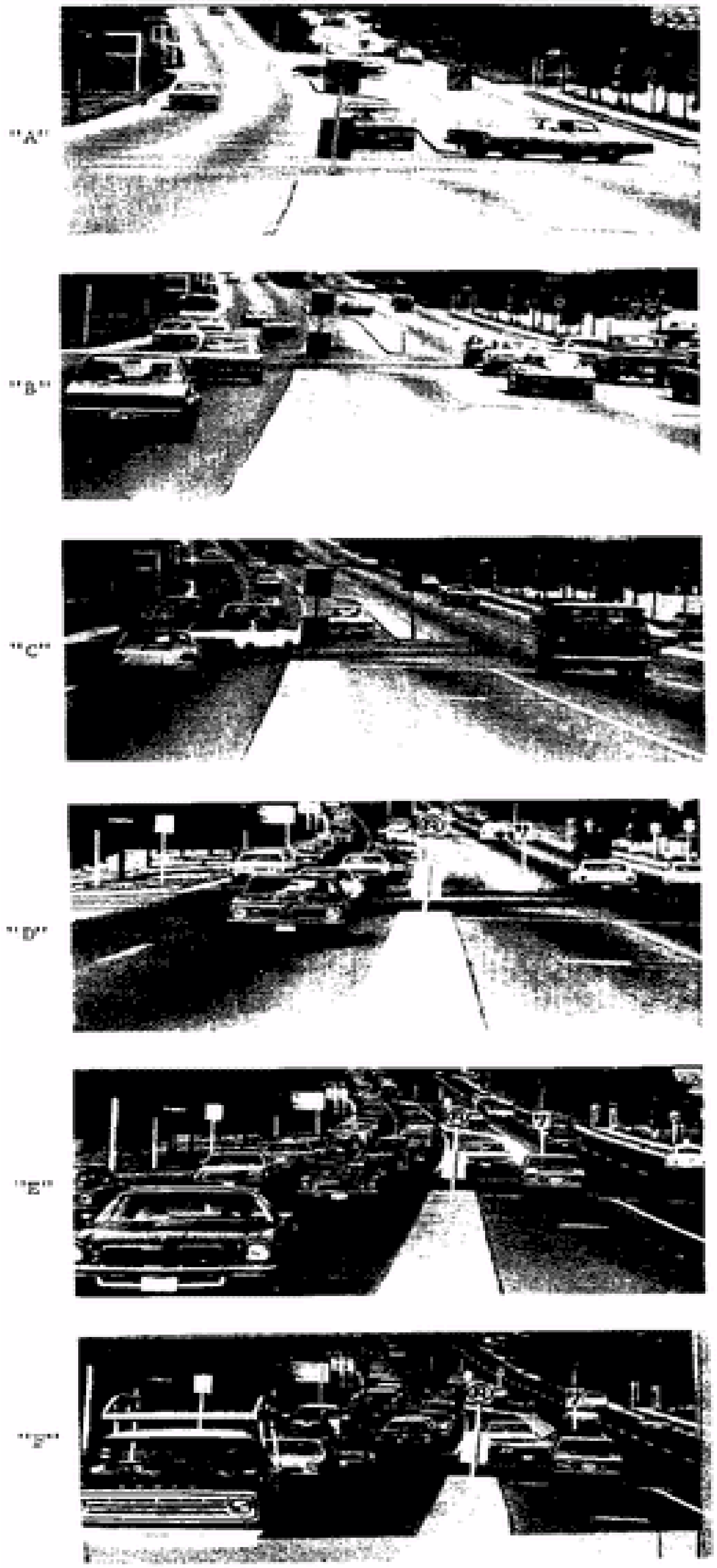


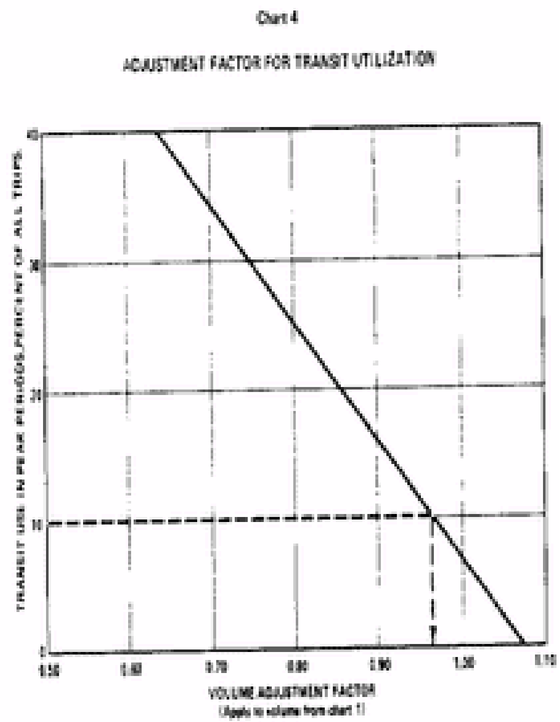
Figure 3. LEVEL OF SERVICE ILLUSTRATIONS

Transit Utilization

Chart 4 provides volume adjustment factors for variations in transit utilization during peak periods. If only the daily transit utilization is known, a rule of thumb that may be applied is that peak period transit use is 1.5-2.0 times the daily use.

Example

Given a peak period transit use of 10 percent (independent of the car ownership) for the area, an adjustment factor of 0.97 is determined. This factor when applied to the results obtained from Chart 1 (34,000 per mile) results in a modified volume of 32,980.

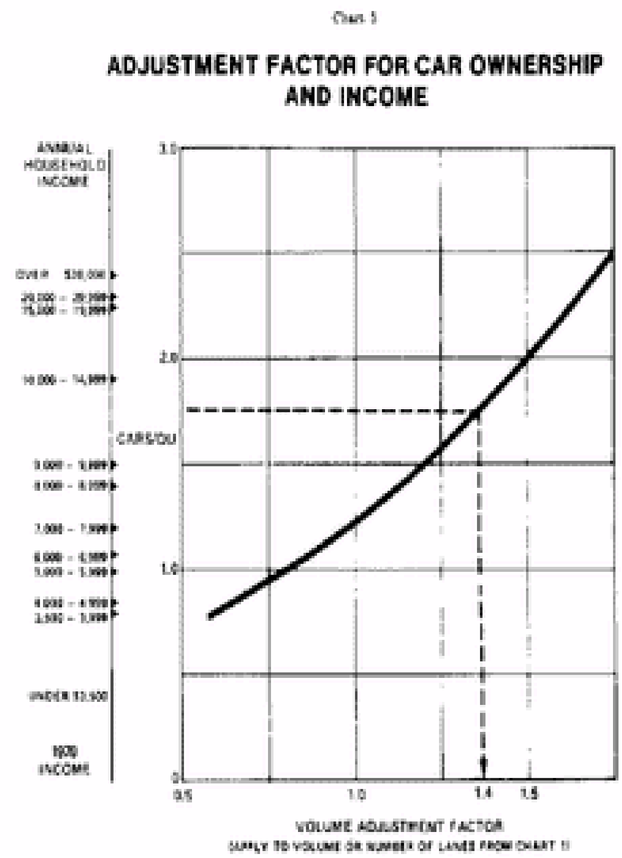


The base condition requiring no adjustment was assumed to be a transit utilization of approximately 7 percent of all person trips in the peak period for suburban subregional areas. Although some big-city downtown areas currently experience much greater peak transit usage (ranging from 25 percent to 50 percent and more), transit use in other parts of the urban region drops off sharply. With greater concern and support for public transit in this country, the percentage share of transit in the future could increase significantly. The effect on traffic volumes and street requirements in suburban subregional areas, however, would be quite limited because of the small amount of current transit use in these areas. For example, if the proportion of peak period transit use were to triple over that assumed as the base, the corresponding street traffic reduction would only be 15 percent.

It should also be noted that transit usage and car ownership are interdependent. Because of this, applying adjustments for both factors is not recommended when substantial (20 percent or more) transit use is anticipated (see note on Chart 4). In that case, only the Chart 4 adjustment should be applied, rather than both the Chart 4 and Chart 5 adjustments.

Example

Given a car ownership of 1.7 cars per dwelling unit which has been determined to be independent of transit usage, Chart 5 indicates an adjustment factor of 1.4. When this factor is multiplied by the volume obtained from Chart 1 34,000 per mile), an adjusted per mile volume of approximately 47,600 is obtained.



Car Ownership

Chart 5 provides the adjustment factor to account for car ownership variations. Every attempt should be made by the user of the guidelines to assess the level of car ownership for the subregion, since this factor strongly influences travel and street requirements. If car ownership estimates are not available, the U.S. census data on car ownership for a comparably developed area may provide a useful guide.

If only household income estimates are available (adjusted to 1970 levels) for the subregion, these can be used in Chart 5 in lieu of car ownership data to develop an approximate adjustment factor. The median income of families and unrelated individuals, as identified in the U.S. Census, may be used as an estimate of household income when applying Chart 5. To arrive at the income level for the subregion, a weighted median income should be computed based on the median income and population of each census tract in the subregion. The income used in Chart 5 is based on 1970 dollars. Adjustment factors for other years can be determined by using the consumer price index found in the <u>United States Statistical Abstract</u>. An example uses a table for the United States, with 1967 as the base. To convert to another year as a base, all the values in the table should be divided by the index for the year desired to be the base and multiplied by

100. For example, to convert to a 1970 base all values should be divided by 116.3. The data shown in the table is also available by major city or standard metropolitan statistical area.[1]

Consumer Price Index
1967 = 100

Year	Index	Year	Index	Year	Index	Year	Index
1952	79.5	1958	86.6	1964	92.9	1970	116.3
1953	80.1	1959	87.3	1965	94.5	1971	121.3
1954	80.5	1960	88.7	1966	97.2	1972	125.3
1955	80.2	1961	89.6	1967	100.0	1973	133.1
1956	81.4	1962	90.6	1968	104.2	1974	147.7
1957	84.3	1963	91.7	1969	109.8	1975	161.2
						1976	170.5

Under special conditions of high transit use, it may not be appropriate to use Chart 5 if Chart 4 is used due to the interrelationship of the transit and car ownership factors (see note on Chart 4).

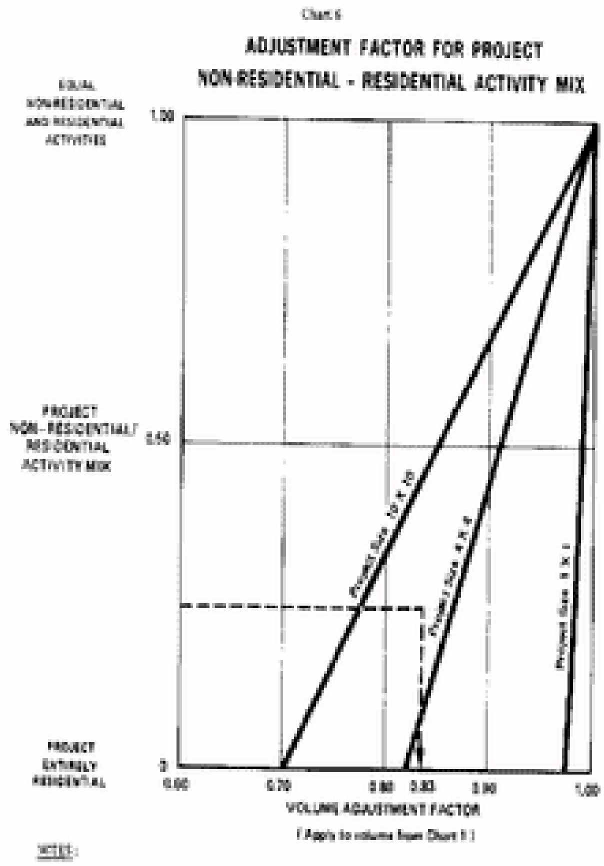
Project Nonresidential/Residential Mix

Suburban developments vary from entirely residential communities to balanced subregional areas that incorporate a mix of employment together with the residential uses. If little employment is provided within the project area for residents, a low mix is used to estimate the volume adjustment factor from Chart 6. On the other hand, if a wide range of opportunities are available, a high mix value is appropriate. (Note that the availability of employment within the project area does not produce actual balanced conditions, since competing external employment still attracts a substantial degree of in-out traffic across the project boundaries.)

1 Handbook of Labor Statistics, 1976 Bulletin 1905, U.S. Department of Labor, Bureau of Labor Statistics, 1976.

Example

Given a 6-mile by 6-mile project area containing 25,000 residents, a residential labor force of 10,000 and 2,500 jobs, a project non-residential/residential activity mix of 0.25 (2,500 jobs/10,000 labor force) is calculated. Then, entering Chart 6 with a 0.25 nonresidential/residential rate and a six by six project area (interpolation required), the adjustment factor is 0.83. This factor is then applied to the Chart 1 volume (34,000 per mile), resulting in an adjusted volume of 28,220 per mile.



The adjustment factors in Chart 6 are given for three project sizes -- 1 mile by 1 mile, 4 miles by 4 miles, and 10 miles by 10 miles. For other project sizes, an interpolation may be made to arrive at the appropriate adjustment factor.

For project areas which are predominantly nonresidential (mix value greater than 1.00), use of Major Generator Charts 8 through 16 is recommended instead of Chart 6.

Freeway Diversion Factor

Freeways can have a significant impact on the traffic carried by arterial streets. On streets parallel to a freeway, traffic volumes are generally decreased by a freeway. This impact is the greatest close to the freeway and decreases on streets farther from the freeway. Conversely, on streets perpendicular to the freeway, particularly those which serve interchanges, traffic volumes are generally increased by a freeway. The amount of volume increase is greatest as the freeway is approached.

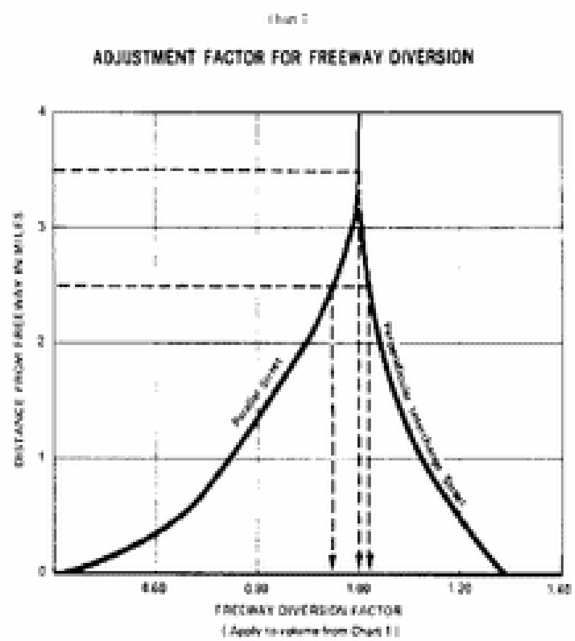
To account for this influence of freeways, adjustment factors are provided in Chart 7. It should be noted that, in contrast to the other charts in this section, the same adjustment factor is not applied throughout the project area, but a different adjustment factor is applied within each mile-wide corridor. The adjustment factors are a function of the distance from the freeway. It is suggested that this distance be measured as a straight line distance (airline distance) from the freeway to the midpoint of each mile-wide corridor. To facilitate the calculations, these adjustment factors should be applied after all the previous adjustment factors have been applied. This approach is illustrated in the following example.

Example

Given a 2-mile by 2-mile project with a freeway located 2 miles from the edge of the project, the effect of the freeway on the surface street traffic is reflected in the following adjustment factors:

At 2.5 miles:
 Parallel streets=.95
 Perpendicular interchange streets=1.02
At 3.5 miles:
 Parallel streets=1.00
 Perpendicular interchange streets=1.00

These freeway adjustment factors are applied to the <u>adjusted</u> volume per mile determined for the entire project area. Using the Chart 1 volume of 34,000 vehicles per mile and the adjustment factors from the previous examples, the <u>adjusted</u> volume per mile is:



34,000 x 0.65 x 1.09 x 0.97 x 1.40 x 0.83 = 27,150 vehicles/mile

This adjusted volume of 27,150 vehicles per mile represents the number of vehicles within each mile-wide corridor of the project. To account for the freeway influence, the volumes on the parallel and perpendicular streets in each mile-wide corridor are:

At 2.5 miles:
- Parallel streets: 27,150 x 0.95 = 25,790
- Perpendicular interchange streets = 27,150 x 1.02 = 27,690

At 3.5 miles:
- Parallel streets: 27,150 x 1.00 = 27,150
- Perpendicular interchange streets: 27,150 x 1.00 = 27,150

MAJOR GENERATOR VOLUMES AND STREET REQUIREMENTS

The primary use of the major generator charts is to estimate traffic and street requirements adjacent to or near concentrated developments (major generators). The guidelines treat major generators individually. For each major generator identified by the user, the guidelines provide an estimate of its traffic generation (Charts 8 through 15). The traffic generator estimate is used to enter Chart 16, from which traffic volumes in a given cardinal direction are derived, as well as the street needs for the anticipated level of service. These volumes and/or street needs are then superimposed upon the subregional traffic (as determined from Chart 1 and applied adjustments) to arrive at the total traffic requirement.

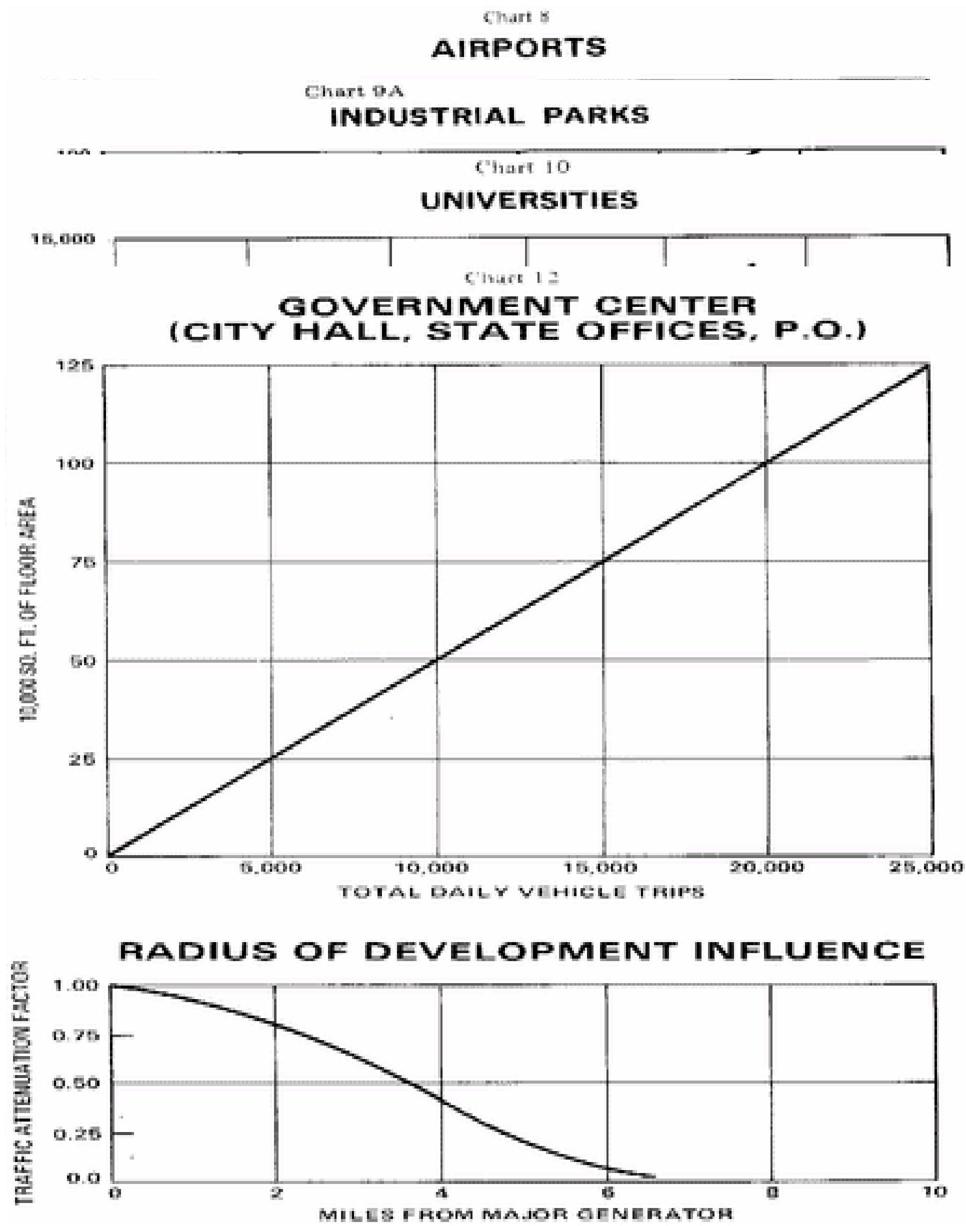


Chart 13

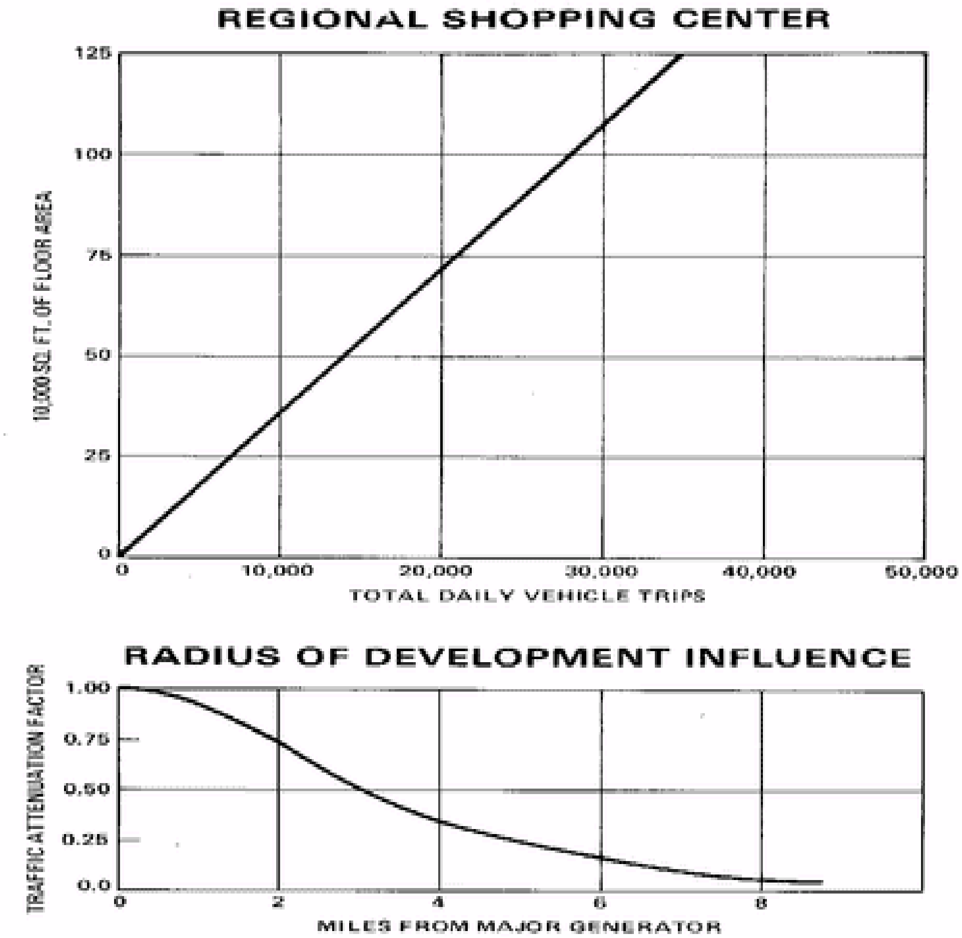
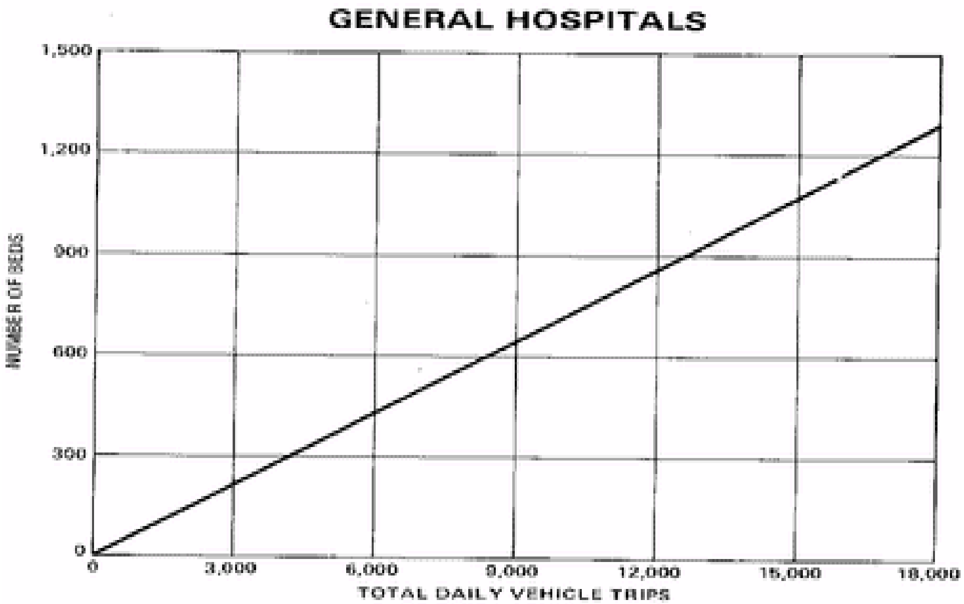

REGIONAL SHOPPING CENTER
10,000 SQ. FT. OF FLOOR AREA
125
100
75
50
25
0
0
10,000
20,000
30,000
40,000
50,000
TOTAL DAILY VEHICLE TRIPS
RADIUS OF DEVELOPMENT INFLUENCE
TRAFFIC ATTENUATION FACTOR
1.00
0.75
0.50
0.25
0.0
0
2
4
6
8
MILES FROM MAJOR GENERATOR

Chart 13A

Note: Use traffic attenuation curve from Chart 13

Chart 14


GENERAL HOSPITALS
NUMBER OF BEDS
1,500
1,200
900
600
300
0
0
3,000
6,000
9,000
12,000
15,000
18,000
TOTAL DAILY VEHICLE TRIPS

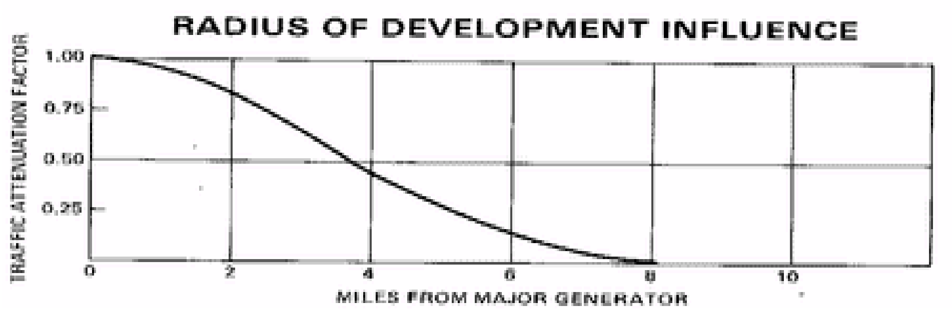
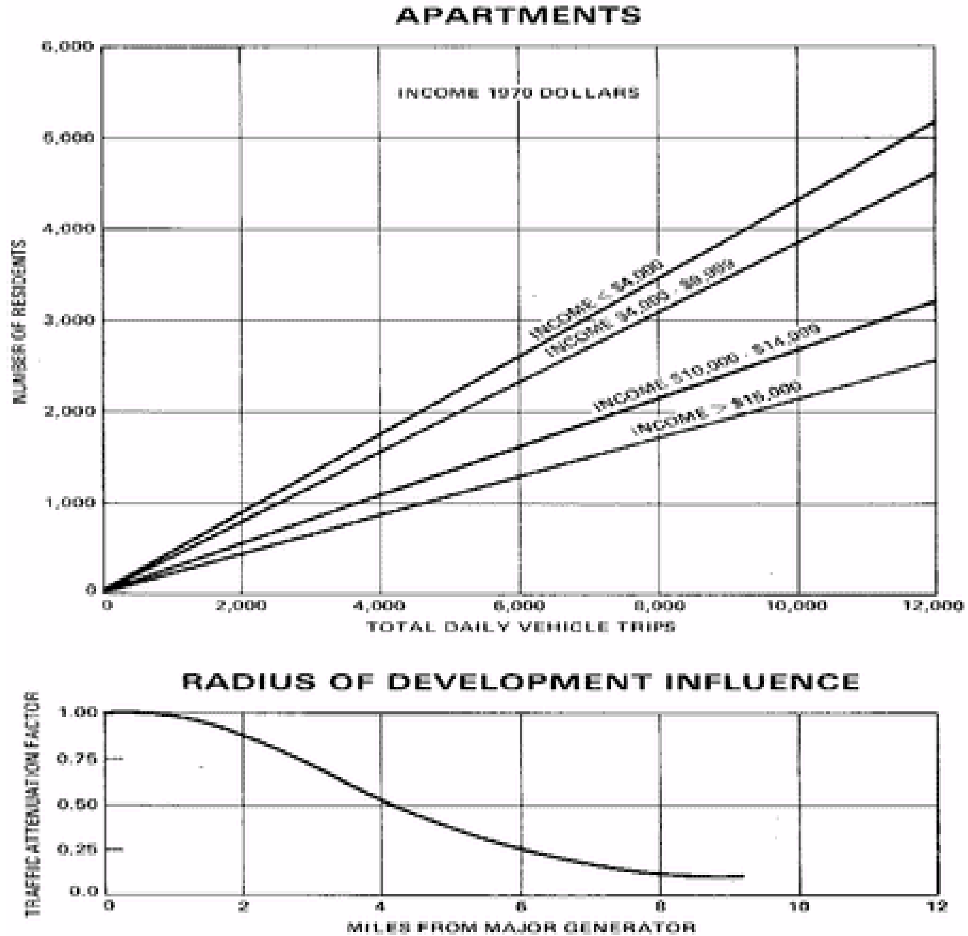
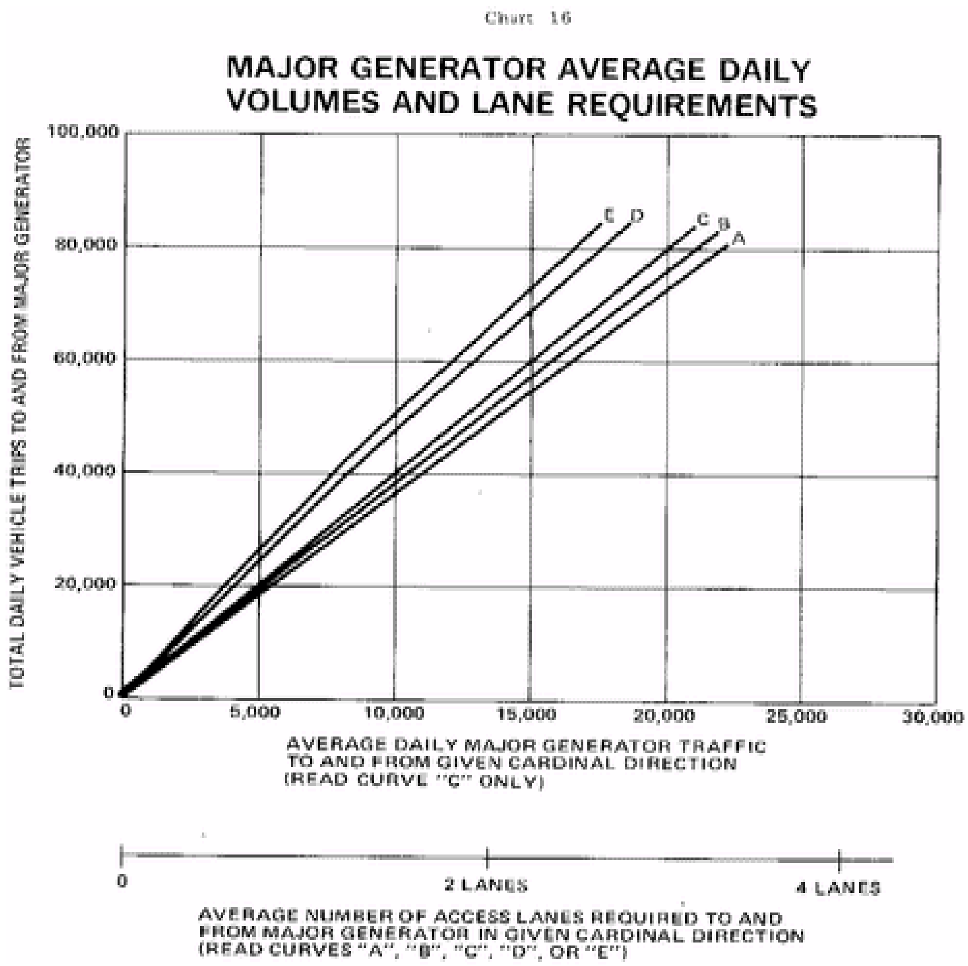

RADIUS OF DEVELOPMENT INFLUENCE
TRAFFIC ATTENUATION FACTOR
1.00
0.75
0.50
0.25
0
2
4
6
8
10
MILES FROM MAJOR GENERATOR

Chart 15


APARTMENTS
INCOME 1970 DOLLARS
NUMBER OF RESIDENTS
6,000
5,000
4,000
3,000
2,000
1,000
0
INCOME < $4,000
INCOME $4,000 - $9,999
INCOME $10,000 - $14,999
INCOME > $15,000
0
2,000
4,000
6,000
8,000
10,000
12,000
TOTAL DAILY VEHICLE TRIPS
RADIUS OF DEVELOPMENT INFLUENCE
TRAFFIC ATTENUATION FACTOR
1.00
0.75
0.50
0.25
0.0
0
2
4
6
8
10
12
MILES FROM MAJOR GENERATOR



Eight distinct types of concentrated development are covered in the guidelines:

Airport	Chart 8
Industrial Park	Charts 9 and 9a
University	Chart 10
Office Center	Chart 11
Government Center	Chart 12
Shopping Center	Charts 13 and 13a
General Hospital	Chart 14
Apartment	Chart 15

Each chart illustrates two relationships. The upper chart expresses typical daily vehicle trips produced by the major generator as a function of land use and socioeconomic characteristics. The number of trip ends is dependent on such characteristics as square feet of floor area or number of employees for industrial parks and office centers, number of students for universities, number of beds for hospitals, and number of residents for apartment complexes. The lower portion of the chart indicates the decline of major generator traffic with increasing distance from the generator. The traffic attenuation at increasing distance reflects the cumulative distribution of trip lengths for various purposes. The reduction of trips at increasing distances from the major generator is reinforced by the availability of more and more streets over which to distribute the traffic.

A good deal of variation has been observed in the trip generation rates of existing major generators. Some of the variation can be accounted for by detailed subclassification of the individual development according to its functional and operational characteristics. Trip generation rates also vary within land uses of the same category. For these guidelines, however, generalized tripmaking relationships have been used to maintain t 'he simplified approach. The major generator charts have been developed using nationwide data; therefore, when local knowledge of the major generator traffic characteristics is available, or where detailed traffic analysis of the generator is feasible, the guidelines should be augmented by this additional information.

Charts 8-15 produce daily vehicle trip estimates, modified by the traffic attenuation factor, if required. These estimates are based on the size of the specific major generator and are used in entering Chart 16 to determine the average daily traffic volumes and lane requirements. Chart 16 assumes directional balance for major generator traffic; if local data indicate a predominance of traffic in certain directions, volumes should be adjusted accordingly. Estimated daily volumes and numbers of lanes are each given as total figures by cardinal direction for the major generator, not in per mile terms. The following is-an example of the application of the charts.

Example: Given a regional shopping, center with 1.25 million square feet of floor area, Level of Service “C” to be provided, Chart 13 indicates a total of about 35,000 daily trips to and from the shopping center. Entering Chart 16 with 35,000 trips and reading to the Level of Service “C” curve, the average daily volume of 8,750 trips to and from the major generator in a given cardinal direction is indicated. (The use of only Curve “C” for estimating traffic demand is specified because traffic demand will not vary with level of service. In contrast, the number of lanes will vary--the greater the level of service, the more lanes will be required.) To estimate the lane requirements, enter Chart 16 with 35,000 trips and read to the desired Level of Service “C” curve. A requirement for two access lanes is indicated by reading down from the 35,000--Curve “C” intersection to the lanes required scale. This indicates a requirement in a given cardinal direction for two traffic lanes for access and egress to the major generator. This number of lanes is required over and above the traffic requirements determined from Charts 1-7 and applies to locations immediately adjacent to the shopping center.

For a location 2 miles away from the shopping center, an attenuation factor of 0.75 is applied. This attenuation factor is obtained from the lower half of Chart 13. Applying this 0.75 factor to the basic volume (35,000 trips) results in a new volume of 26,000 trips. Using Chart 16 with a volume of 26,250 trips, one access-egress lane is required at a distance of 2 miles from the shopping center. These lane requirements are added to the traffic requirements determined from Charts 1-7, after matching the street spacings established for each type of major generator.

If for example, four lanes had been required at the perimeter of the shopping center, the spacing of the lanes should be established in scale with the shopping center dimensions and any street system spacing already established. Once the access-egress street spacing is established in scale with the major generator, these required street lanes may be added to the lane requirements determined previously.

An alternative approach is to determine the traffic to and from the major generator using Chart 16 and add it to the traffic volumes determined from Chart 1. Then the total lane requirements for each mile-wide corridor in the project area are determined using the lower half of Chart 1. This approach is useful in the case where the average daily traffic to and from the major generator is less than 10,000 trips.

SCENARIO 1 -- DETERMINING STREET REQUIREMENTS OF PROPOSED NEW TOWN

A new town is being planned within a low density subregion of a major metropolitan area. As part of the planning effort for this new town, an estimate of the street system requirements is needed. Figure 4 illustrates the general characteristics of the new community.

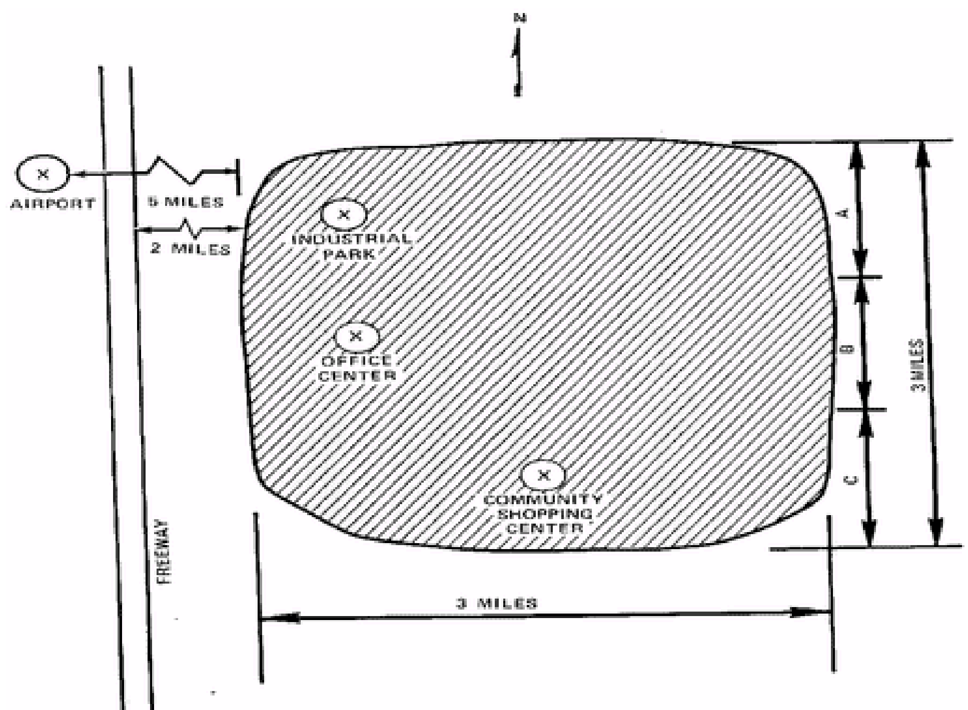


FIGURE 4. PROPOSED NEW TOWN—SCENARIO 1

To arrive at an estimate of the street requirements, the first step is to determine the traffic volumes given the projected residential density of the subregion. This involves the application of Chart 1. The following information is available:

1. Projected population of 55,000 within the 9-square mile area, resulting in a gross density of 6,100 residents per square mile. The projected density of the surrounding subregion is 4,000 residents per square mile.

2. Projected labor force of 24,000, with 12,000 jobs provided within the new town.
3. Forecasted car ownership of 1.7 cars per dwelling unit and 10 percent transit utilization in the peak hour within the subregional area.
4. Desired Level of Traffic Service "C."

Using this information, Chart I is applied in the following manner:

B. Adjustment Factor for Level of Service (Chart 3)

Given: Level of Service = C

Adjustment Factor = F_3 = 1.00

C. Adjustment Factor for Transit Utilization (Chart 4)

Given: Peak period transit use = 10 percent

Adjustment Factor = F_4 = 0.97

D. Adjustment Factor for Car Ownership (Chart 5)

Given: Cars per dwelling unit = 1.7

Adjustment Factor = F_5 = 1.40

E. Adjustment Factor for Project Nonresidential/Residential Activity Mix (Chart 6)

Given: Employment of 24,000 and 12,000 jobs, for nonresidential/residential mix of 0.50 (12,000 jobs ÷ 24,000 residential labor force).

Adjustment Factor = F_6 = 0.93

F. Composite Adjustment Factor

$F_2 \times F_3 \times F_4 \times F_5 \times F_6 =$

$1.27 \times 1.00 \times 0.97 \times 1.40 \times 0.93 = 1.60$

II. Adjusted Volumes from Chart 1

A. 17,000 vehicles/mile x 1.60 = 27,200 vehicles/mile

B. Adjustment Factor for Freeway Diversion (Chart 7)

Given: Distance from western edge of new town to freeway = 2 miles

2.5 miles from freeway = F_7 = 1.02

3.5 miles from freeway = F_7 = 1.00

4.5 miles from freeway = F_7 = 1.00

These adjustment factors are for streets perpendicular to the freeway.

I. Unadjusted Volumes Within the New Town (Chart 1)
Given: Subregion gross residential density = 4,000 residents per square mile
Unadjusted volume = 17,000 vehicles per mile

II. Adjustment Factors for Unique Conditions of the New Town and Surrounding Subregion

A. Adjustment Factor for Project Density and Size (Chart 2)

Given: Project size = 3 x 3 miles (9 square miles)
Subregion: Project density - 1:1.5 (4,000:6,100)

Adjustment Factor = F_2 = 1.27

C. Adjusted volume in project area =
At 2.5 miles from freeway = 27,200 x 1.02 = 27,740 vehicles/mile
At 3.5 miles from freeway = 27,200 x 1.00 = 27,200 vehicles/mile
At. 4.5 miles from freeway = 27,200 x 1.00 = 27,200 vehicles/mile

Estimate the Major Generator Trips in Each Mile-Wide Corridor (see Figure 4 for locations of corridors and major generators)

A. Airport (Chart 8)
Given: 10,000 daily air passengers
Total daily trips = 24,000 (to and from the airport)
Total daily trips in given cardinal direction (Chart 16) = 6,000

Trips within each in mile-wide corridor

Corridor*	Distance**	Attenuation Factor	Trips
A	5.5	0.25	1,500
A	6.5	0.15	900
A	7.5	0.12	700

* A Partial freeway interchange exists to provide access to the airport; if the new town is built a full interchange would be constructed to provide access to the new town. Therefore, it is assumed that the traffic generated by the airport will be primarily within Corridor A.

** Straight line distance in miles.

B. Industrial Park (Chart 9)
Given: 2,000 employees
Total daily trips = 11,900 (to and from industrial park)
Total daily trips in given cardinal direction (Chart 16) = 3,000

Trips within each mile-wide corridor:

Corridor*	Distance**	Attenuation Factor	Trips
A	0	1.00	3,000
A	1	1.00	3,000
A	2	0.95	2,900

C. Office Center (Chart 11)
Given: office center has 500,000 square feet of floor area
Total daily trips = 7,000
Total daily trips in given cardinal direction (Chart 16) = 2,000

Trips within each mile-wide corridor:

Corridor*	Distance**	Attenuation Factor	Trips
B	0	1.00	2,000
B	1	0.95	1,900
B	2	0.85	1,700

D. Community Shopping Center (Chart 13A)
Given: 500,000 square feet of floor area
Total daily trips = 21,000 (to and from shopping center)
Total daily trips in given cardinal direction (Chart 16) = 5,300

Trips within each mile-wide corridor:

Corridor*	Distance**	Attenuation Factor	Trips
C	0	1.00	5,300
C	1	0.92	4,900

E. Estimate Total Major Generator Trips Within Each Mile-Wide Corridor

E. Estimate Total Major Generator Trips Within Each Mile-Wide Corridor

From the preceding major generator analysis, the total major generator trips in each corridor may be determined as follows:

Corridor	Distance From Western Boundary of Project (Miles)		
	0.5	1.5	2.5
A	3,000 + 1,500 = 4,500	3,000 + 900 = 3,900	2,900 + 700 3,600
B	2,000	1,900	1,700
C	4,900	5,300	4,900

The above table reflects the volumes resulting from the major generators at three points within each corridor.

V. Estimate Street Requirements in Project Area*

The total trips within each corridor (adjusted Chart 1 volumes + major generator trips) are:

Corridor	Distance From Western Boundary of Project (Miles)		
	0.5	1.5	2.5
A	4,500 + 27,740 = 32,240	3,900 + 27,200 = 31,100	3,600 + 27,200 = 30,800
B	2,000 + 27,740 = 29,740	1,900 + 27,280 29,100	1,700 + 27,200 = 28,900
C	4,900 + 27,740 = 32,640	5,300 + 27,200 = 32,500	4,900 + 27,200 = 32,100

* Assumes that E-W direction is direction of maximum flow.

From the preceding major generator analysis, the total major generator trips in each corridor may be determined as follows:

Applying the lower half of Chart 1, these anticipated volumes translate into the -following lane requirements within each mile-wide corridor:
Corridors A & C: one 6-lane street
Corridor B: two 2-lane streets at 1-2 mile spacing

Because of the relatively low volumes resulting from the major generators, these volumes were combined with the volumes generated by the residential development. In cases where the major generators contribute a large number of trips to the corridors in the project area, the lower half of Chart 16 may be applied to determine lane requirements resulting from the major generator traffic. Then, these lane requirements may be superimposed over the lane requirements resulting from the residential development.

SCENARIO 2 -- REVERSE APPLICATION OF GUIDELINES

A suburban area is interested in determining how much additional development the existing street system can support. The area is approximately four square miles (roughly two miles to a side), with a density of 4,000 residents per square mile. The existing street system consists of three arterial roadways spaced approximately one-half mile apart and generally oriented in a north-south direction (see Figure 5). The easternmost roadway and the western-most roadway are each four lanes wide, while the remaining roadway is six lanes wide.

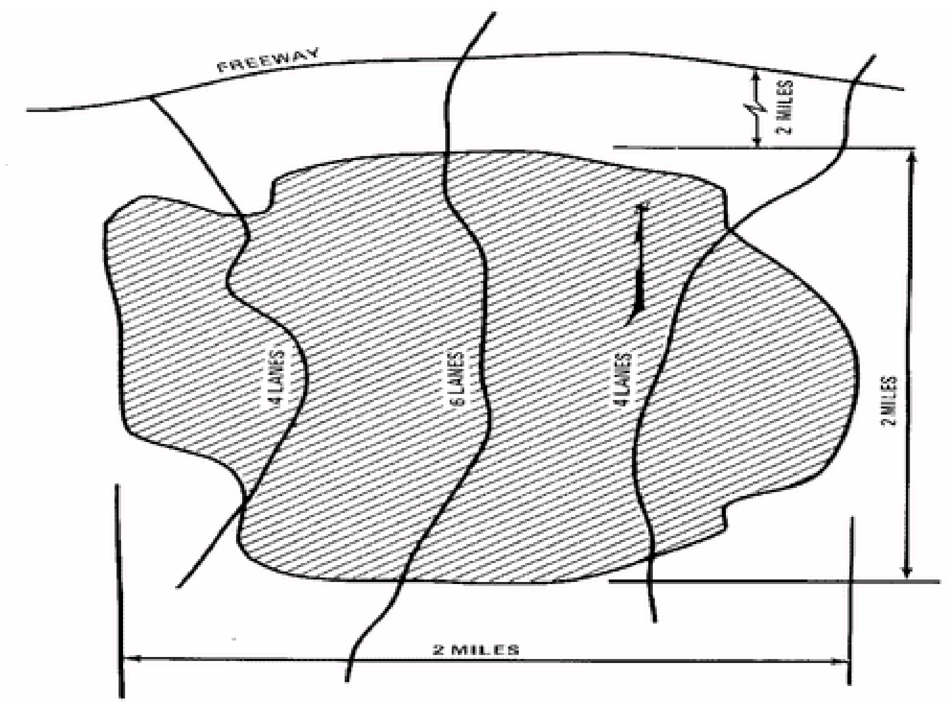


FIGURE 5. PROJECT AREA—SCENARIO 2

To estimate the amount of development the existing street system, can support, the first step is to determine the number of lanes per mile available within the project area. In this case, the total number of lanes per mile is equal to (4+4+6)/2 or 7 lanes per mile. Because the four-lane streets predominate, Chart 1 is entered along the four-lane streets axis with 7 lanes/mile. Reading, up to volumes scale, this results in an average daily north-south volume in a mile-wide corridor of 45,500.

Next, it must be determined whether the assumptions noted on Chart 1 are satisfied. If they are and there are to be no major generators, then the acceptable density for the project area is taken directly off Chart 1. In this case, the density is 8,750 residents per square mile.

However, for this area the Chart 1 assumptions are not satisfied because of the following conditions:

1. Subregion: project density = 1:2.

2. Level of service = D.
3. Cars per dwelling unit = 1.5.
4. Transit use = 10 percent (and independent of cars/d.u.).
5. Project nonresidential/residential activity mix = 0.90.
6. Distance from freeway = 2 miles.

Also, there-are two major generators which are of such size and proximity that they may influence the major street system within the project area. These developments are:

1. Regional shopping center of 1,000,000 square feet located 4 miles from the northern boundary of the project area.
2. Additional residential concentration of 10,000 residents (not previously taken into consideration) located 3 miles from the northern boundary of the project area.

Note: Both of these major generators lie along the northern extension of the 6-lane facility.

Therefore, it is necessary to determine adjustment factors and perform some major generator analysis. This is accomplished in the following .manner:

I. Adjustment Factor for Project Size (Chart 2)
   Given: object size = 2 x = miles (4 square miles)
   Subregion: Project density = 1:2
   Adjustment Factor = F2 = 1.40
II. Adjustment Factor for Level of Service (Chart 3)
   Given: Level of Service = D
   Adjustment Factor = F3 = 0.88
III. Adjustment Factor for Transit Utilization (Chart 4)
   Given: Peak period transit use = 10 percent (and transit use is independent of cars per dwelling unit)
   Adjustment Factor = F4 = 0.97
IV. Adjustment Factor for Car Ownership (Chart 5)
   Given: Cars per dwelling unit = 1.5
   Adjustment Factor = F5 = 1.20
V. Adjustment Factor for Project Nonresidential/Residential Activity Mix (Chart 6)
   Adjustment Factor = F6 = 0.99
VI. Adjustment Factor for Freeway Diversion (Chart 7)
   Given: stance from project edge to freeway = 2 miles
   Adjustment factor at (perpendicular interchange streets):
      2.5 miles = 1. 02 = F7A
      3.5 miles = 1-00 = F7B
VII. Major Generator, Regional Shopping Center (Chart 13)
   Given: regional shopping center of 1,000,000 square feet at a distance of four miles from the northern boundary of the project area.
   Total Daily Vehicle Trips = 28,125 x traffic attenuation factor
   Traffic Attenuation Factor = 0.35
   Total Daily Vehicle Trips in Project = G13 = 9,844
VIII. Major Generator, Apartments (Chart 15)

Given: Number of residents = 10,000 at a distance of 3 miles from the northern boundary of the project area. Average income of residents is in the range, \$4,000 - \$9,999
Total Daily Vehicle Trips = 35,556 x traffic attenuation factor
Traffic Attenuation Factor = 0.75
Total Daily Vehicle Trips in Project = G15 = 26,667

IX. Major Generator Street Needs (Chart 16)
Given: G13 = 9,844   G15 = 26,667
Total daily vehicle trips = G13 + G15 = 36,511
Average Daily Major Generator Traffic = 9,130

Applying Chart 16, this major generator volume translates to a requirement of a little more than one lane, so two lanes, so two lanes are necessary. Since both of these major generators are connected to the project area by the six-lane facility, it can reasonably be assumed that two lanes of this facility were necessary as a consequence of these major generators. That being the case, then four of the six lanes are available for other service to the project area.

At this point, it has been determined that the major generators contributed demand for two lanes of the six-lane facility, leaving essentially three 4-lane roadways within the project area. Also, the adjustment factors, due to anticipated characteristics of the project area, have been determined. Now it is possible to compute the number of lanes per mile and adjustments to the average daily north-south volumes.

The number of lanes per mile is computed by summing the lanes of the major north-south routes in the project area, 4 + 4 + 4 = 12, and dividing by the project's, width, two miles, which yields six lanes per mile. Entering Chart 1 along the four-lane streets axis for six lanes per mile, a north-south volume of 39,000 vehicles is obtained. The adjustment factor to be used is the product of the individual adjustment factors obtained from Charts 2-7. This adjustment factor is:

$F_2 \times F_3 \times F_4 \times F_5 \times F_6$
$1.40 \times 0.88 \times 0.97 \times 1.20 \times 0.99 = 1.42$
$1.42 \times F_{7A}$ $1.42 \times 1.02 = 1.45$
$1.42 \times F_{7B} = 1.42 \times 1.00 = 1.42$

Application of this factor is made in the following simple equation:

(Average Daily Volume) (Adjustment Factor) = Adjusted Average Daily Volume

This equation can be rewritten as follows:

Average Daily Volume = Adjusted Average Daily Volume/Adjustment Factor

It should be noted that this is a reverse application of the procedure; therefore, the average daily volume of 39,000 as determined above is the adjusted volume and not the volume used in Chart 1 to determine residential density. Thus, substituting the appropriate values in the above equation, the average daily volume is 39,000 ÷ 1.45 or 26,900 in the northern half of the project area, and 39,000 ÷ 1.42 or 27,460 in the southern portion.

Entering Chart 1 with an average daily volume of 26,900, a residential density of 5,700 residents per square mile is obtained. This volume represents the density which can be supported by the existing street system in the northern portion. Similarly, a density of 5,900 residents per square mile can be supported in the southern portion. Comparing, these densities--5,700 and 5,900 residents per square mile--with the existing density of 4,000 residents per square mile indicates that the existing street system can accommodate additional development.

SCENARIO 3 -- EVALUATING IMPACT OF PROPOSED MAJOR DEVELOPMENTS

Two major new developments--a regional shopping center and an industrial park--are proposed in a developing suburban area. The major has requested that an analysis be conducted to determine the impact of these proposed developments on the existing street system.

The area that would be immediately affected by these developments is approximately 16 square miles (roughly four miles to a side) and has a density of 4,000 residents per square mile, while the surrounding area has a density of 3,000 residents per square mile. There currently exists a labor force of 26,000 in the project area, with 13,000 jobs in the area. The existing street system in the project area consists of one four-lane street and two two-lane streets, oriented in a north-south direction (see Figure 6).

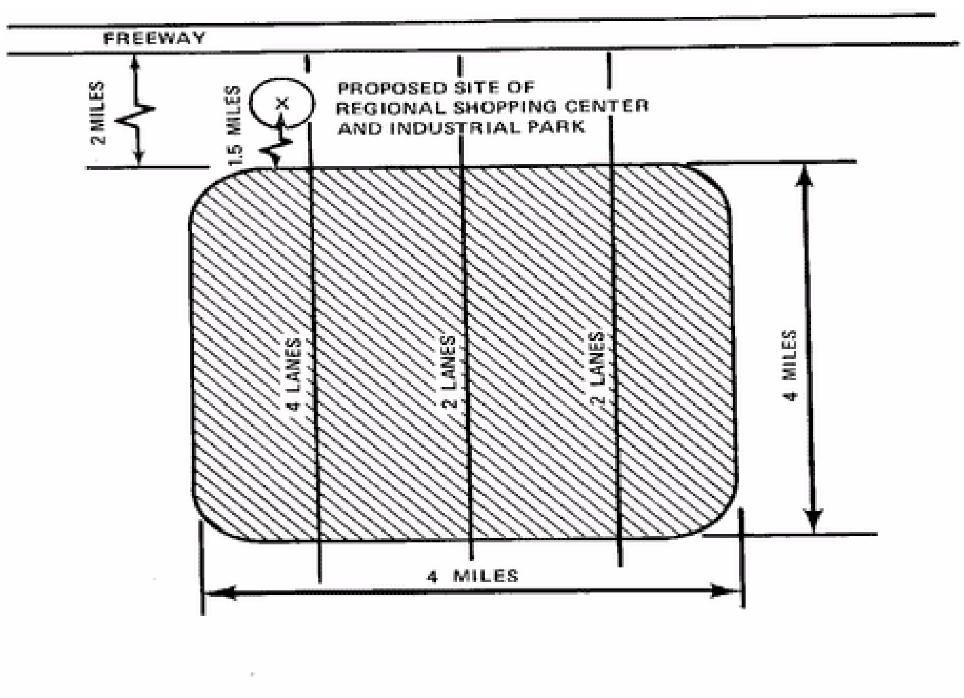


FIGURE 6. PROJECT AREA—SCENARIO 3

A two-part analysis may be applied to determine the impact of the proposed developments on the existing street system. The first part consists of determining if the existing street system is adequate to support the existing- residential density, exclusive of the proposed developments.

The second part involves estimating the lane requirements of the proposed special generators. The following discussion outlines this two-part analysis:

I. Determine if existing street system within the project area is adequate to support the residential density (Charts 1-7).

A. Applying Chart I with a subregional density of 3,000 residents per square mile results in a volume of 11,000 vehicles per mile within the project area. Because the subregional area does not satisfy the assumptions inherent in Chart 1, it is necessary to apply certain adjustment factors.

B. Adjustment factor for density and project size (Chart 2)
Given: Subregion: project density = 1:1.3 (3,000 : 4,000);
project size = 16 square miles

Adjustment factor = F_2 = 1.23

C. Adjustment factor for level of traffic service (Chart 3)
Given: Level of traffic service = C
Adjustment factor = F3 = 1.00

D. Adjustment factor for transit utilization (Chart 4)

Given: Transit use in peak-hour = 5 percent

Adjustment factor = F_4 = 1.04

E. Adjustment factor for car ownership (Chart 5)

Given: Cars per dwelling unit = 1.7

Adjustment factor = F_5 = 1.40

F. Adjustment factor for project nonresidential/residential activity mix (Chart 6)

Given: Employment of 26,000 and 13,000 jobs, for nonresidential/residential mix of 0.50

Adjustment factor = F_6 = 0.91

G. Adjustment factor for freeway diversion (Chart 7)

Given: Distance from project edge to freeway = 2 miles

Adjustment factor at:

2.5 miles = 1.02 = F_{7A}

3.5 miles = 1.00 = F_{7B}

Note: This factor is for perpendicular streets because the direction of maximum flow is perpendicular to the freeway.

The composite adjustment factor is:

$F_2 \times F_3 \times F_4 \times F_5 \times F_6 =$

$1.23 \times 1.00 \times 1.04 \times 1.40 \times .91 = 1.63$

$1.63 \times F_{7A} = 1.66$

$1.63 \times F_{7B} = 1.63$

Thus, the adjusted average daily volume per mile is 11,000 x 1.54, or 18,260 vehicles per mile at a distance of 2.5 miles from the freeway; and, 11,000 x 1.63 or 17,930 vehicles per mile in the remaining sections of the project area. On the basis of these volumes, Chart 1 indicates that I two-lane street per mile is sufficient. The existing system (see Figure 6) currently provides for an average of two lanes per mile; therefore, the existing system adequately supports the current residential density.

The second part of the analysis involves determining the additional lane requirements resulting from the proposed developments (major generators).

II. Determine lane requirements of proposed major generators
   A. Industrial park (Chart 9) located ½ miles from northern edge of project area
      Given: Number of employees = 1,000
      Total daily vehicle trips in immediate vicinity of industrial park = 5,900
      Total daily vehicle trips at ½ miles (northern edge) = 5,900 x 0.98 (attenuation factor) = 5,780
      Total daily vehicle trips at 2 miles = 5,900 x 0.95 = 5,600
      Total daily vehicle trips at 3 miles = 5,900 x 0.87 = 5,130
   B. Regional shopping center (Chart 13) located 1½ miles from northern edge of project area
      Given: One million square feet of floor area
      Total daily vehicle trips in immediate vicinity of shopping center= 28,000
      Total daily vehicle trips at 1½ miles 28,000 x 0.88 = 24,640
      Total daily vehicle trips at 2 miles = 28,000 x 0.75 = 21,000
      Total daily vehicle trips at 3 miles = 28,000 x 0.50 = 14,000
   C. Major generator street needs (Chart 16)

At the immediate vicinity of the proposed developments, the total daily vehicle trips = 33,900 (5,900 + 28,000). Applying Chart 16, this volume of 33,900 translates to a volume of 8,475 in a given cardinal direction. Thus, Chart 17 indicates that, for Level of Service C, a little more than one lane is necessary for access and egress, so two lanes should be provided. At the northern edge of the project (1½miles), the volume is 30,420 (5,780 + 24,640), requiring one lane. Similarly, at the other points in the project area, at least one lane is necessary to serve the major generator traffic.

Considering that no more than two lanes of capacity are required to serve the access/egress requirements of the proposed developments, and two lanes per mile are necessary to support the existing density, the existing street system is adequate to accommodate the anticipated increased demand generated by the proposed developments. This assumes that the access/egress requirements of the major generators can be handled within the corridor having four lanes.

APPENDIX A

Definition of Terms

1. Apartment: A rental dwelling unit located within the same physical structure as at least four other dwelling units on a common lot.
2. Cardinal Direction: One of the four chief points of the compass: north, south, east, west.
3. Community Regional Center: A complex of retail stores having a total gross floor area between 100,000 and 500,000 square feet and having a common parking area.
4. Direction of Maximum Flow: The direction of maximum flow may also be called the primary direction of flow. If the major streets in the project area carry more traffic volume in one direction (for example, in the N.E.-S.W. direction) than any other direction, then this direction (N.E.-S.W.) would be called the direction of maximum flow. Secondary direction flows will be less than primary direction flows in most areas. Because the primary direction of flow normally establishes the size of the major streets in both directions, Chart 1 of the report was developed to estimate primary direction requirements and should be used accordingly. If predictions of traffic in the secondary direction are to be developed, a reduction factor should be estimated from local traffic patterns and applied to the traffic volume estimates given by Chart 1.
5. Employee: A person who works at a commercial or industrial facility.
6. General Hospital: A hospital which does not specialize in the treatment of any one type of illness or any one group of patients.
7. Industrial Park: A grouping of industrial uses in a common park-like area.
8. Level of Traffic Service: See Highway Capacity Manual, Highway Research Board, Washington, D.C., 1965, page 80 ff.
9. Major Barriers to Travel: Barriers are those caused by man-made and topographical features which produce a modified traffic pattern unique to the area and differing from the traffic volumes predicted by the guidelines. Relationships developed in the report assumed relatively direct travel to all parts of the urban area. In Manchester, New Hampshire, for example, the railroad and the river combined to deform travel pattern and funnel traffic into corridors. A freeway through the project area does not qualify as a major barrier because Chart 7 of the report adjusts for the influence of freeways on the traffic volumes on major streets in the project area.
10. Major Street: Major streets in and through the project area are those streets (not freeways and not local streets) which carry the major volume of traffic in and through the project area. These streets may be classified as arterial or major collectors, but because of their high traffic volumes, relative to other roads or streets in the project area, they are considered, for purposes of this manual, to be it major streets."
11. Project Area: That area within the subregion chosen as the analysis area.
12. Region: All areas outside the central city that are socially and economically integrated with the central city.
13. Regional Shopping Center: A complex of retail stores having a total gross floor area of over 500,000 square feet and having a common parking area.
14. Square Feet of Floor Area: The total floor area of an establishment under roof.
15. Student: A person enrolled full or part-time in courses at an educational facility.
16. Subregion, Suburban Area, or Suburban Subregional Area: Smaller than the region which lies outside the central or core city and has relatively uniform residential density.
17. University: A major educational facility granting at least a bachelor degree with a four year curriculum.

APPENDIX B

APPENDIX B

POTENTIAL DATA SOURCES

Required Data	Geographic Level	Potential Sources
Residential Population	Subregion, project area	U.S. Census (by census tract) U.S. Census Urban Transportation Planning Package (UTPP)--by traffic zone Transportation Study Tax Assessor Bureau of Revenue School District Utility Billings Internal Revenue Service State Planning Commission R. L. Polk Company Reuben H. Donnelly Company
Dwelling Units	Subregion	U.S. Census U.S. Census UTPP Transportation Study Tax Assessor Building/Occupancy Permits Building/Health Inspections Planning/Zoning Commission Housing Authority Utility Billings Sanborn Maps R. L. Polk Company Reuben H. Donnelly Company
Autos	Subregion	U.S. Census U.S. Census UTPP Transportation Study Motor Vehicle Registration Reuben H. Donnelly Company
Income	Subregion	U.S. Census U.S. Census UTPP Reuben H. Donnelly Company
Residential Labor Force	Project area	U.S. Census U.S. Census UTPP Transportation Study Business Licensing Employment Security Commission Bureau of Labor Statistics

APPENDIX C - TECHNICAL BASIS FOR GUIDELINES

An integral element in the development of the guidelines was the application of a traffic simulation model. Simulation was required to analytically test a variety of development patterns and determine the traffic volume implications of each. From this data, relationships were derived for use in these street planning guidelines.

Simulation Framework

A two-stage simulation process was used to test alternative development patterns. First, trips were loaded on a regional network. The region selected was 24 miles on a side and divided into 36 zones, each four miles square. A central zone of the region was designated as the stud area. Traffic assigned by the regional model to the stud area zone was then used for further analysis in the second, or study area model, stage.

Regional Network

The regional network is illustrated in Figure C-1. The regional network was drawn and coded before data cards were keypunched. Centroids were numbered first; then nodes were numbered. Each centroid connector was given a length of 0.01 miles and a speed of 25 miles per hour. Arterials were given a speed of 25 miles per hour. Intermediate nodes along arterials were used to analyze turning movements through a zone. Turn penalties of six seconds for a right turn and ten seconds for a left turn were specified. Intrazonal times of 7.68 minutes, representing 3.2 miles, were used for each regional zone.

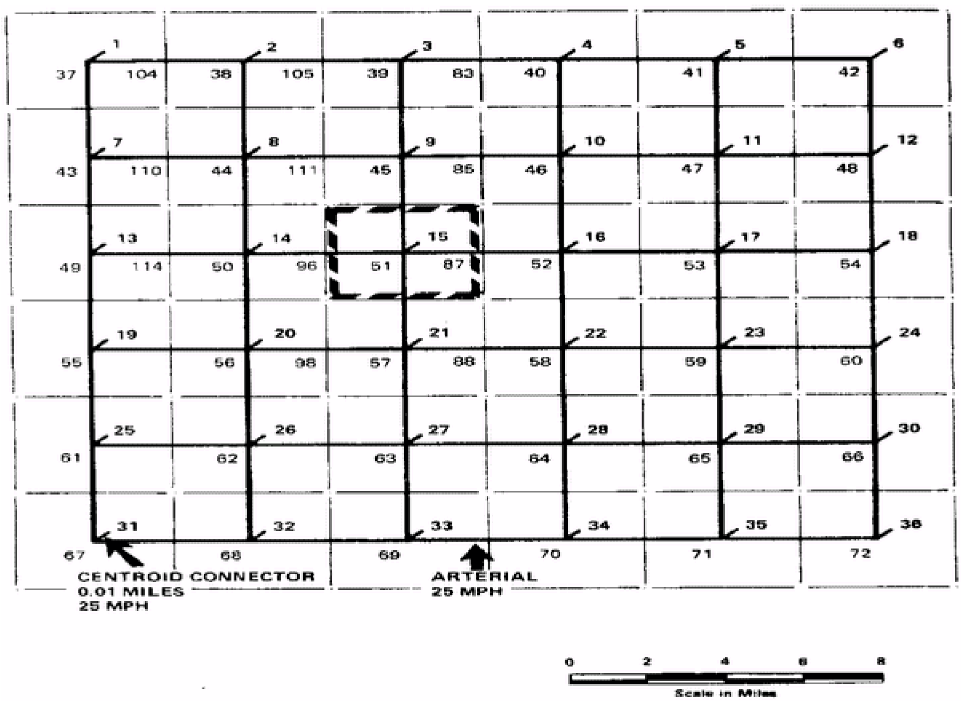


FIGURE C-1. REGIONAL NETWORK

*The simulation modeling and resulting guidelines were developed by Gruen Associates while under contract with FHWA.

<u>**Trip Generation**</u>

For balanced urban development incorporated in each zone, trip attractions are equal in number to trip productions. Special conditions of unbalanced development, such as bedroom zones with excess trip productions, were also tested.

Five trip-purpose categories were used for the simulation. The percentage of each trip type is given in the following table:

Home - Other	30%
Other - Other	22%
Other - Work	11%
Home - Work	21%
Home - Shop	16%

The trip-purpose classification reflects Los Angeles Regional Transportation Study (LARTS) survey data. This urban region is typical of areas experiencing rapid growth and suburban development in recent decades, with a corresponding growth in the highway system. Within the region, large developed areas with relatively few geographic restrictions exist suitable for use in comparing actual suburban development with simulated data. Extensive travel characteristic data were also available for the Los Angeles region, as required, for large-scale traffic simulation.

Trip Distribution

Trips were distributed regionally by use of a Gravity Model. The distribution function uses time as an indicator of separation, with a table of factors corresponding to each minute time increment and combines these effects with a constant of proportionality. The resultant formula is as follows:

$$T_{(i,j)} = \frac{P_i \; A_j \; F_{(t_{i,j})}}{\sum_{x=1}^{n} A_x \; F_{(t_{i,x})}}$$

Where:

$T_{(i,j)}$ = trip produced in zone i and attracted to zone j (analogous to gravitational force)

P_i = trips produced in zone i (analogous to mass of body i)

A_j = trips attracted to zone j (analogous to mass of body j)

$(t_{i,j})$ = travel time in minutes between zone i and zone j (analogous to separation between bodies i and j)

$F(t_{i,j})$ = empirically derived traveltime factor that expresses the average areawide effect of spatial separation on trip interchanges between zones that are $(t_{i,j})$ apart

Friction factors used in the simulation were those developed by LARTS.

After the initial distribution of the Gravity Model, the tables are summed and compared with the input data. The ratio of output to input is computed, which theoretically should approach unity for each zone. New attractions are computed by individual zonal adjustments. The balancing process is repeated for the number of iterations specified or until the error of closure meets a specified limit.

The output from the Gravity Model was converted from production-attraction format to origin-destination format . The origin-destination trip table was then loaded on the network, and the resulting 2 link volumes were plotted on a network map.

<u>Study Area Model</u>

The output from the regional Gravity Model and the loaded network report gave the following results for a study zone:

1. Intratrips, or those trips that have both origin and destination within a zone, are not loaded on the regional network. These are designated as I-I (internal-internal) trips.
2. Internal-external (I-E) trips. These are trips with either origin and destination outside the study zone.
3. Through trips, or external-external (E-E) trips. Both the origin and destination of E-E trips lie outside the study zone.

For a given zone in the region, the magnitude of the three trip types that compose the travel pattern is shown. These were applied to the more fine-grained Study Area Network for further analysis.

The Study Area Network is illustrated in Figure C-2. The area is four miles square, with streets at half-mile intervals. All zones in the study area are one-half mile square. Gateways are located on each street at the study area boundary to facilitate loading of traffic to and from other parts of the region. The actual stud area is bounded by four arterials (32 to 108, 90 to 100, 117 to 91, and 109 to 99). Only one-fourth of the corner zones (1, 9, 73 and 81) are within the study area; hence, each corner zone only received one-fourth of the productions and attractions assigned to the central zones. Similarly, the edge zones (2-8, 10, 18, etc.) only received one-half the productions and attractions as the central zones.

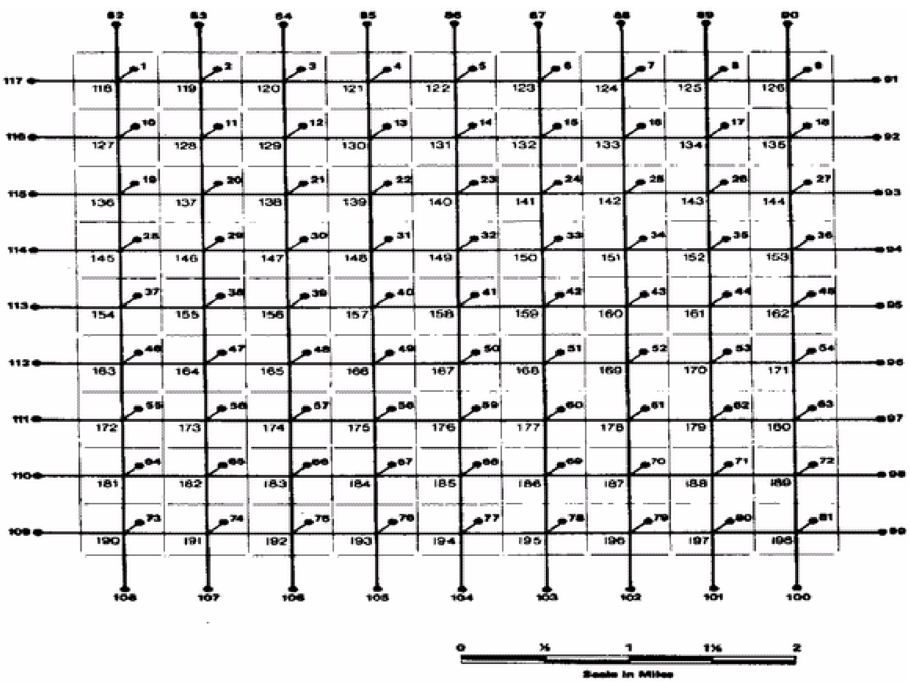


FIGURE C-2. STUDY AREA NETWORK

The I-I trips were applied by dividing the total number of intratrips for the study zone, as determined by the regional run, by 64 to obtain the productions and attractions for each zone. As noted above, corner and edge zones were given a reduced share of productions and attractions. No productions or attractions were assigned to the gateways. The productions and attractions were served as input to the study area Gravity Model. The output of the Gravity Model was loaded on the network and gave I-I volumes.

Internal-to-external trip ends were determined by subtracting I-I productions (equal to 1-1 trips) from total productions. The result was divided among the internal zones for the I to E productions, with interior zones receiving full value, edge zones receiving half value, and corner zones receiving one-fourth value. The internal productions must be balanced by external attractions, so the internal-to-external trip ends were divided by 32 (8 arterials, 4 sides). Each gateway on the edge (82, 90, 91, etc.) received half the zonal attractions, while the center gateways each received full zonal attractions.

External-to-internal trip ends were handled in the same manner. The 1-1 attractions (equal to 1-1 trips) were subtracted from total attractions to obtain E to I attractions. The result was divided by 64 to determine internal zonal attractions and by 32 to determine external zonal productions.

Internal and external productions and attractions were used as input to the study area Gravity Model. The travel time matrix used for I-E trips was modified by adding a prohibitive travel time (99.99 minutes) for all I-I and E-E movements to eliminate these trips. Output from the study area Gravity Model, after converting to O-D format, was loaded on the network to obtain I-E volumes.

The Corridor Volume Report from the regional network run identified E-E trips by directional orientation (east-west trips, east-south trips, etc.). This was used as the trip distribution. Trips were assigned by loading an equal number of trips on each internal arterial with half-trip on the edge arterials. As an example, the east-west E-E trips were divided by 8. The result was loaded on the arterial from 116 to 92, while half the result was loaded on links 117 to 91.

The three types of trips (I-I, I-E and E-E) were summed to obtain the study area network loading. Relationships between trip generation (productions and attractions) and the study area volumes were then analyzed for use in Guideline Charts.

Project Density and Size

Additional simulation runs were carried out for various combinations of regional-project densities and project size, as discussed previously. These combinations were tested to investigate the variations which could be expected under differential density conditions. They supplement the uniform density findings previously discussed. The differential density results were used to develop the adjustment factor curves -given in Guideline Chart 2.

Project Nonresidential/Residential Mix

Further simulation analysis was undertaken to investigate the effects of varying degrees of project nonresidential/residential mix. At one point on the mix scale would be the “balanced” project containing enough employment opportunities and other services to serve all project residents. This balanced project was used as the basis for preparation of Guideline Chart 1. At the other end of the mix scale would be the entirely residential project, from which residents would have to travel for most urban services. The entirely residential project was found to generate fewer total trips, but would induce a somewhat greater volume of traffic per trip due to the longer travel required. The net result, as incorporated in the adjustment factors of Guideline Chart 6, was an overall volume reduction which would approach 20 percent for an entirely residential project. For most projects falling between residential and balanced, the adjustment factor would be determined based on tie calculated value for nonresidential/residential activity mix.

The simulation analysis excluded projects predominantly nonresidential due to the diversity of possible nonresidential activity mixes and traffic patterns. For these predominantly nonresidential projects, use of the Major Generator Charts instead of Chart 6 is recommended.

Freeway Diversion Factor

Freeways can have a significant impact on arterial street volumes. Freeways generally reduce traffic volumes on parallel streets. Close to the freeway, the impact is greatest, decreasing on streets farther from the freeway. Conversely, on streets perpendicular to the freeway, particularly those which serve interchanges, traffic volumes are generally increased by a freeway.

Simulation of alternative regional freeway network configurations and spacing was carried out on a trial basis. It was determined that this approach was neither flexible enough sensitive enough to satisfactorily measure variations in major street volumes due to freeway influence. Accordingly, empirical research published by the City of Los Angeles[2] and the County of Los Angeles was utilized as the basic data source for freeway effects, from which guideline Chart 7 was developed. The Los Angeles[3] traffic data were collected on a before-and-after basis in connection with the construction of regional freeways through the urban area. The empirical findings were supported by independent analysis of detailed traffic forecasts made both with and without a future freeway proposed for region.

Major Generators

Trip length data were reviewed and analyzed by major traffic generators. for these major concentrated developments, traffic requirements may be analyzed at various distances from the generator, since the specific traffic demands decline with distance.

Guideline Charts 8 through 15 each incorporate a traffic attenuation factor curve which reflects the declining traffic demand over distance. The curves are somewhat analogous to cumulative trip length frequency curves. They were developed using trip length data available from various sources, primarily NCHRP Reports 24 and 62, covering airports, shopping centers, hospitals and other major traffic generators.

Street Capacity

Street capacity as used in the guidelines is the number of vehicles that can be carried so that the peak-hour flow at any intersection does not exceed the value at Level of Service C. The intersection capacities calculated by the Capacity Manual method are for peak-hour, peak direction. The ratio of peak-hour, peak direction to daily volume is known as kd(k=two-way

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2 City of Los Angeles, Bureau of Traffic Research, The Short-Term Effects of the Santa Monica Freeway Upon Surface Street Volumes (December 1967).

3 Los Angeles County Road Department, Pomona Freeway on Parallel and Perpendicular Routes (May 1969).

peak-hour volume/daily volume; d=peak direction volume/two-way peak-hour volume). The kd factor selected for use in the guidelines was obtained by comparing observed peak-hour traffic counts with daily counts for a range of intersections. The observed factors ranged from 3.7 percent to 7.8 percent, with an average value of 5.2 percent.