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16. Abstract

Numerous park-and-ride lots are being developed in Texas. This report develops techniques that can be used to estimate the ridership that will occur at park-and-ride lots. The data base used to develop these techniques is comprised of the experiences at the 35 existing park-and-ride lots in Texas. The demand estimation techniques presented are intended to be easy and inexpensive to apply and use only data that are readily available for urban areas in Texas.

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GUIDELINES FOR ESTIMATING PARK-AND-RIDE DEMAND

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Technical Report 1064-1F

Park-and-Ride Demand Estimation
Technical Study Number 2-10-81-1064

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Texas Transportation Institute
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College Station, Texas

July 1981

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DISCLAIMER

ABSTRACT

Numerous park-and-ride lots are being developed in Texas. This report develops techniques that can be used to estimate the ridership that will occur at park-and-ride lots. The data base used to develop these techniques is comprised of the experiences at the 35 existing park-and-ride lots in Texas. The demand estimation techniques presented are intended to be easy and inexpensive to apply and use only data that are readily available for urban areas in Texas.

Key Words: Park-and-Ride, Modal Split, Transit Demand Estimation, Change of Mode Facilities, Bus Rapid Transit, Terminal Design.

SUMMARY

Several alternative techniques are presented to estimate demand at a park-and-ride facility. Utilization of these techniques will provide a range of estimates; the analyst will then need to apply judgment in developing a specific estimate for a specific site.

The techniques developed in this report are based on experiences at existing park-and-ride lots in Texas. Many of these facilities operate at or above capacity. Thus, using those data to estimate "demand" will result in conservative estimates.

Lot Location Guidelines

The estimation procedures set forth assume that the park-and-ride facility has been "properly" located. In general, the guidelines listed below should be followed in locating potential park-and-ride lot sites.

- Lots should be located at least 4 to 5 miles from the activity center served. Given appropriate development patterns, there appears to be no limit concerning how far a successful lot can be located from the activity center.
- Lot utilization increases as corridor congestion increases. The more successful lots occur along freeway corridors with daily traffic volumes per lane in excess of 15,000.
- The lot should be able to intercept traffic upstream of congestion.
- Lots should be developed with both good access and good accessibility.
- Parking at the lot should be free.
- Park-and-ride service should not be expected to compete with local routes, especially if fare differentials exist.

Alternative Demand Estimation Techniques

Park-and-ride lots draw their demand from a rather well-defined watershed or market area. This watershed is generally parabolic in shape, with a vertex 0.5 to 1.0 mile downstream of the lot, an axis of 5 to 7 miles in length following the major artery upstream of the lot, and with a chord of 6 to 8 miles in length. When market areas of multiple lots overlap, this geographic area needs to be adjusted accordingly. In general, there are 1.4 park-and-ride patrons per parked auto.

Market Area Population

Data indicate that relationships exist between ridership and market area population. The following guidelines appear to be applicable.

City	Ridership as a Percent of Market Area Population
Houston	0.7% to 2.0%
Dallas Area	0.4% to 1.3%
San Antonio	varies up to 1.2%
Austin	0.3% to 0.6%
Fort Worth	0.05% to 0.3%
El Paso	0.07% to 0.4%

The data suggest that, at properly located lots in congested corridors with priority bus service, perhaps as much as 2.5% to 3% of the total market area population could be served by park-and-ride.

Modal Split

Existing park-and-ride lots in the Dallas area are typically serving 10% to 20% of demand (i.e., 10% to 20% of the persons living in the market area served by the park-and-ride lot and working in the activity center served by the park-and-ride buses). In Houston, this percentage is typically 15% to 30%.

Data suggest that park-and-ride lots have the potential to serve 50% modal splits.

Regression Analysis

Data for the 35 park-and-ride lots were combined and analyzed in all possible manners to develop equations that can be used to predict park-and-ride patronage. Several of these equations are discussed in the text and in Appendix B. The following represent some of the more applicable equations.

1. Ridership = -160 + 204 (CI) + 0.0034 (MAPOP) $R^2 = 0.57$

   Where:

   CI = congestion index for line-haul roadway (described in more detail in text and in Research Report 205-7).

   MAPOP = total population in the market area

   In most instances this equation predicts ridership at existing lots within 50% of actual ridership.

2. a. Ridership = -86 + 0.8 (MIN) + 0.002 (MAPOP) $R^2 = 0.93$
   Note: Applies to lots with CI $\geq$ 1.3

   b. Ridership = 61 + 0.1 (MIN) + 0.001 (MAPOP)
   Note: Applies to lots with CI between 0.9 and 1.2

   c. Ridership = 7 + 0.43 (MIN) $R^2 = 0.81$
   Note: Applies to lots with CI $\leq$ 0.9

Where:

MIN = a control based on service provided. It equals the minimum of the following 2 variables: 1) auto parking spaces x 1.5 persons/auto; or 2) peak-period bus seats. The equation thus recognizes that, at many existing lots, demand is controlled by facilities provided.

MAPOP = the population in the park-and-ride lot market area

The equations using the MIN variable accept the fact that current park-and-ride patronage is often controlled by either facilities (i.e., parking spaces available) or service (i.e., number of buses providing service to the lot). These equations, in most instances, predicts ridership at existing lots within 25% of actual ridership. Further discussion of the selection of a MIN variable for demand estimation is included in the main body of the report.

Once the ratio of parking spaces to market area population exceeds that characteristic of existing Texas lots, use of any of the demand estimation procedures requires extrapolation of the data base.

Although it appears that provision of priority treatment (i.e., the I-45N contraflow lane) may increase modal splits at park-and-ride lots, the available data were insufficient to definitively establish that fact.

IMPLEMENTATION STATEMENT

Numerous large park-and-ride facilities are being developed in major Texas cities. To date, only limited Texas data have been available to assist in sizing and locating these facilities.

This report presents information that can be used by transportation planners in sizing and locating park-and-ride lots. This report, which provides guidelines for park-and-ride demand estimation, complements the following reports published by the Texas Transportation Institute.

"Park-and-Ride Facilities: Preliminary Planning Guidelines," Research Report 205-2.

"Design Guidelines for Park-and-Ride Facilities," Research Report 205-3.

"Development of Preliminary Congestion Indices for Urban Freeways in Texas," Research Report 205-7.

"Factors Influencing the Utilization of Park-and-Ride--Dallas/Garland Survey Results," Research Report 205-11.

"Houston Park-and-Ride Facilities, An Analysis of Survey Data," Research Report 205-15.

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INTRODUCTION

During the past 5 to 7 years, development of park-and-ride lots has become a significant part of transit development plans in major Texas cities. At present, some 35 park-and-ride lots are in operation in 6 metropolitan areas in Texas, namely Houston, Dallas, Fort Worth, Austin, San Antonio, and El Paso. Several of these cities are actively pursuing the development of additional park-and-ride facilities. In essence, park-and-ride has proven to be a popular travel alternative.

To date, relatively crude procedures have been used to locate and size park-and-ride lots. Generally, in sizing new facilities, either attempts were made to transfer experience from a very limited number of Texas park-and-ride lots, or demand estimation procedures developed outside of Texas were applied to Texas cities. These models often required either extensive computer modelling or input data that were not readily available in Texas.

Use of these procedures provided an "educated guess" regarding potential demand, but not always an accurate prediction. The result of using these procedures has been that some lots have experienced demands much greater than predicted, while others received relatively small demand in relation to the prediction. Thus, inadequate capacity has been provided at some locations, while excess capacity exists at other lots. With per space costs in Houston commonly exceeding $3000, a need exists to develop procedures that can be used to predict potential demand with reasonable accuracy, perhaps within 30%.

Experience has suggested that, for a lot to be heavily utilized, certain lot location guidelines need to be adhered to; these guidelines are set forth in this report. For lots that generally adhere to these guidelines, several alternative procedures are set forth to use in estimating ridership at the park-and-ride facility. These procedures are all based on data collected from park-and-ride lots in Texas. All of these procedures use data that are readily available to transportation planners in Texas. The intent of providing alternative demand estimation techniques is not to determine which technique is "best." Rather, it is suggested that several different techniques be used, and that the resulting estimates provide a range of values that the analyst can use in assessing demand. It appears that the techniques set forth in this report will provide usable estimates of park-and-ride demand in Texas cities.

This report complements the following research documents prepared by the Institute.

- "Park-and-Ride Facilities: Preliminary Planning Guidelines." Research Report 205-2, 1975.
- "Design Guidelines For Park-and-Ride Facilities." Research Report 205-3, 1978.
- "Development of Congestion Indices for Urban Freeways in Texas," Research Report 205-7, 1979.
- "Factors Influencing the Utilization of Park-and-Ride: Dallas/Garland Survey Results." Research Report 205-11, 1980.
- "Houston Park-and-Ride Facilities, An Analysis of Survey Data." Research Report 205-15, 1981.

THE PROBLEM

Park-and-ride systems are a major part of transit operations in Texas. This type of transit service is provided in at least 6 major Texas cities, and considerable additional development of park-and-ride facilities is being pursued in the state.

A problem faced in the development of park-and-ride lots in Texas relates to demand estimation. Critical questions to be answered involve "where should the lot be located" and "how large should it be." Previous research (Research Reports 205-2, 205-3, and 205-11) has addressed certain planning and design issues but has not resolved the demand estimation problem.

To date, inability to estimate demand has not been critical, since it is apparent that a considerable latent demand for high-level transit service exists. As a result, the relatively small number of park-and-ride lots built in Texas cities have, in general, been highly successful. Indeed, if there has been a problem, that problem has been that the lots developed have been too small. Even though most of the existing lots in the state have only operated for 2 to 4 years, approximately 35% of those lots already are operating at their effective capacity, based on parking spaces provided.

As more lots are developed, with per parking space costs in the range of $2500 to $4500, it becomes increasingly necessary to develop techniques that can be used to estimate required lot size. It is also necessary to develop some relatively simple techniques for estimating demand -- techniques that utilize readily available data and do not necessitate large-scale computer modelling to predict ridership at alternative park-and-ride lot sites. Development of such prediction techniques is the objective of this study.

This study provides a quantitative evaluation of 35 Texas park-and-ride lots located in 6 different Texas cities. Two concerns should be recognized at the outset of the study.

- Demand equations developed in this report are designed to be relatively simplistic and include only a minimum number of variables -- variables based on readily available data. As a result, it is critical that considerable study be given to identifying alternative lot locations; unless lots are located in accordance with certain guidelines, it is unlikely that those lots will be successful, or that the demand estimation equations will provide useful estimates.

- The equations are developed using data from existing lots in Texas. At many lot locations, actual demand is constrained based either on facilities available (number of parking spaces) or service provided (number of peak-period bus departures). If more facilities or service were provided at those locations, it is assumed that a greater demand would be served.

These concerns are discussed in more detail in the remainder of this section.

Lot Location Guidelines

In developing alternative sites for park-and-ride facilities, attention should be given to the guidelines outlined below. If several of these guidelines are not adhered to, utilization of the lot will be less than expected and less than the values predicted using the demand estimation techniques developed in this report.

- Most successful lots in Texas are located at least 4 to 5 miles from the activity center served. Most park-and-ride patrons drive less than 5 miles to get to the lot. Since the typical work trip in Texas is about 8 miles in length, it appears that, if a lot is located closer than 4 miles to the activity center, the auto trip will constitute more than half of the total trip to downtown. This may cause the potential user to forego the mode change opportunity.

- Given appropriate development patterns, there appears to be no outer limit concerning how far a lot can be located from the activity center. Successful lots in Texas are located as far as 30 miles from the desired destination.

- The park-and-ride lot should be located in a congested travel corridor. The congestion index which was developed in Research Report 205-7 and provides relative measures of congestion on Texas freeways was found to be a relatively important variable in predicting park-and-ride utilization. The more successful lots in Texas appear to be in corridors with congestion indices in excess of 1.0 to 1.5 (refer to CI in Table 5, Research Report 205-7); as a general guide, this range of congestion index is experienced as average daily traffic per lane approaches about 20,000.

- The lot should be located to allow the facility to intercept traffic upstream of the point where that traffic would otherwise have to encounter intense congestion.

- As the total population in the park-and-ride lot market area or watershed (described in more detail in Research Reports 205-2 and 205-3) increases and as the percentage of that population working in the activity center served by park-and-ride increases, so will park-and-ride utilization. As a result, the magnitude of development at the activity center can also be an important determinant of potential park-and-ride utilization, and variables such as activity center parking costs can be significant in estimating demand.

- Both the accessibility (a measure of the ease with which potential users can get to the general area of the park-and-ride lot) and the access (a measure of how easily users can get into and out of the specific lot site) associated with a park-and-ride lot can influence utilization.

- Although data are not sufficient to conclusively state that parking at the lot should be free, it appears that a parking charge may adversely affect ridership.

- If available park-and-ride spaces are serving "all" the demand from a given watershed, other lots in that same corridor should be located no closer together than 4 to 5 miles.

- "Competitive" local transit routes, especially when a fare differential exists between the local and the park-and-ride service, can siphon off considerable potential park-and-ride utilization.

Demand Constrained By Service and Facilities

The fact that many of the park-and-ride lots in the state are filled to capacity and that buses have numerous standees suggests that, in many instances, facilities and service are constraining the demand; if more parking spaces and more buses were available, a greater park-and-ride ridership would be served. What these lots have demonstrated is that a substantial demand exists for high-level transit service in congested Texas cities. The actual magnitude of that demand remains unquantified in many corridors, simply because sufficient services have not been provided to serve that demand. The estimation guidelines developed in this report are based on existing services in Texas; these guidelines may tend to provide conservative estimates of actual demand and, in congested corridors where plans are made to attempt to serve all demand, utilization of the guidelines will involve extrapolation beyond the range of the data base used to develop the guidelines.

STATE-OF-THE-ART, LITERATURE REVIEW

Many discussions of park-and-ride facilities and park-and-ride transit service include a section on the need and desirability for adequate estimation of future park-and-ride demand. No better example of this need is found than in the UMTA report Park-and-Ride Planning Manual by Kerchowskas and Sen (1).* These authors devote an entire section of their report to outlining the existing techniques for predicting park-and-ride demand. Two general types of prediction techniques are presented in the literature; prediction based on modal split, and prediction based on assumed causal relationships.

Modal Split Techniques

The first technique involves the determination of a modal split, or the probability of mode choice based on socioeconomic characteristics of the potential user population and the level of transit service provided to that population. Williams, Sanderson, and Senior (2) present an example of this type of demand prediction technique. Their model entails predicting the outcome of several decisions that individuals must make concerning how to make their work trip. Origin-destination information and travel costs for various modes of travel are necessary to calibrate this model. The model produces an equation that predicts the demand for parking spaces at a change of mode facility. The authors present no actual data, nor do they provide model validation examples. In fact, the authors concede that one difficulty with their technique is the lack of readily available data.

*Denotes reference number listed at end of main body of report.

A second example of park-and-ride demand prediction via the modal split approach is presented by Allen (3). (This model was originally developed for the North Central Texas Council of Governments by Alan M. Voorhees and Associates, Inc. (4)). The modal split in this technique is determined by calculating the disutilities associated with both auto and transit modes. These disutilities are based on costs associated with travel times, parking, transit fare, and auto operation. The output of this model is a percentage of the potential user population that will use park-and-ride as a function of marginal disutility. Allen reports that this modal split technique predicts the existing usage of park-and-ride lots in Dallas fairly accurately. However, statewide application of this technique was not attempted.

A slightly different modal split approach to park-and-ride demand prediction is presented in a 1978 report prepared by the Texas Transportation Institute that addresses demand prediction (5) and by McCann, et al. (6). Both reports outline techniques for accurately defining potential user populations or market areas. Once the market areas are defined, these techniques attempt to estimate an attraction rate, or percent usage. Only limited examples were presented in both reports.

Finally, general transit demand forecasting as presented by Roulet (7), Brown (8), and the NCHRP Report #187 (9) may be applied to park-and-ride demand estimation. However, the application would require some modification. Because each model contains several complicated equations, this modification may be laborious, and the application may be difficult.

Causal Relationship Techniques

The second general type of park-and-ride demand estimation relies on a statistical analysis, usually multiple linear regression, to establish a relationship between park-and-ride patronage and a variety of causal factors.

This technique involves an initial step of identifying the causal factors that may influence patronage. After causal factors are identified, two data collection strategies are followed in the literature: 1) collect sufficient data to quantify all of the causal factors; or 2) select the most important factors and then collect data to quantify only these elements.

An example of the first strategy is presented in a paper by Abdus-Samad and Grecco (10). They constructed an extensive data base that included information on 93 park-and-ride facilities located in 10 cities. The data collected were a wide range of physical, operational and locational factors. These factors were aggregated into eight weighted variables. Values were assigned to each variable based on its relative contribution to an individual's decision to use park-and-ride. A multiple regression analysis performed on these variables produced a nonlinear parking demand estimation equation containing seven independent variables and having a coefficient of multiple determination (R^2) of 0.77. When applied to predict demand for parking at nine park-and-ride facilities, this equation averages a ± 67 percent error rate. (Highest error: 232%, lowest error: 23%). Because of the extensiveness of the data base required, the effort needed to execute this model may not be congruous with its accuracy.

Rathbone (11) took a slightly different approach to the all inclusive data collection strategy. In constructing his data base, Rathbone first identified six major causal factors. He then collected the available information in order to quantify these factors. With the data base completed, Rathbone conducted a regression analysis on these data to determine the correlations between each causal factor and the number of cars parked at a given park-and-ride lot. When little or no correlation was shown between a variable and park-and-ride usage (parked cars), that variable was dropped from the model. The resulting equation contains two independent variables and is nonlinear. These independent variables are the number of potential users and a transit rating variable. Although the transit rating variable is fairly easy to construct, the exact number of potential users is not always readily available data. The dependent variable is the number of parked cars at a given lot. The application of this equation to the prediction of cars parked at 11 park-and-ride facilities produces error rates as high as 86 percent and as low as zero percent. (Average percent error: ± 32%).

The second data collection approach for the regression based models is presented by Levinson (12). In order to estimate demand for park-and-ride facilities in Boston, Levinson selected only four major causal factors. These factors were CBD employment, CBD parking supply, regional population growth, and transit service. From these factors he developed a two variable, nonlinear equation that predicts potential parking spaces. No actual data or model validation is presented.

Keck and Liou (13) present a multiple-regression based model that may be used to predict park-and-ride demand. The equation contains four independent variables: air distance between a lot and its activity center, travel time difference between auto mode and park-and-ride mode, difference between auto travel cost and park-and-ride travel costs, and combined cost difference of time and travel costs. Again, only limited amounts of data are necessary to execute this model. This model is an aggregated, linear equation. The coefficient of multiple determination (R^2) of the equation is 0.59. The dependent variable in this equation is the percentage of "eligible service users" that actually use the park-and-ride service. "Eligible service users" is defined as those persons living within a given service area and working at a given activity center. The authors present detailed, actual data for two park-and-ride lots. The ridership figures for each zip code area within the lots' market areas were predicted, and the percent errors calculated. This linear model produced an average error rate of ±48 percent (+50% and -46%). The authors point out an interesting flaw in their equation. It predicts some negative percent usages. To correct the flaw, Liou (14) developed two nonlinear equations. These equations use the original four variables, however, not in a linear fashion. The best of these equations eliminates the negative predictions and improves the average percent error to ±22 percent (+17% and -26%). Although these percentage errors are good, it should be remembered that the model was applied to only two park-and-ride lots. Also, the model is restricted to lots where exact potential user populations are known, a difficult value to quantify.

In conclusion, several points about park-and-ride demand prediction models may be drawn from this literature review. First, a demand prediction model should contain a small number of variables thereby reducing the volume of data collection. These variables should be easily quantifiable from readily accessible data sources. The model should contain an equation(s) that is simple, perhaps linear, making use of the model relatively easy. And finally, the model should predict park-and-ride demand for the majority of the lots within the State of Texas with an error rate less than or equal to ±25 percent. It is important to note that the model needs to be predictive rather than descriptive; that is, the variables should be such that they will predict usage at a proposed new lot rather than simply describe usage at an existing lot.

DESCRIPTION OF DATA BASE

Presently, 35 park-and-ride lots are located in 6 major Texas cities. The thrust of this project was to use the experiences at those lots as the data base in developing demand estimation procedures.

All data that might have any influence on lot utilization were collected. First, all possible causal factors that might influence park-and-ride demand were enumerated. Then data were collected to quantify those factors. During the model development phase of this study, all factors that did not influence demand in a statistically significant fashion were eliminated from the data base.

The original data base contained some 26 attributes of the 35 park-and-ride lots operating in the Texas cities of Austin, Dallas (metropolitan area), El Paso, Fort Worth, Houston, and San Antonio. This data collection effort began with the identification and location of the Texas park-and-ride lots. Maps showing the location of each lot with respect to their activity centers and the city's freeway system are shown in Figures 1 through 6. The next step in the data collection effort involved visiting each of the Texas cities that provide park-and-ride service. These visits provided the opportunity to accomplish two data collection tasks. The first of these tasks was to conduct an in-depth, on-site study of each lot. The purpose of these on-site studies was to catalogue thoroughly all of the physical features found at each lot. These physical features included:

- Exact street address of each lot.
- Lot size--parking spaces, kiss-and-ride spaces, handicapped spaces, and bus loading areas.
- Lot amenities--shelters, security personnel, lighting, telephones, newsstand and vending machines, and pavement condition.

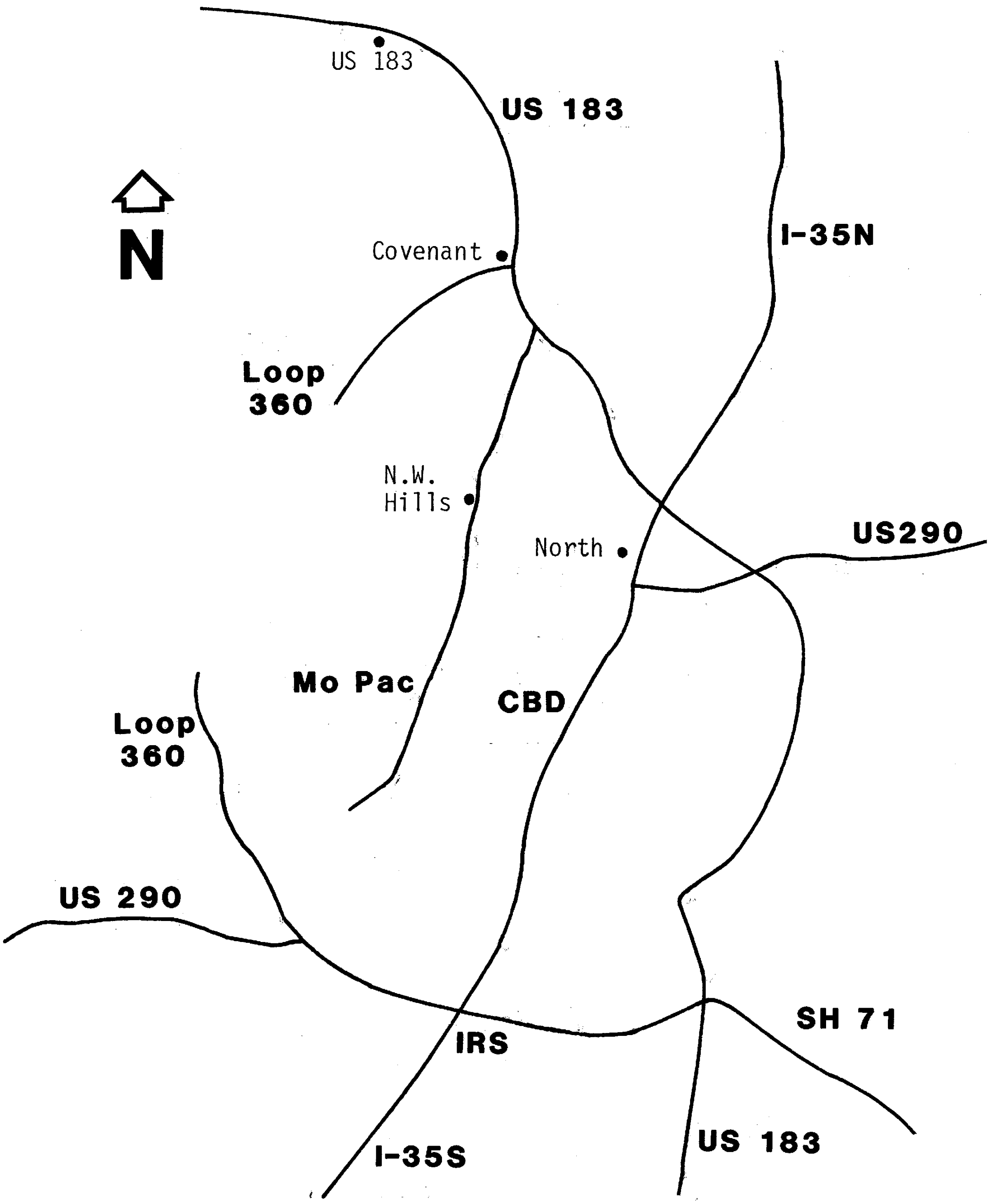


Figure 1: Location of Austin Park-and-Ride Lots

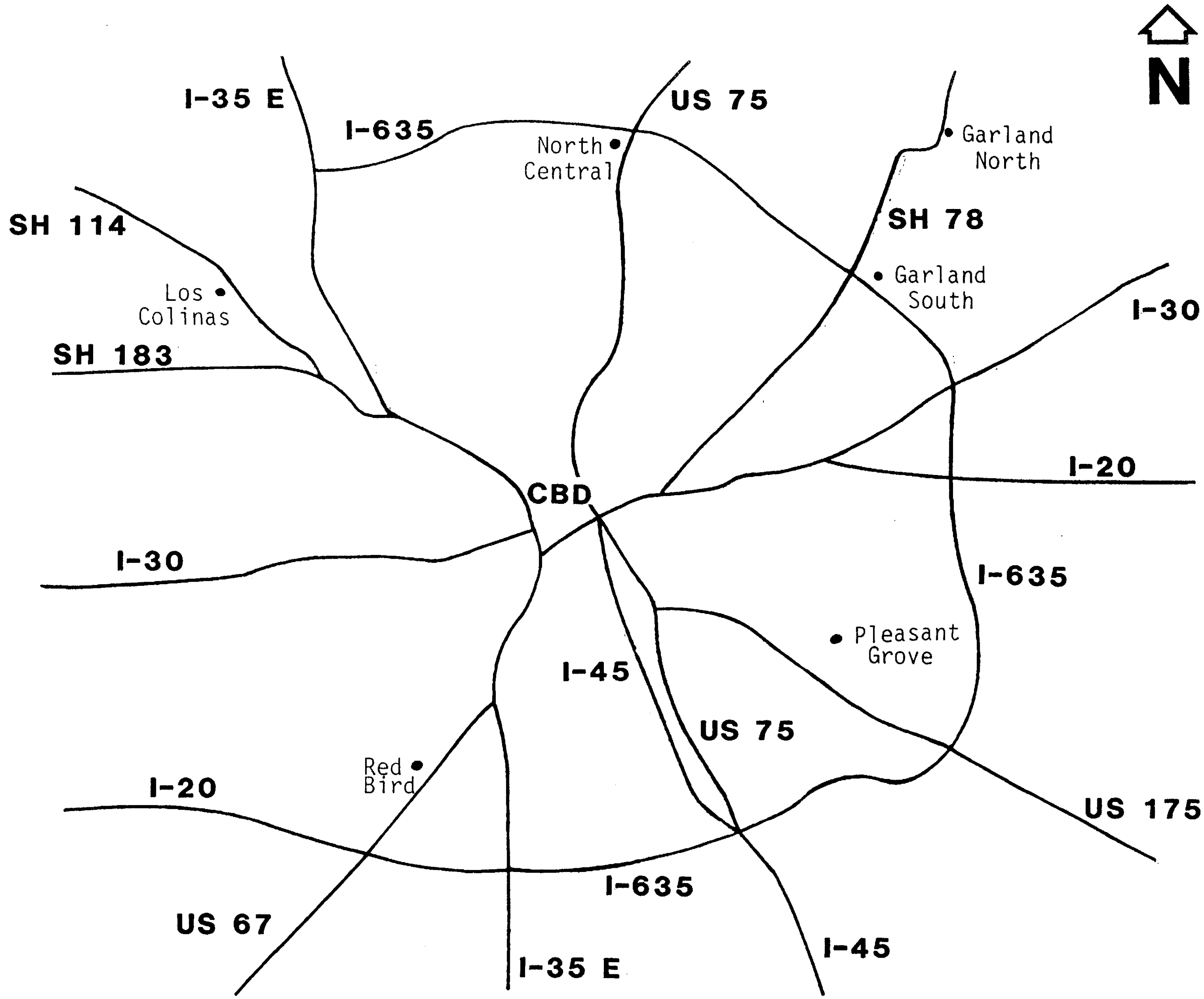


Figure 2: Location of Dallas Area Park-and-Ride Lots

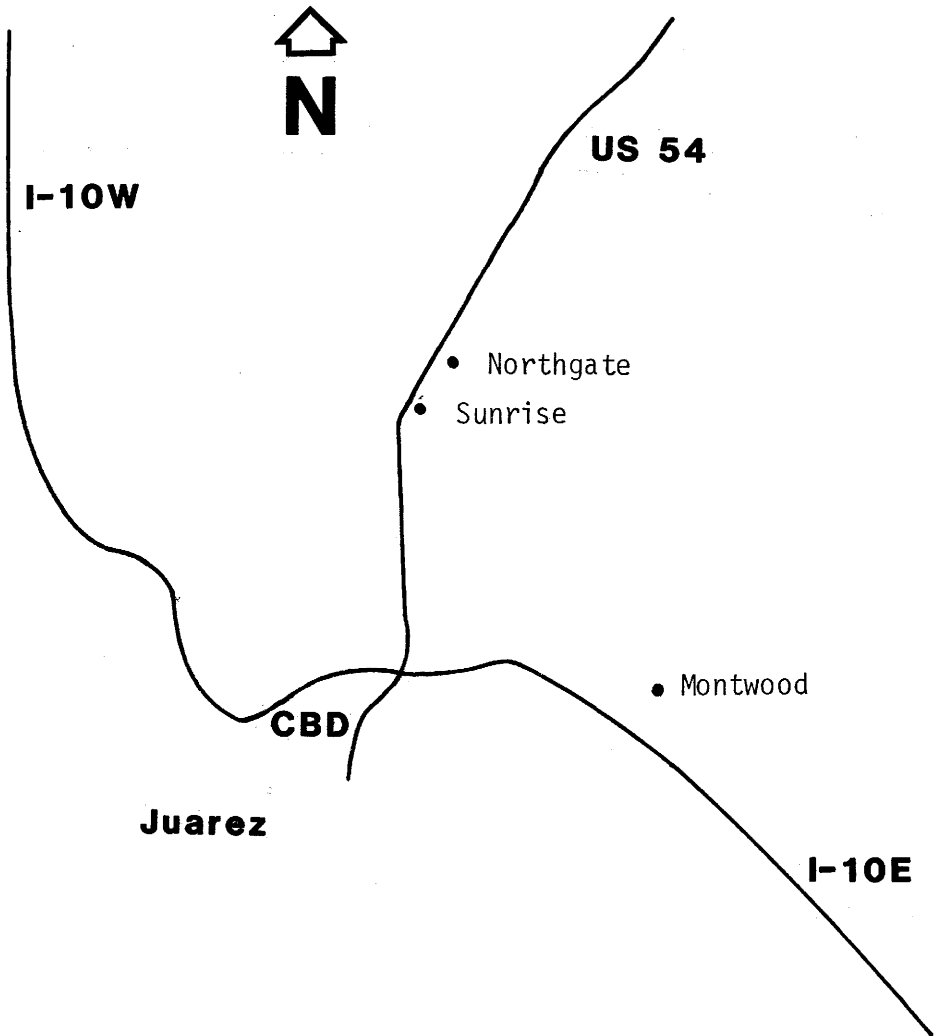


Figure 3: Location of El Paso Park-and-Ride Lots

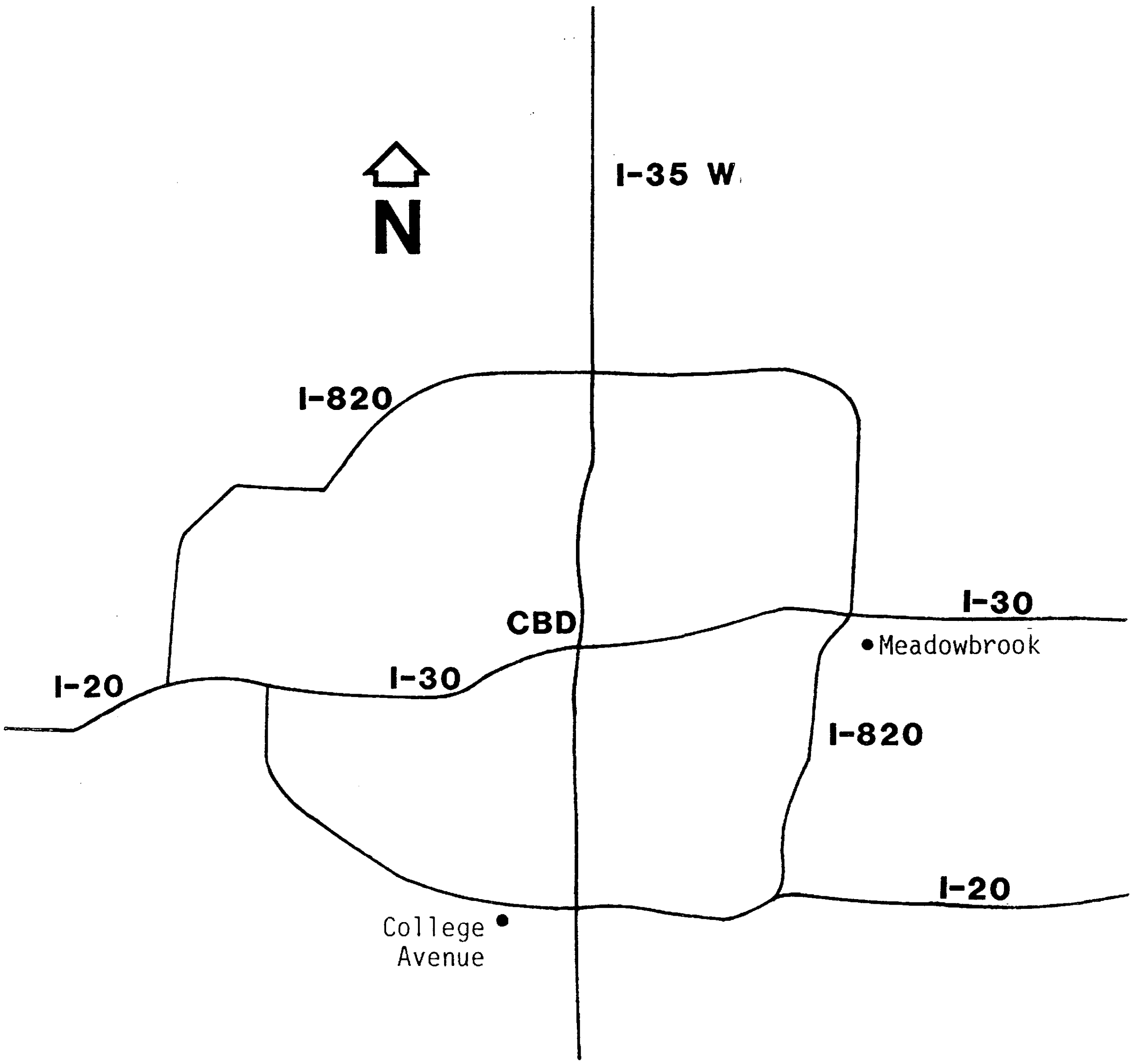
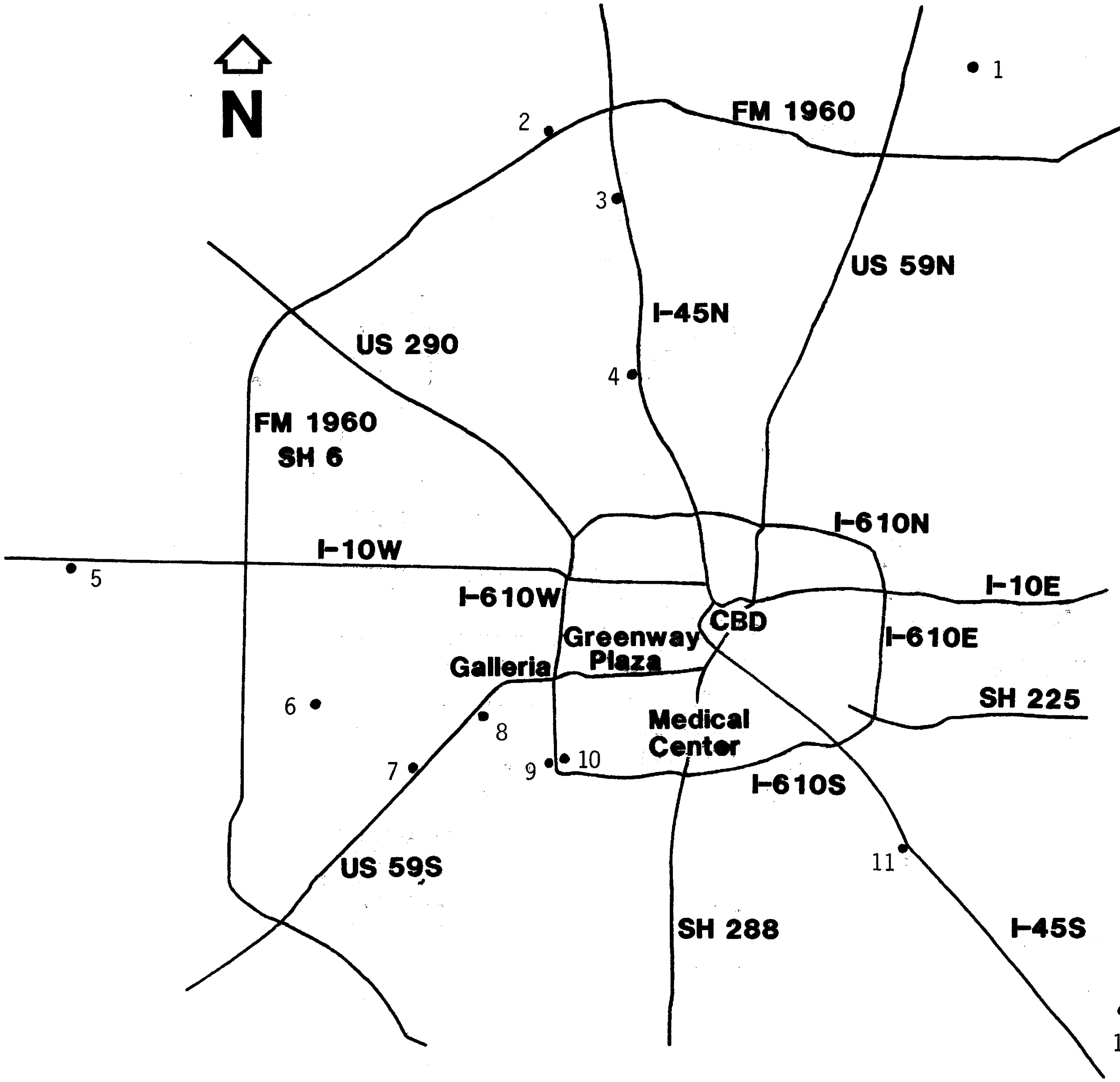


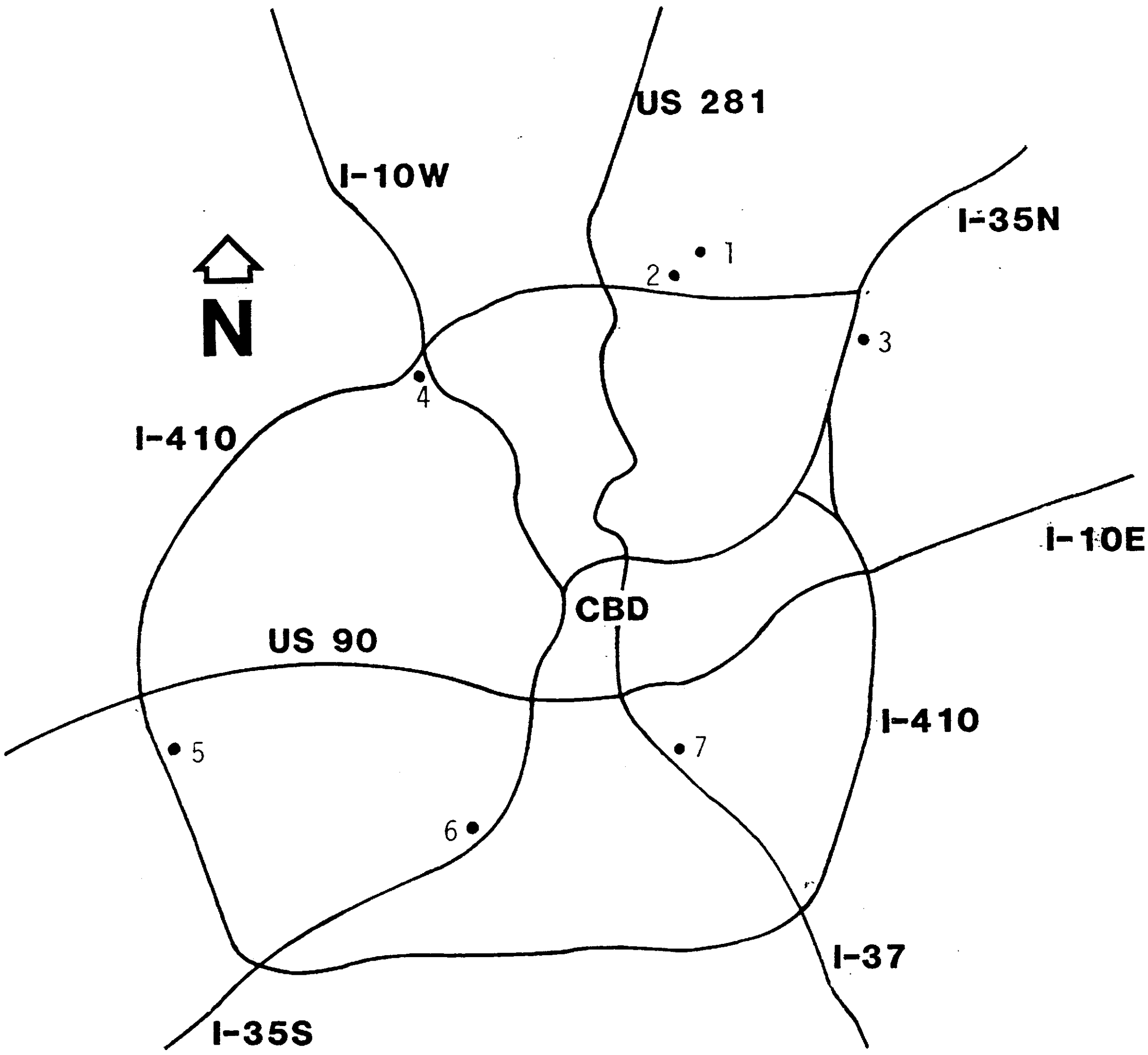
Figure 4: Location of Fort Worth Park-and-Ride Lots



Houston Area Park-and-Ride Lots

1. Kingwood
2. Champions
3. Kuykendahl
4. North Shepherd
5. Mason
6. Alief
7. Westwood
8. Sharpstown
9. West Loop-Beechnut
10. West Loop-Sage
11. Edgebrook
12. Clear Lake

Figure 5: Location of Houston Area Park-and-Ride Lots



San Antonio Area Park-and-Ride Lots

1. Nacogdoches/Bitters
2. Nacogdoches/Broadway
3. Windsor
4. Wonderland
5. Lackland
6. South Park
7. McCreless

Figure 6. Location of San Antonio Park-and-Ride Lots

- General lot access from arterial streets.
- General physical arrangement of the lot.

After the on-site inspections were completed, members of the study team met with the various transportation personnel involved in park-and-ride (refer to Acknowledgements section). These meetings provided the opportunity to complete a second data collection task. The transit and transportation personnel provided the study staff with detailed information on park-and-ride transit service and park-and-ride patronage statistics. The transportation personnel also provided estimates of the activity center parking cost and employment in their cities. All of this information was incorporated into the data base.

A key variable is the population in the "market area" or "watershed" served by a park-and-ride lot. In order to be able to predict ridership at a new lot, it is necessary to identify a characteristic market area shape--the population in that area establishes at least an upper bound on potential lot usage. The Texas Transportation Institute, using surveys (15) to expand upon work performed by the Institute of Transportation Engineers (19), as well as Allen (3), addressed this issue. According to Christiansen and Rathbone, surveys of existing park-and-ride facilities indicate that the market area is roughly parabolic in shape and five miles long and six miles wide (see Figure 7). A license plate survey conducted by Allen indicated similar bounds for market areas. Allen defined the market area as roughly circular in shape with a seven-to eight-mile diameter and the lot located slightly off-center (see Figure 8). The Allen market area indicates far more backtracking by park-and-ride patrons than does the Christiansen and Rathbone market area--2.5 miles as opposed to 0.5 miles. It was decided to use the Christiansen and Rathbone service area for the lots in Austin, Dallas, El

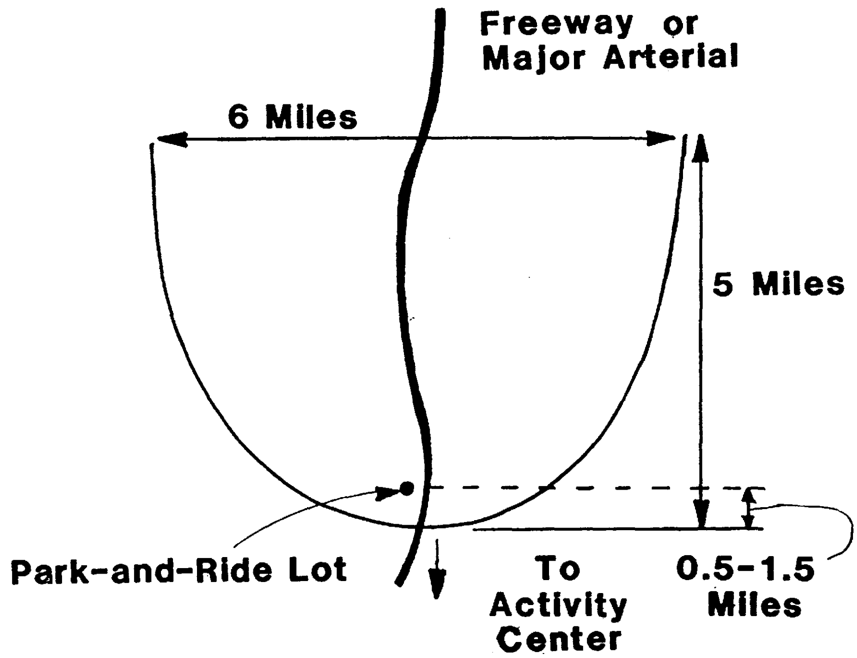


Figure 7: Alternative Shape of Park-and-Ride Market Area (15,19)

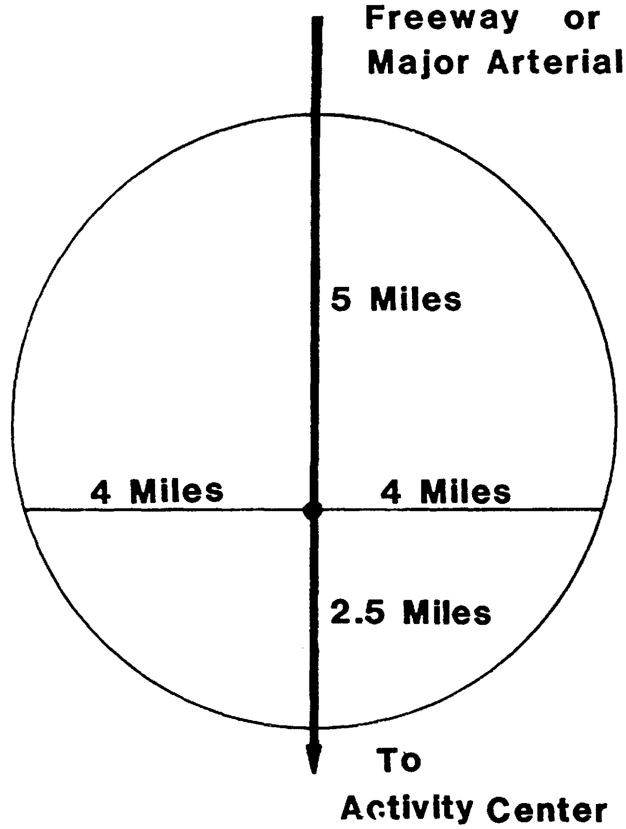


Figure 8: Alternative Shape of Park-and-Ride Market Area (16)

Paso, Fort Worth, and San Antonio. Subsequent survey work (20) performed by the Texas Transportation Institute in Houston suggested that, in that city, the "characteristic" market area was somewhat larger. That survey data suggested that Houston park-and-ride market areas were better defined by a 7 by 8 mile parabola (Figure 9).

With the market areas for each park-and-ride lot defined, the demographic statistics were then collected. The 1970 census publications provided a wide range of demographics; however, much of the information was outdated. Attempts to acquire similar statistics from the 1980 census data were unsuccessful. The only statistic presently available from the 1980 census data is population. Market area populations were determined by first overlaying the appropriate market area parabola on census tract maps. Then the population figures from each census tract lying within the market area were summed. Complete market area population information is presented in Appendix A.

It has frequently been theorized that congestion is an important variable in park-and-ride utilization. As part of previous research (17), Texas Transportation Institute has developed relative measures of freeway congestion in Texas; at the time that research was performed it was hypothesized that the congestion index might help explain park-and-ride utilization. This individual congestion index (ICI) takes into account both the travel time delay due to congestion and the average annual daily traffic (AADT) per lane on a given freeway. The equation is as follows:

$$ICI = \frac{\text{Delay Time in Min.}}{10''} + \frac{\text{AADT/Lane}}{20{,}000}$$

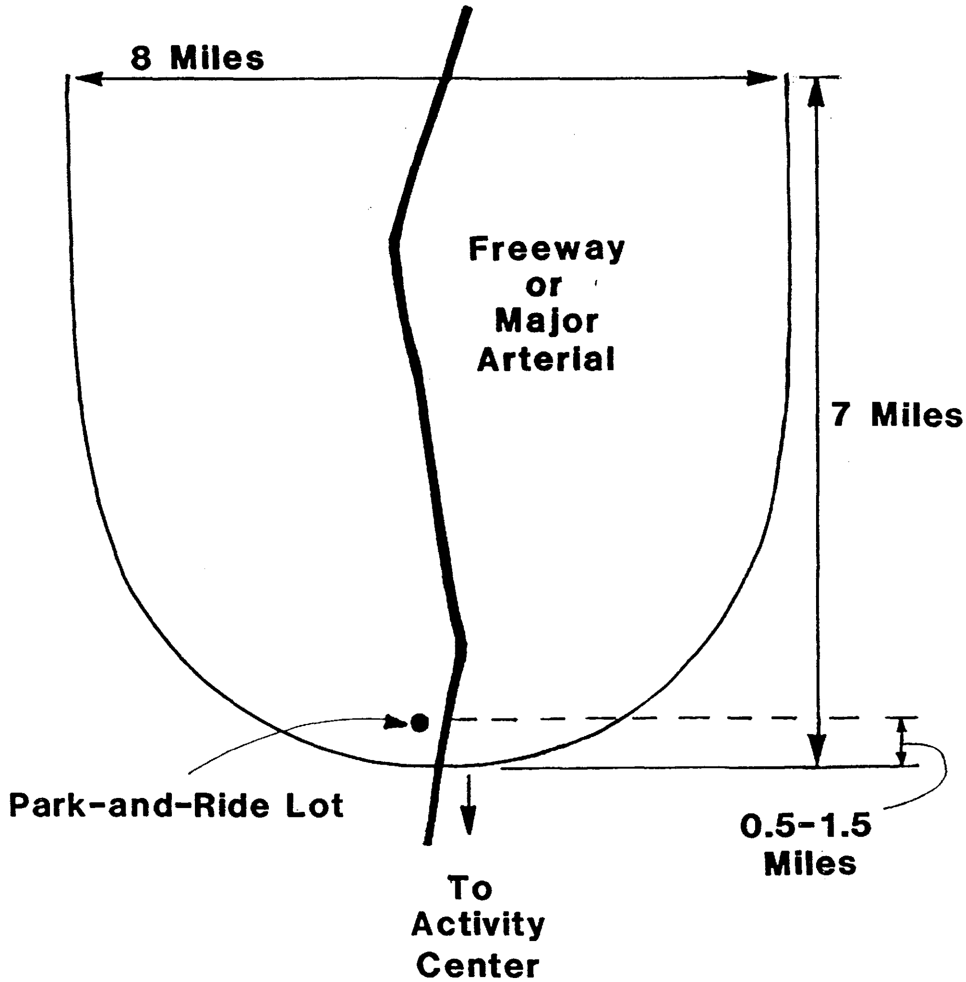


Figure 9: Estimated Shape of Park-and-Ride Market Area for Houston Lots

For this study, the highest ICI encountered on the line haul facility between a park-and-ride lot and its activity center was calculated. These ICIs are shown in Table 1.

The entire data base assembled during this study is presented in two tables. The first, Table 2, presents the data that were eventually incorporated in the demand prediction models. Table 3 presents the remaining information that proved less germane to the modelling effort.

Table 1: Individual Congestion Indices

City and Facility	AADT/Lane	# of Lanes	Delay In Minutes	ICI
AUSTIN				
US 183 N	7,925	6	1.5	0.5
Mo Pac	6,466	6	1.0	0.4
I-35 N	7,188	8	1.5	0.5
I-35 S	18,367	6	2.0	1.1
DALLAS				
Stemmons (I-35 E North)	13,210	10	5.0	1.2
N. Central (US 75 N)	20,517	6	18.0	2.8
Thornton East (I-30 E)	13,400	8	15.0	2.2
Thornton South (I-35 E South)	12,800	8	1.0	0.7
LBJ or North Side (I-635)	20,363	8	2.0	1.2
US 175	6,550	6	2.0	0.5
US 67	7,500	6	2.0	0.6
EL PASO				
I-10 E	11,780	10	3.0	0.9
US 54	8,817	6	1.0	0.5
I-10W	12,775	4	1.0	0.7
FORT WORTH				
West (I-30 W)	22,675	4	8.0	1.9
South (I-35 W South)	13,900	6	3.0	1.0
East (I-30 E)	8,888	8	2.0	0.6
HOUSTON				
Southwest (US 59 S)	21,633	9	11.0	2.2
Katy (I-10 W)	24,457	7	15.0	2.7
North (I-45 N)	19,000	8	15.0	2.5
Eastex (US 59 N)	15,225	8	11.0	1.9
East (I-10 E)	14,863	8	5.0	1.2
Gulf (I-45 S)	24,443	7	15.0	2.7
West Loop (I-610)	25,363	8	8.0	2.1
SAN ANTONIO				
S. Pan Am (I-35 S)	20,425	4	4.0	1.4
I-10W	21,450	4	9.0	2.0
N. Pan Am (I-35 N)	20,110	4	3.0	1.3
US 281 N	10,062	8	2.0	0.7
I-37 S	8,725	8	0.0	0.4
US 90 W	8,775	8	0.0	0.4

Source of Input Data: State Department of Highways and Public Transportation and Research Report 205-7.

Table 2: Data Used In Demand Estimation Equations

City	Lot	Distance To Activity Center (Miles)	Travel Times (Min.)	Activity Center Parking Cost (Monthly)	Parking Spaces	Spaces Used	Riders[1]	# Of Peak Buses	Bus Seats	Priority Treatment	CI[2]	Market Area Population
Austin	North	CBD - 4.8	25	$35.00	260	94	13	1	45	NONE	0.5	20900
		IRS - 8.0	20	$10.00			125	3			1.1	
	US 183 North	CBD - 10.8	32	$35.00	146	25	49	3[6]	43	NONE	0.5	6100
	Covenant	CBD - 7.6	22	$35.00	66	16	31	2	43	NONE	0.4	6000
	N. W. Hills	CBD - 4.7	17	$35.00	27	8	15	2	43	NONE	0.4	27100
Dallas	Garland South	CBD - 11.6	35	$58.00	440	330	550	20	50	NONE	2.2	72800
	Garland North	CBD - 14.7	50	$58.00	320	272	360	13[3]	50	NONE	2.2	27100
	North Central	CBD - 9.8	25	$58.00	1300	185	280	11	50	NONE	2.8	73800
	Las Colinas	CBD - 11.2	35	$58.00	150	54	82	3	50	NONE	1.2	10300
	Red Bird	CBD - 7.7	23	$58.00	315	125	188	7	50	NONE	0.6	28000
	Pleasant Grove	CBD - 8.4	22	$58.00	624	100	150	7	50	NONE	0.5	43100
El Paso	Montwood	CBD - 11.2	20	$40.00	75	52	90	4	47	NONE	0.9	24800
	Northgate	CBD - 12.0	35	$40.00	149	19	24	4	47	NONE	0.5	70200
	Sunrise	CBD - 9.5	30		60	18	24			NONE	0.5	
Fort Worth	Meadowbrook	CBD - 8.6	45	$32.00	25	13	19	2	48	NONE	0.6	41300
	College Avenue	CBD - 8.2	40	$32.00	185	102	145	6	48	NONE	1.0	44400
Houston	Kingwood	CBD - 26.3	48	$69.00	940	306	335	12	47	NONE	1.9	25400
		GP[4] - 34.5	85	$15.00			18			NONE		
	Champions	CBD - 21.0	37	$69.00	280	349	418	10	47	CONTRAFLOW	2.5	51500
		GP[4] - 29.0	59	$15.00			52					
	Kuykendahl	CBD - 16.0	28	$69.00	1300	1025	1100	29	47	CONTRAFLOW	2.5	51200
	North Shepherd	CBD - 9.0	15	$69.00	750	642	751	21	47	CONTRAFLOW	2.5	89600
		MC[5] - 13.5	40	$37.00			154					
	Gulf/Sage	CBD - 8.8	40	$69.00	225	230	348	10	47	NONE	2.7	92400
	Clear Lake	CBD - 22.2	68	$69.00	325	225	340	10	47	NONE	2.7	44800
	Beechnut/ Meyerland	CBD - 10.7	15	$69.00	200	230	377	12	47	NONE	2.2	91700
	Beechnut/Sage	CBD - 9.8	15		210	257	407					
	Sharpstown	CBD - 9.1	21	$69.00	150	200	320	7	47	NONE	2.2	120000
	Alief	CBD - 13.0	45	$69.00	300	241	390	12	47	NONE	2.2	35400
	Westwood	CBD - 14.0	45	$69.00	473	600	848	15	47	NONE	2.2	78000
	Katy/Mason	CBD - 28.0	46	$69.00	170	117	140	5	47	NONE	2.2	12800
San Antonio	Windsor	CBD - 9.0	18	$35.00	167	161	263	6	47	NONE	1.3	49100
	McCreless	CBD - 4.0	8	$35.00	117	30	50	5	47	NONE	0.4	33500
	South Park	CBD - 7.0	16	$35.00	64	26	37	3	47	NONE	1.4	33800
	Lackland	CBD - 11.2	18	$35.00	136	73	126	5	47	NONE	1.4	11600
	Wonderland	CBD - 7.0	17	$35.00	326	474	778	9	47	NONE	2.0	65100
	Naco/Broadway	CBD - 8.0	16	$35.00	60	17	24	5	47	NONE	0.7	30000
	Naco/Bitters	CBD - 10.0	22		63	22	31					

[1]Ridership recorded in two-way person trips per day.
[2]CI = Highest Congestion Index encountered on line haul facility.
[3]The 13 buses shown for Garland North also stop at Garland South and are included in the 20 buses for that lot.
[4]GP = Greenway Plaza
[5]MC = Medical Center
[6]Of these 3 buses, one is express (US 183N Express), the other 2 stop at Covenant and N.W. Hills.

Table 3: Additional Park-and-Ride Data Collected As Part of Study

City	Park-and-Ride Lot	Location	Lot Capacity			Transit Service				Amenities							Shared Lot
			Parking Spaces	Kiss and Ride Spaces	Handicapped Spaces	Fare (One-way)	Peak Headways (Min.)	Midday Service	Express Service	Shelter	Security Personnel	Security Lighting	Newsstand	Vending Machines	Telephone	Pavement Condition	
Austin	North	Airport @ Pampa	260	0	0	$0.70	5[2]	NO	YES	NO	NO	YES	NO	NO	YES	GOOD	YES
	US 183 North	US 183 @ Oceanaire	146	0	0	$0.75	5	NO	YES	NO	NO	YES	NO	NO	NO	FAIR	YES
	Covenant	Loop 360 @ Jollyville	65	0	0	$0.75	30	NO	YES	NO	NO	YES	NO	NO	NO	GOOD	YES
	N.W. Hills	Far West @ Hart	27	0	0	$0.70	30	NO	YES	NO	NO	NO	NO	NO	NO	GOOD	YES
Dallas	Garland South	N.W. Highway @ Jackson	440	12	4	$1.65	2	YES	YES	YES	NO	YES	YES	NO	YES	GOOD	NO
	Garland North	Fifth @ Walnut	320	9	3	$1.65	5	YES	YES	YES	YES	YES	YES	YES	YES	GOOD	NO
	North Central[1]	US 75N @ Coit	1300	0	0	$1.25	10	NO	YES	YES	YES	YES	YES	NO	NO	POOR	YES
	Las Colinas	SH 114 @ O'Connor	150	0		$1.75	30	NO	YES	YES		YES	YES		YES	GOOD	NO
	Red Bird	Ledbetter @ Hampton	315	0	0	$1.25	16	NO	YES	YES	NO	YES	YES	NO	YES	GOOD	YES
	Pleasant Grove	Maddox @ Coston	624	0	0	$1.25	10	NO	YES	YES	NO	YES	YES	NO	NO	GOOD	YES
El Paso	Montwood	Montwood @ Yarbrough	75	0	0	$0.75	10	NO	YES	NO	NO	YES	YES	NO	NO	GOOD	YES
	Northgate	Diana @ Joe Herrera	149	0	0	$0.75	30	NO	YES	NO	NO	YES	NO	NO	NO	FAIR	YES
	Sunrise	Dyer @ Tetons	60	0	0	$0.75	30	NO	YES	NO	NO	YES	NO	NO	NO	GOOD	YES
Fort Worth	Meadowbrook	Sandy @ Monterey	25	0	0	$0.60	35	NO	NO	NO	NO	YES	NO	NO	NO	FAIR	YES
	College Avenue	I-820 @ Crowley	185	0	0	$0.60	30	YES	NO	NO	NO	YES	NO	NO	NO	FAIR	YES
Houston	Kingwood	Lake Houston Pkwy @ Kingwood	940	43	5	$1.65	7	NO	YES	YES	YES	YES	NO	NO	NO	GOOD	NO
	Champions	FM 1960 @ Fritz	280	0	0	$1.40	10	NO	YES	NO	YES	YES	YES	NO	NO	POOR	NO
	Kuykendahl	Kuykendahl @ Demontrond	1300	22	9	$1.40	7	YES	YES	YES	YES	YES	YES	YES	YES	GOOD	NO
	North Shepherd	N. Shepherd @ Stuebner-Airline	750	30	10	$0.90	8	NO	YES	YES	YES	YES	YES	YES	YES	GOOD	NO
	Gulf/Sage	Easthaven @ Ferndale	225	0	1	$0.90	20	NO	YES	NO	NO	YES	NO	NO	NO	GOOD	YES
	Clear Lake	Ramada @ Diana	325	0	0	$1.40	12	NO	YES	NO	NO	NO	NO	NO	NO	GOOD	YES
	Beechnut/ Meyerland	Jackwood @ Endicott	200	0	0	$0.65	25	NO	YES	NO	NO	YES	YES	NO	NO	GOOD	YES
	Beechnut/Sage	I-610 @ Indigo	210	0	1	$0.65	25	NO	YES	NO	YES	YES	YES	NO	NO	FAIR	YES
	Sharpstown	Bellaire @ Larkwood	150	0	0	$0.90	15	NO	YES	NO	NO	NO	NO	NO	NO	GOOD	YES
	Alief	Alief-Clodine @ Cook	300	0	0	$1.15	12	NO	YES	NO	YES	YES	YES	NO	NO	FAIR	YES
	Westwood	Country Creek @ Club Creek	473	0	1	$1.15	7	YES	YES	NO	NO	YES	YES	NO	NO	GOOD	YES
	Katy/Mason	Mason @ Merymount	170	0	7	$1.65	15	NO	YES	NO	NO	NO	YES	NO	NO	GOOD	NO
San Antonio	Windsor Park	I-35 N @ Walzem	167	0	0	$0.75	4	YES	YES	NO	NO	YES	YES	NO	NO	GOOD	YES
	McCreless	S. New Braunfels @ Ada	117	0	0	$0.75	30	YES	YES	NO	NO	YES	YES	NO	NO	GOOD	YES
	South Park	SW Military @ Zarzamora	64	0	1	$0.75	30	YES	YES	NO	NO	YES	NO	NO	YES	GOOD	YES
	Lackland	I-410 @ Evendale	136	0	1	$0.75	8	YES	YES	NO	NO	YES	NO	NO	YES	GOOD	YES
	Wonderland	Gill @ Wonderland	326	15	0	$0.75	10	YES	YES	YES	NO	YES	YES	YES	YES	GOOD	NO
	Naco/Broadway	Broadway @ Gulfmart	60	0	0	$0.75	20	NO	YES	NO	NO	YES	NO	NO	NO	GOOD	YES
	Naco/Bitters	Bitters @ Nacogdoches	63	0	0	$0.75	20	NO	YES	NO	NO	YES	NO	NO	NO	GOOD	YES

[1] North Central is the only lot in Texas that has a parking charge: $0.50 per day.
[2] For IRS bound buses only. The CBD is served by a single AM and PM bus.

DEMAND ESTIMATION GUIDELINES

Using information that is generally available for urban areas in Texas, 3 different procedures can be used to estimate potential park-and-ride utilization. In evaluating a potential lot site, it is suggested that all of these procedures be used to provide a range of estimates. That range can then be used as a basis for decision-making.

The 3 alternative approaches are defined below.

- Market Area Population. The percentage of the total population living in the park-and-ride watershed that is represented by ridership at the park-and-ride lot, i.e., (ridership ÷ market area population) x 100.
- Modal Split. The percentage of the person trips that originate in the park-and-ride "watershed," terminate in the activity center served by park-and-ride, and actually use the park-and-ride service.
- Regression Equations. The data base described previously was evaluated in all possible manners to develop equations that can be used to estimate park-and-ride patronage.

Each of these techniques is discussed in more detail in this section of the report.

Market Area Population

Analysis of data indicates that the population in the park-and-ride lot watershed or market area can be used to gain a "ballpark" estimate of potential park-and-ride utilization. Data used in this analysis are shown in the data base section of this report.

The percentage of the market area population that is represented by ridership varies between Texas cities; however, within Texas cities, for those lots located in accordance with the lot location guidelines stated previously, a "ballpark" range appears to exist. Table 4 summarizes these data.

Table 4: Ridership as a Percentage of Population in the Park-and-Ride Market Area

City and Park-and-Ride Lot	Ridership as a % of Market Area Population	"Guideline" for City
Austin		
North Park-and-Ride	0.6	
US 183 North[1]	0.3	0.3 to 0.6
Dallas Area		
Garland South	0.8	
Garland North	1.3	
North Central	0.4[5]	0.4 to 1.3
Las Colinas	0.8	
Red Bird	0.7	
Pleasant Grove	0.4	
El Paso		
Montwood	0.4	
Northgate[2]	0.07	0.07 to 0.4
Fort Worth		
Meadowbrook	0.05	
College Avenue	0.3	0.05 to 0.3
Houston[6]		
Champions	0.9	
Kuykendahl	2.1	
N. Shepherd	1.0	
Edgebrook	0.8	
Clear Lake	0.8	
Beechnut (both lots)[3]	0.9	0.7 to 2.0
Sharpstown	0.3[7]	(constrained due
Alief	0.9	to size of lots
Westwood	1.1	currently avail-
Katy/Mason	0.7	able)
Kingwood	1.4	
San Antonio		
Windsor Park	0.5[8]	
McCreless	0.2	
South Park	0.1	Varies up to 1.2
Lackland	1.1	
Wonderland	1.2	
Nacogdoches[4]	0.2	

[1]US 183 North includes 3 lots served by the same park-and-ride service -- US 183N, Covenant, and NW Hills
[2]Northgate includes 2 lots served by the same park-and-ride service -- Northgate and Sunrise.
[3]Includes 2 lots -- Myerland and Sage.
[4]Nacogdoches includes 2 lots served by the same park-and-ride service -- Broadway and Bitters.
[5]Dallas North Central ridership is lower than would be expected for several reasons, including paid parking, competing local bus service, poor lot access/accessibility, and lot not located upstream of congestion.
[6]Ridership at most of the Houston lots is constrained by parking spaces available.
[7]Low percentage due to small lot size.
[8]Lot located in a very uncongested corridor and relatively close to activity center.

Variation between cities and between corridors within cities can be at least partially explained by certain characteristics of the urban area that would be expected to influence park-and-ride utilization. Some of these data are shown in Table 5.

Table 5: Ridership as Related to Market Area Compared to Other Indicators of Park-and-Ride Potential, by City

City	Ridership as a % of Market Area Population[1]	"Representative" Congestion Index[2]	Activity Center Size	
			Monthly Pkg. Cost	Employment
Houston	0.7 to 2.0[3]	2.0 to 3.0	$69	158,000
Dallas Area	0.4 to 1.3	1.0 to 2.0	$58	126,000
San Antonio	varies up to 1.2	0.5 to 1.5	$35	38,000
Austin	0.3 to 0.6	0.5 to 1.0	$35	17,000
Fort Worth	0.05 to 0.3	0.5 to 1.5	$32	45,000
El Paso	0.07 to 0.4	0.5 to 1.0	$40	19,000

[1]From Table 1.
[2]A "representative" value for the urban area as selected from Research Report 205-7. In actuality, considerable variation also occurs between corridors within a given urban area.
[3]In general, the Houston percentages are constrained by parking spaces available.

Table 5 suggests that, as has been theorized in previous research reports, park-and-ride becomes a more attractive alternative as congestion and the intensity of activity center development increase. Surveys have shown that saving money is, perhaps, the primary reason people choose park-and-ride. As congestion increases, so would auto operating costs and parking costs.

Figure 10 shows the relationship of percentage of market area population riding the park-and-ride service to congestion index for all the lots studied. Considerable scatter occurs when less than 0.1% of the market area is represented by ridership; these data are typically associated with very

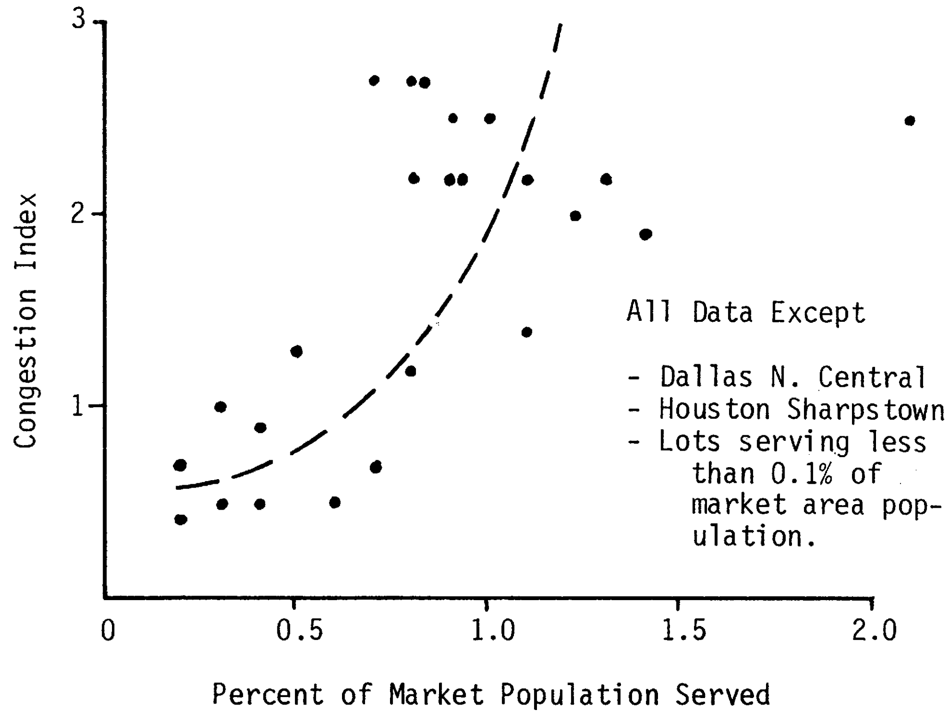


Figure 10: Relationship Between Congestion Index and Percent of Market Area Population Served for Texas Park-and-Ride Facilities.

small (less than 20 riders) park-and-ride facilities. Footnotes to Table 4 provide possible explanations as to why the Dallas North Central and Houston Sharpstown lots are not serving the percentage of the market area that otherwise would be expected. Using the curve shown in Figure 10, the following generalities are made.

- Once the congestion index exceeds 1.5, at least 0.8% of the total population in the market area is likely to use the park-and-ride service. Although several factors are involved in determining the congestion index (CI), a CI = 1.5 relates to an average daily traffic volume per lane of about 20,000.

- Once the congestion index exceeds 0.75, at least 0.4% of the total population in the market area is likely to use the park-and-ride service. An AADT per lane of about 15,000 relates to a CI = 0.75.

- From the data shown in Table 4, it is not possible to identify what the "ultimate" demand for park-and-ride might be--i.e., ridership that might be generated from a highly congested corridor with priority treatment. The Houston lots on I-45N are filled to capacity, and that restricts additional lot usage. As such, the value for Kuykendahl may represent a minimum value for that type of service. It is known that this minimum value holds for at least 1 park-and-ride space per 0.02 market area population. Careful definition of the actual market area, taking into account overlapping market areas in the I-45N corridor, suggests that Kuykendahl, at present, may be serving as much as 2.4% of the market area population; if more parking spaces and buses were provided, it is not unreasonable to assume this percentage would be greater. Indeed, based on today's demand and not accounting for future growth, Kuykendahl may easily be able to serve demand representing 2.5% to 3.0% of the market area population -- or more.

Using only market area population as a variable assumes that all market areas have a similar affinity for the activity center being served. Total market area population is a more readily available variable than is the percentage of that market area population that works in the activity center (analysis of this percentage is discussed subsequently in this section). If there is reason to suspect that different corridors have significantly different affinities to the activity center, census or travel data can be used to make adjustments to the market area population. In some areas, such as Houston, most corridors have a similar attraction to the CBD; for example, in Houston, the Gulf, Southwest, Katy, and North Freeways are all estimated to be serving between 21,000 and 23,000 daily CBD work trips.

Impact of Priority Treatment

Insufficient data are available to accurately assess the impact of priority treatment on park-and-ride utilization. The limited Houston data, as is also the case in the modal split analysis described subsequently, suggest that priority treatment may have some impact on patronage. Again, however, factors such as constraining lot sizes and overlapping market areas confuse the modal split impact analysis. While the priority lots serve over 50% more of the market area population, those lots also provide about 50% more parking spaces per market area population. Riders per available space are similar for both priority and non-priority lots; it is not known if this relationship would hold if the same parking space to market area population ratio characteristic of the priority lots was available at the non-priority lots (Table 6). Table 6 data suggest that available spaces are currently the constraining factors on ridership in Houston for both priority and non-priority lots.

Table 6: Possible Impacts of Priority Treatment On Park-and-Ride Utilization Based on Market Area Analysis, Houston Lots

	% of Market Area Population Using Park-and-Ride	Available Parking Spaces Per Market Area Population	Park-and-Ride Patrons Per Available Parking Space
3 lots with Priority Treatment	1.17%	0.012	0.97
8 lots without Priority Treatment	0.75%	0.007	1.02

Modal Split

The market area analysis described previously assumes that all market areas have an equal affinity to the activity centers being served by park-and-ride. While that approach is simple to apply and uses the most available data, it does not account for the fact that different parts of a corridor or urban area can have different attraction rates to the activity centers being served.

To use this procedure it is necessary to identify that component of the market area population that works in the activity center served by park-and-ride. This information is not always readily available and, as a result, the attractiveness of this approach is diminished due to data availability concerns.

Table 7 summarizes the available modal split data for Texas park-and-ride lots.

The modal split data show a wide spread. Some agreement with the congestion correlation appears to exist; modal splits tend to be relatively high in the more congested corridors.

The following guidelines--recognizing constraints imposed by lot sizes or lots not located in accordance with the lot location guidelines--might be used for park-and-ride analysis.

- **Dallas area lots.** 10% to 20% modal split
- **Houston area lots.** 15% to 30% modal split, with some modal splits in the range of 50%.

Perhaps Table 7 is most helpful in estimating potential modal split. Data shown in that table suggest that, if a lot is located properly and sufficient parking spaces are provided, modal splits in the range of 50% can be attained. That value might be useful in identifying the "upper end" of potential lot size.

Table 7: Estimated Modal Split For Texas Park-and-Ride Lots

City and Lot	Modal Split[1]	Procedure to Estimate Modal Split[2]
Dallas/Garland Area		
Dallas North Central	7% to 8%	TTI Surveys (Research Report 205-11) and census analysis
Pleasant Grove	8%	Census Analysis
Oak Cliff	4%	Census Analysis
Garland, North & South	21%	TTI Surveys (Research Report 205-11)
Houston		
Clear Lake City	52%	Census Analysis
Gulf Edgebrook	24%	Census Analysis
Westwood	10%	TTI Surveys (Research Report 205-15)
Champions	23%	TTI Surveys (Research Report 205-15)
N. Shepherd	27%	TTI Surveys (Research Report 205-15)
Kuykendahl	22%	TTI Surveys (Research Report 205-15)
Kingwood	29%	Census Analysis
Beechnut (2 lots)	13%	Census Analysis
Alief	28%	Census Analysis
Sharpstown	4%	Census Analysis
Katy/Mason	50%	Census Analysis

[1]Modal split is defined as the percent of the market area population working in the activity center served by park-and-ride that uses the park-and-ride service.
[2]In using census data, the percent of the population working in the CBD was obtained from 1970. Due to the massive growth in many of the areas being considered, applying the 1970 percentage to the 1980 market area results in potential error.

Impact of Priority Treatment

As was the case with the market area analysis, data are not sufficient to determine whether priority treatment influences park-and-ride utilization. While the Houston data do suggest that the priority-treatment lots are serving a greater modal share than the non-priority lots, this could be true simply because relatively more parking spaces are presently provided in the priority lot locations. It is not known if the utilization at the non-priority lots would be similar to that of the priority lots if an equivalent number of parking spaces were provided at both locations (Table 8).

Table 8: Possible Impacts of Priority Treatment on Park-and-Ride Utilization Based on Modal Split Analysis, Houston Lots

Park-and-Ride Lots	Modal Split[1]	Available Parking Spaces Per Market Area Population	Park-and-Ride Patrons Per Available Parking Space
3 lots with Priority Treatment	24%	0.012	0.97
8 lots without Priority Treatment	15%	0.007	1.02

[1]Modal split values shown are weighted averages for the lots shown in Table 7.

Regression Analysis

Multiple regression is a common approach to demand estimation. The results of these analyses can be relatively easy to utilize, and the Statistical Analysis System (SAS) package available through the Texas A&M University Data Processing Center simplifies the use of this analytical tool. The data base presented previously in this report provides the information needed to perform the regression analyses.

Estimate of Park-and-Ride Patronage

The objective of any multiple linear regression analysis is to describe, predict, or estimate a dependent or response variable as a linear function of one or more independent or controlled variables (18). The ideal dependent variable for modelling effort is demand for park-and-ride service. Therefore, a measure for demand had to be selected from the data collected. Three potential measures were identified -- average daily park-and-ride ridership, the average number of cars parked at a given lot, and the ratio of parked cars to available parking spaces at a given lot. All three measures of demand were tried as dependent variables in separate regression attempts.

Average daily ridership proved to be the most effective measure of demand in the regression analyses.

The remainder of the park-and-ride data base provided a wide array of potential independent or controlled variables from which to construct the demand estimation equations. Previous research pertaining to park-and-ride, performed by the Texas Transportation Institute and others, provided considerable insight into which factors might be most effective as independent variables. It was thought that market area population, activity center parking cost and freeway congestion indices would correlate well with park-and-ride demand. Other factors that were also considered as independent variables included distance of the lot from the activity center, peak-period bus headways, activity center employment population, and lot amenities.

In order to determine the best set of independent variables to use for predicting park-and-ride patronage, a series of stepwise regression routines were run on all potential dependent and independent variables. The best correlation was found when ridership was used as the dependent variable. With respect to independent variables, it was recognized that the least number of variables possible improved the ease of implementation of the demand prediction model. The highest correlation with the least number of variables practical was found in the following regression equation:

(1) $\text{Ridership} = -160 + 204(\text{CI}) + 0.0034\ (\text{MAPOP}) \qquad R^2 = 0.57$

where CI = freeway congestion index
MAPOP = total population in the market area

This equation can be used to predict park-and-ride ridership using readily available data most of which is contained in the data base section of this report. This is one of many equations evaluated using that data base. Additional equations are included in Appendix B of this report.

The coefficient of multiple determination (R^2) for this equation is not as high as might be desired. The error range for lots in Texas ranged from +551% to -229% (See Table 9). However, for many of the larger lots, this equation estimates within $\pm$50%; the overestimate at most of the larger lots (e.g., Sharpstown and Gulf Sage) is at least partially explained by constraints on parking spaces available at those locations.

Equation (1) as well as several of the equations shown in Appendix B, 2 while using readily available data, do not have as high of an R^2 as might be desired. The percentage error is large at some lots.

Part of the reason for this occurrence is that the ridership at several of the lots included in the data base is not a true reflection of demand; that is, the actual ridership at those lots is either limited by the number of parking spaces provided or the number of buses available to serve the lot. It is hypothesized that, if more spaces or service were provided at these locations, a greater ridership would be served.

As a result, a new variable was developed to better "predict" the ridership at existing lots. Recognizing the constraining factors on ridership, the value of the new independent variable, referred to as MIN, was set equal to the minimum of the number of peak-hour buses multiplied by their capacity and the number of parking spaces multiplied by average auto occupancy for park-and-ride automobiles (1.5).

$$(2) \quad \text{Min} = \min \begin{cases} \text{peak hours buses x bus capacity} \\ \text{or} \\ \text{parking spaces} \quad \text{x 1.5 persons per auto} \end{cases}$$

Table 9. Regression Equation (1), Actual and Predicted Ridership, Texas Park-and-Ride Lots

City and Lot	Actual Ridership	Predicted Ridership	Residual	% Error
Austin				
North Park and Ride	125	135	10	8
US 183 North[1]	50	55	5	10
US 183 Express	45	-58	103	-229
Dallas				
Garland South	550	536	- 14	- 3
Garland North	360	381	21	6
North Central	280	662	382	136[5]
Las Colinas	82	120	38	46
Red Bird	188	58	-130	-69
Pleasant Grove	150	89	- 61	-41
El Paso				
Montwood	90	108	18	20
Northgate[2]	48	181	133	277
Fort Worth				
Meadowbrook	19	103	84	442
College Ave.	145	195	50	34
Houston				
North Shepherd	905	655	-250	-28
Gulf Sage	348	705	357	102
Beechnut[3]	784	601	-183	-23
Sharpstown	320	697	377	118
Alief	390	409	19	5
Westwood	848	554	-294	-35
San Antonio				
Windsor	263	272	9	3
South Park	37	241	204	551
Lackland	126	165	39	31
Wonderland	778	469	-309	-40
Nacogdoches[4]	55	85	30	55

[1] US 183 North includes three lots - US 183 North, Covenant, and NW Hills. These lots are served by the same express bus route.

[2] Northgate includes two lots - Northgate and Sunrise. Both lots are served by the same express bus route.

[3] Beechnut includes two lots - Meyerland and Sage.

[4] Nacogdoches includes two lots - Bitters and Broadway. Both lots are served by the same express bus route.

[5] North Central ridership lower than would be expected for several reasons, including paid parking, competing local bus service, poor access/accessibility, and not located upstream of congestion. For these reasons North Central was left out of further regression runs.

The estimated values for MIN for each of the Texas park-and-ride lots were computed and are shown in Table 10.

MIN is, obviously, based on situations presently occurring at existing lots. If proposed new lots in a given urban area are to be significantly larger or have more bus service than existing lots, use of an equation with the MIN variable involves extrapolation. However, the same is true of any other equation developed using the available data base.

With the new independent variable MIN defined, another stepwise regression routine was run using ridership as the dependent variable. Again,the equation that contained the least number of variables without sacrificing correlation was selected from this regression run. The following equation was the result:

(3) Ridership = -92 + 0.83(MIN) + 0.002 (MAPOP) $\qquad R^2 = 0.93$

$$\text{where MIN} = \min \begin{cases} \text{peak hour buses x bus capacity} \\ \text{or} \\ \text{parking spaces x 1.5 persons per auto} \end{cases}$$

MAPOP = market area population

Although this equation was intended to predict ridership for all park-and-ride lots in Texas, its accuracy was not as high as might be desired for all lots. The percent error rates produced by this equation range from -198 percent to a +325 percent. Table 11 shows the individual ridership predictions.

Upon inspection of the residuals and error rates produced by equation (3), it was noticed that the more accurate predictions occurred for park-and-ride lots located in corridors with higher congestion indices. This observation was not totally unexpected, since the lot location guidelines

Table 10. Estimated Values of the Variable MIN, Texas Park-and-Ride Lots

LOT	# of PEAK BUSES X SEATS =	PARKING SPACES X 1.5*	MIN
Austin			
North Park and Ride	3 X 45 = 135	260 X 1.5 = 390	135
US 183 North[1]	2 X 43 = 86	239 X 1.5 = 359	86
US 183 Express	1 X 43 = 43	146 X 1.5 = 219	43
Dallas Area			
Garland South[2]	20 X 50 = 1000	440 X 1.5 = 660	660
Garland North[2]	13 X 50 = 650	320 X 1.5 = 480	480
North Central	11 X 50 = 550	1300 X 1.5 = 1950	550
Las Colinas	3 X 50 = 150	150 X 1.5 = 225	150
Red Bird	7 X 50 = 350	315 X 1.5 = 473	350
Pleasant Grove	7 X 50 = 350	624 X 1.5 = 936	350
El Paso			
Montwood	4 X 47 = 188	75 X 1.5 = 113	113
Northgate Express[3]	4 X 47 = 188	209 X 1.5 = 314	188
Fort Worth			
Meadowbrook	2 X 48 = 96	25 X 1.5 = 38	38
College Avenue	6 X 48 = 288	185 X 1.5 = 278	278
Houston			
Kingwood	12 X 47 = 564	950 X 1.5 = 1425	564
Champions	10 X 47 = 470	349 X 1.5 = 524	470
Kuykendahl	29 X 47 = 1363	1300 X 1.5 = 1950	1363
North Shepherd	21 X 47 = 987	750 X 1.5 = 1125	987
Gulf Sage	10 X 47 = 470	230 X 1.5 = 345	345
Clear Lake	10 X 47 = 470	325 X 1.5 = 488	470
Beechnut Express[4]	12 X 52 = 624	487 X 1.5 = 731	624
Sharpstown	7 X 47 = 329	200 X 1.5 = 300	300
Alief	12 X 47 = 564	300 X 1.5 = 450	450
Westwood	16 X 47 = 752	600 X 1.5 = 900	752
Katy	5 X 47 = 235	170 X 1.5 = 255	235
San Antonio			
Windsor	6 X 47 = 282	167 X 1.5 = 251	251
McCreless	5 X 47 = 235	117 X 1.2 = 140	140
South Park	3 X 47 = 141	64 X 1.2 = 77	77
Lackland	5 X 47 = 235	136 X 1.5 = 204	204
Wonderland	13 X 52[6] = 676	474 X 1.5 = 711	676
Nacogdoches[5]	5 X 47 = 235	123 X 1.2[7] = 148	148

*1.5 - assumed maximum average auto occupancy.
[1]US 183 North includes three lots - US 183 North, Covenant and NW Hill. These lots are served by the same express bus routes.
[2]Since the buses from Garland North also stop at Garland South, parking spaces are used to establish the MIN values for Garland.
[3]Northgate includes two lots - Northgate and Sunrise. Both lots are served by the same express bus routes.
[4]Beechnut includes two lots - Meyerland and Sage.
[5]Nacogdoches includes two lots - Bitters and Broaserdway. Both lots are served by the same express bus route.
[6]Bus capacity was inflated to account for numerous standees.
[7]Auto occupancy lower than state average.

Table 11. Regression Equation (3), Actual and Predicted Ridership, Texas Park-and-Ride Lots

City	Actual Ridership	Predicted Ridership	Residual	% Error
Austin				
North Park and Ride	125	62	- 63	- 50
US 183 North[1]	50	58	8	16
US 183 Express	45	-44	- 89	-198
Dallas Area				
Garland South	523	601	78	15
Garland North	342	361	19	6
Las Colinas	82	53	- 29	- 35
Red Bird	188	255	67	36
Pleasant Grove	150	285	135	90
El Paso				
Montwood	90	51	- 39	- 43
Northgate Express[2]	48	204	156	325
Fort Worth				
Meadowbrook	19	22	3	16
College Avenue	145	228	83	57
Houston				
Kingwood	353	427	74	21
Champions	470	401	- 69	- 15
Kuykendahl	1045	1142	97	9
North Shepherd	905	906	1	0
Gulf Sage	348	379	31	9
Clear Lake	340	388	48	14
Beechnut Express[3]	784	609	-175	- 22
Sharpstown	320	397	77	24
Alief	390	352	- 38	- 10
Westwood	806	688	-118	- 15
Katy	140	129	- 11	- 8
San Antonio				
Windsor	250	215	- 35	- 14
McCreless	48	91	43	90
South Park	35	40	5	14
Lackland	120	101	- 19	- 16
Wonderland	739	599	-140	- 19
Nacogdoches[4]	55	91	36	65

Note: Actual ridership figures for lots that provide off-peak service are peak-period ridership only.

[1]US 183 North includes three lots - US 183 North, Covenant, and NW Hills. These lots are served by the same express bus route.
[2]Northgate includes two lots - Northgate and Sunrise. Both lots are served by the same express bus route.
[3]Beechnut includes two lots - Meyerland and Sage.
[4]Nacogdoches includes two lots - Bitters and Broadway. Both lots are served by the same express bus route.

call for the lot to be placed in a fairly congested corridor. As a result, the data set was partitioned by congestion indices values. All lots with a congestion index of 1.3 or higher were placed in one group, and those lots with a congestion index less than 1.3 were placed in the other data group.

A linear regression routine was run on the data set containing congestion indices greater than or equal to 1.3. The results from this run resulted in accpetable predictions. The equation that resulted was:

$$(4)\quad \text{Ridership} = -86 + 0.8(\text{MIN}) + 0.002(\text{MAPOP}) \qquad R^2 = 0.93$$

$$\text{where MIN} = \min \begin{cases} \text{peak hour bus x bus capacity} \\ \text{or} \\ \text{parking spaces x 1.5 persons per auto} \end{cases}$$

MAPOP = market area population

(Note: Use for lots with CI's ≥ 1.3 only)

Equation (4) will predict Texas park-and-ride ridership for lots having a congestion index greater than or equal to 1.3 within a ± 24 percent error rate. Exact error rates are shown in Table 12.

Although equation (4) predicts the ridership for large park-and-ride lots, this equation cannot be applied accurately to lots with lower congestion indices. Presently, there are several lots in Texas that are located in less congested corridors. Because a number of these lots have proven to be moderately successful, it was recognized that an equation to predict their ridership would also be useful. For lots with a congestion index between 1.2 and 0.9 the following equation may be used to predict ridership:

Table 12. Regression Equation (4), Actual and Predicted Ridership, Texas Park-and-Ride Lots

City and Lot	Actual Ridership	Predicted Ridership	Residual	% Error
Dallas Area				
Garland South	523	588	65	12
Garland North	342	352	10	3
Houston				
Kingwood	353	416	63	18
Champions	470	392	- 78	-17
Kuykendahl	1045	1107	62	6
North Shepherd	905	883	- 22	- 2
Gulf Sage	348	375	27	8
Clear Lake	340	380	40	12
Beechnut[1]	784	597	187	-24
Sharpstown	320	394	74	23
Alief	390	345	- 45	-12
Westwood	806	672	-134	-17
Katy	140	128	- 12	- 9
San Antonio				
Windsor	250	213	- 37	-15
South Park	35	43	8	23
Lackland	120	101	- 19	-16
Wonderland	739	585	-154	-21

Note: Actual ridership figures for lots that provide off-peak service are peak-period ridership only.

[1]Beechnut includes two lots - Meyerland and Sage.

(5) Ridership = 61 + 0.1(MIN) + .001(MAPOP)

$$\text{where MIN} = \min \begin{cases} \text{peak hour buses x bus capacity} \\ \text{or} \\ \text{parking spaces x 1.5 persons per auto} \end{cases}$$

MAPOP = market area population

Note: Use for lots with CI's between 0.9 and 1.2 only.

For the existing park-and-ride lots in Texas with low congestion indices (1.2 to 0.9), equation (5) will predict ridership within ±24 percent error. (See Table 13). However, equation (5) is not a direct result of a regression analysis run, and, therefore, may not be as accurate as the percent error indicates.

Table 13. Regression Equation (5), Actual and Predicted Ridership, Texas Park-and-Ride Lots

City and Lot	Actual Ridership	Predicted Ridership	Residual	% Error
Austin				
North Park and Ride	125	95	-30	-24
Dallas				
Las Colinas	82	86	4	5
El Paso				
Montwood	90	97	7	8
Fort Worth				
College Avenue	145	133	-12	- 8

Note: Actual ridership figures for lots that provide off-peak service are peak-period ridership only.

The ridership figures for park-and-ride lots that have congestion indices lower than 0.9 did not show any strong causal relationships with any dependent variables. This observation is in agreement with lot location guidelines presented previously. However, should a transit operator for some reason choose to locate a park-and-ride lot in a relatively uncongested corridor, the following equation may be used as a "ballpark" estimate for future ridership.

$$(6) \quad \text{Ridership} = 7 + 0.43(\text{MIN}) \qquad R^2 = 0.81$$

$$\text{where MIN} = \min \begin{cases} \text{peak hour buses} \times \text{bus capacity} \\ \text{or} \\ \text{parking spaces} \times 1.5 \text{ persons per auto} \end{cases}$$

Note: Use for lots with CI < 0.9

As can be seen from Table 14, equation (6) is not extremely accurate. This is the result that can be expected when a park-and-ride lot is located in an uncongested corridor.

Table 14. Regression Equation (6), Actual and Predicted Ridership, Texas Park-and-Ride Lots

City and Lot	Actual Ridership	Predicted Ridership	Residual	% Error
Austin				
US 183 North[1]	50	44	- 6	-12
US 183 Express	45	25	-20	-44
Dallas Area				
Red Bird	188	158	-30	-16
Pleasant Grove	150	158	8	5
El Paso				
Northgate[2]	48	88	40	83
Fort Worth				
Meadowbrook	19	23	4	21
San Antonio				
McCreless	48	67	19	40
Nacogdoches[3]	55	71	16	29

Note: Actual ridership for lots that provide off-peak service are peak-period ridership only.

[1]US 183 North includes three lots - US 183 North, Covenant and NW Hills. These lots are served by the same express bus route.
[2]Northgate includes two lots - Northgate and Sunrise. Both lots are served by the same express bus route.
[3]Nacogdoches includes two lots - Bitters and Broadway. Both lots are served by the same express bus route.

Guidelines For The Selection of MIN

While the equations using the variable MIN do a good job of "predicting" ridership at existing lots, their use in estimating demand at new lots requires estimating the value of MIN. Since MIN can vary considerably between lots in a given urban area, the "best" approach might be to locate an existing lot that is similar to the proposed lot in terms of congestion index, distance to the activity center, and market area population. Using this approach, the value of MIN for the existing lot (Table 10) can be used in the appropriate regression equation to estimate ridership at the new lot.

In the absence of a comparable existing lot that can be used to determine the MIN value, one of two approaches might be used. The values in Table 15 can be applied. These values were obtained for each urban area by averaging the numbers shown in Table 10. Again, it should be noted that, due to the large variation in MIN values for a given urban area, use of the "typical" value increases the error estimate.

Table 15. "Typical" MIN Values For Urban Areas in Texas

Urban Area	"Typical" MIN Value[1]
Houston	600
Dallas	425
San Antonio	250
Austin, El Paso, and Fort Worth	125 to 175

[1]Obtained by averaging the values in Table 10.

Alternatively, since MIN is somewhat related to variables such as market area population, distance to activity center, and congestion index, those values for the proposed new lot can be used to estimate a value of MIN (Figure 11).

Overview of Demand Estimation Procedures

Three procedures are described in this report for estimating demand. The following general guidelines can be used to estimate ridership at properly located park-and-ride facilities.

Market Area Population

This is the percentage of total population in the market area that is represented by ridership at the park-and-ride lot.

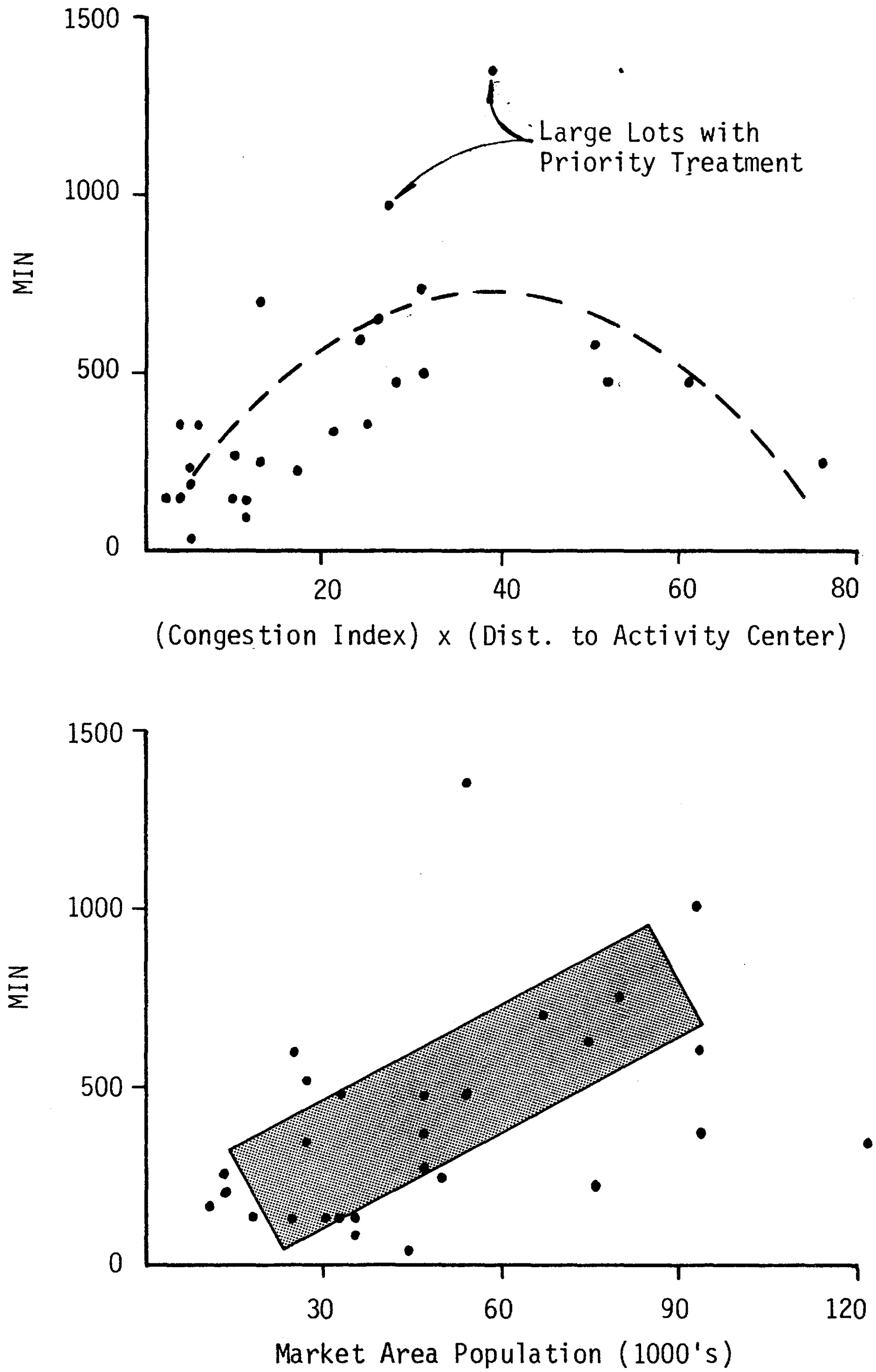


Figure 11: Relationship Between the Variable MIN and Selected Descriptors of Park-and-Ride Lots.

Urban Area	Ridership as a Percent of Market Area Population
Houston	0.7% to 2.0%
Dallas	0.4 to 1.3
San Antonio	varies up to 1.2
Austin	0.3 to 0.6
Fort Worth	0.05 to 0.3
El Paso	0.07 to 0.4

Modal Split

This is the percentage of persons living in the park-and-ride market area and working in the activity center served by the bus service that use park-and-ride.

Urban Area	"Typical" Modal Split
Dallas	10% to 20%
Houston	15% to 30%

Regression Models

The following equations appear to "best" predict park-and-ride patronage. Additional equations are shown in Appendix B.

Ridership = -160 + 204(CI) + 0.0034(MAPOP) $R^2 = 0.57$

Ridership = -86 + 0.8(MIN) + 0.002(MAPOP) $R^2 = 0.93$
Note: Applies to lots with CI $\geq$ 1.3

Ridership = 61 + 0.1(MIN) + 0.001(MAPOP)
Note: Applies to lots with CI between 0.9 and 1.2

Ridership = 7 + 0.43(MIN) $R^2 = 0.81$
Note: Applies to lots with CI less than 0.9

Where:

CI = congestion index

MAPOP = market area population

MIN = the lesser of 1) peak hour buses times bus seated capacity or 2) lot parking spaces times 1.5. Additional discussion of how to select a MIN value is included previously in the text.

AN EXAMPLE APPLICATION[1]

Plans are currently being made to provide a 1-lane, reversible transitway in the median of the Gulf Freeway in Houston (Figure 12). A series of park-and-ride lots are to be developed as support facilities for the transitway. One permanent park-and-ride lot, a 1000-car facility at Edgebrook (Figure 12), already exists in the corridor.

Input Data and Analytical Procedures

- The shape of the watershed area is as defined for Houston previously in this report. 1980 census data are used to determine population in the watershed area. Figure 13 shows population densities in the corridor.
- All demand estimation techniques described in this report were used. The following values were applied.
  - Market Area Population. 2.5% of market area population will represent park-and-ride patronage (the lots will be in a congested corridor with priority treatment provided).
  - Modal Split. 35% of eligible trips will be served by park-and-ride.
  - Regression Equations. Two regression equations are used to estimate ridership. The first equation uses congestion index and downtown parking cost as variables. The second uses market area population and a control based on service provided to estimate ridership.
- While park-and-ride service will be provided to more than one activity center, it is assumed that CBD patronage will represent 85% of total patronage (Table 16).

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[1]This example is based upon work performed for the Texas State Department of Highways and Public Transportation, Houston Urban Office, as part of project 2-10-74-205.

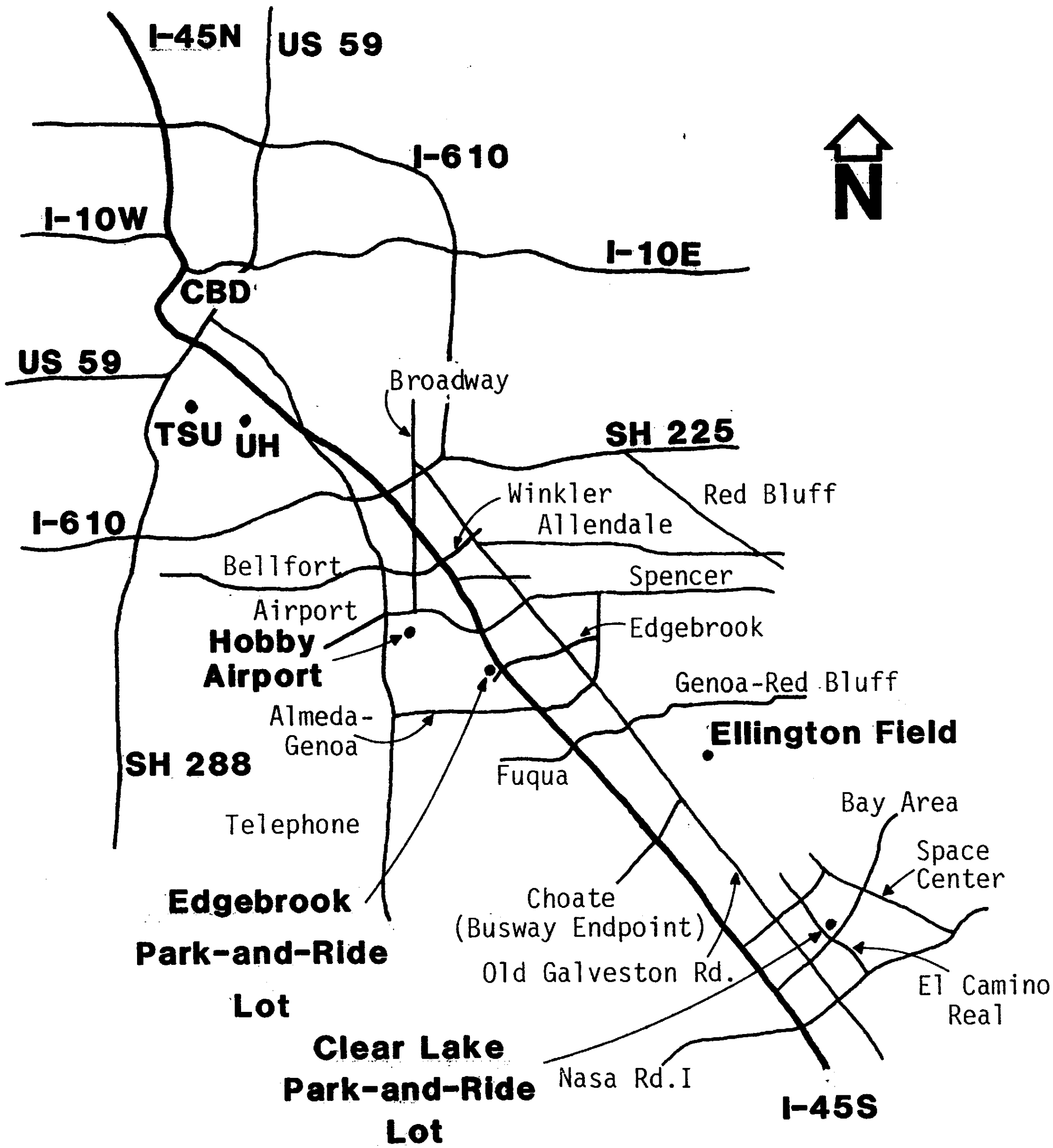


Figure 12: Gulf Transitway Corridor, Houston

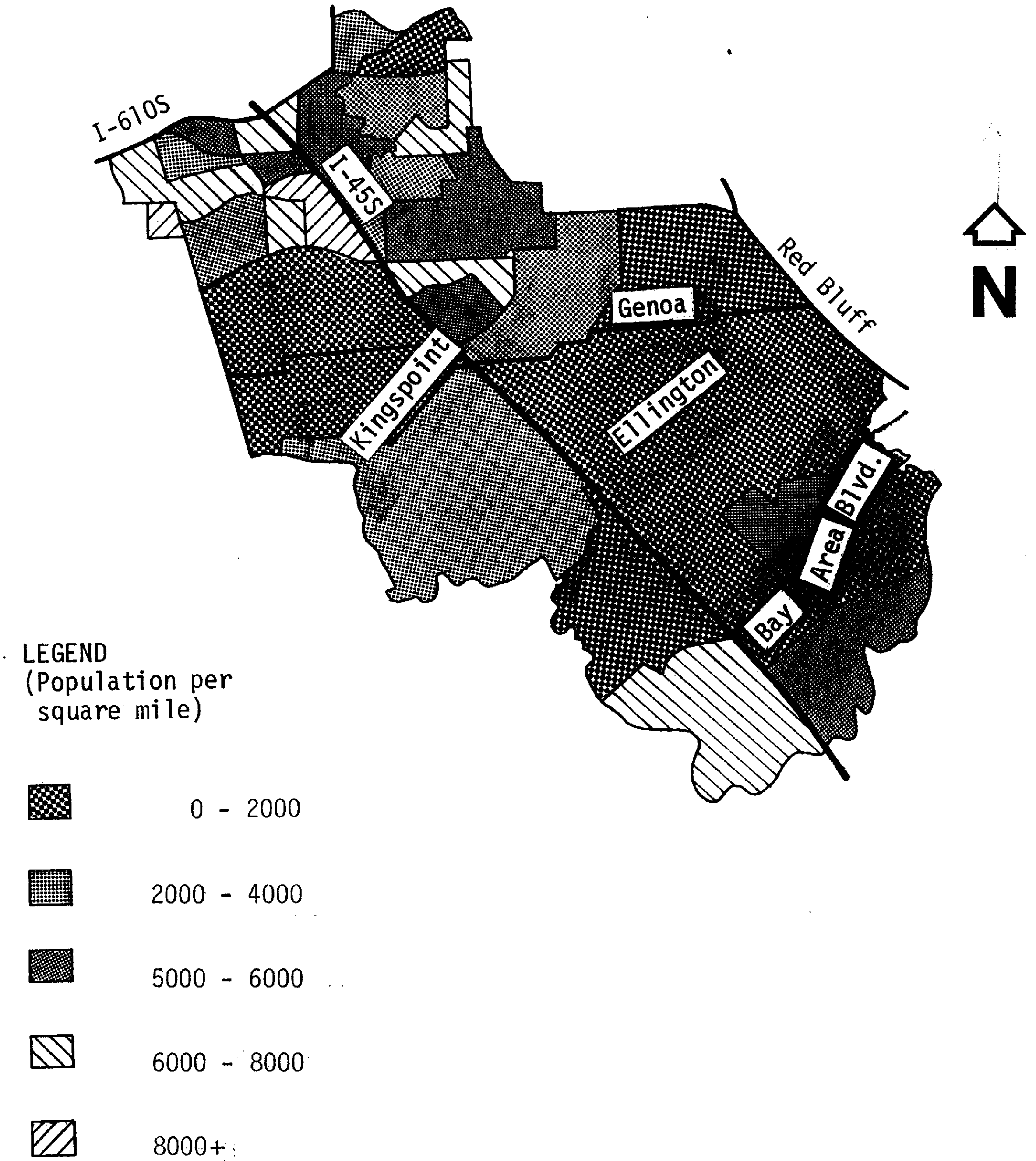


Figure 13: 1980 Population Densities in the Gulf Freeway Corridor, Houston.

Table 16: **Percent of Park-and-Ride Patrons Destined to the CBD, Houston Lots With More Than One Possible Destination**

Park-and-Ride Lot	No. of Destinations Served	Percent of Riders Destined to the CBD
North Shepherd	2	83%
Kuykendahl	3	96
Champions	3	88
Kingwood	3	95

Source: TTI Surveys.

"Typical" Market Area Demand

The land area within a "typical" watershed will be approximately 25 to 30 square miles. As shown in Figure 13, in the Gulf corridor this land is generally developed at 1500 to 3500 persons per square mile. Assuming the watershed houses 70,000 persons, the following general calculations are made.

- 70,000 x 2.5% = 1750 CBD patrons
- Divided by 0.85 to account for non-CBD patrons = 2058 riders
- Divided by 1.4 riders/parked car = 1470 cars.
- Conclusion. For this typical market area, a 1500 car lot would be needed, as a minimum, to serve demand. This size lot may not be adequate to serve demand. This demand is also too large to be served by a single lot. Thus, multiple lots, or lots with overlapping market areas, will probably be needed to serve demand in this Houston corridor.

Watersheds Warranting Further Evaluation

The lot location guidelines presented in this report suggest that no lots would be developed inside Loop I-610. In addition to the distance from activity center considerations, land availability would be a major problem inside the Loop.

It appears that the 5 watersheds described below warrant consideration in park-and-ride planning. These watersheds are shown in Figure 14. Initially, it appears that lots should be located at 4 of these 5 locations.

1. Clear Lake City; a lot in Clear Lake City serving Clear Lake City and points to the southeast. This lot might be located along I-45S in the vicinity of either El Dorado or Bay Area Boulevard.

2. Near Choate Road; this represents the terminus of the busway and is located about 4 miles northwest of Clear Lake City. At present, the area between Choate Road and Clear Lake City is essentially undeveloped. Little park-and-ride demand would be generated at Choate Road if a park-and-ride lot is located both in Clear Lake City and in the vicinity of Almeda-Genoa (a separation of about 6 miles).

3. Almeda-Genoa; a lot in the vicinity of Almeda-Genoa, Kings Point or Fuqua would serve the market area northwest of the Clear Lake City lot (primarily northwest of Choate Road).

4 & 5. Hobby Field; the interchange at College could conceivably serve 2 park-and-ride lots. The existing Edgebrook lot, located about 1 mile south of the interchange, could access the busway at College. It may be desirable to locate a second lot 1/4 to 1/2 mile north of College that would also access the busway at that location.

Each of these market areas is described separately in this section.

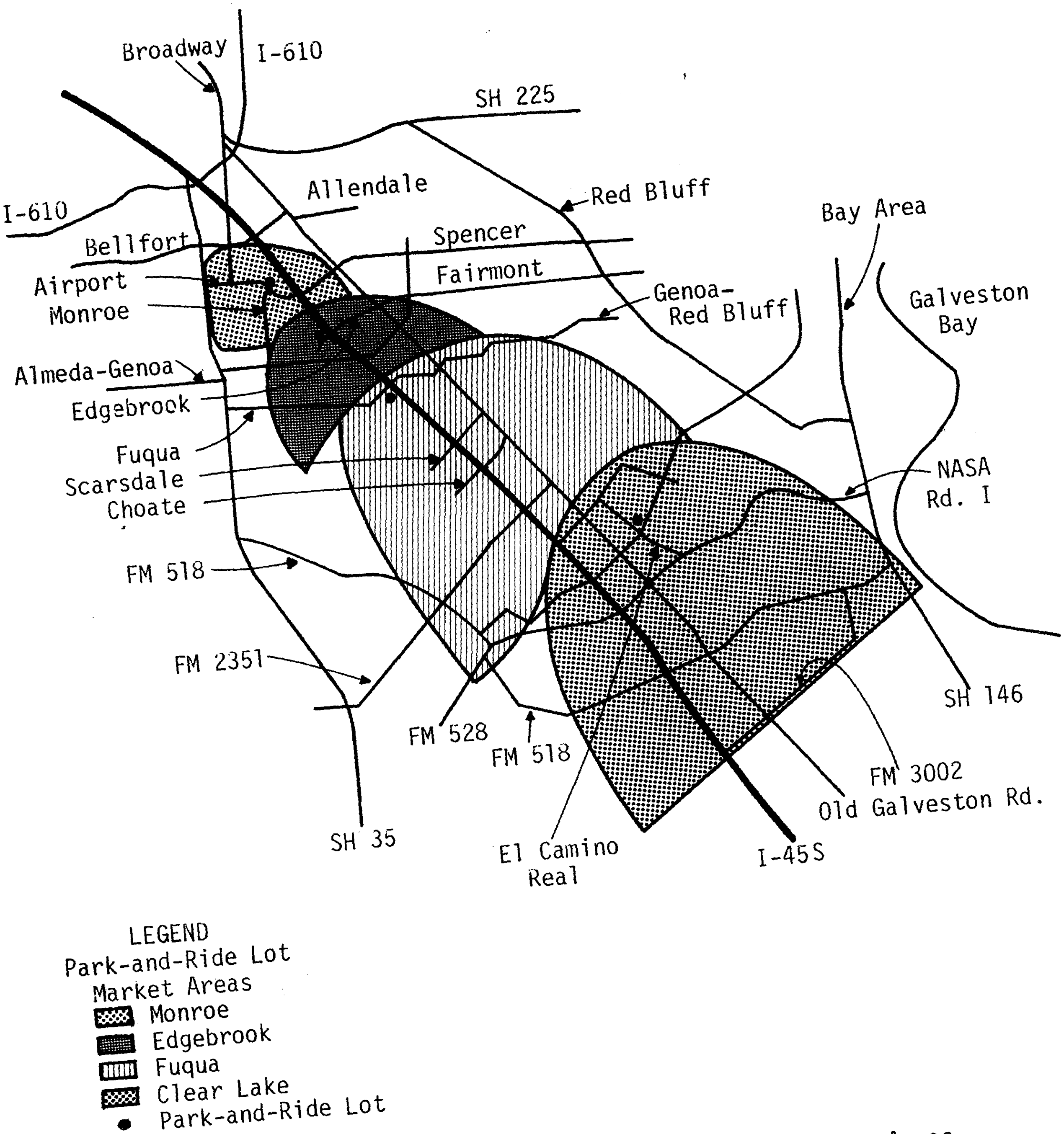
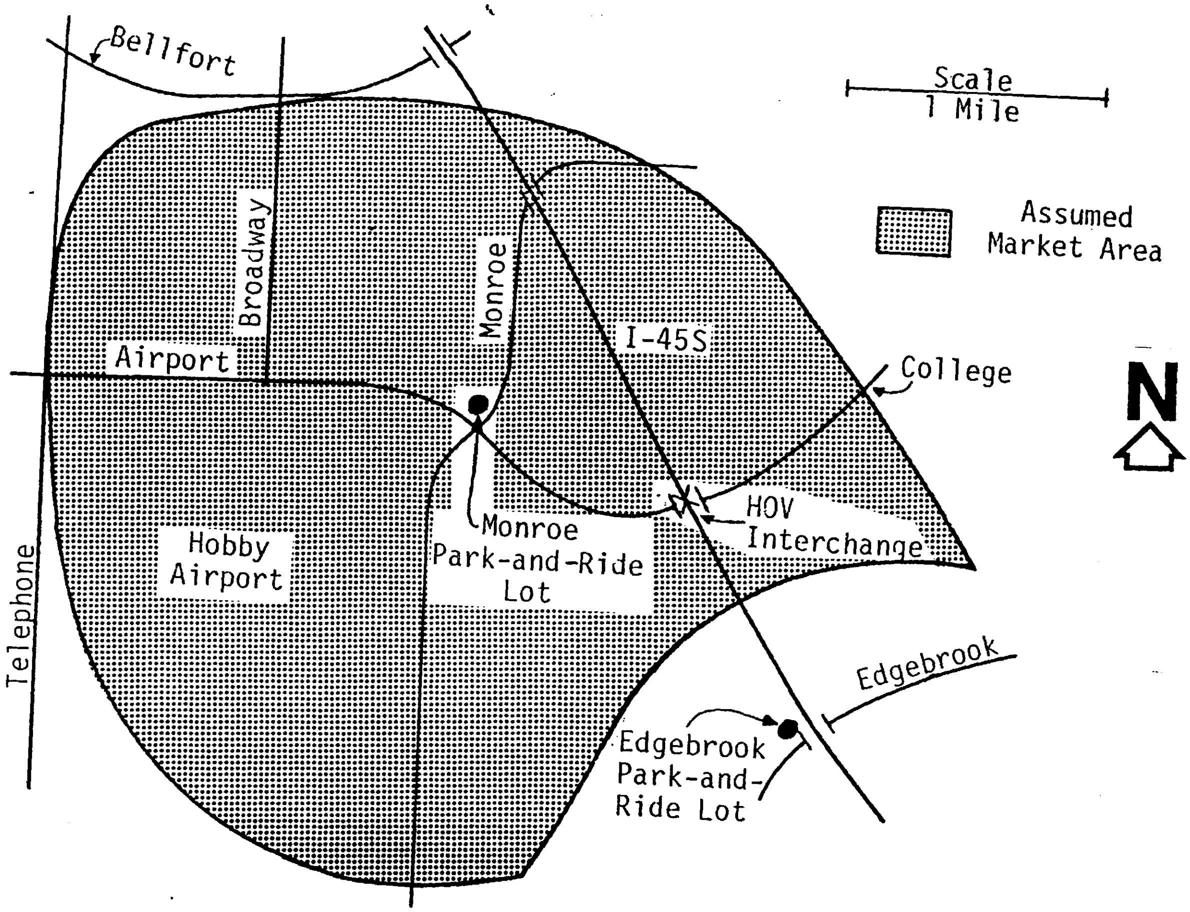


Figure 14: Gulf Freeway Park-and-Ride Lot Market Areas

Evaluation of Individual Lot Locations

Monroe Park-and-Ride (8.5 mi. to CBD)



- The assumed market area, based on the location of the Edgebrook park-and-ride lot, is 3.9 sq. mi.
- Based on 1980 census data, the market area population is 20,000. This is equivalent to a density of approximately 5100 persons/sq. mi.
- Alternative measures of demand. (Assumes 85% of total ridership to CBD and 1.4 riders per parked vehicle).
  - Market Area Population. 20,000 x 2.5% = 500 ÷ 0.85 = 588 ÷ 1.4 = 420 parking spaces.

- Modal Split. 5.2% of market area population works in the CBD (1970 census). 20,000 x 5.2% = 1040 x 35% (modal split) = 364 ÷ 0.85 = 428 ÷ 1.4 = 305 parking spaces.

- Regression. Assume 1985 congestion index (CI) = 2.7. This particular regression equation was used due to the relatively small size of the market area. It appeared inappropriate to initially assume a level of service as would be required to use an alternative equation using the variable MIN.

  - Ridership = -160 + 204 (CI) + 0.0034 (MAPOP)
    = 459 ÷ 0.85 = 540 ÷ 1.4 = 386 spaces

  - Ridership = -86 + 0.8 (MIN) + 0.002 MAPOP
    (use a "typical" Houston value of MIN = 600)
    = 434 ÷ 0.85 = 510 ÷ 1.4 = 365 spaces

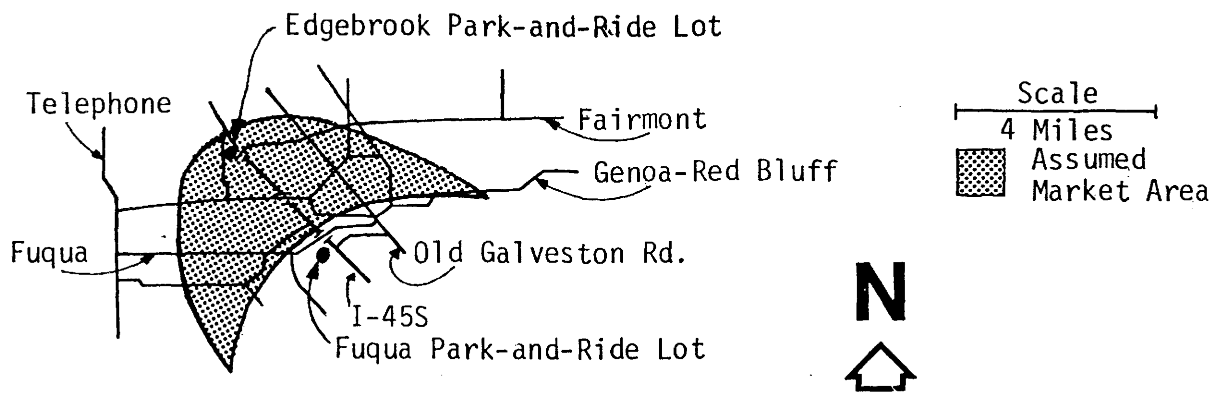
- Suggested Actions

  - All estimates are between 305 and 420 spaces.

  - To serve the demand that would exist today, it appears that 305 to 420 spaces would be needed. Since most of the land in the market area is already developed, providing a lot at least 40% to 50% greater in size than that needed to serve today's demand would appear sufficient.

  - Acquire sufficient land to develop a lot with about 600 parking spaces (6 acres).

Edgebrook Park-and-Ride (10 mi. to CBD)



- A permanent, existing 1000-car park-and-ride lot is located at this site. Approximately 500 cars currently park at this site.

- The market area, assuming lots are also located at Monroe and Fuqua, contains 8.2 sq. mi.

- Based on 1980 census data, the market area population is 32,000. A density of 3900 persons per square mile exists.

- Alternative measures of demand. (Assumes 85% of total ridership to CBD and 1.4 riders per parked vehicle).

  - Market Area Population. 32,000 x 2.5% = 800 ÷ 0.85 = 941 ÷ 1.4 = 672 parking spaces.

  - Modal Split. 3.5% of market area population works in the CBD (1970 census). 32,000 x 3.5% = 1120 x 35% (modal split) = 392 ÷ 0.85 = 461 ÷ 1.4 = 329 parking spaces.

  - Regression. Assume 20 buses serve the lot each peak period (based on service at similar N. Shepherd and Kuykendahl lots) with 50 seats per bus and 32,000 market area population.

    - Ridership = -86 + 0.8 (1000 seats) + 0.002 (32,000) = 778 riders ÷ 0.85 = 915 ÷ 1.4 = 654 spaces.

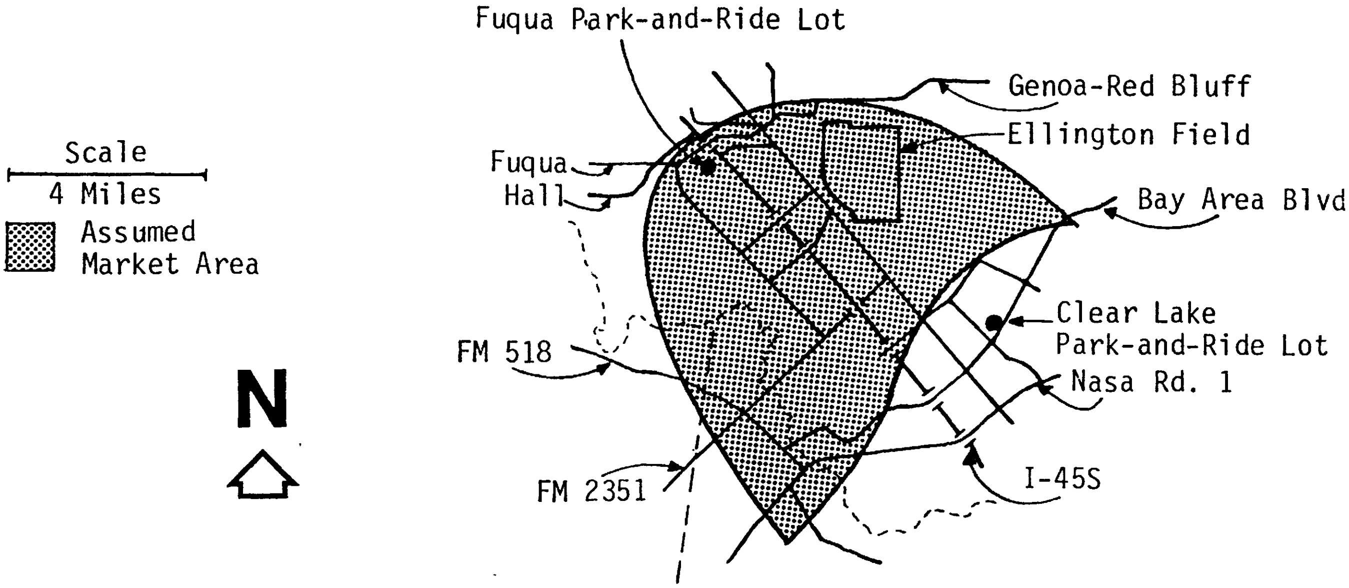
- Suggested Actions

  - Ignoring the low estimate, it appears that about 600 spaces are needed to serve current demand, which agrees well with the 500 car existing usage.

  - Considerable undeveloped land exists in the market area and substantial population increases will occur.

  - Given these estimates, existing usage rates, and development potential in the market area, it does not appear that developing lots at Monroe and Fuqua will negate the need for a 1000-car lot at Edgebrook.

Fuqua Park-and-Ride (12.5 mi. to CBD)



- The market area, assuming that lots are also located at Edgebrook and Clear Lake City, contains 40.1 square miles.

- Based on 1980 census data, the market area population is 35,000. This is equivalent to a density of approximately 870 persons/sq. mi.

- Alternative measures of demand (Assumes 85% of total ridership to CBD and 1.4 riders per parked vehicle).

  - Market Area Population. 35,000 x 2.5% = 875 ÷ 0.85 = 1029 ÷ 1.4 = 735 parking spaces.

  - Modal Split. 3.3% of market area population works in the CBD (1970 census). 35,000 x 3.3% = 1155 x 35% (modal split) = 404 ÷ 0.85 = 475 ÷ 1.4 = 339 spaces.

  - Regression. (Same equation used at Edgebrook lot.)

    - Ridership = -86 + 0.8 (1000 seats) + 0.002 (35,000) = 784 ÷ 0.85 = 922 ÷ 1.4 = 658 spaces.

      Note: If a "typical" Houston MIN value of 600 had been used, this would estimate a 390 space lot.

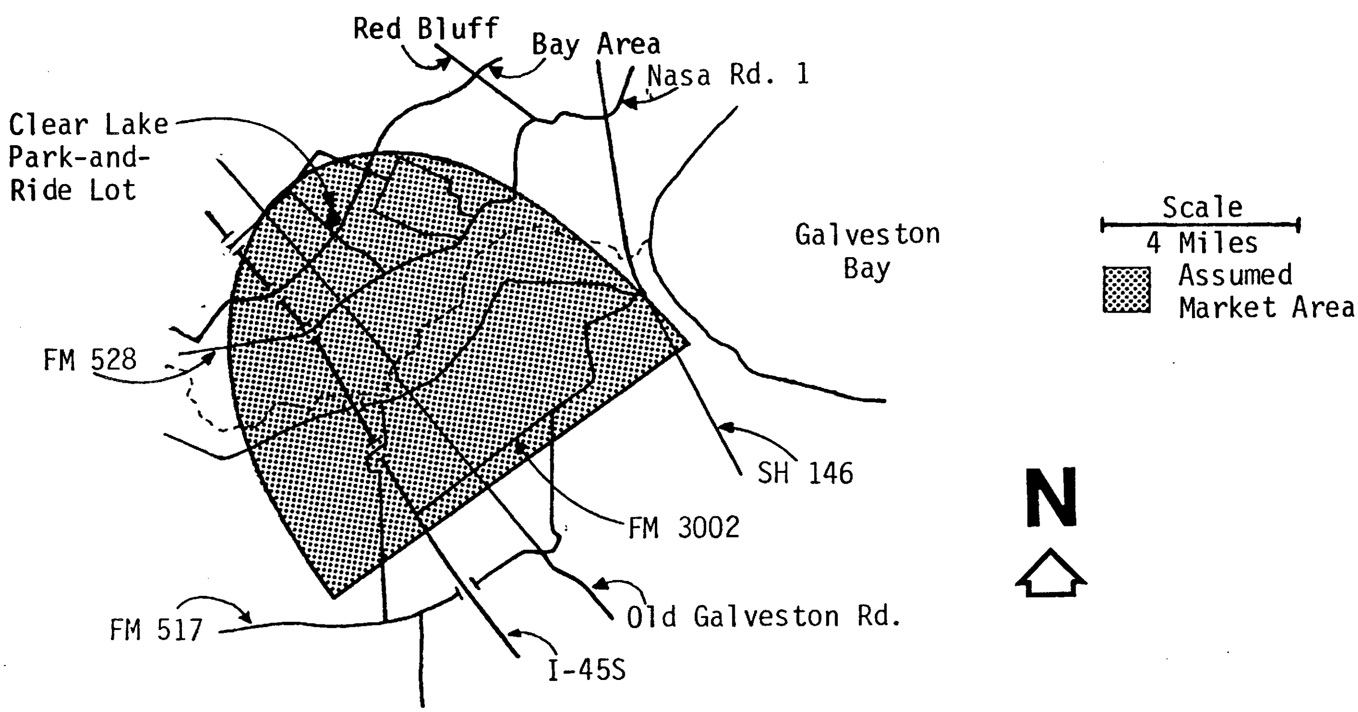
- Suggested Actions

  - It appears that 300 to 700 spaces are needed to serve current demand; the average of 4 estimates is 530 spaces.

- Most of the market area is currently undeveloped. As a result, it might be desirable to acquire land sufficient to serve a demand twice that of the current demand.

- Acquire land sufficient to develop a 1200-space park-and-ride facility.

Clear Lake City Park-and-Ride (19 mi. to CBD)



- An existing 340-space (340 daily riders using 240 spaces) leased lot is to be replaced with a permanent lot.

- The market area, assuming no lots are located further to the southeast, contains 62.2 square miles.

- Based on 1980 census data, the market area population is 50,000. This is equivalent to a density of 800 persons/sq. mi.

- Alternative Measures of Demand (Assumes 85% of total ridership to the Houston CBD and 1.4 riders per parked vehicle).

  - Market Area Population. 50,000 x 2.5% = 1250 ÷ 0.85 = 1470 ÷ 1.4 = 1050 spaces.

- Modal Split. 1.3% of the market area population works in the CBD. 50,000 x 1.3% = 650 x 35% (modal split) = 227 ÷ 0.85 = 267 ÷ 1.4 = 191.

- Regression. (Same equation used at Edgebrook lot).

  - In terms of distance from the CBD, this lot is most comparable to Champions, Kingwood, and Katy/Mason. The average MIN values for those lots is 423.

  - Ridership = -86 + 0.8 (423) + 0.002 (50,000)
    = 352 ÷ 0.85 = 414 ÷ 1.4 = 296 spaces

- Suggested Actions

  - The estimate range is substantial. A very low percentage of the 1970 population worked in downtown Houston.

  - Current usage requires 240 spaces without the busway.

  - Much of the market area is undeveloped.

  - The average of the 3 estimates calls for about 512 spaces.

  - Once the busway opens, the existing, leased lot will probably be too small, especially as more land is developed. In acquiring land for a new lot, a demand of at least twice existing demand should be considered. It appears that land for a 600- to 700-car lot should be obtained.

Summary of Recommendations

Four park-and-ride lots, located between I-610 and Clear Lake City, would appear capable of serving park-and-ride demand. These lots are described in the Table 17 below.

In comparison to the I-45N contraflow lane, this appears reasonable. After over 2 years of operation, 2400 spaces are filled in that corridor and plans are being considered to add about 700 more spaces.

The North Freeway corridor is more highly developed than the Gulf corridor is now. The Gulf corridor will have midpoint access potential and will not open for 3 to 4 years. Thus, 3500 spaces in that corridor appears reasonable based on experience with the contraflow project. Indeed, it is possible that the major constraint on park-and-ride patronage may be bus availability.

Table 17. Summary of Recommendations for the Gulf Freeway Busway Park-and-Ride Facilities

Park-and-Ride Lot	Est. Size 1990 Demand	Status	Distance to CBD (mi.)	Access Point to Busway
Monroe St.	600 spaces	New Lot	8.5	Hobby Airport
Edgebrook	1000 spaces	Existing	10	Hobby Airport
Fuqua	1000 - 1200 spaces	New Lot	12.5	Almeda-Genoa
Clear Lake City	600 - 700 spaces	Leased lot to be replaced by permanent lot.	19	Choate Road
Total, 4 lots	3500 spaces			

CONCLUSIONS

This report presents several alternative techniques for estimating the demand for park-and-ride service in Texas cities. Each technique has limitations, and all assume that the proposed lot is situated in accordance with the lot location guidelines presented in this report.

In planning for new park-and-ride facilities, it is suggested that several of the demand estimation techniques set forth in this report be applied. That analysis will provide a range of estimates. The analyst, using his knowledge of the local area, can use that range to estimate a lot size for a new park-and-ride facility.

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APPENDIX A

Market Areas

APPENDIX A

The data base included in this report presented 1980 population values for park-and-ride lot market areas. Those population numbers were developed by identifying the census tracts included in the market areas. For information purposes, the census tracts included in the market areas are presented in this Appendix.

CITY	LOT	TRACT	POPULATION
AUSTIN	North Park and Ride	* 15.03	1,888
		* 15.04	583
		18.04	4,695
		* 18.05	2,918
		* 18.06	2,874
		* 18.07	1,414
		18.11	758
		18.12	2,450
		18.13	2,813
		* 18.14	310
		* 18.15	206
		TOTAL	20,909
	US 183 North	* 17.09	2,074
		17.10	4,077
		TOTAL	6,151
	Covenant	* 17.06	475
		* 17.08	3,440
		* 17.09	2,074
		TOTAL	5,989
	NW Hills	15.01	5,362
		* 15.04	2,333
		* 15.05	721
		* 17.03	2,247
		17.04	4,817
		* 17.05	930
		* 17.06	594
		* 17.07	2,924
		* 18.17	3,346
		* 18.18	3,815
		TOTAL	27,089
DALLAS	Garland South	181.05	5,897
		* 181.06	1,247
		* 181.09	461
		181.10	3,147
		181.11	4,959
		* 181.12	6,990
		182.01	7,595
		182.02	5,305
		183.00	6,227
		184.01	3,879
		184.02	4,410
		184.03	1,440
		* 185.01	1,014
		186.00	3,606
		187.00	5,129
		188.01	3,195
		188.02	874
		* 189.00	3,528
		* 190.06	1,534
		* 190.07	2,377
		TOTAL	72,814
	Garland North	181.05	5,897
		181.06	3,742
		* 181.07	1,973
		* 188.01	2,396
		* 188.02	291

CITY	LOT	TRACT	POPULATION
DALLAS	Garland North	* 190.06	614
		190.07	4,753
		* 190.08	3,666
		* 190.09	3,786
		TOTAL	27,118
	North Central	* 78.04	1,620
		* 132.00	110
		* 190.03	2,427
		* 190.08	1,833
		* 190.10	6,145
		* 190.11	9,945
		190.12	4,918
		191.00	5,430
		192.01	7,672
		192.02	4,687
		192.03	4,518
		192.04	6,287
		192.05	3,742
		192.06	4,718
		192.07	9,708
		TOTAL	73,760
	Las Colinas	* 141.02	55
		141.03	2,286
		* 141.04	3,251
		* 142.00	858
		* 143.01	2,311
		* 143.03	1,477
		143.04	23
		TOTAL	10,261
	Red Bird	109.00	2,884
		* 110.01	5,822
		111.01	4,098
		* 165.01	221
		* 165.02	3,945
		* 165.03	6,064
		* 165.07	3,185
		* 166.01	1,736
		TOTAL	27,955
	Pleasant Grove	* 92.01	2,313
		92.01	4,199
		* 93.01	513
		* 116.02	2,025
		117.00	7,609
		118.00	5,086
		119.00	5,047
		* 120.00	354
		* 171.00	780
		172.00	5,908
		* 173.01	1,140
		* 174.00	2,350
		* 175.00	1,212
		* 176.01	4,589
		TOTAL	43,125
EL PASO	Montwood	* 43.02	2,035
		* 43.03	1,768
		43.04	14,064
		* 43.05	1,704

CITY	LOT	TRACT	POPULATION
EL PASO	Montwood	* 103.01	5,155
		* 103.02	71
		TOTAL	24,797
	Northgate (and Sunrise)	1.01	4,411
		1.02	8,157
		1.04	7,514
		1.05	12,835
		2.01	8,968
		2.02	7,814
		3.01	6,752
		3.02	6,649
		4.02	6,530
		* 101.00	536
		* 102.02	51
		TOTAL	70,217
FORT WORTH	College Avenue	*1048.02	2,607
		*1054.01	372
		*1054.04	2,623
		*1055.01	2,744
		1055.02	6,119
		1055.03	5,839
		1055.04	7,751
		1056.00	4,901
		1057.01	3,830
		1057.02	2,071
		*1058.00	1,289
		*1060.01	278
		*1109.02	486
		*1110.01	122
		*1110.03	898
		*1110.04	2,496
		TOTAL	44,426
	Meadowbrook	*1013.01	421
		*1065.03	1,240
		*1065.04	4,277
		*1065.05	438
		1115.05	4,996
		*1115.06	958
		*1131.00	2,799
		1216.01	6,081
		1216.04	5,205
		1216.05	3,248
		*1216.06	365
		*1217.01	1,071
		*1223.00	1,162
		*1224.00	2,811
		1225.00	3,509
		*1226.00	1,326
		*1227.00	1,352
		TOTAL	41,259
HOUSTON	Kingwood	249.01	4,961
		249.02	8,449
		249.03	6,928
		* 901.00	5,106
		TOTAL	25,444

CITY	LOT	TRACT	POPULATION
HOUSTON	Champions	* 244.01	1,402
		536.01	11,522
		537.01	5,731
		556.01	4,299
		556.02	8,365
		558.01	4,202
		558.02	11,206
		* 559.01	4,766
		TOTAL	51,493
	Kuykendahl	* 244.01	1,402
		535.00	3,754
		536.01	11,522
		536.02	2,367
		537.01	5,731
		537.02	5,048
		556.02	8,365
		558.02	11,206
		* 599.01	1,778
		TOTAL	51,173
	North Shepherd	* 240.01	990
		* 240.03	526
		* 242.00	320
		530.01	1,564
		530.02	8,070
		530.03	9,245
		531.01	7,840
		531.02	4,526
		531.03	7,612
		* 532.01	4,038
		* 532.02	252
		533.01	4,766
		533.02	11,164
		* 533.03	5,853
		534.01	6,074
		534.02	1,730
		* 535.00	939
		* 537.02	2,524
		* 538.02	3,839
		* 539.00	7,694
		TOTAL	89,566
	Gulf/Sage	* 322.04	1,352
		* 323.02	2,675
		* 324.02	4,585
		* 324.03	18
		* 344.00	251
		* 345.01	1,414
		345.02	2,659
		346.00	4,047
		347.01	5,684
		347.02	4,761
		347.03	2,170
		347.04	6,455
		348.01	4,354
		348.02	8,939
		* 349.02	2,873
		* 357.03	3,254
		* 359.01	11,007
		* 359.02	1,315
		* 370.00	2,452
		* 371.01	18,157
		* 371.02	3,986
		TOTAL	92,408

CITY	LOT	TRACT	POPULATION
HOUSTON	Clear Lake	* 373.00	11,102
		374.00	5,790
		* 375.00	3,118
		*1201.00	1,530
		*1203.00	3,091
		1204.00	3,238
		1205.00	3,715
		*1206.00	789
		*1207.00	947
		*1208.00	1,599
		1212.00	8,557
		1213.00	703
		1214.00	669
		TOTAL	44,848
	Beechnut (Meyerland and Sage)	* 332.00	6,036
		333.00	3,496
		334.00	6,499
		335.01	4,499
		335.02	6,095
		335.03	3,907
		415.01	2,650
		415.02	2,586
		415.03	4,119
		415.04	2,879
		* 416.02	1,563
		416.04	2,802
		416.05	506
		* 427.01	3,305
		427.02	8,864
		428.01	3,381
		428.02	3,053
		429.00	3,621
		430.01	2,592
		430.02	3,989
		431.00	5,478
		432.00	4,791
		* 433.00	4,977
		TOTAL	91,688
	Sharpstown	334.00	6,499
		416.01	4,616
		416.02	4,688
		* 416.03	3,293
		416.04	2,802
		* 417.01	3,356
		425.01	3,393
		425.02	3,686
		425.03	7,454
		425.04	3,504
		426.01	3,848
		426.02	6,048
		427.01	6,610
		427.02	8,864
		* 428.01	2,030
		* 428.02	1,833
		429.00	3,621
		430.01	2,592
		430.02	3,989
		* 431.00	3,289
		432.00	4,791
		433.00	14,931
		434.01	9,172
		434.02	5,090
		TOTAL	119,999

CITY	LOT	TRACT	POPULATION
HOUSTON	Alief	* 436.03	3,451
		437.01	5,604
		437.02	10,398
		* 438.05	3,056
		438.06	1,855
		* 449.00	1,857
		* 701.00	2,503
		* 703.00	6,693
		TOTAL	35,417
	Westwood	* 425.01	1,697
		434.01	9,172
		434.02	5,090
		* 435.01	5,010
		435.02	9,282
		* 436.01	5,856
		436.02	7,808
		436.03	17,255
		437.02	5,199
		* 701.00	8,344
		* 703.00	3,346
		TOTAL	78,059
	Katy/Mason	452.01	4,561
		* 452.02	2,308
		* 449.00	4,951
		* 705.00	738
		* 801.00	228
		TOTAL	12,786
SAN ANTONIO	Windsor	*1205.02	589
		*1212.01	3,579
		*1212.02	5,322
		1213.00	5,067
		*1214.00	2,173
		1215.00	14,749
		1216.02	10,219
		*1218.00	7,430
		TOTAL	49,128
	McCreless	*1408.00	1,274
		1409.00	1,833
		1410.00	3,357
		1411.00	7,685
		1412.00	6,959
		*1413.00	3,047
		1414.00	8,452
		1416.00	447
		*1417.00	397
		TOTAL	33,451
	South Park	1512.00	7,068
		*1513.00	2,231
		1610.00	3,236
		1611.00	7,425
		*1612.00	327
		1613.00	8,904
		*1615.00	4,606
		TOTAL	33,797

CITY	LOT	TRACT	POPULATION
SAN ANTONIO	Lackland	*1616.00	1,433
		*1618.00	3,091
		*1619.00	244
		*1718.00	2,845
		*1719.00	3,934
		*1720.00	90
		TOTAL	11,637
	Wonderland	*1806.00	5,123
		1807.00	7,963
		1808.00	2,920
		1809.01	5,165
		1810.01	3,523
		1810.02	6,234
		1811.00	5,615
		*1812.00	2,939
		1813.00	7,390
		1814.00	1,488
		1815.00	11,278
		*1818.00	3,989
		1915.00	1,522
		TOTAL	65,149
	Nacogdoches	*1206.00	2,805
		*1207.00	1,317
		1209.01	3,156
		*1209.02	1,564
		1210.00	6,053
		*1211.01	6,125
		*1212.01	3,579
		*1212.02	3,548
		*1913.00	1,860
		TOTAL	30,007

*Partial Tract

APPENDIX B

Additional Demand Estimation Equation

Demand Estimation Equations

In addition to the regression equations shown in the text, a considerable number of additional equations were evaluated as part of this project. Some of those equations predict daily ridership with an accuracy comparable to the equations included in the main body of the test. Those equations are shown below.

Ridership = -85 + 256 (CI) R^2 = 0.48

Ridership = 10 + 322 (CI) - 17 (DISTAC) R^2 = 0.55

Ridership = -203 + 263 (CI) + 2.5 (ACPARK) R^2 = 0.62
Note: Applies to lots located 5-15 mi. from activity center

Ridership = -152 + 223 (CI) + 2.3 (ACPARK) R^2 = 0.49
Note: Applies to all lots

Ridership = -311 + 8.23 (ACPARK) + 0.004 (MAPOP) R^2 = 0.47

Where:

CI = congestion index

MAPOP = market area population

DISTAC = distance to activity center

ACPARK = activity center parking cost