TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/TX-90/1196-1

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Development of Planning Values for Urban Freeways in Large Texas Cities

5. Report Date November 1989

6. Performing Organization Code

7. Author(s)
Carol Walters, Christopher Poe and Robert Stokes

8. Performing Organization Report No. Research Report 1196-1

9. Performing Organization Name and Address
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

10. Work Unit No.

11. Contract or Grant No. Study No. 2-10-88-1196

12. Sponsoring Agency Name and Address
Texas State Department of Highways and Public Transportation; Transportation Planning Division
P. O. 5051
Austin, Texas 78763

13. Type of Report and Period Covered
Final - September 1987 - November 1989

14. Sponsoring Agency Code

15. Supplementary Notes
Research performed in cooperation with DOT, FHWA.
Research Study Title: Development of Planning Values for Urban Freeways in Large Texas Cities

16. Abstract

Using data from automatic traffic recorders (ATR) for the years 1973 to 1988 in the Texas cities of Houston, Dallas, Fort Worth, Austin, and San Antonio, this project has studied the planning parameters K and D used to determine design hour volumes.Truck percentages during peak hours have been studied using data from 24-hour manual count stations from 1984 through 1987. Variables identified and tested for signicance in predicting directional K factors (K_d) included weekday ADT per lane, degree of capacity utilization during the peak hour, employment density near the ATR station, length of peak period, and distance from the CBD. Although correlations were found using individual variables, a multivariable regression and analysis produced a highly unstable model over time. Accordingly, ranges of K_d for ranges of each variable are provided for use in determining reasonableness of preselected K and D values. Truck percentages found during peak hours are rarely above 4 percent, except on truck routes or in industrial areas.

17. Key Words
K-Factor, Truck Percentages, Directional Split, Transportation Planning

18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

19. Security Classif. (of this report) Unclassified

20. Security Classif. (of this page) Unclassified

21. No. of Pages 78

22. Price

Form DOT F 1700.7 (8-69)

DEVELOPMENT OF PLANNING VALUES FOR URBAN FREEWAYS IN LARGE TEXAS CITIES

by

Carol H. Walters, P.E.
Associate Research Engineer

Christopher M. Poe
Engineering Research Associate

Robert W. Stokes
Associate Research Planner

Research Report Number 1196-1

Research Study Number 2-10-88-1196

Sponsored by

Texas State Department of Highways and Public Transportation

In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
Arlington, Texas 76011

November 1989

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac

MASS (weight)

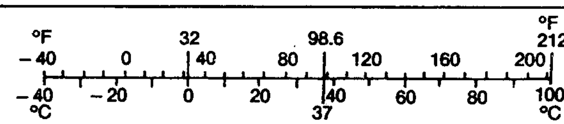
Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

Using data from automatic traffic recorders (ATR) for the years 1973 to 1988 in the Texas cities of Houston, Dallas, Fort Worth, Austin, and San Antonio, this project has studied the planning K and D used to determine design-hour volumes. Truck percentages during peak hours have been studied using data from 24-hour manual count stations from 1984 through 1987. Variables identified and tested for significance in predicting directional K factors (K_D) included weekday ADT per lane, degree of capacity utilization during the peak hour, employment density near the ATR station, length of peak period, and distance from the CBD. Although correlations were found using individual variables, a multivariable regression analysis produced a highly unstable model over time. Accordingly, ranges of K_D for ranges of each variable are provided for use in determining reasonableness of preselected K and D values. Truck percentages found during peak hours are rarely above 4 percent, except on truck routes or in industrial areas.

IMPLEMENTATION

The Texas State Department of Highways and Public Transportation continually reviews and updates its planning process. This study further develops techniques to estimate traffic planning parameters for individual projects so that more precise planning design can be accomplished. Tables reflecting the normal range of these parameters under various urbanized conditions have been developed. These should assist the Department in verifying the reasonableness of planning estimates made for these parameters under current procedures.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views of the Texas State Department of Highways and Public Transportation. This report does not constitute a standard, specification or regulation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES--CONTINUED

LIST OF TABLES

INTRODUCTION

The Texas State Department of Highways and Public Transportation (SDHPT) is responsible for the design, construction, maintenance, and operation of approximately 75,000 miles of highway on the state system. The cost of each of these efforts is directly related to the size of the facility. Therefore, if greater accuracy can be achieved in determining the needed size of a facility, then the SDHPT can be more effective in use of public funding.

Determining the size of a facility involves estimating how much traffic will use the facility during the design hour. Currently, the methodology involves estimating the 24-hour 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 in the design hour. The design hour volume is used to determine the size of the facility, which in turn affects the amount of right-of-way needed, the quantity of materials needed to build the facility, the design of the connections to other sections of freeway or arterial streets, and the effort needed to operate and maintain the highway. In rural regions where traffic volumes are low and right-of-way costs are 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 variability in the planning process can be very costly to the SDHPT. Decisions concerning which facilities can and cannot be justified as cost-effective, as well as the general mobility of a region are hinging on the estimation of the planning parameters.

Extensive research has been conducted on the development of traffic demand forecast models, design guidelines, and methods of construction, as well as optimum ways to maintain and operate our highways. However, there is one area of the planning and design process that has not been given the same detailed investigation as have these other elements. This area is the development of planning parameters: specifically the K-factor (ratio of 30th highest hour to annual average daily traffic), directional split in the design hour, and the percentage of trucks in the design hour. Moreover, the research that has been conducted in this area has concentrated on rural roadways with low ADTs. This research is unique in that it focuses on urban freeways with ADTs as high as 240,000 vehicles per day.

The objective of this research is to investigate whether improvements can be made in the estimation of planning parameters for urban areas and be incorporated in the planning process. This will be accomplished by studying statistical relationships and trend line analyses for K-factors, directional splits, and peak hour truck percentages by facility type, ADT, and location in urban areas.

LITERATURE REVIEW

The primary traffic parameters considered in the highway design process are those relating to traffic volumes, directional distribution of traffic, and traffic composition (1, 2). The basic unit of measure of traffic volume is the average daily traffic (ADT). While ADT is a useful measure of traffic demand, its direct use in the geometric design of highways is not appropriate because it does not indicate the variations in traffic during various months of the year, days of the week, and hours of the day. Current practice is to design highways on the basis of a directional design hour volume (DHV). The selection of an appropriate hour for design purposes typically involves a compromise between providing an adequate level of service for every (or almost every) hour of the year and economic efficiency (2).

Historically, the most commonly used approach in determining DHV involves developing a consistent, predictable relationship between the two-way ADT and the directional design hour (typically during the 30th highest two-way hour of the year) at a specific location. The proportion of the ADT occurring in the design hour is often referred to as K (2).

Although the traffic volume in each direction on two-way facilities tends to balance for longer time periods, such as a day, an imbalance of flow usually exists for the peak periods. For the same ADT, a multilane highway with a high percentage of traffic in one direction during the peak hours may require more lanes than a highway having the same ADT but with a lesser percentage of traffic in one direction. Therefore, a knowledge of the traffic load in each direction (directional distribution) is essential in geometric design (1). The proportion of traffic occurring in the peak direction of travel during peak hours is often denoted as D (2).

A number of procedures which attempt to establish relationships between directional distribution and factors such as time-of-day, facility type and orientation (i.e., radial, circumferential) have been tested. However, efforts to develop significant relationships have not been very successful (3). As a result, current practice is to use local data to develop estimates of D. If local data are unavailable, the Highway Capacity Manual (2) suggests the following approximations for use in the preliminary design of freeways:

Freeway Type	D
Urban Circumferential Freeways	0.50
Urban Radial Freeways	0.55
Rural Freeways	0.65

The K and D factors can be used to estimate the peak-hour, peak-direction traffic volume using the following equation (2):

$$DHV = ADT * K * D$$

The product of the K and D factors is tabulated for a number of facilities in Table 1. The product estimates the proportion of ADT occurring in the maximum direction of the peak hour.

The percentage of trucks, recreational vehicles, and buses in the traffic stream is also an important parameter in designing highways. Vehicles of different sizes and weights have different operating characteristics, which must be considered in highway design. Besides being heavier, trucks generally are slower and occupy more roadway space and consequently impose a greater traffic effect on the highway than passenger vehicles do. The overall effect on traffic operation of one truck is often equivalent to several passenger cars. Thus, the larger the proportion of trucks in a traffic stream, the greater the traffic load and the highway capacity required (1). Current practice is to develop local estimates of the percentage of heavy vehicles (trucks, buses and recreational vehicles) in the traffic stream and to adjust for the presence of these heavy vehicles using the procedures and factors described in the Highway Capacity Manual (2).

Researchers and highway designers have raised a number of questions concerning the validity of current approaches to establishing DHV's. The following sections of this chapter discuss these concerns in detail and present an outline of several alternative approaches that have been suggested to address these concerns.

Table 1. Peak Directional Volumes as a Percent of ADT (K X D X 100) on Freeways and Expressways

City and 1970 Urbanized Area Population	Facility	Number of Lanes	Year	Average Daily Traffic	Peak Directional Volumes: Vehicles	Peak Directional Volumes: Percent of ADT
Atlanta, GA	I-20 E. of CBD @ Moreland Ave.	6	1975	105,100	5,980	5.7
1,172,778	I-75 S. of CBD @ University Ave.	6	1975	110,800	6,200	5.6
	I-20 W. of CBD @ Mozley Drive	6	1975	78,600	4,450	5.7
	I-75 N. of CBD (N. of I-85)	6	1975	72,800	4,500	6.2
	I-85 N. of I-75 @ Monroe Drive	6	1975	90,100	5,500	6.1
Boston, MA	I-93 @ Stoneham Town Line	6-8	1975	80,300	6,270	7.8
2,652,575	S.E. Expressway @ Southampton	6-8	1975	129,000	7,060	5.4
	Rt. 128 @ Burlington Town Line	8	1975	86,400	5,660	6.6
Chicago, IL	Lake Shore Drive @ 49th Street	6-8	1975	61,100	4,120	6.8
6,714,578	Lake Shore Drive @ Aldine	8	1975	117,000	9,380	8.0
Denver, CO	I-25 between 38th Ave. and I-70	6	1974	145,000	7,500	5.2
1,047,311	I-225 between I-25 and Washington St.	6	1974	105,000	5,400	5.1
Detroit, MI	Ford Fwy. (I-94) @ Chrysler Fwy.	6	1975	161,500	5,570	3.4
3,970,584	Jeffers Fwy. (I-96) @ Warren		1974	72,100	4,850	6.7
	Southfield Fwy. (M39) @ Plymouth	6	1973	142,100	6,210	4.4
	Lodge (M10) @ Pallister	6	1972	173,000	5,310	3.1
	Fisher Fwy. @ Lodge	6-8	1972	118,100	5,310	4.5
Houston, TX	I-45 (S) @ Woodbridge	6	1976	106,600	4,910	4.6
1,677,863	US 59 (S) @ Montrose	10	1976	145,900	8,470	5.8
	US 59 (S) @ Rice Ave.	8	1976	162,700	6,730	4.1
Houston, TX	I-45 (N) @ North Loop	8	1976	121,900	7,420	6.0
	I-10 (E) West of Waco St.	8	1976	117,600	7,090	6.0
	I-610 (W) @ Buffalo Bayou	8-10	1976	174,400	9,520	5.4
	I-10 (E) @ North Main	8	1976	125,300	6,640	5.3
	I-10 (W) @ Taylor St.	10	1976	109,500	7,600	6.9
	I-610 (S) West of Main	8	1976	100,300	6,700	6.7
Milwaukee, WI	N-S Fwy. @ Wisconsin		1975	90,310	5,260	5.8
1,252,457	N-S Fwy. @ Greenfield		1975	96,770	5,780	6.0
	E-W Fwy. @ 26th Street		1975	93,280	5,000	5.4
	Airport Fwy. @ 68th Street		1975	62,300	3,520	5.7
New York City, NY	Long Island Expressway	6	1973	165,000	5,300	3.2
16,206,841	FDR Drive	6	1974	117,000	4,400	3.8
	Holland Tunnel	4	1974	61,400	2,400	3.9
	Lincoln Tunnel	6	1974	97,300	4,900	5.0
	Brooklyn-Battery Tunnel	4	1974	46,700	3,400	7.3
San Francisco, CA	Oakland-Bay Bridge (I-80)	10	1973	184,000	8,120	4.4
2,987,850	Southern Fwy. (I-280)	8	1969-73	114,000	6,150	5.4
	Golden Gate Bridge (US 101)	6	1969-73	92,000	5,720	6.2
Washington, DC,	Shirley Hwy. (N. of 4 Mile River)	8	1975	136,000	8,010	5.9
MD, VA	Center Leg Freeway	8	1975	68,000	3,410	5.0
2,481,489	I-95 Bridge (over Potomac)	8	1975	142,700	6,260	4.4
	Baltimore-Washington Pkwy. (District Line)	6	1975	101,300	4,930	4.9
	Woodrow Wilson Bridge	6	1975	97,800	4,620	4.7

Source: Ref. 2.

Current Practice in Determining DHV

For over forty years, the number of lanes required on proposed roadways has been based on hourly traffic volumes. Use of this hourly flow is compatible with conventional measures of capacity and levels of service, and with the availability of an extensive data base from automatic traffic recorders (ATRs); in addition, an hour is a short enough time period to reflect temporal variations of flow throughout the day (4). A major decision for the designer, then, is selecting the most appropriate hourly volume.

In 1921, Johnson (5) suggested that "the average daily traffic throughout the year does not give the number of vehicles that should be provided for, due to the seasonal and hourly variations in the volume of traffic. A road must carry comfortably the usual increase over the average traffic that comes regularly at certain seasons and during certain hours of each day (4)." In 1936, Peabody (6) cautioned against the other extreme by noting that "it is not economical to design surface widths and intersections for a free flow of traffic during those extreme peaks that occur once or twice a year. At such times, some sacrifice must be made in freedom of flow to accommodate the increased volume (4)."

According to a 1979 Institute of Transportation Engineers (ITE) Committee report (4), the basis for current practice in treating fluctuations in hourly traffic volumes was established by Peabody and Normann (7), who suggested that when hourly volumes are ordered and plotted for a year, the volumes change rapidly for the highest 30 hours, but change much more gradually after the highest 50 hours. This has since been referred to as a "knee-of-curve" concept (4). As a consequence, Peabody and Normann suggested that, "it is impractical to design for a greater hourly volume than the value which will be exceeded only during the 30 peak hours each year and that little will probably be saved in the construction cost and a great deal lost in expediting the movement of traffic if a design is used that will not handle the traffic volume exceeded during the 50 peak hours (4)."

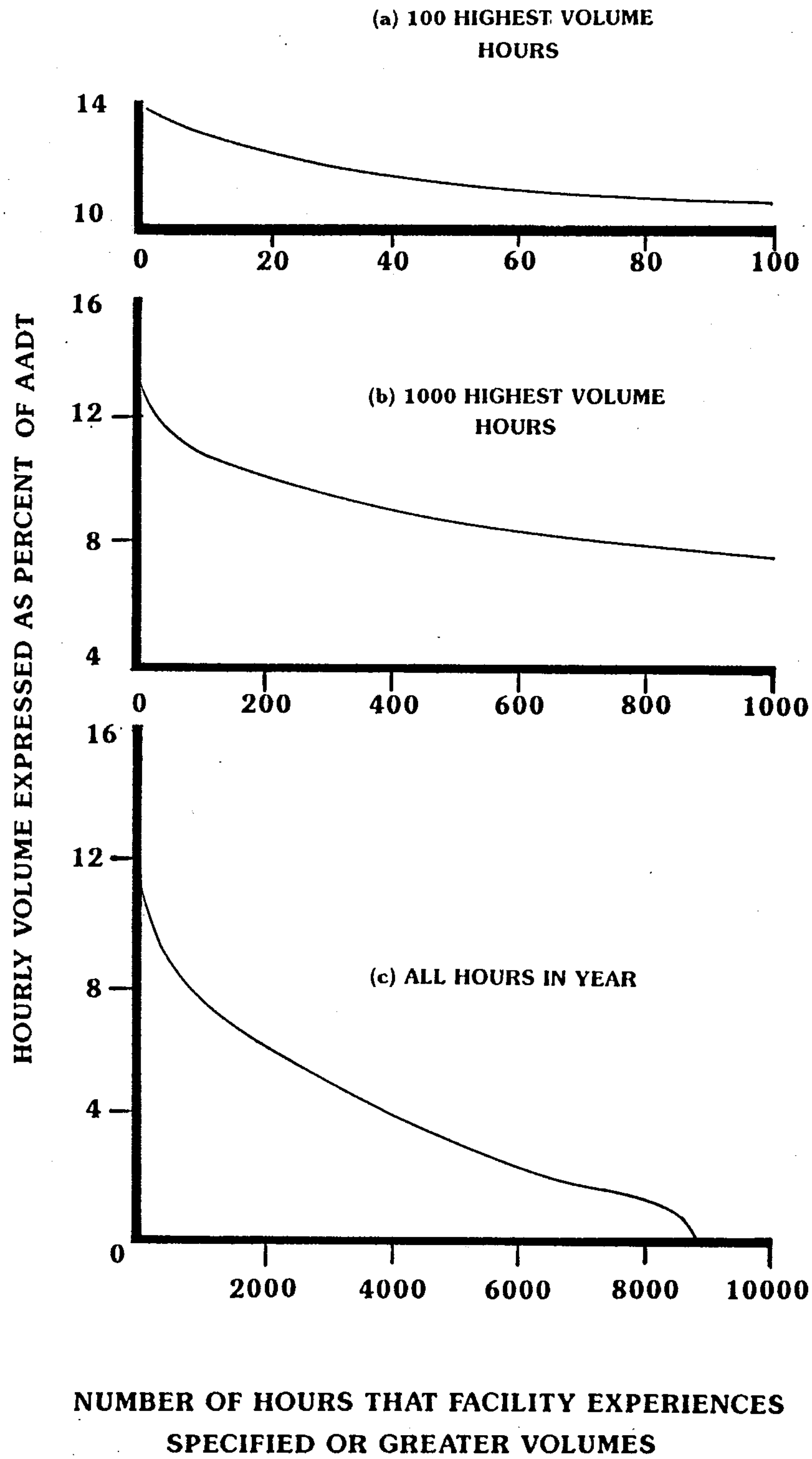
The most authoritative, current recommendations concerning selection of a design traffic volume are those advanced by the American Association of State Highways and Transportation Officials (AASHTO) (1), which recommends basing highway design on an hour between the 10th and 50th highest hour of the year. This range generally encompasses the "knee" of the curve (the area in which the slope of the curve changes from sharp to flat). For rural highways, the knee has often been assumed to occur at the 30th highest hour, which is often used as the basis for estimates of design-hour volume. For urban highways, a design hour in the range of the 10th to 20th highest hour is common (1,2).

The proportion of ADT occurring in the design hour is often referred to as K (2). It is expressed as a decimal, and varies based on the hour selected for design and the characteristics of the subject route and its development environment. Where the K-factor is based on the 30th highest hour of the year, several general characteristics can be noted (2):

1. The K-Factor generally decreases as the ADT on a highway increases.
2. High K-factors decrease faster than for lower values.
3. The K-factor decreases as development density increases.
4. The highest K-factors generally occur on recreational facilities, followed by rural, suburban, and urban facilities in descending order.

While arguments for "knee-of-curve" approaches have a certain intuitive appeal, there does not appear to be any objective evidence which supports the contention that the volumes associated with the knee-of-the-curve are, in fact, the most economical volumes for use in design (4). Several studies (2, 8-10), for example, have emphasized the difficulty in locating a distinct "knee" on hourly volume curves. Figure 1 shows hourly volumes for all hours of the year at a Kentucky counting station. The first and third curves illustrate the continuous nature of the relationship, with no distinct breaks or "knee" in the decreasing hourly volume pattern. The second curve shows a rather spreadout "knee" which could easily be located anywhere within the first 100 hours. These curves illustrate the point that arbitrary selection of a design hour between the 10th and 50th highest hours is not a rigid criterion, and points out the need for local data on which to make informed judgments (2). However, if local information is unavailable, the Highway Capacity Manual (2) suggests the following approximations for K in preliminary design of freeways:

Freeway Type	K
Urban Freeways	0.07 - 0.10
Suburban Freeways	0.10 - 0.15
Rural Freeways	0.15 - 0.20



Source: Ref. 2

Figure 1. Ranked Hourly Volume Distribution Showing Indistinct "Knee"

Planning highway facilities for future use requires predicting the DHV for the design year. This is commonly approached by projecting the ADT for the design year, and then applying a K-factor. The K-factor, in turn, is typically projected as a constant in time, or a selected value that seems appropriate for the type of facility and traffic (4).

Early studies (prior to 1950) found that the ratio between the 30th highest hour and the ADT varied little from year to year on a given facility (4). However, Walker (11), utilizing data collected from 160 rural ATRs over an eight-year period found both declines and increases in the K-factor, with over 71 percent of the highways experiencing declines. Although the mechanism for change is fairly complex, he found a tendency for the K-factor to decline as ADT grows to over 3,000, or if the initial K-factor is greater than 0.15 (4).

Walker notes that "if there is any tendency for the [K] factor to become either larger or smaller with the passing of time, then the rate of change should be determined so that appropriate adjustment can be made in the design-hour volume for any future year. Unless proper adjustment of the factor is made, facilities designed for future traffic will be either overdesigned for their traffic load or they will become congested in a shorter period of time than anticipated, even though the future daily traffic is accurately predicted" (11).

A 1979 ITE Committee report (4) summarized the results of a 1972 Michigan study (12) which analyzed data collected since 1936 on the state's system of automatic traffic recorders. The Michigan study found that, on the average, the K-factor tends to decline with time. However, the rate of decline varied from route to route, and an increasing trend was noted on a few routes. Statistical regression analysis techniques were applied to the historical K-factor data. Fairly good correlations were obtained when the rate of decline was viewed as dependent on both the initial value of the K-factor and the initial ADT. In essence, the K-factor declines less rapidly (as a percentage) on higher volume roads, and more rapidly for roads with higher initial K-factors. The data in Table 2 illustrates these findings (4).

Table 2. Annual Rate of Change of K-Factor (percent)

	Initial K-Factor (percent)		
Initial ADT	10.1 to 15.0	15.1 to 20.0	20.1 +
0 to 2,000	- 0.1287	- 0.2489	-0.6532
2,000 to 6,000	- 0.0985	- 0.2786	-0.6006
6,000 +	- 0.0969	- 0.2129	No Data

ource: Reference 4

Bellis and Jones (13), in a 1963 study that used data from 69 traffic count stations that had been in operation in New Jersey for 10 years, observed downward trends in K-factors comparable to those reported by Walker (11). Bellis and Jones drew the following conclusions from their study (13):

1. The 30th peak hour factors generally decline as the ADT increases.
2. The reduction rate for high 30th peak hour factors is much greater than for low 30th peak hour factors.
3. Low population and sparsely developed areas, on the average, have a high 30th peak hour factor. Any marginal growth, such as housing developments, industry, or shopping centers, tends to lower the design hour factors.
4. Population changes in an area influence the DHV factors accordingly; an increase in population decreases the factors.
5. The capacity of a roadway has no great influence on the DHV factors or the rate of change. It is the increase in ADT due to the increase in the off hours that tends to reduce the DHV ratio to the ADT. Nevertheless, it is recognized that logically, when the potential 30th peak hour volume greatly exceeds the possible (absolute) capacity (such as may be experienced when the number of lanes are reduced for construction), the 30th peak hour factor may be reduced. But this is not supported by the study.

The majority of the studies reviewed suggest that the K-factor is a function of ADT and that it decreases when ADT increases. Sharma and Oh (14) suggest that this may be an oversimplification of the relationship between the K-factor and ADT. Using data from 75 permanent traffic counting stations in Alberta, Canada, Sharma and Oh (14) found that the type of road-use has a great influence on the value of the K-factors. The highest K-factors were found on routes near popular recreation areas, and the lowest K-factors occurred on urban commuter routes. The factors for typical rural routes showed intermediate values. For a given type of road use or nature of travel, the K-factors did not vary significantly with respect to ADT (14). Sharma and Oh (14) conclude that while K-factors may appear to decrease with an increase in ADT, the real cause of the decrement of K-factors is the changing nature of travel or the proportion of the various types of trips, rather than the amount (ADT) of travel.

Other Approaches for Determining DHV

Cost Effectiveness Approach (4)

This approach would base the selection of the DHV on the results of traditional cost-effectiveness analyses (e.g. benefit-cost analysis) in which a comprehensive list of the impacts (both favorable and unfavorable) of alternative courses of action are developed for analysis, evaluation, and decision.

Use of a Range of Design Hours (4)

It has been suggested that for those highways where capacity and level-of-service are important features in a decision process, one should neither be limited to nor automatically select the 30th highest hour as the basis for facility type selection. Rather, a range of top hours should be studied, possibly using the highest 500 hours as a basis for analyzing alternative facility types with respect to providing a desired level-of-service.

DHV from the User's Perspective (4)

The traditional approach of selecting the 30th highest hourly volume as the DHV permits the roadway to experience higher congestion for the 29th highest volume hours of the year, with no consideration as to the amount of congestion and the proportion of the total number of road users who experience this congestion during these 29 highest hours. One approach to providing more uniform service to the users (as contrasted with providing facilities which are equally utilized) is to select a design hour that will provide the desired level-of-service for all but a specified percentage of user hours of travel. This approach has been suggested as a more rational philosophy because it tends to provide more equitable service when measured in terms of user hours of travel.

Traffic Assignment Models (15)

For large urban areas, it has been suggested that instead of forecasting ADT and relying on link specific factors to estimate DHVs, consideration should be given to the development of DHVs from peak hour traffic assignment models. Use of peak assignment models could eliminate the need for the K-factor and could automatically account for directionality. However, peak hour/peak period assignment models are in the early stages of development, and efforts to develop reliable methodologies to predict current and future peak hour conditions based on 24-hour volumes should not be abandoned.

Summary

Planning and designing highways to meet future needs requires predicting the DHV for the design year. Historically, link specific traffic parameters (i.e., K, D, and T factors) have been used to estimate the future DHV from the predicted design year ADT. In practice, highway designs have typically used a DHV concept based on the 30th to 50th highest hourly volume in a year. The predicted DHV is then compared to roadway capacity to determine the extent of improvement needed.

The preceding review of current practice has identified a number of issues regarding the validity of conventional approaches to determining current and future DHV's. For example, there is considerable evidence that K factors vary substantially by roadway location (urban, suburban, rural), roadway type (radial, circumferential) and by trip purpose. Moreover, previous studies have shown that K factors vary considerably over time. Additional research is needed to develop estimation procedures that are sensitive to these spatial and temporal variations in K factors.

CURRENT PRACTICE OF TEXAS SDHPT

Planning and designing highways in Texas is a joint process between the Design Division of the SDHPT in Austin (D-8), individual district offices of the SDHPT, the regional planning offices of the SDHPT, and the Planning Division in Austin (D-10).

Roles of D-8 Design Division and D-10 Planning Division

Supervised by D-8, proposed projects compete on a statewide basis for funding, based upon a formula which incorporates projected vehicle-miles per travel including latent demand on existing congested facilities, and estimated cost of the facility. Future demand in urban areas is usually a combination of regional travel demand models and latent travel demand. Latent travel demand can be estimated from a predictive equation used by the SDHPT which incorporates existing volume-to-capacity ratio, increase in capacity, and facility type. This equation was developed from a limited amount of actual traffic data and exhibits a correlation coefficient of 0.67.

Once a project is approved for planning, 24-hour traffic projections are needed to aid in the geometric and pavement design, determine right-of-way requirements, and allow environmental assessment. D-10, with the aid of the regional planning offices, is responsible for projecting 24-hour traffic volumes on highways, ramps, and frontage roads for a given design year. The process incorporates use of the travel demand assignment models, existing and historical traffic volume counts, and field investigations.

Along with the 24-hour traffic volume projections, D-10 estimates the planning parameters K, D, and T for a facility and a given design year. The planning parameters are used by the district offices to calculate design hour volumes for sizing a facility, designing elements of a facility, and evaluating the environmental impacts of a project. Typically, the closest permanent count station on a similar facility is examined for input into the planning parameters. The travel demand assignment models used in developing design year volumes predict expected average weekday traffic (AWDT) volumes on any given facility. However, the data that is historically collected from the permanent count machines are summarized by average annual daily traffic, including holidays and weekends, and K-factors are developed accordingly. Use of average annual daily traffic produces higher K-factors than is appropriate for use with the average weekday traffic which is produced from the models. An adjustment should be made to these factors before calculating design hour volumes on facilities.

Role of the District Offices

The district offices are provided 24-hour traffic volume projections for the design year of a facility and design parameters for the corresponding design year. With this information, the design-hour volume can be calculated for any segment of freeway, ramp, or frontage road. Hence, the design-hour volume is determined with the estimation of the planning parameters. From the design-hour volume and assuming a per lane capacity for the roadway, the number of lanes on the facility can be identified.

Issues and Concerns

There are some concerns about the planning procedure that have been presented by both the planning division in Austin and the district offices. First, in the current planning process, an estimation is made of each of the planning parameters and then used in an equation of the following form to estimate the design-hour volume, and the required number of lanes:

$$\#\ \text{Lanes} \simeq \text{ADT} \times \frac{[K \times D \times (1+T)]}{[\text{Service Volume}]}$$

There is a range of possible values for each of these parameters, and thus an error associated with each estimation. When these parameters are multiplied together in the equation for estimating design hour volume, the corresponding range of potential "error" is also multiplied. Table 3 shows each of the planning parameters, the usual 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 would all be expected to fall, while the expected service volume would probably rise. Thus, all the "errors" would accumulate, rather than counteracting one another, if the urbanization trend is underestimated. Even if the ADT projections were exact, the magnitude of the "error" in design could be over 50 percent.

Table 3. Effect on Design Due to Variation in Parameters

Factor	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%

Second, the current planning procedure is fairly rigid. The selection of the planning parameters inherently decides the questions about the size of a facility. There is a need for the district offices to incorporate more local information and data at the planning stage. Flexibility and communication regarding selection of parameters between the planning division and the district offices are desirable.

Third, each element of a freeway is designed for its design-hour volume; however, these design hours may not occur at the same time. For example, the mainlanes of a freeway, an entrance ramp, and an exit ramp all must be designed for their design hour volume. 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 because each element may not peak at the same time. Again, the need for local data on travel patterns and behavior of each of the freeways is apparent.

METHODOLOGY FOR ESTIMATING PLANNING PARAMETERS FOR URBAN FREEWAYS

The methodology for estimating planning parameters for urban freeways included examining the data base from the automatic traffic recorder (ATR) stations and the manual count stations. From the count stations in urban areas, the K-factor and directional splits could be examined. From the manual count stations, the vehicle classification could be used to study the daily and peak hour truck percentages. The variables that influence the value of each parameter, along with general trends, could be identified for each of the planning parameters. Then, using regression analysis, a statistical model could be developed to estimate those appropriate parameters. Finally, reference tables could be developed for aid in choosing the appropriate planning parameters for freeways in urban areas.

Automatic Traffic Recorder Stations

The Texas SDHPT has an extensive automatic traffic recorder (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 data is now collected over leased telephone lines in Austin and reduced by the D-10 staff.

The annual report that summarizes the ATR data includes the ADT, the ranking of 24 of the highest 200 two-way volumes with their corresponding K-factor (ratio between each high hourly volume and ADT) and associated directional split, the change in ADT over the past years, average daily traffic volumes summarized by day of week and by season, and average hourly volume for each day of the week.

The Texas Transportation Institute (TTI) obtained the raw data from the ATR stations on tape for the past 15 years. This allowed a look at every hour of the year by direction. The first requirement was to classify which stations represented urban conditions. An initial list of 50 stations was developed based on the station's location within the five major urban areas of Texas: Austin, Dallas, Fort Worth, Houston, and San Antonio. These stations are shown in Figure 2. For each of these stations, the first 100 hours for each year in each direction were extracted by date, time of day, and day of the week, along with

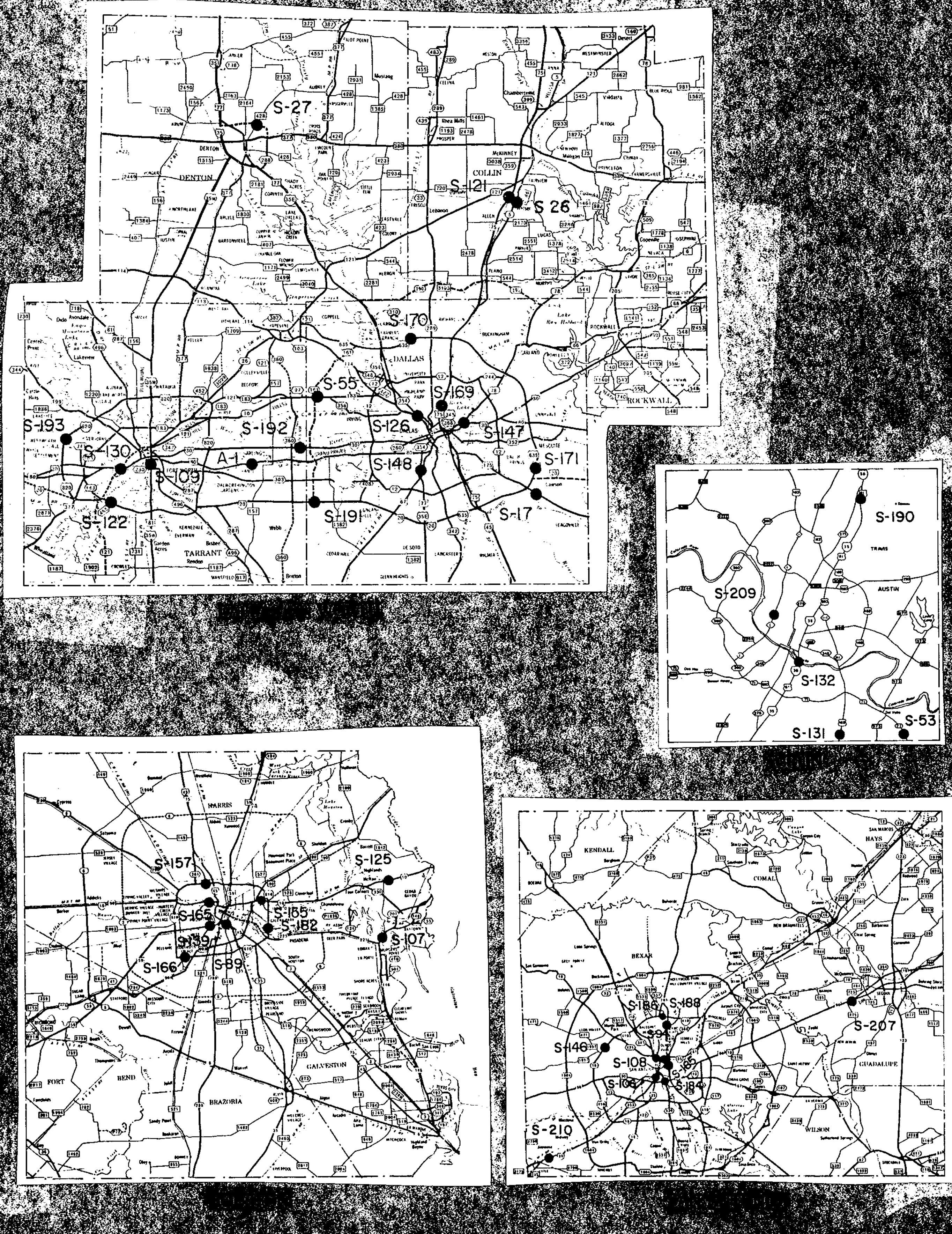


Figure 2. Location of AIR Stations

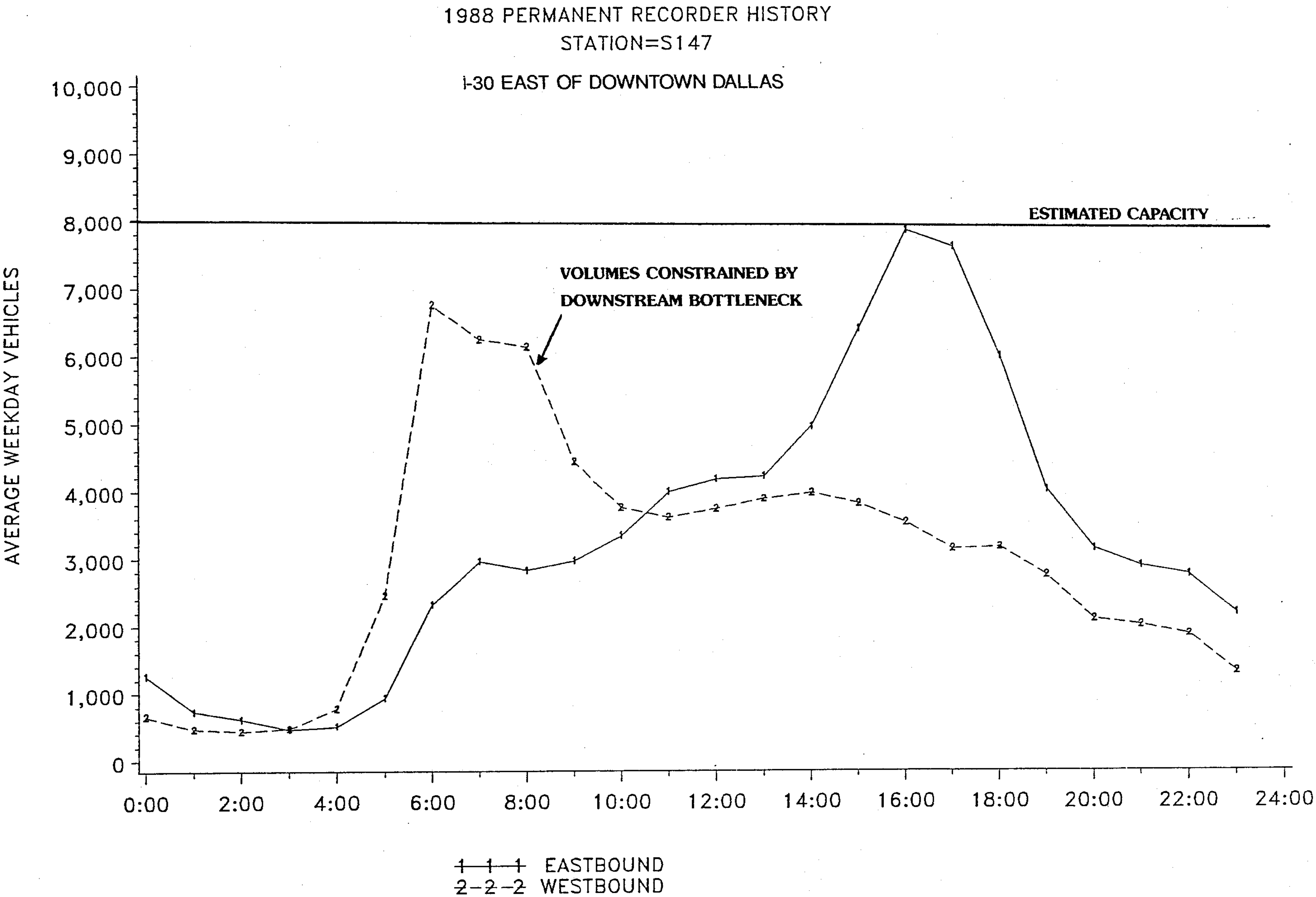
the ADT and AWDT by direction for that year. Volume profiles for the average volumes for each hour of the day by direction were also developed.

Some problems with this data base quickly became evident. First, the location of the stations in the urban area in relation to system constraints and bottlenecks greatly influences the data at each of the stations. Stations located upstream of bottlenecks tend not to reach their theoretical capacity because the bottleneck creates stop-and-go conditions, reducing capacity. This is evidenced by truncated peak profiles, as shown in Figure 3; these conditions have also been field checked by TTI. Similarly, stations located downstream of bottlenecks in effect record a metered volume, since not all of the demand can reach that section of freeway. This often results in lower volumes in one direction than in the other, as shown in Figure 4.

Second, frequently stations are located after exit ramps and/or before entrance ramps. The volumes at the count station may appear well below theoretical capacity when actually the freeway is operating at capacity in the peak hour, because the ramps before and after the station carry significant traffic volumes that do not pass over the count station.

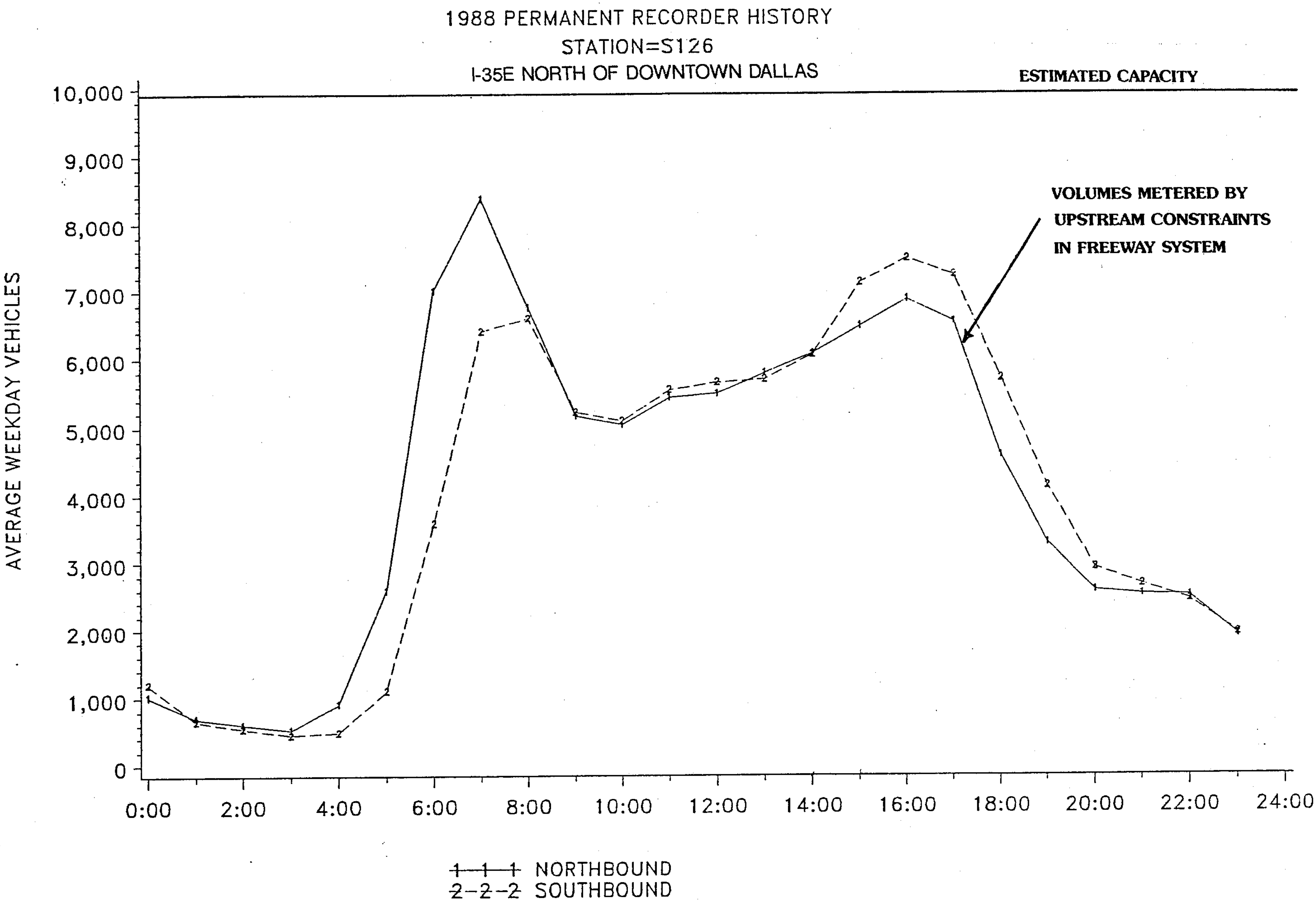
Third, because the count stations collect data by clock hours (i.e. 12:00, 1:00, 2:00, etc.), the actual highest hour of the day may not be detected if it falls between hours; for example, the evening peak hour may be from 4:30 p.m. to 5:30 p.m. When examining the data, if two hours during the peak period have the same volume, it may be due to the peak hour being split between the two clock hours, even demand between both hours, or a constraint in the system causing trips to be spread throughout the peak period. Therefore, a microscopic understanding of how traffic operates at each count station and a macroscopic understanding of travel patterns and constraints of the entire system were needed to fully interpret data at each of the stations.

Fourth, if permanent count stations in the major urban areas are subdivided into radial facilities and circumferential facilities, the permanent count stations on radial facilities are clustered within 1 to 4 miles of the downtown central business district (CBD). Many times there are bottlenecks and constraints in the freeway system within this distance of a CBD. There is another cluster of permanent count stations between 14 and 20 miles from the CBD, but these tend to fall beyond the definition of an urban freeway.



NOTE : HOLIDAYS ARE NOT INCLUDED IN THE WEEKDAY AVERAGE
SOURCE : SDHPT PERMANENT HISTORY TAPE

Figure 3. Volumes Constrained by Downstream Bottleneck



NOTE : HOLIDAYS ARE NOT INCLUDED IN THE WEEKDAY AVERAGE
SOURCE : SDHPT PERMANENT HISTORY TAPE

Figure 4. Volumes Metered by Upstream Constraint

Permanent count stations on circumferential facilities cluster around 6 to 10 miles from a CBD since the major loops around urban areas are within this distance of the CBD.

Fifth, usually there is only one K-factor given for a section of freeway under design. However, the characteristics of a freeway may change through the study limits of a freeway. Because there are no freeway corridors with two permanent count stations, it was not possible to study how K-factors changed within a corridor.

Sixth, some ATR stations, while in "urban" areas are carrying such low traffic volumes that their inclusion in this study was inappropriate. Accordingly, all stations with less than 5000 AWDT/lane were discarded, as were those more than 15 miles from the CBD.

Recognizing these limitations, the data from the ATR stations were further analyzed in hopes of improving upon procedures used in developing the planning parameters. The results of this analysis will be discussed later in more detail as it relates to each of the planning parameters.

Manual Count Stations

The SDHPT also manually collects vehicle classification data at approximately 50 manual count stations surrounding urban areas around the state. These manual count stations are at different locations from the ATR stations, with only a few in common with the permanent count stations. At least one day every three years, data collectors classify vehicles for 24 hours at each of the stations; many stations are counted every year. The SDHPT only keeps records of these complete counts for three to four years; summarized data is published yearly. TTI was given access to tapes of these manual count station data for use in identifying daily truck percentages and truck percentages during the peak hour.

Some of the concerns outlined above for the permanent count stations apply to the manual count stations as well. Additionally, there are fewer manual count stations in the urban areas, and no manual count stations exist on radial facilities inside any of the circumferential freeways in any of the major urban areas. Figure 5 shows the locations of manual count stations in the five major Texas cities.

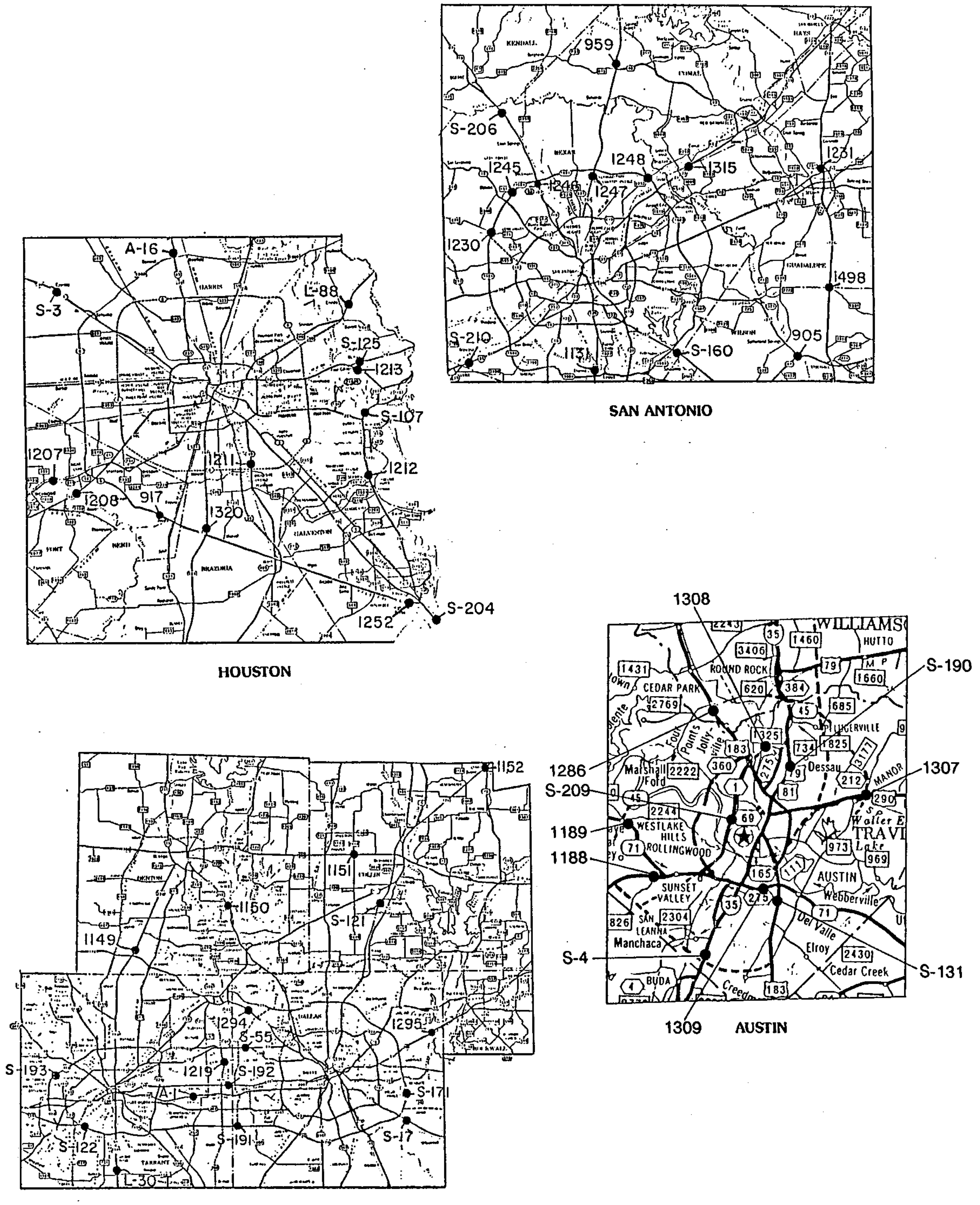


Figure 5. Location of Manual Count Stations

K-FACTOR AND DIRECTIONAL SPLITS FOR MAINLANES

As discussed before, there is greater error introduced in making two estimations than in making only one estimate. Because the raw data were available to calculate a K-factor by direction, a new variable K_D was examined that would eliminate the need to estimate directional split. There were other reasons for examining K_D besides eliminating the number of estimations. First, there is a wider range in values of K_D than K as shown in Table 4.

Table 4. Ranges of K_D and K

Variable	Range
K	7.5 - 11.5
K_D	7.5 - 14.5

Second, the traditional K uses the two-way peak hour volume. Patterns in the directional peak hour volume are hidden when combined with the off-peak volume. Examination of the peak hour volume by direction was more descriptive of the individual stations. Third, frequently the K_D is different by direction at each of the stations due to system constraints and bottlenecks. Fourth, defining a new term such as K_D allows the introduction of weekday ADT, as mentioned earlier, to more precisely fit the output from travel demand models. Thus, K_D is defined as the 30th highest directional hour, divided by the weekday ADT for that direction.

General Trends in K_D and K

Examination of the data from the permanent count stations reveals some general trends in K-factors and K_D factors. However, it must be kept in mind what the data represent. The stations record data at only one point along the freeway corridor; this point may or may not be representative of the overall characteristics of the freeway corridor, depending on the location of the station. Also, each freeway is designed for a specific design year. During any given year, the stations are collecting data from a freeway that may be maturing towards its design year, be in its design year, or be far beyond it. For example, some freeways may not have reached their design year and therefore might have high K-factors, while other freeways might be long past their design year and may have K-factors much lower than anticipated.

There are some general trends in K_D and K-factors at the permanent count stations that can be summarized. First, previous literature discussed a plot of the K-factor with relationship to the ranked hour of the year which formed a "knee of the curve." The "knee" may vary from location to location. In urbanized areas, there has been a flattening out of the "knee." A few locations in Dallas are plotted in Figure 6 along with the traditional rural curve that appears in the AASHTO Green Book. The curve denoted with the diamonds is a less-developed location within the Dallas urban area. This curve has a slight "knee" between the 10th and 20th hours. However, the remaining curves are for significantly urbanized areas in the Dallas region. These curves have almost no "knee," and do not vary much within the first 100 hours.

Second, low K-factors do not necessarily correspond to sites with heavy congestion. There are sites where the congestion is so heavy in the peak hours that trips are being made in off-peak hours causing the K-factor to decrease. However, low K-factors are also a result of trip-making characteristics during the day. Some of the stations recorded even usage throughout the day, resulting in a low K-factor, without ever fully reaching capacity in the peak hour. Figure 7 illustrates such a pattern. Additionally, some stations located near bottlenecks or constraints in the freeway system in the peak hour could not be fully utilized in the peak hour, although there were few constraints during off-peak hours for vehicles to use the facility. This also produced a low K-factor.

Third, K-factors generally decrease over time. For this study, there were fifteen years of data from the permanent count stations to examine (1973 - 1988). Only 24 stations had data for this entire period. Of the 18 radial facility sites, 17 sites observed a decrease in K_D; and out of the 8 circumferential sites, 6 sites had a decrease in K_D. The change in K_D at each of the radial sites is shown in Figure 8, and at each of the circumferential sites in Figure 9.

The magnitude of the change in K_D varied from station to station. There were both large and small changes in K_D for stations with both high and low initial K_Ds. Because each of the stations is at a different point in the maturity of the facility, it was decided that as volumes, land development, and trip-making characteristics changed over time, other variables would account for the change in K_D over time.

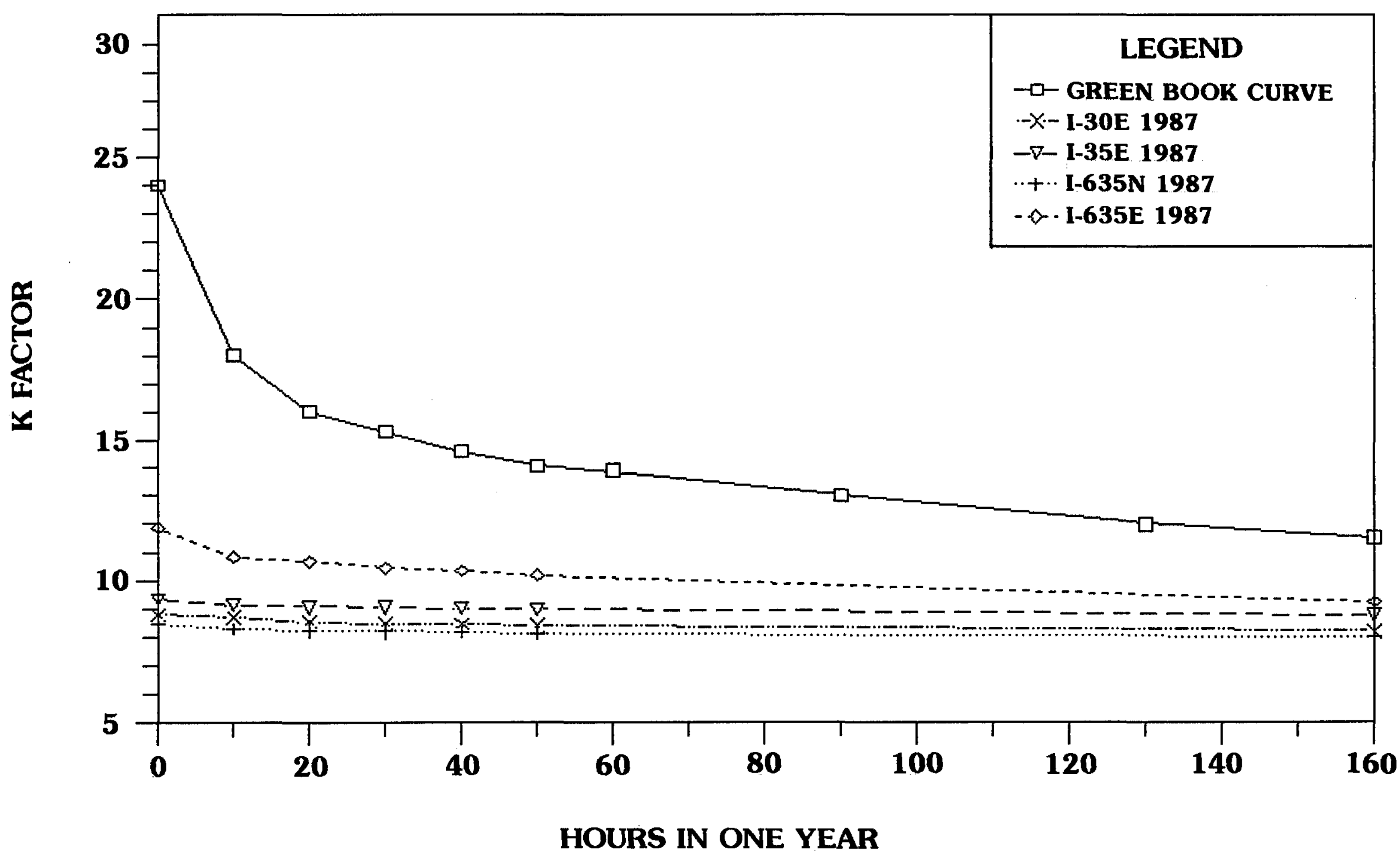
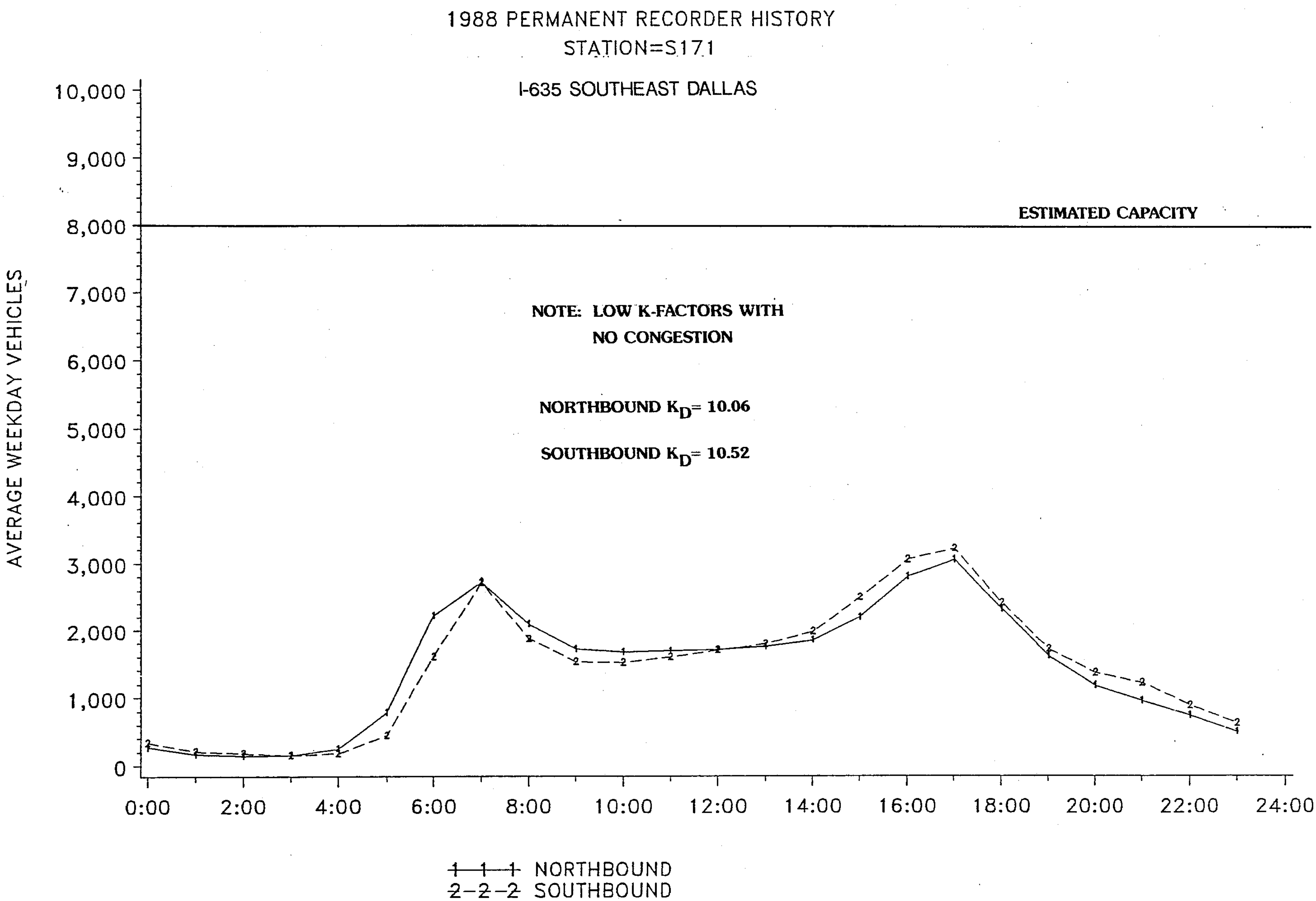


Figure 6. Relationship Between Peak Hours and ADT



NOTE : HOLIDAYS ARE NOT INCLUDED IN THE WEEKDAY AVERAGE
SOURCE : SDHPT PERMANENT HISTORY TAPE

Figure 7. Low K_D With No Congestion

TEXAS URBAN AREAS 1973 - 1988

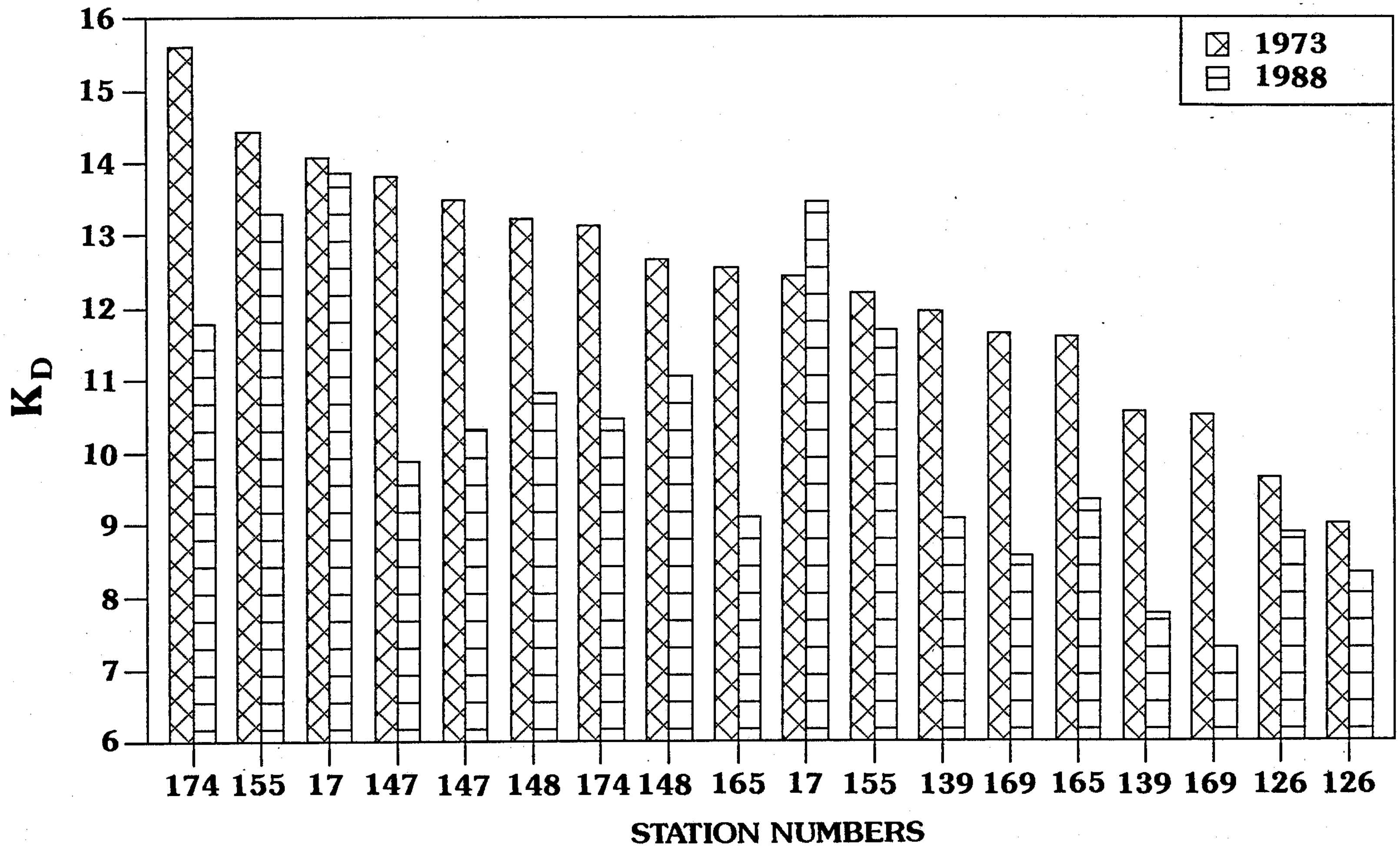


Figure 8. K_D -vs- Time--Radial Facilities

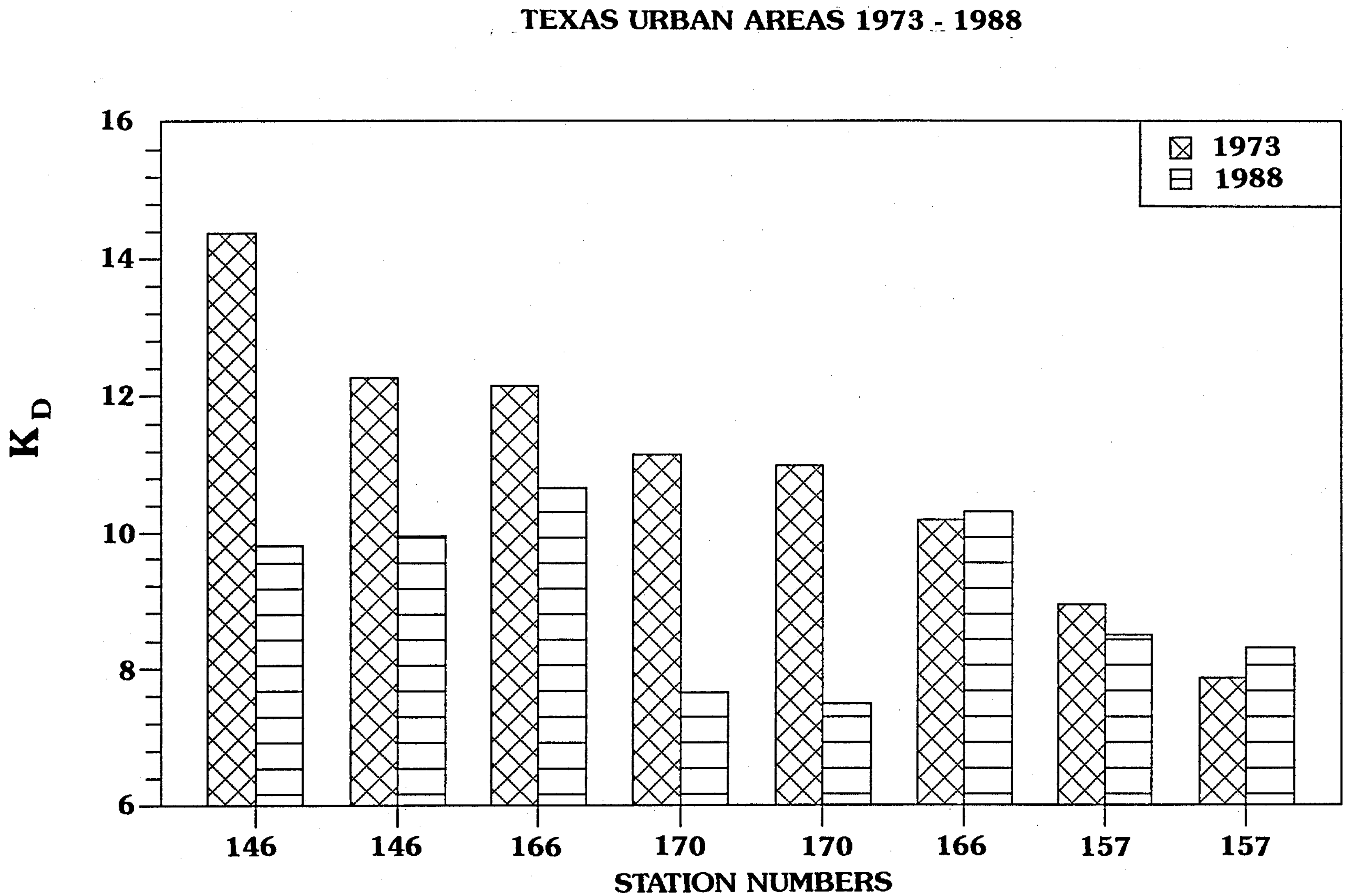


Figure 9. K_D -vs- Time--Circumferential Facilities

Variables Used in Estimating K_D

Many variables were evaluated for their influence on K_D. It is important to evaluate variables for which data readily exist as well as for which data can be generated for the future. These variables included facility type (radial or circumferential), AWDT per lane, distance from the CBD of each city, utilization index (measure of peak hour capacity usage), peak period ratio (measure of peak hour volume to three-hour peak period), employment density in the zones adjacent to the ATR station, and population. The following gives a more detailed description of how each of the variables influences K_D.

Facility Type

Facility type refers to radial or circumferential freeways. The ranges of K_D for the two facility types were different and consequently had different variances. Therefore, the data were separated to examine K_D by facility type. Figure 10 is a scatter-plot showing K_D for all circumferential and radial facilities judged to be urban for 1988. In general, circumferential facilities have lower K_D values than radial facilities that have similar characteristics. This 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, serve high one-way commuting patterns.

AWDT Per Lane

The use of AWDT alone to estimate K_D was not very significant. A graph of all stations showing the annual percent change in AWDT versus the change in K_D is shown in Figure 11. The data is very scattered, implying there is little correlation between change in AWDT and change in K_D.

However, AWDT per lane gives a measure of congestion on a 24-hour basis and had significant correspondence to K_D, as can be seen in Figures 12 and 13. As AWDT per lane increases, K_D decreases, partly because the peak hour may reach capacity and some peak spreading must occur. However, a number of low K_D stations with low AWDT per lane exist as well, where commuting trips are not the dominant pattern. Other reasons may be constrained or metered peak hour volumes. This variable is not the most desirable for

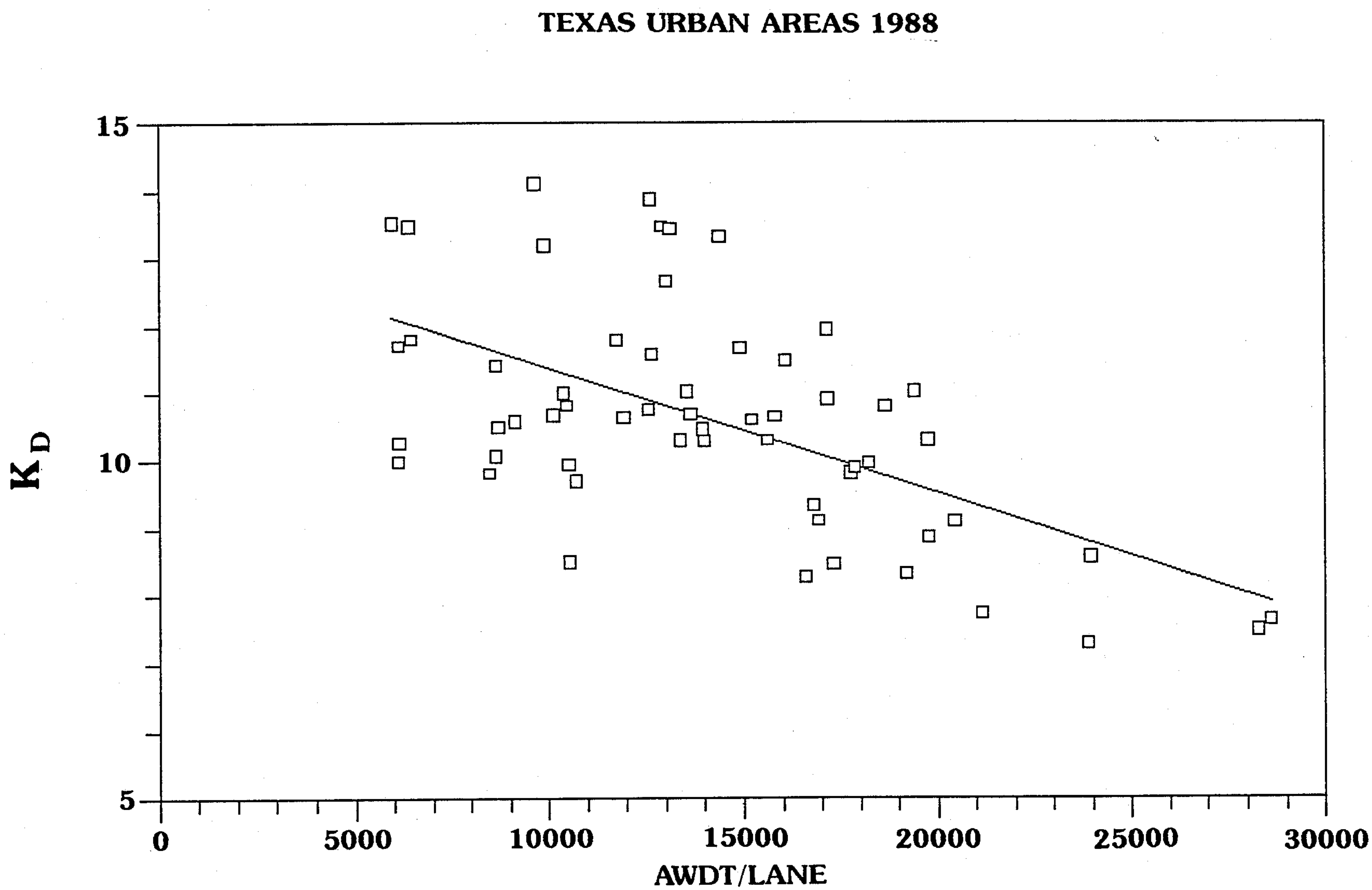


Figure 10. K_D -vs- AWDT Per Lane--All Facilities

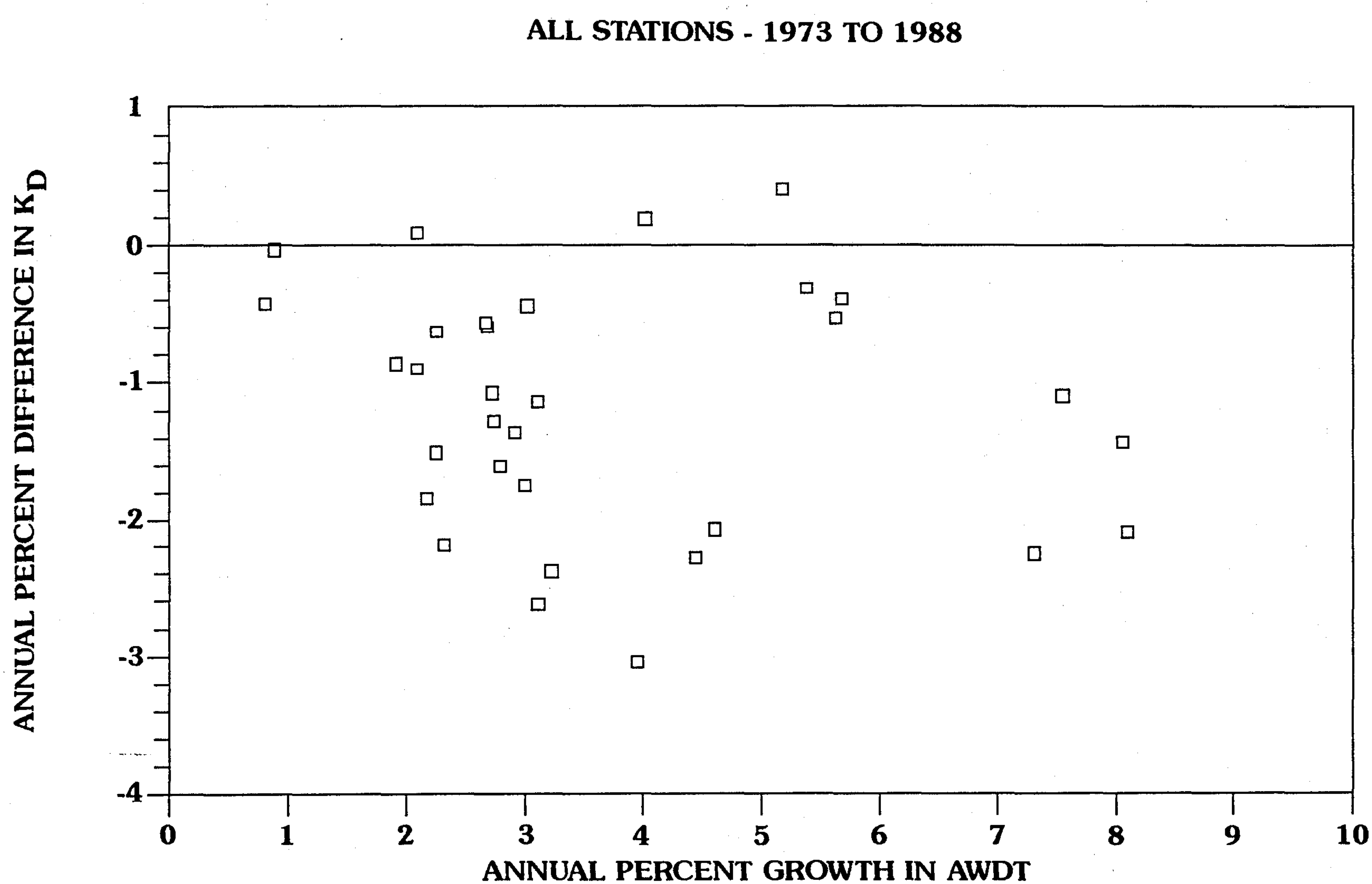


Figure 11. Percent Change in AWDT -vs- Change in K_D

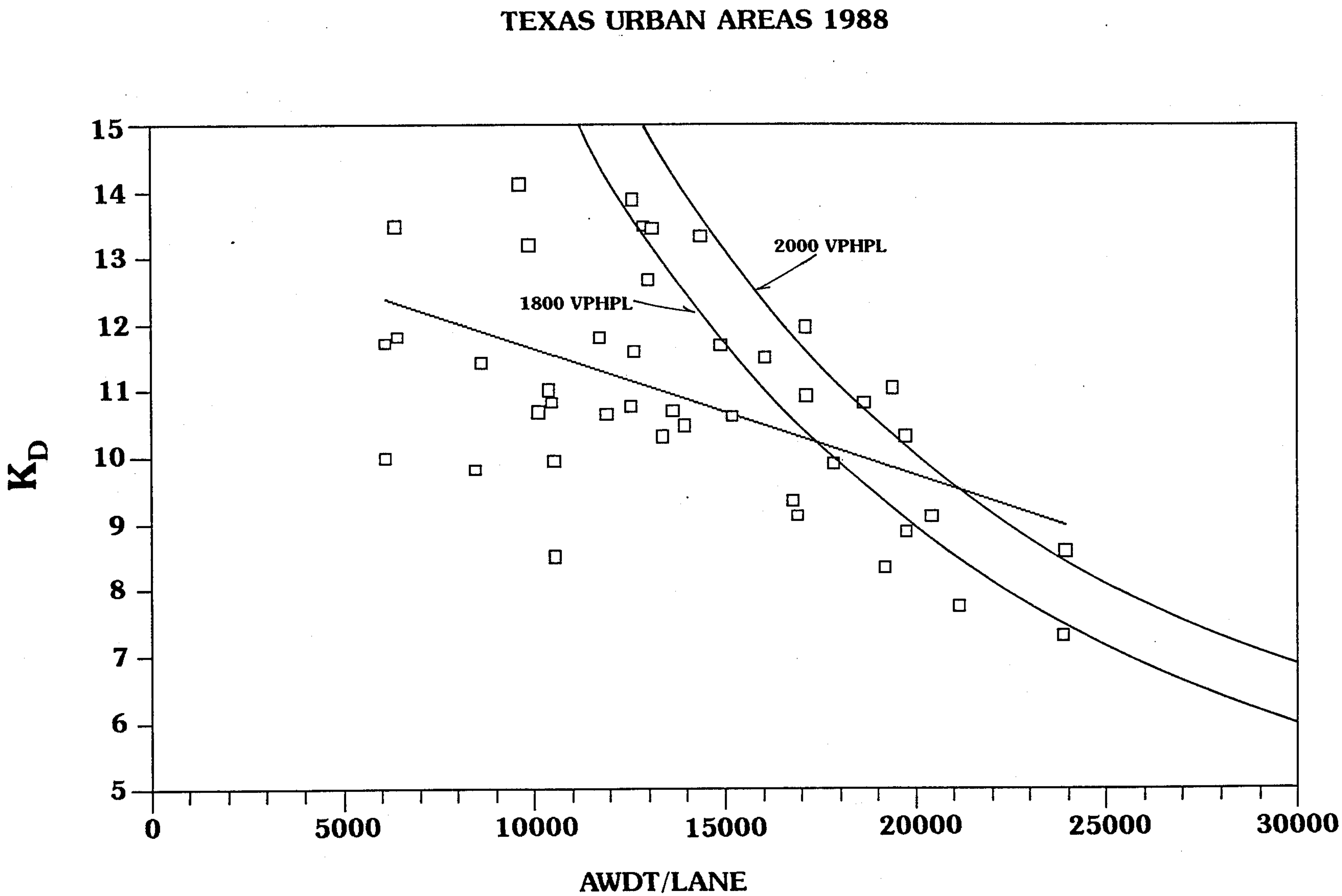


Figure 12. K_D -vs- AWDT Per Lane--Radial Facilities

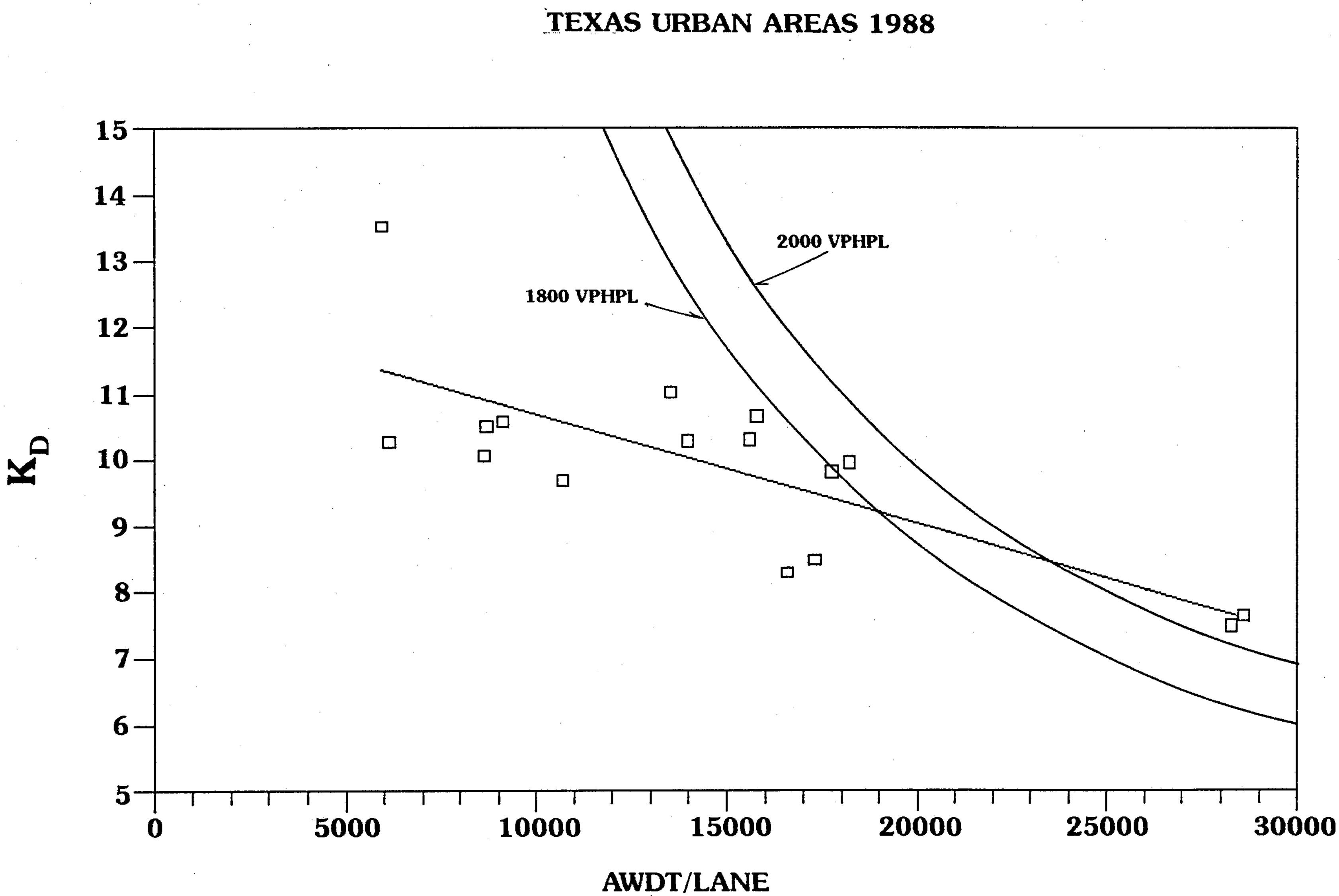


Figure 13. K_D -vs- AWDT Per Lane--Circumferential Facilities

predicting K_D in the future because it requires that an estimate must be made of the number of lanes planned for a facility before an estimation of K_D can be made. This is apt to be a self-fulfilling prophecy, since 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 permanent count stations are within a five-mile radius of the downtown. The correspondence between distance from the CBD and K_D are shown in Figures 14 and 15. 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 it is for radial facilities. This is due to the dependence on downtown commuting patterns prevalent on inner radial facilities, and missing on circumferential.

Utilization Index

Utilization index is a measure of the peak hour usage or a rough volume-to-capacity ratio in the peak hour. For comparison purposes, a capacity of 1800 vehicles per hour per lane (vphpl) was assumed and the volume was the thirtieth 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 16. As may be seen, there is very 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, probably due to commuter traffic, but there is very little use any other time of the day, resulting in high values of K_D. At the same time, there are some very congested stations that have constrained volumes in the peak hour and high volumes for many other hours of the day, resulting in low values of K_D. Figure 17 shows the data for circumferential facilities, and a slightly better correlation is indicated.

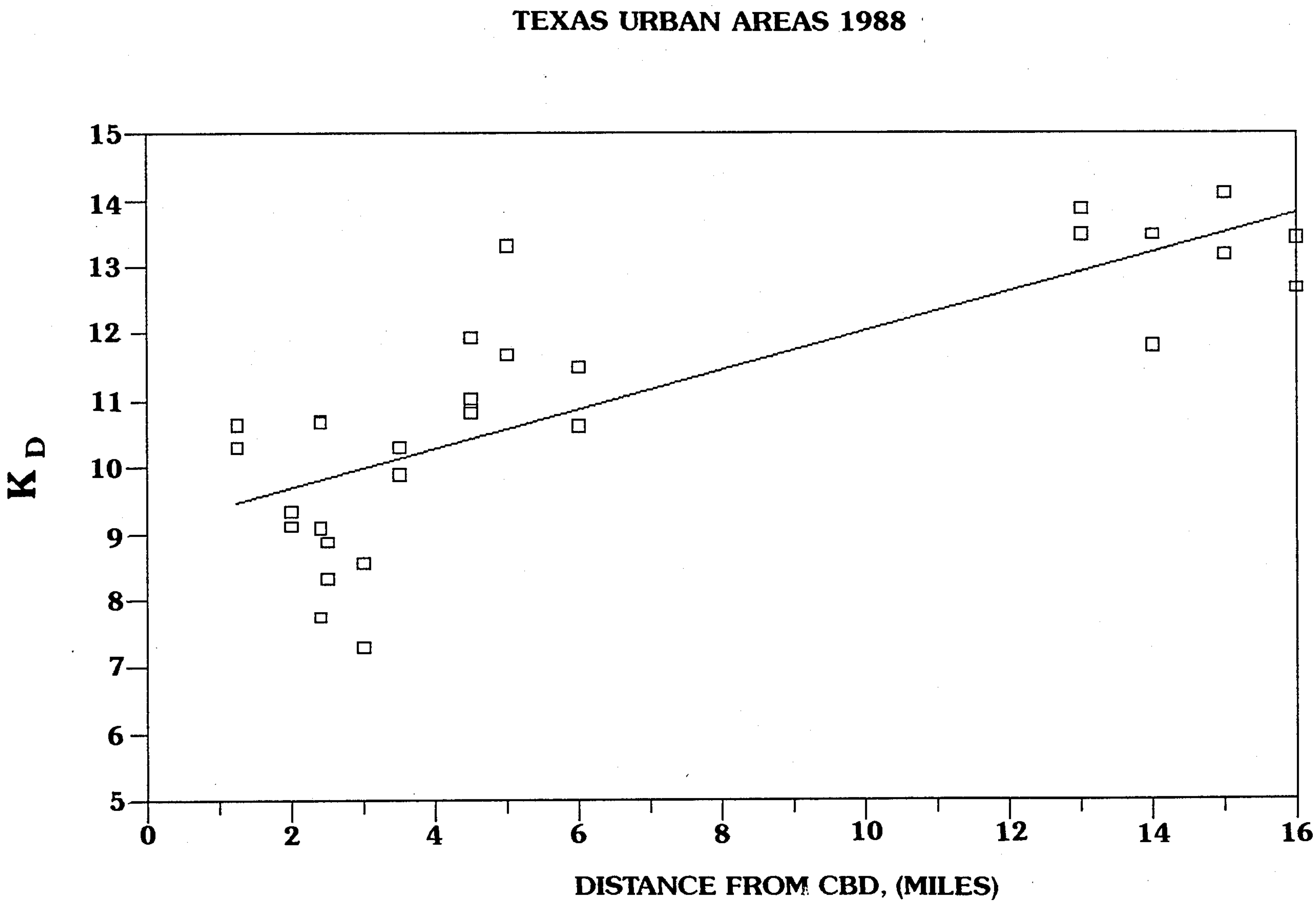


Figure 14. K_D -vs- Distance From CBD--Radial Facilities

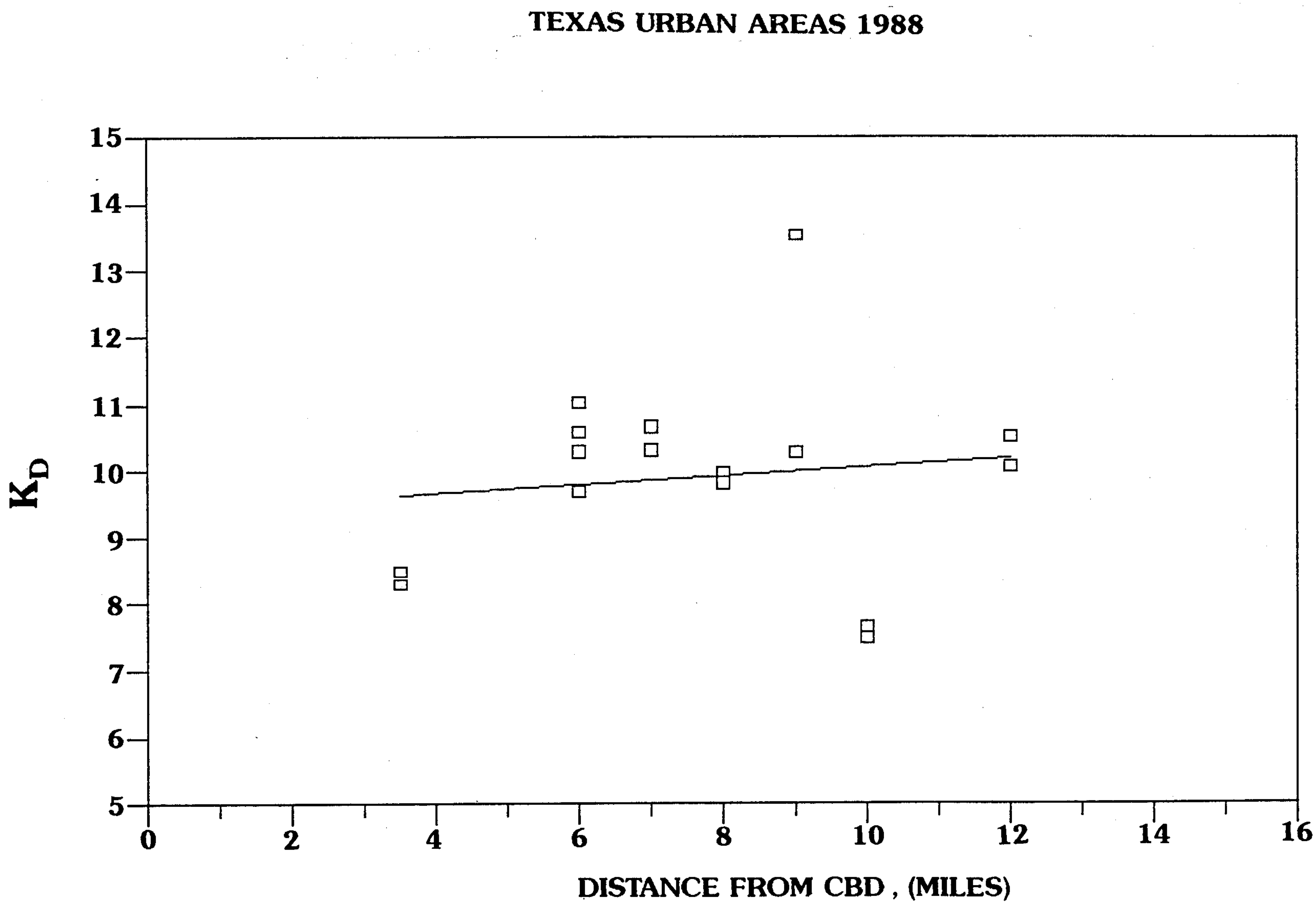


Figure 15. K_D -vs- Distance From CBD--Circumferential Facilities

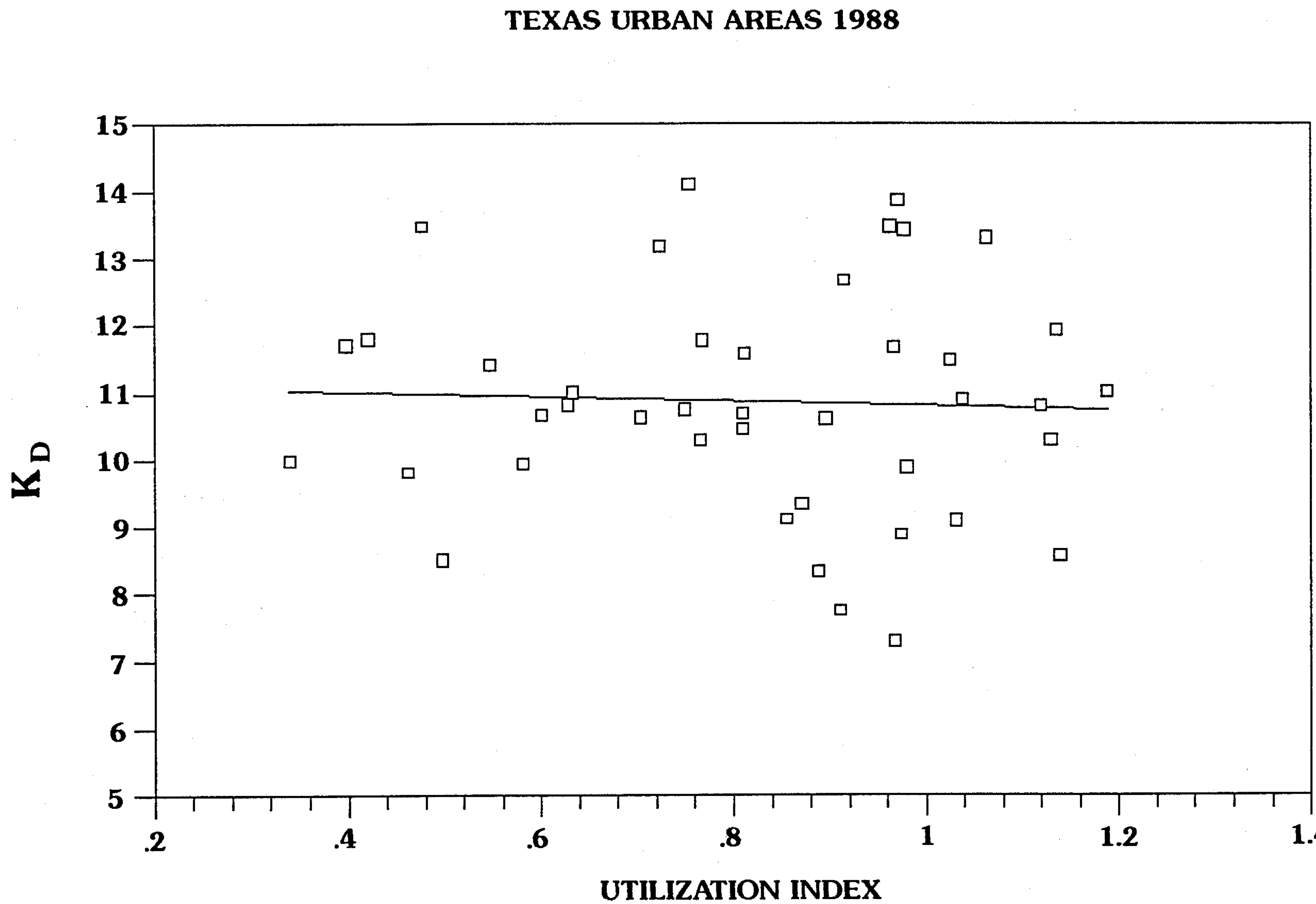


Figure 16. K_D -vs- Utilization Index--Radial Facilities

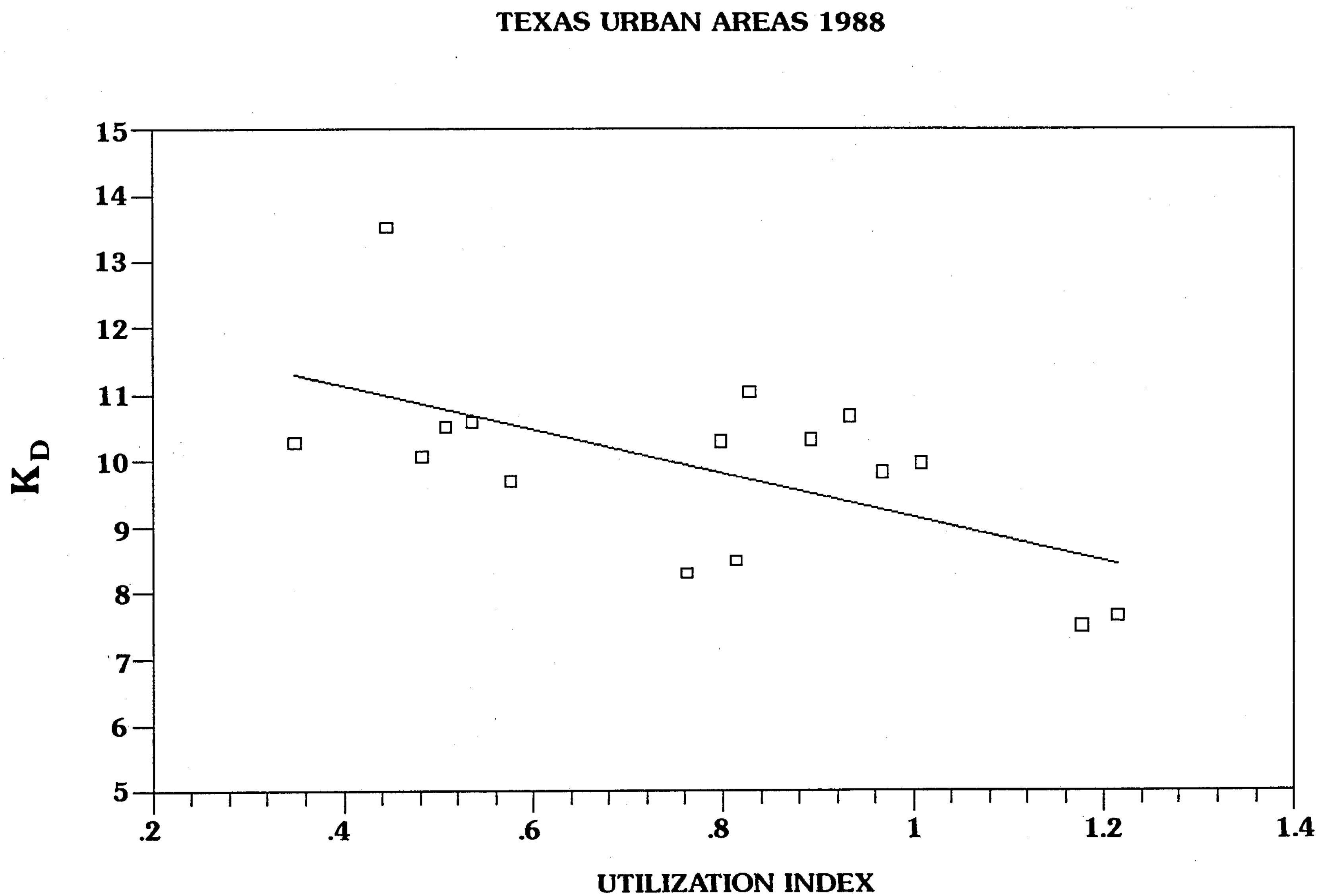


Figure 17. K_D -vs- Utilization Index--Circumferential Facilities

As for using utilization index for future planning, knowing a value for utilization index would in essence be the same 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 a level-of-service (LOS) D in the peak hour. Overall, however, for a variety of reasons as mentioned earlier, this variable is highly unpredictable and therefore not particularly useful for radial freeways.

Peak Period Ratio

The peak period ratio is a measure of congestion in the peak period. A three-hour peak period was assumed, and the peak period ratio is the ratio of the highest hour in the peak period divided by the sum of the total volume in the peak period. A very congested station with even use during all three hours of the peak period could have a peak period ratio of 0.333; conversely, a station with traffic only during the peak hour and very 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 18 and 19 show the correlation for radial and circumferential facilities. Although the data scatter is high in the case of 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 SDHPT were incorporated into a variable. A block two miles by one mile, 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 are shown in Figures 20 and 21 for

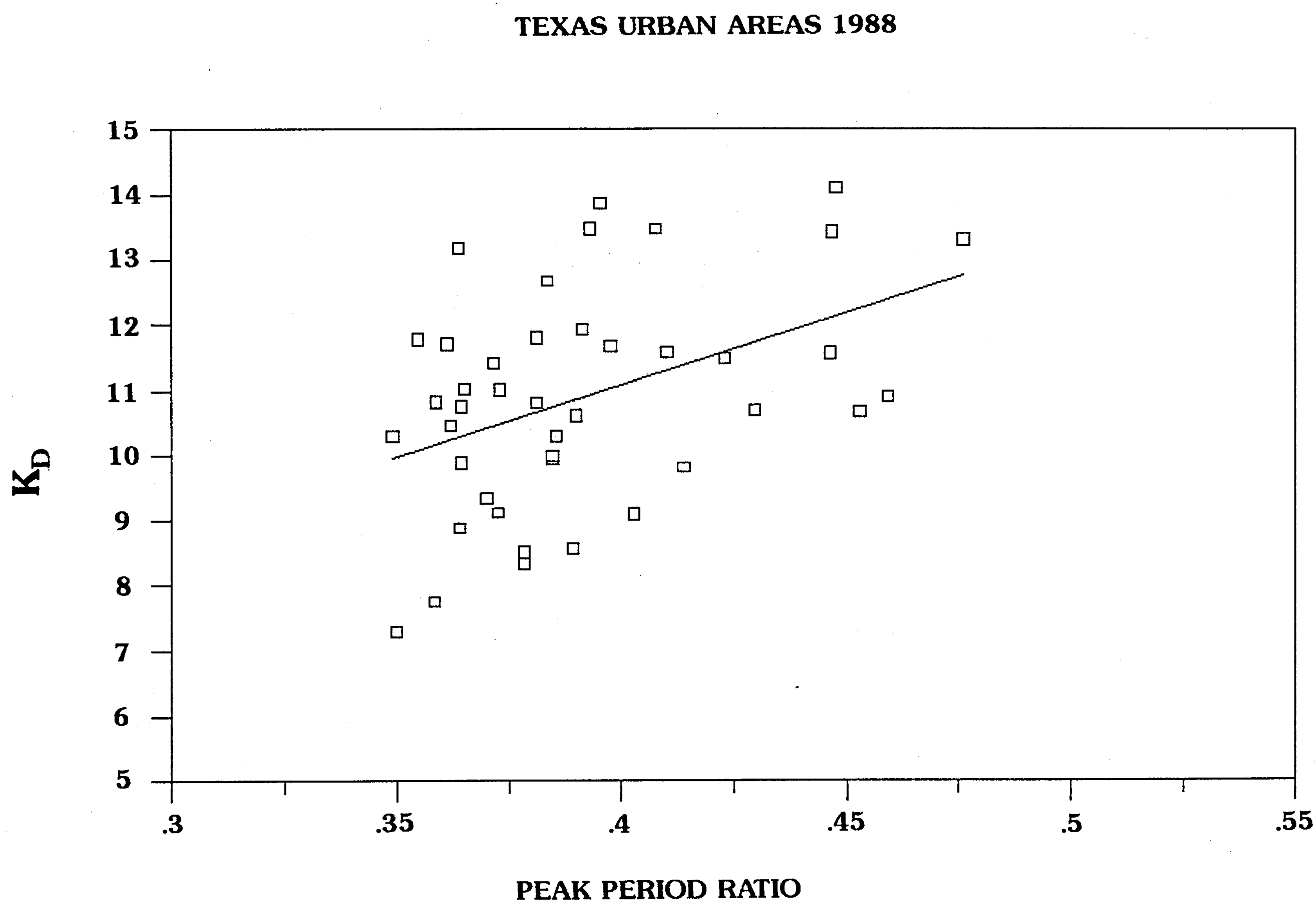


Figure 18. K_D -vs- Peak Period Ratio--Radial Facilities

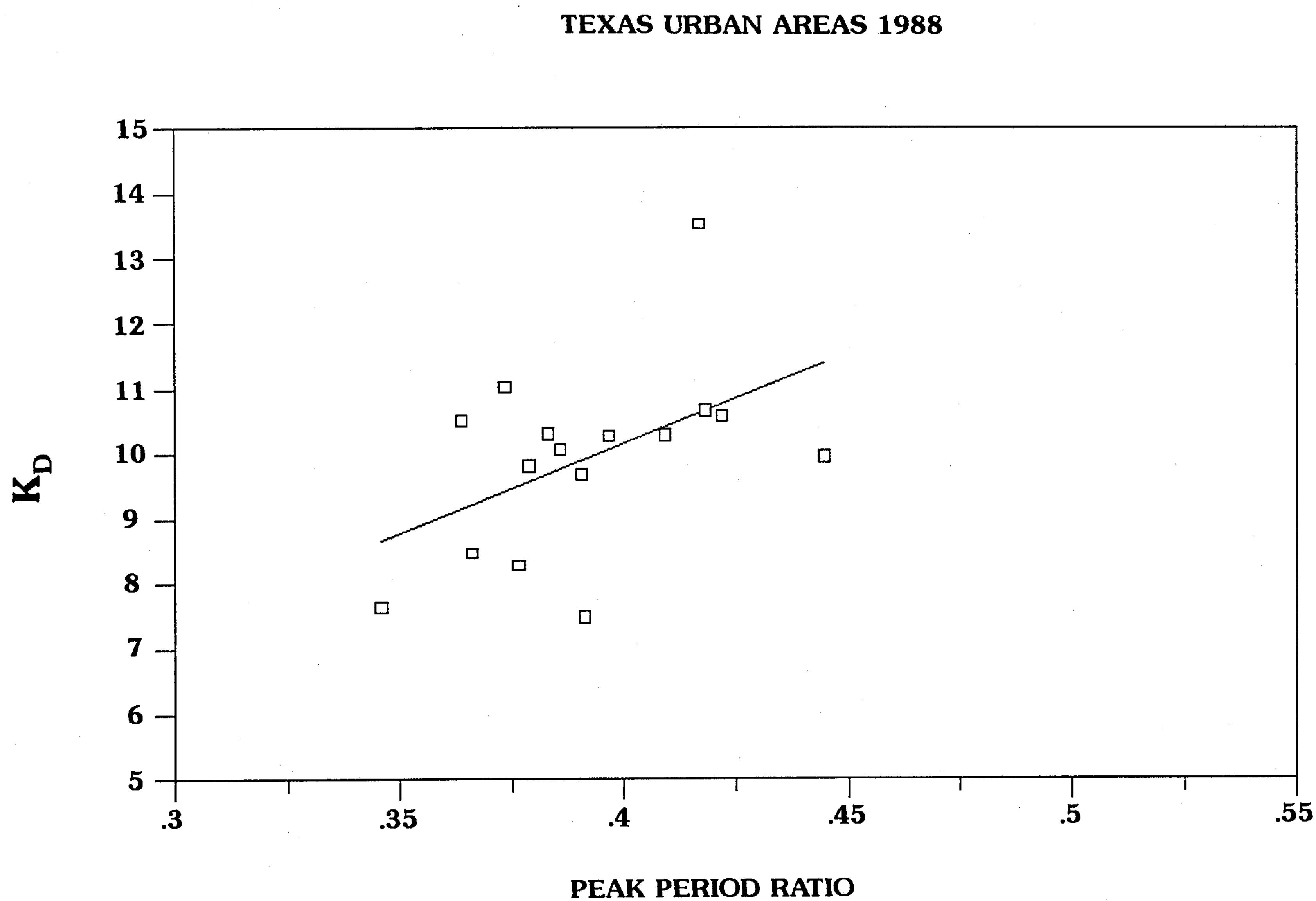


Figure 19. K_D -vs- Peak Period Ratio--Circumferential Facilities

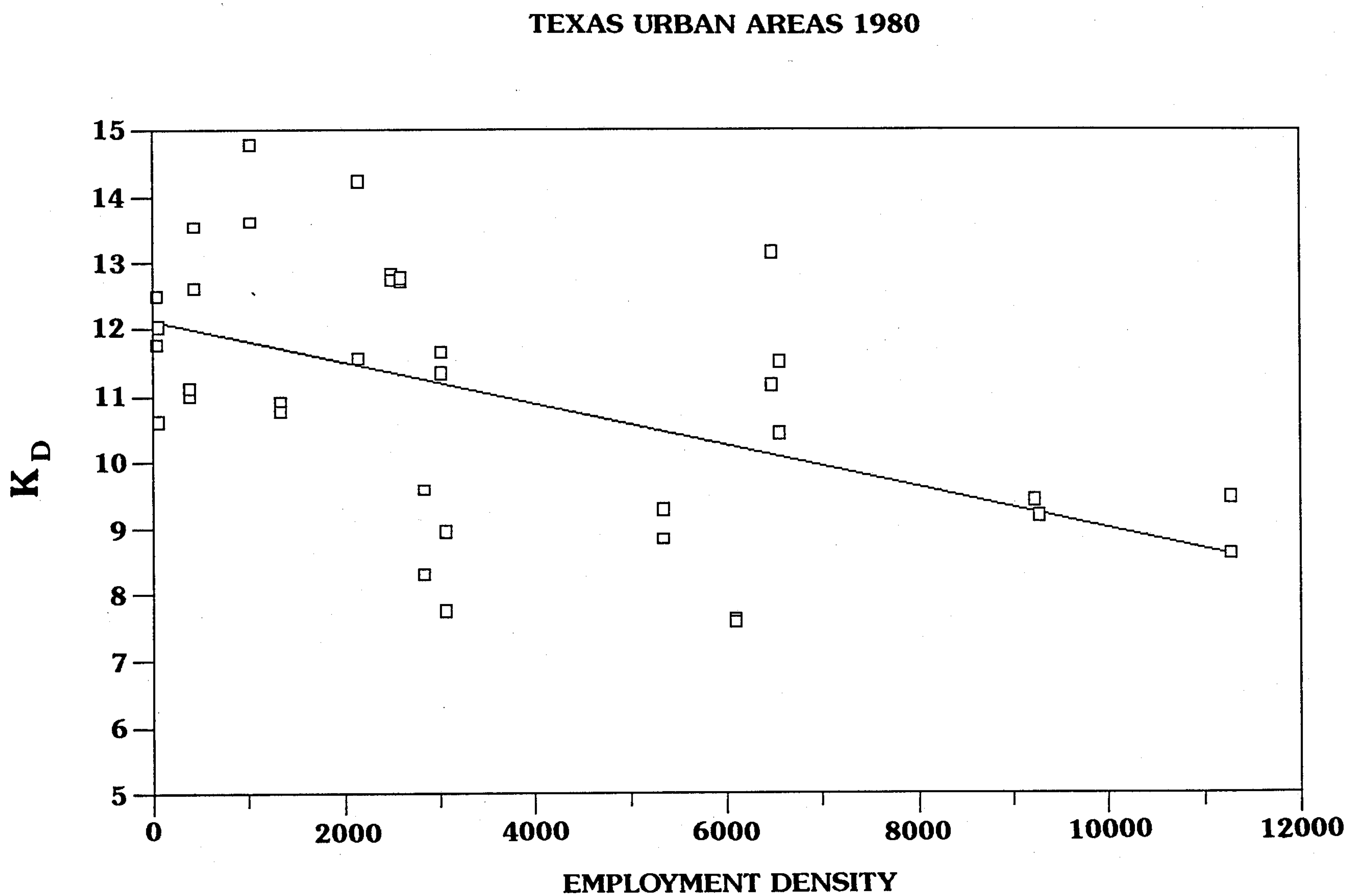


Figure 20. K_D -vs- Employment Density--Radial Facilities

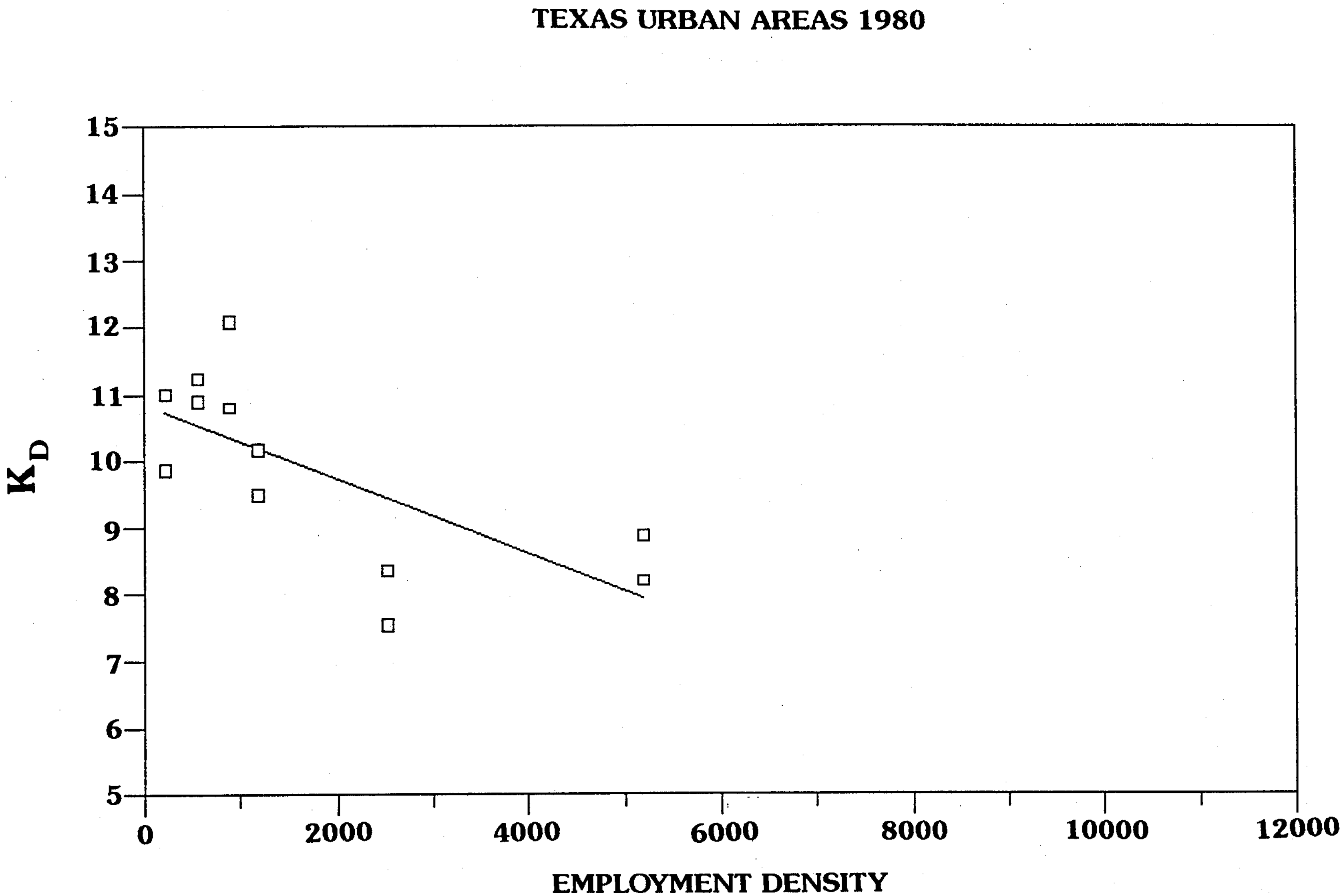


Figure 21. K_D -vs- Employment Density--Circumferential Facilities

radial facilities and circumferential facilities. There was found to be greater correspondence for circumferential facilities than for radial facilities.

STATISTICAL ANALYSIS

Least squares regression analysis was used in an attempt to define a model or models that would predict K_D. The available roadway descriptors--AWDT per lane, distance from CBD, employment density, utilization index, and peak period ratio--were used in the modeling process. For the model development, the distance variable was modified to account for the size of the urban area in which the station was located. In other words, the distance from the CBD was divided by the square-root of the urban area in square miles. This gave only marginally better results. Because data on employment density was only available for 1980 and 1986, these years were used to develop models for estimating K_D and the other years were used to test the prediction capabilities of the best model, using interpolated and extrapolated values for employment density.

Initially, all sites were included in the model development. However, due to differences in the spread of observed values of K_D for the two facility types, sites representing radial and circumferential facilities were modeled separately. This approach was indicated by the difference in the variance of K_D for the two facility types as well as the suspicion that the effects of the roadway descriptors on K_D would be different for the two types of roadways. This last suspicion was correct.

Model development for the two facility types resulted in vastly different predictive equations for K_D. The first major difference between the models is in the variables which are found to be significant to the estimation of K_D. To further understand how each variable relates to K_D and to the other variables, a correlation matrix for both the radial model and the circumferential model are shown in Table 5. The values presented are the Pearson Correlation Coefficients for each of the variables. The range of this coefficient is -1.0 to 1.0, and implies strong correlation for values near -1.0 and 1.0 and weak correlation for values near zero. All the variables proved to have the corresponding negative or positive correlation that was first assumed. The variable with the best correlation for both models, when compared solely with K_D, is AWDT per lane. Distance to the CBD and peak period ratio are more important to the radial model than to the circumferential model; utilization index and employment density are more important to the circumferential model than they are to the radial model. Distance was expected to be less significant for circumferential facilities since the major circumferential routes around urban

Table 5. Correlation Matrix

	Pearson Correlation Coefficients -- Circumferential Facilities					
	K_D	AWDT/LN	Normal Density	Utilization Index	Pk Period Ratio	Employment Density
K_D	1.00000	-0.77319	0.21429	-0.57226	0.35343	-0.70785
AWDT/LN	-0.77319	1.00000	-0.28709	0.95793	-0.18736	0.91105
Distance	0.21429	-0.28709	1.00000	-0.30582	-0.33476	0.04647
Utilization Index	-0.57226	0.95793	-0.30582	1.00000	-0.03503	0.84150
Peak Period Ratio	0.35343	-0.18736	-0.33476	-0.03503	1.00000	-0.31436
Employment Density	-0.70785	0.91105	0.04647	0.84150	-0.31436	1.00000

	Pearson Correlation Coefficients -- Radial Facilities					
	K_D	AWDT/LN	Normal Density	Utilization Index	Pk Period Ratio	Employment Density
K_D	1.00000	-0.66575	0.48458	-0.12771	0.40724	-0.49870
AWDT/LN	-0.66575	1.00000	-0.51266	0.81079	-0.42943	0.27608
Distance	0.48458	-0.51266	1.00000	-0.33238	-0.02838	-0.62016
Utilization Index	-0.12771	0.81079	-0.33238	1.00000	-0.25565	-0.01552
Peak Period Ratio	0.40724	-0.42943	-0.02838	-0.25565	1.00000	0.06615
Employment Density	-0.49870	0.27608	-0.62016	-0.01552	0.06615	1.00000

areas differ considerably in their distance from the CBD. Also, employment density was expected to be more significant for the circumferential routes since employment density contributes to noncommuting trip-making characteristics and off-peak facility usage on circumferential routes. At the same time, distance from the CBD describes the nature of trip generation, commuter patterns, and land development for radial facilities.

It must be noted that the correlation between AWDT per lane and the utilization index is very high, and the ability of a model with both of these variables to estimate K_D is very good because these two variables together are directly proportionate to K_D. This is shown in the following equation:

$$K_D = \frac{\text{Peak Volume}}{\text{AWDT}} = \frac{\text{Peak Volume / Lane}}{\text{AWDT / Lane}}$$

$$= \frac{\text{Capacity}}{\text{Lane}} \times \frac{\text{[Peak Volume/Lane]}}{\text{AWDT/Lane}} \; / \; \frac{\text{Capacity}}{\text{Lane}}$$

$$= \frac{\text{V/C}}{\text{AWDT/Lane}} \times \frac{\text{Capacity}}{\text{Lane}} = \text{Constant} \times \frac{\text{V/C}}{\text{AWDT/Lane}}$$

$$= \text{Constant} \times \frac{\text{Utilization Index}}{\text{AWDT/Lane}}$$

Therefore, models with both AWDT per lane and utilization index were not considered since these variables degenerate because they define an exact relationship with K_D. Further, a high correlation is shown in Table 5 between employment density and both AWDT per lane and utilization index, for the circumferential model, indicating that care must be taken in the use of these variables in the same model due to problems associated with colinearity.

A step-wise regression procedure based on the greatest improvement in R square was used to develop the models (Ref SAS/Statistics). Variables were included in the models based on a significance level of 0.10, which corresponds to 90 percent confidence interval.

The coefficients for the radial and circumferential models developed for the 1980 data base are shown in Table 6. Utilization index was not included due to the previously discussed considerations. With AWDT in the model, the model degenerates; without AWDT, there remains the high correlation with employment density on circumferential facilities. Also, models including and not including AWDT per lane were developed. As discussed before, the estimation of this variable in the future requires an estimation of the number of lanes expected on the facility. Therefore, this variable is less desirable than other variables not requiring iterative steps to approximate them. Only high reliability in a model might justify the need to include AWDT per lane.

Table 6. Comparison of Linear Models for Different Facility Types
1980 Data Base

Variable	Coefficients for Radial Model		Coefficients for Circumferential Model	
	W/AWDT/LN	W/O AWDT/LN	W/AWDT/LN	W/O AWDT/LN
AWDT/LN	-0.000189	N/A	-0.000202	N/A
Distance	2.569	6.203	N/S	N/S
Utilization Index	N/S	N/S	N/S	N/S
Peak Period Ratio	N/S	30.904	N/S	N/S
Employment Density	N/S	-0.000146	N/S	-.000563
Intercept	7.228	-1.975	12.305	10.8614
R^2	0.668	0.573	.597	.501

NOTE: N/S = Not significant to 0.10 level
N/A = Not applicable

When the variables were combined into a multivariable model, the importance of the variables differed from the correlation matrix. In the radial model, AWDT per lane and distance are significant variables (distance and employment density when AWDT per lane is omitted); and in the circumferential model AWDT per lane (employment density when AWDT per lane is omitted) is significant. Examination of the coefficients in Table 6 also reveals differences between the two models.

The examination of data from two different years provided information on the stability, and thus the reliability, of the models. Radial models for 1980 and 1986 are shown in Table 7. Again, examination of the coefficients, R-square, and intercepts reveal different models. For reliable results, the two models would have to be much more similar in form.

Table 7. Comparison of Linear Models for Radial Facilities Between Different Years

Variable	Coefficients for 1980 Radial Model	Coefficients for 1986 Radial Model
AWDT / LN	- 0.000189	N/S
Distance	2.569	N/S
Utilization Index	N/S	N/S
Peak Period Ratio	N/S	38.525
Employment Density	N/S	- 0.000239
Intercept	7.228	- 2.747
R^2	.597	.671

NOTE: N/S = Not significant.

The instability of the models that were generated to predict K_D was also evidenced in another way. The data sets used in the analyses were not complete; isolated missing values for certain descriptors for some sites existed, mostly due to a station not recording data due to construction at that facility. This situation is not uncommon in statistical analysis. However, disturbing differences were present in the models generated when the sites with missing data were included or not included. Stable, reliable models would not have shown these differences.

Eliminating all data points associated with bottlenecks and system constraints did not leave enough observations in the data set to draw statistical conclusions. It was concluded that due to the instability of the models developed for different years from this data set, a prediction of K_D would not be statistically reliable. However, with a larger data set of freeway sections not constrained by various factors and with possible other descriptors of K_D, a multivariable model analysis should not be completely ruled inconclusive. Even though there were not enough observations to test models other than linear, there were indications that a higher order model may better estimate K_D.

TRUCK PERCENTAGES ON URBAN FREEWAYS

The prediction of truck percentages on urban freeways is important to the calculation of capacity needed on these facilities as well as for the noise and air quality calculation needed in the environmental evaluations. In this research, trucks are defined as all vehicles larger than a passenger vehicle, excluding pickups, vans, panel trucks, and buses. The percentage of trucks in urban areas is much less than in the rural areas of the state, mainly due to the high concentration of passenger cars in the urban areas, especially during the peak periods. A graph of the total vehicle volume and the truck volume on I-30 in Dallas, is shown in Figure 22. The truck volume does not vary significantly during the day; however, the truck volume is diluted by the passenger car volume during the peak hours which represent conditions that are being designed for in the design hour volume.

Currently, the procedure for determining peak hour truck percentages is very similar to determining the design-hour volume. There are many manual count stations around the state where 24-hour manual vehicle classification counts are taken. These stations can be referenced to aid in establishing the 24-hour truck percentage for facilities with similar characteristics. D-10 has developed peak hour factors that estimate the ratio of trucks in the peak hour as compared to the 24-hour truck percentage. These factors are classified by facility designation, as shown in Table 8, below:

Table 8. D-10 Factors to Convert 24-Hour Truck Percentages To Peak Hour Percentages

Farm-to-Market Roads	0.75
State Highways	0.66
U.S. Highways	0.60
Interstate Highways	0.45

Using the manual count station data from 1984 to 1987, a check of the peak hour truck percentages in rural areas revealed reasonably good agreement with these factors, and led to the conclusion that the development of a special factor for urban freeways would provide an appropriate extension of the procedures already in use. Figures 23 through 26 illustrate the relationships.

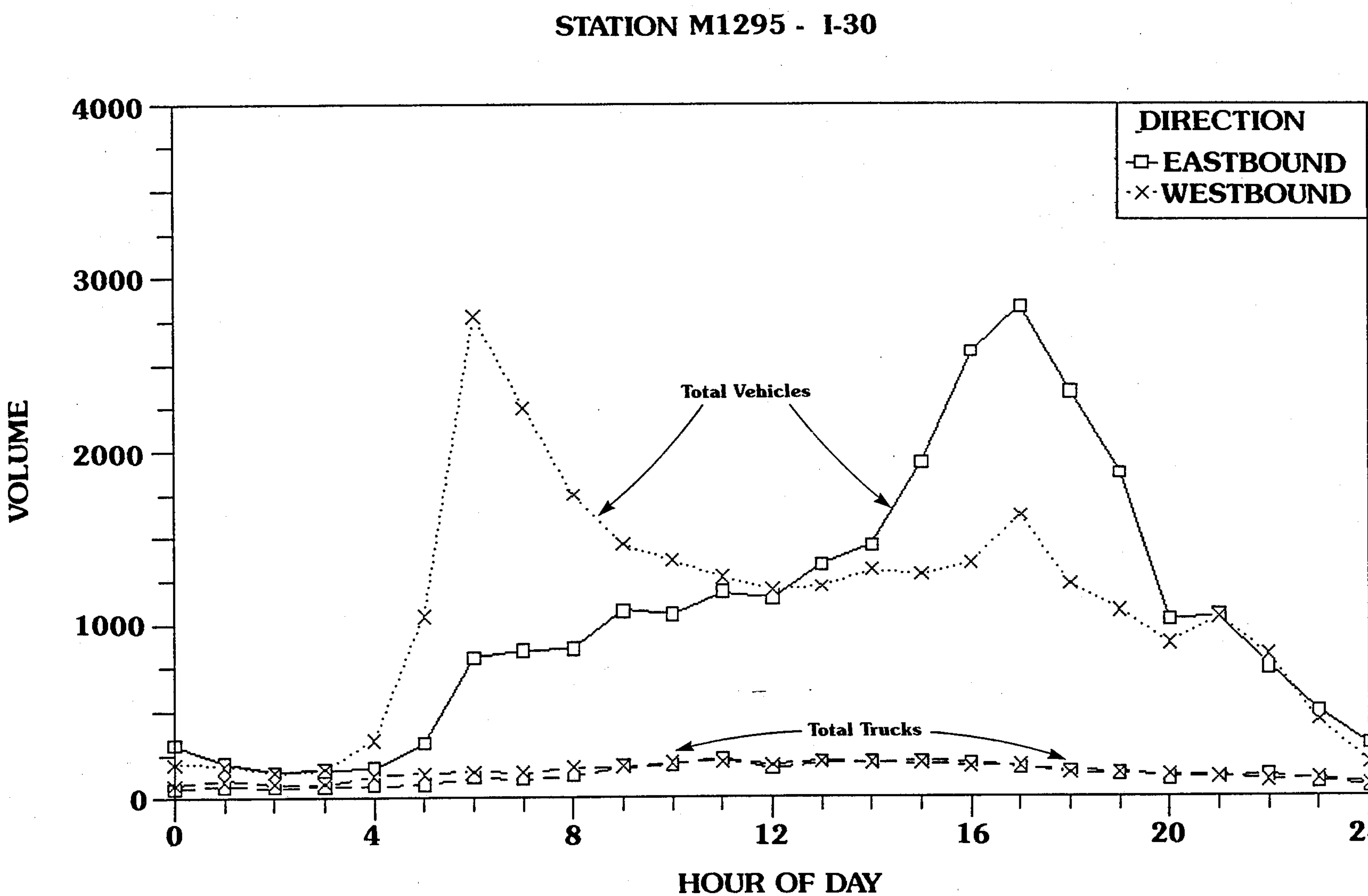


Figure 22. Total Vehicle and Truck Volumes

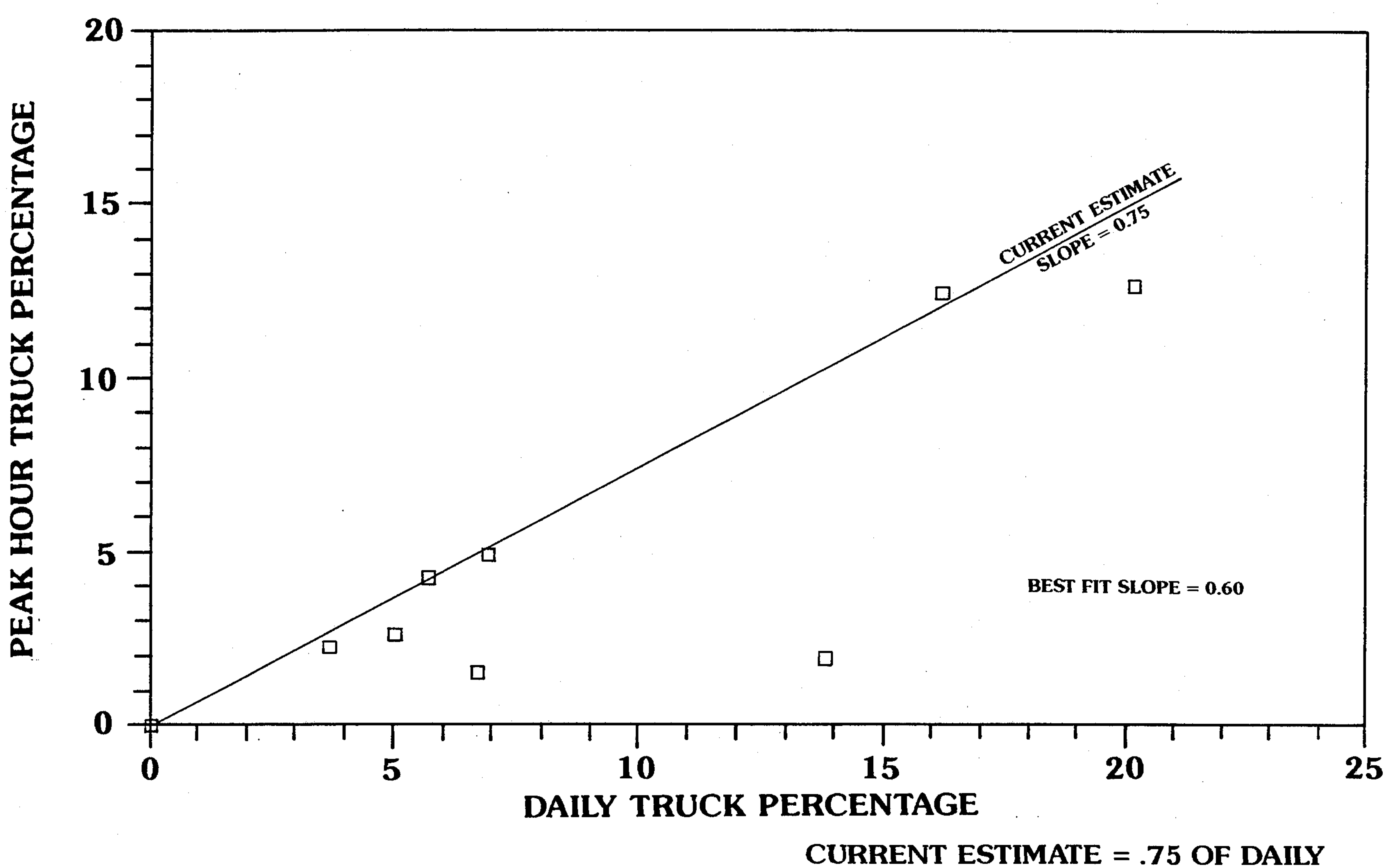
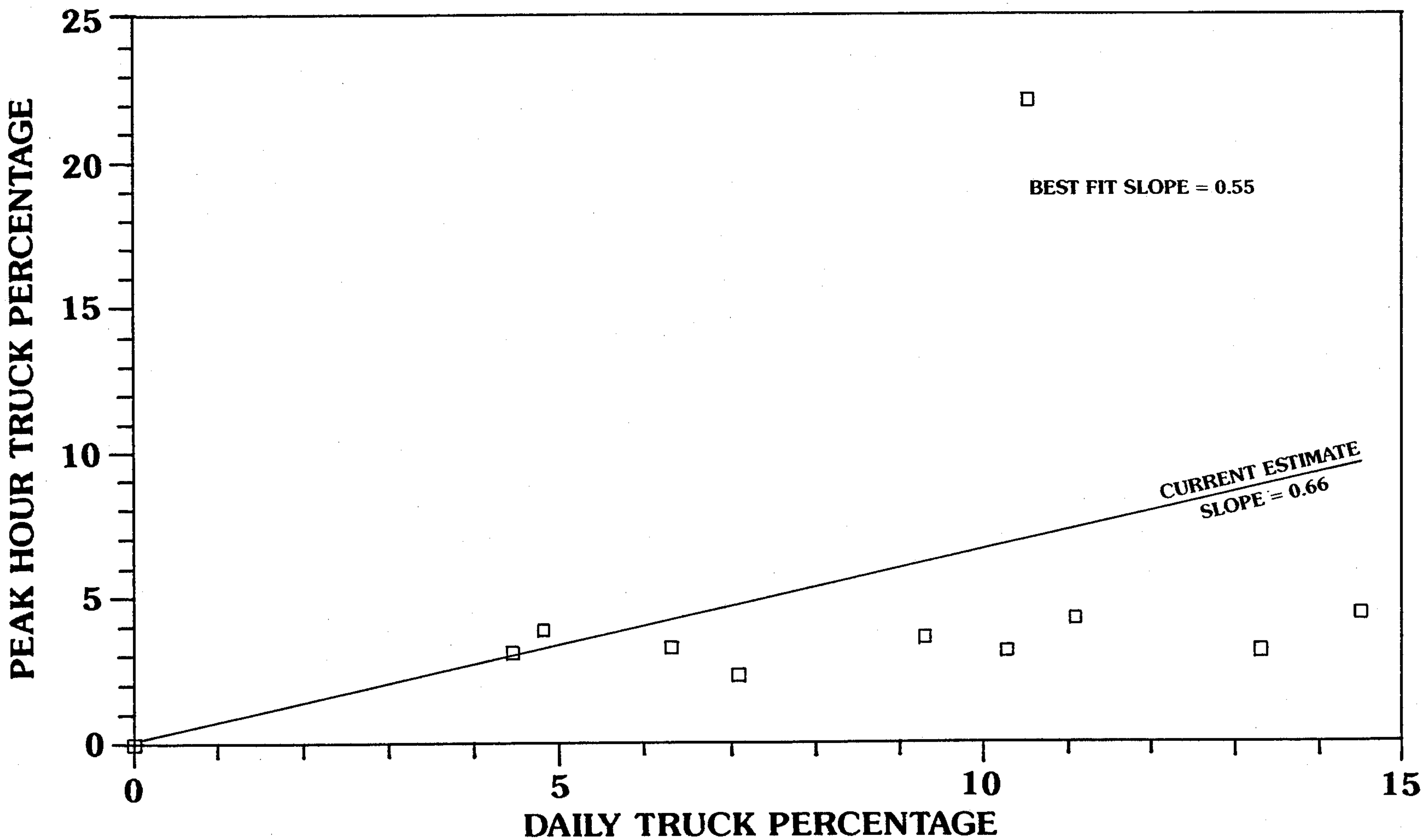


Figure 23. Truck Factors -- Farm-to-Market



CURRENT ESTIMATE = .66 OF DAILY

Figure 24. Truck Factors -- State Highways

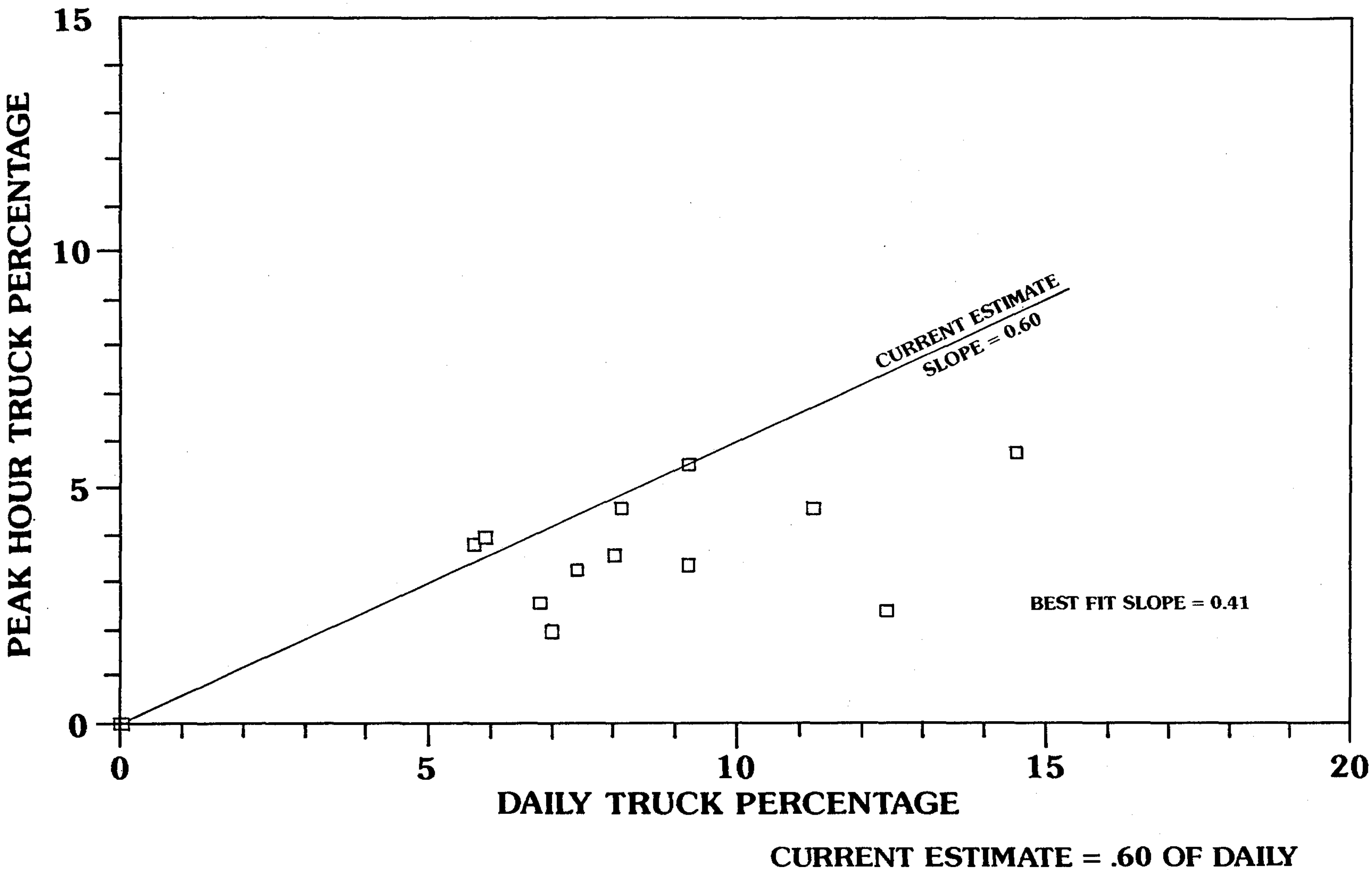


Figure 25. Truck Factors -- U.S. Highways

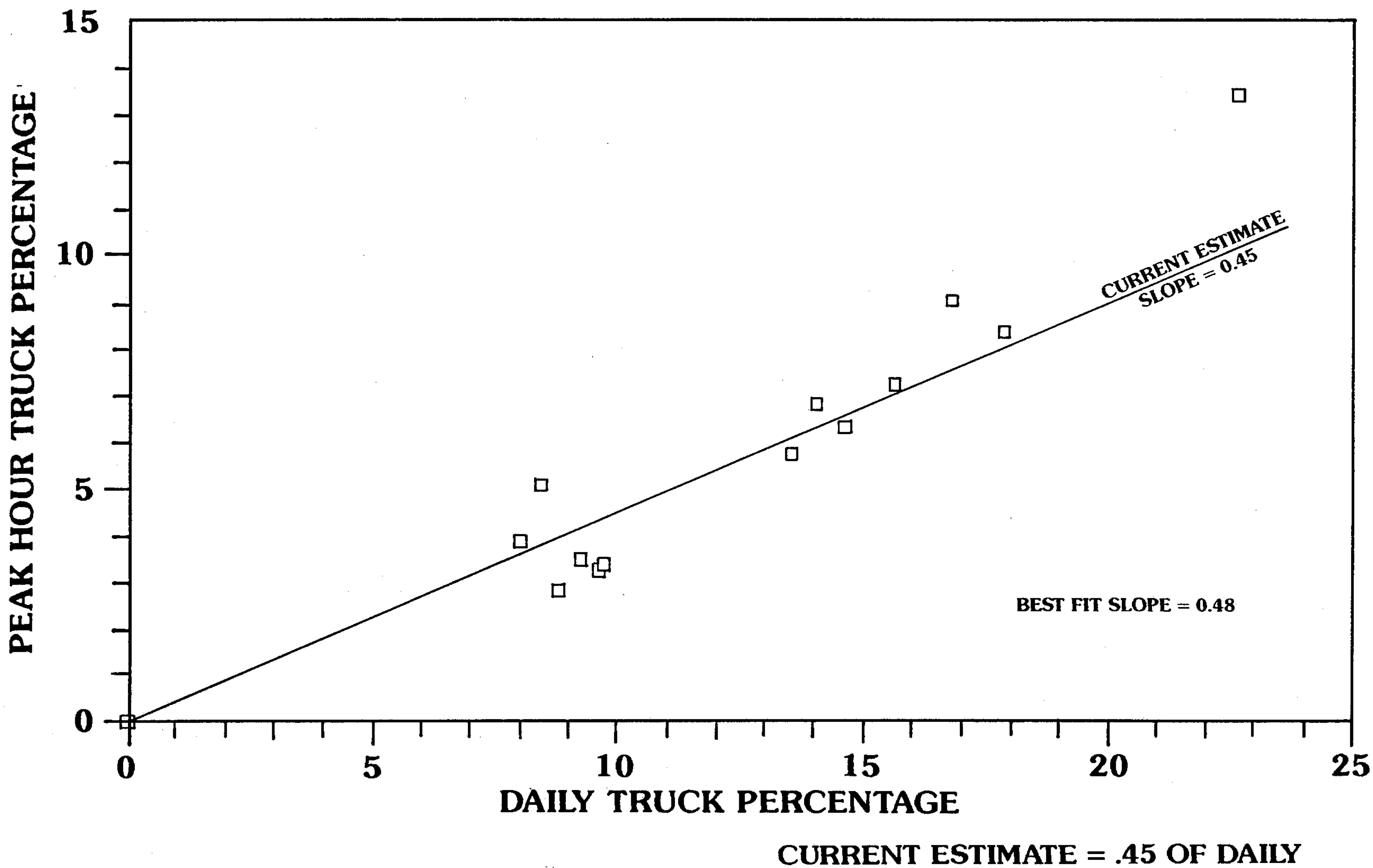


Figure 26. Truck Factors -- Interstates

In analyzing the peak hour truck percentages obtained from the manual count stations, it was necessary to distinguish between those exhibiting rural characteristics and those more properly defined as urban. As was illustrated in Figure 5, none of the manual count stations fall within the interior of the major loop facilities. For instance, two of the Houston stations are more than 15 miles from the center of the central business district and carry less than 1500 total vehicles in the peak direction during the peak hour. Peak hour truck percentages are as high as 15 percent under those conditions. Accordingly, a lower limit of 2000 total vehicles per direction per hour is conservatively established as the definition of an urban condition on a freeway facility. This implies at least a 50 percent utilization on a four-lane freeway. The data for the urban count stations are included in the appendix.

Analysis of the thirteen remaining stations indicates an average peak hour truck percentage of 3.8 percent during 1987, with radial facilities averaging 3.1 percent and circumferential averaging 5.7 percent. Over the four-year study period, the average was a slightly higher 4.8 percent, 4.2 percent for radial and 6.0 percent for circumferential. Figure 27 shows a frequency distribution of the data. Analyzing the peak hour truck percentage as a proportion of the daily truck percentage, the four-year data base yields a factor of 0.49 for all urban freeways, 0.46 for radial, and 0.55 for circumferential. This compares reasonably well with the 0.45 factor now in use for Interstate facilities.

The difficulty in use of the peak-to-daily truck percentage adjustment is that good 24-hour truck data is largely unavailable within the highly urbanized areas. Accordingly, if a factor is applied to urban fringe data, it will only simulate urban fringe peak hour conditions, even if the adjustment factor is correct. For this reason, a further analysis is required of actual peak hour truck percentages within the more highly urbanized areas.

Additional 24-hour manual counts were available in the Houston area, conducted by TTI in 1986. These data are included in the appendix and reflect stations varying in distance from 2 miles to 11 miles from the CBD. Analysis of the results indicates an overall peak hour truck percentage of 3.8 percent, 3.3 percent on radial. There are only two circumferential stations; one, on the I-610 west loop, has a peak hour truck percentage of only 1.5 percent, while that on the I-610 east loop has an 8.2 percent peak hour truck

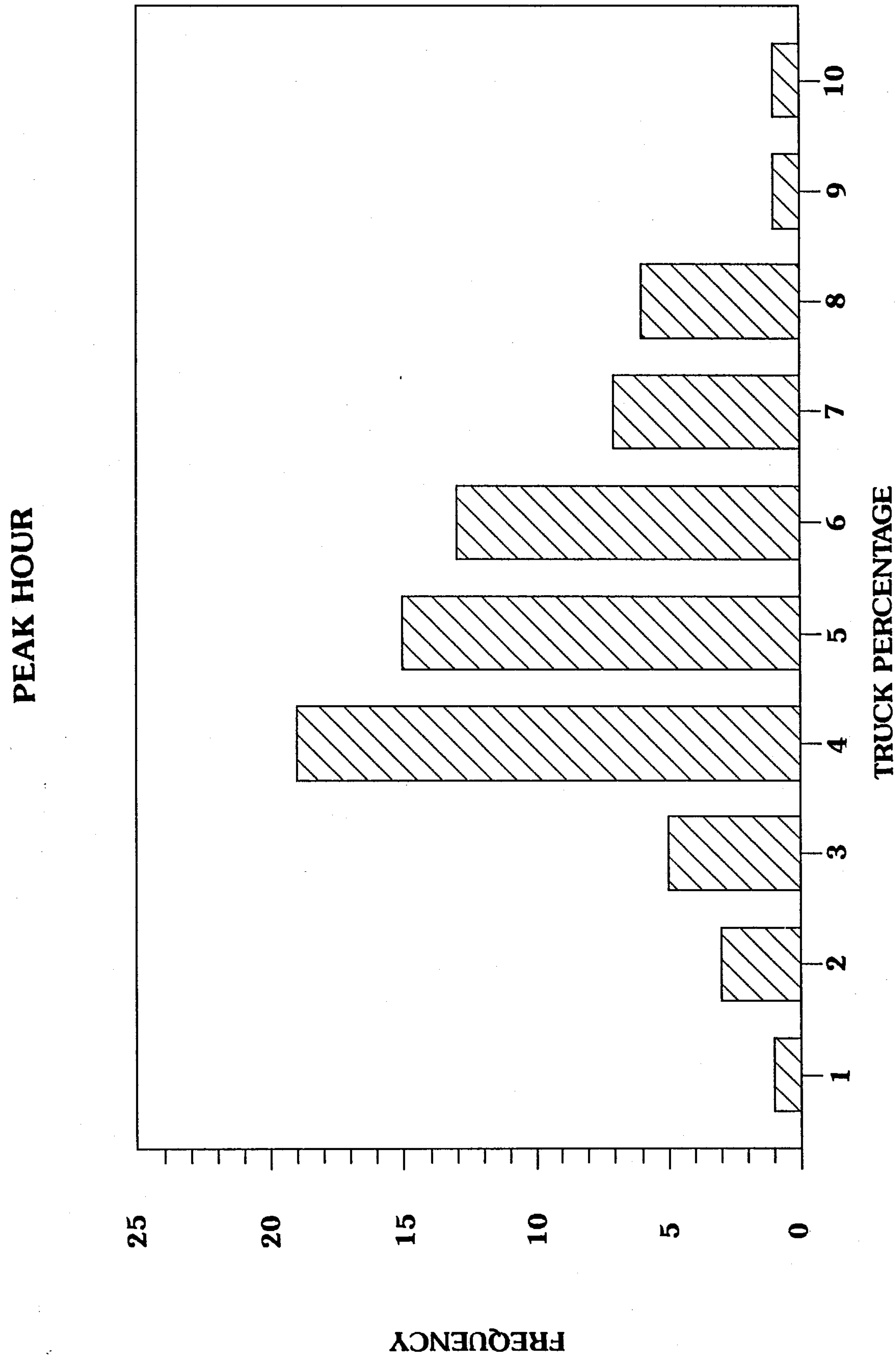


Figure 27. Truck Percentage Frequency--Manual Count Stations

percentage. Thus, the presence of high commuter volumes and/or high truck volumes are variables not fully described by facility type. Figure 28 shows a frequency distribution for the Houston data. The 5 percent and 6 percent peak hour truck percentage locations are the result of industrialized circumferential routes.

Also included in the appendix are peak hour data obtained by TTI in the Dallas/Fort Worth area. Figure 29 shows a frequency distribution of these data. As may be seen, very few locations show a peak hour truck percentage greater than 4 percent. The greatest frequency occurs between 3 and 4 percent, and the average of the data is 2.8 percent, 2.7 percent for radial and 3.1 percent for circumferential.

Analysis of the combined data sets indicates that in general a peak hour truck percentage above 4 percent should be regarded as a relatively rare, site specific occurrence on radial freeways in highly urbanized areas. On certain radial routes serving industrial areas or circumferential facilities serving as truck routes, a higher percentage should be considered. For freeways on the fringe of the urban areas, use of the D-10 standard factor of 0.45 to convert Interstate 24-hour truck percentages to peak hour percentages appears reasonable.

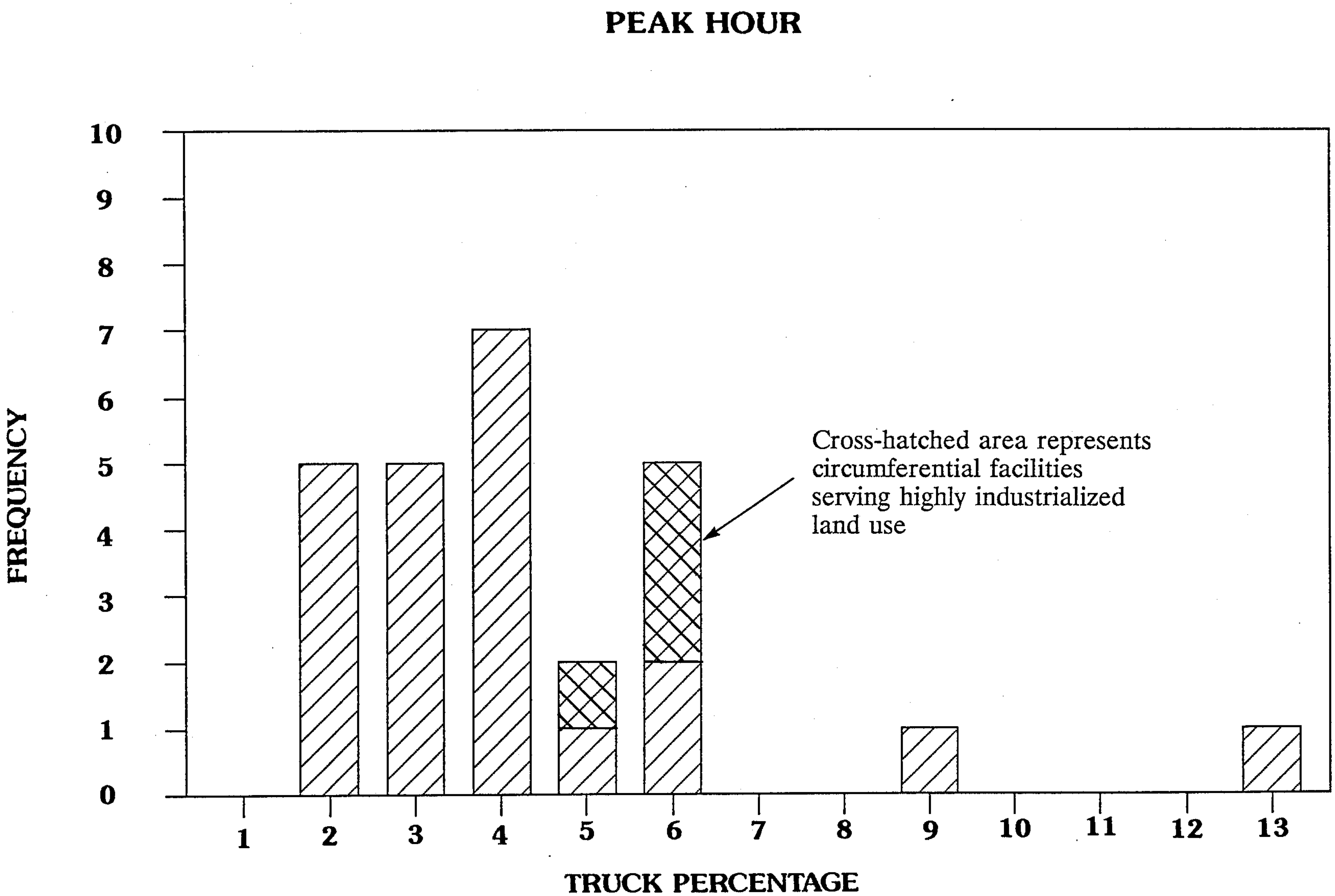


Figure 28. Truck Percentage Frequency--Houston

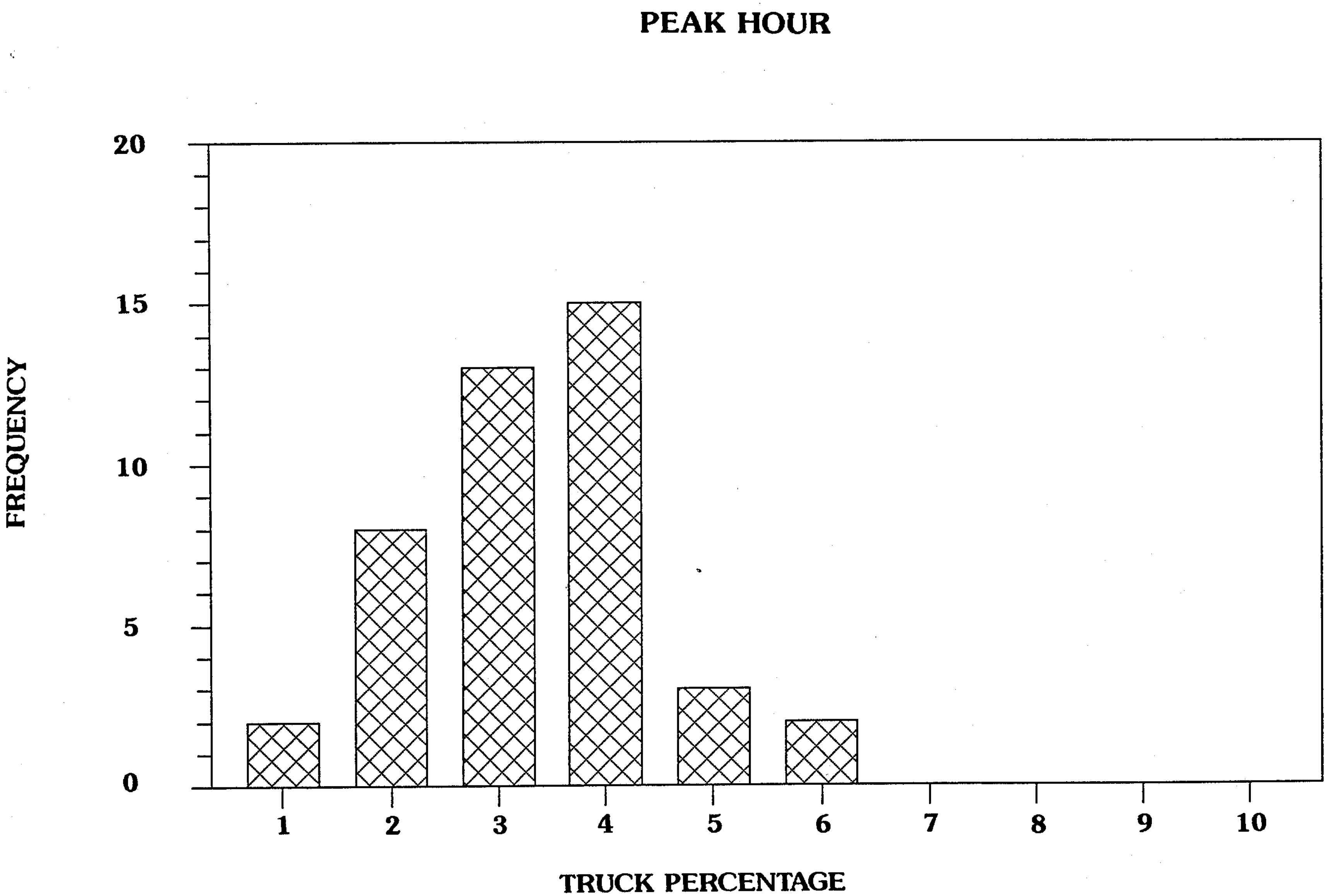


Figure 29. Truck Percentage Frequency--Dallas/Forth Worth

DEVELOPMENT OF REFERENCE TABLES

The purpose of this research is to develop a useful tool to aid in the selection of planning parameters for urban freeways. Engineering judgment and the examination of other permanent count stations with similar operating characteristics work relatively well for rural locations. For urban locations, this research should be incorporated as another input into the existing methodology.

One possible outcome of the research was development of a regression equation that would predict values of K_D. However, the models developed from the data base did not lead to estimations of K_D that were statistically reliable.

Instead of trying to predict K_D exactly, general ranges of K_D in urban areas for each of the significant variables can be summarized. Even though this will not directly give the value of K_D, it provides a helpful guideline to follow in choosing the appropriate value of K_D in an urban area, based on 15 years of data from all the urban permanent count stations in Texas. The ranges of K_D for radial and circumferential facilities found for the different variables are presented in Table 9. This table provides ranges in the data remaining after elimination of all stations constrained by peak hour bottlenecks, stations with less than 10,000 vehicles per day per lane, stations farther than 15 miles 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 under utilized facilities have simply not matured.

This table reflects relationships discussed earlier between the various factors and K_D. 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 peak period ratio rises (indicating a lengthening of the peak), and falls again as employment density increases. For radial facilities only, K_D rises as the distance from the CBD increases; for circumferential facilities only, it falls as the peak hour utilization rises.

Use of Table 9 should allow a check on the reasonableness of K and D factors developed using the standard procedure. First, K_D must be calculated. Ideally, the data collected at the permanent count stations could be reduced to provide K_D directly, the 30th highest directional volume divided by the AWDT in the corresponding direction. However,

Table 9. Ranges of K_D 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 15,000-20,000 20,000 +	10.0-14.0 9.0-12.0 7.0- 9.0	High	10,000-15,000 15,000-20,000 20,000 +	10.0-11.0 8.0-10.0 7.0- 8.0	High
Employment Density	Radial K_D	Correlation	Employment Density	Circumferential K_D	Correlation
0-5,000 5,000-10,000 10,000 +	Highly Variable 9.0-11.0 7.0- 9.0	Medium	0-5,000 5,000-10,000 10,000 +	9.0-11.0 7.0- 9.0 No Data	High
Distance	Radial K_D	Correlation	Utilization Index	Circumferential K_D	Correlation
0-3 miles 3-5 miles 5 + miles	7.0-11.0 10.0-12.0 12.0-14.0	Medium	0.7-0.8 0.8-1.0 1.0 +	10.0-12.0 9.0-11.0 7.0- 9.0	Medium
Peak Period Ratio	Radial K_D	Correlation	Peak Period Ratio	Circumferential K_D	Correlation
.33-.42 .42-.48	7.0-12.0 11.0-14.0	Medium	.33-.42 .42-.48	7.0-11.0 11.0-12.0	Medium
Utilization Index	Radial K_D	Correlation	Distance	Circumferential K_D	Correlation
0.7-0.8 0.8-1.0 1.0 +	Highly Variable	Low	0-3 miles 3-5 miles 5 + miles	Highly Variable	Low

it can be roughly estimated, if more precise data are not available, by use of the formula $K_D = 2 * K * D$. This must also be adjusted to reflect the estimated difference between K based upon ADT, which includes holidays and weekends, and AWDT which does not. If specific data are not available, a factor of 0.92 may be estimated to correct for this discrepancy, so that:

$$K_D = 2 * 0.92 * K * D = 1.84 * K * D$$

The reference table 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, and 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 is reason to consider, but not necessarily, to change the calculated K_D.

FUTURE RESEARCH

In starting a research project, judging the resources available is difficult. The large data base for the permanent count stations seemed at first to lend itself perfectly for this project. However, in the process it became evident that each permanent count station had site specific characteristics that influenced the data. The first step was to eliminate stations without urban characteristics. In further refinement of the data base, stations that were influenced by downstream bottlenecks or upstream constraints were also removed. This left very few stations from which to draw statistical relationships.

In recent years, several urban districts 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. Many times these new stations are located only a couple of miles apart, resulting in many stations along the same freeway. Eventually, this data base could be used to refine the process of selecting K-factors by utilizing several days worth of data, given that the 100th highest hour (occurring weekly) is very little different from the 30th highest hour.

CONCLUSIONS AND RECOMMENDATIONS

This research has focused on the identification of variables affecting K, D, and T factors on urban freeways and on determining the predictability of these parameters using these variables. 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).

The variables tested for significance included facility type (radial or circumferential), AWDT/lane, the degree of peak hour utilization of the facility, the relative number of hours of peak period intensity, the distance from CBD, and the adjacent employment density. While some fairly strong correlations were found on an individual basis, multi-variable regression analysis failed to achieve a better correlation than $R^2 = .70$, unless AWDT/Lane and the utilization index were used together, which violates statistical procedure since they together define K_D. Also, the models proved unstable from year to year.

The problem lies in the data base which is extensive and yet problematical. After eliminating stations not reflective of demand or not fully urban (as yet), too few stations remained to form a significant enough data set to establish a reliable predictive relationship. Consequently, as more permanent count stations come on line, especially, those associated with surveillance, planning parameters should be reevaluated at some future time. Because of the site specific conditions, good communication and flexibility in procedures should be maintained by the district offices and Planning Division in selection of parameters.

Since predictive models have failed to produce a statistically reliable method of calculating K_D, a set of ranges have been developed for K_D under a range of conditions for each variable, and these are recommended for use as guidelines for checking the reasonableness of K_D factors arrived at by traditional means.

Peak hour truck percentages have been studied with the conclusion that values over 4 percent are unusual in the urban areas except where industries are concentrated or along specified truck-routes. It is recommended that higher values be closely checked for accuracy. Radial facilities, in general, experience lower values of peak truck percentages than do circumferential facilities. Use of D-10 factors to predict peak hour truck percentages when 24-hour percentages are known is reasonably correlated; however, more manual count stations within the major circumferential facilities are recommended to determine the appropriate 24-hour truck percentages.

It is additionally recommended that the computer software that generates summaries for the permanent count stations be updated to include the calculation of two other parameters. First, an adjusted K-factor that incorporates AWDT is needed to directly correlate with the volumes predicted from the travel demand models. Second, a K_D-factor is needed that would describe the 30th highest directional hour divided by the AWDT for that direction. The effort to change the software would be justified by the additional aid gained in estimating planning parameters.

REFERENCES

1. American Association of State Highway and Transportation Officials. A Policy on the Geometric Design of Highways and Streets. Washington, D.C. 1984.

2. Transportation Research Board. Highway Capacity Manual. TRB Special Rept. 209. Washington, DC. 1985.

3. Pedersen, N.J., and D.R. Samdahl. Highway Traffic Data for Urbanized Area Project Planning and Design. NCHRP Rept. 255. TRB, Washington, D.C. Dec. 1982.

4. Institute of Transportation Engineers. Reexamination of Design Hour Volume Concepts. ITE Journal. Sept. 1979.

5. Johnson, A.N. The Traffic Census and Its Use in Deciding Road Width. Public Roads, Vol. 4, No. 3. July 1921.

6. Peabody, L.E. Digest of Report on Connecticut Traffic Survey. Public Roads, Vol. 16, No. 11. Jan. 1936.

7. Peabody, L.E. and O.K. Normann. Applications of Automatic Recorder Data in Highway Planning. Public Roads, Vol. 21, No. 11. Jan. 1941.

8. Cameron, N. Determination of Design Hourly Volume. University of Calgary, Dept. of Civil Engineering, Calgary, Alberta. May 1975.

9. Werner, J., and T. Willis. Cost-Effective Level of Service and Design Criteria. Transportation Research Record 699. TRB, Washington, D.C. 1979.

10. Crabtree, J., and J. Deacon. Highway Sizing. Transportation Research Record 869. TRB, Washington, D.C. 1982.

11. Walker, W.P. Trends in the 30th-Hour Factor. HRB Bulletin 167. HRB, Washington, D.C. 1957.

12. Chu, B.P. Michigan's Statewide Traffic Forecasting Model, Vol. III-Design Hour Volume Model Development. Michigan Dept. of State Highways and Transportation. Nov. 1972.

13. Bellis, W.R., and J.E. Jones. 30th Peak Hour Factor Trend. Highway Research Record 27. HRB, Washington, D.C. 1963.

14. Sharma, S.C., and J.Y. Oh. Prediction of Design Hour Volume as a Function of Amount and Nature of Travel. ITE Journal. Feb. 1988.

15. Benson, J.D., C.E. Bell and V.G. Stover. Development of a Peak Period Traffic Assignment Capability. Research Report 454-1F. Texas Transportation Institute, The Texas A&M University System, College Station, TX. Aug 1988.

APPENDIX

Table A-1. Houston Truck Percentages

LOCATION	FACILITY TYPE	DIRECTION	PEAK HOUR PERCENT
HOUSTON:			
US 59S @ HILLCROFT	R	WB	1.5
US 59S @ HILLCROFT	R	EB	1.9
US 290 @ PINEMONT	R	SB	2
US 290 @ PINEMONT	R	NB	3.4
US 59N @ KELLY	R	SB	2.1
US 59N @ KELLY	R	NB	5.1
I-10W @ SILBER	R	EB	2.2
I-10W @ SILBER	R	WB	2.4
I-45S @ COLLEGE	R	SB	3.1
I-45S @ COLLEGE	R	NB	1.4
SH 225 @ SIMMS BAYOU	R	WB	3.1
SH 225 @ SIMMS BAYOU	R	EB	3.2
I-45N @ CROSSTIMBERS	R	NB	3.3
I-45N @ CROSSTIMBERS	R	SB	4.5
I-45N @ CYPRESS CREEK	R	NB	3.9
I-45N @ CYPRESS CREEK	R	SB	4.3
I-10E @ HOLLAND	R	EB	5.3
I-10E @ HOLLAND	R	WB	5.4
I-610E @ BUFFALO BAYOU	C	NB	8.2
I-610E @ BUFFALO BAYOU	C	SB	12.6
I-610W @ BUFFALO BAYOU	C	SB	2.1
I-610W @ BUFFALO BAYOU	C	NB	1.5
US 59S @ MANDELL	R	WB	3.2
US 59S @ MANDELL	R	EB	1.9

STATION	YEAR	DIR		HOUR	PK HR TRUCK VOL	24 HR TRUCK VOL	PK HR VEHICLE VOL	24 HR VEHICLE VOL	PERCENT TRUCK PK HR	PERCENT TRUCK ADT	URBAN TRUCK FACTOR
FORT WORTH											
S122	84	3	P	16	158	1804	2264	21690	.07	.08	.84
		7	P	7	117	1916	2106	24580	.06	.08	.71
	85S	3	P	17	102	1977	2443	23563	.04	.08	.50
		7	P	7	138	2049	2556	24429	.05	.08	.64
	86	3	P	17	104	1880	2759	25468	.04	.07	.51
		7	P	7	147	2071	2554	26193	.06	.08	.73
	87	3	P	16	135	1953	2668	28465	.05	.07	.74
		7	O	16	672		2130		.32		
		3	O	7	74		1761		.04		
		7	P	7	147	1979	2598	30164	.06	.07	.86
30	84	1	P	7	151	2691	3801	27455	.04	.10	.41
		5	P	17	149	2822	3935	28364	.04	.10	.38
	86	1	P	7	133	2381	4090	31264	.03	.08	.43
		5	P	17	138	2686	4513	31767	.03	.08	.36
	87	1	P	7	127	2439	3960	29018	.03	.08	.38
		5	O	7	126		1223		.10		
		1	O	17	154		1503		.10		
		5	P	17	151	2644	4483	32006	.03	.08	.41
S193	84	1	P	16	114	1461	2164	17484	.05	.08	.63
		5	P	17	77	1524	1726	17567	.04	.09	.51
	85S	1	P	16	105	1586	2494	21644	.04	.07	.57
		5	P	7	102	1705	1863	19604	.05	.09	.63
	86	1	P	16	112	1576	2487	21301	.05	.07	.61
		5	P	17	85	1803	2090	22264	.04	.08	.50
	87	1	P	16	107	1500	2779	22276	.04	.07	.57
		5	O	16	99		1854		.05		
		1	O	7	71		1938		.04		
		5	P	7	105	2055	2184	23603	.05	.09	.55
S192	86	3	P	7	151	4179	5301	46074	.03	.09	.31
		7	P	17	174	4332	5035	46096	.03	.09	.37
	87	3	P	7	174	4083	5015	50473	.03	.08	.43
		7	O	7	173		2001		.09		
		3	O	17	197		2688		.07		
		7	P	17	180	3811	4878	48708	.04	.08	.47

STATION	YEAR	DIR		HOUR	PK HR TRUCK VOL	24 HR TRUCK VOL	PK HR VEHICLE VOL	24 HR VEHICLE VOL	PERCENT TRUCK PK HR	PERCENT TRUCK ADT	URBAN TRUCK FACTOR
AUSTIN											
S4	84	1	P	7	105	1619	1590	12682	.07	.13	.52
		5	P	16	144	2029	1867	13546	.08	.15	.51
	85	1	P	7	140	2937	2034	20534	.07	.14	.48
		5	P	17	134	2888	2060	19855	.07	.15	.45
	86	1	P	7	166	2936	2172	22731	.08	.13	.59
		5	P	17	145	3194	2305	22797	.06	.14	.45
	87	1	P	7	119	2582	2241	21196	.05	.12	.44
		5	O	7	127		953		.13		
		1	O	17	106		1295		.08		
		5	P	17	145	3027	2236	20956	.06	.14	.45
S190	84	1	P	17	152	2355	3461	19304	.04	.12	.36
		5	P	7	117	2498	2875	19627	.04	.13	.32
	85	1	P	17	195	4580	3529	31121	.06	.15	.38
		5	P	7	193	4637	3506	32361	.06	.14	.38
	86	1	P	16	193	3851	3458	34742	.06	.11	.50
		5	P	7	224	4498	3896	34980	.06	.13	.45
	87	1	P	17	178	4284	3906	35510	.05	.12	.38
		5	O	17	191		2467		.08		
		1	O	7	209		1977		.11		
		5	P	7	140	4067	3736	36450	.04	.11	.34
S209	87	1	P	17	69	1030	5359	48777	.01	.02	.61
		5	O	17	66		3982		.02		
		1	O	7	42		3286		.01		
		5	P	7	46	1067	5520	47640	.01	.02	.37
1309	86	3	P	7	77	1809	1681	14456	.05	.13	.37
		7	O	7	94		1141		.08		
		3	O	16	117		1022		.11		
		7	P	16	113	1780	1361	13744	.08	.13	.64
1307	84	1	P	7	4	69	234	1196	.02	.06	.30
		2	P	17	36	573	1063	8338	.03	.07	.49
		5	P	17	6	59	88	667	.07	.09	.77
		6	P	17	40	586	1159	8954	.03	.07	.53
	86	1	P	7	15	117	377	2466	.04	.05	.84
		2	P	17	69	1075	1408	14451	.05	.07	.66
		5	P	17	3	113	145	1328	.02	.09	.24
		6	P	17	73	1047	1605	15617	.05	.07	.68

Table A-3. Truck Percentages: Dallas and Fort Worth.

LOCATION	FACILITY TYPE	DIRECTION	PEAK HOUR PERCENT
DALLAS:			
I-35E, SRLT	R	SB	1.6
SH 183 @ O'CONNOR	R	WB	1.8
I-35E @ ANN ARBOR	R	SB	1.9
I-45 @ I-30	R	NB	2.1
I-35E @ EWING	R	NB	2.1
I-635 @ PRESTON	C	WB	2.2
US 75 @ HALL	R	SB	2.3
I-635 @ SKILLMAN	C	EB	2.4
I-30 @ BIGTOWN	R	EB	2.6
SH 183 @ I-35E	R	EB	2.7
I-30 @ I-20	R	EB	2.8
I-30 @ I-20	R	WB	2.9
I-635 @ SKILLMAN	C	WB	2.9
I-30 @ BIGTOWN	R	WB	2.9
I-30 @ BIGTOWN	R	WB	2.9
I-35E @ ZANG	R	SB	3
SH 183 @ SH 114	R	WB	3
I-30 @ I-45	R	WB	3.3
I-45 @ I-30	R	SB	3.4
I-30 @ I-45	R	EB	3.4
LOOP 12 @ I-35E	C	NB	3.6
I-635 N OF I-30	C	SB	3.6
LOOP 12 @ I-35E	C	NB	3.6
I-35E @ SH 183	R	SB	3.7
I-35E @ SH 183	R	SB	3.7
I-635 S OF I-30	C	NB	3.8
I-30 @ US 75	R	EB	4.4
LOOP 12 @ I-35E	C	EB	4.7
LOOP 12 @ I-35E	C	NB	5
FORT WORTH:			
SH 114 @ SH 121	R	EB	1.1
SH 360 @ SH 183	C	NB	1.2
I-820 W OF SH 199	C	EB	1.2
I-820 W OF SH 199	C	WB	1.4
SH 183 @ SH 360	R	EB	1.5
I-20 @ FM 157	R	EB	2.9
I-820 @ RUFF SNOW	C	WB	3.2
I-35W @ FM 1187	R	NB	3.2
SH 121 @ SH 114	R	EB	3.2
I-30 E OF SH 360	R	EB	3.5
I-20 @ FM 157	R	WB	4.5
I-20 E OF SH 183	C	WB	5.1