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16. Abstract

Planning decisions for transportation infrastructure are based largely on forecast travel demand. To make informed decisions, the forecast travel demand must accurately reflect the response in traveler behavior and patterns of travel to changes in the attributes of the transportation system and the people using the system. Travel demand models are one of the tools used to estimate and forecast travel demand.

The objective of this project was to perform an evaluation of the ability of the current modeling process in Texas to forecast travel behavior and patterns within the context of a controlled experimental design. The project attempted to calibrate travel demand models using travel surveys conducted in the San Antonio-Bexar County area in 1969. These models would then be applied to forecast travel behavior and patterns for the years 1980 and 1990, with the results compared to observed conditions. Due to data limitations, researchers did not consider the model developed for 1970 acceptable in terms of meeting the calibration criteria that were established. This negated the application of the model to 1980 and 1990 since the results could not be interpreted with any confidence. A number of recommendations on the model information needs for retention in future model calibration/validation efforts are made. The recommendations provide the basis for examining travel demand models within controlled conditions as a routine part of the modeling process.

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CALIBRATION OF A PAST YEAR TRAVEL DEMAND MODEL FOR MODEL EVALUATION

by

David F. Pearson, P.E., Ph.D.
Research Engineer
Texas Transportation Institute

Patricia L. Ellis
Associate Research Scientist
Texas Transportation Institute

and

Stephen P. Farnsworth
Assistant Research Scientist
Texas Transportation Institute

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The Texas A&M University System
College Station, Texas 77843-3135

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1. INTRODUCTION

Planning decisions for transportation infrastructure are based to a large extent on forecast travel demand. Travel demand models are one of the tools for estimating and forecasting that demand. These models provide information on the expected response in travel behavior and patterns to changes in the attributes of the existing or proposed transportation system and changes in the socio-demographic make-up and distribution of the population the transportation system is designed to serve.

Since the early 1960s, planners have modeled traffic using a four-step process. The steps are trip generation, trip distribution, mode split, and trip assignment. This process was developed and implemented to assist in evaluating major capital improvements. In the 1970s, the traditional four-step modeling process moved from a coarse aggregate approach (which relied on large-scale origin-destination surveys) to a disaggregate approach (which could be implemented with smaller stratified random sample household travel surveys). The disaggregate approach is thought to more accurately reflect traveler behavior and is not dependent on zonal structure. Much of the research associated with the four-step models in the 1970s focused on improved computational algorithms and techniques such as windowing, sub-area focusing, improved traffic assignment algorithms, and mode split modeling techniques.

Limited research has been conducted to evaluate the ability of the four-step modeling process to forecast travel within urban areas. The practice is to "calibrate" each step of the model to a base year and to compare the estimated base year volumes and vehicle miles of travel (VMT) to the base year vehicle counts and counted VMT. While planners use several criteria to judge the performance of the model in the base year, the primary criterion is the comparison of the base year estimated and counted traffic volumes. Planners assume that the model will reasonably forecast future travel demand using the future transportation system and the forecasted socio-economic characteristics of the population as inputs.

The purpose of this project was to perform an evaluation of the travel demand models to forecast travel patterns and traffic volumes for a time period after the base year for which the model is calibrated. While the project was not successful in attaining this objective, it was productive in identifying some of the essential and critical areas of information and data retention necessary to answer questions concerning the travel demand models and their ability to forecast travel. Recommendations on actions necessary to accomplish this retention of information and data are included in the final section of this report.

This report is organized into five sections following the introduction. These sections document the work performed and the results. The first section discusses the peer review panel, which was established for this project. The second section presents the findings of the literature review. The third section discusses the 1970 travel demand model, how it was developed, applied, and the results achieved. The fourth section presents a summary evaluation of the 1970 travel demand model from a calibration perspective including an evaluation of the model results and the comments from the peer review panel. The final section presents a critique of the project and the recommendations based on the findings.

2. PEER REVIEW PANEL

An important element of this project was the establishment of a peer review panel. The development and calibration of travel demand models require a great deal of professional judgment. The potential impact of findings from this project was felt to be significant. The establishment of a panel of experts in this field was essential to ensure that the activities conducted was not biased and was consistent with acceptable practice. Letters were sent to eight individuals asking them to serve on a peer review panel for this project. All eight individuals accepted this invitation. The following individuals agreed to serve on the peer review panel for this research:

Mr. Phillip Reeder	Parsons Brinckerhoff, Quade & Douglas
Mr. Robert Williams	Texas Department of Transportation, Transportation Planning and Programming Division (TPP)
Ms. Janet Kennison	San Antonio-Bexar County Metropolitan Planning Organization (MPO)
Ms. Julie Brown	Texas Department of Transportation, San Antonio District
Dr. Ard Andjomani	University of Texas at Arlington
Mr. Andy Mullins	Houston-Galveston Area Council
Dr. Gordon Shunk	Texas Transportation Institute
Mr. Ken Cervenka	North Central Texas Council of Governments

During the course of this project, the peer review panel met twice. The first time was to review preliminary results, and the second time was to review the model calibration results. Researchers incorporated their comments and suggestions into the sections that follow.

3. LITERATURE REVIEW

Researchers conducted a literature review to identify and review research on the performance of travel demand models in terms of their forecasts. This review did not focus on the development, calibration, and/or validation of travel demand models. It examined research on the performance of travel demand models in a forecasting application since this was consistent with the objective of this project. The identified and reviewed research papers are summarized in the following sections.

Giuliano *(1)* examined the travel demand forecasts from the Urban Transportation Planning System (UTPS) for the Los Angeles, California, area. The forecasts were developed in the early 1960s for the year 1980. Mr. Giuliano's research focused on the forecasts that were developed and compared them to actual outcomes for the Los Angeles region. Mr. Giuliano hypothesized that the UTPS sequential method of forecasting had two fundamental flaws. The first flaw was that the identification of population, employment, and land use established the fundamental parameters of travel behavior, and changes in these assumptions would generate differences between model forecasts and real-world results. The second flaw was the lack of feedback in the modeling steps, which resulted in no interaction between transportation supply and demand. The only exception noted was the network assignment step.

The first comparison made by Giuliano was population and employment. The data presented compared the estimated population and employment versus the actual population and employment for five counties in the Los Angeles region. The forecast 1980 population for the five counties combined was 28 percent higher than the actual 1980 population. Differences for individual counties ranged from 13 to 42 percent, with the forecast estimates being higher than the actual population for every county. Regional employment forecasts were less than the actual employment for 1980 by 13 percent. Differences in employment by county ranged from an overestimate of 37 percent to an underestimate of 31 percent. Obviously, the forecasts of population as well as the distribution of those data were quite different from what actually occurred.

The second comparison made dealt with the first step in travel demand modeling, trip generation. The household trip rates used in the travel demand forecast were stratified by type of dwelling unit and automobile ownership. It was assumed that travel behavior would not change over time and the changes in trip generation would be due to shifts in households by their characteristics. Researchers compared the stratified trip rates used in the 1960s trip generation model to the rates from a 1976 Los Angeles Regional Transportation Study survey. Table 1 presents the comparison of trip generation rates.

The data in Table 1 indicate sizable differences in some categories. These differences were magnified by the corresponding differences in the estimates of the number of households in each category compared to the actual number of households. These differences ranged from a negative 52 percent to a positive 243 percent. For a hypothetical area of 10,000 dwelling units, it was estimated the number of trips would be underestimated by 21 percent. Of that difference, 6 percent was due to the error in the trip generation rates.

Table 1. Daily Automobile Driver Trips Per Household for Los Angeles.

Dwelling Unit	Number of Automobiles	Estimated	Actual	Percent Difference
Single Family	0	1.24	0.15	727%
	1	4.83	4.20	15%
	2+	7.42	8.50	-13%
Multi-Family	0	0.17	0.45	-62%
	1	3.87	3.70	4%
	2+	6.86	7.30	-6%

Source: *(1)*

At the regional level, the underestimate due to the trip rates and the households in each category was offset by the overestimate in the regional population. Net error in the number of trips being estimated was only 4 percent. It was noted that the estimates of trips at the zonal levels and the distribution of trips was likely to be much greater than the overall regional estimate.

Mr. Giuliano did not examine any data relative to trip distribution or mode choice due to a lack of data. A comparison of anticipated to actual usage on selected screen lines in Orange County was presented. This comparison, while interesting, is not considered valid since the forecast assignments were based on a different freeway system than the one that actually existed in 1980. This was noted in the research.

For the Los Angeles data, it was concluded that the trip rate and VMT per capita had increased much more than forecast, while the average length of trips had increased less than forecast. These differences were largely attributed to the errors in the forecasts and distribution of population and employment. The transportation modeling process was lacking in terms of being independent from land-use planning (i.e., no feedback mechanism).

The most interesting aspect of this research was the comparison of the trip rates used in the forecasts with those found in the 1976 travel survey. The differences noted may be related to the variables used for stratifying the trip rates. Type of dwelling and automobile ownership may be highly correlated. No comparison was made for overall weighted automobile driver trips per household for the region. It is unclear whether the differences in rates are due to differences in travel patterns or differences in other socio-economic factors such as household size, income, workers per household, etc.

Zhao and Kockelman *(2)* identified three sources of uncertainty that contribute to errors in travel demand models. The first was "inherent uncertainty," which occurs because of the use of samples to develop travel demand model parameters. The resulting model parameters are thus estimates with associated variations and co-variations. The second was "input uncertainty," which occurs in the data input to the travel demand models. This level of uncertainty would hopefully be quite small for a base year model development but could be quite high for a forecast year where all of the input data would be estimates generated by other models.

The third was "propagated uncertainty," which occurs at each sequential step in the travel demand models. The estimates from each step serve as input to the next step. The uncertainty in each step propagates through each succeeding step in the modeling process. The research by Zhao Kockelman focused on the cumulative effect of the three forms of uncertainty.

The Zhao and Kockelman research used simulation with multiple model runs to examine the impact of a set level of uncertainty through each step of the four-step modeling procedure. The simulation analysis was conducted using a 25-zone network. They found that the average level of uncertainty grew after each of the first three steps (i.e., trip generation, trip distribution, and mode split) in the modeling process. The final step, trip assignment, reduced the compounded uncertainty but not to a level less than the input uncertainty. To identify the most important contributors to overall uncertainty, a step-wise linear regression analysis was used. It was found that the demographic inputs and the trip generation parameters were significant contributors to the overall uncertainty. Overall, uncertainty was not very sensitive to the trip distribution and assignment models. Trip assignment appears to reduce the uncertainties developed in the early model steps.

This research implies that demographic data and the resulting trip generation results are significant in terms of their impact on the results of the travel demand models. Since these determine the total number of trips and where the trips begin and end, this result is not surprising. The trip generation models used were somewhat simplistic, and it is not clear how the model structure might impact the results. It was noted in the research that additional work was needed to examine the impacts of different model specifications.

An Institute of Transportation Engineers (ITE) Informational Report published in 1980, examined the accuracy of past urban transportation forecasts *(3)*. That report was prepared by the ITE Technical Council 6F13 and specifically reviewed the accuracy of some of the forecasts developed in early transportation studies. Much of the data presented in that report dealt with demographic forecasts and how the forecasts compared with actual data. It also discussed some of the assumptions used in the preparation of the forecasts and how those assumptions impacted how well the forecasts matched the actual data. The original intent of the committee had been to examine the forecast travel demand on specific facilities that were included in the transportation plans. It was unable to accomplish that objective because the forecasts were made in the context of much larger transportation systems, which had not been realized. The study did conclude the following:

- There was evidence that the longer the time period for the forecast, the more the forecast would deviate from what actually occurred.

- As the size of the geographic unit used to make the forecast decreases, the likelihood of larger deviations between the forecast and what occurs increases.

- The dispersion of population and employment that occurred during the 1960s and 1970s was not anticipated and included in the forecasts.

- The more items forecast, when kept in proper perspective, could increase the possibility of compensatory errors.

- Forecasts based on extrapolation of trends that are short in duration are risky and subject to wide deviations between the forecasts and actual results.

- Plans based on forecasts made by vested interest groups should be carefully reviewed in light of the assumptions built into the forecasts.

- Airport planning may need a more flexible approach in the development of forecasts.

Unfortunately, this paper did not examine the specific travel demand models and how the forecasts affected those results. While some comparisons were made on a regional level of vehicle registration and automobile trips, it appeared these results were directly impacted by the demographic data used to produce the estimates.

Research by Lam and Tam *(4)* examined the use of transport models and standard evaluation procedures for assessing traffic congestion measures. Their research examined the modeling results with actual data for the Hong Kong region. They compared projections of automobile ownership with actual data for two forecast periods, 1991 and 1996. The estimate of automobile (and motorcycle) ownership in 1991 was 7 percent under the actual value, and in 1996, the estimate was 26 percent under the actual value. The model used for predicting car ownership was not felt to adequately capture the growth that had occurred. This was identified as one of the reasons the estimates of peak hour vehicle movements across selected cordon and screen lines were 16 to 26 percent less than the observed values.

It was noted that part of the underestimates was due to the inappropriate modeling process in assessing the road user response to capacity constraints and road improvements. The increase in car usage was not linearly proportional to the growth in automobile ownership. The Hong Kong transport model was a conventional four-step model that included trip generation, trip distribution, mode split, and trip assignment. The research provided little information in terms of details on the model specifications that were used or the data input to the models. It is difficult to ascertain whether the inaccuracy of the model estimates were due to model specifications or input data.

In 1977, Horowitz and Emslie *(5)* compared forecasted traffic to measured traffic on 78 interstate highway segments in 55 U.S. cities. No discussion or investigation was made on the methods or input data used to forecast the traffic. The forecasts were made between 1968 and 1972 and were for 1975. Measured traffic was 1975 average daily traffic (ADT). When compared to the measured traffic, the majority of forecasts made in both 1968 and 1972 overestimated the 1975 traffic. As a further comparison, roadway segments were grouped into 10 traffic volume ranges and the mean traffic forecast volumes compared to the mean traffic measured in 1975 for each range. This analysis showed that the forecasts overestimated traffic by 11 to 90 percent on roadways of less than 50,000 ADT. Higher volume roadways (over 50,000 ADT) had percent mean error ranges of −2 to +11 percent. This study also quoted the results of several others that the assignment phase of forecasting has more bias than the trip generation, distribution, and mode split phases.

Aitken and White *(6)* conducted a study in the early 1970s of a 1969 traffic forecast made for a new bridge location in Glascow. The forecast was made in 1961 and calibrated to 1961 data. The model used to make the forecast was a basic model in early development that was similar to the current four-step model process. A comparison of the forecast traffic, with counts taken in 1969 for the two roadways approaching the bridge, was made because the bridge was not yet completed. The forecasts overestimated traffic on one segment by approximately 50 percent and on the other by 10 percent.

Aside from the fact that the bridge had not yet opened to traffic and thus, traffic patterns had not yet adjusted to the additional crossing, the study found major discrepancies in forecast zonal data versus what actually occurred. Most zones were forecast to have a higher population than what actually occurred. In one zone, population was forecast to be more than 192,000 and ultimately had only slightly more than 106,000 population. Other zonal population forecasts were found to be about 10 percent higher than actual population. When the land use and population data were changed and a revised forecast made, the volumes on the two approaching roadways were very close. In fact, the model forecast 3,600 vehicles per day for the bridge and on opening day, the counted bridge traffic was 4,100 vehicles per day.

3.1. MODEL VALIDATION AND REASONABLENESS CHECKING

As a part of the Travel Model Improvement Program (TMIP) funded by the Federal Highway Administration, a *Model Validation and Reasonableness Checking Manual (7)* was developed by Barton-Aschman Associates, Inc. and Cambridge Systematics, Inc. Researchers reviewed this document for this project to identify any specific guidelines and criteria that might be documented on the development of a travel demand model. The manual includes guidance on the review and checking of the socio-demographic data used as input to the travel demand models, trip generation, trip distribution, mode split, and trip assignment.

Socio-economic and transportation network data were noted as being critical elements in the travel demand models. The accuracy of these elements could reduce the level of effort needed in subsequent validation steps. Data sources for both model input as well as checks against data being used were listed, with most coming from various census databases. Some national demographic trends (e.g., person per household, vehicles per household, distribution of households by vehicles available, etc.) are presented as useful guides, but no specific criteria are recommended. It is left to the judgment of the individual checking the data to determine whether the data being used is reasonable or not. There are several checks that are described as being useful, but the underlying decision criteria is left to the individual reviewing the data.

Transportation networks (both roadway and transit) are critical elements in the estimation of travel demand. Regional checks suggested include visual inspection of the network by checking ranges of speeds and capacities by facility type and area type. These may be performed by using summaries of miles by functional classes, capacity, or speed as well as calculating average speed or per lane capacity by facility type and area type. Detailed network checks are recommended on network connectivity and network attributes. Some of the checks suggested include building and plotting paths between a zone to all other zones to review path logic and reasonableness.

Building minimum time paths between all zone pairs will also ensure that all zones are connected to the network. Highway attributes in the network may be checked by reviewing values against valid ranges and/or color-coding. Suggested attributes that need checking include link distance, posted speed limit, facility class, area type, number of lanes, tolls or parking costs, and intersection types.

Transit networks may be checked by color codes to help verify access links, transfer points, stop locations, station connectivity, parking lots, fare coding, etc. Route itineraries may also be plotted. System level checks should be performed on minimum and maximum headways and walk or access times to stations/bus stops. Transit speeds may also be checked against highway speeds by functional class.

System performance data discussed in the manual include traffic volumes, speeds (or travel times), and transit ridership. While these are discussed in terms of their use and collection, little in terms of specific guidance is given, e.g., how many traffic counts are necessary, how many cut lines are typically used, etc.

Trip production generation is discussed in terms of two basic types of models, regression and cross classification. Cross-classification models are considered to be superior to the regression models. The validation checks for the trip generation model were to calculate the total person trip productions per household or per capita and compare with values observed in other urban areas. These values were presented in the manual. The rule of thumb recommended was total person trips in motorized vehicles per capita should be over 3.0 and likely in the range of 3.5 to 4.0.

It was also suggested that total person trips by purpose be calculated and compared (in terms of trips per household and percentage of trips by purpose) with values found in other urban areas. If data from a travel survey were available, it was suggested the expanded trips from the survey be compared to the trip estimates from the model at a regional and district level. An additional check is to apply the model trip rates to the households in the survey and measure the difference in the estimated versus observed trips. Again, it is generally suggested that these checks be evaluated in the context of observed data from other urban areas and studies. This leaves the decisions as to what is or is not reasonable up to the individual.

Trip attraction generation is discussed relative to the use of regression models or attraction rate models. The validation of these models should follow the same basic procedures as the trip production models. Specific items to check were the home-based work person trip attractions per total employment, home-based school trips per school enrollment, and home-based shop trips per retail employment. The manual also discusses special generators and the modeling of trips for other purposes. While these discussions are valid and constructive, they are not summarized here because little or no specific criteria concerning what is or is not reasonable are presented. It is left to the judgment of the individual developing and reviewing the model results. Researchers recommend that in the review of productions and attractions by trip purpose, the ratio of the productions to attractions (or vice-versa) should fall between 0.9 and 1.1 prior to balancing. If the ratio falls outside this range, the socio-economic data and trip rates should be reviewed again.

The most common trip distribution model discussed in the manual was the gravity model. The validation tests include comparing average trip lengths by purpose, comparing trip lengths for trips produced versus trips attracted by purpose by area type, and plotting trip length frequency distributions by purpose. The comparison of average trip lengths by purpose should yield no more than a 5 percent difference between the modeled trip length and the observed trips length. If a generalized cost is used as the measure of impedance, the average trip lengths and trip length frequency distributions should be checked by individual components.

The average trip lengths produced and attracted by area type should be checked, and the trip lengths sent and received by the district should be mapped using a geographic information system (GIS). No criteria is given for what is or is not reasonable. The comparison of plotted trip length frequency distributions may be conducted visually or by using a quantitative measure called the coincidence ratio. The coincidence ratio measures the percent of area that "coincides" between two distributions.

If a gravity model is used for trip distribution, it is also suggested that the normalized friction factors be plotted for each trip purpose. Judgment is the basis for determining the reasonableness of these results. Other checks suggested include calculating the percent of intrazonal trips by purpose, comparing observed and estimated district-to-district trip interchanges and major trip movements (e.g., to central business district [CBD]), and stratifying trip lengths and/or trip interchanges by income class. Typically, intrazonal trips account for less than 5 percent of total person trips.

Mode choice models typically vary between different urban areas and are highly dependent on the urban area being modeled and the type of model used. Researchers suggest that the parameters used in the mode choice model be checked against those developed for other urban areas. Data for a number of urban areas are presented in the manual. Validation is typically performed on a disaggregate level where subgroups of observations are compared against modeled results. It is suggested that this be performed using a sample of observations independent of that used for model calibration.

Aggregate validation should also be performed using secondary sources of data to compare to the modeled results. These may include available transit ridership, highway vehicle and automobile occupancy counts at screenlines by time of day, census data, total patronage by mode, and passengers counts by access mode at major stations or transfer points. Additional checks may include average automobile occupancies by trip purpose, percent of single occupant vehicles, home-based work trips by transit as a percent age of total transit trips, mode shares by districts, and average automobile occupancies to/from area types or districts. Comparable data are presented in the manual, but judgment is required to determine when the model estimates are reasonable.

Validation tests for traffic assignment are presented at three levels − system wide, corridor, and link specific. System-wide checks include VMT, vehicle hours of travel (VHT), cordon and screenline volume summaries, and average VMT and VHT per household and per person. Modeled VMT should generally be within 5 percent of the observed regional VMT. This will vary when compared by facility type. VMT per household and person are considered useful measures to determine if the modeled estimate is within reasonable limits. Reasonable ranges of values are 40 to 60 miles per day for large urban areas and 30 to 40 miles per day for small urban areas. Reasonable values of VMT per person are 17 to 24 miles per day for large urban areas and 10 to 16 miles per day for small urban areas.

After examining the VMT, the next step is to compare the observed versus estimated traffic volume on the highway network. This is generally performed for cordon and screenlines. Cut lines are also typically compared at this level. The maximum desirable deviation in total screenline volumes varies depending on the observed traffic counts crossing the screenline (or cut line). General guidance is provided in the manual for this comparison.

It is also suggested that the observed versus estimated volumes for all links with counts be compared. This can be performed visually and various aggregate statistics computed to measure the correlation and validity of the assignment. There are two measures commonly used − the correlation coefficient and the percent root mean square of the error. The region-wide correlation coefficient should be greater than 0.88. One appropriate aggregate percent root mean square error suggested is less than 30 percent. This value may be calculated for all links with counts by facility type and area type. The manual also discusses transit assignment. This is not discussed in this report because it is not applicable to this research.

James *(8)* published a paper on some of the accuracy evaluation tests that may be used for assignment models of large traffic networks. The tests presented in the paper included parametric and non-parametric tests typically that compared assigned volumes with observed (i.e., counted) volumes. Parametric tests are those designed to test the hypothesis about the value of certain parameters assuming the parameters follow some known probability law (e.g., a normal distribution). Non-parametric tests are designed to make inferences about quantities that are not specifically parameters of an assumed probability law. These tests make fewer assumptions about an underlying probability law and can be expected to perform quite well over a spectrum of possible distributions. Most of the tests presented may be used at different levels, e.g., links classified by function.

The non-parametric tests discussed included the mean ratio of assigned to observed values, mean absolute ratio, mean difference, standard deviation of differences, correlation coefficient, mean absolute error, root mean square error, standardized absolute difference link fit index, standardized absolute difference, and Theil's inequality coefficient. The difficulty of all the non-parametric tests is the inability to associate the test results to a statistical significance.

It was pointed out in the paper that statistical tests such as chi-square and Kolomogorov-Smirnov could be used but the results are misleading in terms of individual link assigned and observed volumes. The research examined two parametric tests. These were the likelihood ratio and information gain. Likelihood methods of evaluation may be used to assess the accuracy of gravity model calibration and can be adapted to assignment model assessment. These methods are based on an assumed distribution of sample values (called a likelihood function) where estimates of unknown parameters may be developed by maximizing the likelihood function. The assumption in this test is that flows between any origin and destination zone pair are multi-nominally distributed. As the likelihood ratio approaches unity, this condition is satisfied. The information gain test is derived from Bayes' theorem relating prior and posterior probabilities to a monotonic likelihood. The best fit is obtained as the value approaches zero. The reader is referred to the paper for the mathematical formulation of these tests.

The paper presents the results of these tests for 19 assignments that were run to illustrate their use in evaluating different assignment methods. It is noted in the results that no test of error significance was determined, and while the statistics did point to preferable assignment methods, they did not indicate the precision of the best assignment. Acceptability of an assignment remains a subjective judgment.

3.2. LITERATURE REVIEW SUMMARY

The preceding literature review is not exhaustive nor does it include all of the research reports and articles that were examined in this project. The primary objective of the literature review was to identify research that had examined the accuracy of the travel demand models from the view of the underlying assumptions within the models and within the confines of a controlled experimental design. Unfortunately, none of the research found exactly fit our objective. The majority of the research reviewed dealt with accuracy of the models relative to a comparison of forecasts to observed conditions. While this is relevant, it does not examine the models themselves, and as we found in most, if not all cases, the root cause of discrepancies was the input data (i.e., socio-demographic inputs) and the inability of the individuals forecasting the input data to account for changes that occurred, which impacted the data.

On the positive side, the lack of research in this area lends more credence to the need for this research. Several papers and reports that were reviewed did lend insight into the impacts of the input data on the forecasts and several contained approaches and methods that will prove useful in this project for model calibration and validation.

4. RESEARCH APPROACH OVERVIEW

This research utilized a controlled experimental design. In a controlled experimental design, certain variables that contribute to error or variation in an application result are controlled by ensuring the values input to the process are as accurate as may reasonably be expected. The results of the application (or experiment) may then be attributed to the variables that are not being controlled. For this research, the variables not being controlled are the travel demand models. The variables being controlled are the input socio-economic data and the transportation network.

The initial long-range transportation plan for the San Antonio-Bexar County study was developed in 1964 for the year 1985. Following the completion of a series of origin/destination (OD) travel surveys in 1969 *(9)*, the plan was updated (referred to as a Level II Update) in 1975 to the year 1990 *(10)*. The model developed and used for that update was based on the 1969 OD travel surveys calibrated to a base year of 1969/70.

The approach for this research was to utilize the socio-economic data and transportation network for the San Antonio-Bexar County 1970 travel demand model. The data, consistent with the 1970 census, and the network were used in calibrating a travel demand model for 1970 using the 1969 OD surveys *(9)*. The objective of this research was to calibrate a new travel demand model for 1970 with state-of-the-practice procedures using the OD data. This model would then be applied to socio-economic data for 1980 and 1990 with transportation networks that represented the transportation system for those years. Since the socio-economic data and transportation networks were "controlled," the travel model results could be evaluated and interpreted relative to the model structure and theory when applied in a forecast scenario. The key element to the success of this project was the development and calibration of a travel demand model for 1970.

5. SAN ANTONIO-BEXAR COUNTY 1970 TRAVEL DEMAND MODEL

5.1. OVERVIEW

The purpose of this section is to document the work, results, and findings with respect to the development and calibration of a travel demand model for 1970. This was initiated with a request for the zonal demographic data and transportation network used in the 1970 travel demand model from the Texas Department of Transportation (TxDOT). In addition, the zonal demographic data and network used in 1990 were also requested. Unfortunately, the 1970 zonal demographic data for San Antonio and Bexar County were no longer available. The 1969 transportation network was only available in map form. This lack of data created a situation where the only means for developing and calibrating a 1970 travel demand model was to develop the zonal data and network based on available secondary sources. The work and results are presented and discussed in the remaining portions of this section. Researchers discuss the study area first, followed by trip generation, trip distribution, and trip assignment.

5.2. STUDY AREA

The study area establishes the area that is used for planning and modeling purposes. There are three elements dependent on the study area, which in turn establish the foundation for the subsequent data compilation and model development steps. These areas are the study area boundary, the zone system, and the transportation network.

5.2.1. Study Area Boundary

The study area for the San Antonio-Bexar County Urban Transportation Study (SABCUTS) has changed over time. The 1956 travel survey and 1964 transportation-planning areas were different and both wholly contained within Bexar County. That area was expanded to include all of Bexar County in the 1969 OD surveys *(9)* and in the transportation plan update conducted in 1975 *(10)*. Around 1972, a new area was identified for study, which included portions of Bexar and Guadalupe counties. This area was termed the Randolph Subregion *(11)*. It was identified as a separate planning area associated with the Randolph Air Force Base, located in the northeast portion of Bexar County. After 1975, this subregion was made a part of SABCUTS. In 1990, the study area consists of Bexar County and small portions of Guadalupe and Comal counties. The area selected for purposes of this research was Bexar County and the small portion of Guadalupe County included in the Randolph Subregion. That area was included because of the growth and relationship with the Randolph Air Force Base, which has and continues to be a major economic and travel generator in the SABCUTS area. Figure 1 presents the study area.

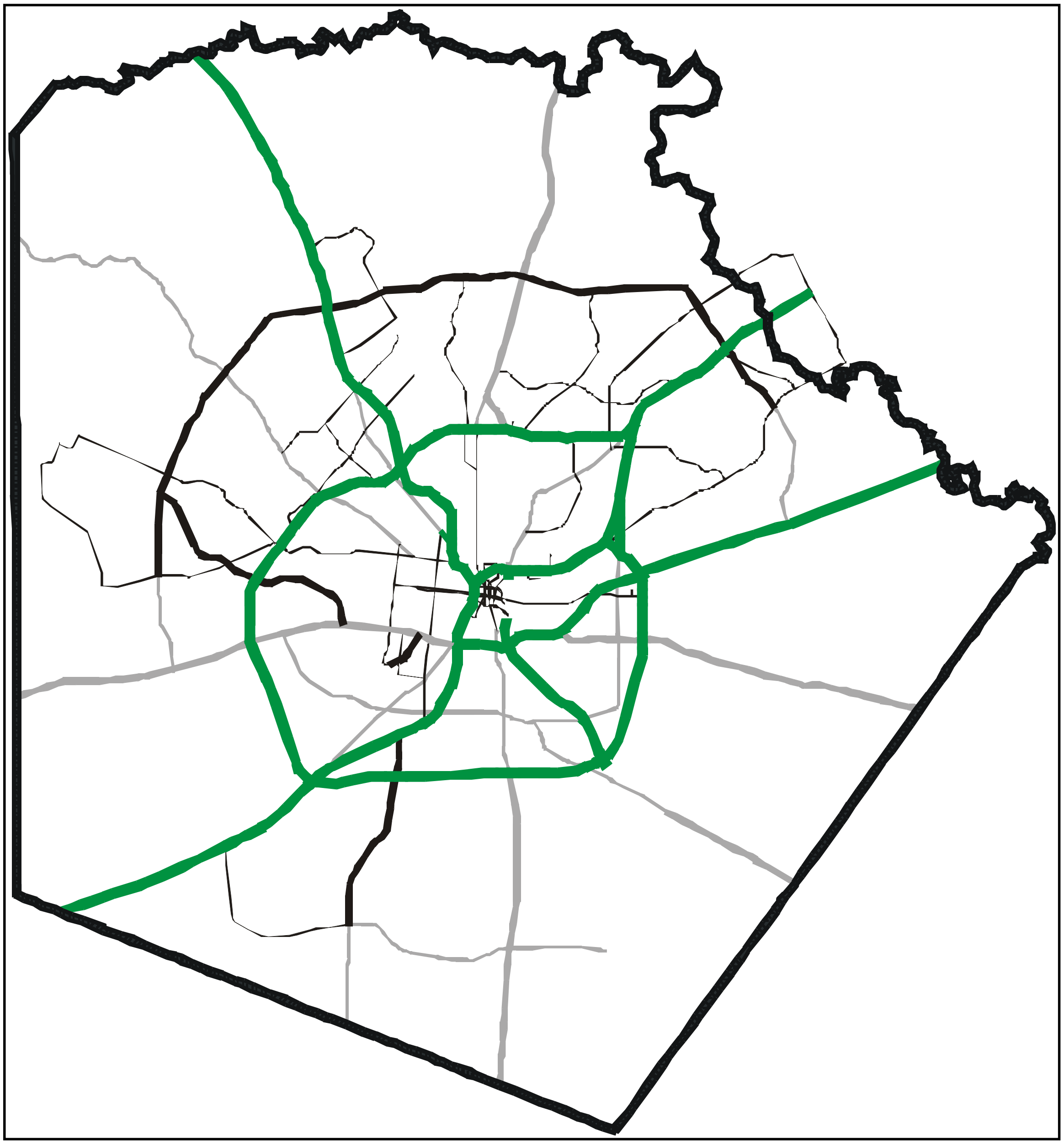

Figure 1. San Antonio-Bexar County Study Area.

5.2.2. Study Area Zone System

After identifying the study area, the next step was to develop the zone system. The 1969 OD study divided Bexar County into 2,539 zones for survey purposes *(9)*. These zones were later combined into 425 survey districts for analysis and reporting purposes. The zones were also combined for modeling purposes to 1,545 (based on archived network maps) internal zones and 24 external stations (locations where a transportation facility crosses the study area boundary). It is unclear when the zone system was modified, but a 1976 research report *(14)* used the 1970 travel demand model with a zone system of 778 internal zones and 24 external stations. The 1990 zone system consisted of 812 internal zones and 28 external stations. The actual zonal boundaries could be identified for only the 1990 zone system. The boundaries for the 425 survey districts were also delineated in the 1969 OD reports *(9)*. Since no zonal boundaries could be found for the systems used for 1969 and 1970, researchers decided to use the 1990 zonal system for this project. The final zone system used for 1970 consists of 812 internal zones and 30 external stations (one is a dummy station that does not exist). Figure 2 presents the transportation analysis zone structure used in this research.

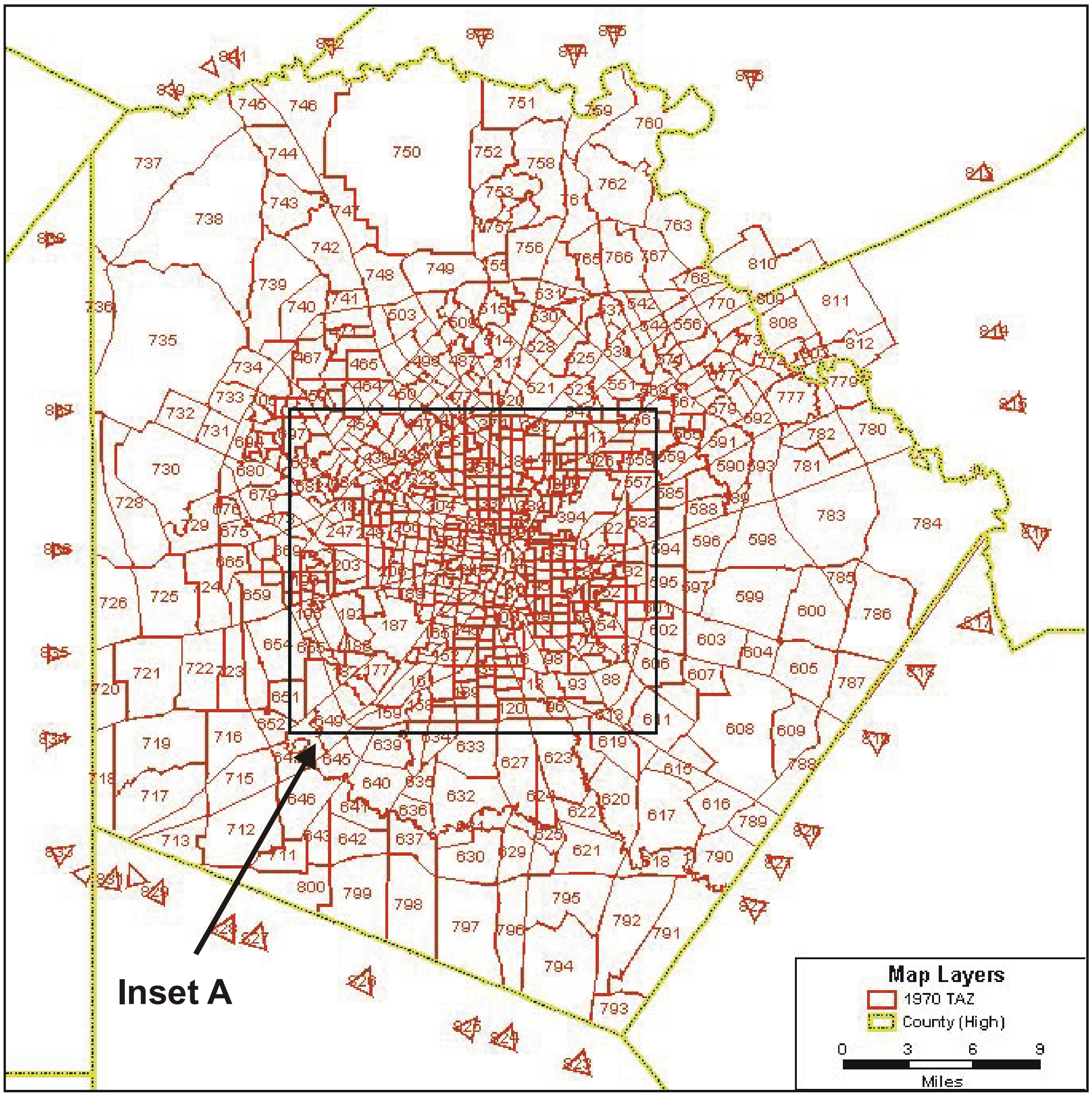

Figure 2. Transportation Analysis Zone Structure.

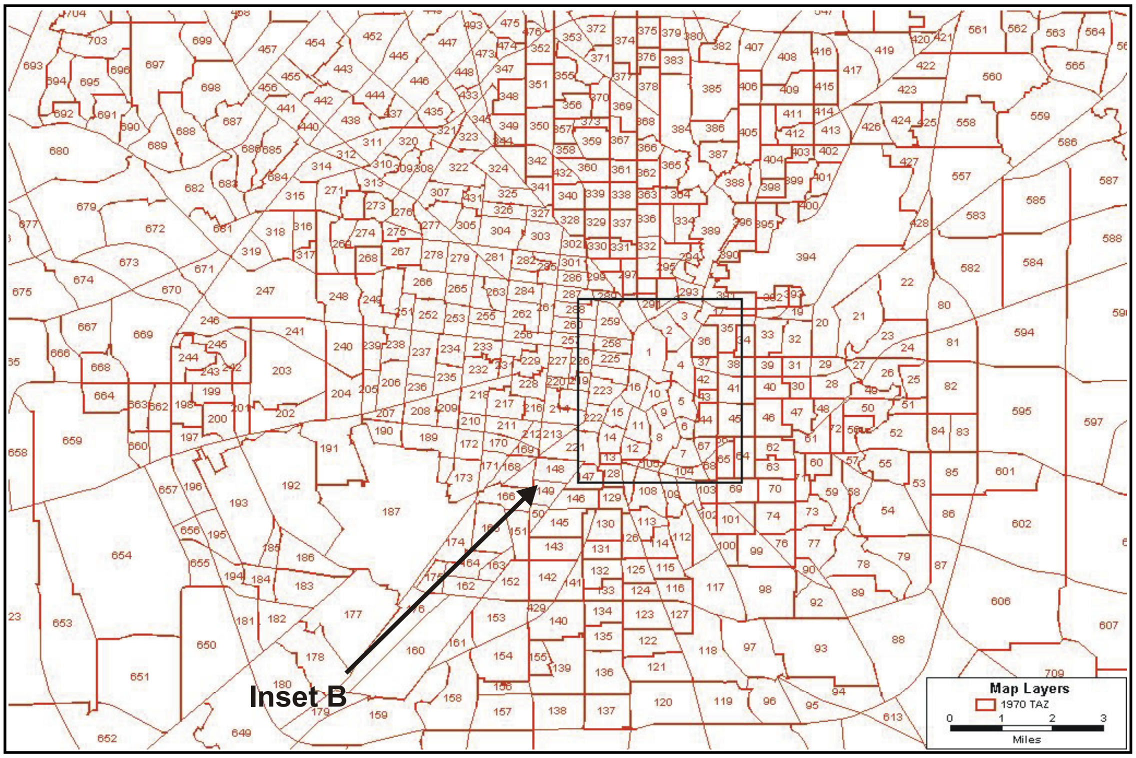

Figure 2. Inset A.

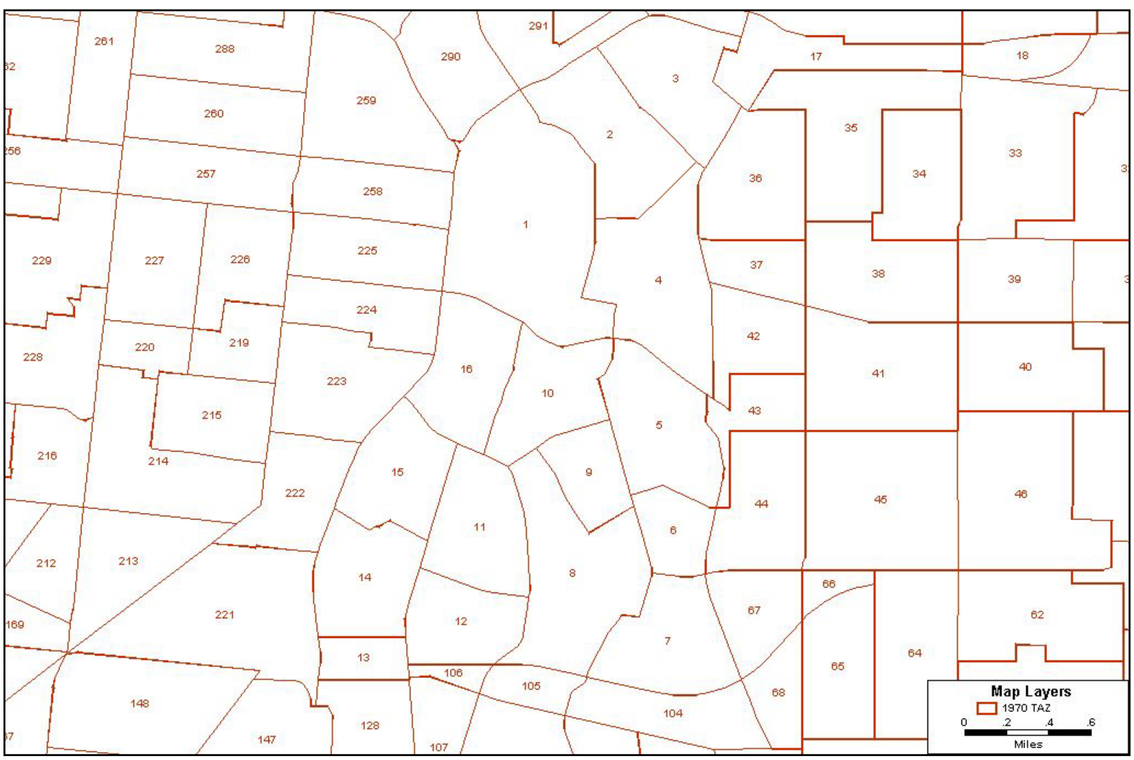

Figure 2. Inset B.

5.2.3. Transportation Network

In a normal modeling sequence, the transportation network and zone system would be identified jointly. Due to the lack of computerized information on the transportation networks used in 1969, 1970, and 1976, researchers made the decision to build a 1970 transportation network from the 1990 transportation network. Maps were found that portrayed the 1969 and 1970 networks used in modeling travel in Bexar County. Unfortunately, these network maps did not include any link attributes but did portray the transportation system that existed at that time. This proved helpful in determining which facilities needed to be removed from the 1990 network. Figure 3 presents the 1990 transportation network with those facilities highlighted that were removed to create a 1970 network.

The removal of links from the 1990 network created situations where some internal zones were no longer connected. These zones were reconnected to links on the revised network. Some additional links were added to the network to correspond to links shown on the 1970 network maps and accommodate zonal loadings. The final 1970 network consists of 4,730 one-way links and 1,667 centroid connectors. The average number of centroid connectors per centroid was 2.05. The 1976 research, which utilized the 1970 travel demand model for Bexar County, reported using a network, which consisted of 10,172 one-way links. The difference in the number of links between the networks indicates the network used in the 1976 research included more transportation facilities and zones than the system used in this research.

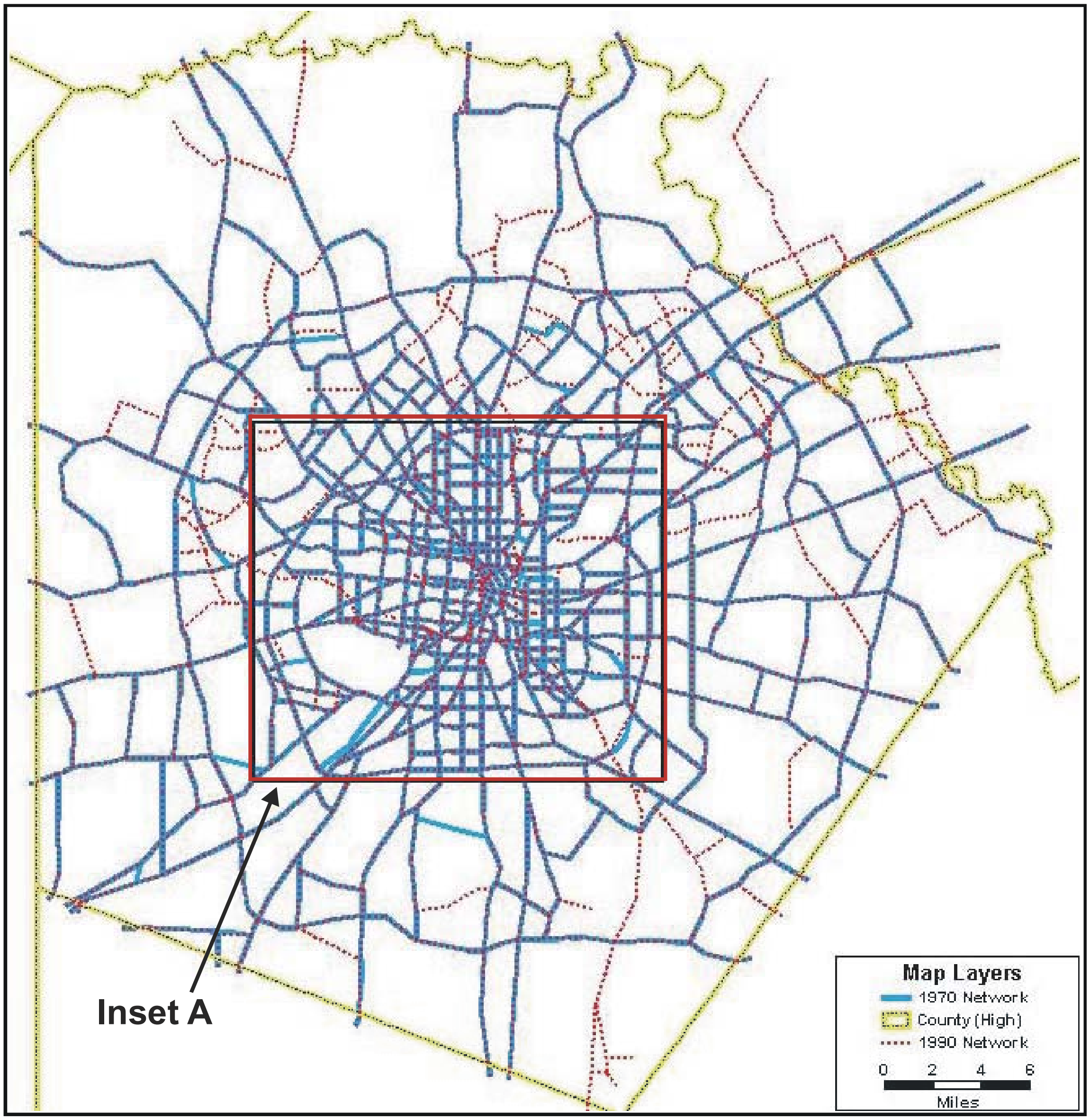

Figure 3. 1970 and 1990 Transportation Networks.

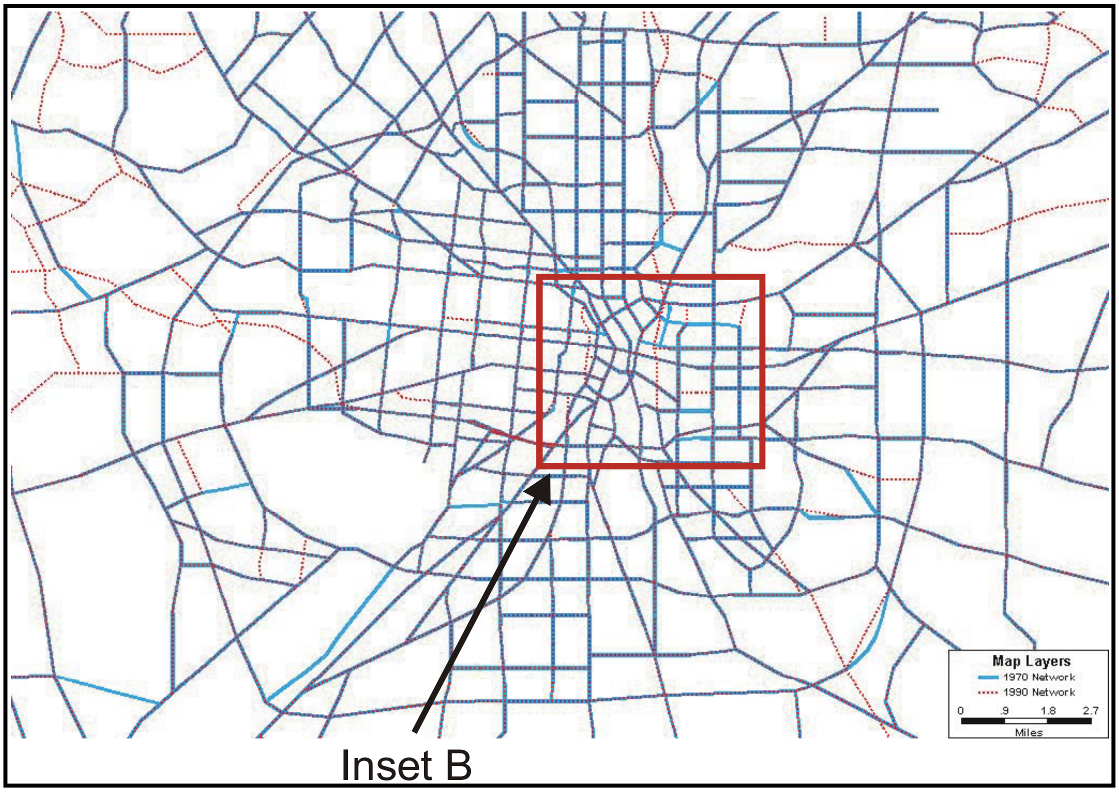

Figure 3. Inset A.

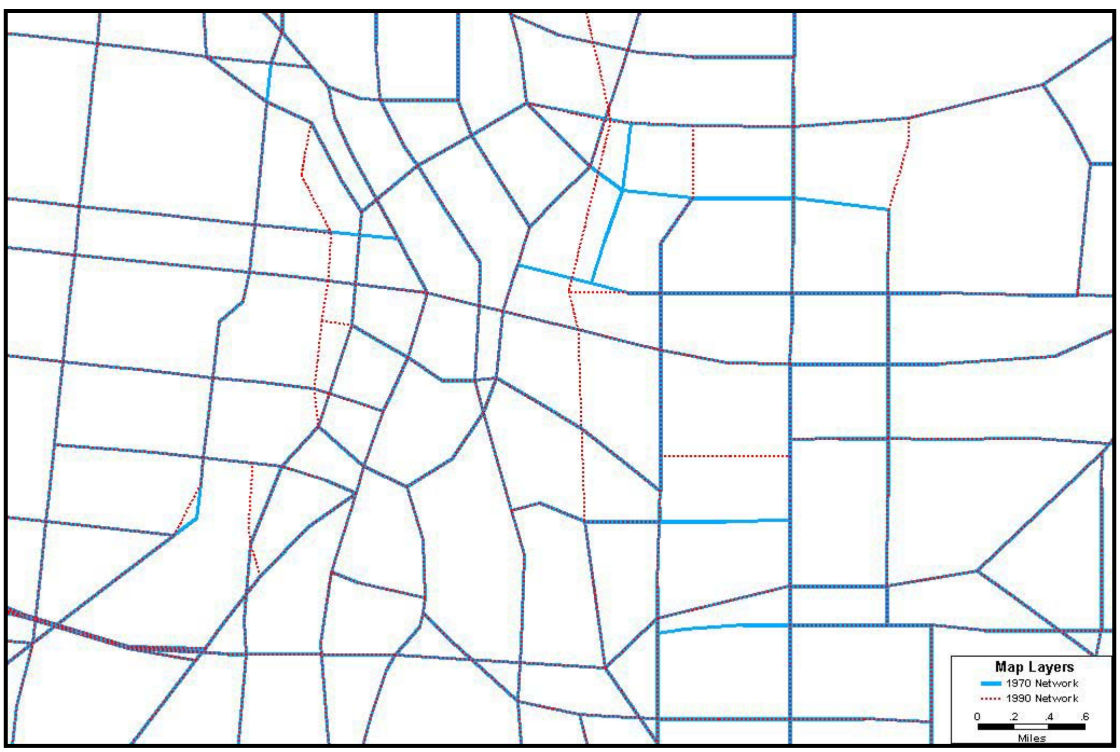

Figure 3. Inset B.

The second major effort in developing the 1970 network was to modify the 1990 link attributes to reflect the conditions in 1970. Link distances did not change but the number of lanes, functional classification, and designated area type in many cases were different in 1970 as compared to 1990. Researchers used secondary data sources to determine the likely number of lanes and functional classification for the 1970 network links. The area type designation was not assigned until the zonal demographic data were developed (discussed in a later section) and the area types established for 1970.

The 1964 street and expressway inventories *(13)* were used to estimate the number of lanes by facility. Unfortunately, these inventories were limited to only the area that encompassed the San Antonio city limits (more or less). The number of lanes for those facilities outside the areas identified in the 1964 inventory were estimated based on the authors knowledge of the study area and professional judgment. The functional classification for the network links was identified from the 1968 Highway Functional Classification map *(10)*.

The categories/classifications used were modified to be consistent with those identified in the 1990 network as shown in the speed/capacity look-up table. The decision was made to use the 1990 speed/capacity look-up table as the initial input to the 1970 model development. Table 2 presents the 1990 speed/capacity look-up table. Adjustments to the values in that table would be made as necessary in the calibration of the model.

Table 2. 1990 Speed/Capacity Look-Up Table.

Functional Class	Functional Class Code	Area Type	Speed (mph)	Capacity (per lane)	Alpha	Beta
Radial Freeway	1	1	40.83	19,200	0.150	4.000
		2	45.36	18,900	0.150	4.000
		3	49.08	18,400	0.150	4.000
		4	52.15	16,700	0.150	4.000
		5	61.85	13,900	0.150	4.000
		6	49.08	18,400	0.150	4.000
Expressway	3	1	28.82	9,800	0.150	4.000
		2	32.38	9,600	0.150	4.000
		3	35.90	9,200	0.150	4.000
		4	39.56	8,100	0.150	4.000
		5	55.64	6,100	0.150	4.000
		6	35.90	9,200	0.150	4.000
Divided Principal Arterial	4	1	16.82	7,500	0.150	4.000
		2	19.41	7,400	0.150	4.000
		3	22.71	7,100	0.150	4.000
		4	26.96	6,200	0.150	4.000
		5	49.43	4,600	0.150	4.000
		6	22.71	7,100	0.150	4.000
Undivided Principal Arterial	5	1	16.82	6,700	0.150	4.000
		2	19.41	6,600	0.150	4.000
		3	22.71	6,400	0.150	4.000
		4	26.96	5,600	0.150	4.000
		5	49.43	4,200	0.150	4.000
		6	22.71	6,400	0.150	4.000

Table 2. 1990 Speed/Capacity Look-Up Table (continued).

Functional Class	Functional Class Code	Area Type	Speed (mph)	Capacity (per lane)	Alpha	Beta
Undivided Minor Arterial	7	1	16.53	5,900	0.150	4.000
		2	19.07	5,800	0.150	4.000
		3	21.20	5,600	0.150	4.000
		4	25.30	5,000	0.150	4.000
		5	45.88	3,800	0.150	4.000
		6	21.20	5,600	0.150	4.000
Divided Collector	8	1	13.32	5,000	0.150	4.000
		2	16.22	4,900	0.150	4.000
		3	18.27	4,700	0.150	4.000
		4	22.82	4,200	0.150	4.000
		5	41.68	3,100	0.150	4.000
		6	18.27	4,700	0.150	4.000
Undivided Collector	9	1	13.32	4,000	0.150	4.000
		2	16.22	4,000	0.150	4.000
		3	18.27	3,800	0.150	4.000
		4	22.82	3,400	0.150	4.000
		5	41.68	2,600	0.150	4.000
		6	18.27	3,800	0.150	4.000
Frontage	11	1	40.00	15,000	0.150	4.000
		2	40.00	15,000	0.150	4.000
		3	40.00	15,000	0.150	4.000
		4	40.00	15,000	0.150	4.000
		5	40.00	15,000	0.150	4.000
		6	40.00	15,000	0.150	4.000

Table 2. 1990 Speed/Capacity Look-Up Table (continued).

Functional Class	Functional Class Code	Area Type	Speed (mph)	Capacity (per lane)	Alpha	Beta
Circular Freeway	12	1	40.83	19,200	0.474	4.000
		2	45.36	19,700	0.474	4.000
		3	49.08	20,100	0.474	4.000
		4	52.15	18,900	0.474	4.000
		5	61.85	16,900	0.474	4.000
		6	49.08	20,100	0.474	4.000

The third major effort in development of the 1970 network was identifying and posting the traffic counts on the network. This was a critical element since it establishes the basis for measuring VMT and evaluating the travel demand model results. Traffic count maps were received from TxDOT showing the location and count volumes on facilities in Bexar County for 1968 and 1971. These data were detailed for facilities located outside the San Antonio city limits, but very limited detail was provided on state-maintained facilities within the city limits of San Antonio. These counts were not the standard saturation counts conducted by TxDOT in support of the travel model development and calibration. These counts were initially the only count data that were located.

These data were used with data from the traffic flow maps published in the 1969 OD report *(9)* and selected count data from the 1976 research *(14)*, which used the 1970 network. These data were posted on the appropriate links and estimated counts prepared manually for those links with no count data. This initial effort resulted in actual count data being posted on approximately 20 percent of the links and estimated counts being posted on the remaining 80 percent of the links. The estimation of count VMT, which resulted from these data, was 7.76 million. The count VMT published in the 1976 research was 9.32 million *(14)*. Further research into the traffic count maps disclosed that the counts posted on those maps were estimated annual average daily traffic (AADT) and not ADT, which is normally used in travel demand modeling for calibration purposes.

This led to a broader search for traffic counts, which resulted in the location of a number of network maps containing both posted assigned volumes and traffic counts for 1969 and 1970. No documentation was found with the maps, and the networks included the 1,545 internal zone system and a 871 internal zone system. The counts posted on the network for the 871 zone system labeled "F-1-R 1970 FOR Assignment" was selected for use in this research. The count volumes were posted on the 1970 network and manual estimates of counts prepared for links with no count volumes. This resulted in 35 percent of the network links with actual count data and estimated counts for 65 percent of the links. The resulting estimate of VMT based on actual and estimated counts on the network was 8.0 million. Figure 4 presents the 1970 network highlighting the links with actual traffic counts. Figure 5 presents a traffic flow band map for the actual and estimated counts.

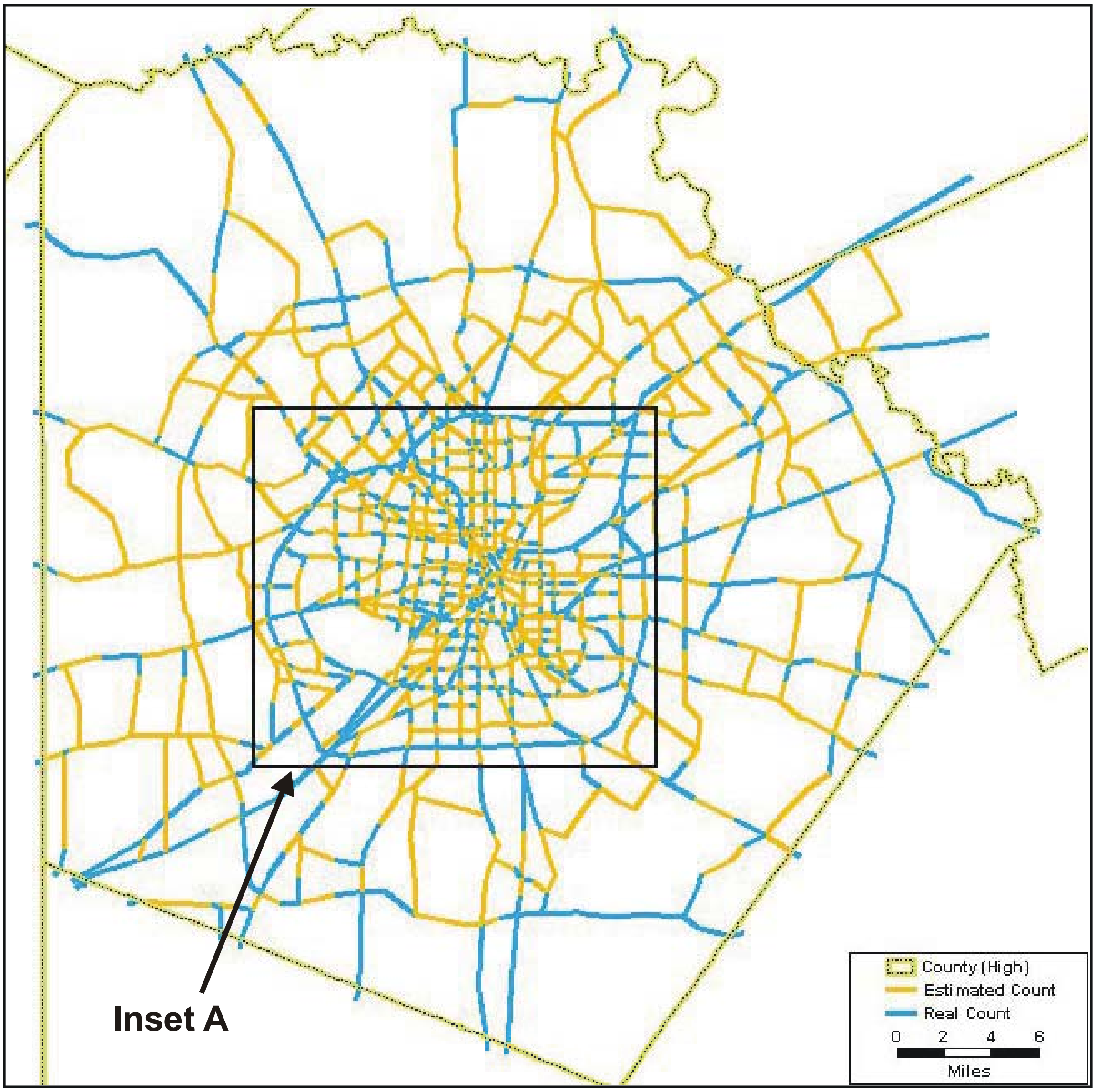

Figure 4. 1970 Network Links with and without Count Data Files.

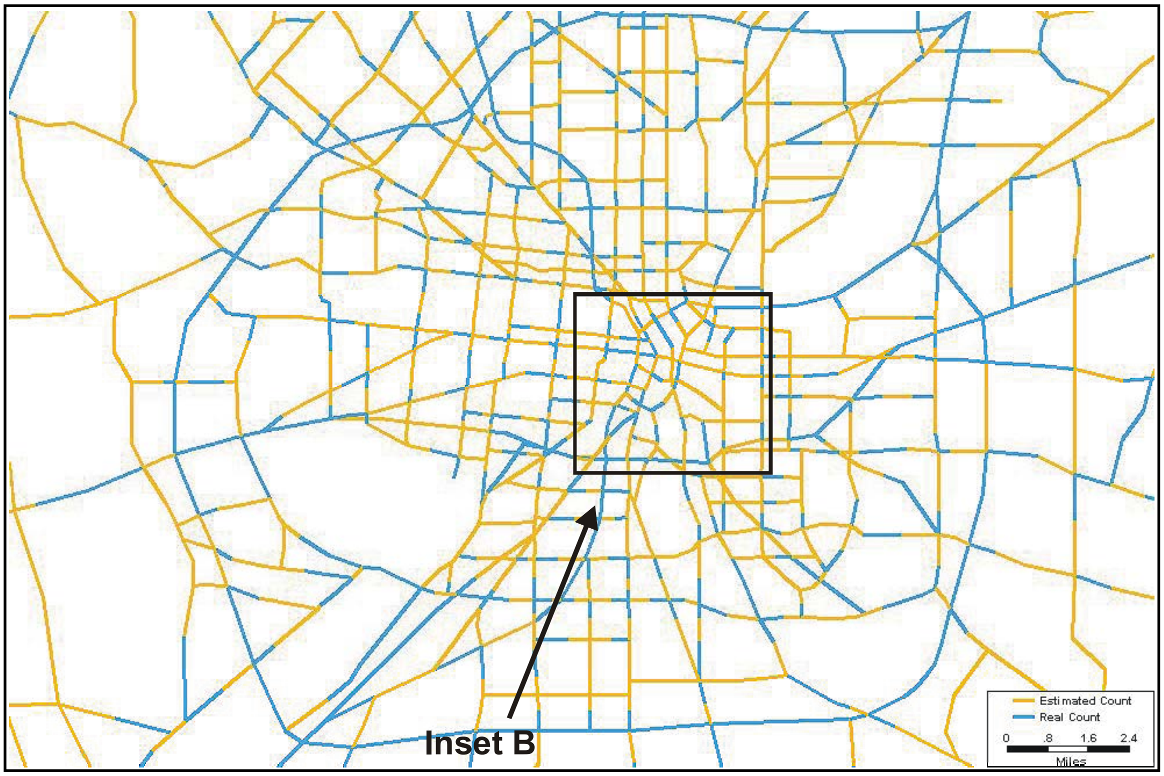

Figure 4. Inset A

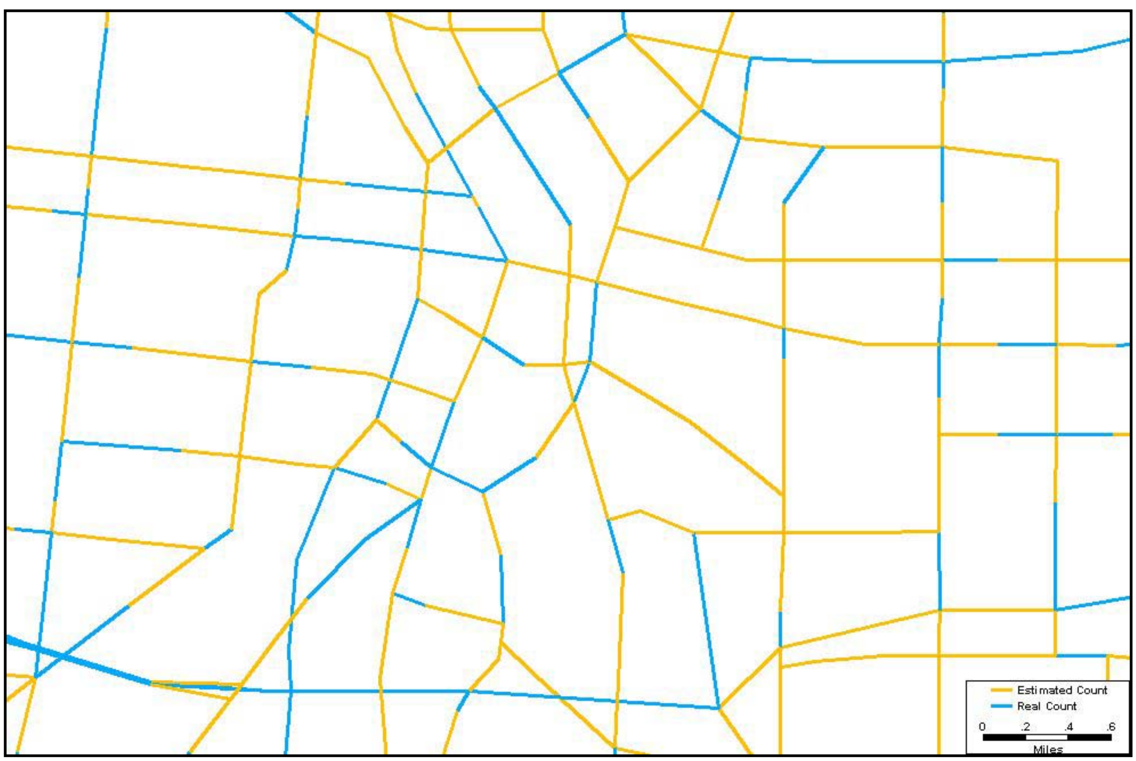

Figure 4. Inset B.

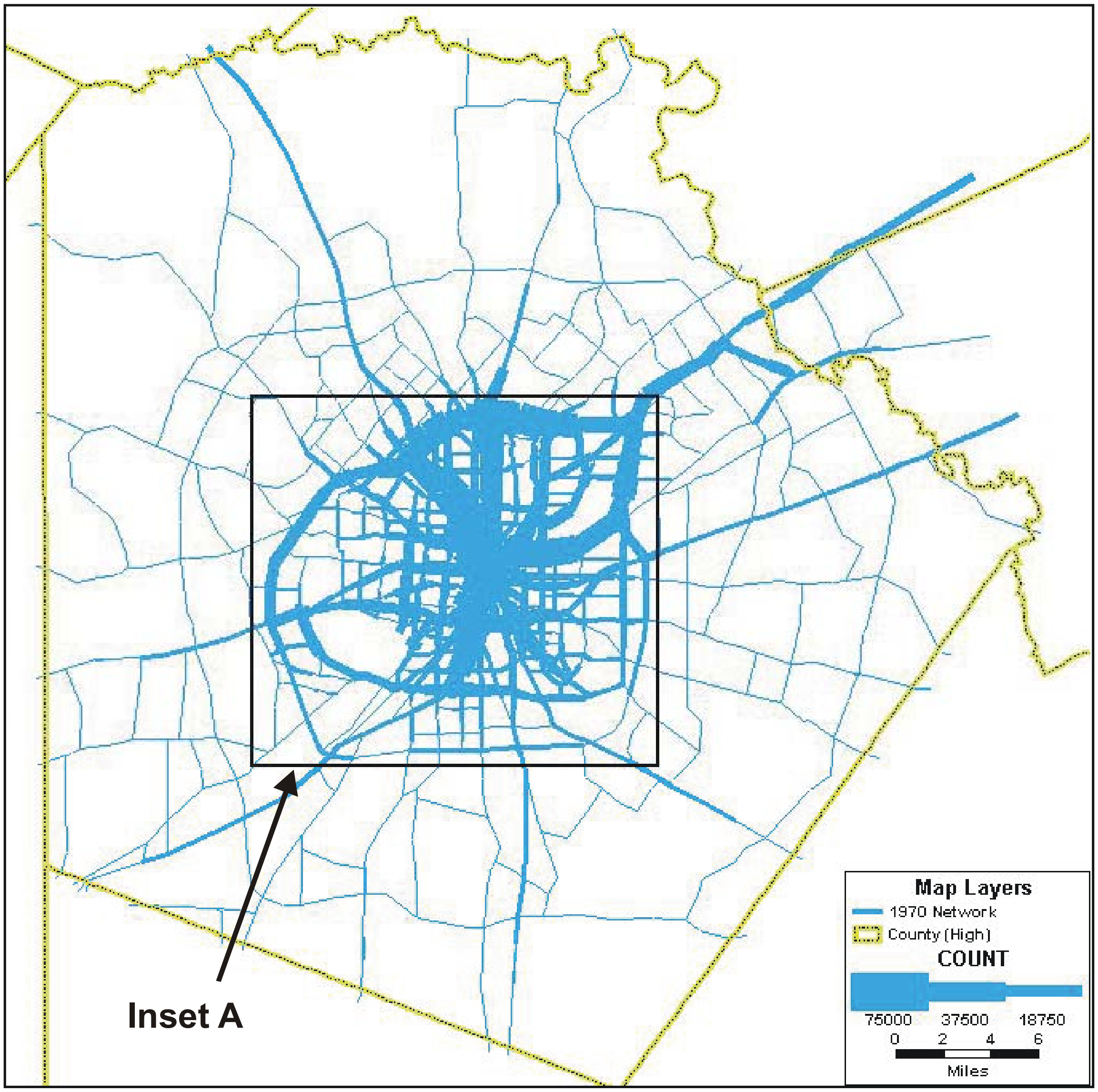

Figure 5. Traffic Count Flow Band Map.

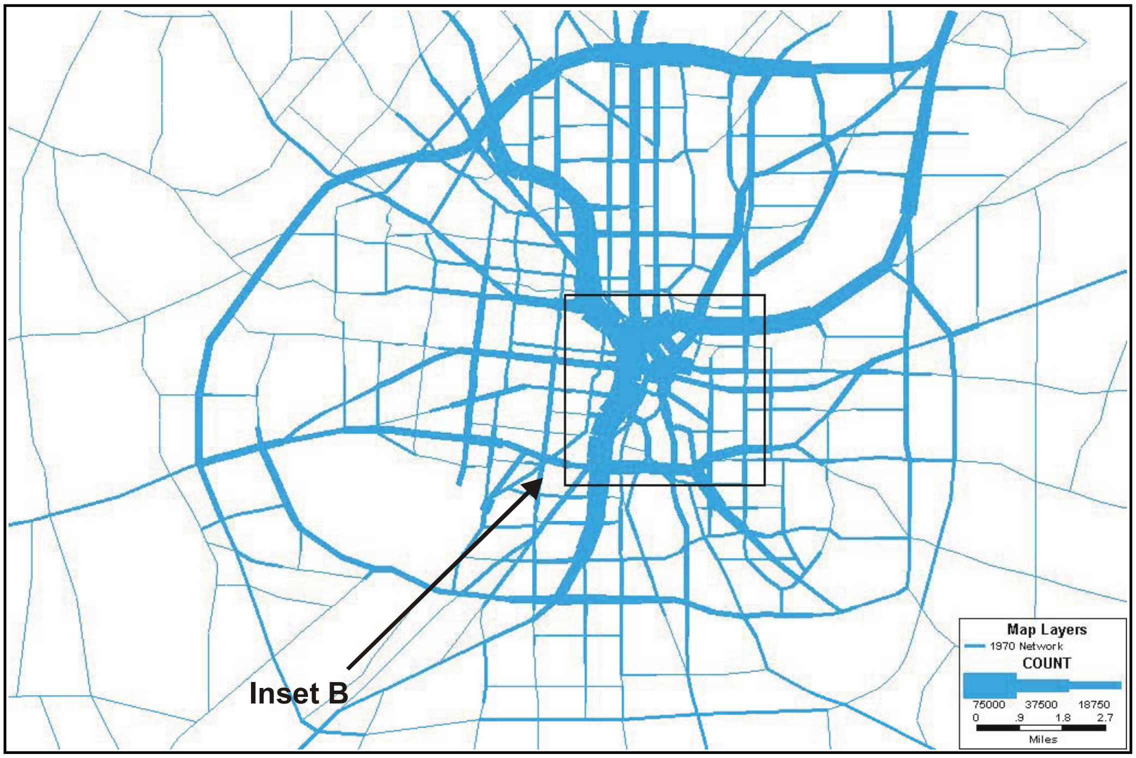

Figure 5. Inset A.

Figure 5. Inset B.

5.3. TRIP GENERATION

Trip generation is the step where the number of trips being produced and attracted are estimated at the zone level for an urban area. This section presents the work involved in compiling and estimating the demographic data and the analysis of the OD survey data from 1969 necessary to estimate the zonal trip productions and attractions.

5.3.1. Data Compilation

Data compilation for trip generation consisted of two major efforts. The first was the development of the demographic data necessary for input to the trip generation step. The second was the processing of the 1969 OD household survey data to develop the production and attraction rates for the trip generation model.

Demographic Data

Since none of the original zonal demographic data was available for use in this research, these had to be generated. The primary data sources used for this effort were the 1970 census, published results from the 1969 OD survey *(9)*, published information from the 1975 Level II Update *(10)*, the Randolph Subregion Transportation Study *(11)*, and data from the 1976 research *(14)*, which was based on the 1970 network and demographic information. The typical socio-economic data necessary for input to the travel demand model consist of the following:

- population residing in each zone;
- number of households in each zone;
- median household income for households in each zone;
- number of basic employees working in each zone; basic employees are those employed in industries with a Standard Industrial Classification (SIC) code 1000 to 4999 (includes mining, construction, manufacturing, transportation, communications, public utilities, and wholesale trade);
- number of retail employees working in each zone; retail employees are those employed in industries with SIC codes 5200 to 5999 (retail trade);
- number of service employees working in each zone; service employees are those employed in industries with SIC codes 6000 to 9799 (includes finance, insurance, real estate services, education services, and government); and
- percent distribution of households by household size and household income for the study area; the distribution reported for the San Antonio Standard Metropolitan Statistical Area (SMSA) from the 1970 census was used for this project.

Additional data identified as needed for the San Antonio-Bexar County study area were military employment at the zone level.

5.3.2. Population and Household Estimates

Table 3 presents the estimates of population, dwelling units, and households identified in various published resources for Bexar County. In 1969 and 1970, travel demand models were developed and applied using trip production rates per dwelling unit. It was concluded based on the comparisons of published data that the term dwelling unit was not synonymous with the term household as used in current travel demand models. Households are occupied dwelling units as applied in current models. The number of dwelling units reported in 1969 most likely included those that were not occupied.

The population in Bexar County in 1970 was reported in the census as 830,460. The population in the San Antonio SMSA (which consisted of Bexar County and Guadalupe County) in 1970 was reported in the census as 864,014. Both population estimates included population residing in group quarters. For Bexar County, the population in group quarters was 36,427, and for the SMSA it was 37,433. The majority of this population group was assumed to reside on military bases within Bexar County.

These numbers are important when estimating the number of households in the study area. The reported average persons per household (i.e., 3.4) in the 1970 census is assumed to not include persons in group quarters. If it does not include persons living in group quarters, the number of occupied households in Bexar County in 1970 would be estimated by dividing the number of persons living in households (794,033) by the average persons per households (3.4) to yield 233,539. If total population in Bexar County was used, this estimate would be 244,253, which is almost equivalent to the reported households of 244,279 for the entire SMSA.

Table 3. Population, Dwelling Units, and Household Estimates for Bexar County.

Year	Data Element	Estimate	Source
1969	Population of Bexar County	825,843	Reference 9, Page 27
1970	Population of Bexar County	830,460	Reference 14, Page 25 & 1970 U.S. Census
1969	Dwelling Units in Bexar County	255,276	Reference 9, Page 39
1969	Dwelling Units in Bexar County	256,640	Reference 14, Page 7
1970	Households in San Antonio SMSA	244,279	1970 U.S. Census, Table 206
1969	Persons per Dwelling Unit, Bexar County	3.24	Reference 9, Page 39
1970	Person per Household, Bexar County	3.40	1970 U.S. Census, Table P-1

Since no population, dwelling unit, or household information was available at the zone level, it was necessary to develop estimates of this data for input to the travel demand model. Data from the 1969 OD survey were reported at a census tract and district level. Bexar County had been divided into 166 census tracts, which were further divided into 425 districts for reporting purposes. The data reported included the census tract number, district number, number of dwelling units, number of automobiles owned, number of persons (total, number five years of age and older, number making trips, number with drivers license, and number enrolled in school), employed labor force, and number of trips (by automobile and total).

The number of districts within a census tract varied from one to 12. Since none of these boundaries were consistent with the zone system selected for use in this project, it was necessary to develop an equivalency system for use in estimating the zonal data. This was accomplished in two ways. The first was to equate the 1970 census block areas to the zone system. The zonal boundaries were manually drawn on the 1970 census block maps. Figure 6 presents an example of how this was accomplished. A table of equivalency was developed by manually recording the census block numbers, which were located in each zone.

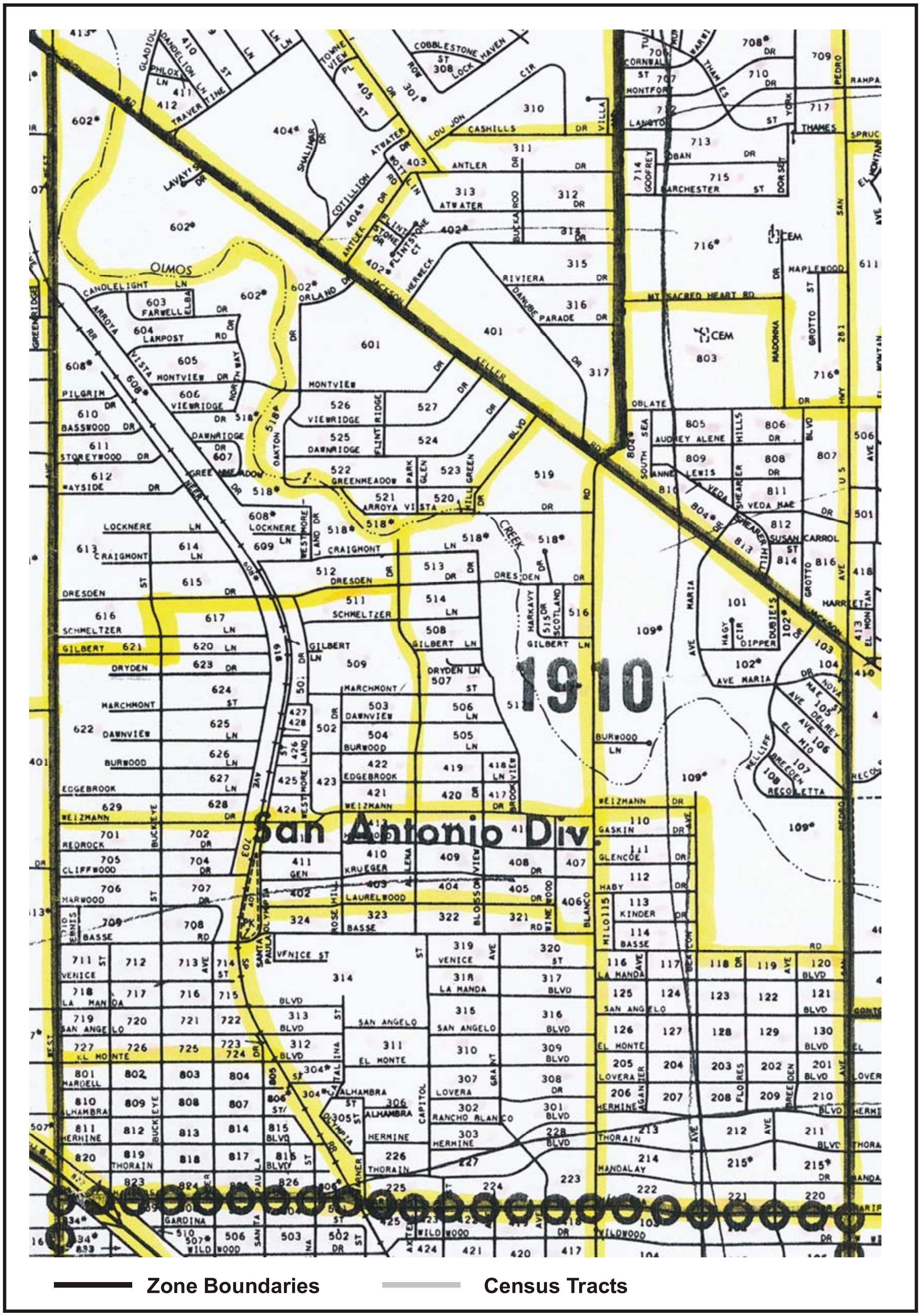

Figure 6. Example Zonal Boundaries.

The census data available at the census block level included population and households. The estimates of zonal population and households were developed by summing the census block data within each zone. Data for the zones in Guadalupe County were estimated using 1970 census tract data and data from the 1972 Randolph Subregion Transportation Study *(11)*. It was interesting to note that the number of households estimated for Bexar County using this methodology was different from that computed from reported data from the 1970 census. For example, the estimate of households generated by summing block data by zone for Bexar County was 244,026, whereas the estimate generated by dividing the population by average household size was 233,539. Researchers decided to use the estimates generated by summing the census block data by zone.

The second equivalency method was established between the zone system and the districts used for reporting the 1969 OD survey results. The zonal boundaries were manually drawn on the maps with the district boundaries. An analyst then manually reviewed each district and estimated the proportion of the district that coincided with the zones. An equivalency table was developed, which related the proportion (i.e., percentage) of each that was within each zone. This was based on professional judgment as to the amount of area involved. While this is recognized as not accurate, it was considered a reasonable means of allocating data reported at the district level to the zone level being used for modeling in this research.

5.3.3. Employment Estimates

The procedure used to estimate zonal employment for the study area was first to develop control totals of employment and then distribute the employment by type to the zones. Table 4 presents the estimates of employment and percent distributions of employment by type identified in various published resources for Bexar County. Current travel demand models estimate zonal trip attractions by purpose using the number of basic, retail, and service employees in the zone. The data in Table 4 demonstrate that employment estimates vary depending on the source. It was also noted that the employment categories reported in the 1969 OD survey were different from the categories used in current models. For purposes of this research, the following equivalencies were assumed:

Industrial	=	Basic
Commercial	=	Retail
Service	=	Service
Other	=	Military and/or Service

The estimates of employment for Bexar County by basic, retail, service, and military were developed as follows:

1. The total employment reported in the 1970 census of 290,003 was selected for this research.

2. The percent distribution of employment by category reported in the SABCUTS Level II Update *(10)* was applied to the total employment to estimate the employment by

category. This resulted in an estimated 85,551 basic employees, 53,361 retail employees, and 151,092 service employees.

3. The reported number of military personnel of 55,000 from the SABCUTS Level II Update was assumed to be included in the service employment estimate.

4. The reported number of civilian employees at military installations of 37,700 from the SABCUTS Level II Update was assumed to be included in the basic employment estimate.

Table 4. Employment Estimates for Bexar County.

Year	Data Element	Estimate	Source
1969	Bexar County Total Employment	286,803	Reference 9, Page 27
1969	Bexar County Total Employment	271,600	Reference 9, Page 31
1970	Bexar County Total Employment	299,200	Reference 10, Page 11
1970	Bexar County Total Employment	290,003	U.S. Census, Table P-2, Place of Work
1969	Bexar County Industrial Employment	44,680	Reference 9, Page 31
1969	Bexar County Commercial Employment	48,890	Reference 9, Page 31
1969	Bexar County Services Employment	50,014	Reference 9, Page 31
1969	Bexar County Other Employment	128,016	Reference 9, Page 31
1970	Percent of Bexar County Total Employment That Is Basic	29.5%	Reference 10, Table I-E, Page 13 [1]
1970	Percent of Bexar County Total Employment That Is Retail	18.4%	Reference 10, Table I-E, Page 13 [2]
1970	Percent of Bexar County Total Employment That Is Service	52.1%	Reference 10, Table I-E, Page 13 [3]
1970	Bexar County Military Personnel	55,000	Reference 10, Figure I-3, Page 10
1970	Bexar County Military Civilian Employment	37,700	Reference 10, Figure I-3, Page 10

[1] Basic was defined as agriculture, construction, transportation, utilities and communication, wholesale, manufacturing, and mining. Source cited was *Economic Analysis*, City Planning Department, San Antonio, Texas, November 1972.
[2] Retail was defined as retail. Source cited was *Economic Analysis*, City Planning Department, San Antonio, Texas, November 1972.
[3] Service was defined as finance, insurance, real estate, business and professional services, medical and professional services, federal government, state government, local government, and private household. Source cited was *Economic Analysis*, City Planning Department, San Antonio, Texas, November 1972.

Military personnel and civilian employment at military installations were separated from the categories of basic and service employment and combined into a category identified as military. The large number of military installations (i.e., six) and related employment were considered significant to warrant treatment as a separate category of employment within the travel demand model.

Employment estimates at the zone level were developed and modified several times as follows:

1. The categories of employment identified in the 1969 OD survey report and the 1975 Level II Update were equated to the categories used in current modeling practice.

2. Using the employment distribution shown graphically in the 1969 OD report, estimates of employment were developed for 65 of the 425 districts. Estimates of employment for the remaining districts were generated analytically based on the reported trip destinations by district in the 1969 OD report after deducting those destinations estimated to residential units. This was performed using an average number of destinations per employee computed from the 1969 OD household survey. Distribution of employment by type was assumed the same as for the region. Employment totals were controlled to the regional estimates by adjusting the district estimates for all districts except the 65, which were estimated from the reported distribution.

3. Researchers developed a proportional relationship between the 425 districts and the 812 traffic analysis zones manually by overlaying the districts on the zone maps.

4. Estimates of employment at the zone level were developed by directly applying the proportional relationship in 3 above to the estimates of employment by type at the district level.

5. The zonal estimates of employment were examined manually and compared to the land use map published in the 1969 OD report. Estimates by type were modified and adjusted to ensure the totals summed to the estimates for the study area.

6. Using data from the 1969 household survey, estimates of home-based work attractions by sector were developed for land use categories equated to basic, retail, service, and military employment. Average home-based work attraction rates were used to estimate the number of employees in each sector by type of employment. These sector estimates were adjusted to the control totals for the study area. The zonal estimates within each sector were adjusted to sum to the totals for each sector.

7. Resulting estimates of attractions at the sector level (from the trip generation model) were compared to the expanded attractions from the 1969 OD household survey. Employment estimates were adjusted between sectors to more accurately reflect the expanded attractions.

8. The employment estimates at the zone level were compared to the estimates of 1990 employment at the zone level. This review concentrated on those zones where employment in 1990 was less than that estimated for 1970 and a determination made as to the reasonableness.

5.3.4. Household Income

In addition to population, households, and employment data, an estimate of the median household income for households in each zone is needed for input to the model. Median household income was not reported at the census tract level by the U.S. Census Bureau until 1980. As a result, 1980 median household income for census tracts was obtained from data files prepared by the San Antonio Planning Department. Using a 1970 census block and census tract to zone table of equals, the 1980 census tract median household income was assigned to each zone on a proportional basis. Researchers then used the consumer price index-urban (CPI-U) to estimate 1970 income from the 1980 income data. Because growth within an area can raise the median household income significantly between census years, these estimates were compared to the census tract median family income and median income for families and unrelated individuals for 1970. Professional judgment was used to adjust the estimates for zones where the estimated 1970 median household income was believed to be too high.

The estimated zonal 1970 median household income was used with the estimated 1970 zonal household data to develop a weighted estimate for regional 1970 median household income. The regional estimate of 1970 median household income was compared to the median household income reported in the 1970 census for Bexar County 1. The zone estimates produce a regional value of $7,377 and the reported median household income for the San Antonio SMSA in 1970 was $7,254.

5.3.5. Distribution of Households

Table 5 shows the distribution of households by income and size for 1970 for the San Antonio SMSA. While these data were reported for the SMSA, it is assumed that the same distribution is applicable to the households within the study area for this research.

5.3.6. Special Generators

As originally envisioned, no special generators were anticipated to be necessary for this research. During the course of the research, it was concluded that there were a number of special generators that were significant enough to warrant treatment as such. While the number of trip productions and attractions for these special generators are estimated exogenously to the model, it is necessary to identify and estimate the demographic data for these developments to ensure the distributions of data to the remaining zones does not include these data. The special generators identified for this project were Randolph Air Force Base (AFB), Fort Sam Houston, Brooks Military Base, Kelly AFB, Lackland AFB, Lackland Annex, Leon Springs Military Reservation, San Antonio International Airport, and the San Antonio State Mental Hospital. These generators were composed entirely of districts, which simplified the estimation of population, households, and employment within those generators. These data are presented in the next section.

Table 5. Distribution of Households by Income and Size – San Antonio SMSA.

Household Income 1970 $	Household Size						Totals
	1	2	3	4	5	6 +	
< 1,000	6,270	2,743	1,741	1,163	796	1,038	13,751
1,000 – 1,999	8,364	4,274	1,508	924	683	958	16,711
2,000 – 2,999	4,606	5,113	2,166	1,054	760	1,528	15,227
3,000 – 3,999	3,776	5,260	2,756	1,580	1,245	2,080	16,697
4,000 – 4,999	2,844	5,376	3,074	2,324	1,606	2,649	17,873
5,000 – 5,999	2,472	4,870	3,324	2,825	1,964	3,112	18,567
6,000 – 6,999	2,147	4,422	3,524	3,238	2,050	3,344	18,725
7,000 – 7,999	1,773	4,584	3,095	3,021	2,254	3,349	18,076
8,000 – 9,999	2,360	7,772	5,689	5,692	3,721	5,598	30,832
10,000 – 14,999	2,035	11,433	9,224	9,281	6,335	7,629	45,937
15,000 – 24,999	784	6,940	5,006	4,951	3,338	3,645	24,665
25,000 +	318	2,201	1,404	1,303	1,011	981	7,218
Totals	**37,749**	**64,988**	**42,511**	**37,356**	**25,763**	**35,912**	**244,279**
Median Income	$2,921	$7,095	$8,023	$8,856	$8,728	$7,970	$7,254
Mean Income	$4,331	$8,831	$9,585	$10,289	$10,320	$9,230	$8,706

Source: 1970 U.S. Census, Detailed Characteristics, Table 206.

Demographic Data Summary

The preceding sections have presented the techniques and methods employed to develop the zonal demographic data estimates for the study area. To a large extent, these descriptions have been general and not intended to be exhaustive. The purpose has been to provide an overview of the findings relative to the data that were available and how it was treated to produce zonal estimates that could be used for developing and calibrating a travel demand model. Table 6 presents the study area demographic data statistics.

Table 6. 1970 Demographic Estimates for San Antonio-Bexar County Study Area.

Data Element	Bexar County	Guadalupe County (Part)	Special Generators	Total
Internal Zones	790	11	11	812
Population	775,954	4,061	54,539	836,377
Households	238,165	1,229	5,861	245,255
Average Household Size	3.26	3.30	9.31	3.41
Total Employment	188,645	716	101,388	290,749
Basic Employment	43,346	0	4,523	47,869
Retail Employment	52,706	360	684	53,750
Service Employment	92,593	356	3,480	96,429
Military Personnel	0	0	55,000	55,000
Military Base Civilian Employment	0	0	37,701	37,701
Weighted Median Household Income	$7,386	$7,753	$6,887	$7,380

1969 Origin Destination Survey

The 1969 OD household survey collected data on 12,477 households. This represented a sampling rate of about 5 percent. Data were stored in two files. The first file had the household data and information, which consisted of the type of residence, number of persons in the household, length of residence, vehicles available, number of students, number of persons employed, total household income, number of trips made, etc. The primary data of interest in this file were the household size and income. Other data of concern were the codes indicating if the household had made any trips and if there were individuals in the households with trips unknown. In the 1969 household survey, when a household was interviewed and one or more household members was not available for the interview, it was noted and adjustment factors were included in the data expansion to essentially impute the trips made by those individuals.

The second file from the household survey was the trip file. It contained information on the trips made by each individual (over the age of five) in the household. Trip information included codes describing the land uses at the trip origin and destination, person making trip, mode of travel, vehicle occupancy (if trip was by automobile), time trip started, time trip ended, purpose of trip (from and to), etc. The primary data of interest were the mode of travel, vehicle occupancy, land use at both the origin and destination, and the purpose of the trip (from and to).

The 1969 OD household survey data were processed to review the household data file and the trip data file to ensure the files were consistent. This is similar to current practice of checking and editing household survey data. Researchers noted a number of discrepancies in the data files. To maintain consistency with the methods used currently in processing household survey data, households and their recorded trips were removed and not included in the analysis when the following situations were identified:

- The household had persons who were not interviewed and trips were unknown. In the 1969 survey, trips were evidently imputed for these individuals. This is not current practice.

- The household had reported zero trips, but trip records were found in the trip data file for the household. This appeared to be a result of data-entry errors.

- The household had reported trips where the trip purpose between successive trips was inconsistent. For example, a trip record indicated a person went from home to shop and the next trip was reported as "serve passenger to work." Detailed review of these found some to be the result of data-entry errors, but some appeared to have missing trips.

This editing resulted in the removal of a number of households. It did not consider the need to reduce the number of zero-trip households. The full data set for the 1969 OD survey included 1,414 households that reported no travel. This number was reduced to 1,112 to reflect the reduction in the sample households due to editing. Zero-trip households were removed from the data file in proportion to the number observed in the survey by household size and income. Note that some of the zero-trip households were found to contain trip records in the trip file and had been removed.

The net result was the number of households included in this research were reduced from 12,477 to 11,086. The total number of person trip records found in the raw data set for the 12,477 households was 96,313, an average of 7.7 per household. The number of automobile driver trips in the raw data set was 60,930, an average of 4.88 per household. The number of person trip records for the 11,086 households was 84,487, an average of 7.6 per household and the number of automobile driver trip records was 53,888, an average of 4.86 per household.

While processing the data, trips were also linked according to current practice. When one or more stops are made between home and work (either direction) for the purpose of changing mode of travel or serving the passenger (e.g., pick up or drop off), the intermediate stops are removed, and the trip is identified as a home-based work trip. The trip linking reduced the number of person trips from 84,487 to 83,072, an average of 7.5 per household. The number of automobile driver trips was reduced from 53,888 to 52,581, an average of 4.74. This process increases the number of home-based work trips and reduces the number of home-based non-work and non-home based trips. The total number of trips are also reduced. Linking reduced the total number of trips in the survey less that 2 percent.

The household survey data were processed to aggregate households and person trips by six categories of household size and 12 categories of household income. Table 7 presents the number of surveyed households stratified by household size and income. Table 8 presents the number of observed person trips for the same stratification. Trip rates (i.e., person trips per household) were compared statistically column-to-column and row-to-row using a "Z" test *(16)*. The "Z" test compares the difference between two means and based on the number of observations and variance, computes a value, which if it exceeds 1.96 (95 percent confidence level) indicates the difference between the two estimates is statistically significant (i.e., the two means are different). Adjacent stratification cells with mean trip rates that had no statistical difference may be combined. The average trip rates were compared by row and column to identify those cells that could be combined to reduce the number of categories. Tables 9 and 10 present the "Z" statistics for the row and column comparisons. Since very little difference was indicated between the income categories, the same statistics were computed and reviewed for trip rates by trip purpose. Based on professional judgment and this analysis, researchers decided to stratify households by five categories of household size and income by five ranges of medium household income. Table 11 shows these.

Table 7. Number of Surveyed Households by Income and Size in 1969 OD Survey.

Household Income 1970 $	Household Size						Totals
	1	2	3	4	5	6 +	
< 3,000	999	621	220	125	74	188	2,227
3,000 – 3,999	149	346	201	137	103	178	1,114
4,000 – 4,999	119	343	202	186	136	224	1,210
5,000 – 5,999	138	322	228	211	185	231	1,315
6,000 – 6,999	85	253	188	188	125	172	1,011
7,000 – 7,999	65	201	207	145	107	180	905
8,000 – 8,999	28	193	167	141	117	144	790
9,000 – 9,999	28	198	154	151	99	73	703
10,000 – 12,499	26	228	212	223	132	157	978
12,500 – 14,999	5	110	92	96	73	65	441
15,000 – 24,999	4	72	64	71	56	31	298
25,000 +	3	35	13	15	16	12	94
Totals	**1,649**	**2,922**	**1,948**	**1,689**	**1,223**	**1,655**	**11,086**

Table 8. Number of Person Trips by Income and Size in 1969 OD Survey.

Household Income 1970 $	Household Size						Totals
	1	2	3	4	5	6 +	
< 3,000	1,996	1,846	893	627	469	1,043	6,874
3,000 – 3,999	427	1,464	1,181	884	834	1,477	6,267
4,000 – 4,999	349	1,683	1,353	1,470	1,236	2,233	8,324
5,000 – 5,999	491	1,700	1,637	1,719	1,991	2,453	9,991
6,000 – 6,999	301	1,324	1,472	1,795	1,270	2,172	8,334
7,000 – 7,999	263	1,174	1,675	1,331	1,213	2,400	8,056
8,000 – 8,999	117	1,238	1,415	1,384	1,553	1,887	7,594
9,000 – 9,999	106	1,360	1,352	1,529	1,428	877	6,652
10,000 – 12,499	127	1,550	1,926	2,564	1,968	2,671	10,806
12,500 – 14,999	25	803	932	1,219	1,061	1,158	5,198
15,000 – 24,999	6	482	730	852	1,058	658	3,786
25,000 +	8	291	181	239	251	220	1,190
Totals	**4,216**	**14,915**	**14,747**	**15,613**	**14,332**	**19,249**	**83,072**

Table 9. "Z" Statistic for Column-to-Column Comparisons of Mean Trips per Household.

Household Income 1970 $	Household Size				
	1 vs. 2	2 vs. 3	3 vs. 4	4 vs. 5	5 vs. 6+
< 3,000	-4.90	-2.53	-1.30	-1.08	0.65
3,000 – 3,999	-3.21	-2.82	-0.70	-1.38	-0.16
4,000 – 4,999	-4.35	-2.80	-1.35	-1.00	-0.69
5,000 – 5,999	-3.35	-2.85	-1.07	-2.24	0.11
6,000 – 6,999	-2.63	-3.34	-1.64	-0.47	-1.61
7,000 – 7,999	-2.39	-2.83	-1.00	-1.41	-1.16
8,000 – 8,999	-2.06	-2.26	-1.11	-2.02	0.09
9,000 – 9,999	-3.12	-1.94	-1.09	-2.29	1.05
10,000 – 12,499	-1.37	-2.63	-2.13	-2.01	-0.97
12,500 – 14,999	-0.83	-1.98	-1.37	-0.75	-1.04
15,000 – 24,999	-4.26	-2.52	-0.25	-2.12	-0.50
25,000 +	-2.29	-1.19	-0.31	0.04	-0.33

Table 10. "Z" Statistic for Row-to-Row Comparisons of Mean Trips per Household.

Household Income 1970 $	Household Size					
	1	2	3	4	5	6 +
< 3,000 vs. 3,000 – 3,999	-2.63	-3.77	-2.83	-1.60	-1.21	-2.86
3,000 – 3,999 vs. 4,000 – 4,999	-0.15	-1.59	-1.09	-1.52	-0.72	-1.47
4,000 – 4,999 vs. 5,000 – 5,999	-1.26	-0.79	-0.61	-0.25	-1.26	-0.55
5,000 – 5,999 vs. 6,000 – 6,999	0.03	0.09	-0.74	-1.30	0.43	-1.43
6,000 – 6,999 vs. 7,000 – 7,999	-0.66	-0.98	-0.28	0.31	-0.73	-0.43
7,000 – 7,999 vs. 8,000 – 8,999	-0.12	-0.81	-0.39	-0.49	-1.03	0.13
8,000 – 8,999 vs. 9,000 – 9,999	0.31	-0.59	-0.28	-0.23	-0.53	0.53
9,000 – 9,999 vs. 10,000 – 12,499	-0.72	0.09	-0.29	-1.06	-0.22	-2.18
10,000 – 12,499 vs. 12,500 – 14,999	-0.04	-0.53	-0.76	-0.71	0.15	-0.27
12,500 – 14,999 vs. 15,000 – 24,999	1.25	0.52	-0.62	0.32	-1.28	-0.70
15,000 – 24,999 vs. 25,000 +	-0.56	-0.90	-0.53	-0.79	0.57	0.37

Table 11. Household Stratification Categories.

Household Income Ranges	Household Size Categories
0 – 2,999	1
3,000 – 4,999	2
5,000 – 6,999	3
7,000 – 9,999	4
10,000 +	5+

5.3.7. Model Development

Data necessary for the trip generation model were developed from the household and other survey data reported from the 1969 OD study. The objective was to develop models to estimate home-based work (HBW), home-based non-work (HBNW), non-home-based (NHB), truck-taxi (TT), non-home-based external local (NHB Ex-Lo), external local (Ext-Loc), and external through (Ext-Thru) trip productions and attractions. HBW trips are those with either end of the trip at home and the other at work. HBNW are those with either end of the trip at home, and the other is not at work. NHB trips are those with neither end of the trip at home. Truck-taxi trips are those made by commercial vehicles (generally trucks) and taxis. NHB Ex-Lo trips are those internal trips (i.e., both ends are within the study area boundary) made by individuals who do not live in the study area. Ext-Loc trips are those trips where one end of the trip is inside the study area and the other is outside the study area. Ext-Thru trips are trips that traverse the study area without stopping, i.e. both ends of the trip are outside the study area. The 1969 OD survey included three distinct data collection efforts, a household survey, an external station survey, and a commercial vehicle-taxi survey.

Trip Productions

The model for estimating trip productions for HBW, HBNW, and NHB trips was a cross-classification model. This type of model uses trip rates stratified by household income and size (categories shown in Table 11). The household survey data were processed to sum the number of households and trips by the stratification levels shown in Table 11. These trip rates were computed for both person trips and automobile driver trips. The resulting trip rates are shown in Tables 12 through 17. The scope of work for this project was designed to apply person trip rates and develop person trip tables and then apply factors (by purpose) to convert the person trips to vehicle (i.e., automobile driver) trips prior to assignment. After reviewing the factors that would be applied, researchers decided that the use of a single factor for converting person trips to vehicle trips would not recognize the differences in person trips and automobile driver trips by household income and size. As a result, researchers decided to model automobile driver trips using the trip rates as observed in the 1969 OD survey (i.e., Tables 15-17).

Table 12. 1970 HBW Trip Production Rates (Person Trips per Household).

Household Income (1970 $)	Household Size				
	1	2	3	4	5 +
0 – 2,999	0.24	0.50	0.85	0.98	1.00
3,000 – 4,999	0.78	1.20	1.81	1.88	1.97
5,000 – 6,999	1.13	1.71	1.95	2.18	2.37
7,000 – 9,999	1.48	2.24	2.54	2.60	2.72
10,000 +	1.18	2.44	2.80	2.84	3.30

Table 13. 1970 HBNW Trip Production Rates (Person Trips per Household).

Household Income (1970 $)	Household Size				
	1	2	3	4	5 +
0 – 2,999	1.32	2.11	2.69	3.46	4.20
3,000 – 4,999	1.43	2.68	3.61	4.54	6.03
5,000 – 6,999	1.54	2.58	4.08	5.26	7.42
7,000 – 9,999	1.55	2.78	4.44	5.40	8.51
10,000 +	1.74	3.17	4.78	6.85	10.57

Table 14. 1970 NHB Trip Production Rates (Person Trips per Household).

Household Income (1970 $)	Household Size				
	1	2	3	4	5 +
0 – 2,999	0.44	0.36	0.52	0.58	0.58
3,000 – 4,999	0.69	0.69	0.86	0.87	1.02
5,000 – 6,999	0.88	0.97	1.45	1.37	1.27
7,000 – 9,999	0.98	1.34	1.44	1.71	1.77
10,000 +	1.45	1.42	2.31	2.35	2.79

Table 15. 1970 HBW Trip Production Rates (Auto Driver Trips per Household).

Household Income (1970 $)	Household Size				
	1	2	3	4	5 +
0 – 2,999	0.10	0.31	0.52	0.55	0.65
3,000 – 4,999	0.54	0.93	1.43	1.45	1.46
5,000 – 6,999	0.99	1.40	1.61	1.79	1.87
7,000 – 9,999	1.36	1.88	2.22	2.15	2.14
10,000 +	1.03	2.14	2.41	2.50	2.71

Table 16. 1970 HBNW Trip Production Rates (Auto Driver Trips per Household).

Household Income (1970 $)	Household Size				
	1	2	3	4	5 +
0 – 2,999	0.78	1.18	1.23	1.40	1.40
3,000 – 4,999	1.06	1.72	2.12	2.27	2.19
5,000 – 6,999	1.33	1.81	2.46	2.94	2.88
7,000 –9,999	1.38	2.01	2.89	3.07	3.48
10,000 +	1.55	2.44	3.27	4.03	5.09

Table 17. 1970 NHB Trip Production Rates (Auto Driver Trips per Household).

Household Income (1970 $)	Household Size				
	1	2	3	4	5 +
0 – 2,999	0.28	0.23	0.34	0.32	0.32
3,000 – 4,999	0.57	0.50	0.68	0.58	0.59
5,000 – 6,999	0.82	0.79	1.10	1.04	0.87
7,000 –9,999	0.92	1.08	1.13	1.35	1.21
10,000 +	1.32	1.20	1.89	1.84	2.12

A specific model for estimating truck and taxi trip productions was not necessary. Current practice is to develop an estimate of the total truck-taxi productions and distribute them to the zones based on the truck-taxi attraction model. The total truck-taxi productions of 129,744 were taken directly from the 1969 OD survey report *(9)*.

Researchers estimated the number of non-home-based external local trip productions based on two assumptions. The first assumption was that 55 percent of the non-commercial vehicle trips observed at external stations were made by non-residents. This assumption is consistent with observed data from external station surveys conducted in Victoria, Corpus Christi, and Austin. The number of non-commercial vehicle trips at the external stations was estimated based on the reported percentage of commercial and non-commercial vehicles surveyed at the stations in 1969. It was then assumed that each of these would generate four internal non-home-based trip productions. The total number of non-home-based external local trips estimated was 44,518. Table 18 presents the external stations and the counts at those stations.

Researchers estimated external local trip productions (see Table 18) using published data in the 1969 OD survey report *(9)*, traffic counts posted on the 1969/70 assignment maps, and traffic counts published by TxDOT for 1970 for the San Antonio District. The data published in the 1969 OD survey report had to be adjusted to account for the inclusion of the area in Guadalupe County. Estimates of external through trips were developed using the 1969 OD survey reported data *(9)*. The percentage of through trips observed in the 1969 external station survey was assumed to be applicable for the stations in Guadalupe County on the same facility. For those facilities not surveyed in 1969, an average percentage of through trips was used to estimate the number of through trips. The estimated number of external through trips was 3,106 (Table 18 shows a total of 6,212, which is double because each through trip is counted twice, once entering and once leaving).

Table 18. Estimated 1970 Counts and through Trips at External Stations.

Facility Name	Zone	Vehicle Count	Thru Trips
IH 35 North	813	13,760	1,282
FM 78 North	814	2,310	10
IH 10 East	815	9,240	914
FM 2538	816	140	14
FM 1346	817	240	0
US 87 East	818	2,220	88
FM 3432	819	100	0
US 181East	820	4,470	194
FM 1303	821	220	10
US 281 South	822	4,250	650
Pleasanton Road	823	200	0
SH 16 South	824	2,580	164
Somerset Road	825	320	20
FM 476	826	490	74
FM 2790	827	470	98
Dummy Link	828	0	0
IH 35 South	829	4,280	820
FM 132	830	2,780	60
Wisdom Road	831	460	16
Macdona-La Coste	832	990	18
US 90 West	833	4,510	816
FM 1957	834	260	8
FM 471	835	370	8
SH 16 North	836	1,110	52
Boerne Stage Road	837	100	0
IH 10 North	838	5,560	652
FM 2696	839	220	0
US 281 North	840	2,510	226
Smithson Valley Road	841	40	0
FM 2252	842	620	18
Totals		**64,820**	**6,212**

Trip Attractions

The attraction models were developed using data from the household survey and published information from the commercial and external surveys conducted in the 1969 OD study *(9)*. Current attraction models stratify attraction rates by area type, employment type, and households. Since the attraction models use area type as a stratification level, it was necessary to designate the area type for the zones. It was not reasonable to use the same area types as defined in the 1990 study area because area type reflects development density, which changes over time.

Area type is based on a measure of development density, which is computed using the size of a zone (acres) and the estimates of population and employment in the zone. Zones designated as CBD are developed manually and kept constant over time. For San Antonio and Bexar County, due to the high military presence, the military bases were designated as a separate area type. The density measure for a zone is computed as the sum of two measures: 1) the zone population divided by the number of acres in the zone, and 2) the employment in the zone multiplied by a coefficient and divided by the number of acres in the zone *(17)*. The coefficient used is the ratio of the population for the study area divided by the employment in the study area. The area type designations and density measures used in this study are shown in Table 19. It should be noted that the zones designated as area type 1, CBD, are developed manually and held constant for future years.

Table 19. Criteria for Area Type Designations.

Area Type	Density Measure	Number of Zones
CBD	≥ 90	3
Urban	≥ 30 and < 90	30
Urban Fringe	≥ 15 and < 30	162
Suburban	≥ 5 and < 15	193
Rural	< 5	415
Military	Not Applicable	9

After designating the area type for each zone, the zonal data were processed to sum the population, households, total employment, basic employment, retail employment, and service employment by area type. The household survey data were processed to sum the number of attractions by the land use code at the destination end and trip purpose. A total of 10 land use codes were used in the 1969 OD household survey. These were aggregated into five categories, as shown in Table 20.

The attraction trip rates were developed as follows:

1. Expanded attractions by trip purpose were computed by land use category from the 1969 OD household survey. The 10 land use categories used in the survey were aggregated into residential and four types of employment, i.e., basic, retail, service, and military. Using total employment (for Bexar County) and total households, average attraction rates were computed for each trip purpose stratified by residential, basic, retail, service, and military.

2. Zones were designated by area type based on the estimated population and employment density within the zone.

3. The number of households and employment by type were summed by area type.

4. Based on the proportional relationship between districts and zones, the number of expanded attractions by trip purpose were computed by area type and trip purpose.

5. An initial estimate of attractions by trip purpose and area type was developed by multiplying the average attraction rates from Step 1 by the number of households, basic employees, retail employees, service employees, and military employees as computed in Step 3.

Table 20. Aggregation of Survey Land Use Categories.

1970 Survey Land Use Category	Model Category
Residential	Residential
Industrial	Basic
Utilities-Transportation	Basic
Retail	Retail
Services	Service
Entertainment	Retail
Parks	Basic
Agriculture	Basic
Military	Military
Public Buildings	Service

It should be clarified at this point that the 1969 OD household survey was conducted in Bexar County. The assumption made in these analyses is that the model developed using data for Bexar County may be reasonably applied to the entire study area being used in this research. Table 21 presents the attraction rates for HBW, HBNW, and NHB trips.

Table 21. Attraction Models for San Antonio-Bexar County Travel Demand Model.

Area Type	Land Use Category	Home-Based Work	Home-Based Non-Work	Non-Home-Based
CBD	Residential	0.08	0.19	0.18
	Basic	1.69	0.27	0.20
	Retail	1.31	2.09	1.29
	Service	1.46	1.03	0.48
	Military	1.00	0.16	0.08
Urban	Residential	0.08	0.40	0.27
	Basic	1.54	0.57	0.30
	Retail	1.20	4.44	1.91
	Service	1.33	2.19	0.72
	Military	0.91	0.33	0.12
Urban Fringe	Residential	0.09	0.44	0.28
	Basic	1.78	0.63	0.31
	Retail	1.38	4.96	1.97
	Service	1.54	2.45	0.74
	Military	1.05	0.37	0.12
Suburban	Residential	0.08	0.48	0.29
	Basic	1.59	0.68	0.36
	Retail	1.23	5.32	2.07
	Service	1.37	2.62	0.78
	Military	0.94	0.40	0.13
Rural	Residential	0.08	0.43	0.21
	Basic	1.52	0.61	0.24
	Retail	1.18	4.79	1.50
	Service	1.32	2.36	0.56
	Military	0.90	0.36	0.09
Military	Residential	0.08	0.44	0.38
	Basic	1.67	0.62	0.43
	Retail	1.30	4.89	2.73
	Service	1.45	2.41	1.02
	Military	0.99	0.37	0.17

Attraction rates for truck-taxi trips were developed in a similar manner. An initial set of rates were borrowed (in this project from the 1990 San Antonio model) and applied to the zonal data summed by area type. An adjustment factor was computed by dividing the estimated total truck-taxi trips from the 1969 OD report by the total attractions computed by applying the borrowed rates to the zonal data. This factor was applied to the borrowed rates to produce a set of attraction rates for truck-taxi trips stratified by households and employment type. The attraction rates for non-home based external local trips were assumed to be the same as non-home based trips. Table 22 presents the truck-taxi attraction rates.

Table 22. Truck-Taxi (Commercial Vehicle) Attraction Rates.

Area Type	Residential	Basic	Retail	Service	Military
CBD	0.08	0.46	0.48	0.25	0.25
Urban	0.09	0.40	0.40	0.22	0.22
Urban Fringe	0.10	0.40	0.30	0.13	0.13
Suburban	0.10	0.73	0.45	0.19	0.18
Rural	0.10	1.03	0.43	0.29	0.29
Military	0.10	0.73	0.45	0.19	0.19

Special Generators

Special generators are those developments that are unique in travel characteristics. These travel characteristics make these types of development difficult to model using standard production and attraction rates. As a result, these are typically models exogenously to the standard models with estimates of trip productions and attractions input directly into the trip generation model. It was initially thought that identifying special generators would not be necessary, but after reviewing the preliminary results of the model applications, the decision was made to treat the military bases, the San Antonio International Airport, and the San Antonio State Hospital as special generators to improve the modeling results. These generators were isolated in individual districts in the 1969 OD survey report, which provided the opportunity to compute trip productions and attractions directly from the OD survey data. The survey data were processed to sum the productions and attractions by purpose for the districts that contained the special generators. Table 23 presents the results.

Table 23. Special Generator Production and Attraction Estimates.

Special Generator	Zone	HBW		HBNW		NHB		Truck-Taxi		NHB-ExLo	
		Prod	Attr	Prod	Attr	Prod	Attr	Prod	Attr	Prod	Attr
Brooks AFB	93	522	2,784	1,154	1,685	1,061	1,061	121	121	494	494
SA State Hospital	98	126	1,305	106	1,374	753	753	135	135	0	0
East Kelly AFB	165	0	2,399	0	251	292	292	218	218	241	241
Kelly AFB	187	875	37,980	2,880	3,651	4,122	4,122	1,104	1,104	3,526	3,526
Lackland AFB	192	313	9,364	1,299	4,819	2,322	2,322	544	544	2,868	2,868
Lackland AFB	193	209	6,243	866	3,212	1,548	1,548	362	362	1,912	1,912
Fort Sam Houston	394	248	17,070	5,393	14,244	7,735	7,735	1,220	1,220	6,409	6,409
SA International Airport	521	515	5,954	83	4,298	2,161	2,161	548	548	0	0
Lackland Annex	654	118	1,095	274	519	224	224	10	10	792	792
Camp Bullis	750	22	368	120	128	42	42	41	41	33	33
Randolph AFB	777	1,140	10,733	3,508	6,048	2,333	2,333	382	382	1,241	1,241

Regional Distribution

One of the key elements for the trip generation model is the regional distribution of households by size and income. This corresponds to the same stratification used in developing the trip production rates. The stratification levels were presented earlier in Table 11. Using those strata and the 1970 San Antonio SMSA Regional Distribution from the census shown in Table 5, the regional distribution was developed and is presented in Table 24.

Table 24. 1970 Regional Distribution of Households in San Antonio-Bexar County Study.

Household Income (1970 $)	Household Size					Totals
	1	2	3	4	5	
0 - 2,999	7.88%	4.97%	2.22%	1.29%	2.36%	18.72%
3,000 - 4,999	2.71%	4.35%	2.39%	1.60%	3.10%	14.15%
5,000 - 6,999	1.89%	3.80%	2.80%	2.48%	4.29%	15.26%
7,000 - 9,999	1.69%	5.06%	3.60%	3.57%	6.10%	20.02%
10,000 +	1.28%	8.42%	6.40%	6.36%	9.39%	31.85%
Totals	**15.45%**	**26.60%**	**17.4%**	**15.30%**	**10.54%**	**100.00%**

Source: 1970 U.S. Census, Table 206.

5.3.8. Model Application and Results

The data developed in the previous sections were input to the trip generation program TRIPCAL5. This program applies the trip production rates for HBW, HBNW, and NHB to the zonal data cross classified by household size and income to estimate the zonal trip productions for each purpose. The attraction rates for those purposes are applied to the zonal data to estimate the zonal attractions. The attractions are balanced to ensure the total productions and attractions for the study area are the same.

Total trip productions for truck-taxi and NHB Ex-Lo trips were input directly to TRIPCAL5. Zonal attractions were estimated using attraction rates for these purposes applied to the zonal data. The zonal attractions were adjusted to ensure the total attractions for the study area equaled the input total trip productions. The zonal productions were then set equal to the adjusted zonal attractions. This is consistent with current practice.

Table 25 presents the results from TRIPCAL5 with the balancing factors for each trip purpose. The balancing factors are well within the acceptable limits of plus or minus 5 percent for HBW and 10 percent for HBNW and NHB. The factors for truck-taxi and NHB Ex-Lo trips are large but considered acceptable for purposes of this research. The total truck-taxi trip productions from the 1969 OD study were used and are considered relatively accurate. The NHB Ex-Lo trip productions were estimated using borrowed data and the attractions estimated assuming the same rates as those developed for NHB trips. It should be noted that the relatively good balancing factors for HBW, HBNW, and NHB trips are a result of the method used to develop the attraction models. The same data used to develop the production rates were used to develop the attraction rates, so it would be expected the totals would be close.

Table 25. TRIPCAL5 Results.

Trip Purpose	Type	Control Total	Un-Scaled Modeled	Special Generator	Balancing Factor
HBW	Productions	392,305	385,985	6,320	1.000
	Attractions		289,451	95,295	1.026
HBNW	Productions	614,153	598,470	15,683	1.000
	Attractions		566,020	40,229	1.014
NHB	Productions	251,608	251,608	22,593	1.000
	Attractions		238,497	22,593	0.960
Truck-Taxi	Productions	129,744	89,915	4,685	1.391
	Attractions		89,915	4,685	1.391
NHB Ext-Local	Productions	44,518	238,497	17,516	0.113
	Attractions		238,497	17,516	0.113

In a normal modeling application, the data in Table 25 would represent the best estimates at that stage in the model development. This research is unique in that the results shown in Table 25 may be compared to published estimates of trips from the 1969 OD study and the research conducted in 1976 which was based on the 1970 travel demand model. Table 26 presents this comparison for the automobile driver trips. There are considerable differences in the estimates.

Table 26. Trip Generation Comparisons (Automobile Driver Trips).

Element	1969 O-D Estimate	1976 Research	1970 Model
HBW Trips	373,361	413,705	392,305
HBNW Trips	744,987	664,473	614,153
NHB Trips	347,257	343,165	251,608
Total Internal Trips	1,465,605	1,421,343	1,258,066
Population	825,843	830,460	836,377
Households (HH)/Dwelling Units (DU)	255,276 DUs	256,640 DUs	245,255 HHs
Employment (Total)	271,600	Not Reported	290,749
Internal Trips/HH	5.74	5.54	5.13
Internal Trips/Capita	1.77	1.72	1.50
Internal Trips/Employee	5.40	-	4.33

The differences noted in Table 26 may be due to a number of factors. Some of these include:

- The methodology used to expand the survey data in 1969 and 1970 was performed on a zonal basis and included adjustments for persons making trips unknown (i.e., where individuals were absent during the household interview) as well as adjustments for trips forecast versus counted across screenlines within the study area. This methodology could not be replicated because the data were not available.

- It is unclear from the survey documentation how unoccupied dwelling units were treated and accounted for in the survey data expansion.

- The number of dwelling units used in the survey expansion in 1969 and 1970 was much higher than the number of households reported in the census and used in this research.

- The zonal data used in this research may be significantly different from that used in the 1969 and 1970 studies. This could significantly impact the results, especially for the variables used in stratifying the zonal data.

- The processing of the survey data to link trips will reduce the total number of trips and disproportionately increase the number of HBW trips. Linking was not performed in 1969 and 1970.

Additional review of the 1969 OD survey data revealed some inconsistencies that were difficult to explain. The percentage of trips by trip purpose as reported in the 1969 OD and 1976 research reports are not consistent with the percentages in the non-expanded survey data. Table 27 presents these data. It was expected that the percentage of non-home-based trips would change in this research since trips were linked. The expansion methodology used in 1969 and 1976 altered the proportional distribution of trips by purpose, and no documentation was found to explain how or why this occurred.

Table 27. Percentage of Home-Based and Non-Home-Based Automobile Driver Trips.

Source	Total Trips	Percent Home-Based	Percent Non-Home-Based
Full un-expanded OD trip records	60,930	77.9%	22.1%
Unlinked OD trip records after removing bad samples	53,088	78.5%	21.5%
Linked trip file unexpanded	52,581	80.7%	19.3%
Expanded linked trips (as developed in this research)	1,258,066	80.0%	20.0%
1969 Expanded OD trips	1,465,605	76.3%	23.7%
1976 Expanded OD trips	1,421,343	75.9%	24.1%

5.3.9. Model Evaluation

In terms of general accepted criteria for trip generation results, the 1970 trip generation model appears to produce reasonable results. When compared to published estimates of trips for 1969 and 1970, the model produces results that are significantly lower in total trips. This is disturbing because the total number of automobile driver trips is 14 percent less than the 1969 OD survey estimates. This is expected to produce lower estimates of vehicle miles of travel.

5.4. TRIP DISTRIBUTION

Trip distribution is the step in the modeling process where the number of trips traveling between zone pairs is estimated. The current model is ATOM2, which is a modified version of the gravity model where the number of trip interchanges between zone pairs is a function of the impedance or travel time between the zone pairs and the number of attractions at the destination zone. The input data to the trip distribution model are the impedance matrix, which contains the travel time between all zone pairs, the zonal productions and attractions output from trip generation, and the trip length frequency distribution (TLFD) (for each trip purpose), which shows the percentage of trips that are expected to occur at each impedance level (i.e., at each minute of travel time). The impedance matrix is output from the processing of the network to determine the minimum time paths between all zone pairs. The zonal productions and attractions are output from the trip generation step. The next section presents the process used to develop the TLFDs from the 1969 OD survey data.

5.4.1. Trip Length Frequency Distributions

In current practice, TLFDs are developed using survey data. The data are processed to sum the number of trips (by purpose), which are observed at each impedance measure (i.e., travel time) based on the zone of origin and zone of destination. It was initially thought that TLFDs could be modeled using the reported average trip lengths by purpose. This was initially performed, but the results proved to be less than acceptable. Researchers concluded that the reported average trip lengths were based on the networks being modeled in 1969. A method was developed using the 1969 OD survey data with the impedance matrix for the 1970 network to develop TLFDs by purpose for this research.

The 1969 OD survey data included the district where each trip originated and the district where each trip ended. It also included a code describing the type of land use at the origin and destination end of each trip as well as the purpose of the trip. The districts coded in the data file were assumed to be the same as presented in the 1969 OD survey report, which showed a total of 425 districts. The numbering convention was consistent. Using the proportional relationship developed between the 425 districts and the 801 transportation zones (inside of Bexar County), expanded trip tables were developed for HBW, HBNW, and NHB trips. The following steps illustrate this process for a trip that originated in District 25 and ended in District 105.

- The proportional allocation of the origin district was assigned to the zones, which were included in the district. For example, 15 percent of District 25 fell within Zone 40; 45 percent of District 25 fell within Zone 42; and 40 percent of District 25 fell within Zone 46. This resulted in 0.15 trips originating in Zone 40, 0.45 trips originating in Zone 42, and 0.40 trips originating in Zone 46.

- The proportional allocation of the destination district as assigned to the zones were included in the district. For example, 65 percent of District 105 fell within Zone 87; 10 percent of District 105 fell within Zone 75; and 25 percent of District 105 fell within Zone 73. This resulted in 0.65 trips ending in Zone 87, 0.10 trips ending in Zone 75, and 0.25 trips ending in Zone 73.

- The trip movements between the zones comprising Districts 25 and 105 were estimated by multiplying the proportion of each trip originating in a zone by the proportion that ended in a zone. For example:

  Trips from Zone 40 to Zone 87 = 0.15 × 0.65 = 0.0975 trips
  Trips from Zone 40 to Zone 75 = 0.15 × 0.10 = 0.0150 trips
  Trips from Zone 40 to Zone 73 = 0.15 × 0.25 = 0.0375 trips

Trips from Zone 42 to Zone 87 = 0.45 × 0.65 = 0.2925 trips
Trips from Zone 42 to Zone 75 = 0.45 × 0.10 = 0.0450 trips
Trips from Zone 42 to Zone 73 = 0.45 × 0.25 = 0.1125 trips

Trips from Zone 46 to Zone 87 = 0.40 × 0.65 = 0.2600 trips
Trips from Zone 46 to Zone 75 = 0.40 × 0.10 = 0.0400 trips
Trips from Zone 46 to Zone 73 = 0.40 × 0.25 = 0.1000 trips

All of the trip records were processed to build a trip table with trip purpose, mode of travel, etc.

District-to-district movements of commercial vehicles and external local trips were processed in a similar manner to build zone-to-zone trip tables for those purposes. NHB external local trips were assumed to have the same TLFD as NHB trips.

The 1970 network was processed using the speed capacity look-up table, and an impedance matrix was output showing the minimum travel time between all zone pairs. The zone-to-zone trip tables were processed and the travel time added to the trip records. The trip records were then processed to sum the number of trips by purpose and travel time to generate the TLFDs and compute average trip length in travel time. Intrazonal trips (i.e., those trips began and ended in the same zone) were distributed to the first three-to-four minutes depending on trip purpose, using professional judgment. Figures 7 through 11 present the resulting TLFDs. The unusual spike in the observed external-local trips at 19-20 minutes (Figure 11) was due to a large number of trips observed between the IH 35 station and Randolph Air force Base. Table 28 presents the average trip lengths in travel time and distance. The average trip length in minutes presented in Table 28 for HBW, HBNW, and NHB are less than that documented for the 1970 travel model in Reference 14. That research reported the average trip length for HBW trips as 14.38 minutes, HBNW trips as 9.28 minutes, and NHB trips as 10.18 minutes. These differences may be attributable in large part to the differences in the networks. The network used in the 1976 research consisted of 10,172 one-way links. The network used in this research consisted of 4,730 links. This difference in detail could explain the differences in average trip length.

Table 28. Average Trip Lengths (1969 OD Trip Tables).

Trip Purpose	Average Trip Length (Minutes)	Average Trip Length (Miles)
HBW	13.76	7.69
HBNW	8.91	4.95
NHB	8.80	4.63
Commercial Vehicle	9.25	4.83
External-Local	31.21	21.48

5.4.2. Trip Distribution Model Application and Results

Trip distribution was performed using the Texas Trip Distribution model. This model uses a modified form of the gravity model called the "Atomistic" trip distribution model. The current version of this software is ATOM2. The inputs to the model are the balanced trip productions and attractions by trip purpose for each zone, the interzonal and intrazonal travel times based on the transportation network (and the speed capacity look-up table), and the TLFDs for each trip purpose. The trip distribution model outputs trip tables by trip purpose that show the number of trips interchanged between all zones. The model was run individually for each trip purpose.

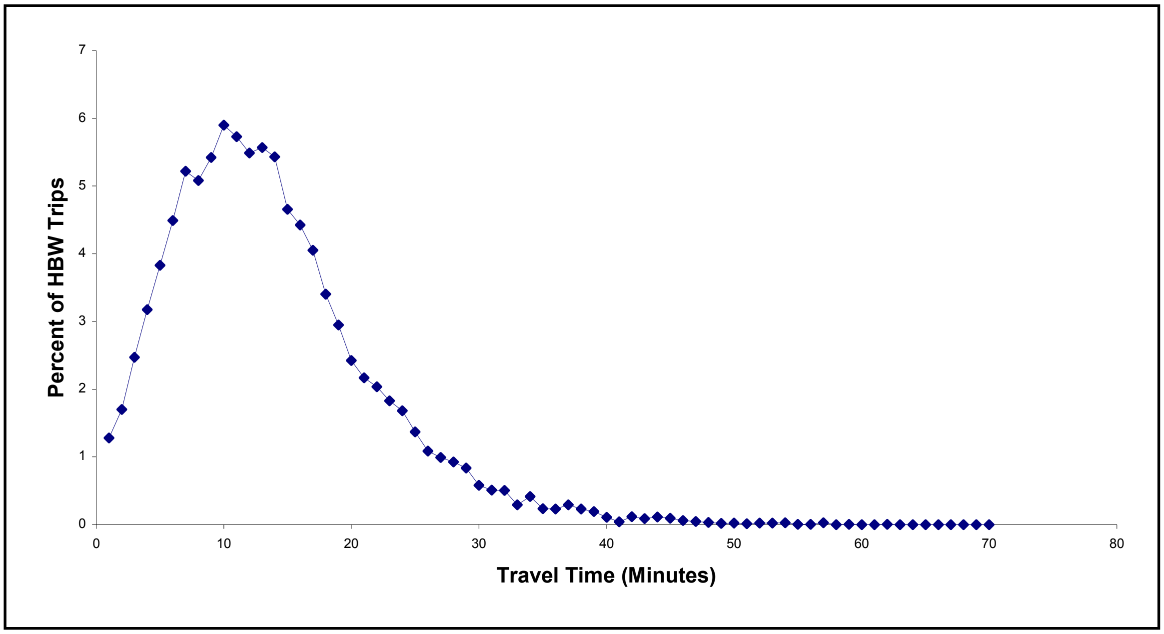

Figure 7. HBW TLFD.

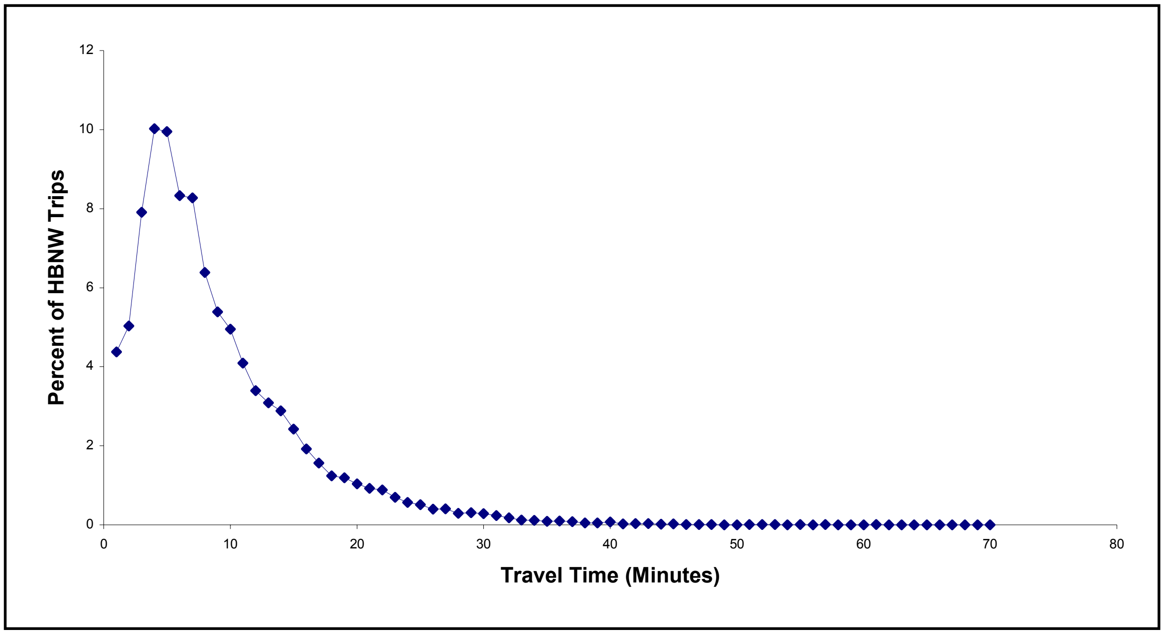

Figure 8. HBNW TLFD.

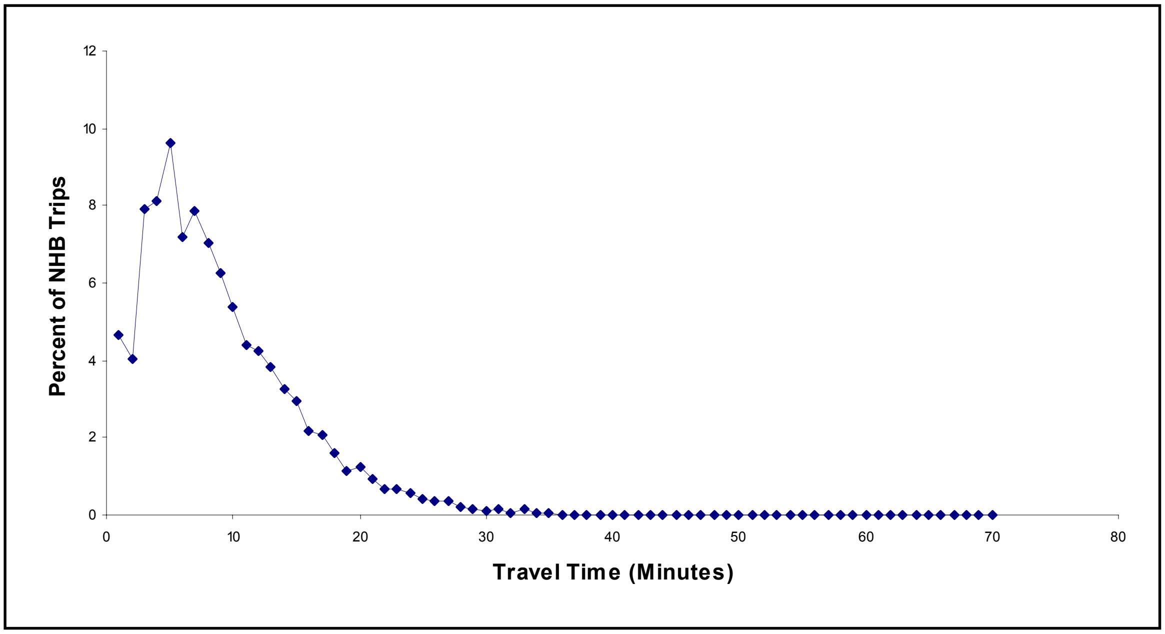

Figure 9. NHB TLFD.

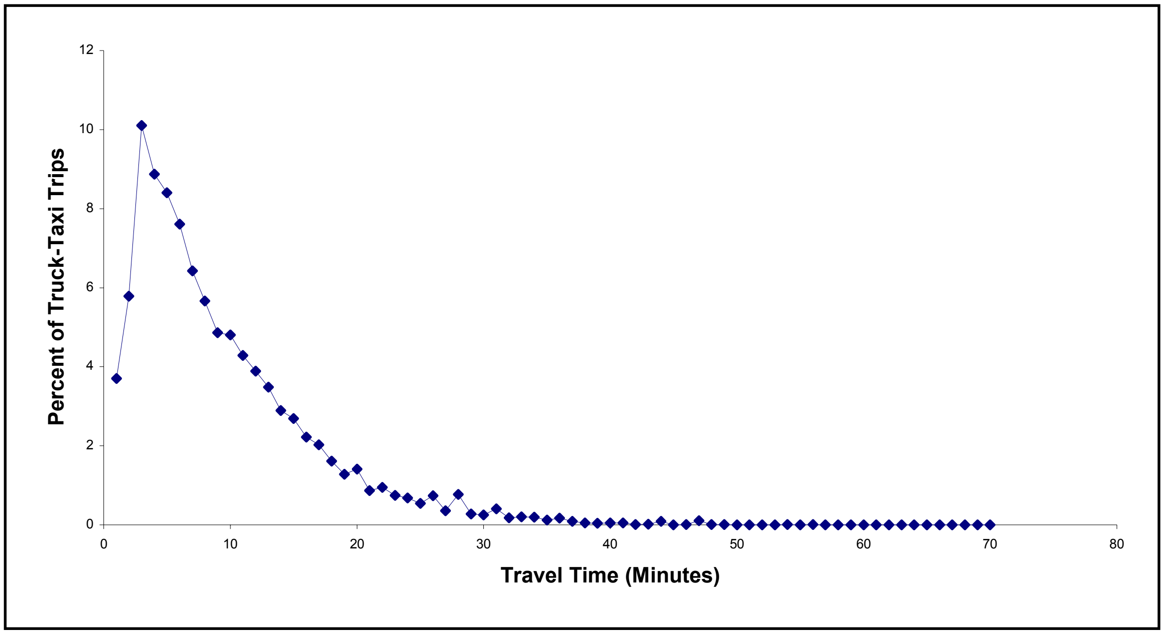

Figure 10. Truck-Taxi TLFD.

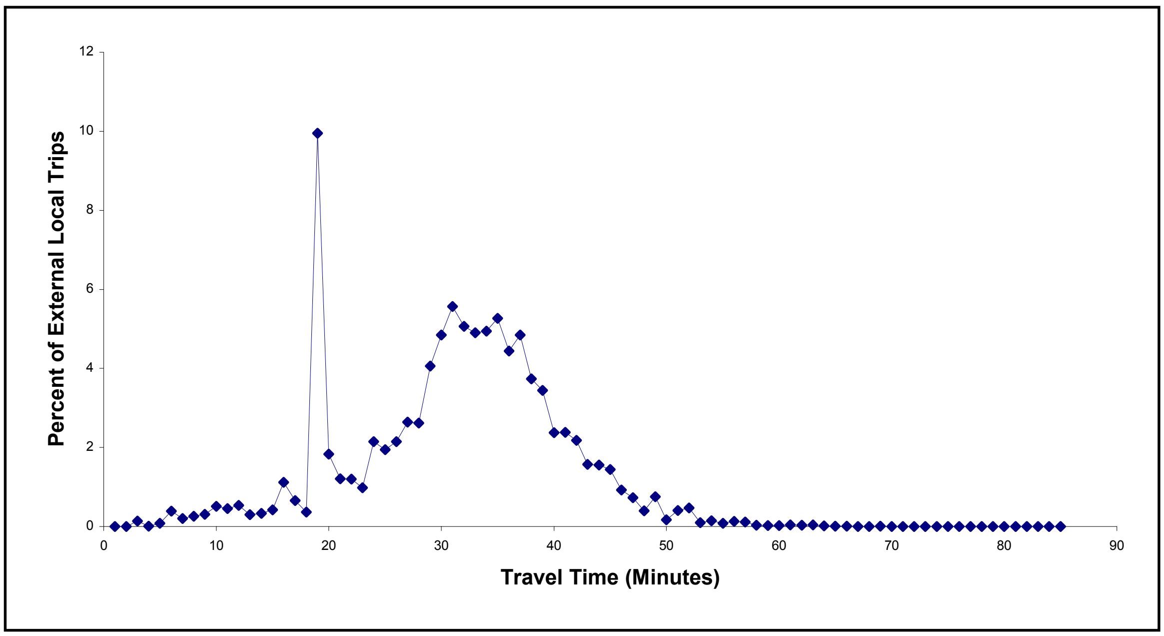

Figure 11. External Local TLFD.

Calibration of the trip distribution model is accomplished by: 1) finding a suitable match between the desired number of attractions (estimated in trip generation) and the distributed number of attractions for each zone, and 2) finding a suitable match between the desired mean TLFD and the mean trip length and TLFD produced by the trip distribution model for each trip purpose. Since the trip distribution model is run separately for each trip purpose, the results are presented for each.

HBW Trip Distribution Results

The trip distribution model was run with the HBW zonal trip productions and attractions input with the TLFD as computed from the 1969 OD survey data. The desired mean trip length was computed as 13.8093 minutes. The resulting mean trip length from the trip distribution model was 13.81 minutes, a difference of less than 0.005 percent. Figure 12 presents a plot of the HBW zonal attractions input (indicated as desired) versus the resulting zonal attractions output from the trip distribution model. The solid line shown in Figure 12 represents where the data would fall if a perfect match were obtained. The results from the trip distribution model are very close to a perfect match. Figure 13 presents a similar plot where the zones were aggregated into 35 sectors and the desired sector attractions plotted versus the resulting sector attractions output from the trip distribution model. Again, the results are very close, indicating the model was able to match the input HBW attractions very well. Figure 14 presents a plot of the input TLFD and the TLFD output from the trip distribution model. The line shown in Figure 14 represents the TLFD, which was output from the trip distribution model, while the data points shown represent the input TLFD. The agreement is very good. These figures indicate that the HBW trip distribution model replicates the input data and criteria very well.

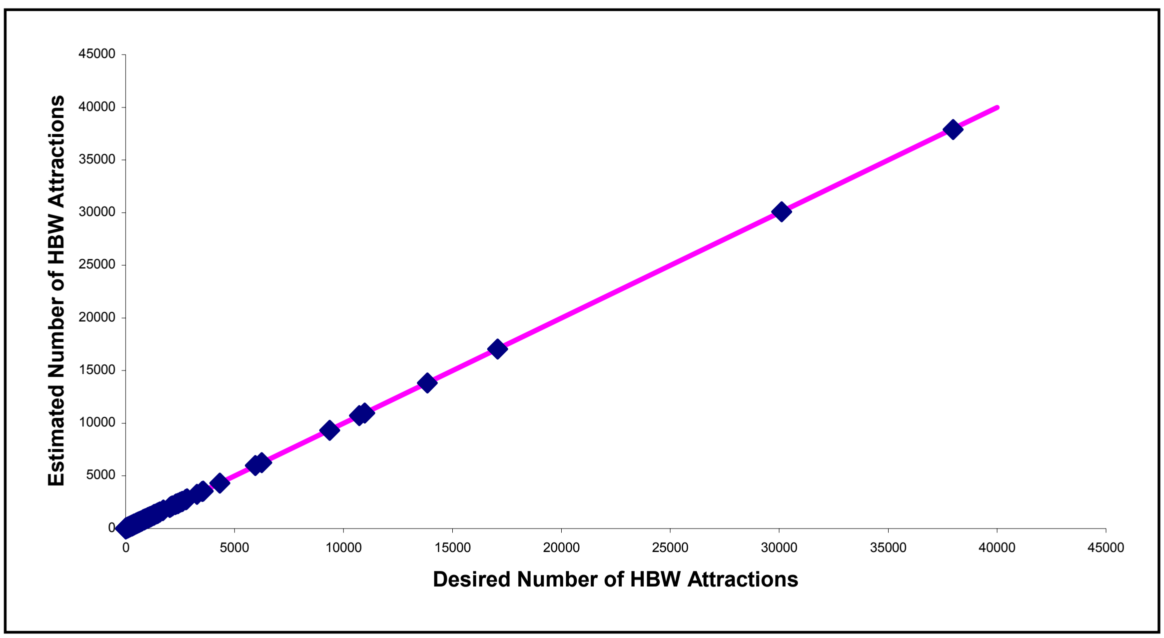

Figure 12. Estimated Zonal HBW Attractions vs. Desired HBW Attractions.

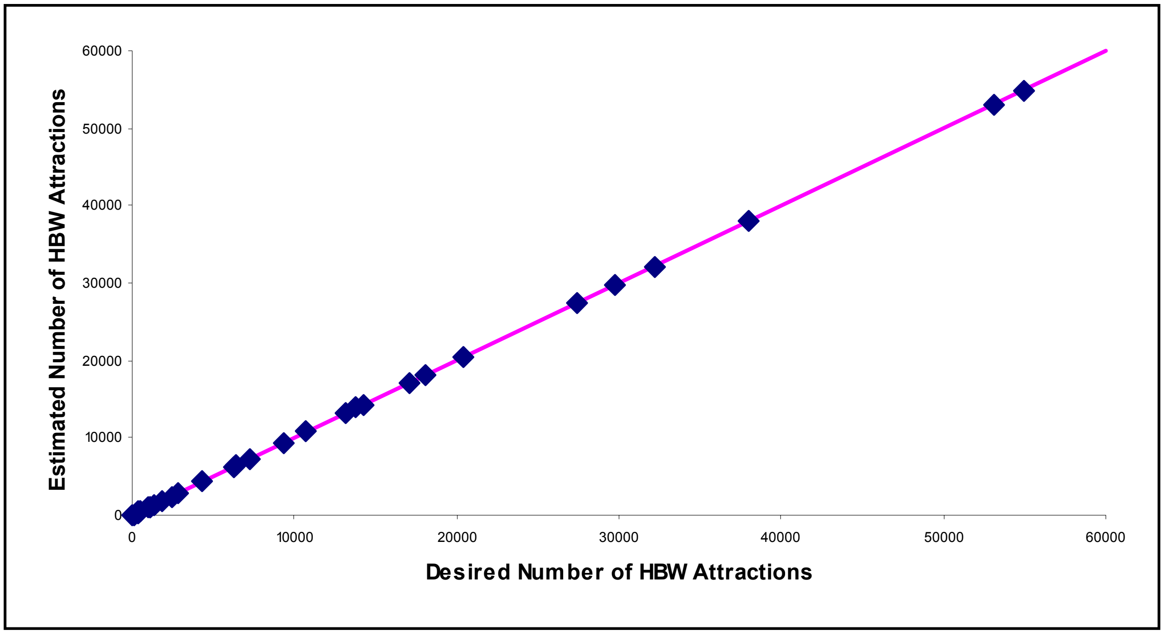

Figure 13. Estimated HBW Attractions at the Sector Level vs. Desired Attractions.

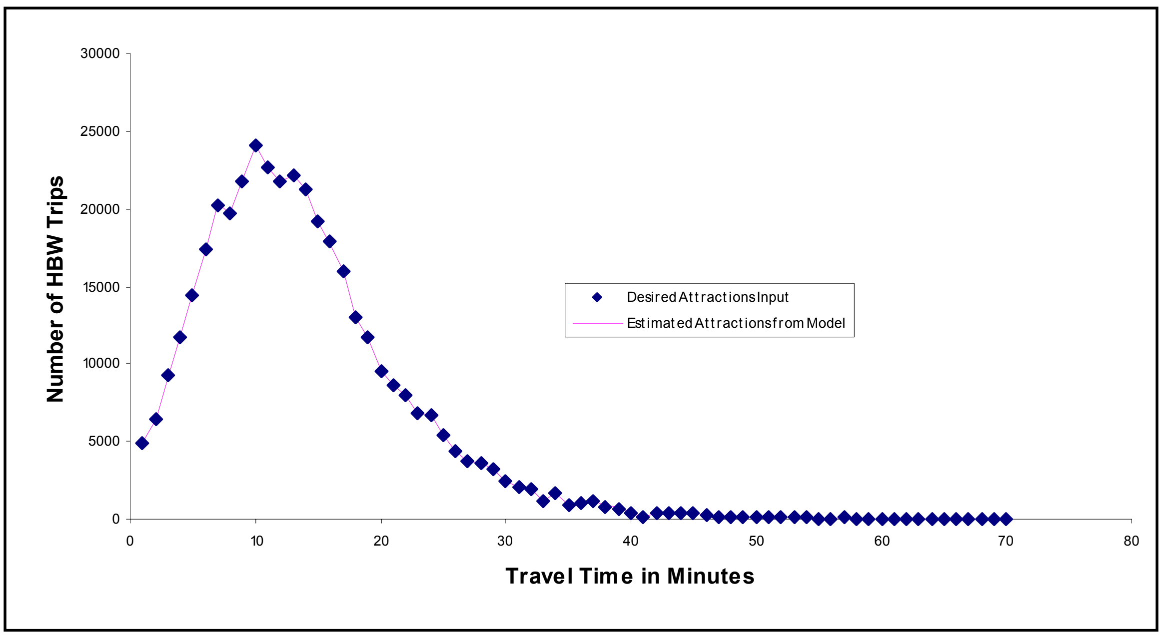

Figure 14. HBW TLFD Results from Trip Distribution.

HBNW Trip Distribution Results

The trip distribution model was run with the HBNW zonal trip productions and attractions input with the TLFD as computed from the 1969 OD survey data. The desired mean trip length was computed as 9.005 minutes. The resulting mean trip length from the trip distribution model was 9.036 minutes, a difference of 0.3 percent. Figure 15 presents a plot of the HBNW zonal attractions input (indicated as desired) versus the resulting zonal attractions output from the trip distribution model. The solid line shown in Figure 15 represents where the data would fall if a perfect match were obtained. The results from the trip distribution model are very close to a perfect match. Figure 16 presents a similar plot where the zones were aggregated into 35 sectors and the desired sector attractions plotted versus the resulting sector attractions output from the trip distribution model. Again, the results are very close, indicating the model was able to match the input HBNW attractions very well. Figure 17 presents a plot of the input TLFD and the TLFD output from the trip distribution model. The line shown in Figure 17 represents the TLFD, which was output from the trip distribution model, while the data points shown represent the input TLFD. The agreement is very good. These figures indicate that the HBNW trip distribution model replicates the input data and criteria very well.

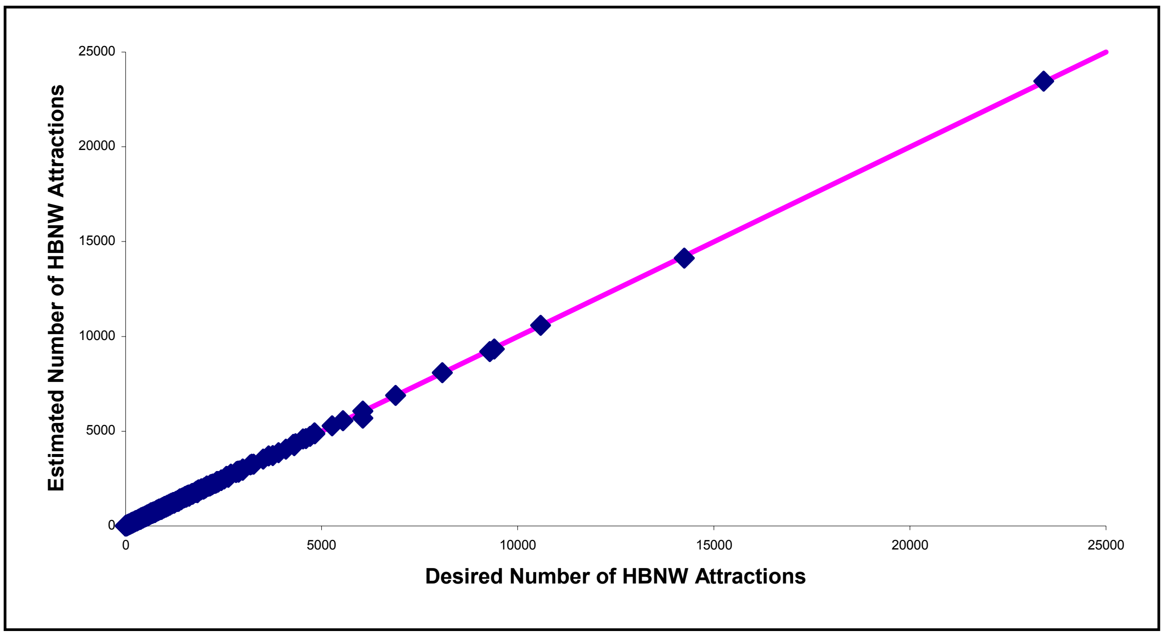

Figure 15. Estimated Zonal HBNW Attractions vs. Desired HBNW Attractions.

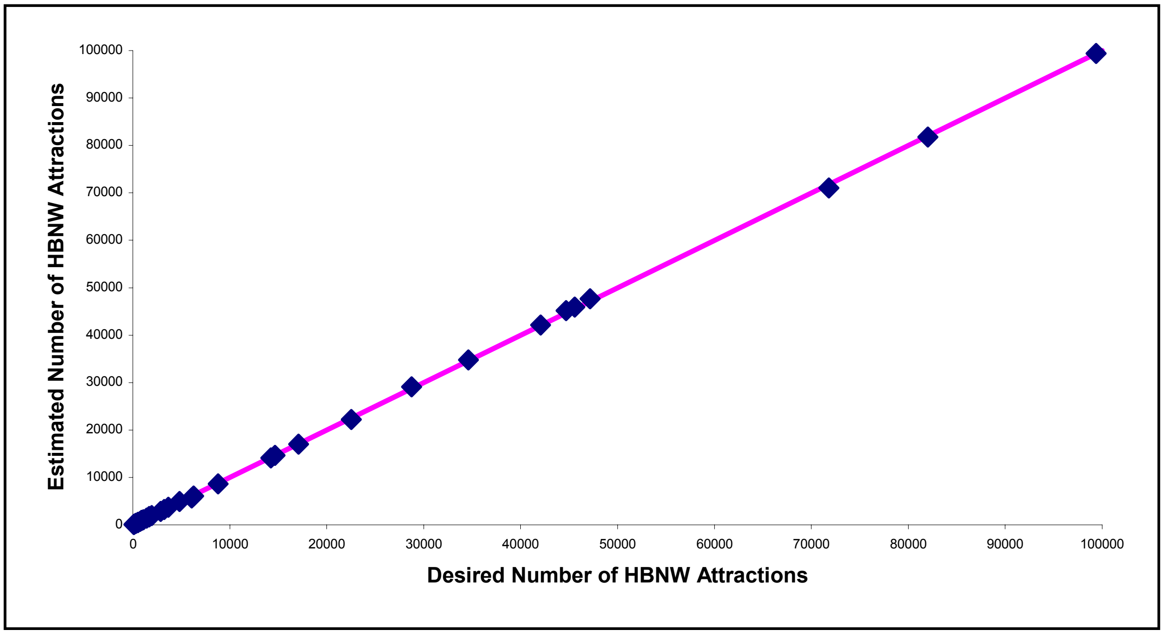

Figure 16. Estimated HBNW Attractions at the Sector Level vs. Desired Attractions.

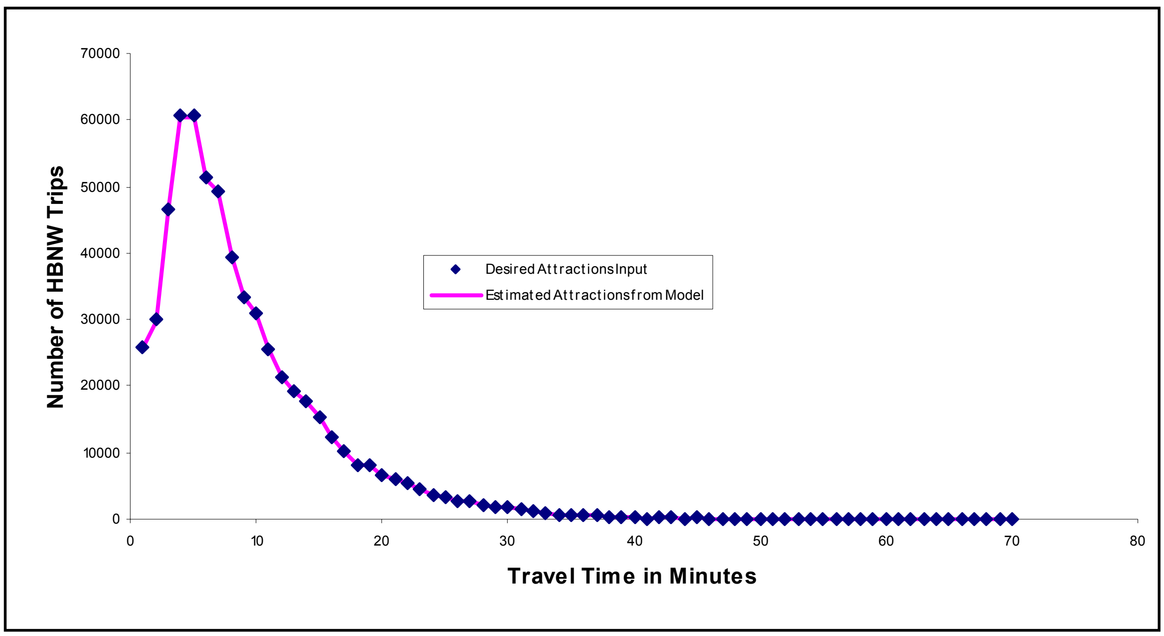

Figure 17. HBNW TLFD Results from Trip Distribution.

NHB Trip Distribution Results

The trip distribution model was run with the NHB zonal trip productions and attractions input with the TLFD as computed from the 1969 OD survey data. The desired mean trip length was computed as 8.899 minutes. The resulting mean trip length from the trip distribution model was 8.904 minutes, a difference of less than 0.06 percent. Figure 18 presents a plot of the NHB zonal attractions input (indicated as desired) versus the resulting zonal attractions output from the trip distribution model. The solid line shown in Figure 18 represents where the data would fall if a perfect match were obtained. The results from the trip distribution model are very close to a perfect match. Figure 19 presents a similar plot where the zones were aggregated into 35 sectors and the desired sector attractions plotted versus the resulting sector attractions output from the trip distribution model. Again, the results are very close, indicating the model was able to match the input NHB attractions very well. Figure 20 presents a plot of the input TLFD and the TLFD output from the trip distribution model. The line shown in Figure 20 represents the TLFD, which was output from the trip distribution model, while the data points shown represent the input TLFD. The agreement is very good. These figures indicate that the NHB trip distribution model replicates the input data and criteria very well.

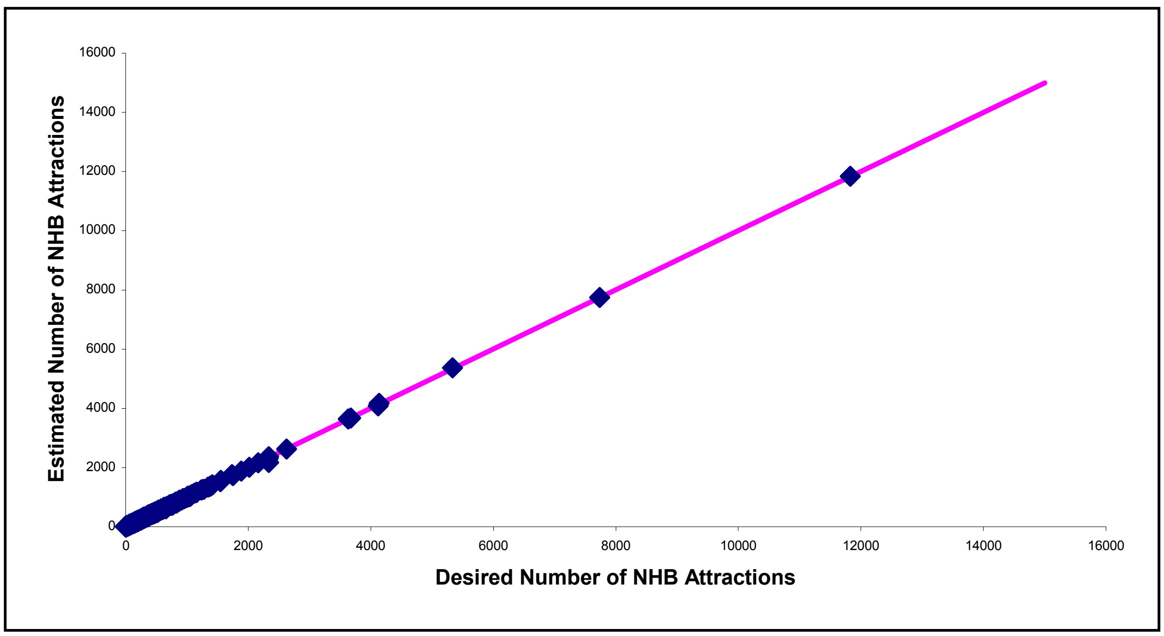

Figure 18. Estimated Zonal NHB Attractions vs. Desired NHB Attractions.

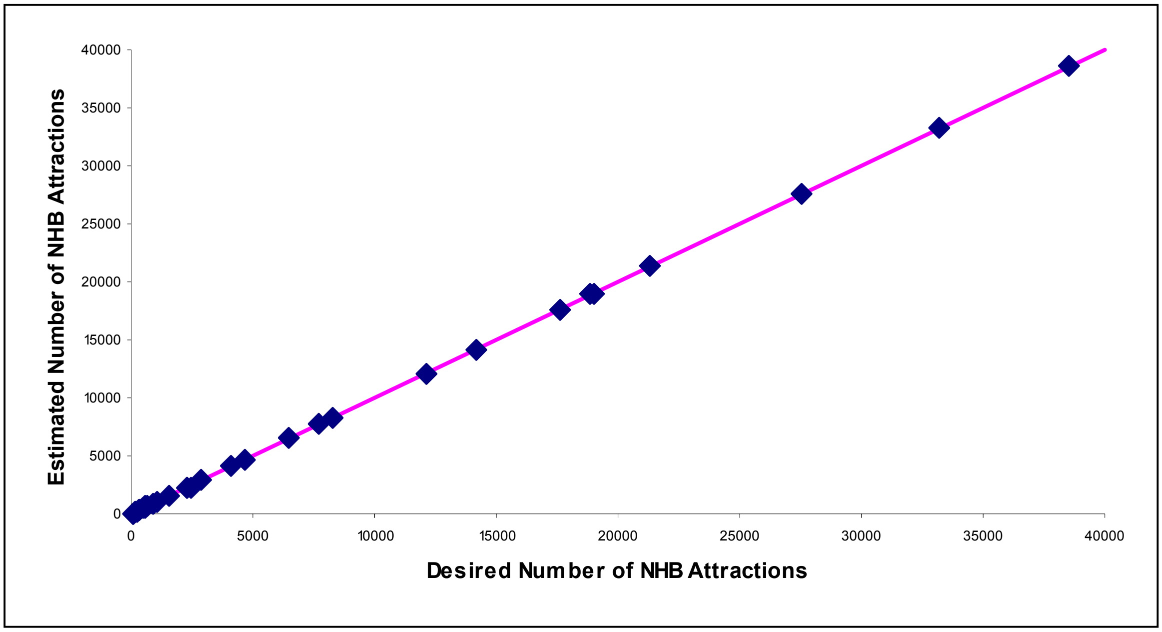

Figure 19. Estimated NHB Attractions at the Sector Level vs. Desired Attractions.

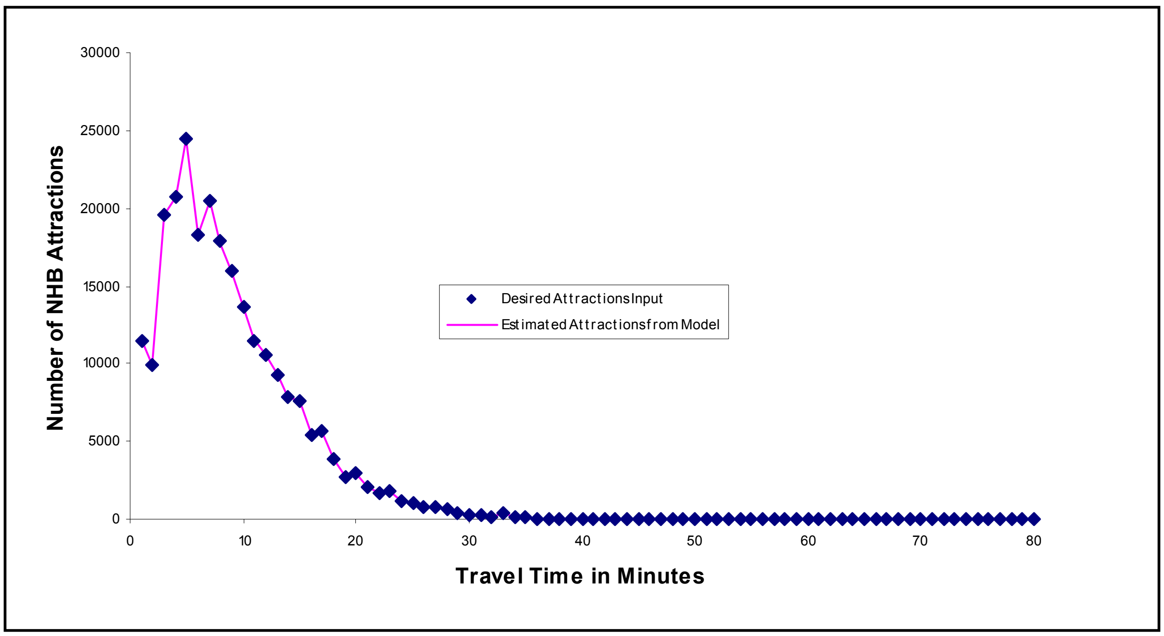

Figure 20. NHB TLFD Results from Trip Distribution.

Truck-Taxi Trip Distribution Results

The trip distribution model was run with the truck-taxi zonal trip productions and attractions input with the TLFD as computed from the 1969 OD survey data. The desired mean trip length was computed as 9.387 minutes. The resulting mean trip length from the trip distribution model was 9.408 minutes, a difference of less than 0.3 percent. Figure 21 presents a plot of the truck-taxi zonal attractions input (indicated as desired) versus the resulting zonal attractions output from the trip distribution model. The solid line shown in Figure 21 represents where the data would fall if a perfect match were obtained. The results from the trip distribution model are very close to a perfect match. Figure 22 presents a similar plot where the zones were aggregated into 35 sectors and the desired sector attractions plotted versus the resulting sector attractions output from the trip distribution model. Again, the results are very close, indicating the model was able to match the input truck-taxi attractions very well. Figure 23 presents a plot of the input TLFD and the TLFD output from the trip distribution model. The line shown in Figure 23 represents the TLFD, which was output from the trip distribution model, while the data points shown represent the input TLFD. The agreement is very good. These figures indicate that the truck-taxi trip distribution model replicates the input data and meets the calibration criteria.

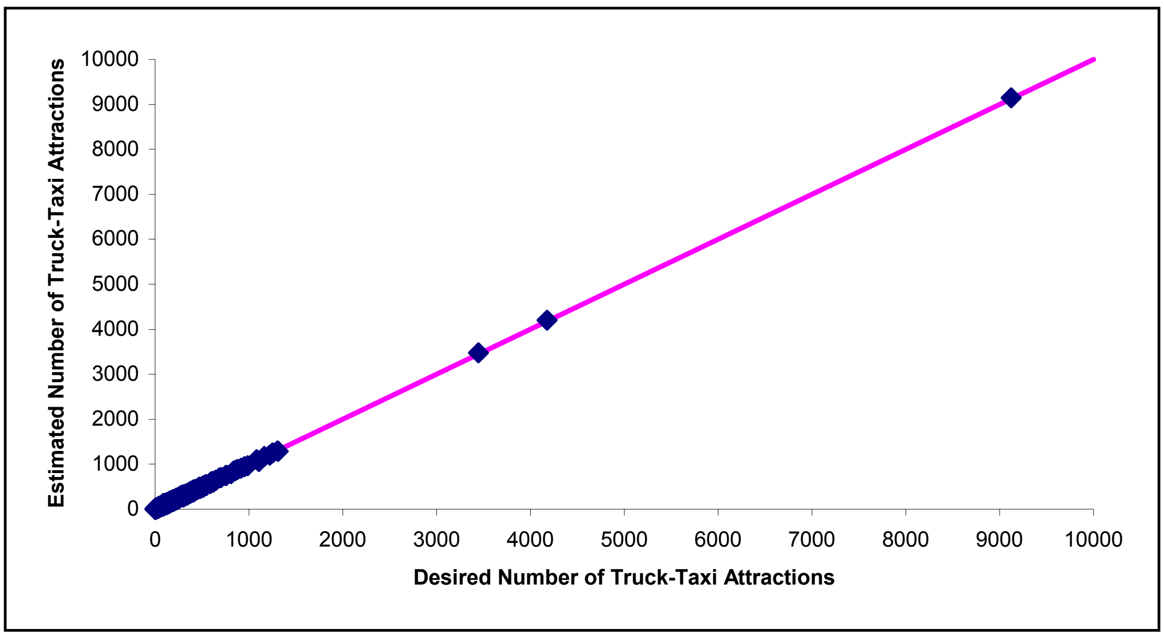

Figure 21. Estimated Zonal Truck-Taxi Attractions vs. Desired Attractions.

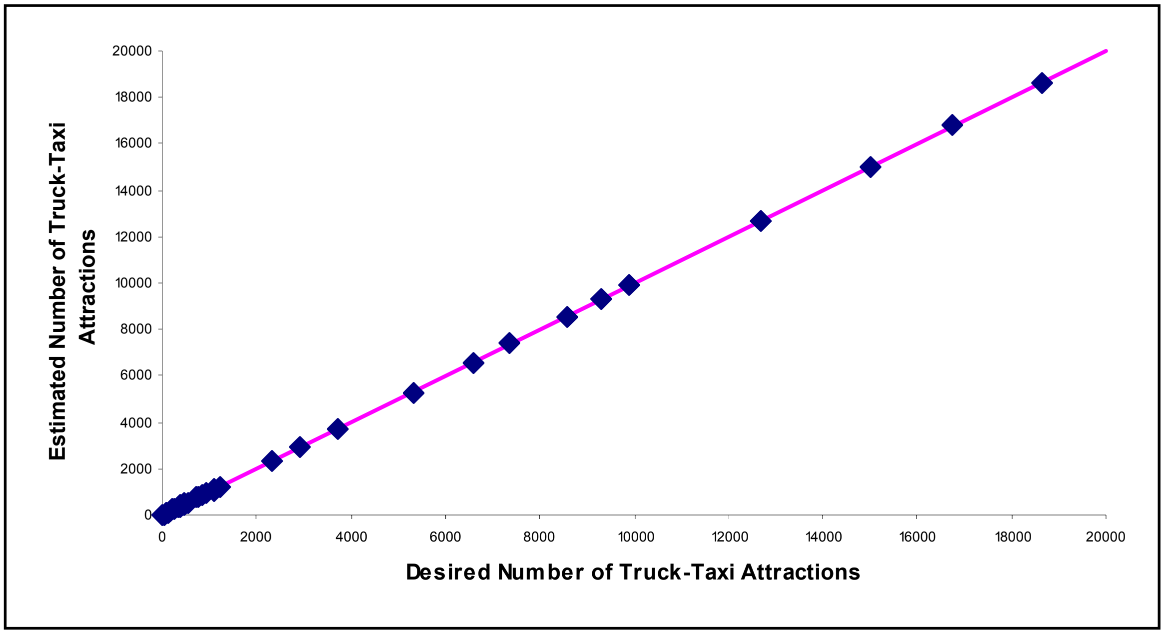

Figure 22. Estimated Truck-Taxi Attractions at the Sector Level vs. Desired Attractions.

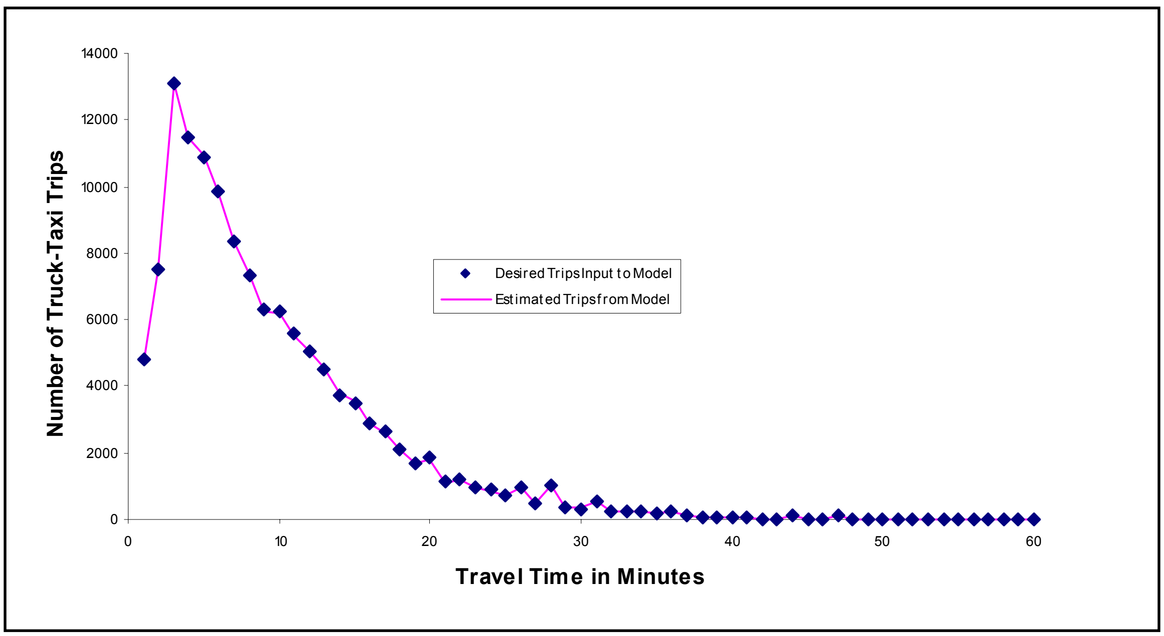

Figure 23. Truck-Taxi TLFD Results from Trip Distribution.

Non-Home-Based External Local Trip Distribution Results

The trip distribution model was run with the NHB External Local zonal trip productions and attractions input with the NHB TLFD as computed from the 1969 OD survey data. The desired mean trip length was computed as 8.899 minutes. The resulting mean trip length from the trip distribution model was 8.895 minutes, a difference of less than 0.05 percent. Figure 24 presents a plot of the NHB External Local zonal attractions input (indicated as desired) versus the resulting zonal attractions output from the trip distribution model. The solid line shown in Figure 24 represents where the data would fall if a perfect match were obtained. The results from the trip distribution model are very close to a perfect match. Figure 25 presents a similar plot where the zones were aggregated into 35 sectors and the desired sector attractions plotted versus the resulting sector attractions output from the trip distribution model. Again, the results are very close, indicating the model was able to match the input NHB External Local attractions very well. Figure 26 presents a plot of the TLFD input to the trip distribution model and the TLFD output from the model. The line shown in Figure 26 represents the TLFD, which was output from the trip distribution model, while the data points shown represent the input TLFD. The agreement is very good. These figures indicate that the NHB External Local trip distribution model replicates the input data and meets the calibration criteria.

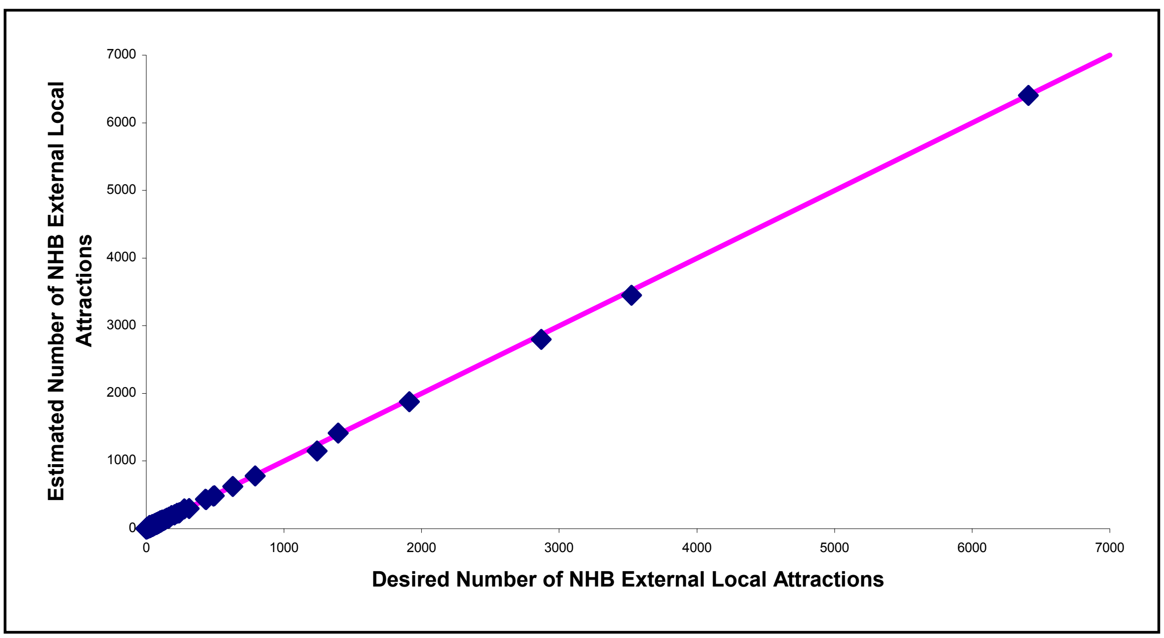

Figure 24. Estimated Zonal NHB External Local Attractions vs. Desired Attractions.

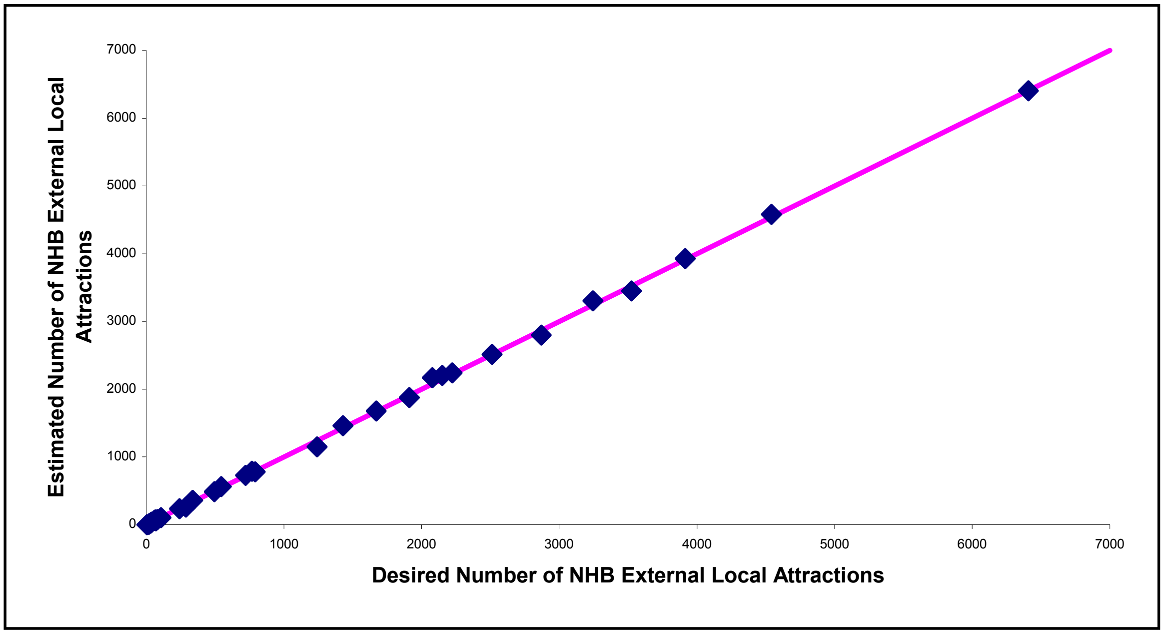

Figure 25. Estimated NHB External Local Attractions at the Sector Level vs. Desired Attractions.

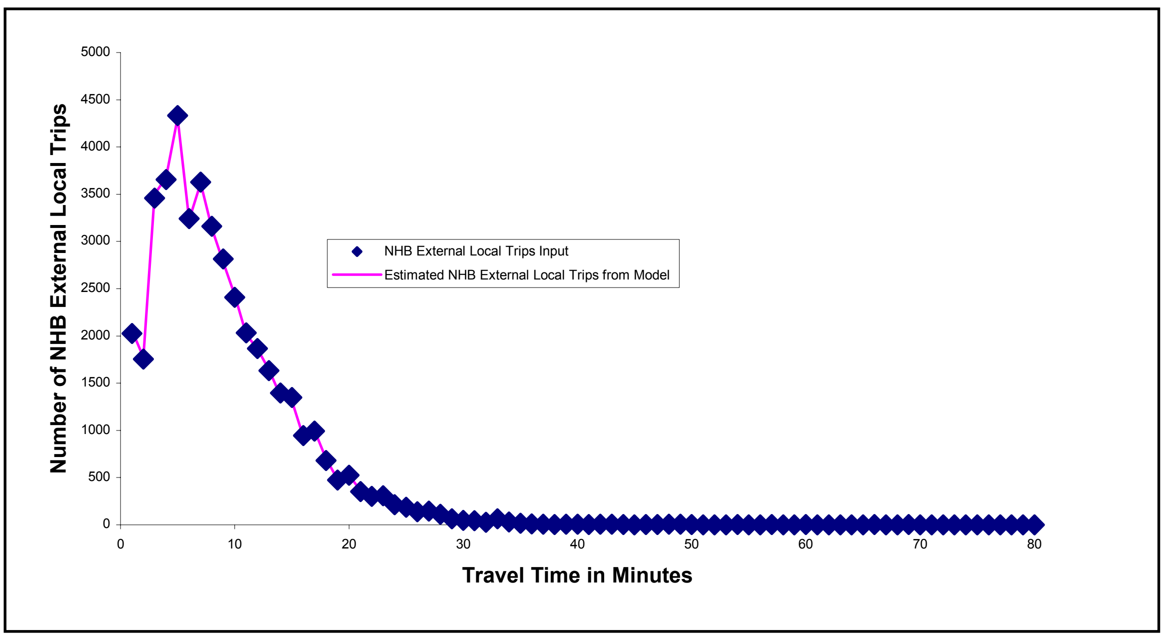

Figure 26. NHB External Local TLFD Results from Trip Distribution.

External Local Trip Distribution Results

The trip distribution model was run with the External Local zonal trip productions and attractions input with the External Local TLFD (see Figure 11) as computed from the 1969 OD report *(9)*. Calibrating the trip distribution model for external local trips was performed differently than that for the other trip purposes. External local trips are unique in that they originate as trip productions at the perimeter of the area, and the attractions to the internal zones are estimated based on the estimated zonal NHB trip productions. The distribution model then attempts to match the desired zonal attractions and the input trip length frequency distribution.

For the external local trips, an initial distribution model was run to estimate friction factors. These friction factors were then smoothed manually and input to the trip distribution model. The results were reviewed, with primary emphasis given to matching the average trip length. The friction factors were adjusted to yield approximately the same average trip length and a friction factor to travel time relationship that was generally declining as travel time increased.

Figure 27 shows the friction factors obtained from the first trip distribution run (i.e., unsmoothed) and the final manually smoothed friction factors. The desired mean trip length was computed as 31.213 minutes. The resulting mean trip length from the trip distribution model (using the smoothed friction factors) was 31.028 minutes, a difference of less than 0.6 percent. Figure 28 presents a plot of the External Local zonal attractions input (indicated as desired) versus the resulting zonal attractions output from the trip distribution model. The solid line shown in Figure 28 represents where the data would fall if a perfect match were obtained.

The results from the trip distribution model are not as good as those obtained for other trip purposes. This is not considered unusual due to the nature of external local trips. Figure 29 presents a similar plot where the zones have been aggregated into 35 sectors and the desired sector attractions plotted versus the resulting sector attractions output from the trip distribution model. Again, the results are not as good as obtained for the other trip purposes but are considered acceptable because the average trip length achieved in the distribution matched that from the survey data.

Figure 30 presents the plot of the TLFD that was observed from the survey data and that resulted from the trip distribution model using the smoothed friction factors. As can be seen in Figure 30, the two distributions are similar in shape, but the mode for each occurs at different times. The reason the distributions have about the same mean trip length has to do with the single observation in the survey at the travel time of 19 minutes. This was a high volume of trips observed in the survey between the external station on IH 35 North and the Randolph Air Force Base. While this was observed data, no attempt was made at this time to force the model to replicate that movement. The less than perfect match of the TLFD combined with the relatively low volume of external local trips was not felt to have a significant impact on the overall model results.

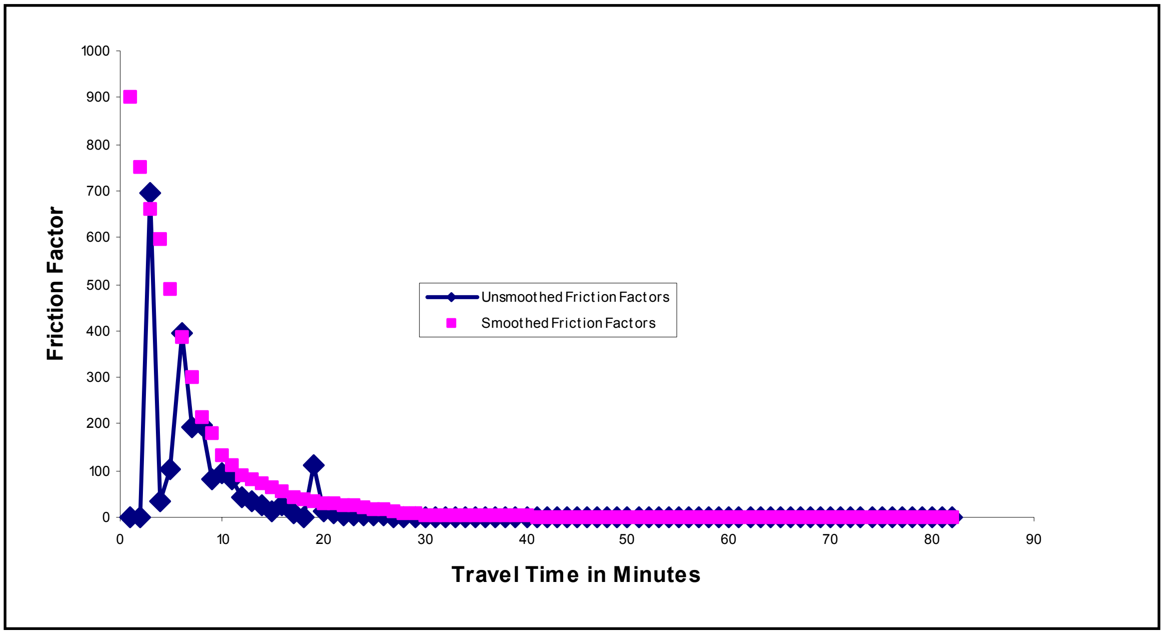

Figure 27. Unsmoothed and Smoothed Friction Factors.

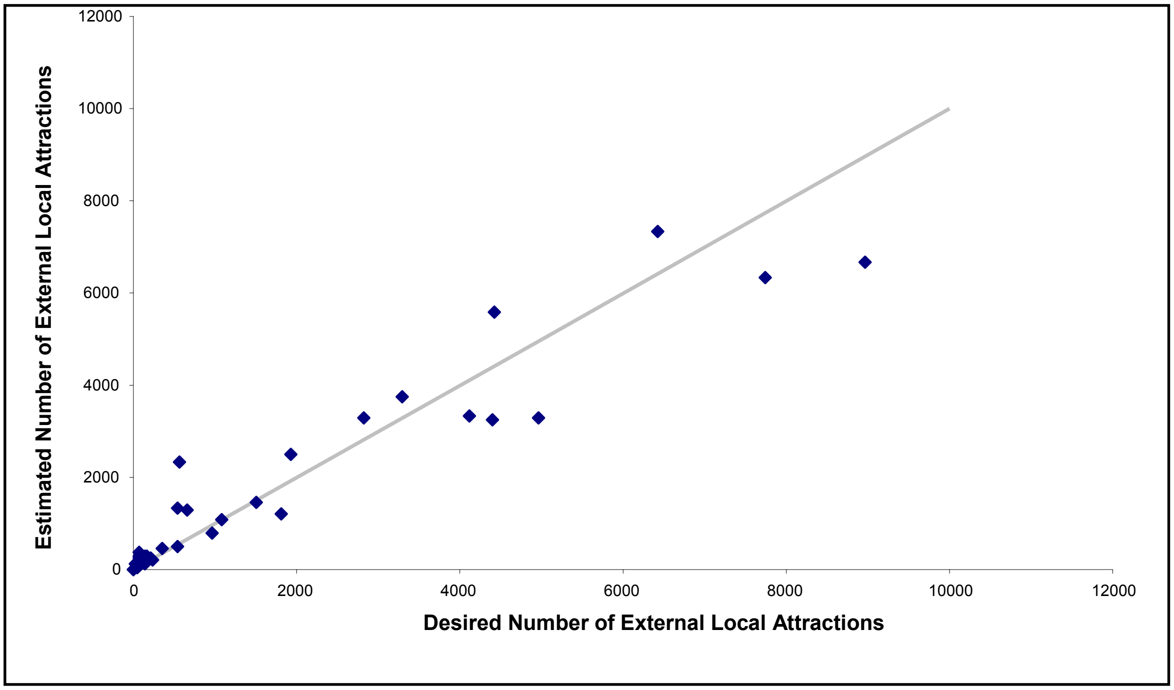

Figure 28. Estimated Zonal External Local Attractions vs. Desired Attractions.

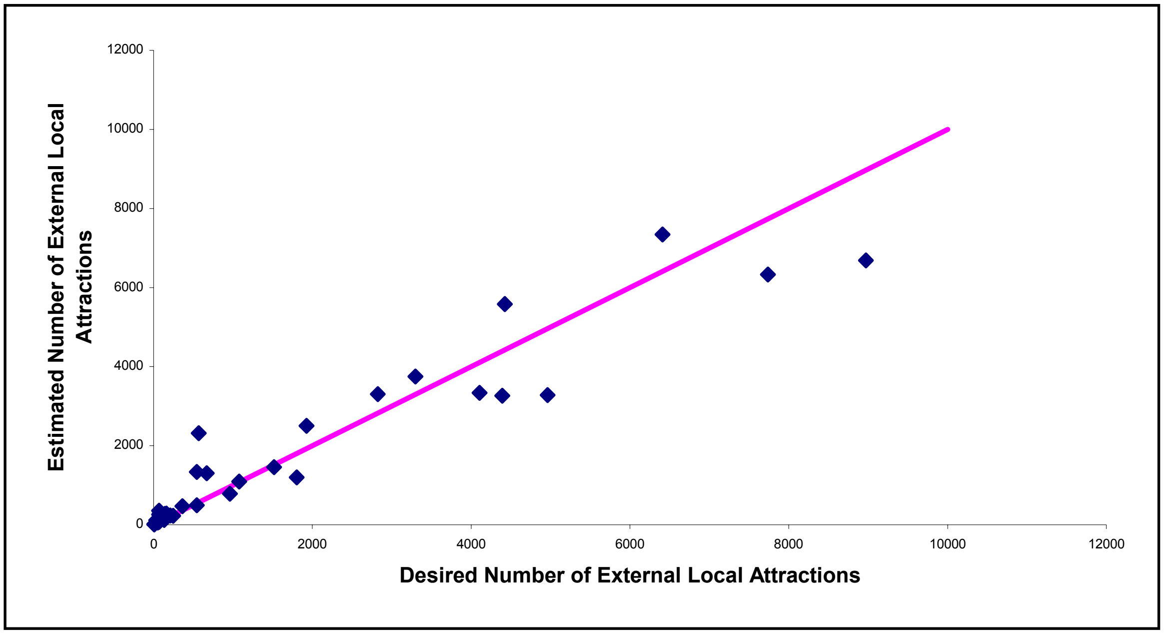

Figure 29. Estimated External Local Attractions at the Sector Level vs. Desired Attractions.

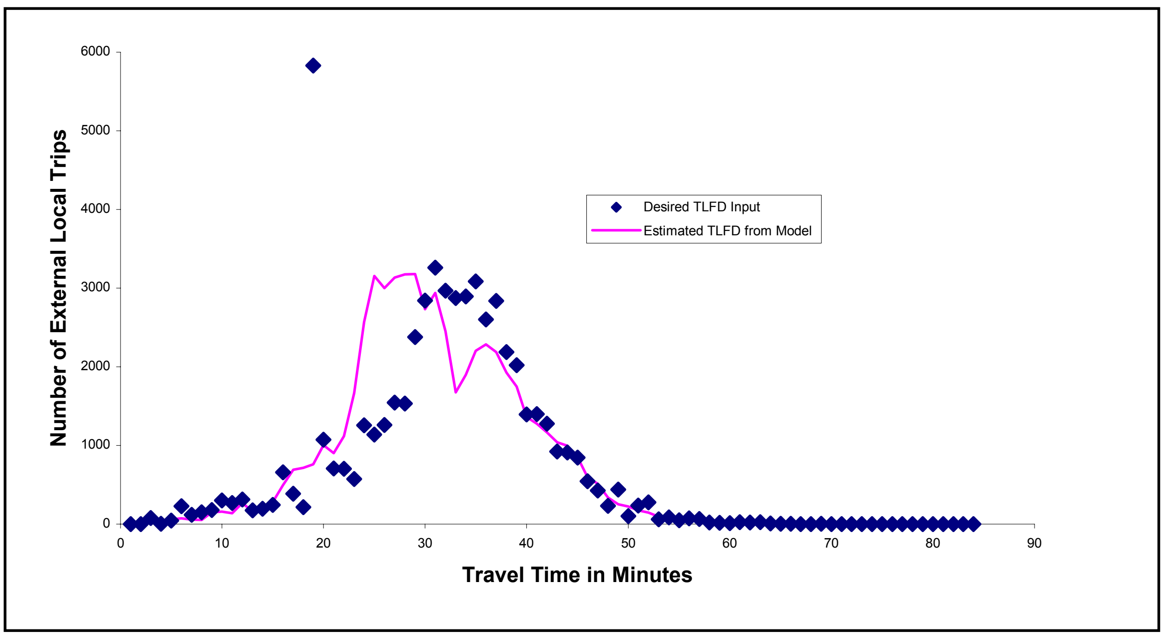

Figure 30. External Local TLFD Results from Trip Distribution.

5.4.3. Trip Distribution Model Evaluation

In terms of generally accepted criteria for calibration of a trip distribution model, the trip distribution results for 1970 produce reasonable results. With the exception of the external local trips, the model replicates the desired average trip length, TLFD, and matches the zonal attractions from the trip generation model. The individual trip tables by purpose produced in the trip distribution step were converted from production attraction tables to origin destination tables by inverting the production attraction trip table, summing it with the initial production attraction trip table and dividing the zone-to-zone movements by two. This is accepted practice for converting production attraction trip tables to origin destination trip tables. The origin destination trip tables for all purposes were summed to produce a total trip table for input to the next step, traffic assignment.

5.5. TRAFFIC ASSIGNMENT

Traffic assignment is the fourth step in the travel demand modeling process. For this research, it is the third step since no mode choice modeling is being performed. Traffic assignment is the process of identifying the routes (on the transportation network) that will be used to travel between zones. The traffic assignment algorithm selected for this research is the equilibrium assignment. This assignment is an iterative method where the link speeds are adjusted after each assignment using the Bureau of Public Roads (BPR) equation, which relates changes in link speed to changes in the assigned volume. The BPR function is specified as follows:

$$T = T_0\left[1 + 0.15(V / C)^4\right]$$

Where:

- T = congested link travel time,
- T_0 = original (free flow) link travel time,
- V = assigned traffic volume, and
- C = the link capacity.

The coefficients in the BPR function (i.e., 0.15 and 4.0) may vary by type of facility to reflect different levels of service in terms of capacity on those facilities. The default values in the software (TransCAD) used in this research are 0.15 and 4.0. These values represent a level of service (LOS) E capacity. This implies that the assigned volume on a network link must approach a capacity on the link representing a LOS E (next to the worst level of F) before the congested speed will be significantly modified to divert assigned volumes to other links in the network.

The equilibrium assignment procedure begins with an all-or-nothing assignment where all trips between zone pairs are assigned to the path (i.e., route) representing the minimum time path. Travel time between zones is computed based on the link distance and speeds as identified in the speed/capacity look-up table (see Table 2). After this assignment, the travel times on the network links are adjusted using the BPR function and a second all-or-nothing assignment performed using the adjusted travel times between all zone pairs. This procedure is repeated with the results of each iteration being weighted to assure that the total travel time for all trips on the network is minimized. An equilibrium state is achieved when no trips may be assigned to alternate routes and a reduction in overall travel time is achieved.

The OD trip table produced from trip distribution was assigned to the 1970 transportation network initially using the speed/capacity look-up table from the 1990 travel demand model and the default values for the BPR function. After reviewing the results, the process of adjustments, changes, and modifications were implemented to improve the results of the model. These included:

- corrections to demographic data at the zonal level;
- addition/deletion of links in the transportation network;
- changes in the functional classifications of facilities on the network;
- modifications to the speed/capacity look-up table to achieve a better balance of assigned volumes between different functional facilities (e.g., the speed differential between freeways/expressways and arterials were reduced to get more volumes assigned to the arterials); and
- the coefficients in the BPR function were modified to reflect level of service capacities of C for freeways and expressways. This was performed to divert more traffic from the freeways and expressways to the lower functionally classified facilities.

Each of the items listed required different steps in the model to be redone. Each time the speed/capacity look-up table was modified, the network was reprocessed to develop a new travel time matrix between all zone pairs. This also required reprocessing the 1969 OD survey data to produce the TLFDs and average trip lengths for trip distribution. All of these steps were done to calibrate and improve the model results. The results presented in the next section represent the final results as presented to the peer review panel.

5.5.1. Model Application and Results

An equilibrium assignment was run using the speed/capacity look-up table shown in Table 29. The speeds and BPR coefficients are different from the 1990 values shown in Table 2. The assignment process is the culmination of all of the previous steps in model development. While each model step was discussed individually relative to its application, results, and evaluation, the assignment step produces output that may be evaluated in many different ways. Model calibration is determined based on how well the assigned volumes match counted volumes on the transportation network. For the 1970 San Antonio-Bexar County model, these comparisons involve a significant number of estimated counts rather than actual counts. As mentioned in earlier discussion of the San Antonio-Bexar County Study area, only 35 percent of the network links had actual count data. Table 30 presents the number and percentage of network links with actual and estimated counts. Typically for model calibration, the desired percentage of links with actual counts is approximately 65 percent. Researchers recommend that greater than 65 percent of the freeway and arterial links have actual counts *(18)*. The data in Table 30 indicate only 37 percent of the freeway and arterial links meet these criteria.

The sum of vehicle counts (actual and estimated) on all links was 19,731,852. The sum of assigned volumes on all links was 19,683,272. The percent error region wide is less than 1 percent. This is well within the recommended level of plus or minus 5 percent *(18)*. Table 31 presents the percent error by functional classification with the recommended error limits. The data in Table 31 indicate the model falls within the recommended error limits with the exception of frontage roads. There were only two links in the network classified as frontage road, so the large difference for that functional class is not considered significant. Overall, the model appears to perform well in terms of the percent error by functional class.

In terms of the region wide VMT, the 1970 model VMT matches the counted VMT very well. The counted volume VMT was 8.02 million, and the assigned volume VMT was 8.09 million, a difference of less than 1 percent. This is well within acceptable criteria for region modeled versus counted VMT estimates. Note these estimates do not include VMT for any facilities except those on the network less the centroid connectors. It should also be noted that the counted VMT of 8.02 million is significantly less than the reported count VMT of 9.3 million *(14)*.

Figures 31 and 32 present comparisons of modeled VMT versus count VMT for links stratified by functional classification and area type. The facilities with the worst results represent only 10 links out of the 2,363 links in the network. For links stratified by functional class and area type, it is desirable that the modeled VMT match the counted VMT by plus or minus 10 percent. With the exception of facilities classified as expressway, divided collector, and frontage road, the plus or minus 10 percent criteria are met. The modeled VMT versus count VMT are low for area type 1 and 2 but generally meet the criteria for area types.

Table 29. 1970 Speed/Capacity Look-Up Table.

Functional Class	Functional Class Code	Area Type	Speed (mph)	Capacity (per lane)	Alpha	Beta
Radial Freeway	1	1	40.83	19,200	0.474	4.000
		2	44.36	18,900	0.474	4.000
		3	45.00	18,400	0.474	4.000
		4	46.00	16,700	0.474	4.000
		5	50.00	13,900	0.474	4.000
		6	46.08	18,400	0.474	4.000
Expressway	3	1	40.83	9,800	0.150	4.000
		2	45.36	9,600	0.150	4.000
		3	49.08	9,200	0.150	4.000
		4	52.15	8,100	0.150	4.000
		5	61.85	6,100	0.150	4.000
		6	49.08	9,200	0.150	4.000
Divided Principal Arterial	4	1	27.00	7,500	0.150	4.000
		2	28.00	7,400	0.150	4.000
		3	31.00	7,100	0.150	4.000
		4	35.00	6,200	0.150	4.000
		5	39.00	4,600	0.150	4.000
		6	35.90	7,100	0.150	4.000
Undivided Principal Arterial	5	1	27.00	6,700	0.150	4.000
		2	28.00	6,600	0.150	4.000
		3	30.00	6,400	0.150	4.000
		4	35.26	5,600	0.150	4.000
		5	38.00	4,200	0.150	4.000
		6	32.31	6,400	0.150	4.000

Table 29. 1970 Speed/Capacity Look-Up Table (continued).

Functional Class	Functional Class Code	Area Type	Speed (mph)	Capacity (per lane)	Alpha	Beta
Undivided Minor Arterial	7	1	25.00	5,900	0.150	4.000
		2	26.00	5,800	0.150	4.000
		3	28.00	5,600	0.150	4.000
		4	33.00	5,000	0.150	4.000
		5	36.00	3,800	0.150	4.000
		6	25.26	5,600	0.150	4.000
Divided Collector	8	1	13.32	5,000	0.150	4.000
		2	16.22	4,900	0.150	4.000
		3	18.27	4,700	0.150	4.000
		4	22.82	4,200	0.150	4.000
		5	31.00	3,100	0.150	4.000
		6	18.27	4,700	0.150	4.000
Undivided Collector	9	1	23.00	4,000	0.150	4.000
		2	24.00	4,000	0.150	4.000
		3	26.00	3,800	0.150	4.000
		4	31.00	3,400	0.150	4.000
		5	34.00	2,600	0.150	4.000
		6	18.27	3,800	0.150	4.000
Frontage	11	1	40.00	15,000	0.150	4.000
		2	40.00	15,000	0.150	4.000
		3	40.00	15,000	0.150	4.000
		4	40.00	15,000	0.150	4.000
		5	40.00	15,000	0.150	4.000
		6	40.00	15,000	0.150	4.000

Table 29. 1970 Speed/Capacity Look-Up Table (continued).

Functional Class	Functional Class Code	Area Type	Speed (mph)	Capacity (per lane)	Alpha	Beta
Circular Freeway	12	1	40.83	19,200	0.474	4.000
		2	44.36	19,700	0.474	4.000
		3	46.08	20,100	0.474	4.000
		4	48.00	18,900	0.474	4.000
		5	51.00	16,900	0.474	4.000
		6	46.08	20,100	0.474	4.000

Table 30. 1970 Network Links with Actual and Estimated Vehicle Counts.

Functional Classification	Total Number of Links	Links with Actual Counts		Links with Estimated Counts	
		Number	Percentage	Number	Percentage
Radial Freeway	161	118	73%	43	27%
Expressway	8	4	50%	4	50%
Divided Principal Arterial	74	33	45%	41	55%
Undivided Principal Arterial	702	227	33%	475	68%
Undivided Minor Arterial	831	236	28%	595	72%
Divided Collector	5	1	20%	4	80%
Undivided Collector	521	136	26%	385	74%
Frontage	2	0	0%	2	100%
Circular Freeway	61	58	95%	3	5%
Total	2,365	813	34%	1,552	66%

Table 31. Percent Error by Functional Classification.

Functional Classification	Recommended Error Limit[1]	1970 Model Percent Error
Freeways	Less than 7%	4.5%
Principal Arterials	Less than 10%	3.1%
Minor Arterials	Less than 15%	0.2%
Collectors	Less than 25%	2.1%
Frontage Roads	Less than 25%	55.6%

[1] Reference (*18*).

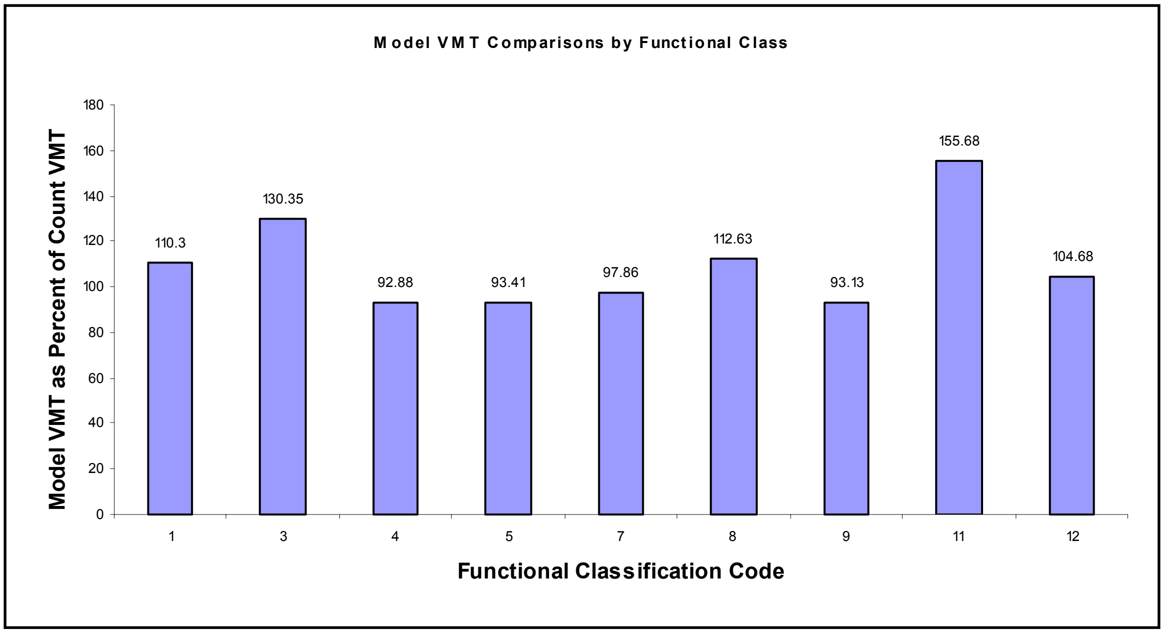

Figure 31. Model VMT Comparison to Count VMT by Functional Class.

<u>Code</u>	<u>Functional Class</u>	<u>No. Links</u>
1	Radial Freeway	159
3	Expressway	8
4	Divided Principal Arterial	74
5	Undivided Principal Arterial	702
7	Undivided Minor Arterial	831
8	Divided Collector	5
9	Undivided Collector	521
11	Frontage	2
12	Circular Freeway	61

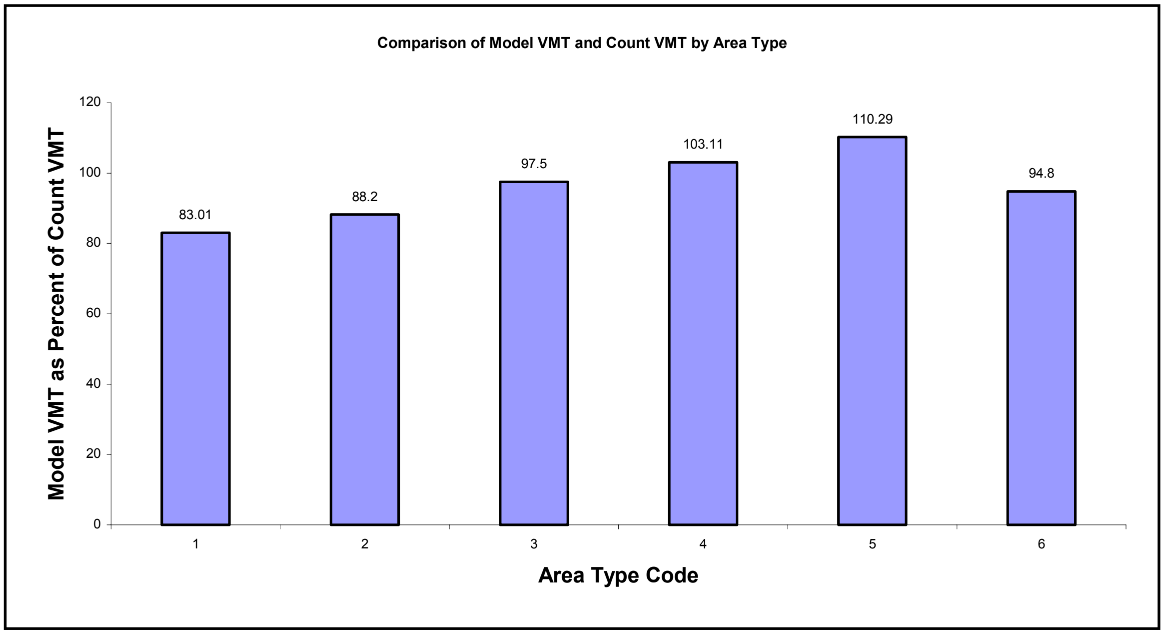

Figure 32. Model VMT Comparison to Count VMT by Area Type.

Area Code	Area Type Description	No. Links
1	Central Business District	28
2	Urban	146
3	Urban Fringe	557
4	Suburban	642
5	Rural	985
6	Military	5

Figure 33 presents a comparison of assigned volumes and count volumes for links grouped by volume group. The data presented shows that the maximum difference in total assigned volumes is less than 20 percent of the count volumes for links within any volume group. The percent differences are mostly acceptable. The percent difference for the volume group 60,000 plus is not considered acceptable. Figure 34 presents a different plot that shows the percent root mean square for each of the count volume groups. The percent root mean square is a composite measure of how much deviation there is between the assigned and counted volumes on the links within each volume group. Researchers expected that the percent root mean square will decline as the volume group gets larger. The data in Figure 34 are consistent with this expectancy. It is noted, however, that typical percent root mean square values for the high volume ranges are less than 15 percent. The results of the 1970 model are higher than 15 percent for the high volume groups.

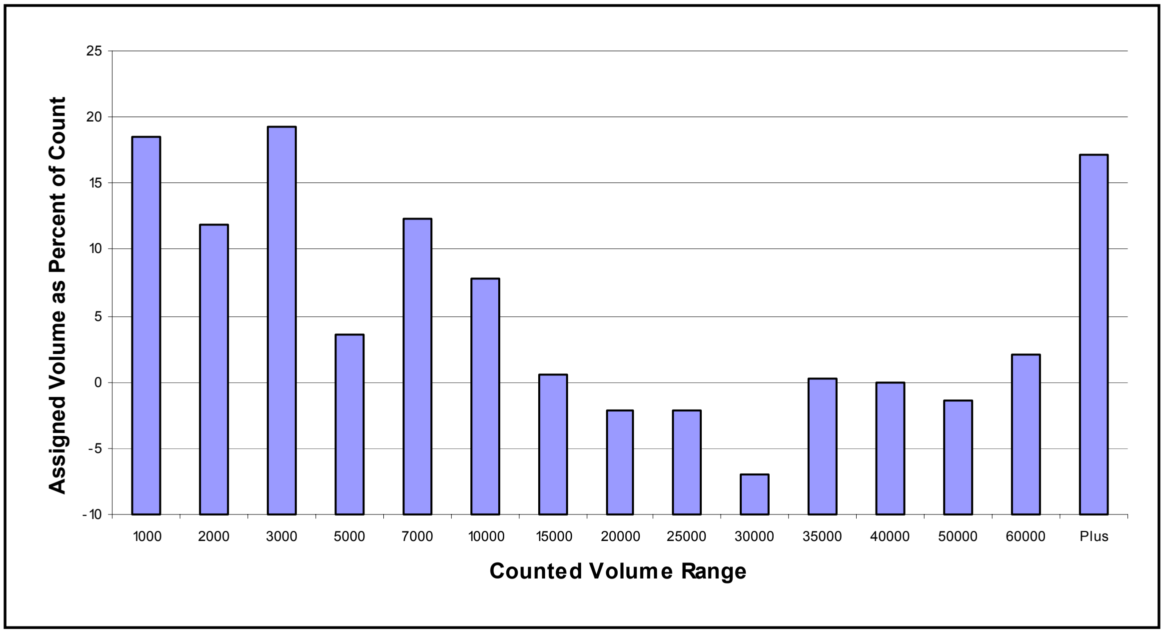

Figure 33. Assigned Volume as Percent of Count Volume for Links Grouped by Count Volume.

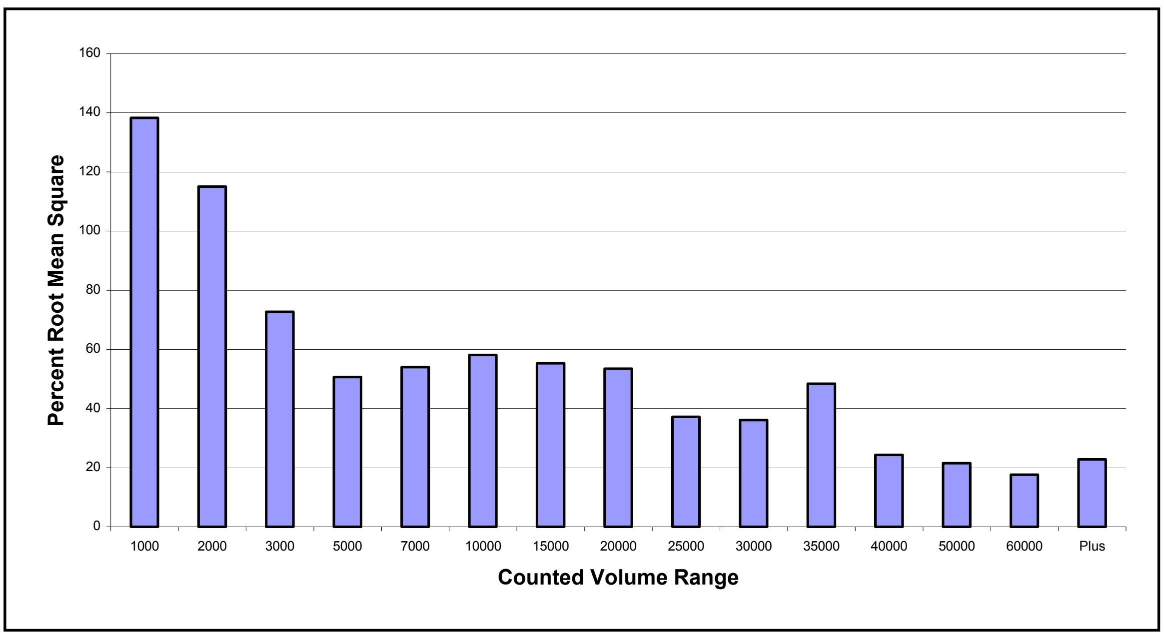

Figure 34. Percent Root Mean Square for Assigned vs. Counted Volumes for Links Grouped by Counted Volume Ranges.

For the assigned VMT by functional classification, the expected distribution of VMT for a large urban area is 40 percent on freeways and expressways, 27 percent on principal arterials, 18 to 22 percent on minor arterials, and 8 to 12 percent on collectors *(18)*. The 1970 modeled VMT had 47 percent on freeways and expressways, 33 percent on principal arterials, 16 percent on minor arterials, and 5 percent on collectors. These differences may be due in large part to the network being used. The 1970 network was not as detailed as that used in the original 1970 model, and the lack of detail would tend to put more VMT on the higher functional classified facilities. It should also be recognized that the expected distribution values were published in 1990 and may not be applicable to what would be expected in 1970.

A total of 73 cut lines were used to evaluate the performance of the 1970 model with respect to travel movements within corridors in the study area. These were consistent with the cut lines used in the 1970 model, as depicted on the network maps with assigned and counted volumes. Due to the changes (i.e., the reduction in network detail) in the network used for this 1970 model, some of the cut lines (four) only had one link. These were excluded from evaluation. Figure 35 presents the 1970 network used in this research with the cut lines illustrated. Table 32 presents the comparison of assigned and counted volumes for the cut lines. The desired level of performance for a model is for the assigned volumes to match the counted volumes within plus or minus 15 percent for each cut line.

The cut lines in Table 32 with count volumes that have a value greater than 0 as the last digit indicate those cut lines where there were differences in the original 1970 network and the network being used in this research. These differences were noted because the count volumes could not be used directly from the original 1970 network, and modifications were required. For the 69 cut lines shown in Table 32, only 37 (54 percent) meet the criteria of the assigned volume being within plus or minus 15 percent of the count volume. Figure 36 presents the percent difference in assigned and counted volumes plotted versus the counted volumes for the cut lines. The solid line in Figure 36 represents the desired level of plus or minus 15 percent. Just over half of the data points fall below the desired level of accuracy.

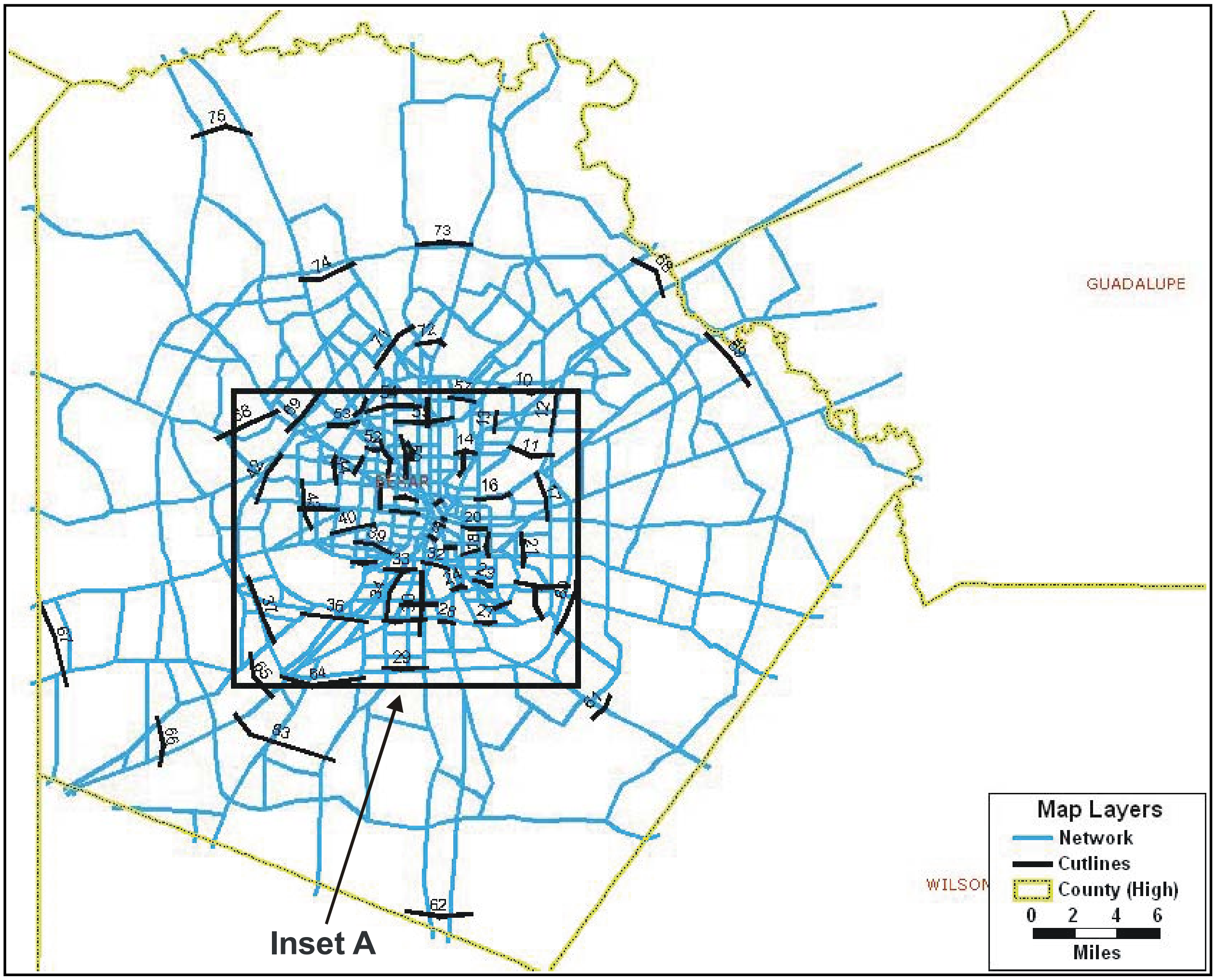

Figure 35. Cut Line Locations.

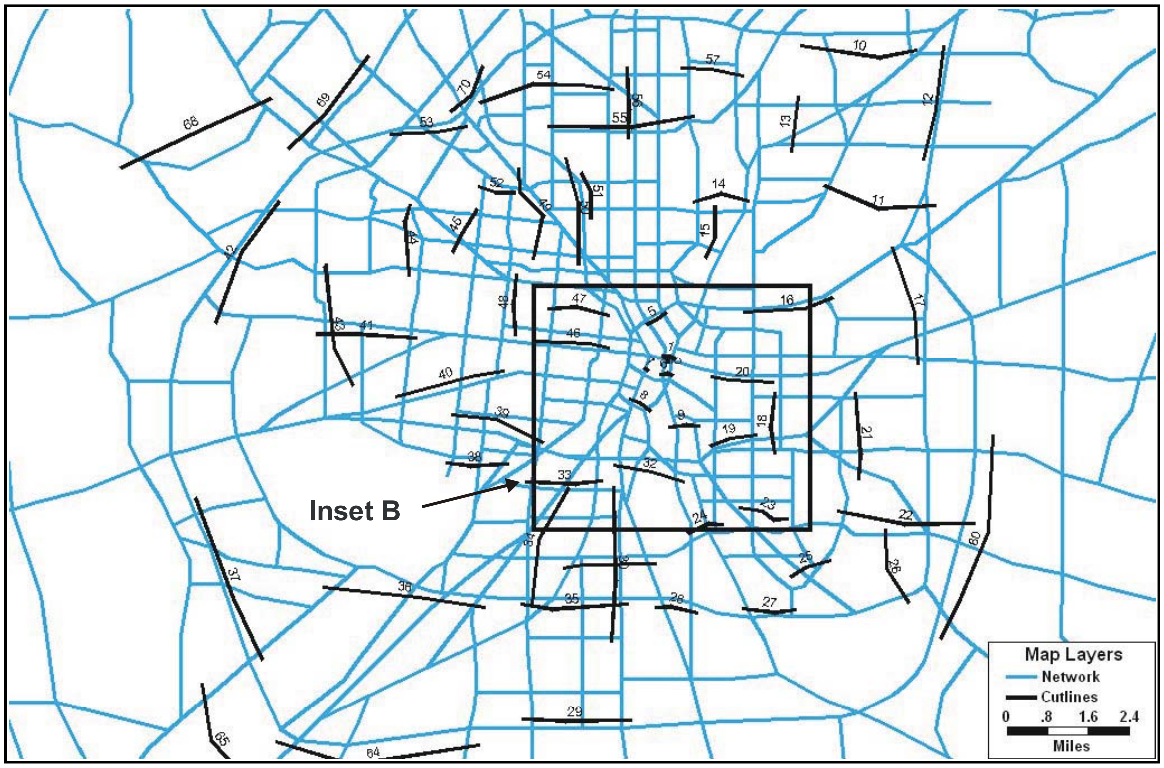

Figure 35. Inset A.

Figure 35. Inset B.

Table 32. 1970 Counted and Assigned Volumes by Cut Line.

Cut Line Number	Number of Links	Count Volume	Model Volume	Percent Difference
1	2	68,582	59,242	13.62
5	2	60,380	54,029	10.52
6	2	39,831	59,121	-48.43
8	2	33,740	33,086	1.94
9	2	32,980	37,166	-12.69
10	2	21,360	24,091	-12.79
11	3	60,330	62,929	-4.31
12	3	26,760	30,851	-15.29
13	3	20,821	22,042	-5.86
14	2	37,320	32,683	12.43
15	2	20,962	21,565	-2.88
16	2	30,580	49,888	-63.14
17	4	60,700	65,517	-7.94
18	3	30,442	47,869	-57.25
19	2	24,150	39,337	-62.89
20	2	21,550	25,543	-18.53
21	3	15,821	17,683	-11.77
22	4	21,210	16,799	20.79
24	3	26,591	24,798	6.74
25	3	27,700	27,952	-0.91
26	2	12,340	5,583	54.75
27	2	11,200	8,028	28.32
28	2	17,580	17,783	-1.16
29	3	4,260	4,858	-14.03
30	5	41,430	36,424	12.08

Table 32. 1970 Counted and Assigned Volumes by Cut Line (continued).

Cut Line Number	Number of Links	Count Volume	Model Volume	Percent Difference
31	3	51,140	44,643	-12.70
32	3	29,322	33,896	15.60
33	3	86,890	84,598	-2.64
34	4	48,470	32,004	-33.97
35	4	35,960	39,340	9.40
36	4	15,790	14,888	-5.71
37	4	20,290	22,987	13.29
38	3	38,011	40,345	6.14
39	3	43,400	42,794	-1.40
40	3	36,070	30,010	-16.80
41	3	8,680	12,065	39.00
42	3	6,600	8,959	35.74
43	3	14,100	16,749	18.78
44	3	12,560	11,174	-11.03
45	3	24,130	17,513	-27.42
46	2	17,260	26,214	51.87
47	2	19,211	42,306	120.22
48	2	33,540	31,289	-6.71
49	4	42,751	29,581	-30.81
50	5	102,210	102,454	0.24
51	2	41,581	42,070	1.18
52	2	13,250	23,348	76.21
53	3	26,300	37,891	44.07
54	4	78,211	71,727	-8.29
55	5	77,080	56,403	-26.83

Table 32. 1970 Counted and Assigned Volumes by Cut Line (continued).

Cut Line Number	Number of Links	Count Volume	Model Volume	Percent Difference
56	3	20,801	17,407	-16.32
57	2	17,611	21,786	23.71
58	2	13,792	15,788	14.47
59	2	8,380	10,563	26.05
60	3	6,960	9,859	41.65
62	2	4,610	4,727	2.54
63	3	12,330	15,534	25.98
64	3	14,220	17,278	21.51
65	2	10,850	14,319	31.97
66	2	7,490	8,191	9.35
67	2	5,501	6,207	12.83
68	2	7,830	8,399	7.27
69	3	13,620	16,718	22.75
70	2	37,270	37,556	0.77
71	4	17,041	14,764	-13.36
72	2	24,830	11,413	-54.03
73	2	3,350	2,684	-19.87
74	2	10,500	11,751	11.92
75	2	5,881	6,537	11.15
Totals		1,934,294	1,991,596	2.96

The VMT per capita for 1970 was computed and compared to estimates of VMT per capita for other urban areas in Texas for the same time period. These data were obtained from unpublished records but are believed to represent the estimates developed from the travel demand models for those areas. Table 33 presents this comparison. The estimate of 9.68 from the 1970 travel demand model developed in this research is 14 percent less than that estimate published in the 1976 research *(14)* and 34 percent less than that estimated in the original 1970 travel demand model (assumed to be the source). In comparison with other urban areas in 1970, the estimate of 9.68 appears low.

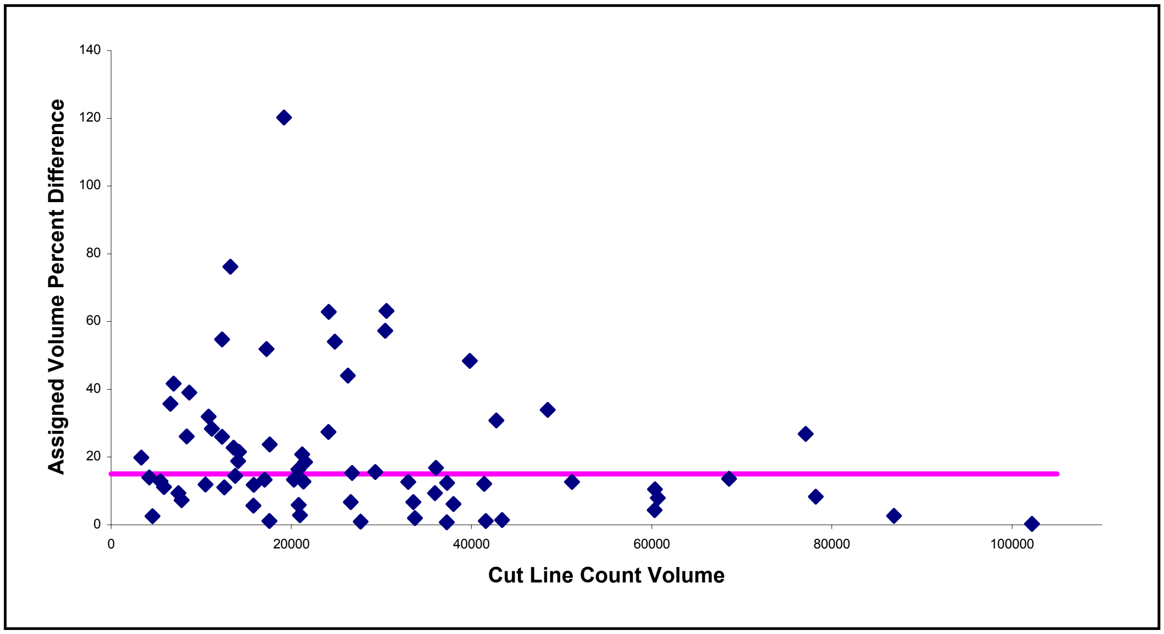

Figure 36. Percent Difference in Assigned and Count Volumes for Cut Lines.

Table 33. VMT Per Capita Comparisons.

Urban Area	Year	VMT Per Capita
Abilene	1970	12.40
Austin	1970	12.86
Corpus	1970	11.14
El Paso	1970	9.20
Houston-Galveston	1970	15.48
Lubbock	1970	10.53
San Angelo	1970	8.41
San Antonio (1970 Model)	1969	14.61
San Antonio (1976 Research)	1970	11.23
San Antonio (Current Model)	1970	9.68
Texarkana	1970	11.22
Wichita Falls	1970	10.56

5.5.2. Assignment Model Evaluation

The results of the trip assignment in some respects met the criteria for model calibration. The total assigned VMT for the study area matches the counted VMT. The assigned VMT by functional classification and area type meet generally accepted criteria with a few exceptions. The comparison of assigned and counted volumes at the cut line level falls short of meeting the criteria generally used for that performance measure. The reason for this may be the distribution of demographic data at the zone level, especially the employment estimates.

In terms of reasonableness of the modeled VMT by functional classification, the model appears to have too much VMT assigned to freeways and principal arterials. This may simply be a result of the aggregate nature of the network being used in this model development. The assignment model produces results that are a direct result of the previous steps in the model development and the assumptions made in developing the transportation network (i.e., functional classification, number of lanes, speed capacity look-up table). Subsequent runs of the assignment model established that there was little congestion in the system. The assignment results were for the most part simply all-or-nothing assignments.

Modification of the coefficients for the BPR function used in the equilibrium assignment to raise the level of service on freeways and expressways did divert some of the assigned traffic to other facilities and improved the results, but only marginally. The discrepancy between the counted VMT in the model and that published in the 1976 research *(14)* of 8.02 million and 9.3 million respectively indicates a significant difference in the count data being used for calibration of the model. These data are not a function of the model and serve as an independent measure of the model results. Count data for this model were found for only 35 percent of the links. The modeled VMT per capita for 1970 appears significantly lower than expected based on data from other urban areas and estimates for the original 1970 model in San Antonio and Bexar County.

6. SUMMARY EVALUATION OF THE 1970 TRAVEL DEMAND MODEL

The 1970 travel demand model developed for the San Antonio-Bexar County study area was based on data from the 1969 OD survey, the 1970 census, published transportation studies for the area, and information from the 1990 travel demand model for that area. The purpose of this section is to present a summary of the 1970 travel demand model and its results in terms of model calibration.

6.1. CALIBRATION CRITERIA

The criteria for calibrating the 1970 travel demand model were more stringent than would normally be applied in a model development. This was the result of having published data available for comparison of model results. In a typical model development, estimates of data such as total trips, trips by purpose, average trip length, VMT, etc. would result primarily from the model development and application. Establishing the reasonableness of the model estimates would be accomplished by comparing the results against national standards, previous models, or estimates from other urban areas.

In this research, data were available from published research and various reports. Researchers assumed for the purpose of this research that these estimates were correct. The following criteria were considered in evaluating the model results relative to its accuracy and reasonableness:

- The number of vehicle trip productions by trip purpose should reasonably match those estimates published in the 1969 San Antonio-Bexar Count OD survey *(9)* and in the 1976 National Cooperative Highway Research Program (NCHRP) research report FHWA-RD-76-43 *(14)*. Since the model being developed in this research used a different method for trip generation and linked trips according to current practice, it was recognized that some differences would be found between the number of trips by trip purpose.

- The scaling factors for balancing trip productions and attractions by purpose should be reasonable and meet generally accepted criteria.

- The average trip length in minutes should reasonably match those estimates published in the 1976 NCHRP research report *(14)*. It was recognized that the network being used in this research was considerably different from that used in the 1976 research, so some judgment would be necessary to determine what was and was not a reasonable match.

- The TLFD and average trip length by trip purpose output from trip distribution should reasonably match the values input to the model.

- The VMT estimates from the model should reasonably match the published VMT estimates from the 1976 NCHRP research. This was considered valid criteria since the model used in that research was the 1970 travel demand model for the San Antonio-Bexar County area.

- The model estimates should meet generally accepted criteria for calibration in terms of modeled VMT estimates by functional class, area type, regional, and cut lines.

6.2. 1970 MODEL CALIBRATION EVAUATION

This discussion presents an evaluation of how the 1970 travel demand model performed relative to the calibration criteria discussed in the previous section. Much of what is presented is a summary of information contained in other sections of this report. To reduce the amount of repetitive information, where appropriate, the data presented earlier will be referenced.

The vehicle trips estimated in the 1970 model were 14 percent less than the estimated vehicle trips in the published 1969 OD travel survey. When compared to the number of vehicle trips in the 1976 research, the 1970 estimate is slightly improved with the difference being 13 percent less. The 1970 estimate of HBW vehicle trips is higher than the 1969 survey estimate by just over 5 percent but is less than the 1976 research estimate by just over 5 percent. The 1970 estimates of HBNW and NHB trips are less that the 1969 survey and 1976 research estimates by 18 to 28 percent. Table 25 presents the actual numbers.

The significance of these differences is their potential impact in terms of estimates of VMT and the results of comparing modeled volumes against counted volumes. This difference will propagate through the entire modeling process. The distribution of vehicle trips by purpose was different between the 1969 survey, the 1976 research, and the 1970 model. As expected, the 1970 model had a higher percentage of HBW vehicle trips (31.2 percent) than the 1969 survey (25.5 percent) or the 1976 research (29.1 percent). This may be partially explained by the trip linking used in the processing of the survey data. The 1970 model estimate of NHB trips as a percentage of the total was 20 percent, much less than that for the 1969 survey (23.7 percent) and the 1976 research (24.1 percent). Interestingly, the 1970 model estimate was closer (in percent terms) to the observed distribution than the estimates from the 1969 survey or the 1976 research.

In the evaluation of the scaling factors applied to balance the trip productions and attractions, the results were very good with the factors ranging from 0.96 for NHB to 1.026 for HBW. These factors were expected to be very close since the attraction models were developed using the same data set as the production models. The scaling factor for truck-taxi trips was 1.39, which was considered acceptable.

When comparing the average trip length from the 1970 model to the trip lengths reported in the 1976 research, the differences were just over 4 percent for HBW, 4 percent for HBNW, and just over 13 percent for NHB. These were the only comparisons that could be made. For all three trip purposes, the 1970 model average trip length was less than the average reported in the 1976 research. Assuming both networks had the same average speeds, this difference would translate into the 1970 travel demand model estimating less VMT than the estimate in the 1976 research. It is difficult to gage how much of these differences may be due to the differences in the level of network detail between the 1970 model and the 1976 research. The trip distribution model was able to replicate the estimated trip length frequency distribution from the 1969 survey.

The estimated count VMT for the 1970 model network was just over 8 million. The count VMT in the 1976 research was 9.3 million, a difference of nearly 16 percent. There are two factors that impact this difference. First is the level of network detail used in the 1976 research. The network contained over 10,000 one-way links as compared to less than 5,000 in the 1970 model network. The second factor is the number of links with actual counts. Only 35 percent of the links in the 1970 model network had actual counts (as determined from the old 1970 network maps with posted assigned and count volumes). This is just over half of what is normally considered acceptable for model calibration.

The 1970 model produced VMT estimates by functional class, area type, and for the study area that was within acceptable limits for matching the count VMT for the same categories. The total count VMT for the 1970 model was significantly less than that reported in the 1976 research. The evaluation of assigned and count volumes by cut line for the 1970 model found just over half as meeting the general criteria of plus or minus 15 percent. In this respect, the 1970 model did not meet generally acceptable criteria.

6.3. PEER REVIEW PANEL

The results of the 1970 model application were presented to the peer review panel for discussion and comments. The consensus reached by that group was that the 1970 travel demand model was not calibrated. The panel felt that the lack of data limited the research effort and created sufficient questions in the results to taint any research findings. The importance of the research project in terms of its findings and how those might impact current and future modeling efforts warranted a higher standard for model calibration, which was not met in their opinion. The panel agreed that the primary reason the model could not be calibrated was the lack of demographic data (primarily employment) and information on the transportation network and vehicle counts for 1969/1970. The panel also agreed that this research question was still a critical need and the current project should provide recommendations on the data and information that needed to be archived and retained in order to accomplish this work at a future date.

7. PROJECT CRITIQUE AND RECOMMENDATIONS

The objective of this research was to develop and calibrate a 1970 travel demand model for the San Antonio-Bexar County area. Once calibrated, the model was to be applied to estimate travel demand for the area for 1980 and 1990. The 1980 and 1990 transportation systems were to mirror the transportation systems that existed at those times. The demographic data input to the models were to represent the data collected in the respective censuses.

The research design was intended to be a controlled experiment where variables that normally contribute to variation and error would be controlled (i.e., the transportation system and the input demographic data). The elements that would result in variation and error would be the travel demand models. The result would provide a measure of the ability of the travel demand models to forecast travel.

Unfortunately, the research project did not accomplish its original objectives. The project was predicated on several assumptions concerning available data. In 1970, following the completion of a comprehensive OD survey in Bexar County, a travel demand model was developed and calibrated for the San Antonio-Bexar County area. Researchers expected that the transportation network and zonal demographic data for that model would be available for this research project. This was not the case, and as a result, the efforts in this research were expended in the development of the network and demographic data using a 1990 zonal system. The 1970 census data were used to numerate and distribute the population and households to the zone system.

The employment estimates were generated using secondary sources and allocated to the zones based on a number of assumptions. A model was subsequently developed and run for 1970. The results were significantly different from published data for the 1969-70 period to raise doubt on the interpretation of any model results obtained by forecasting travel for 1980 and 1990. Researchers concluded that a 1970 model could not be calibrated for the San Antonio-Bexar County area sufficiently to warrant the continuation of the research and the application of the model to the years 1980 and 1990.

While the research project did not accomplish all of the objectives as originally proposed, it did clarify the importance of the retention of data and model results for the purpose of future analysis of models to address the original objectives of this research. It is recognized that the need to determine the ability of current modeling practice to predict future travel within the context of a controlled experimental design still exists. In light of this, Table 34 presents a recommended action plan for the retention of information/results necessary to accomplish an evaluation of model results in the future.

Table 34. Recommended Action Plan.

Action	Responsible Agency	When	Coordination	Frequency	Key Data Elements	Form
1. Retain Base Year Transportation Network	Transportation Planning and Programming Division	Following Completion of Base Year Model Calibration / Validation	None	Prior two Base Year Model updates and / or Re-validations	Link Attributes, Saturation and Estimated Counts on each Link, Speed Capacity Look-up Table	Electronic TransCAD Compatible
2. Retain Base Year Zone Boundaries	Transportation Planning and Programming Division	Following Completion of Base Year Model Calibration / Validation	With Metropolitan Planning Organization and District Planning Office	Prior two Base Year Model updates and / or Re-validations	Zone Boundaries	Electronic Geographic Information System that is TransCAD Compatible
3. Retain Saturation Count Maps / Data	Transportation Planning and Programming Division	Every 3 to 5 years when saturation / off system counts are done	With Metropolitan Planning Organization and District Planning Office	Each time saturation/off system counts are done	Facility Name, location of count, count, type of count (ADT, AADT, axles divided by two, Adjusted for seasonal / axle loadings)	Electronic PDF or PEG or Geographic Information System that is TransCAD compatible
4. Retain TripCAL5 Base Year Model Setup	Transportation Planning and Programming Division	Following Completion of Base Year Model Calibration / Validation	None	Prior two Base Year Model updates and / or Re-validations	All Data in Setup File Used to run TripCAL5 and Estimate Trip Productions and Attractions for Base Year	Electronic ASCII Input File for TripCAL5
5. Retain Trip Distribution Model Setups and Runs	Transportation Planning and Programming Division	Following Completion of Base Year Model Calibration / Validation	None	Prior two Base Year Model updates and / or Re-validations	ATOM2 input file setups including trip length frequency distributions and calibrated friction factors for each trip purpose modeled in Base Year	Electronic ASCII files for input to ATOM2 Trip Distribution Model

Table 34. Recommended Action Plan (continued).

Action	Responsible Agency	When	Coordination	Frequency	Key Data Elements	Form
6. Retain All Trip Tables	Transportation Planning and Programming Division	Following Completion of Base Year Model Calibration / Validation	None	Prior two Base Year Model updates and / or Re-validations	Trip Tables for Each trip purpose modeled in Base Year. The output from Trip Distribution for each Trip Purpose	Electronic Files compatible with TransCAD
7. Retain Results of Each Step in Base Year Model	Transportation Planning and Programming Division	Following Completion of Base Year Model Calibration / Validation	None	Prior two Base Year Model updates and / or Re-validations	Trip Generation Results, Trip Distribution Results, Mode Split Model Results, Trip Assignment Results	Electronic Output Files from TripCAL5, ATOM2, Mode Split Model Results, and TransCAD Assignments

The above data files should be clearly delineated and retained on computer disk(s) marked to indicate the urban area that was modeled. The above data will enable TxDOT or the MPO to recreate the base year model calibration/validation, if needed, as well as apply the model to a future year where the input data and network may be controlled to allow the evaluation of how well the models perform in a forecast scenario.

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