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An Investigation of the Transferability of Trip Generation Models and the Utilization of aSpatial Context Variable

Jerry Don Everett
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Jerry Don Everett entitled "An Investigation of the Transferability of Trip Generation Models and the Utilization of aSpatial Context Variable." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Civil Engineering.

Arun Chatterjee, Major Professor

We have read this dissertation and recommend its acceptance:

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Accepted for the Council:

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Vice Provost and Dean of the Graduate School

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An Investigation of the Transferability of Trip Generation Models and the Utilization of a Spatial Context Variable

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Jerry Don Everett
August 2009

DEDICATION

This dissertation is dedicated to my family. Without the love and support of my wife, Mary, I would have never achieved this goal. The love of my daughters, Danielle and Ashley, provided indescribable encouragement and motivation. My brother, Jesus, who is also my Lord and Savior, provided the resolve to complete the task. It is by His strength and not by my own ability that this work was accomplished.

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The author is grateful to the Tennessee Department of Transportation for funding the research and data collection upon which the early stages of this research were based. Additionally, the author would like to thank the Ohio Department of Transportation for providing the data for the Ohio study areas included in this research. The provision of data by the Nashville Area Metropolitan Planning Organization and the Knoxville Regional Transportation Planning Organization was also much appreciated. The work of Ms. Bing Shi and Ms. Linda Daugherty in collecting and processing the Jackson and Lakeway data was invaluable.

ABSTRACT

The cost of collecting data for travel demand modeling is high and increasing each year. Data collection costs could easily exceed the annual budget of a metropolitan planning organization (MPO) in small or medium-sized area. Many of these agencies borrow or transfer data and/or models from other areas since they cannot afford the cost of collecting local data. This study included two primary research objectives. The first was to test the appropriateness of transferring commonly used trip generation models from one urban area to another under specific circumstances. The second was to improve the transferability of models by including a variable reflecting the spatial context of households, the basic unit of trip generation used in most MPO models. The data utilized for this research were drawn from four separate travel surveys and included data for 11 metropolitan planning areas in two states

The key finding of this research was that a meaningful consistent measure of spatial context can be included in trip generation models, and it can make these models more generic and transferable. This finding that the transferability of trip production models can be improved by including an additional variable called “Area Type” should be helpful to many MPOs, which have to borrow models or survey data from other areas. The data needed for developing this variable should not pose any difficulty since it is based on population data, which is readily available from the US Census Bureau. Further, the algorithm needed to stratify grid cells and the households located in them into different categories of Area Type is available in many geographic information system software packages including TransCAD, which is widely used by MPOs of all sizes.

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Chapter 1 - BACKGROUND

Introduction

The issue of the transferability of travel relationships utilized in travel demand modeling is best understood in the context of the historical development and evolution of the processes employed today. The analysis and forecasting of travel demand in the U.S. has been data intensive since the inception of modern highway planning in the mid 1900's. During the early days of transportation planning researchers investigated and attempted to understand the basic relationships between travel, land use and the socio-demographic characteristics in urban areas. As an understanding of these linkages grew over time analysts began to look for ways to represent these relationships with mathematical equations. The desire was to be able to represent what was actually happening in an urban area with regard to travel through the use of models. These models were to be an abstraction of reality with an understanding that not all of the nuances of a region's travel would be understood or portrayed. The hope has been that the models would adequately represent what is occurring in the present based on the travel data collected. Then if one assumed that the basic relationships between the travel, socio-demographic and land use characteristics that these models represented remained the same over time the models could be used to forecast future travel for that region.

The cost of collecting data for travel demand modeling is high and increasing each year. A household-based travel survey collected using a computer aided telephone interviewing system (CATI) can easily cost $175 per household (HH). For a small or medium-sized urban area that needs a survey sample of 1500 households to develop their travel models the cost could be $225,000 or more just for data collection. This amount could easily exceed the annual budget of the agency responsible for this task. However, modelers and researchers often argue that additional detailed data are needed so that activity-based models can be developed to replace trip-based models.

Many also contend that data collection efforts should be much more frequent so the increasing impact of the use of information and communications technology on travel behavior can be better understood and modeled.

This cost is a severe deterrent for many local planning agencies. To make this point the state of Tennessee will be used as an illustrative example. As of year 2000 Tennessee has 11 areas with an urbanized population of 50,000 or more. Each of these areas is required to have a Metropolitan Planning Organization (MPO), which is responsible for conducting both short and long term transportation planning for the area. Of these 11 areas only four have conducted travel surveys in the last 30 years. Two of the 11 areas have newly established MPOs and so they have a short history, but due to the cost involved, neither of these areas currently has plans to ever conduct a local travel survey. Both of the new MPOs have working travel models that were developed from "borrowed" travel relationships, which were established for a similar–sized area during the 1970's. Tennessee's four largest MPOs each have collected household travel survey data over the past nine years. However, in most of these communities this was the first household travel data collected in four decades. Valuable information is now available on trip rates and how daily travel varies as a function of household size, income, automobile ownership, etc. for each of these four areas from the travel surveys. The total contract cost for these survey efforts was over $700,000 not including MPO staff time. The obvious question is, "why can't the other MPOs in the state utilize the data collected for the four larger urban areas for their own models?"

The common answer to the above question is that key travel parameters may be unique for a given urban area. Therefore, the preferred current practice is for each MPO to conduct data collection in their respective areas. These data are typically only used by that one MPO. However, in past decades when resources were very limited the mathematical relationships developed from these data were sometimes transferred from one area to another. However, there was only limited guidance for transferring these

relationships in a systematic way. (Sosslau, et al., 1978; Martin, et al., 1998) Usually the only criterion used was that the two areas should have a similar size population.

The questions facing the planners at the MPOs in Tennessee described in this example and also by planners in other areas of the country are: "What is the most effective way to utilize the limited resources that can be spent on gathering data and developing travel forecasting models at the local and statewide levels? Can data be borrowed from other areas, and how can it be used for developing models for the local area of interest?"

Recent research has shown that aggregate (area-wide) trip rates for Memphis, Nashville and Knoxville are very similar. (Wegmann, et al., 2004) This indicates that at least some travel characteristics such as trip generation rates may not be as unique to a specific urban area in Tennessee as once thought. So it may be possible to transfer mathematical relationships such as cross-classification tables from one urban area to another of similar size. Further, it may be possible to use the survey data instead of the models from one area to another and develop slightly different models, if necessary. However, some criteria and guidance are needed to decide in which cases a transfer of models and/or data would be justified. Transfer in this context is defined as utilizing data, relationships or models developed for one urban area in a different urban area.

Objective of this Research

This study includes two primary research objectives: (1) test the appropriateness of transferring trip generation relationships from one urban area to another under specific sets of circumstances and (2) improve the transferability of models by including a variable reflecting the spatial context of households, the basic unit of trip generation used in most MPO models.

Research Questions:

The research objectives will be achieved by investigating the following research questions:

1. Regional Context versus Population Size. Historically the size of an urban area as measured by its population has been a key or perhaps the only criterion upon which the selection decision of a suitable area from which to transfer trip generation rates is made. One research question that has not been resolved is: “Which is more appropriate -- transferring from a similar sized urban area in a different region or state of the country, or transferring from an urban area of a different size that is located within the same state?” Survey data collected using very comparable survey instruments and survey methods are available from two different states one in the Southeast and one in the Midwest. These data will be utilized to develop trip generation rates, which will then be compared through statistical analysis to identify regional differences, if any. Given the level of comparability between the data collection efforts it will be assumed that most of the variability attributable to differences in survey methods, commonly present in such comparisons, would be limited or nonexistent in this case.

2. Spatial Context within Urban Areas. Transferring trip generation relationships from one area to another is not a new idea. Researchers who have made successful transfers and those whose attempts failed have both noted that a key to success is transferring to and from areas that have a similar context. The broad research question that has not yet been answered is, “What are the key attributes of the context?” The context for travel characteristics would certainly include demographic, attitudinal and geographic characteristics, but it is not obvious which characteristics are most significant. For example, do demographic differences such as the distribution of families by life cycle stage and an area’s racial make-up play a key role, or are economic characteristics such as income level distribution and employment type distribution more important?

Alternatively, perhaps land use related factors such as density of the transportation network or degree of urbanization are important. The number of potentially significant variables related to context is so large that it would be very difficult to implement a research design that would isolate the impact of each one. It is not feasible to expect to reach a definitive conclusion on the issue from a single study. However, one important area of interest is the spatial organization of development within urban areas. For example, are there differences between travel characteristics of households in the urban core compared to those in the suburbs that are attributable specifically to the location within an urban area? Researchers to date have found it difficult to identify measurable variables that capture the impact of land use intensity and location that can be incorporated in a consistent way into trip generation analysis. Given this difficulty few researchers have included such considerations in their transferability analyses.

Therefore, the following more focused research question will be investigated: "Can a meaningful measure of urbanization be included in trip generation models to reduce the difference between models from different areas and thus improve transferability?" For example, urban areas could be divided into urban and suburban districts rather than as a single region. Then separate trip generation rates could be generated for these districts. If a consistent definition is used in different urban areas one could compare trip rates at both the regional level and the district level.

Chapter 2 - LITERATURE REVIEW

Trip Generation

Trip generation analysis is a key element of the urban transportation planning process. (Guidelines, 1967) Since trip generation is the first step of the "four-step modeling process" errors made here may be carried through the entire process. Of course, it is possible that these errors could be offset by errors made in other steps of the travel demand modeling process, but it is also possible that these errors will be enlarged by those of the other steps. Trip generation models are used to predict the number of trip ends generated by an individual household or a traffic analysis zone for a specified time period such as a 24-hour day or a peak period. There are two types of trip ends associated with each trip, productions and attractions, and separate models typically are used to predict each of these types.

Productions are defined as the home end of a home-based trip, or the origin of a non home-based trip. Household income, auto ownership, number of workers per household are some of the variables used as predictors for trip productions. Residential density, and the distance of a zone from the central business district (CBD) also may be used as predictor/independent variables, but these are not commonly used. Attractions are defined as the non home end of a home-based trip, or the destination end of a non home-based trip. Trip attraction predictors may include zonal employment, zonal floor space and accessibility of the work force. (Meyer, et al. 2001)

Trip generation models are typically based on mathematical relationships between trip ends and the socioeconomic characteristics of the residents of the zone generating the trips or the activity characteristics of the land use attracting the trips. Trip generation models are normally developed by trip purpose because trip purpose has a strong influence on travel destination and mode-choice, which are analyzed in subsequent steps of the modeling process. Area-wide production and attraction totals should be

equal. However, since they are estimated using separate models the totals do not usually match, and so the analyst must balance the two. In most cases more reliable data are available for developing the trip production models, so they are assumed to be better predictors of trips, and the attractions in each zone are balanced to productions by using a ratio of total productions to attractions. (Meyer, et al., 2001) Though a few other methods are available, there are two methods predominantly used to model trip generation in the United States (US) -- regression equations and cross-classification tables.

Transferability of Trip Generation Models

The transferability of trip generation models has been studied many times in various ways over the past forty years. Selected examples of these studies are discussed here. In an interesting analysis conducted in 1974 the spatial transferability of trip generation models was tested comparing a large urban area to both a rural area and to two smaller urban areas in southeastern Wisconsin region. (Martinson, 1974; Chatterjee et al., 1977) A comparison was made of cross-classified trip rates between a large urban area, Milwaukee, two smaller urban areas, Kenosha and Racine, and the rural area in the region. The trip rates were based on data collected in 1972. A statistical measure labeled "Q" statistic, which was based on cell means, the number of observations and cell variances was developed to allow for statistical testing between comparable groups of cells of the cross-classification tables developed for each of the areas. The findings indicated that there was a significant difference between large urban and rural trip rates for all trip purposes. However, the difference in the trip rates between the large urban area (pop. = or > 1,000,000) and the small urban areas (pop. = slightly more and slightly less than 100,000) was not significant except in two cell comparisons. The two cells for which differences were indicated were for non home-based trip rates of Milwaukee and Kenosha and home-based shopping rates for Milwaukee and Racine.

Similar research was performed as part of a National Cooperative Highway Research Program (NCHRP) project a few years later. (Grecco, et al., 1976) The analysis conducted by Martinson included only areas in the Wisconsin region. The NCHRP 167

project team extended the testing to small urban areas in different regions of the country. This second round of testing included Elizabethton, TN with a population of about 20,000, Murray, KY with a population of about 27,000 and Paducah, KY with a population of around 45,000. Comparisons were made using the same “Q” statistic as in the previous study for three trip purposes: home-base work, home-based other and non home-based. Additionally, Elizabethton’s trip rates were compared with Racine’s. In most of these comparisons a statistically significant difference was found. The authors concluded that due to these mixed results modelers should be cautious when transferring trip generation models spatially, i.e., from one area to another, and should not presume the validity of transferring trip generation rates. (Martinson, 1974; Grecco, et al., 1976)

A study with a different focus investigated the comparability of the distribution of trips by purpose in small and medium-sized cities. Little or no origin and destination travel data were available for urban areas in the state of Wyoming. (Kristoffersen, et al., 1977) The analysis was intended to develop synthesized trip generation distributions for three Wyoming cities – Laramie, Casper, and Cheyenne – each of which had a population of less than 100,000. Four different sets of regression equations for three trip purposes: home-based work, home-based other and non home-based were acquired from the highway departments. Then each set of equations was applied using socioeconomic data from twenty-one areas that ranged in population from 5500 to 107,500. Then mean values for trips estimates were calculated for each area by purpose. The study then tested the correlation between each purpose’s percentage of the total number of estimated trips and the area’s population. This study was based largely on travel data/relationships borrowed from other locations. The primary conclusion of this study was that trip purpose distribution was independent of city size. Distributions of 22.3% home-based work, 48.3% home-based other and 29.4% non home-based trips were recommended for use in Wyoming when local data are not available.

An analysis based on seven urban areas in Indiana with populations between 50,000 and 250,000 tested spatial transferability of trip generation rates and also developed a framework for making such transfers. (Mahmassani, et al., 1979) In this study trip generation characteristics were examined at three levels of aggregation: area-wide, zonal and household. These researchers found that the distribution of trips by purpose was not similar between urban areas. Within an individual area the distribution of trips by purpose was found to vary among socioeconomic groups. It was also found that area-wide trip frequency parameters should only be transferred between areas when the areas have a similar socioeconomic distribution of households. For example, it would be desirable for the two areas to have similar distributions of households based on income or vehicle ownership level. Further, the authors suggested that aggregate trip generation relationships mask the causal aspect of the relationships and great care should be taken when borrowing such equations. They instead recommended the use of disaggregate household models, which they believed can be transferred more successfully.

A 1995 study in South Africa investigated both full and partial transfers of trip production models among intercity, intra-city and intra-regional locations. (Wilmot, 1995) Three independent data sets were used for this study. The first set included data collected in 1981 from seven residential areas in four separate South African cities. The locations of the residential areas within the cities varied from inner city to satellite town, and sample sizes ranged from 66 to 103 households per area. The second data set was from five towns in the Pretoria-Witwatersrand-Vereeniging region of South Africa collected in 1985 with sample sizes ranging from 247 to 253 per town. The third data set included data from seven districts around Cape Town collected in 1984. The sample sizes for each district ranged from 48 to 174 households per area. Linear regression models for total trips were developed for each of the 19 sub-areas of the three data sets. This study included transferring these 19 linear regression models a total of 208 times among the sub-areas of a given data set. However, the comparisons were performed using only models for areas within the same data set to eliminate

inconsistencies that could have occurred due to differences in variable definitions and procedures. The purpose of the study was to gain a better understanding of the general conditions that influence the transferability of trip-generation models.

The range of transfer conditions and the number of transfers permitted the authors of the South African study to draw several inferences regarding the conditions that affect transferability. Key observations were that the quality of local data, model quality and household income differences directly impact one's ability to assess transferability. When all models transferred were considered, the transferred models explained an average of 57% of the variation in trip making, however when locally estimated constants were used to replace transferred constants the percentage rose to 87%. Thus, it was concluded that the best approach was to conduct a partial transfer where models are transferred and then updated with local data to reflect local conditions.

The Willamette Valley in Oregon includes three MPOs: Portland, Salem, and Eugene. Medford, which lies further south, has comparable characteristics and so it is often linked with the MPO areas. In 1994/1995, a household survey was conducted throughout the region. Using those data, a variety of statistical tests were performed with regard to travel demand. The most notable of these tests involved model transferability. Models were developed for each locale. Then, survey data were combined from all the areas and a single combined model was developed. Based on statistical comparisons the findings were that the trip generation and mode choice parameters were very close when comparing the local models and the combined one. One key advantage that the Oregon study had was that all data were collected from a common survey instrument. This likely provided a truer test of transferability than some previous studies. Survey methodology is often a difficult variable to control in comparative studies. (TMIP, 2004/2005; ODOT, 2000)

The Ohio Department of Transportation funded a statewide household travel survey with the data collection period between 2001 and 2003. (Casas, 2004) The study area

consisted of all counties in the state except those within the Cincinnati, Cleveland and Columbus MPO boundaries since each of those areas had recently completed their own survey. Travel data were collected from over 16,100 households for one 24-hour travel period for weekdays Monday through Thursday.

Extensive analysis was conducted of these data to determine the best way they could be utilized in the development of travel demand models in the state. (Bernardin-Lochmueller, 2004) A portion of that analysis focused on comparing the average trip production rates of various combinations of the urban areas in the state. For example, the data from the three large urban areas of Toledo, Dayton and Akron were combined and compared to three different combinations of the data from the smaller urban areas. Trip rates were compared on a cell-by-cell basis between cross-classification tables developed for each area by trip purpose, using analysis of variance (ANOVA) techniques. The overall finding was that the trip rates for Lima, Springfield and Mansfield were statistically similar and so their data should be combined. However, there were enough differences between the other urban areas so that the recommendation was that models be developed independently for each of those areas.

A recent study comparing trip generation models for the Israeli cities of Tel Aviv and Haifa concluded that the models produced statistically different results when transferred spatially. (Cotrus, et al., 2005) This study compared and contrasted the trip generation characteristics and models of person level trips. The models were disaggregate multinomial linear regression and Tobit models, which were developed based on 1984 and 1996/1997 household surveys in each metro area. The researchers concluded that in order for trip generation models to be transferable they need to account for variables not normally included in models such as income, land use and spatial structure, the transportation system, accessibility and more detailed socio economic and life style variables.

Transferability of Travel Survey Data

A few researchers have suggested that it may be better to “borrow data” from other areas for model development rather than borrowing previously developed models. (Stopher, et al., 2001) Synthetic household travel data have been developed for both U.S. and Australian urban areas using large travel surveys and large socio-demographic data sets. These “artificial” data sets are based on actual survey data from one source and individual HH member data collected via another source such as the Census. Thus, the travel characteristics of the population of the study area are borrowed from individuals with similar characteristics to the individuals in the study area.

These procedures have relied upon Classification and Regression Tree Analysis methods to categorize households and individuals within a travel survey data set into homogenous groups based upon a number of dependent variables such as household size, household income, number of cars available, etc. Next, frequency distributions are developed to capture the variation in the values of each characteristic of interest. Then samples of households and individuals are obtained from Census data for the local area of interest and linked to the simulated travel characteristics for the household categories noted above. Finally, a random sample of the households and the associated travel characteristics is drawn from the newly created ‘population’ as one would do in a travel survey. Travel relationships can then be developed based on this sample of households and the associated travel characteristics. It has also been demonstrated that the performance of this procedure can be significantly enhanced by “updating” the sample with local data through a statistical procedure call Bayesian updating. (Wilmot, et al., 2000)

These data borrowing procedures, though intriguing, present a few difficulties. First, the requirement for a large disaggregate sample of household or person level socio-demographic data can be problematic. The Public Use Micro-data Sample (PUMS), based on the Decennial Census, has historically been relied upon as the source of such data in the U.S. The PUMS file is comprised of either a one percent or five percent

sample of the household records within a PUMS area or PUMA, which typically has approximately 100,000 individuals. This is a good source of data; however, many small-sized urban areas have a population of less than 100,000, and so their PUMA will likely cover an area much larger than the actual area of interest. For example, PUMA number 47050 covers nine counties in east Tennessee including Hamblen and Jefferson. However, the Lakeway MPO which is located within that PUMA only includes Hamblen county and a portion of Jefferson county. Thus, one would either need to accept the differences between the study area boundaries and the PUMA boundaries, or develop a method to account for the differences in the household attributes in the study area and those in the PUMA area.

Second, those who have successfully implemented the development of synthetic travel data have relied upon the National Personal Transportation Survey (NPTS) as the source of travel survey data. The reason that the NPTS has been selected for this purpose is that the procedures used for developing the synthetic travel data benefit from a very large sample and the NPTS has a sample size that is 10 or more times larger than most household travel surveys. Though the current wave of the NPTS will be fully funded, it appears that the future of national level household travel surveys is uncertain given the tremendous level of difficulty encountered in gaining political support necessary to fund this round of data collection.

Finally, the procedures utilized to develop synthetic travel data rely on sophisticated statistical analysis. The areas that would most benefit from such procedures are small and medium-sized urban areas that would likely not have the required statistical expertise to undertake the challenges of implementing the method as prescribed.

Summary of Literature Review

At the present time the appropriateness of transferring trip generation relationships from one area to another is still in question. However, the Quick Response Planning Guides (Sosalau, et al., 1978; Martin, et al., 1998) published by TRB as *NCHRP Report 187*

and *NCHRP Report 365* have done much to promote transferability by providing default trip rates and trip distribution parameters to support quick response planning procedures. The reports assist areas as they undertake comprehensive transportation planning even if local travel data are not available.

It should be noted that the optimal way for making such a transfer of models has yet to be determined conclusively. Some progress has been made in transferring data rather than transferring already developed trip generation relationships. However, the complexity of developing these synthetic data may limit its application in small and medium sized urban areas. Finally, though there is agreement that the context of the areas involved in the transfer should be comparable, the parameters that should define the context are still not clearly known or well understood.

Chapter 3 – ISSUES RELATED TO THE TRANSFER OF TRIP RATES

Introduction

The evaluation of the transferability of trips rates is not as straight-forward as it may first seem. Geographic and socio-demographic differences between urban areas are readily acknowledged by planners and researchers. Some of these differences are easily quantifiable and can be controlled for the purpose of comparisons of trip rates among urban areas. Historically the residential population is the measure most commonly used to control for differences between areas. Other differences are more difficult to measure and account for; however, the advent of geographic information systems (GIS) and the development of more detailed data sets make such analysis more feasible.

The goal of an analysis of the transferability of trip rates is to compare and contrast the trip-making behavior of similar individuals or similar households in different areas. A major assumption is that if one could control for geographic and socio-demographic differences, the travel rates of the two areas would then be closely aligned if travel behavior were truly similar in the two areas. However, what often is not considered is that the data used to develop the travel rates in the comparisons may have been collected using differing definitions for variables and/or the data collection procedures may have been different. These definitional and procedural differences often are impossible to control for and may not even be known to the analyst. Thus, if these differences are significant the conclusions resulting from the analysis may be distorted or even incorrect. The discussion in this chapter acknowledges the variation in average trip rates that occurs in U.S. urban areas. It also provides a discussion of some of the key definitional and procedural differences that have been identified. An explanation of some of the steps taken to minimize the impact of these issues on this research is also provided.

Typical Average Trip Rates

A review of the literature indicated that there was a wide variation in the reported average trip rate per household and trip rate per person in different urban areas. Typical values were identified and are reported in Table 3-1. (Wegmann, et al., 2009) Generally accepted trip rate values from national data sources can be found in the 'notes' of FHWA's travel demand forecasting course (FHWA, 1994), which indicate that typically trip rates range from 8.5 to 10.5 person trips/household. National Cooperative Highway Research Program Report 365 (Martin, et al., 1998) provides trip rates shown in Table 3-2 based on urban area population. The household travel surveys conducted for the Jackson and Lakeway MPOs in Tennessee (Wegmann, et al., 2009) revealed the weighted average trip rates shown in Table 3-3. Data collected for two other Tennessee urban areas through recent household travel surveys resulted in the average trip rates shown in Table 3-4. (NuStats, 2001; NuStats, 1998)

Definitional and Procedural Considerations

It is important to garner an understanding of how the household travel surveys used to collect the data were administered and how individual variables were defined prior to comparing the average travel rates between two areas. Without that understanding it will be difficult to assess if similarities or differences found between rates are due to travel behavior or are a consequence of the difference in data collection procedures. Several of the key subjects where differences commonly occur are discussed below.

Definition of a Household

The first issue to be decided when one conducts a household travel survey is what definition of a household will be employed. This definition must consider several factors. Traditionally non-residents of a household who happen to be visiting on the travel day are not included in the survey unless the person(s) is staying with the household for an extended period of time. Similarly individuals who reside in group

Table 3-1 - Range of Typical Trip Rates

Characteristic	Range in Rates	Typical Values
Person Trips/hh	6.75 - 15.0	7.0 – 9.0
Vehicle Trips/hh	6.25 - 14.0	---
Person Trips/person	3.5 - 5.5	4.0 – 5.0

Table 3-2 - NCHRP 365 Trip Rates

Urbanized Area Pop.	Person Trips/Household
50,000 – 200,000	9.2
200,000 – 500,000	9.0
500,000 – 1,000,000	8.6
>1,000,000	8.5

Table 3-3 - Tennessee Small MPO Trip Rates

Trip Rate	Jackson	Lakeway
Person Trips/HH	8.4	9.2
Person Trips/Person	3.36	3.64
Population	92,010	102,820

Table 3-4 - Tennessee Medium and Large MPO Trip Rates

Trip Rate	Knoxville	Nashville
Person Trips/HH	8.21	8.20
Person Trips/Person	3.37	3.15
Population	489,040	1,101,410

quarters and institutions such as prisons are typically not eligible participants for a household travel survey. These conventions are widely accepted and were followed in the conduct of all the surveys used for collecting the data analyzed in this study.

One aspect of the definition of a survey household that can vary substantially is the minimum age of a survey participant. All adult household members are typically included in general travel surveys, so the pertinent issue is the minimum age of children who should be included in the survey. Often the decision hinges on the following two premises:

1. Children, especially the very young who have not yet started school, commonly travel in the company of older household members whose travel is captured by the survey.

2. Children traveling independently tend to make non-automobile trips, near home or school, and these trips usually are not included in travel demand modeling even if they were captured by a survey.

Based on these factors and the perception of added cost for each additional individual surveyed many household surveys conducted in the US in the past few decades have not included young children. The decision about including children's trips can have a substantial impact on average trip rates. An analysis of the impact of children's travel has not historically found its way into the transportation literature. However, one recent study found that for data collected from South Jersey, 14% of all trips were made by children. (Bricka, et al. 2004) The three most common alternative policies regarding the inclusion of children, found in the literature, are 1) to include all household members regardless of age, 2) to include only those above the age of 5, and 3) to include only those above the age of 16. In the recent statewide survey conducted for Ohio the travel characteristics of all household members were included (NuStats, 2004). At the other extreme the most recent household travel study conducted for Chattanooga included

only the travel of individuals over the age of 16 (Wegmann, et al., 2004). Surveys conducted in the Nashville and Knoxville areas included all children above the age of five. The Jackson and Lakeway studies also included travel characteristics for all household members over the age of 5 years (Wegmann, et al., 2009).

Definition of a Trip

Prior to comparing trip rates of one community to another it is important to understand the details of the survey procedures utilized and how a trip is defined. A few decades ago most household travel surveys were surveys of "trips", which are movements between two different locations. Participants were asked to record their trips when they moved from one location to another. The emphasis was on capturing the primary purposes for making the trips, for example going to/ from work or shopping. However in recent years many MPOs have preferred to conduct activity surveys. In activity surveys not only is the change of location recorded, but detailed information about the activities in which the respondent participated at each location are also obtained. Additionally, emphasis is placed on noting all changes in the traveler's location even the short stops made along the route from an origin to a major destination. For example in the recent Jackson/Lakeway surveys eleven activity/travel purpose categories were used including: activities at home; paid work; school; volunteer work; pick-up/drop-off person; social, recreational, church; catch a bus, train or airplane; shop; personal business (pay bills, visit doctor, etc.); eat meal (outside the home); and other. A few areas have even started utilizing time-use surveys where even more details are captured about the individual's activities along with a thorough accounting of how much time is spent for each activity.

The most recent household travel surveys conducted in Ohio, Nashville and Knoxville were activity surveys. In order to be as consistent as possible with regard to study procedures, all travel data used for this research were gathered using activity survey principles. In the Lakeway and Jackson surveys the household members were requested to include all travel related to a change in place (Wegmann, et al., 2009). So

en-route stops such as eating meals, purchasing gas were noted. The inclusion of these en-route stops affects the total number of trips and percent of trips in each purpose category as compared to the traditional trip survey. The distribution of trips by purpose could vary substantially among ‘activity’ and ‘trip’ surveys, or between two ‘activity’ surveys that utilized a different set of activity definitions. For example, in one activity survey an en-route stop at Starbucks for a cup of coffee on the way to work from home could be defined as a ‘home-based other’ trip and the second leg from Starbucks to work would be coded as a ‘non home-based’ trip, whereas in a trip survey the two trips are coupled together and coded as a single home-based work trip. This latter case is known as the ‘linking’ of trips. For this example, when the stop at Starbucks is ignored, the home-based work trip becomes a ‘linked’ trip. This difference in travel survey analysis procedure may be reflected in the fact that both the Jackson and Lakeway surveys had a lower percent of home-based work trips and a higher percentage of non home-based trips than what is shown in the FHWA guidance information (FHWA, 1994), which is based on “linked” trips. Table 3-5 presents a comparison of the trip information from these sources.

Table 3-5 - Trip Purpose Distributions

	FHWA Guidelines	**Jackson**	**Lakeway**
HBW	18 – 27%	15.6%	14.7%
HBO	47 – 54%	48.2%	48.2%
NHB	22 – 31%	36.2%	37.1%

Days of Week and Seasons of the Year for Survey Data Collection

Most household travel surveys are conducted for the purpose of collecting data for use in travel demand models. Typically these models are developed to represent average weekday in either the autumn or spring season in the region. However, some areas are now attempting to model weekend travel as well. Thus, another key data collection decision to be made is what days of the week should be eligible travel days to meet the goal of the model. Most transportation professionals agree that travel varies by day of the week and time of the year. However, there is not a consensus of opinion with regard to what days should be included in travel surveys or during which months the data should be collected. The following examples illustrate this point.

It is often assumed that Tuesday, Wednesday, and Thursday are the most typical days of the week for travel, and thus for some survey data collection is limited to these three days. The Oregon Statewide survey noted a range of 7.42 vehicle trips per household on Mondays to 9.12 vehicle trips per household on Fridays (ODOT, 2000). The Tuesday, Wednesday, and Thursday vehicle trip rates were 7.74, 8.33 and 7.57 respectively. An analysis of the 2001 National Household Travel Survey (NHTS) add-on for the Des Moines Area MPO concluded: “The most heavily traveled three days of the week in terms of the percent of the vehicle trips per day of the week were Monday and Friday with 15% each, and Tuesday with 17.4%. The remaining four days of the week had the following proportions: Saturday with 14.6%; Wednesday with 13.2%; Sunday with 12.2%; and Thursday with 11.8% of the weekly trips”. (Kane, 2004) When using person trips, “the rankings change slightly. Saturday rated highest among person trip/day, with 16.1%, Tuesday was second, with 15.8%, and Sunday was third, with 15.4%. The remaining four days of the week had the following proportions: Monday 15.3%; Friday 14.1%; Wednesday 12.3% trips; and Thursday 11.1% of the weekly person trips. These NHTS data indicated that the days people most typically travel are the weekend days and Tuesdays. While the rankings do vary by day between the vehicle trip category and person trip category, Wednesdays and Thursdays are not among the three most heavily/typically traveled days of the week in either category.”

(Kane, 2004) It should be pointed out that trip purposes and trip destinations for weekend days are expected to be very different from those of weekdays.

The spring and autumn are commonly selected as the seasons to conduct household travel surveys because they are assumed to have more typical travel conditions. During summer most schools are not in session and many people make vacation trips, therefore summer months usually are excluded for travel surveys except in special cases. Winter months are not considered typical due the impact of weather conditions on travel in some parts of the country. However, in some cases finding typical travel periods may be difficult. Data collected from Des Moines found some of the peak travel months to be in the summer and winter seasons as noted in Table 3-6. Oregon researchers found a range of trip rates from 9.1 person trips/household in May to 4.8 person trips/household in December as noted in Table 3-7. (ODOT, 2000) So it is clear that daily and seasonal variations can occur and may vary by locality. The Lakeway and Jackson surveys used in this research were conducted over a period seven months to limit the impact of seasonal variation. It is also a standard practice to discontinue data collection around major holidays; however, the specific holidays considered to be major may vary by region of the country and from one survey to another. The surveys conducted for Jackson and Lakeway ceased data collection during three holiday periods: Thanksgiving, Christmas, and New Years (Wegmann, et al., 2009). All five weekdays were eligible survey days for these two survey areas and weekend travel was excluded from the survey, which is common for household travel surveys conducted by MPOs. The NHTS survey is an anomaly in that it considers all seven days of the week as eligible travel days.

Table 3-6 - Peak Travel Months - Des Moines Area 2001 NHTS Add-On

Vehicle Trips		Person Trips	
Month	**Percent**	**Month**	**Percent**
August	11.7	August	12.3
October	10.2	December	10.9
December	10.0	October	10.5
November	9.8	September	10.2
January	9.6	July	9.9
September	9.6	January	9.3
July	9.5	November	9.3
March	8.0	March	7.4
April	7.9	April	7.3
February	5.5	February	5.3
June	4.1	June	3.8
May	4.1	May	3.7

Table 3-7 - Average Daily Trips per Household by Month for Oregon

Month	Trip Rate
April	8.73
May	9.03
June	8.86
August	8.94
September	7.65
October	8.09
November	6.36
December	4.85

Miscellaneous Issues

A number of factors over which researchers have no control can potentially impact the results of a household travel survey. For example, surveys are often planned months or even years in advance of the actual data collection period. It is possible, even likely, that local, regional or national economic conditions will not be the same if a survey is conducted in the same geographic area at two points in time. A major change in economic conditions is likely to affect travel habits. Of course, it is also very possible that surveys are conducted in one area during very good economic times and in a different area during poor economic times. Though very similar definitions and procedures may be used in all these surveys, the resulting travel rates could be very different due to differing economic conditions. It may not be feasible to consider all possible issues that could influence travel during data collection periods. However, it may be helpful to take note of a few additional concerns that were identified during this research effort.

Zero Trip Making Households

When one conducts a large-scale travel survey it should be expected that a portion of the participating individuals and households would not make any trips on their travel day. The question then becomes what is the expected number of zero trip making individuals and households. If this is known, then it can serve as a check for the survey procedures. For example, if an inordinate number of households report no trips, it could be that some of these are actually “soft refusals”, i.e. some people reported no trips so they can end the survey phone call more quickly.

During the literature review the technical reports documenting several household surveys were closely reviewed. Occasionally an unusual circumstance was reported. One example found was that approximately 13% of the Knoxville households had not traveled on their survey day. This high percentage was attributed to “sickness” specifically for ‘flu’ (NuStats, 2001). It is likely that similar situations occur during data collection in other areas but are not documented in the survey reports. The number of

households reporting zero trips in Jackson and Lakeway were monitored closely during the survey process. The final counts indicate that six percent of the households in Jackson and nine percent of the households in Lakeway reported that no member of the household traveled on the survey day (Wegmann, et al., 2009).

Travel Variation over Time

Currently in some urban areas, transportation planning is dependent on survey data collected as far back as the 1970's. Common sense would suggest that both the data and models resulting from the 1970's survey would be outdated due to changes in travel patterns and changes in the amount of travel occurring in an area during the last several decades. However to substantiate that assumption it is instructive to perform comparisons of survey findings for different times for the same area. For example, it is clear from two surveys conducted in Kansas City, one in 1990 and the other in 2004 that travel behavior did change over time. Though some variation might be attributed to the fact that there were a few minor changes in survey procedures, it is likely that most of the differences are due to a transformation of the population's demographic profile and fundamental changes in life style and travel behavior. As shown in Table 3-8 the area had an average trip rate of 12.0 person trips/household in 1990 versus 10.4 person trips/household in 2004 (Bricka, 2004). The key lesson learned for spatial transferability from these Kansas City data is that since travel may change over time it is preferable to borrow and transfer recently collected trip data or models instead of data that is several years old.

Table 3-8 - Methods, Design and Average Trip Rate - Kansas City

Feature	1990	2004
Study Area	5 counties & portions of 2 others	7 counties
Survey Method	Phone recruit/Mail back	Computer aided telephone interviewing recruit/retrieve
Participants	All HH Members 1+	All HH Members
Season	Fall	Spring
Days of Week	Tues – Thurs	Mon – Fri
Sample Size	1,221	3,049
Household Trip Rate	12.0	10.4

Summary

There is not a standard method for collecting travel survey data. Definitions of variables and data collection procedures utilized are often very different from one survey to another and may be dependent upon the standard practices of data collection firms or the preferences of a given client. The resulting data and ultimately the models developed from those data may reflect these differences. Substantial variations in values of several travel characteristics were noted in this chapter. Some differences were clearly due to real differences in travel while others may have been resulted from variations in procedures. The details of survey element definitions and procedure are often not well documented and may not even be known to the analyst attempting to compare data sets or models. When these differences are significant the conclusions resulting from an analysis may be distorted or even incorrect.

Chapter 4 – STUDY AREA CHARACTERISTICS AND DATA COLLECTION PROCEDURES

Travel surveys are conducted and travel demand models are developed to meet the specific forecasting needs of a given study area. Ideally a systematic approach is taken to identify these needs and the data needed to develop the forecasting models are determined. Then surveys appropriate to collect those data are designed and implemented. The possibility of these data being compared with data from surveys conducted in other areas or even used to develop models for other areas is rarely, if ever, considered. At the present time there are no generally accepted standards for the collection of household travel survey data in the U.S. Given these facts it should be expected that differences would exist between the surveys conducted for different study areas by different survey contractors at different points in time even though they share a common goal of gathering data from which to develop travel demand models. However, it is not clear to what extent the differences in survey procedures cause differences in the resulting data and models.

Since the models are intended to represent the travel characteristics of a study area the survey is designed to gather data that is representative of the travelers of a specific area. There are, of course, numerous differences between study areas including size, geography, topography, demographics, transportation system and so on. Again the relation between a study area's characteristics with the trip generation characteristics of those residing in the study area is not clearly established. It should be added that certain travel characteristics especially "mode choice" are known to be influenced by the size and density of an urban area.

What the literature has shown is that the more differences there are between the "context" and/or socioeconomic characteristics of two study areas the less likely they are to have similar trip making patterns. By inference it is likely that the opposite is also

true that the more commonalities two areas have the more likely they are to have similarities in their trip making.

The purpose of this chapter is two-fold. First, some of the characteristics of the study areas included in this research will be described, any known differences will be highlighted, and major similarities will be discussed. Second, the survey procedures and definitions used to gather the data for each study area will be described, important similarities in survey design will be noted and relevant differences will be acknowledged.

The data utilized for this research was drawn from four separate travel survey projects, and the research database included data for 11 distinct metropolitan planning areas in two states. Table 4-1 provides general information about each area and its associated survey. All data reported here are for the area covered by the travel survey for that MPO. For example, the Youngstown metro area includes one county in Pennsylvania, but the Youngstown survey included only the Ohio portion of the metro area; so the population and size of the area noted in Table 4-1 and those that follow it are only for the Ohio part of the Youngstown area. (Casas, 2004) The surveys conducted for Knoxville and Nashville were sponsored by the respective local MPOs and conducted by NuStats, Inc. (NuStats, 2001; NuStats 1998) The surveys of the Ohio areas were part of a statewide survey sponsored by the Ohio Department of Transportation and conducted by NuStats, Inc. The Lakeway and Jackson surveys were conducted for this research and an associated project sponsored by the Tennessee Department of Transportation (TDOT), and these were conducted by the University of Tennessee Social Science Research Institute for the Center for Transportation Research. (Wegmann, et al. 2009)

Table 4-1 - Study Areas and Associated Survey Characteristics

MPO Size	Study Area	Population	Survey Year	Number of Survey Households	Number of Survey Persons
Small	Jackson, TN	92,010	2007	472	1161
	Lakeway, TN	102,820	2007	498	1146
	Lima, OH	108,540	2003	1328	2858
	Mansfield, OH	128,780	2003	1304	2885
	Springfield, OH	144,620	2003	1349	3110
Medium	Canton, OH	378,070	2003	1319	3117
	Youngstown, OH	481,980	2003	1251	2903
	Knoxville, TN	489,040	2000	1538	3727
Large	Toledo, OH	721,785	2003	2176	4817
	Dayton, OH	805,670	2003	1950	4354
	Nashville, TN	1,102,410	1998	2204	5630

Study Area Characteristics

Study areas for this research were selected based on the availability of data, the size of the area based on residential population, and the compatibility of the survey procedures. Survey data for Nashville and Knoxville had been used in a previous research project and were the starting point of this research. (Wegmann, et al., 2004) Survey data were also needed from small MPOs in Tennessee to test the comparability of their travel characteristics to the larger MPOs in Tennessee as part of a TDOT research project. Since no data existed for any of the small MPOs in the state, two areas were selected, and these are the Jackson MPO and the Lakeway MPO. The latter MPO includes both Morristown and Jefferson City. A household travel survey was conducted to gather data for each of the households of the survey sample. Figure 4-1 shows the location of the four Tennessee study areas. (Wegmann, et al, 2009) The Ohio data were selected because they represented a range of sizes of MPOs similar to those in TN and were in a different state and region of the country. Additionally, the Ohio data were collected by the same survey firm responsible for collecting the Knoxville and Nashville data using similar methods and procedures. The MPO boundaries used for the Ohio travel surveys are shown in Figure 4-2. (Casas, 2004)

When using population size to differentiate the study areas they fall neatly in small, medium and large groups as seen in Table 4-1. The group of small MPOs is the largest with five members including Jackson, Lakeway, Lima, Mansfield and Springfield. The total population of these areas ranges from 92,000 for Jackson up to almost 145,000 for Springfield. The medium and large groups each include three members. Canton, Youngstown and Knoxville are in the medium-sized group while Toledo, Dayton and Nashville comprise the group of larger MPOs. The population of the medium-sized MPOs ranges from about 379,000 in Canton up to 489,000 for Knoxville. The group of large MPOs has the widest range of total population with Toledo having only about 722,000 compared to Nashville which had over 1.1 million people. All population values

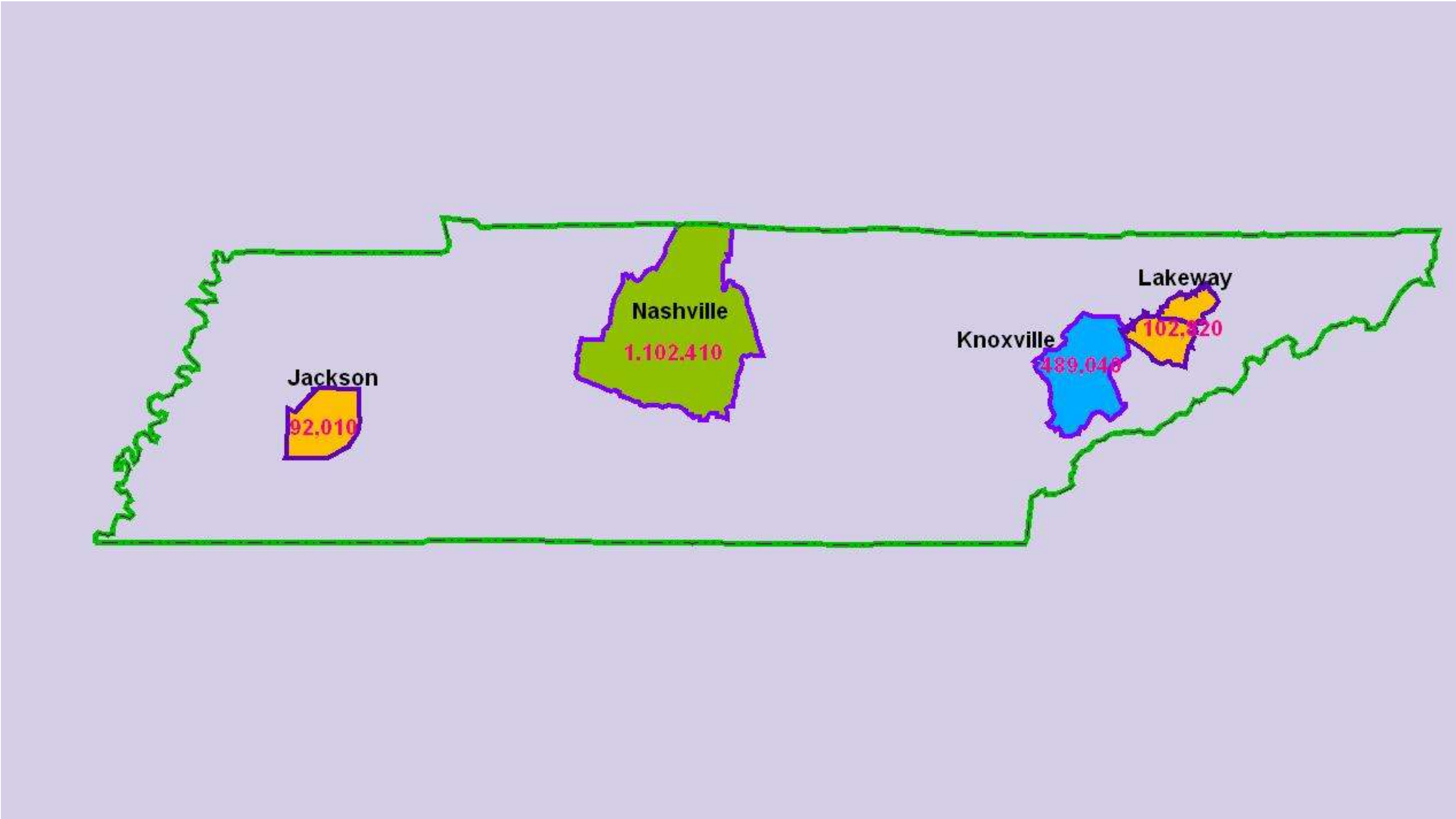

Figure 4-1 - Tennessee Study Areas

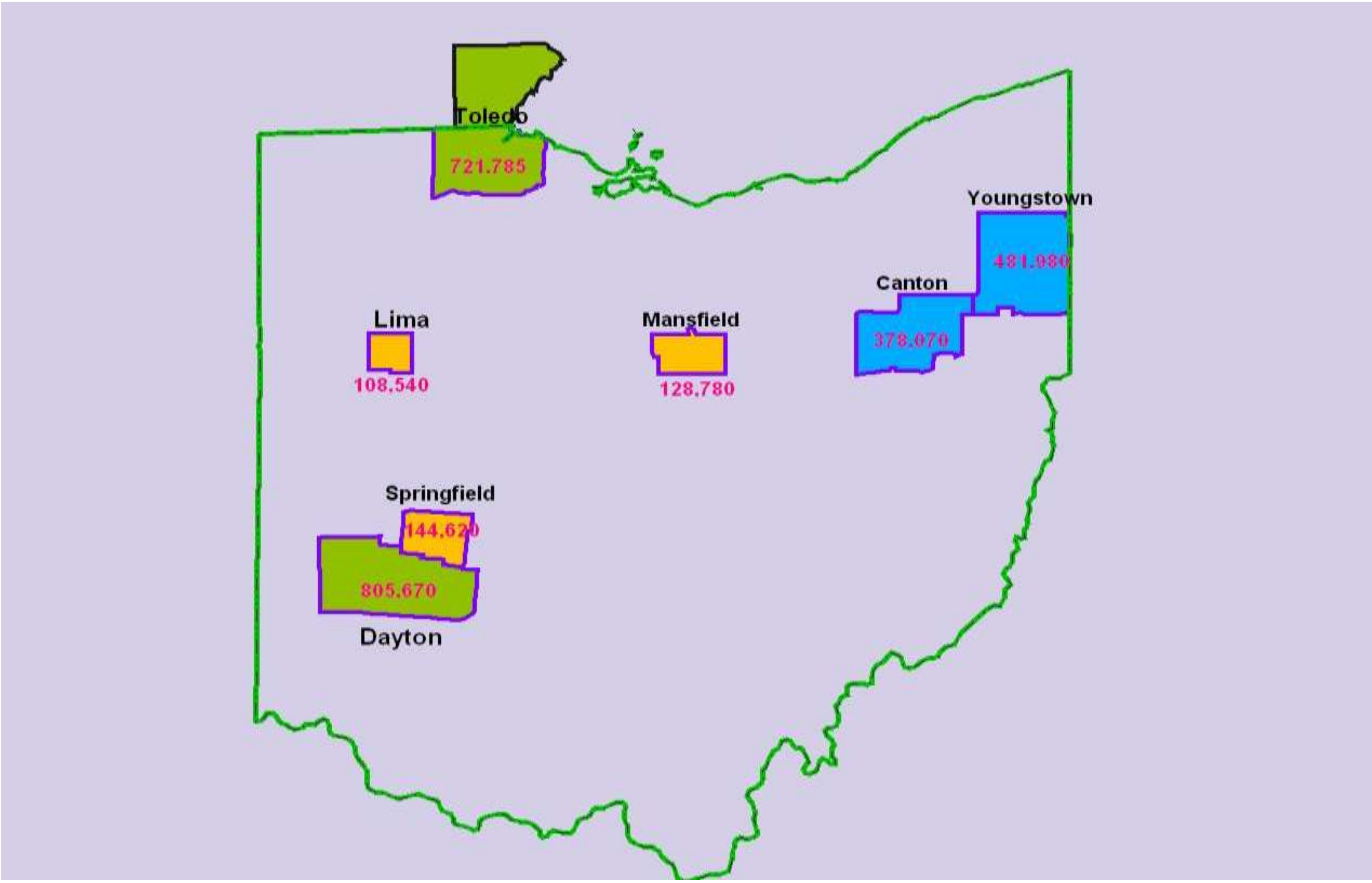

Figure 4-2 - Ohio Study Areas

and characteristics presented in this study are from the Census 2000 count of the US population unless otherwise noted.

The small MPOs are relatively similar in size as can be observed from Table 4-2. All but one is comprised of a single county with the Lakeway MPO consisting of all of Hamblen and a portion of Jefferson County. They range in land area from 403 square miles in Springfield to almost 560 square miles in Jackson. Though it has the largest land area of the small MPOs, the Jackson study area has the smallest population; thus it also has the lowest population density with about 165 persons per square mile. Lakeway, Mansfield and Lima each average more than 200 person per square mile and the Springfield area is the most densely populated of the small MPOs with 359 persons per square mile. All land areas used for this research are based on county size information extracted from TransCAD version 4.7 data files.

Two of the three medium-sized study areas consist of two counties each while the Canton study area is limited to Stark County, Ohio. It follows that Canton has the smallest land area of only 580 square miles while the Youngstown and Knoxville areas include 1056 and 1092 square miles respectively. The population density of the medium-sized areas ranges from 448 persons per square mile in Knoxville to over 650 in Canton.

The two Ohio study areas in the large MPO category are each comprised of 3 counties with Toledo consisting of two counties in Ohio and one in Michigan. Nashville is a bit of an outlier based on its size since it not only has the highest population count but the population is spread over five counties. The values of the other measures of size for the group of large MPOs have much wider ranges than either the small or medium-sized MPO groups. The land area of Dayton is only 880 square miles while Toledo contains over 1500 square miles and Nashville includes over 2800 square miles. Though the Nashville area has the largest population it also has the largest land area by far; thus it has a low level of population density of just 386 persons per square mile

averaged over the entire study area. Toledo has a somewhat higher population density at 474 persons per square mile and Dayton is the most densely populated by a wide margin at 916 persons per square mile. It should be noted that Tennessee study areas have the lowest population density in each of the size classes.

The proximity of the small and medium-sized MPOs to a larger urban area is also noted in Table 4-2. Though not explicitly analyzed in the research this measure of proximity can be discussed qualitatively. The proximity of one area to another larger area can impact travel patterns for commuting to and from work and for some home-based other trips such as shopping. It has been hypothesized that the impacts could be significant for the category of smaller MPOs. Jackson and Lima are the most isolated each being approximately 70 miles from the nearest larger urban area. Mansfield is only a little less isolated in that it is about 60 miles from larger urban areas. Though 60 or 70 mile commutes to work are not unheard of in Tennessee or Ohio there is likely much less personal travel interaction between these three areas and their neighboring large urban areas than would be the case for Lakeway and Springfield which are much closer to a larger urban area.

Socio-demographic characteristics of the study areas are presented in Table 4-2. It is recognized that the characteristics of an area's population are constantly changing. The surveys were conducted over a period of several months at four different points in time. Socio-demographics of an area for the same time period of data collection would provide a strong linkage with the travel data. However, actual measures of these parameters are rarely available between the decennial censuses. Therefore, a common time frame was used for socioeconomic data, and the year 2000 was selected for this purpose.

The most obvious difference between the areas is the variation in the change in population between 1990 and 2000. All of the Tennessee study areas experienced

Table 4-2 - MPO Area Characteristics

MPO Size	MPO Area (Counties)	2000 Pop	Land Area (sq miles)	Area Average Pop Density (per/sq mile)	Proximity to Medium or Large Urban Areas
Small	Jackson (Madison)	92,010	559	165	70 miles to Memphis
	Lakeway (Hamblen/Jefferson)	102,820	490	210	35 miles to Knoxville; 215 miles to Nashville
	Mansfield (Richland)	128,780	499	258	60 miles to Columbus, Canton or Akron; 80 miles to Toledo
	Lima (Allen)	108,540	406	267	70 miles to Dayton & Columbus
	Springfield (Clark)	144,620	403	359	25 miles to Dayton & 45 miles to Columbus
Medium	Knoxville (Knox/Blount)	489,040	1092	448	180 Miles to Nashville
	Youngstown (Trumbull; Mahoning)	481,980	1056	456	40 Miles to Akron
	Canton (Stark County)	378,070	580	652	25 miles to Akron and 45 miles to Youngstown
Large	Nashville (Davidson, Rutherford Sumner, Williamson & Wilson)	1,102,410	2859	386	NA
	Toledo (Lucas; Wood; Monroe, MI)	721,785	1521	474	NA
	Dayton (Greene; Miami; Montgomery)	805,670	880	916	NA

robust grown during that period with population increase ranging from a low of 15.7% for Knoxville to a high of 24.6% for the Nashville area. The population changes in the Ohio areas are in stark contrast to those of the Tennessee areas. The population change in the Ohio areas ranges from a negative 2.0% growth in the Youngstown area to a very modest 2.8% increase in the population for the Canton area during the entire decade of the 1990's.

The number of persons per household is relatively consistent among areas in both states and in all three size categories with a low of 2.43 in Knoxville and a high of 2.67 in Lima. The median age for each area is around 36 years with Nashville having a low of 34.4 years and Canton with the high of 38.3 years. Nashville has the lowest percent of the population that is over 65 years-of-age while Youngstown has the highest with almost 17% of its population over the age of 65.

Annual income can be an important predictor of trip making at the household level and many modelers prefer it over other variables when developing travel demand models. However, it is often difficult to persuade people to accurately self report household income in travel surveys. Income related questions often have the highest rates of non response from survey participants. Therefore the number of household vehicles available is often used as a surrogate for income when developing trip generation models. At the aggregate level mean annual household income can be used to compare the relative level of affluence of geographic areas. Table 4-3 reports this measure for each study area. The Lakeway area had the lowest average household income of any study area at $56,000 while Springfield and Jackson had the highest income among the small MPOs at $64,500 and $65,300 respectively. The mean household income for medium-sized areas ranged from $61,400 for Youngstown to $66,800 for Canton. The large MPO category had the greatest variation in average income. Toledo and Dayton have mean annual household incomes similar to the medium-sized areas at $65,200 and $69,900 respectively. However, the mean

Table 4-3 - Socio Demographic Characteristics of Tennessee and OH Study Areas

MPO Size	MPO Area	2000 Population	Population % Change 1990-2000	Number of HHs	Persons per HH	2000 Mean HH Income	2000 Median Age	2000 Percent 65+
Small	Jackson	92,010	17.4%	35,670	2.58	$65,300	34.9	12.2%
	Lakeway	102,820	22.7%	40,600	2.53	$56,000	36.9	13.1%
	Lima	108,540	-1.2%	40,720	2.67	$61,700	36.4	14.1%
	Mansfield	128,780	2.1%	49,570	2.60	$58,500	37.8	14.2%
	Springfield	144,620	-1.9%	56,660	2.55	$64,500	37.6	14.7%
Medium	Canton	378,070	2.8%	148,490	2.54	$66,800	38.3	15.1%
	Youngstown	481,980	-2.0%	191,580	2.52	$61,400	36	16.8%
	Knoxville	489,040	15.7%	201,390	2.43	$65,700	36.6	13.0%
Large	Toledo	721,785	0.1%	283,132	2.56	$65,200	34.8	12.3%
	Dayton	805,670	0.5%	323,370	2.49	$69,900	36.5	13.4%
	Nashville	1,102,410	24.6%	432,610	2.60	$80,800	34.4	10.0%

household income for the Nashville area was $80,800 which was almost $11,000 per year greater then the next most affluent study area.

It is recognized that the employment characteristics of an area may change over time; however, it may be instructive to look at a snapshot in time of the employment situation in each of the study areas. Comparable data were available for all areas for year 2001 and so it was selected as the time of comparison. (Woods and Poole, 2002) Several different employment characteristics are provided in Table 4-4. The number of persons employed in each study area tracks very closely with the size of the study area population as one would expect. The only instance of an area not following this pattern is Lima which has about 3000 fewer jobs than Lakeway though Lakeway has almost 6000 fewer people. The period around 2001 when this employment information was collected with a period of strong employment evidenced by the fact the only one area, Youngstown, had an unemployment rate of 6.0 or greater. Both Knoxville and Nashville had very low rates of unemployment at 2.8% while the other areas had rates ranging from 4.0% in Canton to 5.5% in Lakeway. There is some variation in the number of workers available per household in the study areas with Youngstown having only 1.18 members of the labor force per household while Jackson had 1.45.

Table 4-4 also presents a breakout of the percentage of employment that is in four major categories -- service, manufacturing, retail and government -- for each of the study areas. There is considerable difference in the proportions of employment in the four categories among the smaller MPO areas though it is not dramatic. For example, both the service and government categories have a spread of 7 percentage points with Jackson having just over 25% service employment compared to 32.5% in Lima while Lakeway has 9.2% government employment versus 15.8% in Jackson. Each of the small areas had close to 20% employment in manufacturing except Lima that had 17.9%. Though only 14.5 percent of those employed in Lakeway worked in the retail sector each of the other small areas had between 16.5% and 19.9% working in this category.

Table 4-4 - Employment Characteristics of Tennessee and Ohio Study Areas

MPO Size	MPO Area	2001 Total Employment	Percent Unemployed	Labor force per HH		Employment Categories			
				employed	all	Service	Manufacturing	Retail	Gov't
Small	Jackson	48,820	4.7%	1.37	1.45	25.3%	20.6%	16.5%	15.8%
	Lakeway	52,310	5.5%	1.29	1.36	30.7%	19.7%	14.5%	9.2%
	Lima	49,220	5.0%	1.21	1.27	32.5%	17.9%	18.2%	10.9%
	Mansfield	58,200	5.2%	1.17	1.24	26.7%	21.8%	19.0%	12.8%
	Springfield	66,550	5.2%	1.17	1.24	28.7%	19.5%	19.9%	11.6%
Medium	Canton	185,280	4.0%	1.24	1.29	30.2%	20.2%	18.2%	9.3%
	Youngstown	213,240	6.0%	1.11	1.18	30.0%	17.1%	20.0%	11.4%
	Knoxville	252,580	2.8%	1.25	1.29	30.4%	9.8%	19.4%	13.7%
Large	Toledo	358,984	4.3%	1.26	1.33	30.6%	15.6%	18.5%	12.5%
	Dayton	392,230	4.1%	1.21	1.26	31.1%	16.6%	17.5%	13.9%
	Nashville	583,810	2.8%	1.35	1.39	35.9%	10.3%	17.1%	9.7%

The medium-sized areas had strikingly similar proportion of their workforces working in the service sector with each having about 30%. However, there are large differences in the manufacturing category with Knoxville having on 9.8% in the sector while Youngstown and Canton had 17.1% and 20.2% respectively. The proportion of those working in retail and government jobs was fairly similar with retail employment ranging from 18.2% for Canton to 20% for Youngstown and government employment ranging from 9.3% for Canton to 13.7% for Knoxville.

The largest differences in the percent employment in the larger metro areas is the fact that Nashville had on 10.3% manufacturing employment compared with 15.6% for Toledo and 16.6% for Dayton. All three large areas have greater than 30% employed in the service sector with Toledo having the lowest at 30.6% and Nashville having the highest at 35.9%. Retail employment is very similar between study areas and government employment ranged from 9.7% in the Nashville area up to 13.9% in Dayton. Table 4-5 presents summary level travel survey results for each of the areas included in this research. The average person trips per household ranged from 9.20 trips per household for Lakeway to 7.71 trips per household for Lima. It is difficult to detect a strong pattern for average household trip rates by area size. For "trips per person" there is almost no difference on average between the smaller and medium-sized areas while the larger areas have slightly lower average trip rate per person. Lima, Youngstown and Dayton are clearly lower than the other areas when comparing trips at the HH level and the difference carries over to per person trip rate for Lima.

Table 4-5 - Average Trip Rates for Tennessee and Ohio Study Areas

MPOs	Population	Avg. Person trips/ household**	Avg. Person trip/ person***
Jackson, TN*	92,010	8.42	3.36
Lakeway, TN*	102,820	9.20	3.64
Lima, OH	108,540	7.71	2.89
Mansfield, OH	128,780	8.49	3.26
Springfield, OH	144,620	8.03	3.15
Canton, OH	378,070	8.76	3.45
Youngstown, OH	481,980	7.56	3.00
Knoxville, TN*	489,040	8.21	3.37
Toledo, OH	721,785	8.06	3.15
Dayton, OH	805,670	7.76	3.12
Nashville, TN*	1,102,410	8.20	3.15

*Travel by children under age 5 not included.

** Weighted average trip rates from survey reports

***Calculated based on weighted average trips divided by average person per household from Census 2000

Survey Data Collection Procedures

The data used in this research were gathered through four separate survey projects at different points in time and these had slightly different requirements. However, the data were collected using the same basic process and very similar definitions and procedures. This section provides a description of the design and implementation of the four travel studies conducted for the Ohio and Tennessee study areas. The Jackson and Lakeway data were collected explicitly for research so the greatest level of detail is known about this survey. Therefore, the process used in Jackson and Lakeway will be presented first and the similarities and differences between the Jackson and Lakeway study and the three other surveys will be discussed later.

Jackson and Lakeway Survey Process

The surveys for Jackson and Lakeway were conducted using the same definitions and procedures. The bulk of the data collection occurred simultaneously, however once the data had been checked it was determined that a few additional households were needed to reach the goals in the Jackson area. Therefore, the study was extended by a few months in an attempt to include some additional households. The Jackson study was conducted between October 2006 and January 2008 and the Lakeway study between October 2006 and May 2007. Only those data collected for Jackson between October 2006 and May 2007 were utilized for this research. The Jackson study included households (HHs) only in Madison County while the Lakeway study included all of Hamblen County and three zip codes in Jefferson County, which are 37890, 37877 and 37760. Figures 4-3 and 4-4 show the geographic distribution of surveyed HHs for the Jackson and Lakeway study areas respectively. The figures show that the concentration of survey households in each area coincides with the concentration of the population in those areas. The purpose of these studies was to determine travel patterns of households in these geographic areas based on self-reported trip making by local residents.

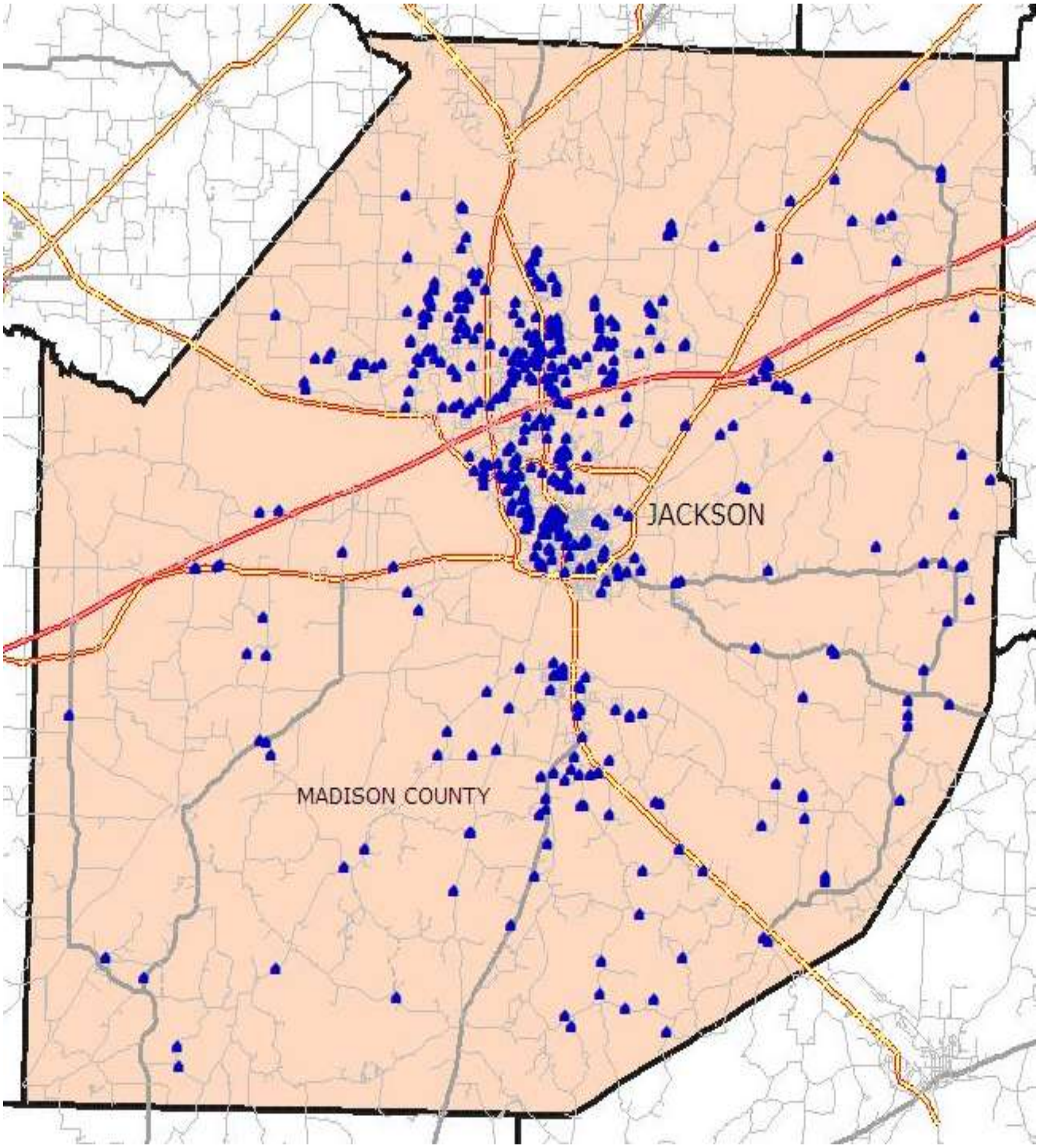

Figure 4-3 - Jackson Survey Area Households

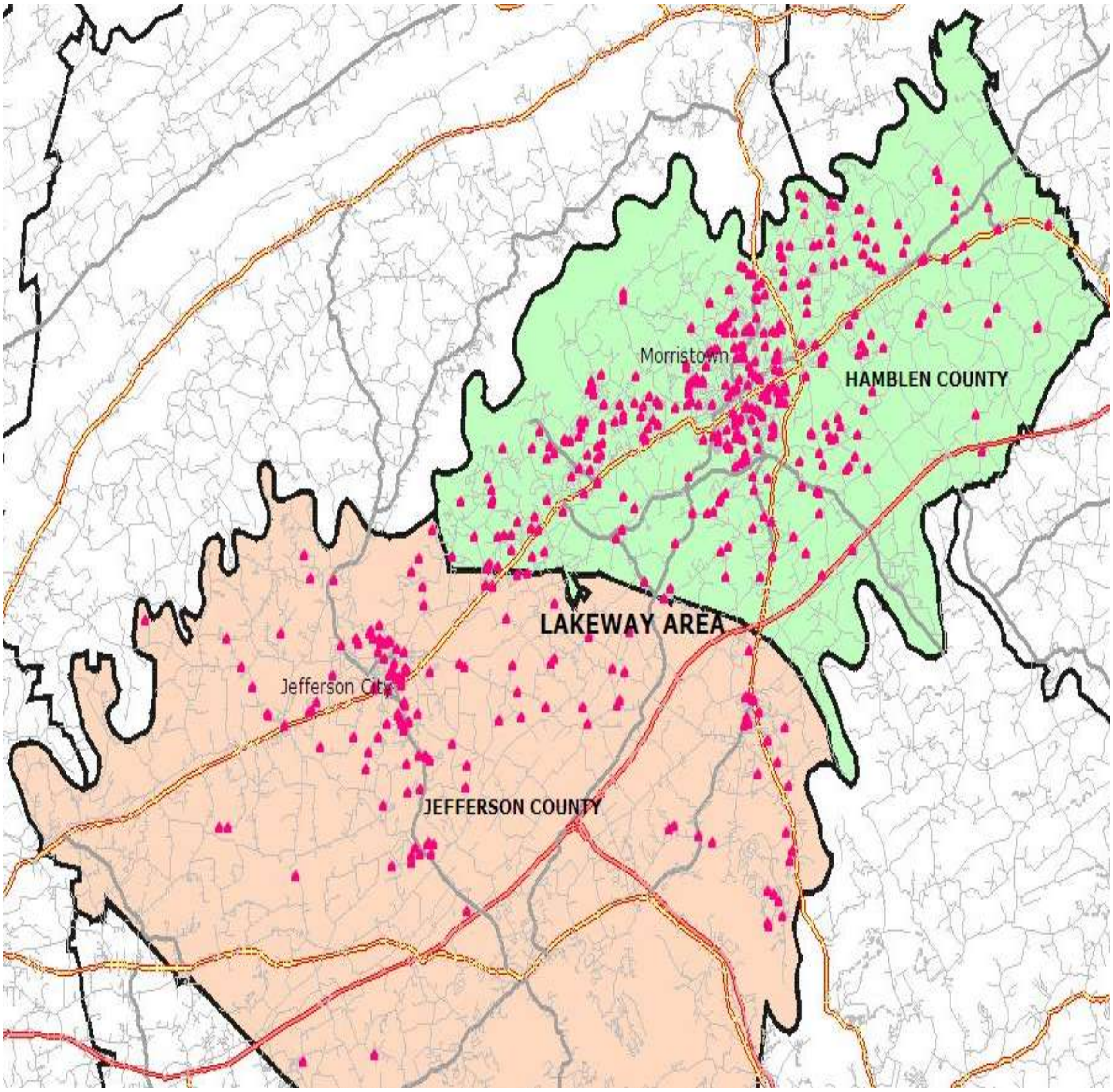

Figure 4-4 - Lakeway Survey Area Households

Data were collected in two stages. For stage one a survey instrument was designed and used specifically for recruiting households to participate in the study. Stage two utilized a separate instrument to obtain travel information from each member of the participating households. The data were collected utilizing a computer-assisted telephone interviewing (CATI) system.

Participants for these studies were recruited utilizing a 'random digit dialing' (RDD) sample from the study areas. The sample was purchased from the Market Systems Group. Letters were mailed to the households for which addresses could be secured to introduce them to the study in advance of the initial telephone call. For those households who did not receive a letter, the study was introduced during the recruiting interview. Households who agreed to participate were assigned a "travel day" and were asked to record their travel for a 24-hour period. All weekdays were eligible as travel days; however, the specific travel dates for each household were randomly assigned. Travel dates were generally assigned no less than four days and no more than seven days after the recruitment date. Study quotas were developed for each region so that households typically less likely to participate in this type of study such as households with larger numbers of members and/or fewer vehicles would be included in the final tally.

A total of 928 households were recruited for Jackson and 849 from Lakeway to participate in the study. Efforts to retrieve the travel information from the households began the day after their assigned travel day. Travel information was retrieved for all household members over the age of four.

Survey Instruments and Materials

All data collection for the household travel studies was completed by the University of Tennessee's Social Science Research Institute (SSRI) utilizing their computer aided telephone interviewing (CATI) system. Survey instruments were developed to collect data at two separate stages of the study. Information from the first stage, the recruitment stage, was saved and imported for use in the retrieval stage.

The survey followed a seven step process:

1) A letter was mailed to households with known addresses to familiarize them with the study and prepare the household for a recruitment call.

2) A recruitment call was made to solicit participation in the travel study, to gather household demographic information, and to assign a travel date.

3) A packet was assembled and mailed to each household that contained personalized travel diaries and additional information regarding the purpose of the study.

4) A reminder call was made to the household the night before their scheduled travel day.

5) A retrieval interview was conducted to secure travel information for each member of the household.

6) Incentives were mailed to the recruited households who were eligible to receive them.

7) Data was compiled and checked for accuracy. Addresses that had not been previously assigned X and Y coordinates were geocoded.

Each step is described in more detail below.

Prenotification Letter

A prenotification letter was mailed to all households in the telephone sample for which an address was available. The purposes of this letter were to introduce the study and to increase the cooperation rate. Official letterhead and envelopes with the University of Tennessee's logo were used for the mailing. These letters provided an additional level of legitimacy to the study and assisted the interviewers in building rapport with the households. Receipt of these letters helped to dispel suspicions that the purpose of the phone calls was to gather household information for unethical or illegal purposes. The template for the prenotification letters can be found in Wegmann, et al., 2009.

Recruitment Interview

The purpose of the recruitment interview was to introduce the travel study to each household contacted and to encourage participation in the study. After the initial introduction and when a household had agreed to participate, an interview was completed to obtain household and person level demographic information. This information included gender and age of each member of the household, employment status for each member, number of vehicles in the household and household income. The recruitment survey instrument can be found in Wegmann, et al., 2009.

Information Packet

An information packet was mailed to each household on the day following their recruitment. The outer envelope had the official University of Tennessee logo on it and the message, “Survey Materials Enclosed”, stamped on the outside with orange ink. The packet included a cover letter further explaining the study, identifying the sponsoring agency, and providing phone numbers for members of the research team in the event participants had any questions. A pamphlet was included that had been designed to provide further information about the goals of the study. Personalized diaries were also included for each household member over the age of four. The diaries were designed for participants to record each trip made during the travel day and its relevant characteristics so recollection of that information would be improved during the retrieval interview. A label was attached to the front of each diary that included the first name of the household member, the last name of the household member, the Household Identification Number, and the travel date. A business reply envelope was enclosed in the packet for participants to return their diaries after their travel information had been retrieved.

Reminder Call

A reminder call was placed to each household one day before the scheduled travel date. The purpose of the call was fourfold: to confirm the information packet had been received; to confirm that the travel day was still acceptable; to remind the participant of

their travel date; and to answer any questions about how to record the travel information. If the information packet had not been received, the travel date was rescheduled for the same day of the following week and a new packet was mailed. If the participant indicated an unwillingness to participate on their schedule date, efforts were made by the interviewers to reschedule the interview date, and travel diaries for the new date were mailed to the household.

Retrieval Interview

The process of retrieving the travel information from each household member began the day following the assigned travel date. These interviews were completed utilizing the CATI system. Often several calls had to be made to each household to retrieve the data for each traveler. Measures were taken to ensure that a complete record of travel was provided. For example the CATI system was programmed to prompt the interviewers to probe for additional trips or stops that might not have been recorded in the diaries. To assist in the identification of precise travel locations an electronic list of businesses and their addresses was available to the interviewers as a reference. The retrieval questionnaire can be found in Wegmann, et al., 2009.

Incentives

Due to the difficulty in recruiting households with certain demographics, i.e. those with no vehicles, and larger households with few vehicles, a Wal-Mart gift card was offered as an incentive to participate in the survey to some households. When the travel diaries were returned, the gift card was mailed. A ‘thank you’ letter and receipt of payment form was enclosed with the gift card.

Data Compilation and Quality Checking

A number of “behind the scenes” steps were required to complete the travel survey process. The progression of the data through the process is outlined in Table 4-6.

Table 4-6 - Data Flow Process

Stage	Stage Description	Progression Criteria
1	Geocoding of business and school addresses to begin a master list. Addresses assigned a LOCID with associated X/Y coordinate	• None
2	Generate sample	• None
3	Household address matched for sample	• If address could be assigned, go to Stage 4 • If address could not be assigned, go to Stage 5
4	Prenotification letter mailed	• None
5	Recruitment Interview – households are recruited to participate in travel study. Demographic information for all household members is gathered and travel date is assigned.	• If interview is completed, go to stage 6 and stage 7 • If interview is not completed, sample management rules are applied and number may be reattempted
6	Household, employment, and school data submitted for geocoding	• If employment/school address is successfully geocoded a location identification number (LOCID) is assigned • If household address is successfully geocoded then a LOCID is assigned • If household can not be successfully geocoded then the record is flagged for verification during retrieval interview

Table 4-6. Continued.

Stage	Stage Description	Progression Criteria
7	Travel diary packet is prepared and mailed	• Go to Stage 8
8	Reminder call – Recruited households are contacted to confirm receipt of travel diaries, to be reminded of travel date, and to answer any questions	• If diaries have been received, go to stage 9 • If diaries have not been received, confirm address information and reassign travel date to following week, go to stage 7 • If household refuses, household is assigned to specialized interviewer for conversion
9	Travel Day – Household members record travel on assigned day	• None
10	Retrieval interview – The first retrieval call is placed the day following travel day.	• If all information is retrieved for household, go to stage 11 and stage 13 • If some information is retrieved, call backs are scheduled • If travel was not completed on assigned day, go to stage 5 • If household refuses, household is reassigned to specialize interviewer for conversion
11	Travel diaries returned – Incentives are mailed when the diaries are returned.	• If diaries are returned, go to stage 12 • If diaries not returned, no progression

Table 4-6. Continued.

Stage	Stage Description	Progression Criteria
12	Incentives mailed – Wal-Mart gift cards are mailed with a receipt and return envelope. Households are requested to sign the receipt and return in the business reply envelope.	• None
13	Data Processing – data is reviewed and prepared for geocoding	• If data meets criteria for completeness, go to Stage 14 • If data does not meet criteria for completeness, requests for callbacks/ verifications are made
15	Data Quality checks – data is reviewed to ensure quality standards	• If passes, go to Stage 16 • If data does not pass, household assigned for callback/verification
16	Process complete	• None

Travel Surveys of the Other Areas

The Nashville, Knoxville and Ohio surveys were all completed prior to the initiation of the Jackson and Lakeway study. All three were activity surveys and the same company, NuStats, was responsible for conducting each. The technical reports of each study was reviewed and it was determined that many definitions and procedures were the same. Though some details are not provided in the reports it was assumed that the unreported procedures would not be significantly different since the same firm conducted all three studies. A brief description of each survey is provided below and some of the key characteristics are presented in Table 4-7.

<u>Nashville</u>

The 1998 Nashville Travel Behavior Study was a comprehensive analysis of travel patterns in the Middle Tennessee area. This analysis was an effort initiated by the Nashville Area Metropolitan Planning Organization to collect and analyze travel behavior data from those living in the five county study area as well as those traveling through the region. Household survey data were collected from a sampling of residents in each of the five counties Davidson, Rutherford, Sumner, Williamson and Wilson. The purpose of the effort was to collect data suitable for updating and improving the old travel demand model, to characterize travel in the region and ultimately to identify transportation needs in the region. (NuStats, 1998)

Household travel data were collected during the period from October 1997 until April 1998 from all household members age 5 and older for a 24-hour period. The survey was designed to collect weekday travel from a representative sample of households with telephones in the region via a computer aided telephone interviewing system. Demographic data were collected through a screening call from 2,706 households and one-day travel diary information were completed by all eligible members of 2,204 households. Household level information included dwelling type, ownership status, household size, household income, and vehicles owned or available. Person level data

Table 4-7 - Key Survey Characteristics

Characteristic	Jackson and Lakeway	Nashville	Knoxville	Ohio Areas
Travel Period	1-24 hour day	1-24 hour day	1-24 hour day	1-24 hour day
Travel Days	All weekdays	All weekdays	All weekdays	Monday through Thursday only
Minimum age for including travel	Everyone age 5 and above	Everyone age 5 and above	Everyone age 5 and above	Everyone regardless of age
Activities	• Activities at home • Paid work • School • Volunteer work • Pick-up/drop-off person • Social, recreation/church • Catch a bus, train or airplane • Shop • Personal business (pay	• Drop off/pick up someone • Visit friends/relatives • Eat meals away from home • Social/recreation/ entertainment • Shop • Doctor/dentist/other prof • Other family/personal bus. • Religious or civic • Work at home • Work at regular jobsite	• Personal activities at home • Internet use at home • Work at home • Work (other than at home) • Internet use at work Telecommunications at work (teleconferencing, videoconferencing) instead of travel • School - Junior college, college/university, vocational school	**In Home Activities** • Eat meal • Paid work • Shopping by catalogue, internet, TV • Social/recreational • Sleeping • Other (specify)

Table 4-7. Continued.

Characteristic	Jackson and Lakeway	Nashville	Knoxville	Ohio Areas
Activities	• bills, doctor, dentist etc.) • Eat meal (outside the home) • Other (please specify)	• Work at other place • School at regular place • School activity at other place • Sleep • Other activities at home • Other activities not at home	• School – Day care, kindergarten, elementary, middle, high) • Shopping – incidental (gas, 1 bag of groceries, supplies) • Shopping – major (clothing, furniture, autos, appliances, more than 1 bag of groceries, etc) • Personal business (bank, post office, haircut, dry cleaning, pay bills, dentist, etc) • Medical (doctor visits, surgery, physical therapy, etc) Eat meal outside of home	**Out of Home Activities** • Paid work • School • Volunteer work • Pick-up/drop-off • Social, recreation/ church • Catch a bus, train or airplane • Transfer from bus or train • Shop • Personal business • Eat meal • Go for a drive • Other (specify)

Table 4-7. Continued.

Characteristic	Jackson and Lakeway	Nashville	Knoxville	Ohio Areas
Activities			• Social/recreational (visit, entertainment, exercise, outdoor sports) • Civic activities (vote, volunteer, community meeting) • Church activities • Pick-up/drop-off passenger • Other activity (SPECIFY)	
Variables	Basic household and person variables and variables for calculating trip generation and distribution models	Approximately 41 household, 35 person and 51 trip variables were recorded or computed.	Approximately 20 household, 35 person and 22 trip variables were recorded or computed.	Approximately 30 household, 30 person, 8 guest, 33 trip and 32 guest trip variables were recorded or computed.

included age, gender, driver’s license, mobility impairment, type and address of employment, number of jobs held, type and address of schools if enrolled and others. Trip data for an entire 24 hour period were collected and included the origin and destination of each trip, the time each trip began and ended, mode of transportation, the activities at each destination, and the reason for making the trip. (NuStats, 1998)

Knoxville

The 2000 Knoxville Urban Area Household Travel Behavior Survey was a comprehensive study of travel behavior in Knox and Blount counties in Tennessee. The purpose of the survey was to collect weekday travel characteristics of household members (age 5 and older) during a 24-hour time frame. The data were to be used by the Knoxville Urban Area Metropolitan Planning Organization (MPO) to improve their transportation models and to identify transportation system needs in the region.

The survey collected data from households using a computer-assisted telephone interviewing system between November 2000 and February 2001. This survey conducted by NuStats was based on a random sample of households in the two study area counties. Households were contacted by telephone and recruited to participate by completing a travel log for each household member over age five. A total of 2,674 households were contacted to participate in the survey. Demographic interviews were conducted to collect the following key data items about the households and their members: household size, number of vehicles, household income, dwelling type, age, gender, driver’s license, work status and address, school status and address. Following demographic interviews, 1,704 households (64%) agreed to complete 24-hour activity logs. Household members were asked to record their travel destination locations, travel mode, trip duration, persons traveling and destination activity. After the data were processed, it was determined that 1,538 households (58%) provided complete data. (NuStats, 2001)

Ohio

The 2001-2003 Ohio Statewide Household Travel Survey (Statewide Travel Survey) was conducted between August 2001 and May 2003 by NuStats. The project was conducted through the sponsorship of the Ohio Department of Transportation (ODOT). The purpose of the study was to update the statewide database of household socioeconomic and travel information. These updated data were then used to refine travel estimates, models, and forecasts throughout Ohio. Data were collected for the nine smallest MPOs including Toledo, Lima, Dayton, Springfield, Akron, Canton, Mansfield, Steubenville and Youngstown. Additionally, households were surveyed statewide in rural areas that lay outside the MPO boundaries. Data from Akron, Steubenville and the rural areas were not used in this research due to considerable differences in demographics.

The travel period for this survey was for 24 hours and covered a weekday, Monday, Tuesday, Wednesday, or Thursday. Travel dates were not assigned to the weekday preceding or following a holiday. A total of 22,413 households were recruited to participate in the study. Of these, 16,494 households provided personal and travel/activity data. This information was retrieved from all household members regardless of age. The data for a total of 16,112 households passed all quality checks and were deemed acceptable. (Casas, 2004)

Summary

Some of the key characteristics of the study areas included in this research were described in this chapter. The study areas were different in several ways, however not dramatically so by most measures. Often the differences were slight making it difficult to identify patterns either by area size or location of the study areas. However, the Tennessee study areas were clearly less densely populated than those located in Ohio. The survey procedures and definitions used to gather the data for each study area were

also described. Many similarities in survey design were noted and at least two key differences were found. The Tennessee studies excluded children below age five from the travel data collection, while all household members were included in the Ohio survey. Additionally, there was considerable variation in the level of activity detail collected.

Chapter 5 – COMPARISON OF TRADITIONAL MODELS FOR TRANSFERABILITY

Statistical Tests for Comparing Cross-Classification Models

A statistical measure, which was designed for the purpose of comparing cross-classification models and used in a few previous studies, was identified and selected for use in this research. This “Q” statistic was employed to compare entire cross-classification tables and also, when necessary, subgroups of table cells. The “Q” statistic utilizes cell means, variances and sample sizes. It was first used by Martinson, in 1974 and later applied by Grecco, et al. in 1976 and by Chatterjee, et al. in 1977. The equation below explains how the “Q” statistic is developed:

Eq. 5-1 $Q = \sum_i \sum_j (X_{ij} - Y_{ij})^2 / (S^2 x_{ij} / n_{ij} + S^2 y_{ij} / m_{ij})$.

Where,

X_{ij} is the cell mean of the ith row and the jth column of the trip rate matrix for Area 1.
Y_{ij} is the cell mean of the ith row and the jth column of the trip rate matrix for Area 2.
S^2x_{ij} is the cell variance of the ith row and the jth column for Area 1.
S^2y_{ij} is the cell variance of the ith row and the jth column for Area 2.
n_{ij} is the number of observations (samples) in the ith row and the jth column for Area 1.
m_{ij} is the number of observations (samples) in the ith row and the jth column for Area 2.

The null hypothesis for the statistical test is that the cell means of the two matrices being compared are not significantly different, i.e., they are similar. The test statistic ‘Q” is to be calculated and compared to the value of χ^2 for i x j degrees-of-freedom (i x j = number of cells) at the level of significance of 0.05. If the “Q” statistic is larger than the critical chi squared ($\chi^2_{0.05}$), the null hypothesis is to be rejected signifying that the trip rates as a group for the two areas are in fact different.

The number of sample observations in each cell may vary considerably from cell to cell and can also vary from area to area for the same cell. It is desirable to exclude from the comparisons the values based on only a few observations. Traditionally a minimum of about 30 observations per cell is used for this type of analysis, and so 30 was the target number of minimum observations for comparisons made for this research. In a few cases a cell with a slightly lower number of observations was included in the analysis. For example, in the Knoxville study area the “1 person and 2 vehicle” cell values are based on 27 households. However, when the cell variances of the two groups are similar, statisticians indicate that using a sample number slightly smaller than 30 is an acceptable practice. (Arsham, 2009) In some cases the cells in the cross-classification tables were combined to eliminate cells with very few observations and create cells with acceptable numbers of observations.

The activity data were converted to trip estimates by purpose for each data set using comparable trip purpose definitions. Cross-classification models were then developed for three trip purposes – home-based work (HBW), home-based other (HBO), and non home-based (NHB). Further, a model for total trips, i.e., all three purposes combined, was also developed. The models for total trips, HBO trips and NHB trips were developed based on household size and the number of vehicles available to the household. However, the HBW models were developed by crossing the number of workers in the household by the number of vehicles available. With eleven study areas under consideration and four models in each area a total of 44 cross-classification models were developed for this research. Comparisons between study areas were then made for each of the four trip models based on study area size and state. Thus all study areas with each size category were compared to one another and each study area within a state was compared to the other study areas in that state regardless of their size. Forty area to area comparisons were made for each trip model for a total of 160 comparisons.

Comparison of Models by Study Area Size and Location

Cross-classification trip generation models were developed for all study areas based on commonly used household characteristics, and comparisons were made between these traditional models. The results of the comparisons between the study areas in the small size category will be reported first. The Jackson and Lakeway data sets had the fewest overall sample size with only 474 and 498 households respectively. Thus it was known that they would be the most limiting cases regarding the number of households per cell and ultimately the number of cells available for comparison. Therefore, an initial analysis was conducted comparing Lakeway and Jackson's trip rates using only cells with a minimum sample of 30 households. A second set of test was conducted that included cells that did not have exactly the minimum of 30 households, but that had no less than 20 per cell in each community.

The Jackson to Lakeway comparison will be used as an illustrative example of how all the comparisons were conducted. Figures 5-1 through 5-4 provide examples of detailed comparisons for the Lakeway and Jackson "Q" analysis, including: each cell's average trip rate, variance and the number of samples (in a cell). The five cells in the "Q" table at the bottom with no shading were used for the first level analysis, the three cells with light colored hatching and the first five cells were used for the second level of analysis. The cells with dark red background were not used in any comparison. The models for HBW trips had only five cells that meet the minimum requirements so the results are the same for both comparisons. It should be pointed out that the trip rates for home-based work trips are based on households with at least one employed person.

The statistical analysis determined that at a .05 level of significance, the null hypothesis can be accepted for all trip rate comparisons between Jackson and Lakeway as shown in Table 5-1. For this case the results are the same whether the comparison is based on eight cells some of which had less than 30 observations or on those five cells which had 30 or more observations. For the sake of consistency the remaining comparisons

will be reported based on using only cells having 30 or more observations for each area unless noted in the narrative discussion of that comparison. Details regarding the calculation of each Q will not be provided. Instead the resulting Q, the number of cells compared, the critical chi square value and the acceptance or rejection of H_0 will be reported. However, cases will be noted when the inclusion or exclusion of a single cell having a number of observations near thirty would change the determination for that comparison.

This finding of “no significant difference” between the average trip rates for total household trips and each trip purpose suggests that the households of these two Tennessee communities have similar trip generation rates. Further, this suggests the validity of transferring trip rate models between Jackson and Lakeway.

Total Trips

Jackson

Mean Trip Rate

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	3.90	6.63	7.48
2	4.19	8.60	13.62
3+	-	8.53	13.32

Cell Variance

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	6.29	20.55	20.99
2	7.76	28.45	73.05
3+	-	17.80	64.27

# of Samples

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	7	6	
1	80	27	23
2	21	107	77
3+	2	36	88

Lakeway

Mean Trip Rate

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	4.13	7.24	12.67
2	4.00	8.82	12.70
3+	2.50	8.29	15.61

Cell Variance

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	9.44	28.46	53.97
2	6.47	31.50	58.56
3+	4.29	19.58	46.52

# of Samples

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	27	3	
1	87	38	24
2	31	84	70
3+	8	52	74

Q

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	0.283	0.246	8.520
2	0.062	0.076	0.474
3+	n/a	0.066	3.859

Figure 5-1 - Example Q Calculation for Total Trips in Jackson and Lakeway

HBO Trips

Jackson

Mean Trip Rate

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	1.68	3.89	5.09
2	1.86	3.89	7.22
3+	-	2.72	6.28

Cell Variance

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	2.70	8.64	14.17
2	3.03	9.21	23.94
3+	-	4.38	22.83

# of Samples

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	7	6	
1	80	27	23
2	21	107	77
3+	2	36	88

Lakeway

Mean Trip Rate

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	1.92	3.95	7.67
2	1.74	3.87	6.30
3+	1.13	3.69	7.31

Cell Variance

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	3.31	10.59	22.41
2	3.20	9.61	20.73
3+	0.70	7.24	13.78

# of Samples

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	27	3	
1	87	38	24
2	31	84	70
3+	8	52	74

Q

# of Vehicles	HH Size 1	HH Size 2	HH Size 3+
0	n/a	n/a	
1	0.802	0.006	4.295
2	0.058	0.002	1.394
3+	n/a	3.606	2.381

Figure 5-2 - Example Q Calculation for HBO Trips in Jackson and Lakeway

NHB Trips

Jackson

Mean Trip Rate

		HH Size		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	1.50	2.15	1.78
	2	1.52	3.58	4.49
	3+	-	3.89	4.64

Cell Variance

		HH Size		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	3.06	7.52	4.09
	2	2.16	15.32	23.65
	3+	-	10.27	21.20

# of Samples

		HH Size		
		1	2	3+
# of Vehicles	0	7	6	
	1	80	27	23
	2	21	107	77
	3+	2	36	88

Lakeway

Mean Trip Rate

		HH Size		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	1.82	2.53	3.58
	2	1.42	3.69	4.54
	3+	1.13	3.06	5.61

Cell Variance

		HH Size		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	4.38	10.58	12.78
	2	2.65	16.36	21.09
	3+	1.84	9.35	25.12

# of Samples

		HH Size		
		1	2	3+
# of Vehicles	0	27	3	
	1	87	38	24
	2	31	84	70
	3+	8	52	74

Q

			HH Size		
			1	2	3+
Q	# of Vehicles	0	n/a	n/a	
		1	1.156	0.259	4.561
		2	0.053	0.036	0.004
		3+	n/a	1.481	1.621

Figure 5-3 - Example Q Calculation for NHB Trips in Jackson and Lakeway

HBW Trips

Jackson

Mean Trip Rate

		# Employed Persons		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	1.32	0.67	
	2	1.39	2.29	1.00
	3+	1.28	2.59	3.86

Cell Variance

		# Employed Persons		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	1.25	1.33	
	2	1.45	1.86	2.00
	3+	1.29	2.18	4.03

# of Samples

		# Employed Persons		
		1	2	3+
# of Vehicles	0	7	6	
	1	63	3	
	2	59	82	2
	3+	36	59	21

Lakeway

Mean Trip Rate

		# Employed Persons		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	1.14	2.33	4.00
	2	1.43	2.28	3.00
	3+	1.32	2.96	3.16

Cell Variance

		# Employed Persons		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	1.03	2.67	0.00
	2	1.53	1.98	2.00
	3+	1.68	3.36	2.70

# of Samples

		# Employed Persons		
		1	2	3+
# of Vehicles	0	27	3	
	1	56	6	2
	2	65	64	2
	3+	34	57	19

Q

		# Employed Persons		
		1	2	3+
# of Vehicles	0	n/a	n/a	
	1	0.795	3.125	#DIV/0!
	2	0.035	0.002	2.000
	3+	0.025	1.443	1.465

Figure 5-4 - Example Q Calculation for HBW Trips in Jackson and Lakeway

Table 5-1 - Statistical Comparison: Lakeway versus Jackson

	Statistical Test Results							
	All cells with 30 or more HHs in each community				**All cells with 20 or more HHs in community**			
Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho	Q	n	Critical $\chi^2_{.05}$	Ho
Total Trips	4.76	5	11.1	Accept	13.59	8	15.5	Accept
Home-Base Other	8.19	5	11.1	Accept	12.54	8	15.5	Accept
Non Home-Based	4.30	5	11.1	Accept	9.17	8	15.5	Accept
Home-Based Work	2.30	5	11.1	Accept	2.30	5	11.1	Accept

Ohio Small Study Area Comparisons

The comparison of the two small Tennessee study areas provided one example of the validity of transferring trip rates from one small area to another small area. Next comparisons were made using the data for the three small MPO areas in Ohio -- Lima, Mansfield and Springfield.

Values of the “Q” statistic were determined for each of the comparison pairs of small Ohio study areas, and the results are presented in Table 5-2. A finding of “no significant difference” was recorded for all trip purposes between Lima and Springfield and for all but the home-based work category for Mansfield and Springfield. It is unusual to find a difference between areas in the work trip category. In this case 54% of the total Q value came from a single cell, the one employee by 3+ vehicles cell. The comparison of total trips and home-based other trips for the Lima and Mansfield showed significant difference while the trip rates for non home-based and home-based work trips were not different. The difference in total trips was based mostly on two cells -- the ‘1 vehicle by 2 and 3+ household members’ cells had a combined 55% of the total value of Q. Once these differences were identified the socio demographic and employment characteristics for the two areas were reviewed, but no obvious differences were found in the measures reported in Chapter 4. The home-based other trip category is somewhat of a “catch all” and usually comprises the largest portion of total trips of any of the three basic trip purposes. The activity data for these areas permitted home-based other trips to be further disaggregated into shopping, school and a more narrowly defined home-based other purpose. This sub-categorization of HBO trips was performed for Lima and Mansfield and then new cell means and cell variances were developed for each area. Finally, Q values for school, shopping and the “new” HBO trip purposes were calculated. Both the school and new HBO comparisons resulted in the Ho being accepted, however there did appear to be a significant difference between shopping trip rates for the two areas. Based on the comparison of the small study areas within the same state for the two states of Tennessee and Ohio, it appears that in general the transferability of trip rates among the smaller areas within a state is valid.

Comparisons of Small Study Areas between Ohio and Tennessee

So far it has been established with some degree of confidence that the smaller Tennessee areas have similar trips rates to one another and that the smaller Ohio areas do as well. It should be pointed out that data for all the small Ohio areas were collected at the same time using the same procedures by a single survey firm. Similarly the data for the small Tennessee areas were gathered at the same time using the same procedures by the same survey team. The next logical step was to compare the trip rates of small areas in the two different states. In these tests two additional sources of variations have the potential to cause differences in trip rates: one is the culture and other social characteristics of the states, and the second is the survey procedures and definitions. If trip rates are found to be similar between small Tennessee MPOs and small Ohio MPOs, then the approach of transferring trip rates between the small areas in different states can be advanced. Therefore, tests were conducted using the Q statistic to compare Lakeway and Jackson respectively with Lima, Mansfield and Springfield. The results are provided in Table 5-3.

The results presented in Table 5-3 show some consistent patterns. Home-based other and home-based work trips were found to be similar for every comparison between the areas in Tennessee and Ohio. Conversely non home-based trips were not found to be similar for any of the comparisons. The difference in non home-based trip rates appears to have led to the total trips being different for most cases of comparison, the exception being the comparison between Jackson and Mansfield. The consistent differences found in the non home-based trip category prompted a more detailed look at both the Q values for these areas and the data from which the Qs were developed. In a few Jackson cases the Q value for a single cell contributed disproportionately to the overall Q statistic. For example, the Q for the “two person-two vehicle” cell in the Jackson versus Springfield comparison was 9.67 accounting for 69% of the overall Q statistic. However, most of the non home-based comparisons showed consistent differences in many cells. Interestingly, in every case where significant differences were found, the Tennessee areas had higher mean trip rates for the majority of the cells in

Table 5-2 - Results of Comparisons between Small Ohio Study Areas

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Lima – Mansfield					
	Total Trips	26.71	9	16.92	Reject
	Home-Based Other	21.94	9	16.92	Reject
	Non Home-Based	15.14	9	16.92	Accept
	Home-Based Work	5.08	6	12.59	Accept
Lima - Springfield					
	Total Trips	9.11	9	16.92	Accept
	Home-Based Other	8.77	9	16.92	Accept
	Non Home-Based	5.07	9	16.92	Accept
	Home-Based Work	9.01	6	12.59	Accept
Mansfield – Springfield					
	Total Trips	13.88	9	16.92	Accept
	Home-Based Other	15.46	9	16.92	Accept
	Non Home-Based	12.16	9	16.92	Accept
	Home-Based Work	13.00	6	12.59	Reject

Table 5-3 - Results of Comparisons between Small TN and Small OH Study Areas

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Jackson – Lima					
	Total Trips	19.96	5	11.07	Reject
	Home-Based Other	10.92	5	11.07	Accept
	Non Home-Based	28.70	5	11.07	Reject
	Home-Based Work	3.51	5	11.07	Accept
Jackson – Mansfield					
	Total Trips	7.84	5	11.07	Accept
	Home-Based Other	4.89	5	11.07	Accept
	Non Home-Based	21.37	5	11.07	Reject
	Home-Based Work	4.19	5	11.07	Accept
Jackson - Springfield					
	Total Trips	14.02	5	11.07	Reject
	Home-Based Other	4.32	5	11.07	Accept
	Non Home-Based	29.10	5	11.07	Reject
	Home-Based Work	5.85	5	11.07	Accept
Lakeway – Lima					
	Total Trips	23.09	7	14.07	Reject
	Home-Based Other	11.75	7	14.07	Accept
	Non Home-Based	38.9	7	14.07	Reject
	Home-Based Work	5.23	5	11.07	Accept
Lakeway – Mansfield					
	Total Trips	16.7	7	14.07	Reject
	Home-Based Other	7.76	7	14.07	Accept
	Non Home-Based	29.68	7	14.07	Reject
	Home-Based Work	7.51	5	11.07	Accept
Lakeway - Springfield					
	Total Trips	23.52	7	14.07	Reject
	Home-Based Other	12.36	7	14.07	Accept
	Non Home-Based	37.06	7	14.07	Reject
	Home-Based Work	4.61	5	11.07	Accept

the cross-classification tables. This suggests that one should be careful when transferring trip rates between smaller MPOs especially those for non home-based trips. It is not known if the differences can be attributed to, travel behavior, or differences in procedures for conducting and coding the surveys in the two states.

Comparisons of Small Study Areas to Larger Areas in the Same State

Comparisons were made between the small study areas and the larger areas within the same state. When the larger MPO areas in Tennessee were compared with Lakeway and Jackson a number of differences were found. Table 5-4 shows that when the average trip rates are compared between Knoxville and Jackson, and between Knoxville and Lakeway, there were "no significant differences" for home-based work trip rates or for home-based other trip rates in the Knoxville-Jackson comparison. All other trip rates were different When comparisons were made for Nashville and Lakeway, and Nashville and Jackson, in all cases the null hypothesis was rejected except for home-based other trips, which means that the trip rates were different except in the case of home-based other trips. For each case where the null hypothesis was rejected the values of the mean trip rates of Lakeway and Jackson were higher than those for Knoxville and Nashville in the cells of the cross-classification tables that made major contributions to the Q statistic. In about half the 16 comparisons in Table 5-4 the cells for 2 persons per household with 2 household vehicles accounted for 45% or more of the total Q statistic.

Note that the Nashville data set used in this analysis was not the original full data set as was the case in the other study areas. Though all the data elements necessary to conduct this research were included it is possible that the Nashville data could have a systematic error. Nashville had unusually low and different work trip rates from most every other study area analyzed. Though it is possible that work trip travel in the Nashville area is different from the other study areas the possibility also exists that between the time the data were originally collected and the time the data were provided

for this research a change in an activity code for a large number of trips or other error may have been introduced into the data set.

Lima, Mansfield and Springfield of Ohio were also compared to the two medium-sized and two large urban areas in Ohio. Table 5-5 provides the results of the comparisons with the medium-sized areas and Table 5-6 presents the results of the comparisons of the small with the large-sized areas. The results of these comparisons are very different from those for Tennessee with 7 of the 12 small to larger OH areas showing no statistical differences at all. Only 8 of the 48 or 16.6% of the statistical tests resulted in a rejection of the null hypothesis. Four of the eight failures were for the home-based other trip category and three were for total trips. The cases where a difference was found in total trips occurred in areas where a difference in home-based other trips also occurred indicating that the HBO trip differences were the likely cause of the differences in total trips. By a slim margin the home-based work trips were found to be different between Springfield and Toledo. A definitive answer as to why these tests showed the small Ohio areas to be much more similar to the medium and large-sized Ohio areas in contrast to the findings for similar tests in Tennessee cannot be provided. However, three hypotheses can be put forward. It could be that travel in Ohio is indeed more similar in the study areas than travel in Tennessee. It is also possible that had a richer sample been available with enough households to bring the sample size to the minimum of 30 in an additional four cells in the Tennessee small areas, then fewer differences would have been found between the areas. Finally, it could be that some of the differences found in Tennessee are attributable to the fact that the data were collected at three different times using slightly different procedures.

Table 5-4 - Results of Comparison of Small TN Areas to Knoxville and Nashville

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Jackson – Knoxville					
	Total Trips	13.04	5	11.07	Reject
	Home-Based Other	6.40	5	11.07	Accept
	Non Home-Based	17.35	5	11.07	Reject
	Home-Based Work	3.75	5	11.07	Accept
Lakeway - Knoxville					
	Total Trips	24.98	7	14.07	Reject
	Home-Based Other	20.74	7	14.07	Reject
	Non Home-Based	17.77	7	14.07	Reject
	Home-Based Work	3.31	5	11.07	Accept
Jackson – Nashville					
	Total Trips	21.44	5	11.07	Reject
	Home-Based Other	10.2	5	11.07	Accept
	Non Home-Based	25.64	5	11.07	Reject
	Home-Based Work	39.57	5	11.07	Reject
Lakeway - Nashville					
	Total Trips	32.77	7	14.07	Reject
	Home-Based Other	10.18	7	14.07	Accept
	Non Home-Based	31.24	7	14.07	Reject
	Home-Based Work	38.63	5	11.07	Reject

Table 5-5 - Results of Comparisons of Small and Medium-sized OH Areas

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Lima - Canton					
	Total Trips	21.02	9	16.92	Reject
	Home-Based Other	19.78	9	16.92	Reject
	Non Home-Based	8.18	9	16.92	Accept
	Home-Based Work	0.46	6	12.59	Accept
Lima - Youngstown					
	Total Trips	12.14	9	16.92	Accept
	Home-Based Other	14.35	9	16.92	Accept
	Non Home-Based	8.14	9	16.92	Accept
	Home-Based Work	1.97	6	12.59	Accept
Mansfield - Canton					
	Total Trips	12.10	9	16.92	Accept
	Home-Based Other	15.09	9	16.92	Accept
	Non Home-Based	8.13	9	16.92	Accept
	Home-Based Work	5.04	6	12.59	Accept
Mansfield - Youngstown					
	Total Trips	12.14	9	16.92	Accept
	Home-Based Other	14.35	9	16.92	Accept
	Non Home-Based	8.14	9	16.92	Accept
	Home-Based Work	1.97	6	12.59	Accept
Springfield - Canton					
	Total Trips	9.37	9	16.92	Accept
	Home-Based Other	17.15	9	16.92	Reject
	Non Home-Based	4.87	9	16.92	Accept
	Home-Based Work	8.93	6	12.59	Accept
Springfield - Youngstown					
	Total Trips	4.96	9	16.92	Accept
	Home-Based Other	10.43	9	16.92	Accept
	Non Home-Based	5.92	9	16.92	Accept
	Home-Based Work	9.00	6	12.59	Accept

Table 5-6 - Results of Comparison between Small and Large-sized OH Study Areas

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Lima - Toledo					
	Total Trips	13.05	9	16.92	Accept
	Home-Based Other	4.46	9	16.92	Accept
	Non Home-Based	11.89	9	16.92	Accept
	Home-Based Work	7.54	6	12.59	Accept
Lima - Dayton					
	Total Trips	10.39	9	16.92	Accept
	Home-Based Other	9.86	9	16.92	Accept
	Non Home-Based	8.36	9	16.92	Accept
	Home-Based Work	3.63	6	12.59	Accept
Mansfield - Toledo					
	Total Trips	17.38	9	16.92	Reject
	Home-Based Other	17.38	9	16.92	Reject
	Non Home-Based	12.12	9	16.92	Accept
	Home-Based Work	7.55	6	12.59	Accept
Mansfield - Dayton					
	Total Trips	18.12	9	16.92	Reject
	Home-Based Other	17.13	9	16.92	Reject
	Non Home-Based	14.59	9	16.92	Accept
	Home-Based Work	2.35	6	12.59	Accept
Springfield - Toledo					
	Total Trips	7.83	9	16.92	Accept
	Home-Based Other	3.18	9	16.92	Accept
	Non Home-Based	7.58	9	16.92	Accept
	Home-Based Work	13.65	6	12.59	Reject
Springfield - Dayton					
	Total Trips	2.45	9	16.92	Accept
	Home-Based Other	5.43	9	16.92	Accept
	Non Home-Based	5.77	9	16.92	Accept
	Home-Based Work	6.06	6	12.59	Accept

Comparisons of Medium and Large Areas

The medium-sized and large areas were also compared according to both their size and the state in which they were located. The results of the comparison between the medium-sized areas are presented in Table 5-7. The results are mixed for this set of evaluations in that at least one trip purpose was found to be different for each of the comparisons; however the null hypothesis could be accepted for 75% of the comparisons. The main culprit causing the differences once again was home-based-other trips. Canton appears to have very high home-based-other trip rates especially for the "3+ household size by 2 and 3+ vehicle" cells. Not only did those cells present differences between the small and medium-sized Ohio areas presented earlier but they also accounted for several of the differences in Table 5-7. The "Knoxville with Youngstown" evaluation indicated a difference in non home-based trips of the two areas following a trend discovered when comparing the Tennessee and Ohio small areas.

Table 5-7 - Results of Comparisons of Medium-sized Areas

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Canton – Knoxville					
	Total Trips	12.70	9	16.92	Accept
	Home-Based Other	36.81	9	16.92	Reject
	Non Home-Based	8.34	9	16.92	Accept
	Home-Based Work	3.88	6	12.59	Accept
Canton – Youngstown					
	Total Trips	18.96	9	16.92	Reject
	Home-Based Other	18.91	9	16.92	Reject
	Non Home-Based	14.39	9	16.92	Accept
	Home-Based Work	2.05	6	12.59	Accept
Youngstown - Knoxville					
	Total Trips	5.92	9	16.92	Accept
	Home-Based Other	14.46	9	16.92	Accept
	Non Home-Based	34.80	9	16.92	Reject
	Home-Based Work	6.95	6	12.59	Accept

Eight comparisons were made between the medium-sized and large areas included in this research and the results are presented in Table 5-8. Interestingly the results can be categorized fairly neatly based on the state where the study areas are located. The first four comparisons presented are between Ohio areas and overall the travel between the medium-sized and large areas was found to be fairly similar. However, in three of the four comparisons there were differences in the home-based other category. Note that the two comparisons which include Canton where the higher than typical trip rates for some cells were discussed previously were both found to be different from the larger Ohio areas.

When making comparisons between medium and large areas with one area in Tennessee and the other in Ohio, total trips were found to be the same in all three cases and non home-based trips were found to be different in each case. Recall that all the cases of comparison of small areas between the states also found a difference in non home-based trips. Home-based work trips for Youngstown and Nashville were also found to be different. The same issues with the Nashville data discussed previously could apply to this finding.

A comparison of the models for Knoxville with Nashville also indicates no significant difference between average trip rates for total trips, and further there were no differences between their non home-based or home-based other categories either. However, a very large Q statistic was determined for home-based work trips. Again the work trip difference may be real or could be the result of a data coding issue. The "no significant difference" finding between Knoxville and Nashville is essentially the same finding as a previous study (Wegmann, et al. 2004) except in that study no differences were found in home-based work trips either. However, the data used for Nashville in the Wegmann study only included a subset of 1245 Nashville households for which complete information was available.

Table 5-8 - Results of Comparisons between Medium and Large Areas

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Canton - Toledo					
	Total Trips	12.85	9	16.92	Accept
	Home-Based Other	17.99	9	16.92	Reject
	Non Home-Based	7.96	9	16.92	Accept
	Home-Based Work	7.92	6	12.59	Accept
Canton - Dayton					
	Total Trips	11.86	9	16.92	Accept
	Home-Based Other	17.83	9	16.92	Reject
	Non Home-Based	14.40	9	16.92	Accept
	Home-Based Work	3.00	6	12.59	Accept
Youngstown - Toledo					
	Total Trips	9.37	9	16.92	Accept
	Home-Based Other	13.27	9	16.92	Accept
	Non Home-Based	9.13	9	16.92	Accept
	Home-Based Work	8.78	6	12.59	Accept
Youngstown - Dayton					
	Total Trips	10.31	9	16.92	Accept
	Home-Based Other	18.31	9	16.92	Reject
	Non Home-Based	5.68	9	16.92	Accept
	Home-Based Work	1.09	6	12.59	Accept
Youngstown - Nashville					
	Total Trips	6.59	9	16.92	Accept
	Home-Based Other	5.48	9	16.92	Accept
	Non Home-Based	27.45	9	16.92	Reject
	Home-Based Work	117.17	6	12.59	Reject
Knoxville - Toledo					
	Total Trips	11.38	9	16.92	Accept
	Home-Based Other	19.46	9	16.92	Reject
	Non Home-Based	21.35	9	16.92	Reject
	Home-Based Work	10.33	6	12.59	Accept
Knoxville - Dayton					
	Total Trips	14.28	9	16.92	Accept
	Home-Based Other	27.64	9	16.92	Reject
	Non Home-Based	34.30	9	16.92	Reject
	Home-Based Work	9.50	6	12.59	Accept

Table 5-8. Continued

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Knoxville - Nashville					
	Total Trips	4.93	9	16.92	Accept
	Home-Based Other	13.39	9	16.92	Accept
	Non Home-Based	6.53	9	16.92	Accept
	Home-Based Work	97.80	6	12.59	Reject

Comparisons of Large areas

Finally, the similarities and differences in the models for the large study areas in each state were evaluated. When Toledo and Dayton were compared no differences were found, however at least two categories of trip rates were found to be different when the Ohio areas were compared to Nashville. The work trip rates for the Ohio areas compared to Nashville resulted in very large values for the Q-statistic and some possible reasons for this were discussed previously. The differences in the work trip rates between Toledo and Nashville likely contributed strongly towards the difference in total trips between the areas since no statistical differences were found for either the home-based other and non home-based trip categories. A cell by cell comparison of the models found that the mean trips for most cells of the home-based other and non home-based were comparable. However, the cell mean for Nashville was lower in every case of the home-based work trips.

The Dayton to Nashville comparison produced very interesting results in that no difference was found in total trips, but differences were found in each of the three basic trip categories. A review of the cross-classification models found that Dayton had higher mean trips rates in six of nine home-based other cells, Nashville had higher rates in 5 of 9 non home-based cells, and Dayton had higher values in all six of the work trip cells. The result was that the differences in the rates by trip category essentially cancelled themselves out resulting in similar total trip rates.

Summary

The focus of this chapter was the statistical comparison of trip generation models developed for three different sizes of study areas in two states. The comparisons were made to test research question, “Which is more appropriate -- transferring from a similar sized urban area in a different region or state of the country, or transferring from an urban area of a different size that is located within the same state?”

The analyses included eleven study areas with four trip purpose models in each area resulting in the development of a total of 44 cross-classification models. Comparisons between pairs of study areas were then made for each of the four trip purpose models. All study areas within each size category irrespective of their state were compared to one another, and each study area within a state was compared to the other study areas in the same state. Forty area-to-area comparisons were made using each of the four types of models for a total of 160 comparisons.

The findings with regard to the research question were mixed. Of the 40 area-to-area comparisons 11 had no differences for any trip purpose, 10 had a difference in one trip type, 15 had differences in two trip types and four were found to have differences in three trip purposes. Disaggregating the results to the trip category level shows that 108 of the 160 comparisons found no difference; however, 52 of the comparisons did result in a difference.

Table 5-9 - Results of Comparisons between Large Study Areas

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Toledo - Dayton					
	Total Trips	10.21	9	16.92	Accept
	Home-Based Other	6.04	9	16.92	Accept
	Non Home-Based	12.57	9	16.92	Accept
	Home-Based Work	7.53	6	12.59	Accept
Toledo - Nashville					
	Total Trips	18.50	9	16.92	Reject
	Home-Based Other	12.87	9	16.92	Accept
	Non Home-Based	13.11	9	16.92	Accept
	Home-Based Work	145.01	6	12.59	Reject
Dayton - Nashville					
	Total Trips	12.32	9	16.92	Accept
	Home-Based Other	18.98	9	16.92	Reject
	Non Home-Based	24.86	9	16.92	Reject
	Home-Based Work	160.84	6	12.59	Reject

Chapter 6 – INCLUDING AREA TYPE VARIABLE IN TRIP GENERATION MODELS FOR IMPROVING TRANSFERABILITY

The trip production models that were examined in Chapter 5 are in the form of cross-classification tables developed using the household characteristics of 'number of vehicles available' and 'household size' or 'number of household workers'. The use of these socioeconomic characteristics of households is typical in the models used by many small and medium-sized metropolitan planning organizations around the country. Whether these characteristics are sufficient to explain the variations in household trip rates is a key question to address when transferring a model from one area to another. Of the 40 area-to-area (different pairs of urban areas) comparisons, 11 had no differences for any trip purpose, 10 had a difference in one trip type only, 15 had differences in two trip types and four were found to have differences in three trip categories. Additionally, 108 of the 160 comparisons of individual models (by trip purpose) found no difference in a specific category of trips. So based on these findings one could argue that trip making is more similar between areas than it is dissimilar. However, with 52 of the trip categories showing some level of difference, a case could also be made that considerable divergence was discovered among the trip rates in the study areas and that transferability of these models may be questionable.

Nevertheless, it is possible that the differences among the models of various areas are attributable to some extent to the weakness or limitation of the models with regard to the variables or characteristics of households used to develop the cross-classification tables of trip rates. It may be possible to further account for the differences and reduce the frequency of rejecting the null hypothesis of no difference by disaggregating the data sets into groups of households based on another characteristic associated with the households and trip making.

One way that some of the larger metro areas with more advanced modeling capabilities have been able to improve trip generation models is by using a variable representing

the “area type” in their models. The concept of “area type” is recognized in travel demand modeling and traffic engineering practices as a means to reflect some of the important effects on travel behavior and transportation system performance that are associated with different development patterns and travel environments. Area type provides a convenient way of classifying diverse parts of a region that are intuitively understood to be different even though the exact definitions and boundaries of these sub-areas may be imprecise. In short many modelers believe that there is something about the development pattern that influences travel behavior, and they try to develop a quantitative measure for area type to be able to stratify traffic analysis zones in different groups or categories according to this measure. However, it is understood that area type can be a surrogate for characteristics influencing travel which may be difficult to account for explicitly.

Typically, traffic analysis zones (TAZ) and highway network links are classified into three, four or even more area type categories, such as central business district (CBD), urban, suburban or rural. These classifications provide a convenient way to stratify trip rates, roadway capacities, speeds, etc. For example, it is fairly common to develop roadway capacities of different functional classes of roads for planning level applications according to area types.

Area types at the TAZ level are intended to capture the effects of differences in urban design features, development density, and/or pedestrian friendliness on trip making behavior. For example, trip generation rates for vehicle trips would be expected to be lower in CBDs since making vehicle trips may be more burdensome and people have more opportunities to make non-motorized trips. (TMIP, 2008) Ideally a quantitative index should be developed to represent variations in area type by combining selected characteristics of TAZs although a qualitative classification scheme also can be used.

MPO Approaches for Developing Area Types for Modeling

Area type is used to represent a range of characteristics that vary from one portion of a metropolitan area to another. The number of area types used and the formula used to categorize portions of the study area into different area types vary among MPOs that have employed this approach. The degree of refinement is dependent on several factors including the primary and secondary purposes for including area type in a model, the preferences of the local agency and/or the model developer, data availability, nature of the metropolitan area, resources available for developing the formulation, and other factors. A few examples of the actual use of area type in modeling by MPOs and descriptions of the formulations were identified and presented here as a point of reference for this research.

The Denver Regional Council of Governments (DRCOG) uses area type in their existing 4-step modeling process. However, the model is in the process of a major overhaul. The current model user's guide provides a brief description of the procedure and also lists a major caveat. The model guidance indicates that area type is used in their model for a number of model components. But few details are provided about how it is used. The area type procedure in the model calculates the population and employment density within 0.5 mile of each traffic analysis zone centroid, and uses that to determine the area type (CBD, Fringe, Urban, Suburban, or Rural). After the initial use of area type variable in the modeling procedure, DRCOG staff members adjust the results using planning judgment. In particular, they seek to maintain consistency between model years. For example, they do not want drastic changes to occur in zonal classification, such as a zone that is urban in 2001 becoming suburban or rural in 2010. (DRCOG, 2004)

The Delaware Valley Regional Planning Commission (DVRPC) uses area types, derived from population and employment for each TAZ, throughout its modeling process. Trip rates are developed for each area type, and network speeds and capacities are a function of area types in DVRPC's model. The Planning Commission

views area type as the key indicator of the intensity of travel activity occurring in a zone rather than zone size, land use, etc. It is considered a critical item of information in their models. The documentation indicates that it affects all four steps of the travel forecasting process. It is used to select the coefficients in the trip generation analysis, set the terminal and intrazonal travel times for the trip distribution models, define the diversion curves that are to be used in the modal split analysis, and set the link parameters for highway traffic assignment. The area type code is also viewed as a useful means for interpreting, categorizing and summarizing model output data.

DVRPC area type designations are made using two primary steps. First, a measure of travel intensity is calculated for each TAZ as a starting point for grouping them into area type categories. This intensity of activity is estimated by computing the following factor for each zone:

Eq. 6-1

$$\text{Intensity Factor} = \frac{\text{Population} + 2.37 \text{ X Employment}}{\text{Land Area (acres)}}$$

The employment multiplier of 2.37 used in this equation was empirically derived and the model documentation indicates that it has demonstrated stability over time. The resulting value of the computed intensity factor establishes the initial area type for each zone depending on which of six specified ranges it falls into. It is not clear on what basis the ranges were developed; however, the six categories are labeled CBD, fringe of CBD, Urban, Suburban, Rural and Open Rural.

The area types are then plotted on a traffic analysis zone map and the results are reviewed. Manual adjustments are made to ensure continuity between the area types; for example, the modelers try to avoid cases of misclassification such as a traffic analysis zone in an urban area which includes a large park being labeled "open rural" as a result of the automated application of the intensity factor formula. (DVRPC, 2008)

In the New York Best Practice Model (NYBPM), the area type is defined in terms of a general measure of the development character of sub-areas, based on the density of both residential and employment development in each zone and its vicinity. The NYBPM procedure determines in which of ten ranges of both population and employment densities a particular area belongs, and based on this two-way consideration, assigns one of the 11 distinct area type classifications to each zone. In forecasting applications, this approach automatically adjusts area type with future year socio-economic data forecasts for various zones. This allows for changes in development scale and mix to be reflected in the NYBPM, both in the travel demand models that incorporate area type as an explanatory variable and in capacity estimates of highway network links. The area type affects trip generation and trip attraction rates, speed and network capacity, car ownership and mode choice. Area type is calculated from the population density and employment density of a TAZ. The calculation of area type for a given zone is also impacted by the population and employment of the neighboring zones. In other words, the area type calculation is based on geographical "buffering" of the employment and population data in a 0.75 mile radius of each zonal centroid. (Parsons, 2005)

The Atlanta Regional Commission's (ARC) travel demand model is segregated into 7 area types. These area types are determined for each zone on the basis of the floating population and employment densities. This floating density is determined by adding the population and employment for all the zones whose centroids are within a mile radius from the centroid of the zone being considered, and dividing by the cumulative area of all the zones. The use of this floating density performs a smoothing function by helping to minimize the effects of localized development characteristics. The region's employment is broken down into three broad categories, retail, commercial and industrial. These three employment types are then multiplied by trip generation factors indicating the number of trips generated due to the employment type. The factors are 10.0 for retail, 1.0 for commercial, and 0.3 for industrial. The population and

employment densities are calculated for each zone based on the demographic data provided for a given census year. The zones are then ranked on the basis of the population density and employment density separately. The 7 area types are then based on a matrix distribution of population and employment densities.

The area type, for a traffic analysis zone in the ARC model, is a measure of the general density in and around the traffic analysis zone. These area types range from the highest density (CBD area types) to the lowest densities (Rural area types). The Atlanta area types have been given names, which are indicative of the densities they represent. The names of the area types (ranging from the highest to the lowest density) are: CBD; Urban Commercial; Urban Residential; Suburban Commercial; Suburban Residential; Exurban; Rural. These same area types are used to determine the speeds and capacities of links, using a look-up table. A link is assigned an area type based on the zone it is located in, and the zone location is determined by the closest zone centroid to either the a-node or the b-node of the link. (ARC, 2008 and TMIP 2008)

The Sacramento Area Council of Governments has taken an even more advanced approach to handling area type considerations in their trip generation estimation for their travel demand model. They are using parcel/point data for their travel model, and have moved away from the TAZ-level approximations of area type in favor of buffered parcel values. To account for density and land use mix they depend on totals of households and jobs of different types within 1/4 and 1/2 mile of each parcel. To account for street level variables they developed a measure based on classifying and coding each intersection in the region as one of three types: 1-legged, 3-legged, or 4-legged. The 1-legged intersections are cul-de-sacs, the 3-legged are "T" intersections and the 4-legged are full street intersections. Geographic buffers of the densities of each type of intersection are determined for 1/4 and 1/2 mile areas around each parcel. The expectation is that higher rates of "good" intersections (3-legged and 4-legged) correlate with higher pedestrian, bike, and transit mode shares. Further, higher vehicle miles

traveled per household are expected to be correlated with higher rates of cul-de-sacs (1-legged). (TMIP, 2008)

The analysis of these MPO modeling reports provided several relevant insights. The use of an area type measure is considered to be very important by many agencies charged with the responsibility of travel demand modeling. A standard definition of area type was not found and though the measure often has common elements such as population or employment density, it tends to be tailored to the needs and experience of each area. In all cases reviewed procedure was applied at the zonal level except for one where it was applied at the parcel level. Given how customized the measures are for each area and the fact that they are usually zone based, it is not clear that specific measures of area type currently in use by MPOs would be readily transferable to other areas.

A Transferable Area Type Measure

A shortcoming of the currently used approach for transferring trip generation models is the lack of consideration of land use and spatial context associated with the households and their travel. Often a transfer between areas is made based only on the total population of each of the two areas. This weakness can be overcome by including variables that directly account for one or more aspects of the spatial context of trip making such as land use, urban design, network density, street connectivity, etc. However, this task presents a serious challenge for small and medium sized urban areas where resources may be limited with respect to the availability of staff and time. One way to overcome the difficulty of developing a composite quantitative measure is to use a surrogate measure such as area type based on general characteristics of development patterns. However, such a general and qualitative classification scheme may be unique for an area and may not be transferable to other areas. What is needed for transferability is a framework that would allow for common definitions and measurements tested in multiple regions of the country. Such a framework is essential

for comparative research and analysis so as to establish a consistent approach to account for land use and other related parameters that impact travel behavior even if an indirect measure is used. The framework should have three characteristics: first, it must be based on a measure that can be calculated consistently regardless of the location; second, it must be based on a consistent geographic unit (thus it would not be suitable to use locally specific geography such as TAZs); and third, it should be straightforward to understand and implement by staff at small and medium-sized MPOs.

Various frameworks and procedures could be developed meeting these criteria. However, instead of inventing a new procedure a system that had previously been used for transportation analysis was identified as an acceptable starting point and is described below.

> "Miller and Hodges of Claritas, Inc. tackled this issue and established a standard framework for defining urbanization categories (area types) using relational population densities. Their system defines a grid system across the entire study area. The grid is based on 1/30th degree of latitude and longitude, which creates cells with an area of about four square miles.
>
> The total population of a given cell and its eight surrounding cells (a 3x3 grid) divided by the total area of all nine cells determines the given cell's grid density. Claritas then ranks all of the grid cell densities for the US into one hundred equal groups (a scale of 0 to 99). The highest grid cell density in a 5-mile radius (5x5 grid, excluding the corners) determines the local density maximum in an area. Population centers emerge where grid cell densities only decrease moving away from a local maximum and no other local maximum with a greater density appears. The basic grid cell structure is depicted in Figure 6-1.
>
> Area type classifications depend on the calculated grid cell densities and population center densities. Simple grid cell densities define rural areas (grid cell densities less than or equal to 19) and small towns (grid cell densities greater than or equal to 20 and less than or equal to 39). Claritas considers population center densities greater than 79 as urban areas; second cities comprise remaining population center densities. Areas around second city and urban areas form suburban areas. Lines of different slopes distinguish suburban areas around the population centers of second cities and urban areas." (Ross, et al., 1997)

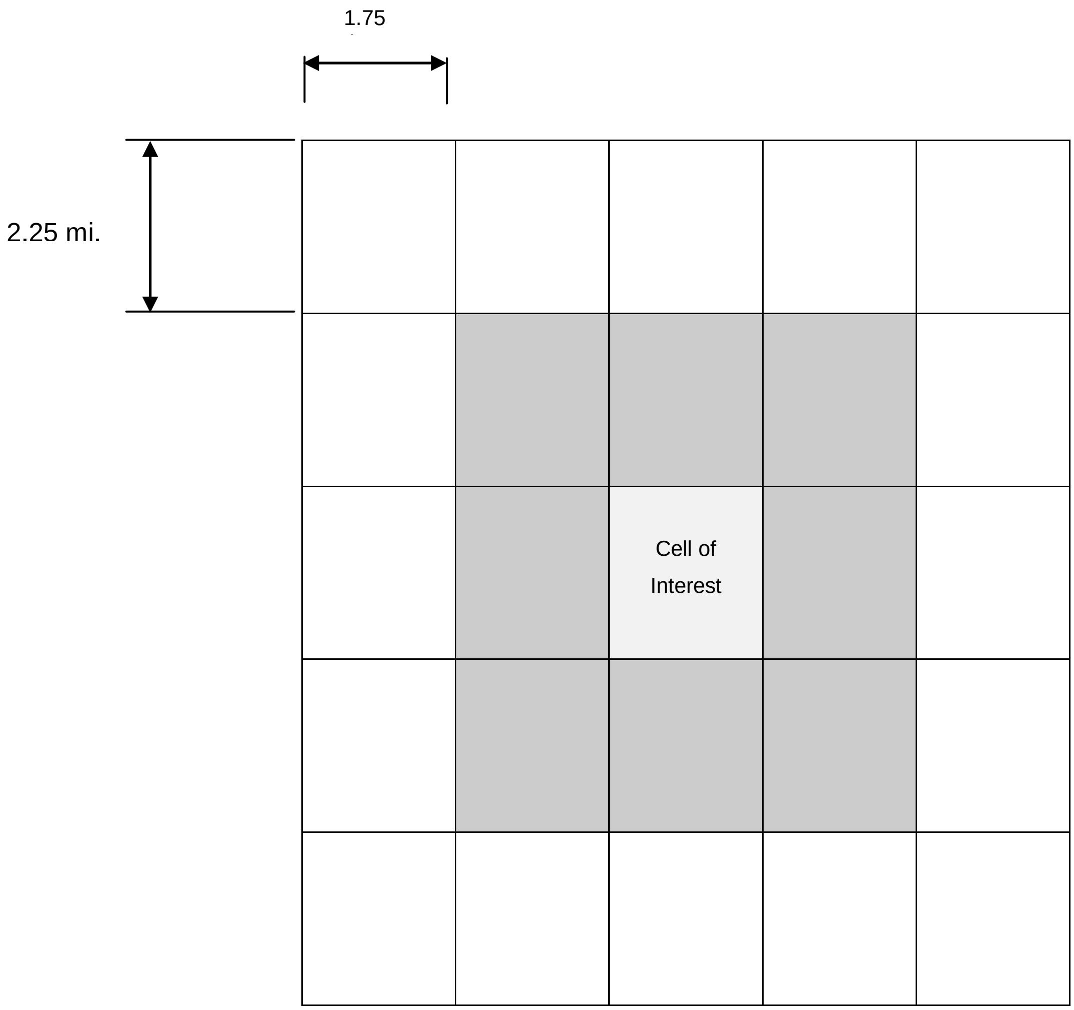

Figure 6-1 - Claritas Urbanization Grid Method

The Claritas procedure was used to attribute data in recent National Personal Transportation Surveys and has thus become an accepted option within the transportation planning research community. This concept was adapted to provide a common framework for the regions investigated in this study. The goal was to develop an approach that was robust enough to account for differences between study areas while being straightforward enough to be easily understood and applied by the typical analyst working at an MPO in a small area. The initial plan was to closely follow the system developed by the Claritas researchers, and so a test was conducted to investigate the feasibility of the approach using TransCAD.

TransCAD is a GIS based travel demand modeling software package. It has the unique ability to serve as the platform for all four steps of the travel demand modeling process while fully integrating powerful GIS capabilities into the analysis. TransCAD currently has a large share of the market for travel demand modeling software in the US and is especially popular among small and medium-sized areas. Thus a decision was made to use TransCAD as the primary software tool to conduct this analysis.

A grid system covering the entire study area including Ohio, Tennessee, the area in between (Kentucky and Indiana) and the state of Michigan (since it includes a part of the Toledo study area) was developed. This first grid system followed the Claritas model with grid lines every 1/30th degree of latitude and longitude and the resulting grid cells covering about four square miles each. A GIS overlay was used to estimate the population residing within each grid cell based on the Census 2000 block level geography. Once each grid cell was attributed with a population estimate the next step was to implement the Claritas contextual density calculations. However, at that point in time it was discovered that even the latest version of TransCAD lacked the capability of implementing the calculations of the Claritas procedure as described above due to limitations in the software's adjacency functionality. After conferring with the technical support team for TransCAD it was determined that this feature would not be available in the near future in TransCAD. Though there was an option to pursue the implementation

of the Claritas procedure in an alternative GIS system, it was decided that if the proposed approach was too complex to be included in TransCAD then perhaps it was too difficult to be readily implemented by the transportation planning practitioners. Further, it was not obvious that this complex procedure would have any greater advantage over simpler procedures.

It was decided to develop a straightforward measure of area type based on simple population density. After further consideration it was also decided that though grid cells covering four square miles were appropriate for an analysis of the entire nation a finer resolution was desirable for individual urban areas. The four square mile grid cells would have contained a large number of survey households, thus producing very aggregate data with little variation in population density for the different sections of a study area. It was decided to use a grid system based on 1/60th degree of latitude and longitude, which created cells with an area of about one square mile each. These grid cells were only about a quarter of the size of the Claritas cells. It may be added that an area of one square mile usually is considered the average size of a neighborhood in single family residential areas.

A qualitative evaluation of the one square mile grid cell system was made by overlaying the grid system with traffic analysis zones for several areas and visually comparing the two geographic units. The size of TAZs typically varies substantially within a metro area with the most densely populated urban areas having very small TAZs covering only a few blocks and TAZs in outlying areas covering many square miles. Given the variation in TAZ size it was not possible to match their size with a uniform grid; so the target was to select a grid size that was not so small as to produce an overwhelming number of cells but not so large that the desired resolution in the most urban portion of the study areas would be lost. It was found that in the most urban (dense) portion of a study area a grid cell contained several TAZs. However, as one moved away from the CBD the size of the grid cells and the TAZs became more closely aligned, and in the more rural sectors a TAZ often contained several grid cells. The results were very

similar for all of the Ohio and Tennessee study areas considered, thus it was determined that a one square mile grid size was an acceptable size for this application.

Once the grid system was selected the overlay procedure was repeated to attribute the new grid cells with residential population using Census 2000 block geography as the data source. The grid system included 218,440 cells in total for an average of about 43,700 per state with the actual number of grid cells in a state dependent of the size of each state. Ohio, for example, had a total of 41,394 grid cells that were at least partially within its borders. Next the population density was calculated for each grid cell by dividing the total population within each cell by the area of that cell. The total 2000 population for Ohio of 11,353,140 people resulted in a statewide mean of approximately 275 people per square mile with the density for complete grid cells ranging from a minimum of zero to a maximum of 17,878 persons per square mile. The grid system is shown in Figure 6-2 with light blue lines for the Lima and Mansfield areas. The small black dots indicate the location of a single household within each study area.

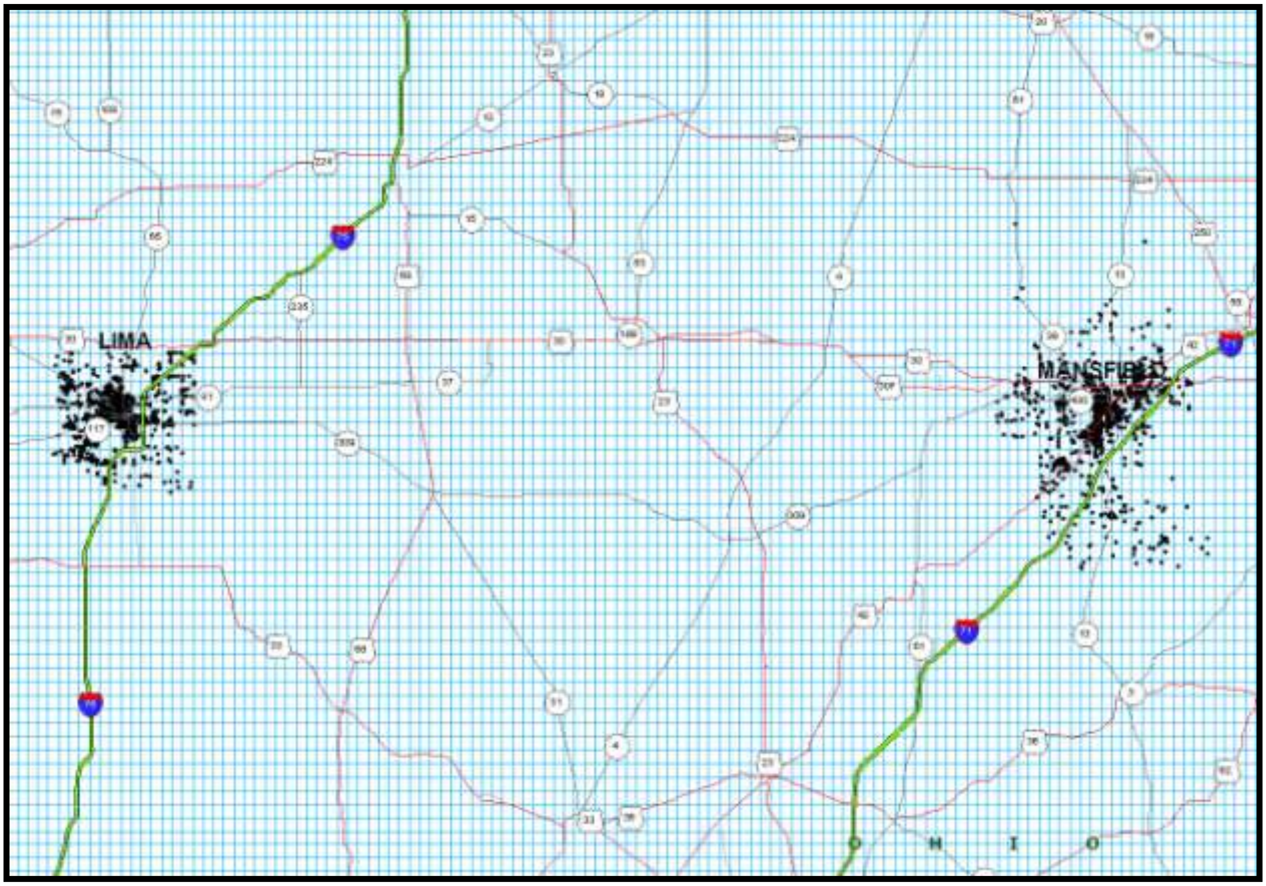

Figure 6-2 - Example of the Grid System Showing Lima and Mansfield

Application of Population Density to Define Area Types

With the grid framework in place and the population density of each cell determined the degree of urbanization across the entire two-state study area (Ohio and Tennessee) was defined in a consistent manner. The next step was to attribute the households in the study areas being analyzed with the value of the population density in the cell in which they are located. Prior to taking this step a decision was needed as to which of the eleven individual urban areas would be included in this portion of the analysis. The procedure could be used to make more refined comparisons between all areas where differences were reported based on the Q statistics calculated in Chapter 5. Recall that 29 of the 40 area-to-area comparisons found a difference in at least one trip category. However, the purpose of this research was to investigate the validity of the approach, which does not need an exhaustive analysis of all possible permutations. Thus only a sample of cases where differences were found was evaluated further. Six of the 29 comparisons resulting in differences included Nashville as one of the study areas. Considering possible problems with the Nashville data it was decided that tests using other areas would be more fruitful so these six comparisons were not considered further. The 29 comparisons for which a difference was found also included eight with either Jackson or Lakeway as one of the study areas. The data sets for these two areas included less than 500 households each; thus they were not good candidates for this procedure since the sample size for each cell would be greatly reduced once the data were further categorized into area types.

The remaining candidates for further investigation included eleven pairs of Ohio areas and four pairs of Knoxville with Ohio areas. A decision was made to first test the procedure using only the Ohio study areas. This eliminated the potential for differences due to variations in survey procedures and other factors related to differences between the States from impacting the results. If the area type procedure could be demonstrated successfully with the Ohio cases, then further tests could be conducted using the Knoxville study area. The only remaining decision was which of the Ohio-to-Ohio cases

should be studied further. Six of the eleven comparisons found differences in only one trip purpose category and in each case the Q statistic was relatively close to being acceptable. The remaining five cases had differences in the home-based other category of a magnitude that resulted in a difference in the total trip category also. It was decided that selecting these five to investigate offered the most potential for demonstrating the validity of the area type procedure. The five comparisons and their original findings are presented in Table 6-1.

The last key decision to be made was about the method to be used to group the data to form the three area types for each study area to be compared.   TransCAD offers at least seven different methods including simply forming groups with the same number of features in each, developing groups with equal sizes of intervals and other more sophisticated methods for selecting the threshold values of each area type. The method selected for this analysis is called "Optimal Breaks" in TransCAD. The TransCAD User's Guide describes this method as follows: "Each class is a cluster of values that minimizes within-group variance using the Fisher-Jenks Algorithm version of

the optimal method of irregular class creation. This method is sometimes called natural breaks." (Caliper, 2008)

With this algorithm breaks are typically uneven, and are selected to separate values where large changes in value occur. Typically, the method applied in GIS packages was developed by Jenks in the early 1970's which was in turn based on Fisher's earlier work. The basic steps for the typical application of Jenk's methods are as follows:

> Step 1: The user selects the attribute, *x*, to be classified and specifies the number of classes required, *k*
>
> Step 2: A set of *k*-1 random or uniform values are generated in the range [min{*x*}, max{*x*}]. These are used as initial class boundaries

Table 6-1 - Previous Ohio Area Comparisons Selected for Further Study

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Lima – Mansfield					
	Total Trips	26.71	9	16.92	Reject
	Home-Based Other	21.94	9	16.92	Reject
	Non Home-Based	15.14	9	16.92	Accept
	Home-Based Work	5.08	6	12.59	Accept
Lima - Canton					
	Total Trips	21.02	9	16.92	Reject
	Home-Based Other	19.78	9	16.92	Reject
	Non Home-Based	8.18	9	16.92	Accept
	Home-Based Work	0.46	6	12.59	Accept
Mansfield - Toledo					
	Total Trips	17.38	9	16.92	Reject
	Home-Based Other	17.38	9	16.92	Reject
	Non Home-Based	12.12	9	16.92	Accept
	Home-Based Work	7.55	6	12.59	Accept
Mansfield - Dayton					
	Total Trips	18.12	9	16.92	Reject
	Home-Based Other	17.13	9	16.92	Reject
	Non Home-Based	14.59	9	16.92	Accept
	Home-Based Work	2.35	6	12.59	Accept
Canton – Youngstown					
	Total Trips	18.96	9	16.92	Reject
	Home-Based Other	18.91	9	16.92	Reject
	Non Home-Based	14.39	9	16.92	Accept
	Home-Based Work	2.05	6	12.59	Accept

Step 3: The mean values for each initial class are computed and the sum of squared deviations of class members from the mean values is computed. The total sum of squared deviations (TSSD) is recorded

Step 4: Individual values in each class are then systematically assigned to adjacent classes by adjusting the class boundaries to see if the TSSD can be reduced. This is an iterative process, which ends when improvement in TSSD falls below a threshold level, i.e. when the 'within class variance' is as small as possible and 'between class variance' is as large as possible. True optimization is not assured. The entire process can be optionally repeated from Step 1 or 2 and TSSD values compared. (de Smith, 2009)

Analysis Process

As shown in Table 6-1 the five Ohio area-to-area comparisons included six different areas Lima, Mansfield, Canton, Toledo, Dayton and Youngstown. All households included in these six study areas were attributed with the population density of the grid in which it was located. The household data sets for a pair of two areas being compared were combined to form a new data set. The Optimal Breaks method in TransCAD was then applied to the data set to segregate it into a rural, suburban and urban area types. The resulting population density range for each area type and the associated number of households for each area for all five comparisons are presented in Table 6-2. Figure 6-2 shows the results of classifying the households for the Mansfield area. The green dots represent households with a rural location, the yellow dots indicate a suburban location and the red dots show households with an urban location.

The procedure for selecting the thresholds for each area type provided a common analysis framework for each comparison, while at the same time permitted the definition of the area type categories to vary somewhat. The expectation was that this would provide the most suitable grouping of households by area type for each comparison

Table 6-2 - Population Density (per/sq. mi.) Ranges and Related HH Sample Sizes

Comparison Areas	Area Type	Population Density Range	Number of Households	
Canton - Lima			Canton	Lima
	Rural	1899 and below	611	766
	Suburban	1900 to 3999	509	311
	Urban	4000 and above	199	251
			1319	1328
Mansfield - Lima			Mansfield	Lima
	Rural	1299 and below	674	594
	Suburban	1300 to 3499	413	327
	Urban	3500 and above	217	407
			1304	1328
Mansfield - Toledo			Mansfield	Toledo
	Rural	2069 and below	897	656
	Suburban	2070 to 4899	295	1067
	Urban	4900 and above	112	453
			1304	2176
Mansfield - Dayton			Mansfield	Dayton
	Rural	1839 and below	826	688
	Suburban	1840 to 4299	366	898
	Urban	4300 and above	112	364
			1304	1950
Canton – Youngstown			Canton	Youngstown
	Rural	1669 and below	584	563
	Suburban	1670 to 3799	514	509
	Urban	3800 and above	221	179
			1319	1251

pair. The maximum density (persons per square mile) to be considered rural ranged from 1299 in the Lima-Mansfield comparisons to 2069 in the Toledo-Mansfield comparison. The minimum value of urban ranged from 3500 in Lima-Mansfield comparison to 4900 in the Toledo-Mansfield evaluation.

Results of Ohio Comparisons

Separate cross-classification models for total trips and home-based other trips were developed for each of the three area type classes in the six urban areas included in this portion of the study. Note that the Optimal Breaks method resulted in the urban area type group having relatively few households with Mansfield having only 112 in two comparisons. Due to these small sample sizes the cross-classification models for the urban areas were simplified by collapsing the tables down to six cells. The three categories of household size used were 1, 2 and 3+ and the two categories of vehicles available used were 0 and 1+. However, only the 1+ cells of the vehicles available had enough households to be usable. A decision was made not to further collapse the vehicle classes because zero vehicle households are known to have significantly different travel behavior than households with at least one vehicle thus combining them would likely skew the results.

The results from this analysis are presented in Table 6-3. The findings from the original comparisons are presented as well as points of reference. The original results are shown in the rows labeled “All” under area type indicating that they were based on all households in the area without further stratification by area type. A review of these results finds some clear patterns. First, most of the comparisons with the households disaggregated by area type were determined not to be statistically different. In fact the null hypothesis (Ho) could be accepted in 24 of the 30 cases or 80% of the comparisons. The second finding is that some differences do remain. In four of the five area-to-area comparisons at least one of the evaluations indicated that a difference existed. Only for the Mansfield-Toledo evaluation it was found that both total and home-based other trip rates did not differ for any area type. Note that two cells in the Lima cross-classification table had fewer than 30 households.

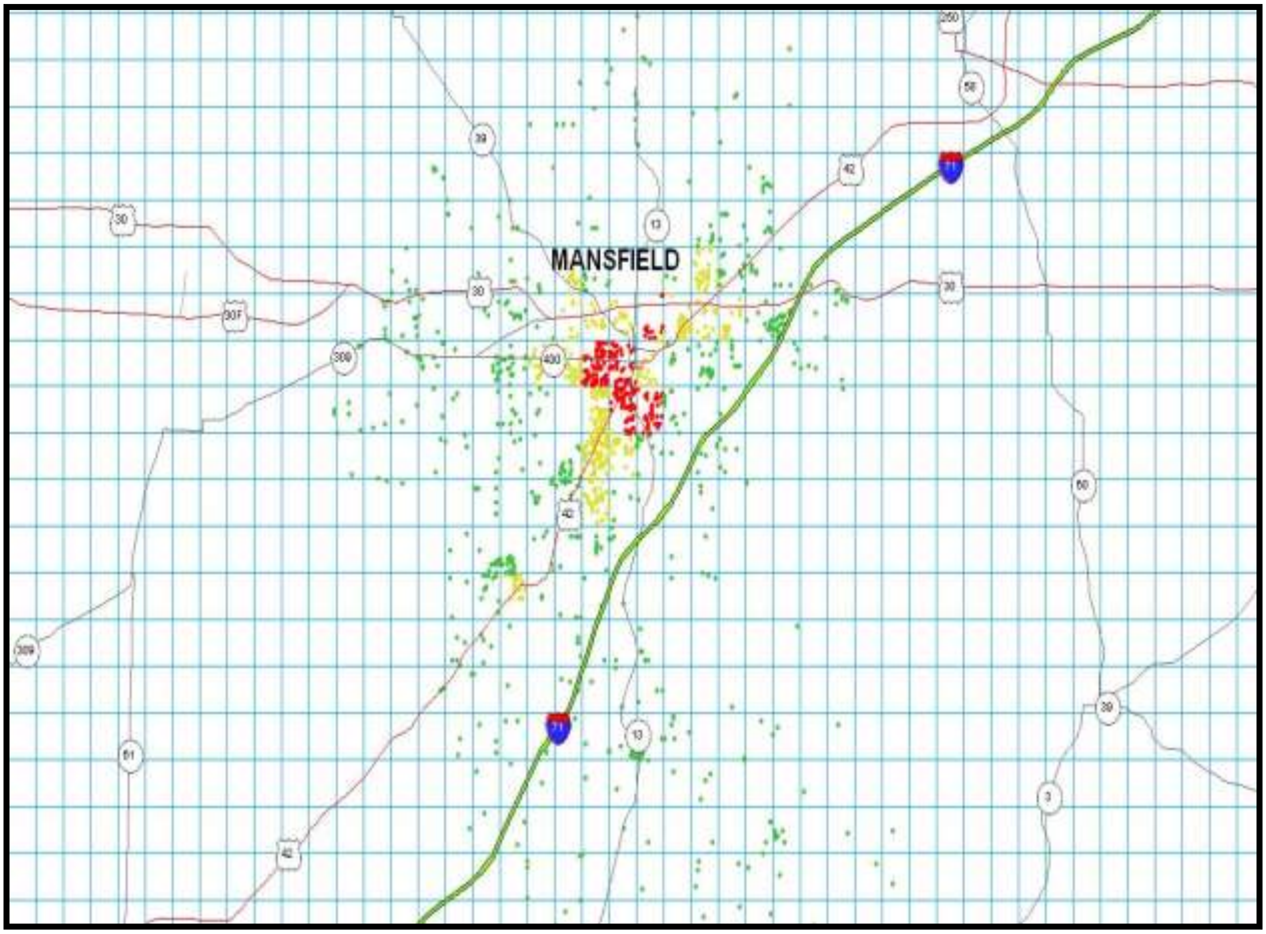

Figure 6-3 - Close-up of Mansfield Grid and Households Categorized by Area Type

Table 6-3 - Statistical Results of Ohio Analysis Based on Area Type

Comparison Areas and Trip Purpose	Area Type	Q	n	Critical $\chi^2_{.05}$	Ho
Lima – Mansfield					
Total Trips	**All**	**26.71**	**9**	**16.92**	**Reject**
	Rural	4.58	6	12.59	Accept
	Suburban	7.57	5	11.07	Accept
	Urban	5.99	3	7.81	Accept
Home-Based Other	**All**	**21.94**	**9**	**16.92**	**Reject**
	Rural	2.98	6	12.59	Accept
	Suburban	15.09	5	11.07	Reject
	Urban	3.06	3	7.81	Accept
Lima - Canton					
Total Trips	**All**	**21.02**	**9**	**16.92**	**Reject**
	Rural	5.61	6	12.59	Accept
	Suburban	20.14	5	11.07	Reject
	Urban	2.27	3	7.81	Accept
Home-Based Other	**All**	**19.78**	**9**	**16.92**	**Reject**
	Rural	6.32	6	12.59	Accept
	Suburban	19.95	5	11.07	Reject
	Urban	1.26	3	7.81	Accept
Mansfield - Toledo					
Total Trips	**All**	**17.38**	**9**	**16.92**	**Reject**
	Rural	7.60	6	12.59	Accept
	Suburban	8.95	5	11.07	Accept
	Urban	3.48	3	7.81	Accept
Home-Based Other	**All**	**17.38**	**9**	**16.92**	**Reject**
	Rural	6.89	6	12.59	Accept
	Suburban	5.64	5	11.07	Accept
	Urban	5.83	3	7.81	Accept
Mansfield - Dayton					
Total Trips	**All**	**18.12**	**9**	**16.92**	**Reject**
	Rural	9.46	7	14.07	Accept
	Suburban	4.03	7	14.07	Accept
	Urban	5.89	3	7.81	Accept
Home-Based Other	**All**	**17.13**	**9**	**16.92**	**Reject**
	Rural	4.80	7	14.07	Accept
	Suburban	3.29	7	14.07	Accept
	Urban	11.46	3	7.81	Reject

Table 6-3. Continued

Canton – Youngstown					
Total Trips	**All**	**18.96**	**9**	**16.92**	**Reject**
	Rural	9.39	6	12.59	Accept
	Suburban	18.77	6	12.59	Reject
	Urban	6.19	3	7.81	Accept
Home-Based Other	**All**	**18.91**	**9**	**16.92**	**Reject**
	Rural	11.21	6	12.59	Accept
	Suburban	21.79	6	12.59	Reject
	Urban	6.07	3	7.81	Accept

An investigation was conducted to determine if the inclusion of these cells was impacting the finding of a difference for the suburban area type. If those three cells were excluded from the analysis then no statistical difference would have been indicated between Lima and the other areas -- Mansfield and Canton -- for home-based other trips.

However, the finding of a difference in total trips in the suburban areas in Lima and Canton would have remained unchanged.

Finally, this disaggregate analysis permits one to hone in on the source of differences when they exist. For these evaluations there appears to be a real difference in mean trip rates between Lima and Mansfield, Lima and Canton and Youngstown and Canton in the suburban areas for home-based other trips. Further in the two Canton comparisons the disparities in home-based other trips are large enough to result in a difference in total trips. After taking a closer look at the cell level HBO rates, it is clear that Canton has high mean trip rates for most household size by vehicles available groupings than were found in Youngstown or Lima. The only non-suburban difference found was for the Mansfield-Dayton comparison in the urban area type for home-based other trips. Overall, there were six cases of rejection of the null hypothesis, and the area type 'suburban' was involved in five of these cases (out of six). Consideration was given to further refining the area type categorization by adding a fourth category.

However, the relatively small sample of households in four of the six study areas would have limited the usefulness of further disaggregation and so it was not pursued.

Results of Knoxville Comparisons

The results of the comparisons for Ohio areas to one another showed enough promise for reducing the differences between the models to warrant further testing. The Nashville data set had already been eliminated as an option due to possible problems with the data set and the Jackson and Lakeway data sets were too small to be subdivided further by area type. That left the Knoxville data set as the only Tennessee data suitable for further testing. Recall from Chapter 5 that a few differences were found between Knoxville and four Ohio areas -- Canton, Youngstown, Dayton and Toledo. Between Knoxville and Canton only home-based other trips were found to be different, and between Knoxville and Youngstown only non home-based trips were previously found to be different. However, the previous tests indicated differences between Knoxville and Dayton, and Knoxville and Toledo areas in both home-based other and non home-based trip categories. These two area to area comparisons were selected for additional study. The results from the original evaluations are shown in Table 6-4 for easy reference.

Table 6-4 - Previous Knoxville Comparisons Selected for Further Study

Comparison Areas	Trip Purpose	Q	n	Critical $\chi^2_{.05}$	Ho
Knoxville - Toledo					
	Total Trips	11.38	9	16.92	Accept
	Home-Based Other	19.46	9	16.92	Reject
	Non Home-Based	21.35	9	16.92	Reject
	Home-Based Work	10.33	6	12.59	Accept
Knoxville - Dayton					
	Total Trips	14.28	9	16.92	Accept
	Home-Based Other	27.64	9	16.92	Reject
	Non Home-Based	34.30	9	16.92	Reject
	Home-Based Work	9.50	6	12.59	Accept

The same steps were followed as with the Ohio-to-Ohio comparisons for developing the area type categories. The Knoxville household data were combined with the Toledo and Dayton data respectively to form two new data sets. The Optimal Breaks method in TransCAD was then applied to each data set to segregate it into a rural, suburban and urban area types. The resulting population density range for each area type and the associated number of households for each area are presented in Table 6-5. The Dayton and Toledo households were relatively well distributed among area types though the suburban category had the largest share of households for each study area. The key item to notice is that the distribution of Knoxville data among area types is very uneven. In both cases about two-thirds of the households are placed in the rural category, one third in the suburban and only 14 households were included in the urban category. The 14 urban households for Knoxville were located in the same grid cell, which had a population density of 9399 persons per square mile. However, none of the other 1524 Knoxville households were located in grid cells with a density above 3824 persons per square mile. Given these distributions comparisons were made only between the rural and suburban area types.

The results revealed a fairly clear pattern. Once the households are grouped by area type and the mean trip rates are compared, the differences previously found for home-based other trips disappeared. However, even after disaggregating the data by area type differences still were found in three out of the four comparisons for non home-based trips.

Summary

The feasibility of including a measure of area type to enhance the transferability of trip production models between areas was investigated and reported in this chapter. Area type was found to be a commonly used measure in large area MPO models though it is usually defined differently for each MPO. Area type is recognized as a surrogate for many parameters that differentiate geographic sections of a metropolitan area. A

framework was established to develop and use a consistent measure of area type in different areas, and this was implemented by disaggregating the household trip data into rural, suburban and urban sub-areas for seven of the original eleven study areas using population density as a criterion. Seven area to area comparisons of trip rates were made after incorporating area types in the models. The result showed some improvement for transferability. However, some differences still remain especially for the suburban category.

Table 6-5 - Population Density Ranges and Associated HH Sample Sizes

Comparison Areas	Area Type	Population Density Range	Number of Households	
Knoxville - Toledo			Knoxville	Toledo
	Rural	2099 and below	1088	666
	Suburban	2100 to 5269	436	1135
	Urban	5270 and above	14	375
			1538	2176
Knoxville - Dayton			Knoxville	Dayton
	Rural	1899 and below	1040	707
	Suburban	1900 to 4699	484	966
	Urban	4700 and above	14	277
			1538	1950

Table 6-6 - Statistical Results of the Knoxville Analyses Based on Area Type

Knoxville – Toledo					
Home-Based Other	**All**	**19.46**	**9**	**16.92**	**Reject**
	Rural	9.73	6	12.59	Accept
	Suburban	10.63	8	15.51	Accept
	Urban	n/a			
Non Home-Based	**All**	**21.35**	**9**	**16.92**	**Reject**
	Rural	11.37	6	12.59	Accept
	Suburban	16.63	8	15.51	Reject
	Urban	n/a			
Knoxville - Dayton					
Home-Based Other	**All**	**27.64**	**9**	**16.92**	**Reject**
	Rural	8.65	6	12.59	Accept
	Suburban	9.61	6	12.59	Accept
	Urban	n/a			
Non Home-Based	**All**	**34.30**	**9**	**16.92**	**Reject**
	Rural	17.12	6	12.59	Reject
	Suburban	23.55	6	12.59	Reject
	Urban	n/a			

Chapter 7 - SUMMARY AND CONCLUSIONS

This study included two primary research objectives. The first was to test the appropriateness of transferring commonly used trip generation models from one urban area to another under a few specific circumstances. This issue was investigated using the following research question: "Which is more appropriate -- transferring from a similar sized urban area in a different region or state of the country, or transferring from an urban area of a different size that is located within the same state?" The second research objective was to improve the transferability of models by including a variable reflecting the spatial context of households, the basic unit of trip generation used in most MPO models. This objective was examined through the following research question: "Can a meaningful measure of urbanization be included in trip generation models to reduce the difference between models from different areas and thus improve transferability?"

The research was conducted in three major steps or stages. First, a review of literature was conducted and background information was gathered. This stage also included the search for data sources and the collection of some new data for this research. Then a large number of comparisons were made of trip generation models for different areas of two states (Tennessee and Ohio) to determine how similar or dissimilar these models were and whether transferring the model of one area to another would be valid or not. Finally, the quantitative analysis was extended to develop a procedure for identifying area types within a study area based on density and testing to determine if the differences between models can be reduced by incorporating area type in the models.

The review of literature found that at the present time the appropriateness of transferring trip generation relationships from one area to another is still in question since previous studies had mixed findings. It was also ascertained that the optimum way for developing and transferring models has yet to be determined conclusively. The existing trip production models for small and medium sized urban areas in most cases

use only socioeconomic characteristics of households to explain the variations in trip rates. Based on the experience of a few large MPOs it appeared that the models could be improved by incorporating a locational variable to reflect the spatial context of households. However, a uniform procedure for developing such a variable was neither recognized nor used in practice.

Further, the background research found that there is not a standard method for collecting travel survey data. Definitions of variables and data collection procedures utilized are often different form one survey to another and may be dependent upon the standard practices of data collection firms. The resulting data and ultimately the models developed from those data may reflect these differences. The details of survey element definitions and procedures often are not well documented and may not even be known to the analyst attempting to compare data sets or models. When these differences are significant the conclusions resulting from a comparative analysis may be distorted or even incorrect.

The data utilized for this research were drawn from four separate travel surveys and included data for 11 metropolitan planning areas in two states. These data sets were selected partly because there was some degree of uniformity in survey procedures. All data sets except those for the Jackson and Lakeway areas were collected by a single survey firm. The Jackson and Lakeway data were collected using procedures and definitions that mimicked those of the other surveys. Given the level of compatibility between the data collection efforts, it was assumed that the variability attributable to differences in survey methods would be limited in this case.

The initial quantitative analyses included eleven study areas with four trip purpose models in each area resulting in the development of a total of 44 cross-classification models for this portion of the research. The analysis was based on a comparison of cross-classification tables developed using the number of vehicles available and household size or number of household workers. These models are typical of those

used by many small and medium-sized metropolitan planning organizations around the country.

Comparisons between pairs of study areas were then made for each of the four trip purpose models. All study areas within each size category irrespective of their state were compared to one another, and each study area within a state was compared to the other study areas in the same state. Forty area-to-area comparisons were made with four trip categories in each case for a total of 160 comparisons.

Of the 40 area-to-area comparisons 11 had no differences for any trip purpose, 10 had a difference in one trip type, 15 had differences in two trip types and four were found to have differences in three trip purposes. Examining the results at the trip category level shows that 108 of the 160 comparisons found no difference. However, 52 of the comparisons did result in a difference at the trip category level. Based on these measures one could argue that trip making is much more similar between areas than it is dissimilar. There is a strong likelihood that using a transferred cross-classification model would result in a reasonable approximation of the travel behavior that a locally derived model would have produced. These findings may provide adequate justification for many small and medium-sized areas, which could never afford to collect their own data, to continue to borrow models or data from other areas. However, a case could also be made that considerable divergence was discovered between the trip rates in the study areas to advance transferability as statistically valid on a general basis.

Ideally, this research would have provided guidance regarding the criteria for selecting a suitable area from which to transfer models or data. Unfortunately, the findings with regard to the first research question were mixed. Comparisons between areas in different states but having a similar size residential population were made for small, medium and large MPO categories. The small Tennessee and Ohio areas were similar in many ways, however a statistical difference was found for non home-based trips in each of the six comparisons. A number of indications were found to suggest that trip

rates are similar between the medium-sized MPOs, but two cases of differences were also found -- one for home-based other and one for non home-based trips. Several differences were identified in comparing the large urban area in Tennessee to those in Ohio. However, the concerns about the Nashville data set makes those differences difficult to interpret.

The results of comparing areas of a different size but located within the same state were varied as well. The comparisons of the small areas in Tennessee (Jackson and Lakeway) to the larger MPO areas (Knoxville and Nashville) resulted in numerous statistical differences. On the other hand only home-based work trips were found to be different when comparing Knoxville and Nashville. Comparing areas located in the state of Ohio but of differing size resulted in a clear pattern. Few differences were found for total trips, non home-based trips or home-based work trips. However, many of the areas did have statistical differences in the home-based other category.

Now to directly address the first research question, "Which is more appropriate -- transferring from a similar sized urban area in a different region or state of the country, or transferring from an urban area of a different size that is located within the same state?" The results from these analyses lead to a clear conclusion regarding this question. That conclusion is that the results are too mixed for one to make a solid determination.

The first research question lacked a definitive answer. However, the research conducted for the second question made it possible to further account for the causes of the differences among the models, which were examined, and a way to reduce the differences was found. This was accomplished by introducing a new variable into the development of the trip production models, "area type". Area type is a commonly used measure in larger area MPO models though it was usually defined differently for each application. Area type was used as a surrogate for the many parameters that differentiate geographic sections of a metropolitan area. A framework was established

to use a consistent measure of area type between MPOs and implemented by disaggregating the household trip data into rural, suburban and urban sub-areas for seven of the original eleven study areas. Then new cross-classification models were developed for each of the area types for each of the MPO areas selected for this part of the research.

Seven area-to-area comparisons were made using the three area types for those trip purpose categories for which statistical differences had been found previously. Each of these area-to-area comparisons had improved compatibility through the inclusion of area type. The results of the Mansfield-Toledo comparisons showed no statistical differences among the area type models. The only difference found for the Mansfield-Dayton comparisons was for home-based other trips in the urban portion of the study areas. The Canton-Youngstown and Canton-Lima comparisons showed no differences for the rural or urban comparisons, however both had statistically different mean trip rates in suburban areas for home-based other trips and total trips. Differences in home-based other trips rates between Knoxville and the two large areas in Ohio, Dayton and Toledo, were no longer found when the comparisons were made using the area type models. However, in three of the four comparisons differences were still apparent for non home-based trips in the case of Knoxville comparisons.

The answer to the second research question was much more definitive than the first. This research demonstrated that a meaningful consistent measure of urbanization can be included in trip generation models in multiple areas. Further, the results with respect to the model transfers were improved by the inclusion of the area type variable.

By design this research has a strong practical orientation. The issue of the transferability of trip generation models is real and is faced by many urban areas especially those of small and medium size. The finding of the research that the transferability of trip production models can be improved by including an additional variable called “Area Type” should be helpful to many MPOs, which have to borrow

models or survey data from other areas. The data needed for developing this variable should not pose any difficulty since it is based on population data, which is readily available from the Census. Further, the algorithm needed to stratify different grids and the households located in them into different categories of Area Type is available in the TransCAD software package, which is widely used by MPOs of all sizes. This research is likely to contribute to the advancement of the state-of-the-practice of developing and using trip generation models.

The transferability of travel data and models is a topic that is ripe for further study. Numerous issues were raised by this research, which need additional investigation. A few will be discussed here. First, would the transfer of other models such as trip distribution be aided by the inclusion of a variable such as area type? If the data were segregated by area type then area type specific trip length frequency distribution curves could be developed along with friction factors of gravity models, which may be more transferable between MPO areas. Second, to what extent do survey procedures and definitions result in differences in travel data and can the differences be quantified? One approach to studying this issue would be to conduct a meta-analysis of a large number of surveys. Surveys could be grouped by key aspects of survey procedures/definitions such as activity versus trip, inclusion of all children versus excluding the very young, etc. and then one could mine the data to identify trends in the travel behavior values that could be correlated to a particular survey characteristic. The results of the research on this topic could encourage the adoption of much needed standardized survey definitions and practices. A third area where further study would be beneficial includes the various facets of developing the area types. The most appropriate grid size, the best measure to differentiate area types, the algorithm used for developing the categories and other aspects of the process could be evaluated further.

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