Development of Appropriate Design-Hour Volumes for Urban Freeways in Large Texas Cities

CAROL H. WALTERS AND CHRISTOPHER M. POE

In the planning and design process, 24-hr volumes in the design year are converted to design hour volumes (DHVs) by using *K* factors [ratio of 30th-highest-hour two-way volume to two-way average annual daily traffic (ADT)], *D* factors (directional split during the 30th-highest hour), and *T* factors (percentage heavy vehicles in the DHV). Lack of precision in selection of these parameters can make a ±50 percent difference in the design of urban freeways. The procedures used to select these factors in Texas urban areas have been examined, and refinements to the process are proposed. Using data from automatic traffic recorder (ATR) stations for 1973 to 1988 in the Texas cities of Houston, Dallas, Fort Worth, Austin, and San Antonio, along with manual classification data for 1984 to 1988, *K, D*, and *T* factors have been studied under increasingly urban conditions. Emphasis has been placed on the *K* and *D* factor research. Variables identified and tested for significance in predicting DHVs included facility type (radial or circumferential freeway), weekday ADT per lane, degree of capacity utilization during the peak period, employment density near the ATR station, length of peak period, and distance from the central business district. Although the initial data sets have yielded an unstable model over time using a multivariable regression analysis, ranges of K_D (*K* factor by direction) for ranges of each variable are developed for use in determining reasonableness of preselected *K* and *D* values.

Determining the number of lanes required for an urban freeway (new or expanded) involves estimating how much traffic will use the facility during the design hour. Currently, the methodology involves estimating the 24-hr volume that is expected to use the facility in the design year and multiplying that volume by planning parameters that will calculate the amount of traffic expected by direction in the design hour. The design-hour volume (DHV) influences the size of the facility, the amount of right-of-way needed (which may or may not be feasible to acquire), and the overall cost of the project. In rural areas where traffic volumes are low and right-of-way costs are also relatively low, the precision of the planning process is not as critical; however, in urban areas where traffic volumes are high and costs for right-of-way along freeway corridors continue to escalate, any imprecision in the planning process can be very costly. In extreme cases, a high estimation on required size of a facility may introduce such insurmountably high costs that it may preclude approval of any improvement at all, if a benefit-cost approach is used to determine priorities among projects. In short, decisions concerning which facilities can and cannot be justified as cost-effective, as well as the general mobility of a region, hinge on estimation of the DHV.

Texas Transportation Institute, Texas A&M University System, 1600 E. Lamar Boulevard, Suite 120, Arlington, Tex. 76011.

Extensive research has been conducted on the development of travel demand forecast models, as a means of estimating 24-hr volume, and on design, construction, maintenance, and even operation of the nation's highways. However, little research has focused on the development of planning parameters, such as the *K* factor [ratio of two-way 30th-highest hour to two-way annual average daily traffic (ADT)], directional split in the design hour (*D*), and percentage of trucks (*T*) present in the DHV. Moreover, the research that has previously been conducted on *K* factors has concentrated on less urbanized roadways with low ADT. This research is unique in that it focuses on urban freeways with ADT as high as 240,000 vehicles per day (vpd).

The objective has been to investigate whether improvements can be made in the estimation of planning parameters for urban areas that can be incorporated into the planning process. Specifically, this research has identified issues and concerns in the process as it is generally employed and has drawn on a large data base to test whether the various parameters can be reliably predicted if certain future conditions have been forecast. Statistical relationships and trend line analyses for *K* factors, directional splits, and peak-hour truck percentages have been studied in relation to facility type, ADT, degree of congestion, employment density, and location within the urban area. Emphasis is placed on the results of the research on *K* and *D*.

ISSUES AND CONCERNS

The following are some general concerns about the current planning procedure that merit discussion. These concerns were developed in concert with planners and designers from the Texas State Department of Highways and Public Transportation (SDHPT).

Design Sensitivity

The magnitude of potential over- or underdesign caused by multiple estimations of the planning parameters is an issue of concern. In the current planning process, an estimation is made of each of the planning parameters. These parameters are used in an equation of the following general form to estimate the DHV and, then, the required number of lanes (*N*):

$$N \geq ADT * [K * D * (1 + T)]/[\text{service volume}] \quad (1)$$

Service volume assumes level terrain (≤2 percent grade) for simplicity. There is a range of plausible values that can be chosen (on the basis of existing conditions on similar facilities) for each of these parameters and, thus, a potential error associated with each estimation. When these parameters are used together in the equation for estimating the number of lanes, the corresponding range of potential error is also multiplied. Table 1 presents each of the planning parameters, the usual accepted ranges for each of these values, and the variation from the mean. Typically, as an area develops from rural to urbanized, *K, D*, and *T* factors would all be expected to decrease, whereas the expected service volume would probably increase. Thus, all the errors would compound, rather than cancel one another, if the urbanization trend is under- or overestimated. Hence, even if the ADT projections were exact, the magnitude of the error in design could be more than 50 percent.

A simple, if exaggerated, example may clarify the point: a freeway expected to carry an ADT of 120,000 vpd in the design year is estimated to have a *K* factor of 0.12 and a *D* of 70 percent, on the basis of existing data on a nearby freeway; the nearest truck count exhibits an 8 percent truck factor. These factors are then furnished by the planner to the designer for use in establishing the DHV. On the basis of a desired level of service (LOS) of *D* or better, a maximum service flow rate of 1,700 passenger cars/hr/lane (pcphpl) is selected by the designer. The freeway would need to be 7 lanes in each direction, or 14 lanes. Another planner might see an urbanization trend in the population and employment forecast and select a *K* factor of 0.09, a *D* factor of 60 percent, and a *T* factor of 3 percent. A service volume of 1,900 pcphpl might be selected by the designer (traffic counts on freeways in urban areas in excess of 2,200 vehicles per hour per lane are becoming increasingly common). This calculation would mean that a freeway of four lanes in each direction, or an eight-lane freeway, would probably be sufficient. In many cases, those selecting the parameters for use in calculating the DHV are not involved in design and are not fully aware of the tremendous impact these factors have on facility design.

Need for Site-Specific Values

A single *K* and *D* value is normally used for planning and design of a freeway, which may be many miles in length with highly variable usage patterns. The design of ramps and merging, weaving, and diverging areas are all dependent on DHVs computed using these factors. However, data obtained on existing facilities do not support the conclusion that main lanes and their adjacent ramps exhibit similar peaking patterns. Figures 1 and 2 show peaking characteristics on the main lanes and adjacent ramp pairs for a radial freeway through an area of high employment in Dallas. A ramp pair is defined as two ramps that are expected to have balanced 24-hr volumes because trips made on one ramp in one direction have a return trip on the other ramp in the return direction. Ratios of peak-hour volume to daily volume on the ramp pairs vary ±35 percent from the *K* factor on the main lanes, averaging 10 percent higher, and the directional splits on ramp pairs in the corridor vastly exceed that of the freeway main lanes.

TABLE 1 EFFECT ON DESIGN BECAUSE OF VARIATION IN PARAMETERS

Parameter	Range of Values	Variation from Mean	Effect on Facility Size
K	.08 - .12	± 20 %	± 20 %
D	.50 - .70	±17 %	± 17 %
T	.02 - .10	±67 %	± 4 %
Service Volume	1700 - 2000 pcphpl	± 8 %	± 8 %
N, Number of Lanes			± 58 %

Need for Separate Peak Periods

Each element of a freeway is designed for its own DHV; however, these design hours may not occur at the same time. For example, the main lanes of a freeway, an entrance ramp, and an exit ramp all must be designed for their DHV. However, although the freeway and one of the ramps may peak during one peak period, the other ramp may peak during the other peak period. Designing each element for the same peak period may cause overdesign of some of the elements, particularly for weaving sections. The need for local data on peak-hour travel patterns and behavior of each of the freeways is apparent.

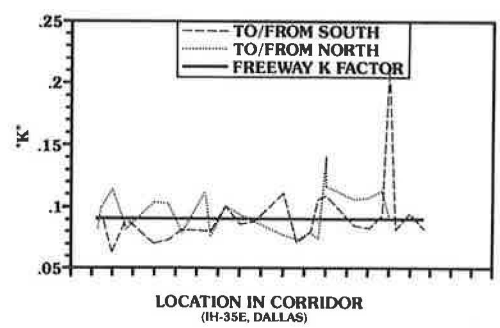

FIGURE 1 Comparison of freeway *K* factor with *K* factor on adjacent ramp pairs.

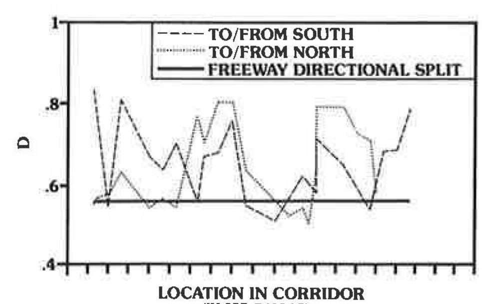

FIGURE 2 Comparison of freeway *D* factor with *D* factor on adjacent ramp pairs.

System Effects

System effects—freeway sections constrained from capacity improvement—are virtually neglected in this planning process. Use of a high K factor for a facility integral with others operating at a low K factor is unrealistic, unless there is an identifiable way to load or unload the extra peak-hour capacity thus provided on the new or improved facility. Peak-hour volumes will likely be either metered or constrained by upstream or downstream congestion. These volumes are capped by system constraints, whereas 24-hr volumes have ample capacity to grow, causing a lower K factor coupled with unused capacity even during the peak.

Weekday Traffic Versus Daily Traffic

There is a need for consistency in the definition and use of planning parameters. K factors are normally estimated from automatic traffic recorders (ATRs), which allow continuous data collection over a year. ADT, the sum of a year's worth of data divided by the number of days in that year, includes holidays and weekends and is thus lower than an average weekday calculation (AWDT). K factors are calculated as the ratio between the 30th-highest hour during the year and the ADT, both for two-way traffic. The problem comes in the application of these K factors to arrive at the DHV. Typically, design year ADT has been estimated in urban areas through use of a travel demand model, which simulates typical weekday travel. Use of the standard K factor with these ADT values introduces a potential overdesign in the vicinity of 10 percent.

Directional Design Hour

The calculation of DHV on the basis of two-way volume multiplied by the directional split that happens to be associated with the 30th-highest hour may not accurately predict the directional 30th-highest hour. In some instances, the one-way volume during the 30th-highest hour is lower than that occurring during the 200th hour. Use of a directional K factor (K_D, the ratio of the 30th-highest one-way hour to the one-way ADT) might offer a simple solution to this problem. It would also eliminate one planning parameter and, thus, one more opportunity for accumulated error.

Effects of Time

K and D factors both tend to decline over time. Use of current data to predict future K factors for design may fail to incorporate the predictable effects of urbanization, which can include significantly increased volumes of off-peak trips and off-peak direction trips generated by new commercial land uses. Low K factors generally are associated with high congestion; however, some of the data exhibited low K factors because of multiple land uses with trips spread out throughout the entire day and relatively low congestion levels. The selection process for these parameters should involve consideration of these trends.

Peak-Hour Truck Percentages

The use of truck percentages to adjust DHV to equivalent passenger-car volumes for design can have a major effect on the sizing and design of facilities, but appropriate peak-hour, peak-direction vehicle classification data are scarce. Typically, 24-hr data from a limited number of manual classification sites in mostly rural or urban fringe areas are used, applying standardized adjustment factors (that are based on facility type and originally derived from these sites) to adjust for peak-hour conditions. Given the relatively small number of truly urban sites, the potential exists for the percentage of trucks in the design hour to be grossly overestimated for routes with typical urban commuting traffic. On routes with high volumes of commuting traffic, the volume of trucks tends to remain fairly constant throughout the day. However, automobiles exhibit heavy peaking characteristics, overwhelming the trucks during the peak hour in the peak direction, which naturally lowers the percentage of trucks.

METHODOLOGY FOR ADDRESSING CONCERNS

Specific recommendations were developed to minimize the impacts of each factor of uncertainty in the planning process. The following paragraphs describe the methodology for addressing the eight concerns identified with the current process for developing DHV:

1. Design sensitivity,
2. Need for site-specific values,
3. Need for separate peak periods,
4. System effects,
5. Weekday traffic versus daily traffic,
6. Directional design hour,
7. Effects of time, and
8. Peak-hour truck percentages.

The first four issues indicate a critical need for planning parameters to be selected with a high degree of attention given to local travel patterns. Although this emphasis introduces additional time and cost into a planning process that is generally underfunded and overcommitted, the potential savings are great, both in terms of avoiding overdesign (which results in unusable capacity) and avoiding underdesign (which results in congestion that could have been avoided). It is recommended that the planning staff, following the development of ADT values for design purposes, work closely with those involved in design to ensure that realistic parameters are assigned to each section of roadway, including special attention to one-way flows on ramps and direct connections. Collection of representative peak-period data is imperative when there are multiple constraints to pursuing the ultimate design.

The fifth issue is relatively easy to address. A K_w factor (based on weekdays only, excluding holidays) can be easily calculated from ATR data. It is this factor that should be applied to the 24-hr volumes resulting from travel demand models. Calculations of ADT for other purposes, such as pavement design and environmental impact, should proceed on the basis of appropriately reduced volumes from the travel demand models.

The sixth issue, like the fifth, is easily addressed through ATR data. As mentioned, the data reduction program could be modified to seek the 30th-highest volume in each direction, and a directional K factor could be calculated as the ratio between that hour and the AWDT in that direction. This calculation would yield a K_D factor (which would also include the K_w factor), that could be applied directly to the one-way volumes from travel demand models, as adjusted by the transportation planning department, to calculate the DHV.

The seventh and eighth issues involve careful study of the elements involved in the effect of urbanization on the planning parameters. The remaining paragraphs deal with the analysis of ATR data over time on various types of facilities under differing levels of urbanization in the major cities of Texas. In the interest of brevity, the subject of trucks is treated elsewhere. However, results indicated that, in general and except for special identifiable cases, a peak-hour directional truck percentage on radial freeways in highly urbanized areas in Texas rarely exceeds 4 percent, with that on circumferential freeways being slightly higher. For example, the average in the Dallas–Fort Worth metroplex is 2.7 percent for radial freeways and 3.1 percent for circumferential freeways.

ANALYSIS OF *K* AND *D* FACTORS OVER TIME

The methodology for estimating planning parameters for urban freeways used several years of data from ATR stations to examine K and D factors. In order to simplify the analysis and gain more precision, a combined K and D factor was used that also incorporated AWDT as its basis. As discussed, this factor offers a potential benefit to the planning process in that it reduces the number of estimations needed to calculate the DHV and makes the resulting K factor usable with travel demand models. Therefore, K_D is defined as the 30th-highest directional hour divided by the AWDT for that direction, and it is this parameter with which the remaining analysis deals. Variables that influence the value of K_D, along with general trends, were identified, and development was begun using regression analysis on a statistical model to predict K_D under the influence of these variables. Finally, reference tables were developed to aid the transportation engineer in choosing appropriate values of K_D for planning freeway improvements in urban areas.

ATR Data for Urban Stations

The Texas SDHPT has an extensive ATR system throughout the state. The system consists of induction loop detectors placed in the lanes of the highways that continually collect traffic volumes for every hour of the year. The Texas Transportation Institute (TTI) obtained tapes of raw data from the ATR stations for the past 15 years and compiled an initial list of 50 stations for study in Austin, Dallas, Fort Worth, Houston, and San Antonio. Some problems with this data base quickly became evident:

- ATR stations on radial freeways were often congested, obscuring K factors as a measure of demand because of truncated peaks, as shown in Figure 3.

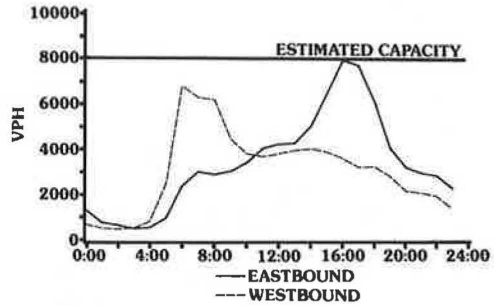

FIGURE 3 Truncated peaks not reflective of demand: IH-30 east, Dallas.

- Clock-hour data may obscure the true peaks, causing peaks to appear truncated when they are not.
- Many ATR stations are between heavy exit and entrance ramps, resulting in apparently below-capacity flow rates, even on facilities known to be operating at or near capacity.
- Many of the 50 stations in the urban areas carried less than 5,000 ADT per lane and were therefore discarded as not reflecting urban traffic characteristics.

Recognizing these limitations, the ATR data were further analyzed to identify likely descriptors of urbanization acting over time to influence the values of K_D. The variables identified and their individual relationships with K_D are described in the following subsection.

Variables Used in Estimating K_D

Many variables were evaluated on a preliminary basis for their influence on K_D. Variables were selected for evaluation on the basis of their potential as descriptors of the differences in K_D under varying urban conditions. It was essential to select variables for which data readily exist and for which data can be estimated for the future. Preliminary analyses of each variable were conducted, and the variable list was refined to include six that showed promise: facility type (radial or circumferential), AWDT per lane, distance from the central business district (CBD) of each city, utilization index (measure of peak-hour capacity usage), peak-period ratio (measure of peak-hour volume to 3-hr peak period), and employment density in the zones adjacent to the ATR station.

Facility Type

Facility type refers to radial or circumferential freeways. The ranges of K_D for radial and circumferential freeways were different enough to suggest that the data should be separated to examine K_D by facility type. In general, circumferential facilities have lower K_D values than radial facilities that have similar characteristics. This difference can be attributed to a diversity of trips throughout the day and two-way peaking during each peak period on many circumferential facilities. Radial facilities, unless constrained or serving multiple types of land use, often serve high one-way commuting patterns.

AWDT per Lane

The use of AWDT alone to estimate K_D was not very significant. However, AWDT per lane as a measure of use on a 24-hr basis had significant correspondence to K_D, as indicated in Figures 4 and 5. As AWDT per lane increases, K_D decreases, partly because the peak hour may reach capacity and cause some peak spreading to occur and partly because high-activity areas remain busy all day, diluting the effect of purely commuting traffic. Another factor may be peak-hour volumes that are constrained or metered by connections with other facilities. A number of low K_D stations with low AWDT per lane were found as well in areas where commuting trips are simply not a dominant pattern. This variable is not the most desirable for predicting K_D because an estimate must be made of the number of lanes planned for a facility before an estimation of K_D can be made. This estimation is apt to be a self-fulfilling prophecy, because K_D controls the number of lanes designed for a given per-lane capacity.

Distance from CBD

The distance from the CBD was another variable with significance in estimating K_D. Even though the major urban areas vary in size and development intensity, the majority of the ATR stations are within a 5-mi radius of the CBD. The correspondence between distance from the CBD and K_D is shown in Figures 6 and 7. K_D increases the farther the stations are from the CBD. The relationship between distance and K_D is, as expected, less significant for circumferential facilities than for radial facilities. This difference is due to the dependence on downtown commuting patterns that is prevalent on radial facilities and missing on circumferential facilities. Further, circumferential routes serve a cross-town pattern of trips that are relatively independent of the distance from the CBD. To account for the variety in sizes of the cities studied, the distance variable for each city was normalized by dividing it by the square root of the area of the city.

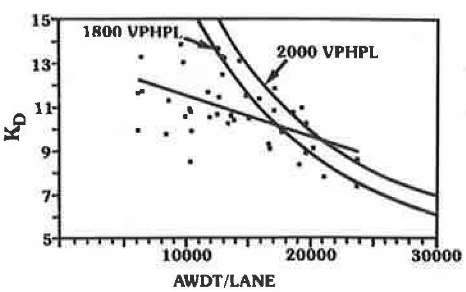

FIGURE 4 K_D factor versus AWDT per lane on radial freeways in urban areas.

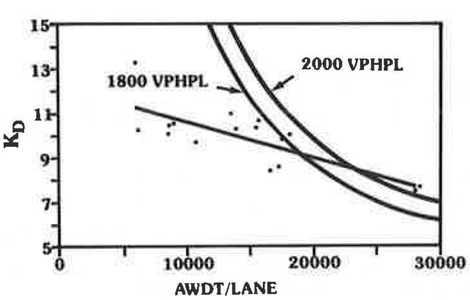

FIGURE 5 K_D factor versus AWDT per lane on circumferential freeways in urban areas.

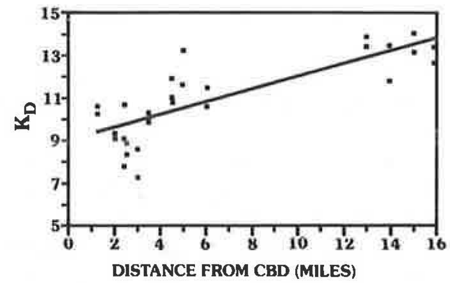

FIGURE 6 K_D factor versus distance from CBD on radial freeways in urban areas.

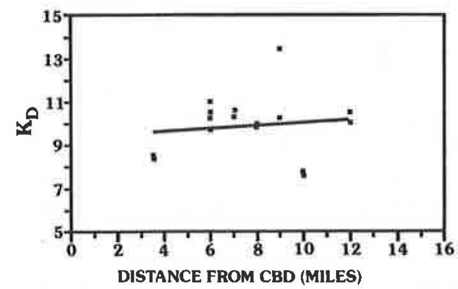

FIGURE 7 K_D factor versus distance from CBD on circumferential freeways in urban areas.

Utilization Index

The utilization index is a measure of the peak-hour usage or a rough volume-to-capacity ratio in the peak hour. For comparison, a capacity of 1,800 vehicles per hour per lane (vphpl) was assumed, and the volume was the 30th-highest hour of the year for a station by direction. A high utilization index suggests a congested peak hour; therefore, as the utilization index increases, K_D should decrease due to trips being made outside the peak hour. The relationship of K_D and utilization index for radial facilities is shown in Figure 8. As can be seen, there is little correlation between utilization index and K_D; the expected negative slope is barely discernible, and the data are highly scattered. Examination of the data reveals a number of stations with high peak-hour usage and thus a high utilization index (probably by commuter traffic), but there is little use any other time of the day, resulting in high values of K_D. At the same time, there are some congested stations that have constrained volumes in the peak hour, and thus a low utilization index, and high volumes for many other hours of the day, resulting in low values of K_D. Figure 9 shows the data for circumferential facilities, as well as a slightly better correlation.

As for using utilization index for future planning, knowing a value for the utilization index would be essentially the same

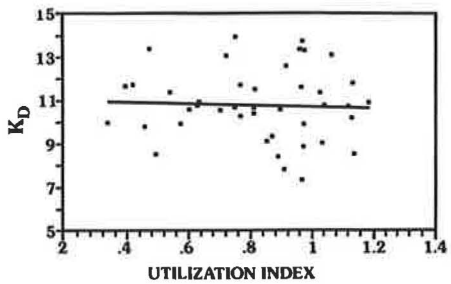

FIGURE 8 K_D factor versus utilization index on radial freeways in urban areas.

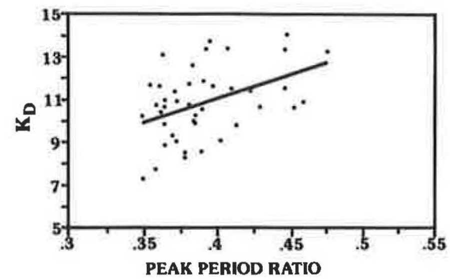

FIGURE 10 K_D factor versus peak-period ratio on radial freeways in urban areas.

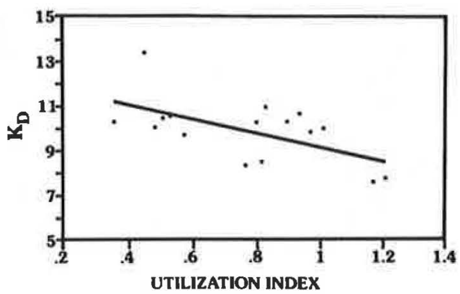

FIGURE 9 K_D factor versus utilization index on circumferential freeways in urban areas.

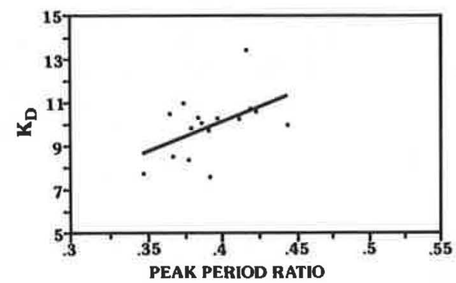

FIGURE 11 K_D factor versus peak-period ratio on circumferential freeways in urban areas.

as knowing the value of K_D; however, for planning purposes, a desired level of usage during the peak hour could be chosen and used as an input in estimating K_D. For example, choosing a utilization index of 0.9 might mean accepting an LOS of D in the peak hour. Overall, however, this variable is highly unpredictable and therefore not particularly useful, at least for radial freeways.

Peak-Period Ratio

The peak-period ratio, a rough measure of the length of the peak period, is calculated by dividing the highest hourly volume in the 3-hr peak period by the sum of the total volume in that peak period. A congested station with even use during all 3 hr of the peak period could have a peak-period ratio of 0.333; conversely, a station with traffic only during the peak hour and little traffic in the shoulder hours of the peak period would have a peak-period ratio approaching 1.0.

As the peak-period ratio decreases, the value of K_D also decreases, reflecting congestion and consequent travel increases outside the peak. Figures 10 and 11 show the correlation for radial and circumferential facilities, respectively. Although the data scatter is high for radial facilities, a pattern is discernible; for circumferential facilities, the correlation is weak or nonexistent.

Employment Density

Employment density is the measure of employment around the permanent count stations. The employment assumptions used in the traffic assignment models by the Texas SDHPT were incorporated into a variable. A block 2 mi by 1 mi, with the permanent count station at the center, was identified for each station, and the employment figures for all serial zones within the block were divided by the actual total area of the serial zones. Types of employment were not disaggregated.

As employment density increases, the value of K_D decreases. The increase in employment generates more trips in off-peak hours, which in turn results in lower values of K_D. The relationship of employment density and K_D is shown in Figures 12 and 13. Greater correspondence was found for circumferential facilities than for radial facilities.

Results of Statistical Analysis

In general, the results from the statistical analysis proved disappointing. Although some fairly strong correlations were found on an individual basis, multivariable regression analysis

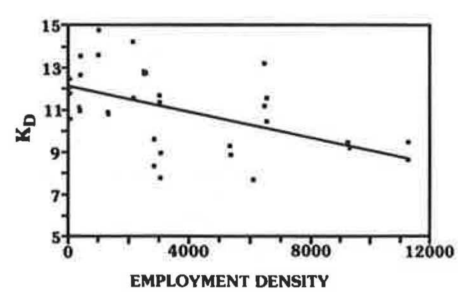

FIGURE 12 K_D factor versus employment density on radial freeways in urban areas.

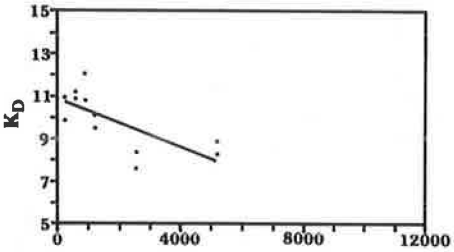

FIGURE 13 K_D factor versus employment density on circumferential freeways in urban areas.

failed to achieve a better correlation than $R^2 = 0.70$, unless AWDT per lane and the utilization index were used together, which violates statistical procedure because together they define K_D. Also, the models proved unstable from year to year.

The problem lies in the data base, which is extensive but problematical. After eliminating stations not reflective of demand (because of congestion) or not fully urban, too few stations remained to form a significant enough data set to establish a reliable predictive relationship for the variables tested. However, the methodology developed for analysis exhibits promise if a larger, usable data base were available. In recent years, several urban districts in Texas have been installing permanent traffic recording equipment for future surveillance systems. Therefore, advantage may be taken of the increase in permanent counting capabilities throughout urban areas to expand the data base, and it is hoped this type of regression analysis may eventually allow an estimate of K_D to be calculated directly.

Development of Reference Tables

The purpose of this research has been to develop a useful tool to aid in the selection of planning parameters for urban freeways. Because the models developed from the data base did not lead to estimations of K_D that were statistically reliable, a reference table was developed for use as a guide in determining reasonable ranges of K_D under various types of conditions. Before establishing this table, the data were further qualified by eliminating data constrained by peak-hour bottlenecks, stations with less than 10,000 vehicles per day per lane, stations farther than 15 mi from the CBD, and stations with less than 70 percent capacity utilization during the peak hour. This step eliminated the extreme variability found in stations not experiencing conditions reflective of appropriate design hours in urban areas. In effect, constrained stations fail to reflect demand, and underutilized facilities have simply not matured.

The ranges of K_D found for each of the variables are presented in Table 2, separated into radial and circumferential facilities. In general, K_D is lower for circumferential than for radial facilities for equal values of the variables. K_D falls as AWDT per lane increases, falls as the peak-period ratio rises (indicating a lengthening of the peak), and falls again as em-

TABLE 2 RANGES OF K_D FACTOR FOR RADIAL AND CIRCUMFERENTIAL FACILITIES

RADIAL			CIRCUMFERENTIAL		
AWDT/LN Range	Radial K_D	Correlation	AWDT/LN Range	Circumferential K_D	Correlation
10,000-15,000	10.0-14.0		10,000-15,000	10.0-11.0	
15,000-20,000	9.0-12.0	High	15,000-20,000	8.0-10.0	High
20,000 +	7.0-9.0		20,000 +	7.0- 8.0	
Employment Density	Radial K_D	Correlation	Employment Density	Circumferential K_D	Correlation
0-5,000	Highly Variable		0 - 5,000	9.0-11.0	
5,000-10,000	9.0-11.0	Medium	5,000-10,000	7.0- 9.0	High
10,000 +	7.0-9.0		10,000 +	No Data	
Distance	Radial K_D	Correlation	Utilization Index	Circumferential K_D	Correlation
0-3 miles	7.0-11.0		0.7-0.8	10.0-12.0	
3-5 miles	10.0-12.0	Medium	0.8-1.0	9.0-11.0	Medium
5 + miles	12.0-14.0		1.0 +	7.0- 9.0	
Peak Period Ratio	Radial K_D	Correlation	Peak Period Ratio	Circumferential K_D	Correlation
.33-.42	7.0-12.0	Medium	.33-.42	7.0-11.0	Medium
.42-.48	11.0-14.0		.42-.48	11.0-12.0	
Utilization Index	Radial K_D	Correlation	Distance	Circumferential K_D	Correlation
.7-0.8	Highly Variable	Low	0-3 miles	Highly Variable	Low
0.8-1.0			3-5 miles		
1. +			5 + miles		

ployment density increases. For radial facilities, K_D rises as the distance from the CBD increases; for circumferential facilities, it falls as the peak-hour utilization rises.

Table 2 allows a check on the reasonableness of K and D factors developed using current procedures. First, K_D must be calculated. Ideally, the data collected at the ATR stations could be reduced to provide K_D directly—the 30th-highest directional volume divided by the AWDT in the corresponding direction. However, if more precise data are not available, it can be approximated by use of the following formula:

$$K_D = 1.84 * K * D \quad (2)$$

This formula can be derived as follows:

$$K_D = \text{30th-highest-hour volume (one-way)} \div \text{AWDT (one-way)} \quad (3)$$

which can be approximated as

$$K_D = [\text{30th-highest-hour volume (two-way)} * D] \div [\text{AWDT (two-way)}/2] \quad (4)$$

$$K_D = \text{ADT} * K * D/(\text{AWDT}/2) = 2 * K * D * (\text{ADT}/\text{AWDT}) \quad (5)$$

The ratio ADT/AWDT has been found to vary by ATR station, but a reasonable value from the data is 0.92. Thus,

$$K_D = 2 * K * D * 0.92 = 1.84 * K * D \quad (6)$$

Table 2 can be used to check whether the calculated K_D falls into the ranges for the various variables observed from this data set. The ranges of K_D are divided into radial and circumferential facilities; for each facility type, the variables are listed in order of their correlation with K_D. Each variable is described by whether there is high, medium, or low correlation between that variable and K_D. If a calculated K_D falls outside the range of a highly correlated variable, there is evidence from the data set that the K_D should be adjusted. If a calculated K_D falls outside the range of a medium- or low-correlation variable, there may still be reason to consider a change in the calculated K_D.

CONCLUSIONS AND RECOMMENDATIONS

This research has focused on the process of selection of planning parameters used in the calculation of DHV and on determining the predictability of these parameters under measurable urbanization trends. The importance of precision has been established, in that design may be significantly affected by the assumptions implicit in the choice of the parameters. The major recommendation made from these findings is that those responsible for the selection of planning parameters should work closely with those responsible for design. To the greatest extent possible, local data on peak-hour traffic patterns should be provided to the planners to be incorporated into the selection of these parameters, and the variability along the corridor should also be accounted for, especially where ramps and direct connections are concerned.

The parameters K and D have been reduced to one parameter, K_D, to provide greater precision in the analyses, with K_D representing the 30th-highest directional volume as a percent of the average weekday directional volume (AWDT_D). It is recommended that this single parameter be provided for design purposes because 24-hr volumes from travel demand assignment models reflect weekday forecasts by direction, and thus the conversion to DHV can be made directly. Annual summaries of data from the ATR stations could also be revised to include the calculation of two new parameters: (a) an adjusted K factor that incorporates AWDT for weekdays only and (b) a K_D factor, defined as the 30th-highest directional hour divided by the AWDT for that direction.

The variables tested for significance included facility type (radial or circumferential), AWDT per lane, the degree of peak-hour utilization of the facility, the relative number of hours in the peak period, the relative distance from the CBD, and the adjacent employment density. Unfortunately, too little data were usable, which prevented development of a statistically reliable predictive model; however, as more permanent count stations come on line, this potential should be reevaluated. Increasing efforts toward developing freeway surveillance, communication, and control systems will result in many more usable data locations where 24-hr as well as peak-hour freeway volumes can be monitored by 15-min increments. These data will result in a wealth of opportunity to further address the predictability of K_D under varying circumstances.

Because reliable predictive models are not yet available, a set of ranges has been developed for K_D under a range of conditions for each variable, and these ranges are recommended for use as guidelines in checking the reasonableness of estimated K_D factors.

ACKNOWLEDGMENT

This research was sponsored by the Texas State Department of Highways and Public Transportation, in cooperation with FHWA, U.S. Department of Transportation.

Publication of this paper sponsored by Committee on Freeway Operations.